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A Novel Study of Semiconductor Material as a Substrate Layer for Microstrip Patch Antenna

Praveen Kumar E[1], Sundaravadivelu S [2]

[1]Department of ECE, SSN College of Engineering, Chennai, India
[2]Professor, Department of ECE, SSN College of Engineering, Chennai, India

***Abstract*— *This paper describes about the solarcell antenna which is an integrated device used for trans-receiving the RF signal and generates DC voltage simultaneously. Solarcell Antenna consists of Microstrip patch antenna and Solarcells, during integration various parameters of antenna such as substrate (dielectric materials used), shape of the patch, dimensions of feed are to be obtained for desired frequency range. Different shapes of patches, dielectric materials are taken into account and compared with the results in which Microstrip Patch model suits the best for 2.4GHz frequency. We have integrated Solarcells and Microstrip patch antenna using CST Microwave studio software so that it can act as stand-alone system in remote places for various applications such as disaster alert system, moving vehicles, remote sensing, and meteorological surveillance.*

Keywords*— *Solarcell antenna, Microstrip patch antenna, Solarcells..

I. INTRODUCTION

Electrical energy is used as a source requirement for the use and operation of wireless communication. Applications like environmental monitoring system, remote sensing and disaster alert system, needs a net-independent power supply which is preferably reliable by use of renewable energy i.e., photovoltaic cell, an advanced technology distinguished by reliability, longevity and eco-friendliness [1]. Besides that antennas requires to receive or transmit electromagnetic waves. Solar cell generator or photovoltaic cells and antenna are individual devices. Integrating them into a single system produces more compactness by reducing the space, cost and also acts as stand-alone system which has higher radiation energy. Even one solar cell can be used for the conversion of solar radiation to produce electrical energy. The electrically conductive contacts of the solarcell are simultaneously used as an antenna for transmission or reception of electromagnetic waves [2]. In this, solar cell is sandwiched between the platforms of radiating patch and ground plane.

II. USAGE OF PHOTOVOLTAIC CELLS IN MICROSTRIP PATCH ANTENNA DESIGNS

2.1 Equivalent circuit of Microstrip Patch and Solarcell Antenna

In order to provide higher gain and efficiency, the substrate material used in Microstrip patch antenna should be lossless as possible. Numerous measurements have shown, in that RF point of view the solarcell and Microstrip patch antenna are nearly to be equal. The equivalent circuit comparison of Microstrip patch antenna and Solarcell are represented in the figure 1.

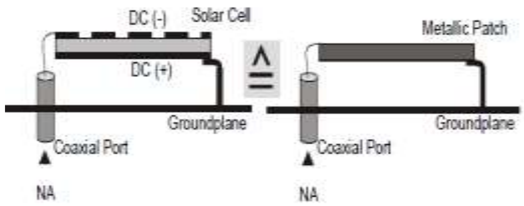

Fig. 1: Equivalent circuit of Microstrip patch antenna and Solarcell

To know whether the dielectric layer (insulator) of Microstrip patch antenna can be replaced by solarcells (semi-conductor) detailed study is done. The electromagnetic interference and back-off current from solarcells into feed of the antenna can be avoided by common ground [3], [4]. Insulation layer is added between solarcells and patch such that the above mentioned problems can be neglected [5], [6].

2.2 Design for Microstrip patch antenna

2.2.1 Rectangular Patch Antenna: The 2-D view of Rectangular Microstrip patch antenna is shown in the figure 2. To determine the width (W) and length (L) of the Rectangular Microstrip patch antenna [7], [8], we can directly substitute the resonant frequency (f_r), height of the substrate (h), and substrate dielectric constant (ε_r) values into the equation (1). The width (W) of the Rectangular Microstrip patch antenna is obtained.

$$W = \frac{C}{2 f_r \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (1)$$

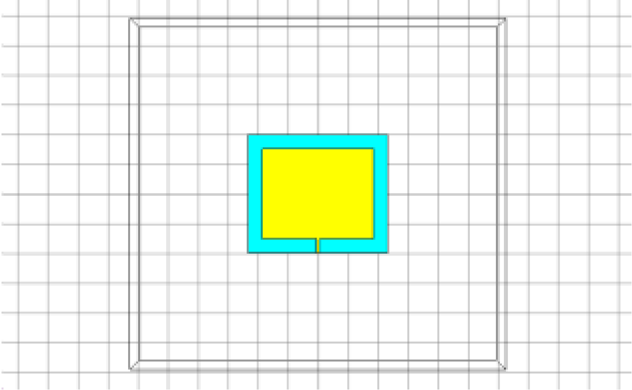

Fig. 2: 2-D view of Rectangular Microstrip patch antenna

Length (L) of Rectangular Microstrip patch antenna can be found by substituting the width (W), resonant frequency (f_r), height of the substrate (h), substrate dielectric constant (ε_r) values into the equation (2) to get effective dielectric constant (ε_{eff}) which is determined as:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (2)$$

and equation (3) gives effective length (L_{eff}),

$$L_{eff} = \frac{C}{2 f_r \sqrt{\varepsilon_{reff}}} \quad (3)$$

Further substituting in equation (4) we get the extended length (ΔL).

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.3)\left(\frac{W}{h} + 0.8\right)} \quad (4)$$

Henceforth, the actual length of the Rectangular Microstrip patch antenna is

$$L = L_{eff} - 2\Delta L \quad (5)$$

Further optimization is done in dimensions of patch to produce better performance.

2.2.2 Circular Patch Antenna: The 2-D view of Circular Microstrip patch antenna is represented in the figure 3. The area (a) of Circular Microstrip patch antenna is obtained by substituting the resonant frequency (f_r), height of the substrate (h), and substrate dielectric constant (ε_r) values into equation (6),

$$a = \frac{f}{\left\{1 + \frac{2h}{\pi\varepsilon_r f}\left[\ln\left(\frac{\pi f}{2h}\right) + 1.7726\right]\right\}^{\frac{1}{2}}} \quad (6)$$

Effective Area (a_e) can be determined using equation (7)

$$a_e = a\left\{1 + \frac{2h}{\pi\varepsilon_r a}\left[\ln\left(\frac{\pi a}{2h}\right) + 1.7726\right]\right\}^{\frac{1}{2}} \quad (7)$$

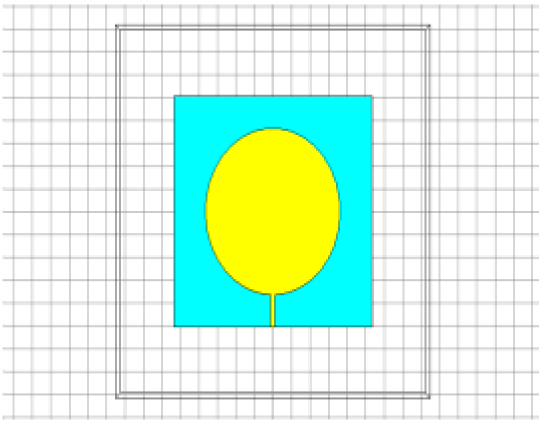

Fig. 3: 2-D view of Circular Microstrip patch antenna

Substituting effective area (a_e) value in equation (8), we get the area of the circle which is further more optimized in

$$f_r = 1.8412 \times \frac{C}{2\pi a_e \sqrt{\varepsilon_r}} \quad (8)$$

dimensions of the patch to yield high performance characteristics of the antenna [6].

2.2.3 Square Patch Antenna: The area (a) of the square patch is determined by considering rectangular microstrip patch antenna width (square - all sides are equal, rectangle- opposite sides are equal so W=a). Substituting the known resonant frequency (f_r), substrate dielectric constant (ε_r), height of the substrate (h) into equation (1) to get the area of Square Microstrip patch antenna which is further more optimized for its dimensions to get better antenna performance[7], [8]. The 2-dimensinal view of the Square Microstrip patch antenna is represented in the fig. 4.

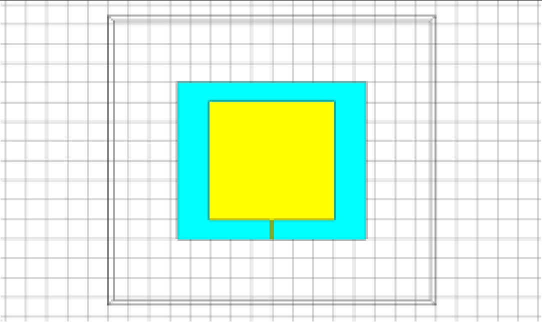

Fig. 4: 2-dimensinal view of Square Microstrip patch antenna

III. SUBSTARTE SPECIFICATION

Multilayered substrate is considered to perform both RF and DC production simultaneously. A solarcells or Photovoltaic cells of 55x85mm dimension, which consists of 8 cells in serial combination in order to produce 6V [3], [4]. To avoid the electric conductivity between patch of antenna and solarcell insulating material should be used. In order to attain high optical transparency such that solarcell efficiency is increased by transparent insulating material called as PMMA (Poly Methyl Methacrylate).

IV. SOLARCELL MICROSRIP PATCH ANTENNA

First, three different shapes of patch antenna such as square, circle and rectangle is considered. Next, Microstrip patch antenna is simulated for these different patches using a standard substrate FR-4 and observed their characteristics. Later by changing the substrate material to PMMA antenna parameters are analyzed. The table 1 shows the detailed design specification consideration of Rectangular Microstrip patch antenna.

Table.1: Design specification of Rectangular patch

Parameters	Specification
Substrate material	PMMA
Dielectric constant	2.8-4
Substrate thickness	1.6mm
Patch thickness	0.035mm
Ground material	copper
Width of Patch	37mm
Length of Patch	30.11mm
Feed width	1.45mm
Feed length	-22.71mm

The table 2 shows the detailed design specification of Circular Microstrip patch antenna. The table 3 shows the detailed design specification of Square Microstrip patch antenna. From the comparison table, it is clear that rectangular patch antenna showed S11(dB)-17.48, directivity(dBi)-5.31, gain(dB)-4.78, bandwidth(%) -8.71 during PMMA as substrate material. Circular and square patch antenna showed lower performance. Table 4 illustrates the comparison between different patch.

Table 2: Design specification of Circular patch

Parameters	Specification
Substrate material	PMMA
Dielectric constant	2.8-4
Substrate thickness	1.5mm
Patch thickness	0.035mm
Ground material	copper
Area of Patch	36.5mm
Length of Patch	30.11mm
Feed width	1.45mm
Feed length	-18mm

Circular and square patch antenna showed lower performance. Table 4 illustrates the comparison details of different patch.

Table.3: Design specification of square patch

Parameters	Specification
Substrate material	PMMA
Dielectric constant	2.8-4
Substrate thickness	1.6mm
Patch thickness	0.035mm
Ground material	copper
Area of Patch	37mm
Feed width	1.45mm
Feed length	-22.71mm

From the comparison table results, S11 parameters for different patches are plotted and represented using figure 5. Rectangular Microstrip patch Solarcell antenna is designed by integrating Rectangular Microstrip patch antenna by adding solarcells.

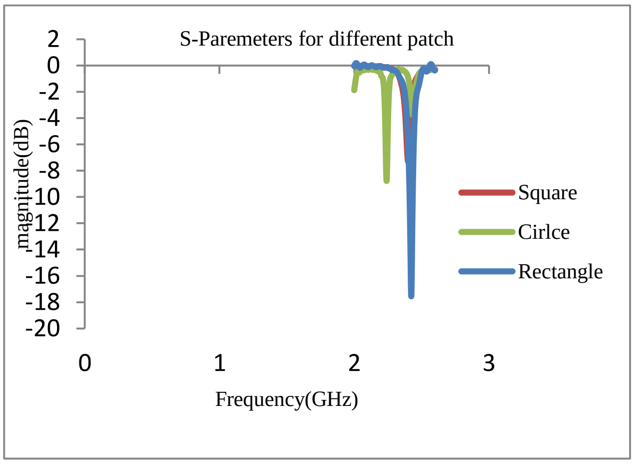

Fig. 5: S11 parameters for different patche

Table.4: Comparison table of different patch

Patch Shapes	S11 (dB)	Directivity (dBi)	Gain (dB)	Bandwidth
Rectangular	-17.48	5.31	4.78	8.71
Circular	-8.78	4.43	3.81	1.77
Square	-7.28	3.95	3.5	2.15

V. RESULTS AND DISCUSSION

Microstrip patch antenna for various shapes of patch and substrate material is compared and from the comparison it is concluded that Rectangular Microstrip patch antenna has higher performance. The 2-D view of Rectangular Microstrip patch Solarcell antenna is represented in the figure 6. Design specification of Rectangular Microstrip patch solarcell antenna is shown in the table 5. S11 parameters plot of Rectangular Microstrip patch solarcell antenna is shown in the figure 7. Obtained results from the design of Rectangular Microstrip patch solarcell antenna is tabulated in table 6. Block diagram of Rectangular Microstrip patch Solarcell antenna is represented in the figure 8. The designed Rectangular Microstrip patch Solarcell Antenna produces 6V.

Table.5: Design specification of Rectangular microstrip patch solarcell antenna

Parameter	Specification
Substrate Material(layer1)	Solarcell (55x85mm)
Substrate Material(layer2)	PMMA
Dielectric constant(layer 1)	4.3
Dielectric constant(layer 2)	2.8-4
Substrate Thickness(layer1)	2.3mm
Substrate Thickness(layer2)	1.6mm
Patch thickness	0.035mm
Ground material	copper
Width of patch	37.80mm
Length of the patch	28.80mm
Feed width	0.7mm
Feed length	-7.5mm

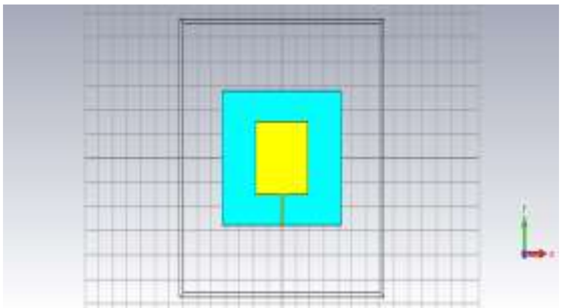

Fig. 6: 2-D view of Rectangular Microstrip patch Solarcell Antenna

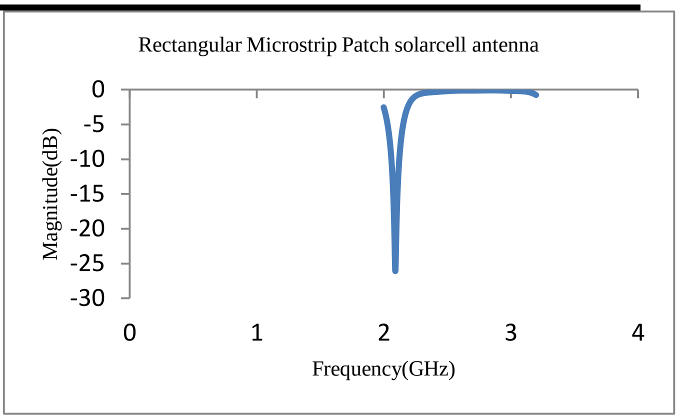

Fig. 7: S11parameters of Rectangular Microstrip patch Solarcell Antenna

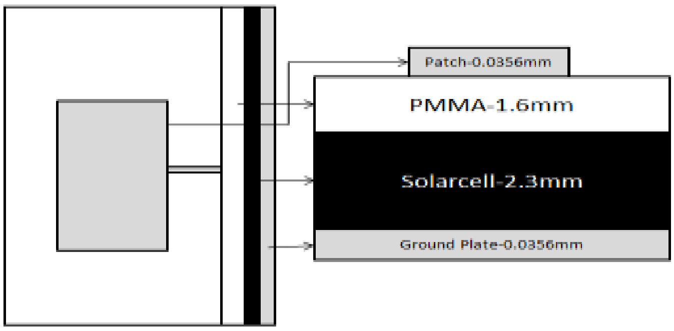

Fig. 8: Block diagram of Rectangular Microstrip patch Solarcell Antenna

Table.6: Results of Rectangular Microstrip patch Solarcell antenna

Patch Shapes	Rectangular
S11(dB)	-25.67
Directivity(dBi)	7.09
Gain(dB)	6.45
Bandwidth	6.531

VI. CONCLUSION

Different shapes of microstrip patch such as circular, rectangle and square are realized using substrate material as PMMA are compared and its performance is analysed. By comparing the different patches, Rectangular patch antenna shows the better performance such as high directivity, gain and bandwidth. So, Rectangular patch antenna is considered for designing solarcell antenna. Shift in frequency, high gain and directivity are inferred from the proposed antenna, if solarcell is used along with PMMA as substrate materials. The scope of remote communication is increasing more and more, so it is insufficient to feed electricity through grid for remote access. In such places, solarcell antenna will be more compact as well as can act as stand-alone system without any maintenance. The scope of Solarcell antenna increased day by day. Energy of solarcell can be increased by forming array based on serial combination of solarcells. Optically transparent patch antenna can be designed to avoid malfunctioning of solarcells. Two or more patch can be added together to form array for MIMO communication and IOT (Internet of Things) Technology.

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