Development of a New Slit-Slotted Shaped Microstrip Antenna Array for Rectenna Application

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***Abstract*—These paper presents a new 3X3 array design using a microstrip patch array antenna to operate at 2.45GHz. The aim of this antenna array construction is to obtain high directivity. The element of the array is microstrip square patch antenna using V-shaped symmetric-slit along with rectangular slot in diagonal direction at the centre of square patch radiator to achieve the circularly polarized radiation and each element is fed by inset feed. The size and feed position of the single microstrip square patch is determined through the theoretical design and CST microwave studio software simulation. Based on which an array of six elements with equal sizes and equal spacing is designed on a planar substrate. The simulation results in this paper can be used as design reference for the practical design of the rectenna.**

***Index Terms*—Array antenna, microstrip antenna, rectenna, slit-slot, V shaped, square patch, feed, circular polarization.**

I INTRODUCTION

The rectifying antenna (rectenna) is an important component in wireless power transmission (WPT) system [1] Its antenna receives a wireless signal and then its rectifying circuit converts that AC energy into DC power. Most rectenna elements and rectenna arrays are developed for frequencies below 15GHz. Rectennas operating at millimetre-wave frequencies have the advantages of compact size and higher overall system efficiency for long distance transmission [2].

The antenna plays a significant role in the overall rectenna performance. It is one of the critical components needed to realize the desired high efficiency for different operating frequencies and for different input powers. For any WPT system high conversion efficiency is required.

There have been many rectennas reported,including different operating frequencies and different input powers. For example, a compact 5.8 GHz rectenna,which used a stepped-impedance dipole antenna, was presented in [3] with a high conversion efficiency of 82%.A 35 GHz rectenna array was reported in[4] that achieved a 35% efficiency when the input power density was 30 mW/cm2.Broad-band (2-18 GHz) rectenna arrays that recycle ambient microwave energy were presented in [5].A 2.45 GHz hybrid sensitive rectenna system that used zero-bias microwave Schottky diodes,was reported in [6].

Components for microwave-power transmission have traditionally been focused at 2.45 GHz considering that the frequencies below 3 GHz are not strongly attenuated by the atmosphere even under a severe weather condition [7] 2.45 GHz is thought of as a proper frequency for the application of power transmission between ground-to-ground, ground-to-space, and space-to-ground. However, for the space-to-space application the operating frequency can be increased to allow power transmission over much longer distances with the smaller antenna and rectenna.

Several antennas for CP radiation have been designed over the last few years using a circular ring, e.g., with stripline hybrid coupler feed at 2.45 GHz [8], with microstrip feed at 1.5GHz [9], and with coplanar waveguide and coaxial line feed at 2.45 GHz [10]. To the best of our knowledge, few rectenna for CP radiation have been proposed so far [11], [12]. Furthermore, these rectennas are intended for the operation at relatively high power densities. An annular ring-slot rectenna designed for low power densities and operating at 5.2 GHz was introduced in [13].

This paper presents a study of a 3X3 square patch antenna array with circular polarization and a V-shaped slot,designed as an RF receiver using CST microwave software. In this study, the design of the square antenna array was chosen because of its relevance in terms of power, size and directivity. The parameters discussed as follows include return loss, voltage standing wave ratio and radiation pattern.

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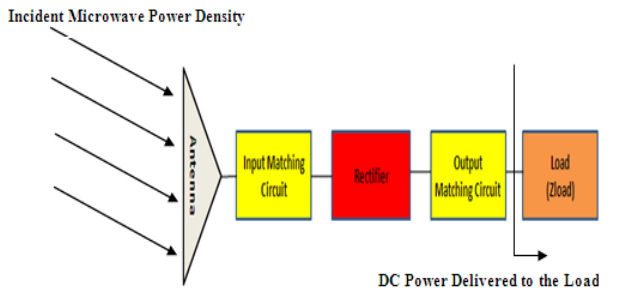

Figure 1. The Block diagram of the rectenna.

II Design Procedures

The antenna element is a square with an inclined slot in the center and V shaped slot at the corner. The slot technique is a way to obtain a circularly polarization. The antenna is feeding by a microstrip line having a characteristic impedance of 100Ω, this antenna was mounted on a FR4 substrate. The antenna dimensions are presented in Figure.2.

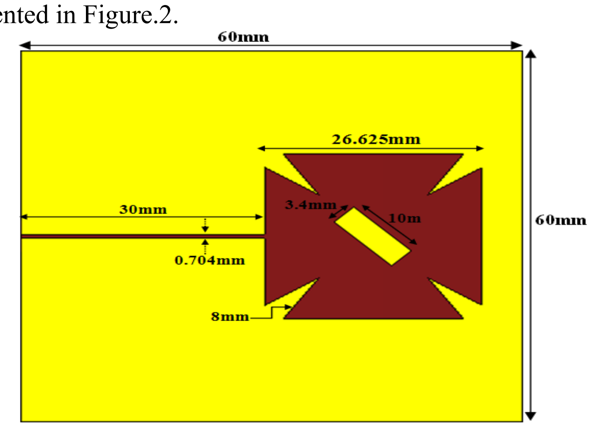

Figure.2: The square antenna structure

III Results and Discussion

3.1 Return Loss

The antenna is optimized and simulated by using CST Microwave Studio. The optimization was focused on the matching impedance and the slot dimensions. The substrate used in this conception is the FR4 substrate with:

- the relative permittivity $\varepsilon_r = 4.4$,
- the thickness $h = 1.58mm$
- and the dielectric loss $\tan(\delta) = 0.001$.

As shown in Fig.3, the S11 is equal to -21.52dB for the operating frequency 2.45 GHz which means good matching input impedance.

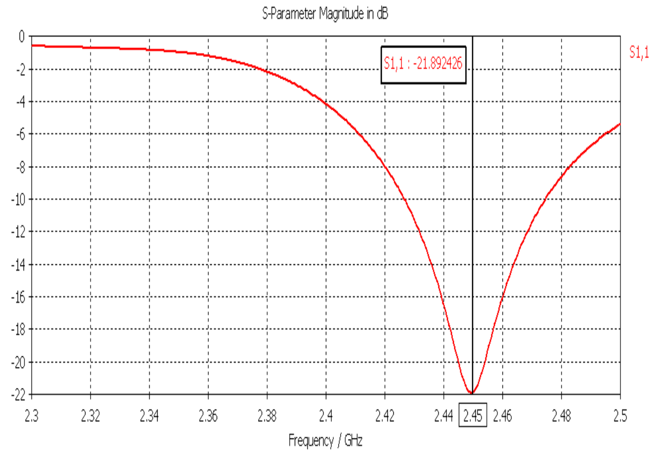

Figure .3: return loss vs frequency

3.2 Voltage Standing Wave Ratio

Fig. 4 shows the VSWR obtained, for 2.45 GHz it is 1.17, which is within the recommended range. The result obtained indicates that the transmitter and antenna is well matched. Maximum possible amount of energy is absorbed at the input terminal with a minimum reflected power.

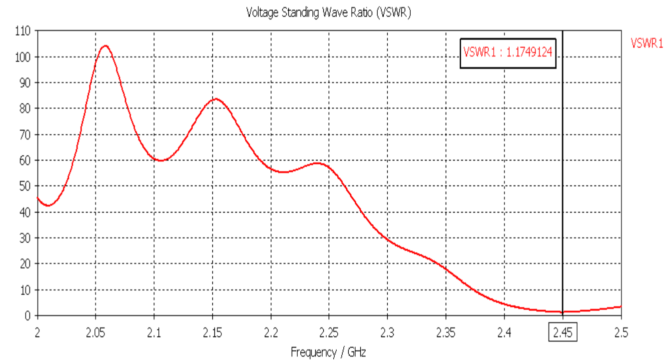

Figure.4: VSWR vs frequency

The Smith chart shown in Fig.5 indicates that the connection is well matched.

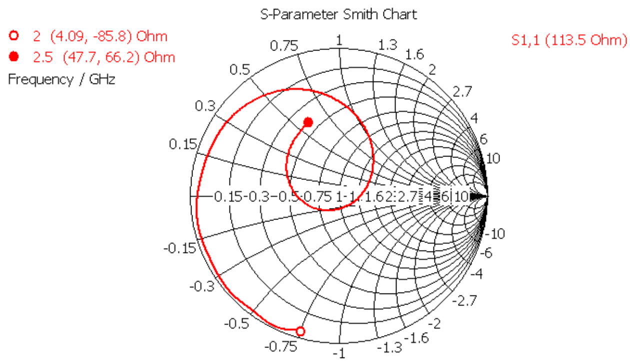

Figure.5: S (11) Smith chart

3.3 Radiation Pattern

Fig.6 presents the 3D radiation pattern with the structure below at 2.45 GHz. Fig.7 shows the polar view directivity of radiation pattern for simulation square patch antenna. The radiation pattern in the angular width (3dB) for theta component is 99.7° and main lobe direction is about 2.0 °.

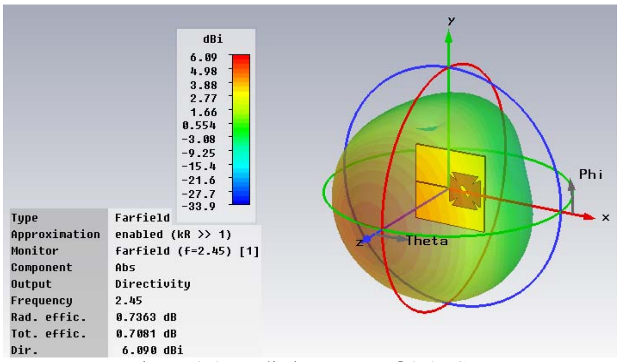

Figure.6: 3D radiation pattern @2.45 GHz.

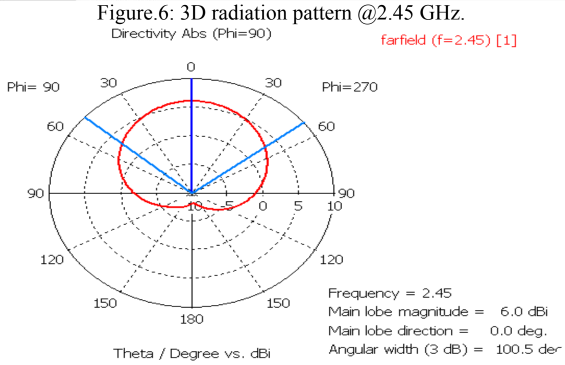

Figure.7: 2D polar radiation pattern @2.45 GHz.

IV Array Design

We have started from the elementary antenna optimized before; we arrived to model an array of six elements patches with the arrangement shown in fig.8, this new arrangement minimizes the effects of coupling and the generation of higher modes, also it can occupy a reduced area for such an antenna array of the same number of the elements.

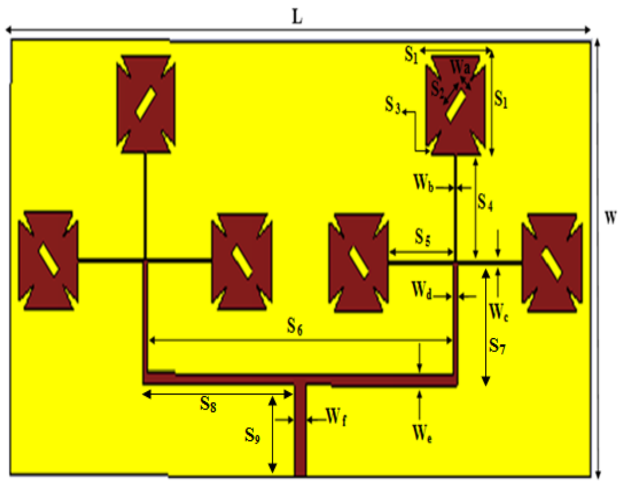

Figure.8: 3X3 slotted patches array .

The table.1 below shows the various parameters of the square patch antenna array developed. The characteristic impedances of the microstrip lines being used for feeding elements of the array is given in the following table.2.

TABEL.1:
ARRAY PHYSICAL DIMENSIONS

Parameters	W	W_a	W_b=W_c	W_d	We	W_f
Value(mm)	118.6	3.3	0.704	2.123	3.044	5.12
Parameters	L	S_1	S_2	S_3	S_4	S_5
Value(mm)	261.8	26.52	10	8	29.29	33.044
Parameters	S_6	S_7	S_8	S_9		
Value(mm)	137.87	33.04				

TABLE.2:
MICROSTRIP LINE IMPEDANCES

4Impedance	Z_c	Z_d	Z_e	Z_f
Value(Ω)	100	61.237	50	35.35

4.1 Return Loss

Fig.9 shows the S11 result of the developed array for the operating frequency at 2.45 GHz with return loss of -29.22dB.

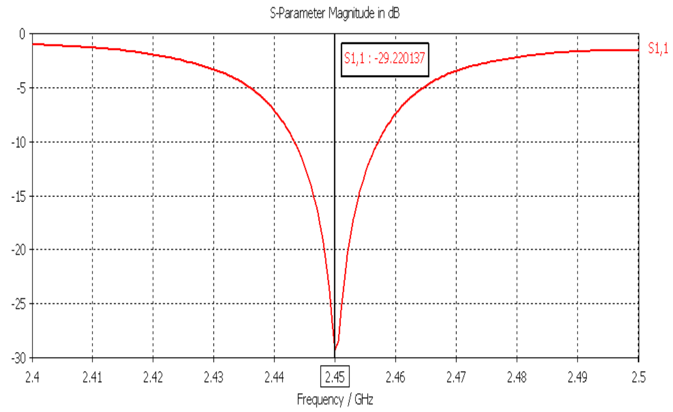

Figure .9: Simulation result for return loss for the 3X3 array

4.2 Voltage Standing Wave Ratio

As shown in Fig. 10 the VSWR obtained from the simulation at 2.45 GHz for the 3X3 array is 1.07, which is within the recommended range.

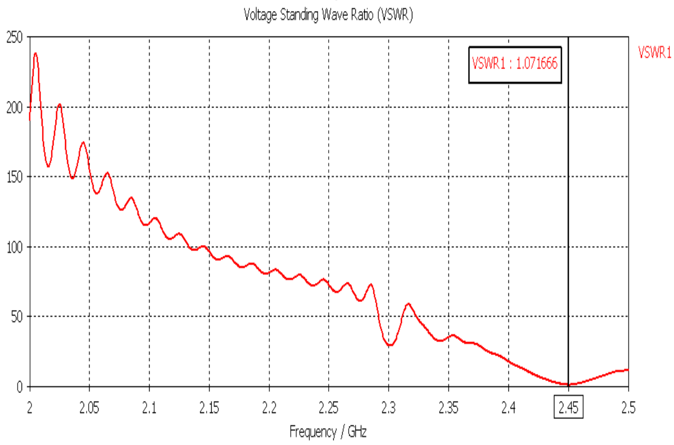

Figure.10. : 3X3 array Simulation result for VSWR.

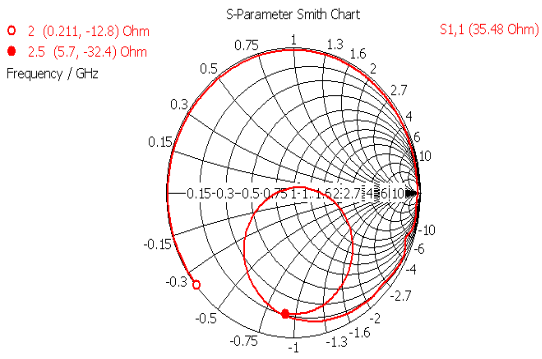

Figure.11: S(11) Smith chart

4.3 *Radiation Pattern*

The radiation pattern taken for the far-field at 2.45 GHz is indicated by the 3-D view in Fig. 12. The maximum normalized gain for simulation of 3x3 array square patch antenna that can be achieved is 9.153dBi.

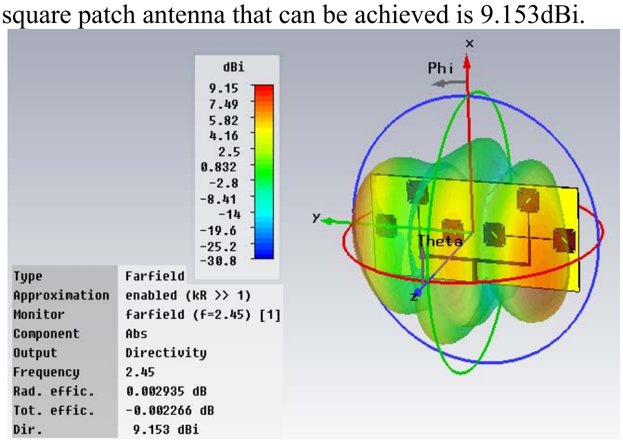

Figure.12: 3D radiation pattern for the antennas array @ 2.45 GHz

Fig.13 shows the polar view directivity of radiation pattern for simulation 3X3 array square patch antenna with 9.1 dBi of main lobe magnitude. The radiation pattern in the angular width (3dB) for theta component is 29.6˚ and main lobe direction is about 49.0 ˚.

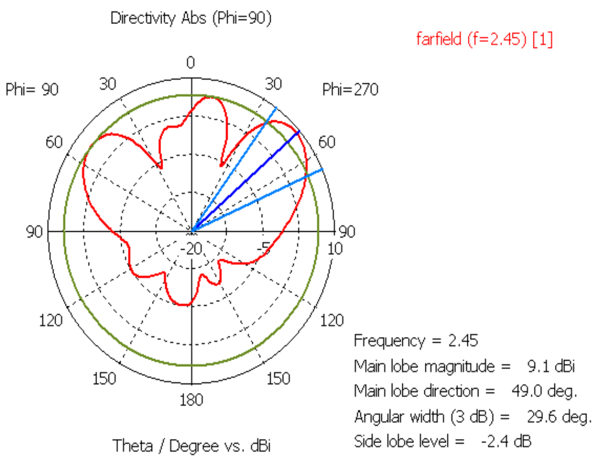

Figure.13: 2D polar radiation pattern @ 2.45GHz

The results indicate that the design has the ability to focus energy in a particular direction. However, which is perfectly suitable for wireless power transmission

CONCLUSION

This study permits to develop and validate array square antennas with circular polarization due to the use of the inclined slot in the center of the square patch. The array validated is then suitable for rectenna system which will permit to increase the efficiency of the RF-DC conversion system, by increasing the gain and directly increasing the received power at the input of the rectenna.

The array antenna optimized has been successfully designed and simulated using CST microwave software. The performance criteria extracted from the software includes return loss, VSWR and radiation pattern, provide clear indication that the array design is suitable for wireless power transmission. Hence, the research can be extended further for fabrication and testing of prototype as future work.

The procedure used in this study can be exploited for other frequency band suitable for wireless power transmission applications.

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