Analysis of Performance on Ultra Wideband Circular Patch for Solar Cell Antenna Design

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Analysis of Performance on Ultra Wideband Circular Patch for Solar Cell Antenna Design

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Abstract. In this paper, a design of Ultra Wide-Band microstrip antenna based on circular microstrip patch for solar cell is proposed. In solar antenna design, researchers used several types of substrates materials in constructing the antenna. Two types of substrates that analyze and study by the researcher are Polyimide and Poly (methyl methacrylate) polymer matrix substrates. For this specific research study, the designed and analyzed methodology is conducted using CST microwave studio software using two types of substrates which are polyimide (Lossy) with dielectric constant equal to $\varepsilon r = 3.5$ and Poly(methyl methacrylate) polymer matrix with dielectric constant equal to $\varepsilon r = 4.9$. This analysis is to compare the bandwidth performance of polyimide and Poly (methyl methacrylate) polymer matrix substrate that been use in solar antenna's studies by many researches. For these types of research analysis, the aim of this study specifically to have a material that gives high performance in bandwidth. Choosing of suitable material as the substrates also one of the ways to improve the antenna design performances. Broader bandwidth will have the capability to transfer higher data rates. Performances characteristics of the microstrip circular patch antenna of each of the substrates materials designs are also obtained and compared.

1. Introduction

In order to synchronous with the rapid growth in wireless communication systems, a huge demand in wideband antennas designs to satisfy high gain and large bandwidth for the high capability to transmit and receives big data rates. Ultra-wideband (UWB) technology was released in February 2002 by the Federal Communication Commission's (FCC), to cover the frequency band 3.1–10.6 GHz [1].

Solar cell generator and antenna are two different devices. Integrating them into a single system need to follow several requirements such as area, cost, and the most important is to be a stand-alone system which is reliable and function as it is [2]. Research and development on radio frequency harvesting, renewable energy, and solar cell antenna design currently high in demand.

Microstrip patch antenna is well-known to have limitation in impedance bandwidth. In previous research papers, bandwidth performance of a circular patch antenna with PMMA substrates gives 1.77% in [2]. Rectangular polyimide loop antenna design was found to have a -10dB impedance bandwidth of approximately 350MHz in [5]. Microstrip patch is the popular design and widely used by many researchers for several reasons which are low in profile, light in weight, simple in design development and optimization, and planar structure [6]. In solar antenna design, researchers used several types of substrates materials in constructing the antenna.

In this study, the objectives are to design an antenna with different substrates and to compares the bandwidth performance which gives broader bandwidth for the capability to transmits and receives high data rates. Two types of substrates that analyze and study by the researcher are Poly (methyl methacrylate) PMMA polymer matrix [2] and Polyimide [4]. Thus, the bandwidth performances are compared based on two substrates and materials that provide broader bandwidth performance is presented.

2. Research Methodology

2.1. Identification of Project Requirement.

Design requirements under this analysis are to have a circular shape microstrip patch antenna design with two types of substrates materials which are Polyimide with a dielectric constant value equal to 3.5 and PMMA with a dielectric constant value equal to 4.9. The simulation of a patch antenna is done using CST microwave studio software.

2.2 Related formulas and calculation

In designing circular patch antenna [3], there is only one degree of freedom to control which is the radius of the patch. Formulae of radius is given by

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

Where,

$$F = \frac{8.791 \: x \: 10^9}{f_r\sqrt{\varepsilon_r}} \quad (2)$$

This equation 1 is ignoring the fringing effect. For circular patch antenna with substrates dielectric constant, and thickness, h = 1.6mm, the effective radius considered is given by equation 3.

$$a_{e=} \, a\left\{1+\frac{2h}{\pi\varepsilon_r a}\left[\ln\left(\frac{\pi a}{2h}\right) + 1.7726\right]\right\}^{\frac{1}{2}} \quad (3)$$

Thus, effective radius is calculated using equation 3.

3. Antenna Design

Design requirements under this analysis are to have a design with two types of substrates materials which are Polyimide with a dielectric constant value equal to 3.5 and PMMA with a dielectric constant value equal to 4.9 and thickness of the substrate is 0.76mm. Parameter involves as table 1 below.

Table 1: Circular patch design measurement

Parameters		Measurement (mm)
Patch radius	a	8
Length of the feed line	Ps	7
The height of the patch	hp	0.07
The height of the substrate	hs	0.76
Width of gap	Wg	2.4
The width of the feed line	Ws	1.0

The proposed design circular microstrip patch antennas are shown in figure 1 and figure 2.

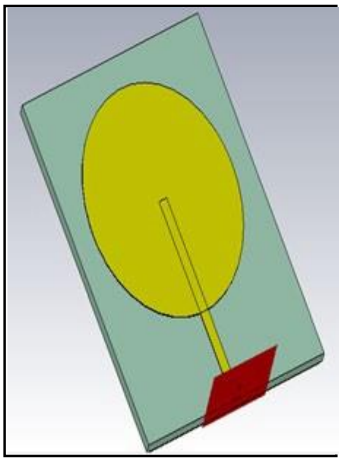

Figure 1. Circular microstrips patch 3D-design.

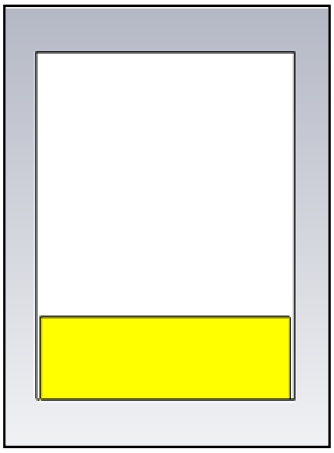

Figure 2. Circular microstrips patch back-view; partial Ground Plane

4. Simulation results

4.1 Polyimide substrate

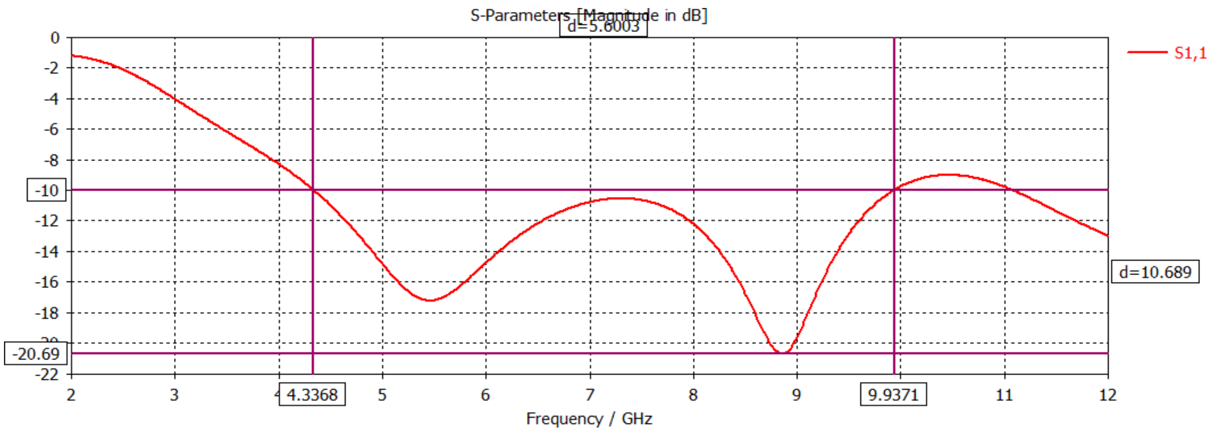

Figure 3. Return Loss S11

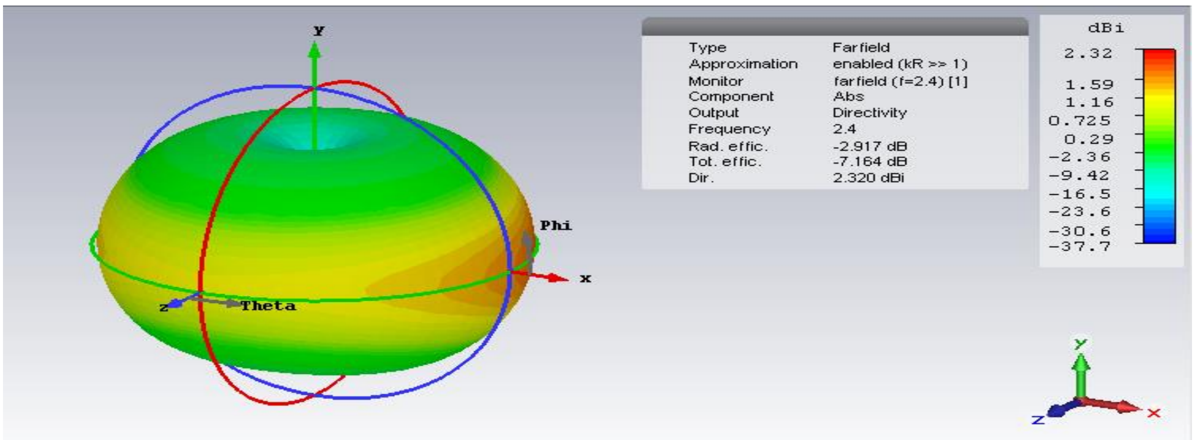

Figure 4. Farfield Directivity Abs in 3D-View.

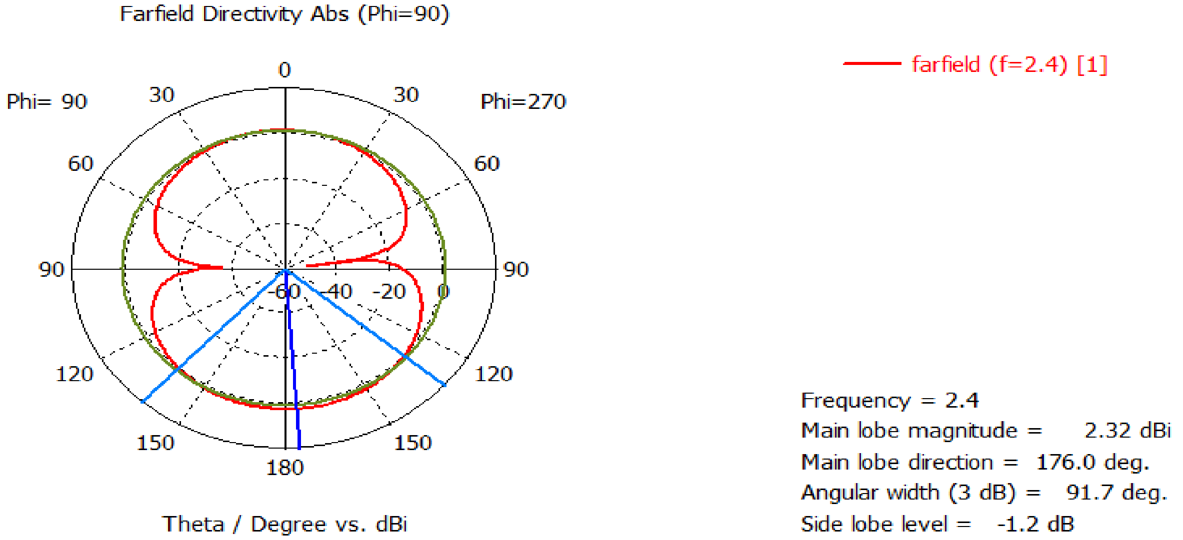

Figure 5. Farfield Directivity Abs in Polar Form.

4.2 Poly (methyl methacrylate) PMMA polymer matrix substrates

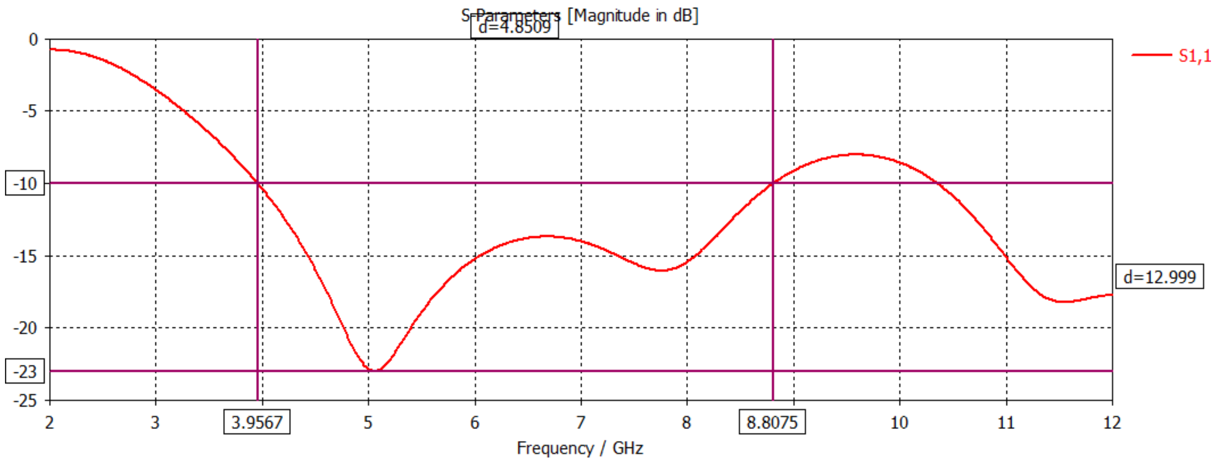

Figure 6. Return Loss S11.

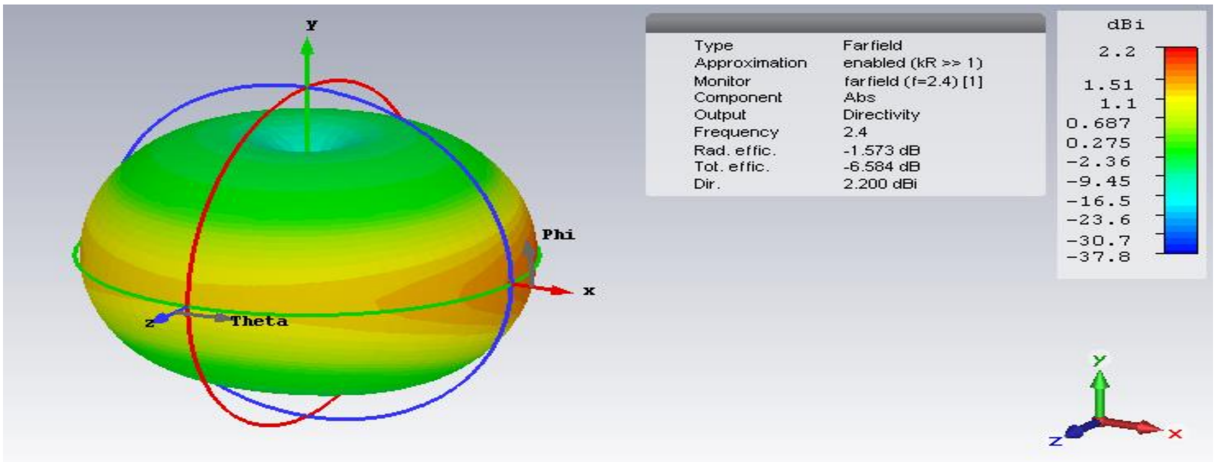

Figure 7: Farfield Directivity Abs in 3D-View.

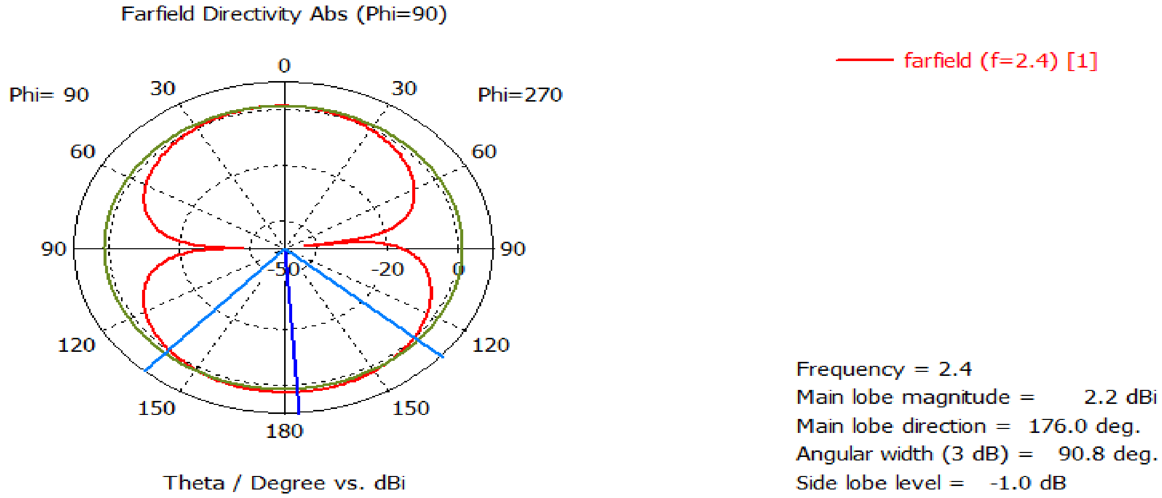

Figure 8. Farfield Directivity Abs in Polar Form.

5. Discussion

Figure 9 shows the simulated return loss for the ultra-wideband antenna using a circular patch by stripe line-feed of both substrates.

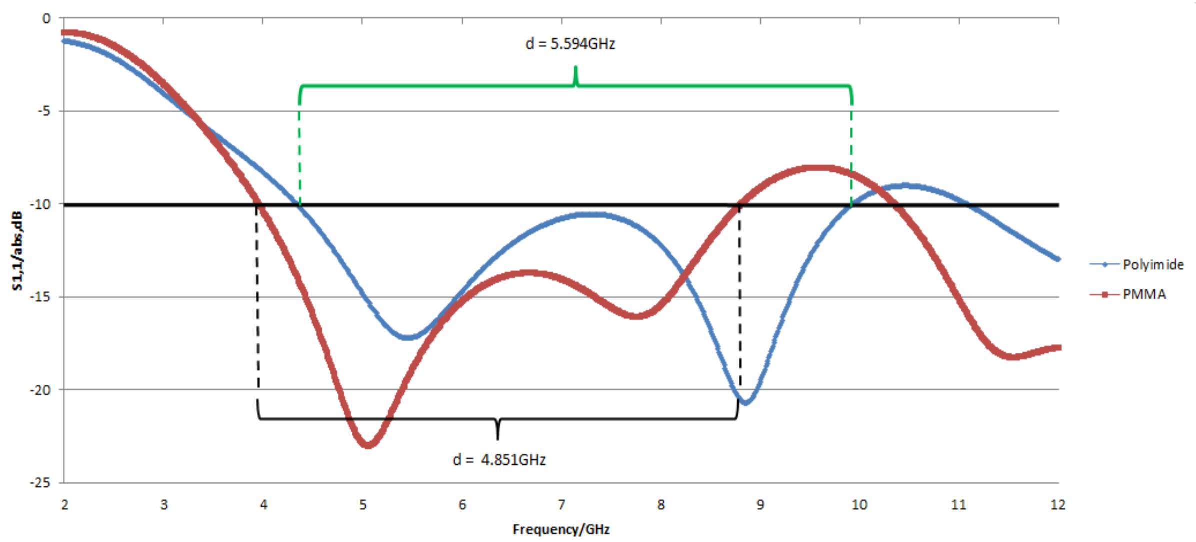

Figure 9. Comparison of S_{11} performances.

From the results, for polyimide substrate, the frequency range obtained for return loss less than -10dB is started form 4.3368GHz to 9.9371GHz which gives 5.6GHz for bandwidth. On the other hands, for PMMA substrate, the frequency range obtained for return loss less than -10dB is started form 3.9567GHz to 8.8075GHz and gives an output of 4.851GHz in bandwidth. The polyimide substrates produced 5.594GHz of bandwidth, meanwhile, for PMMA substrate; the antenna produced 4.851GHz of bandwidth, and thus, polyimide gives broader bandwidth compared to PMMA as substrates. Both of the bandwidth's results satisfy the UWB as defined by FCC. Results comparison of others performances tabulated for both substrates in Table 2 below.

Table 2: Comparison of performances

1D Results / S-parameters	Substrates	
	Polyimide	PMMA
Return Loss, S_{11}(dB)	-20.7	**-22.3**
Directivity (dBi)	**2.32**	2.2
Gain (dB)	0.49	**1.87**
Bandwidth (GHz)	**5.6**	4.85
Side lobe level (dB)	-1.2	-1.0

The PMMA substrate has better result for return loss S11 compared to Polyimide. The PMMA substrate provides -23dB, whereas Polyimide only -20.7dB. For the directivity performance, Polyimide and PMMA shows very close results to each other with 2.32dBi and 2.2dBi respectively. PMMA has 1.87dB of gain, higher than polyimide. The less side lobe level, the better result achieved, thus, the PMMA gives the lowest side lobe level compared to the polyimide in this design analysis.

6. Conclusion

Ultra Wideband (UWB) microstrip antenna based on circular patch antenna design integrated with solar cell has been designed, simulated and discussed. From the results above, polyimide provides 15 % wider bandwidth instead of PMMA substrates; therefore, an UWB circular patch solar cell antenna design with polyimide as the substrates has the high capability to transmit and receives big data rates for Wi-Fi application.

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