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PERFORMANCE EVALUATION OF MICROSTRIP SQUARE PATCH ANTENNA ON DIFFERENT SUBSTRATE MATERIALS

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Abstract

The demand of small size electronic systems has been increasing for several decades. The physical size of systems is reduced due to advancements in integrated circuits. With reduction in size of electronic systems, there is also an increasing demand of small and low cost antennas. Patch antennas are one of the most attractive antennas for integrated RF front-end systems due to their compatibility with microwave integrated circuits. To fulfill the demand of integrated RF front-end systems, a design of micro strip patch antenna for 60GHz microwave applications has been introduced. This antenna maintains a maximum gain of 7.91dB for far field region with respect to paraboloidal rectangular aperture antenna. It is actually a coaxial probe fed antenna for impedance matching with 50 ohms coaxial cable. This antenna works well in the frequency 60GHz with a maximum at 60.15GHZ. It is basically a low cost, light weight, medium gain and narrow band antenna for microwave applications such as a feeding element for other antennas and in research institutes as a reference antenna. It can also be used at the output of signal conditioning circuit for receiving signals from micro electromechanical sensors.

Keywords: Square patch, substrate materials.

1. INTRODUCTION:

Communication using electromagnetic radiation (expect for light) began early in last century. Most of the early systems used very long wavelengths (low frequencies), which travelled great distances. Later it was discovered that higher frequencies could bring other advantages to communications. Microwaves are easier to control (than longer wavelengths) because even small antennas could direct the waves very well. This control leads to confinement of energy into a tight beam (expressed as narrow beam width). This beam can be focused on another antenna dozens of miles away, making it very difficult for someone to intercept the conversation.

Microwaves are commonly used in various aspects of everyday life. At microwave frequencies the physical size of high gain antenna becomes small enough to make practical the use of suitably shaped reflectors to produce the desired directivity [1]. Nowadays for various commercial applications such as short range transmission of signals, medical applications, mobiles and laptops there is requirement of an antenna which consumes very less space and can be mounted easily in the equipment and still have efficient directive radiation pattern. One such antenna design, which is very famous these days, is micro strip patch antenna [2].

Micro strip antennas have been used in many civilian and government applications

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despite of their advantages and disadvantages. Sometimes disadvantages are counted as advantage e.g., for narrow band applications the antenna itself can act as a filter for unwanted frequency components, so small bandwidth is counted as an advantage. Micro strip antennas include Wireless Personal Area Network (WPAN) and good performance in antenna technology and low cost. Different techniques have been suggested to achieve antenna integration within a single chip [3].

In this paper a simple design of micro strip patch antenna at 60GHz applications is proposed. Micro strip patch uses conductive strips or patches formed on the top surface of a thin dielectric substrate separating them from a conductive layer on the bottom surface of the substrate and constituting a ground for the antenna [4]. A patch is typically wider than a strip and its shape and dimensions are important features of the antenna.

2. DESIGN CONSIDERATIONS:

A micro strip antenna in its simplest form consists of a sandwich of two parallel conducting layers separated by a single thin dielectric substrate. The lower conductor functions as a ground plane and the upper conductor functions as radiator [5]. The simplest patch antenna uses a half wavelength long patch and a larger ground plane. Larger ground plane gives better performance but of course makes the antenna bigger. Among different shapes of micro strip patch elements such as rectangular, square, dipole, triangular, circular and elliptical for better radiation characteristics we use rectangular micro strip patch antenna. The resonant length of the antenna determines the resonant frequency [6]. The patch is in fact electrically a bit larger than its physical dimensions due to the fringing fields. The deviation between electrical and physical size is mainly dependent on the PCB thickness and dielectric constant. The patch that introduced here has been made of conducting material copper. The design parameters define the operation and performance of the patch antenna [7]. In this paper the patch dimensions taken along X-axis and Y-axis is 0.15 cm and the substrate dimensions taken along X-axis and Y-axis is 1 cm respectively. The substrate thickness is 0.03 cm. The feed location along X and Y axis are 0 and 0.05 respectively. The coaxial inner and outer radius is 0.004 and 0.014 respectively and coaxial feed length is 0.04 cm. For good performance, a substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation.

The design also checks for maximum power transfer by matching the feed line impedance to the impedance of the patch antenna [8]. The different feeding techniques used for impedance matching are micro strip line, coaxial probe, Proximity coupling and aperture coupling. Micro strip line: In this Impedance matching is easier. And feed can be fabricated on some substrate as single layer to provide planner structure. But disadvantage is we must use transformer to match impedance and it excites cross polarization. Coaxial probe: Probe location is used for impedance matching. Ease of insetting and low radiations is advantages of probe feeding. Proximity coupling: Proximity coupling offers some opportunity to reduce feed line radiation while maintaining a relatively thick substrate for the radiating patch [9]. The input impedance of antenna is affected by the overlap of the patch and the feed line, and by the substrates. However due to multilayer fabrication the antenna thickness increases. Aperture coupling: No spurious radiation escapes to corrupt the side lobes or polarization of the antenna. However due to multilayer fabrication antenna, thickness increases [10].

Among this coaxial probe is used for impedance matching, as it is ease of insetting and low radiation and also used with plated for multi layer circuits. Micro strip antennas are versatile in the sense that they can be designed to produce a wide variety of patterns and polarizations, depending on the mode excited and the particular shape of the patch used [11].

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3. FABRICATION METHODOLOGY:

Various techniques are available for fabrication of micro strip patch antenna. . If the substrate is flexible, conformal antennas are possible. Feed line and matching networks are fabricated along with antenna structure. The fabrication of strip antenna was designed using Auto CAD. Etching is done with the standard photolithographic processes. In order to transfer the mask image on electro plated copper PCB board photolithography technique was used. The cut size pieces of PCB sheets were cleaned to remove the surface impurities using organic solvents and then dried with hot air gun before coating the positive photo resist (PPR) on it. The PPR coated substrate was pre-baked in an oven at 90 degrees to remove the solvent and stuffing the film. The baked substrate was exposed on indigenously developed mask aligner with inbuilt exposure system and mask as prepared earlier [12]. The accuracy of etching process also ensures uniformity of different parts over a production run. The main reason for using micro strip patches is the ability to construct array antennas with the feed network and the radiating elements on a single surface. This arrangement means that the antennas are fed by a micro strip connected directly to the patch [13].

Substrates:

Different substrate materials are used in this present simulation work and their properties are mentioned as follows. Benzocyclobutene (BCB): BCB is frequently used to create photosensitive polymers. BCB-based polymer dielectrics may be spun on or applied to various substrates for use in Micro Electro-Mechanical Systems (MEMS) and microelectronics processing. Applications include wafer bonding, optical interconnects, low-K dielectrics, or even intracortical neural implants. DiClad laminates are woven fiberglass/PTFE composite materials for use as printed circuit board substrates [14]. Using precise control of the fiberglass/PTFE ratio, DiClad laminates offer a range of choices from the lowest dielectric constant and dissipation factor to a more highly reinforced laminate with better dimensional stability. DiClad laminates are frequently used in filter, coupler and low noise amplifier applications, where dielectric constant uniformity is critical. They are also used in power dividers and combiners where low loss is important. RT/duroid 5880LZ filled PTFE composites are designed for exacting stripline and microstrip circuit applications. The unique filler results in a low density, lightweight material for high performance weight sensitive applications. The very low dielectric constant of RT/duroid 5880LZ laminates is uniform from panel to panel and is constant over a wide frequency range. Applications include airborne antenna system, Lightweight feed networks, Military radar systems, Missile guidance systems and Point-to-point digital radio antennas.

4. SIMULATION RESULTS:

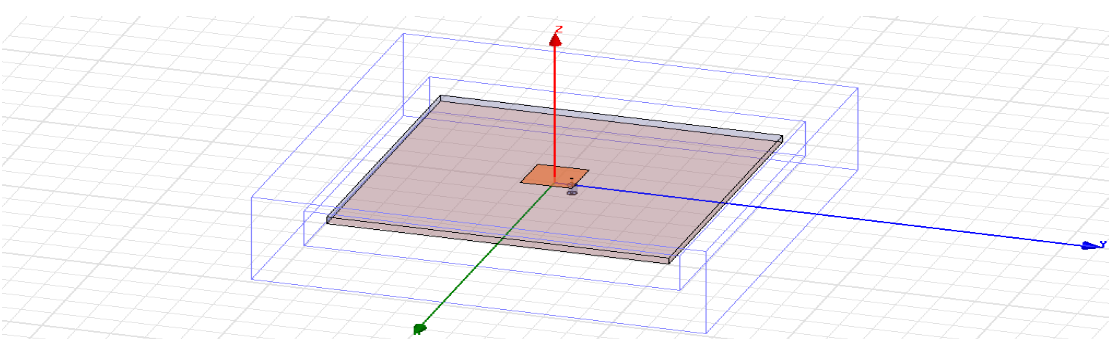

Figure (1) Ansoft-HFSS Generated Square patch model

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Figure (1) shows the Ansoft-HFSS generated model for microstrip square patch array antenna. Different substrate materials are considered and simulated by placing them on the proposed model at 60GHz. The table (1) shows the physical parameters of different substrate materials.

Substrate material	Dielectric constant (ϵ_r)	Frequency f_r (GHz)	Effective dielectric constant (ϵ_{eff})	Loss tangent value (δ)
RT-Duroid-5880	2.2	60	2.1144	0.0011
RT-Duroid-5870	2.33	60	2.2352	0.0011
Neltec NX 9240	2.4	60	2.3002	0.0010
Arlon Diclad 522	2.5	60	2.3931	0.0010
Benzocyclobuten	2.6	60	2.4859	0.0010

Table (1) Substrate materials with Permittivity

Return loss curve

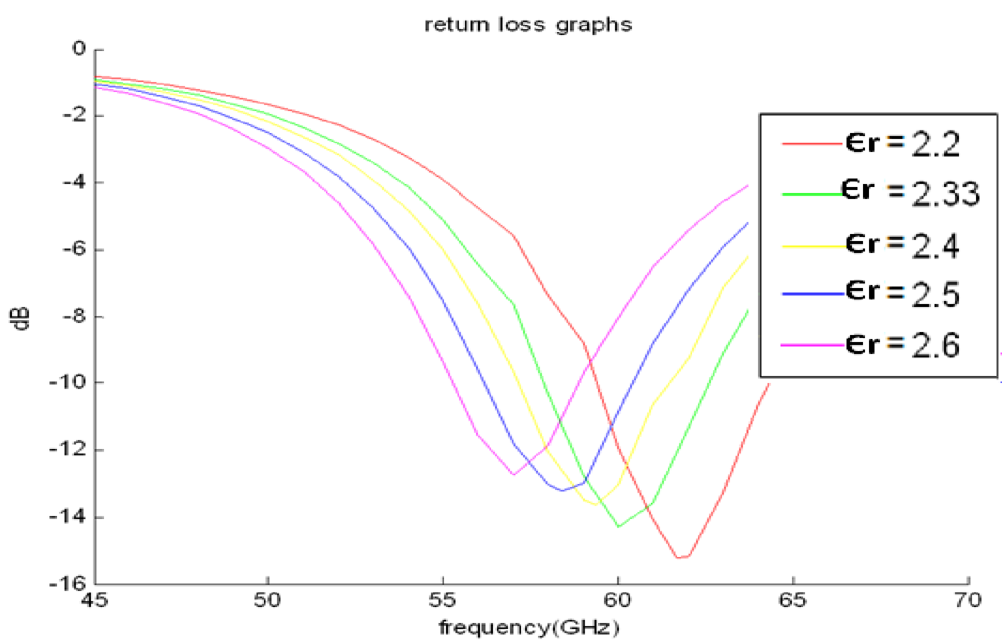

Figure (2) Return loss

The return loss values obtained for different substrate materials with different dielectric constants 2.2, 2.33, 2.4, 2.5, 2.6 are -15.23dB, -14.30dB, -13.82dB, -13.21dB and -12.74dB respectively. All the values are having the return loss of <-10dB.

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VSWR graphs:

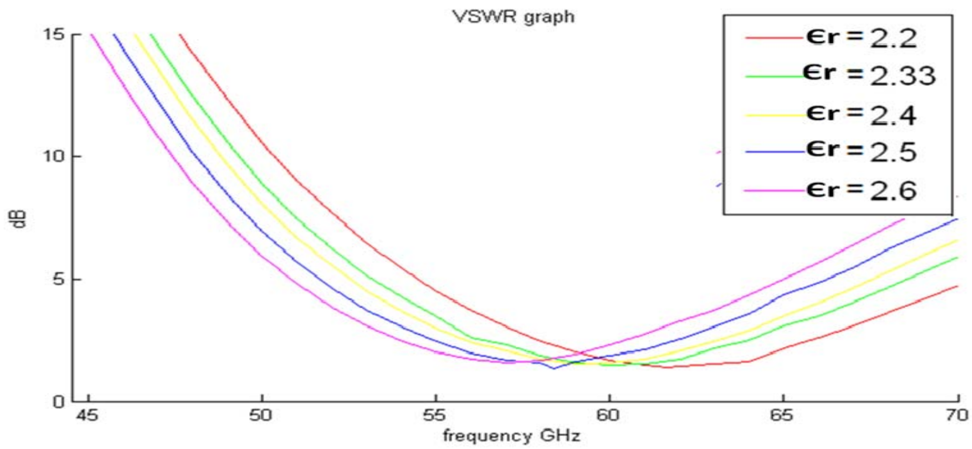

Figure (3) VSWR graph

The VSWR<2 is obtained at the resonant frequency and the VSWR values for different dielectric constants 2.2, 2.33, 2.4, 2.5, 2.6 are 1.41, 1.47, 1.51, 1.55, 1.59 respectively.

Input impedance smith chart:

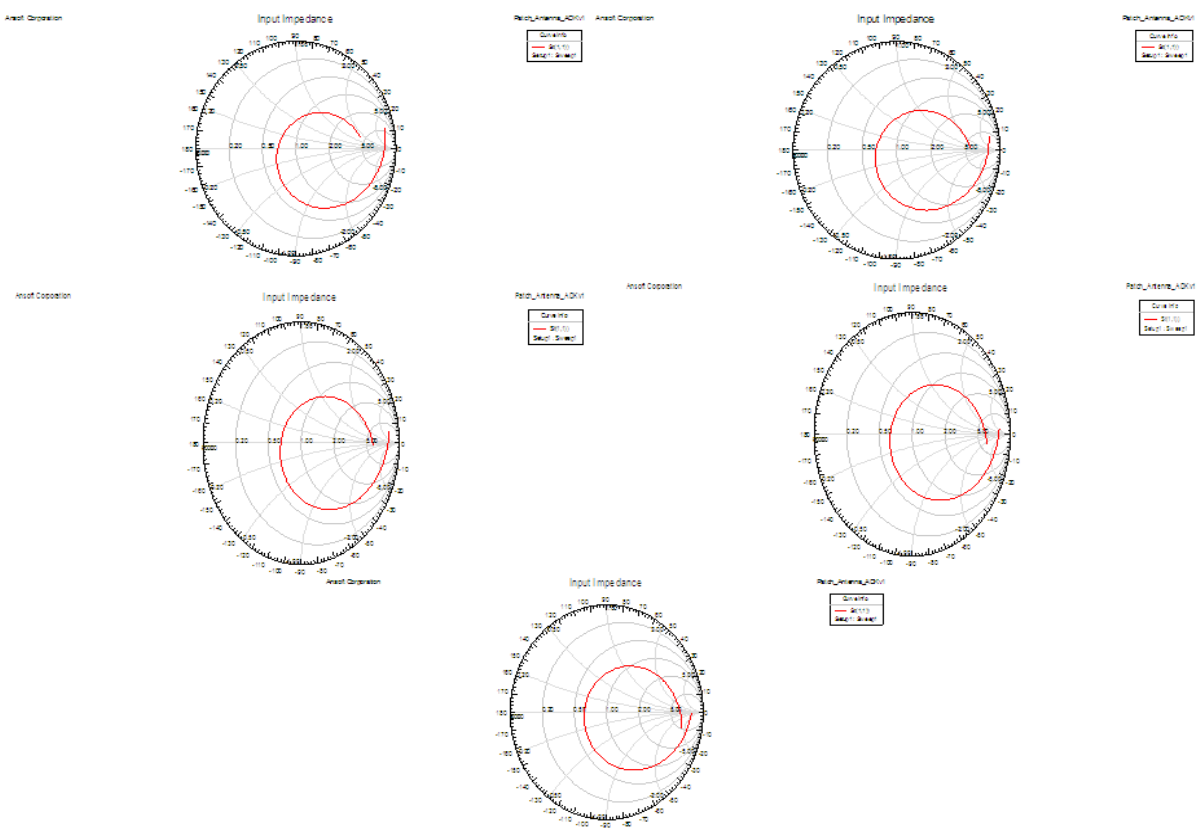

Figure (4) Input impedance smith charts

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Input Impedance Values at 60 GHz						
S.NO		For ϵ_r=2.2, δ=0.0011	For ϵ_r= 2.33, δ=0.0011	For ϵ_r= 2.4, δ=0.0010	For ϵ_r= 2.5, δ=0.0010	For ϵ_r= 2.6, δ=0.0010
1	rms value	0.6182	0.6123	0.6117	0.6129	0.6163
2	Gain margin	14.838	14.037	13.615	13.100	12.664
3	Phase margin	192.32	188.39	186.09	182.81	179.33
4	Gain cross over	45.00	45.00	45.00	45.00	45.00
5	Phase cross over	61.29	59.79	59.00	57.95	56.94
6	Upper cut off	53.66	52.40	51.76	50.91	50.10
7	Band width	53.66	52.40	51.76	50.91	50.10

Table (2) Input impedance parameters

Figure (4) gives the input impedance smith chart for the different cases of square patch with respect to different substrate materials. The parameters simulated from the smith chart curve are tabulated in the table (2). Figure (5) and (6) shows the 3D and 2D gains for the proposed model with different dielectric constant values. The maximum 2D gain values obtained for dielectric constants 2.2, 2.33, 2.4, 2.5 and 2.6 are 7.91, 7.81, 7.77, 7.67 and 7.58 dB respectively. A gain of more than 7dB is obtained at each case and this is showing a good agreement for the applicability of the antenna for these materials. The maximum directivity values obtained for dielectric constants 2.2, 2.33, 2.4, 2.5 and 2.6 are 6.21 at 90^0, 6.08 at 90^0, 6.01 at 95^0, 5.90 at 95^0 and 3.76 at 90^0 respectively.

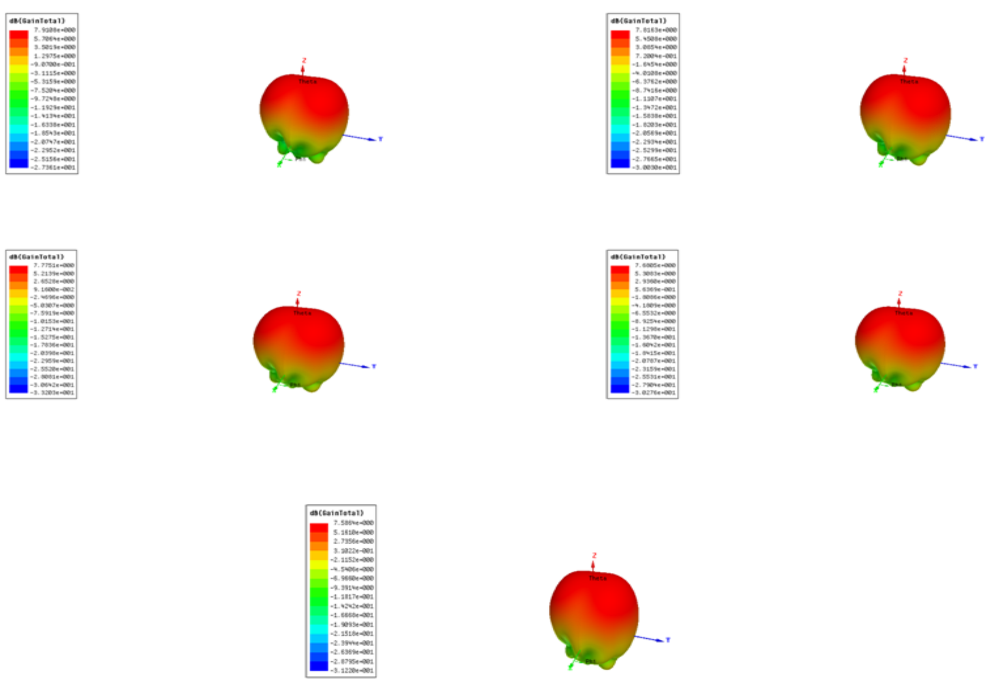

Figure (5) 3D gain

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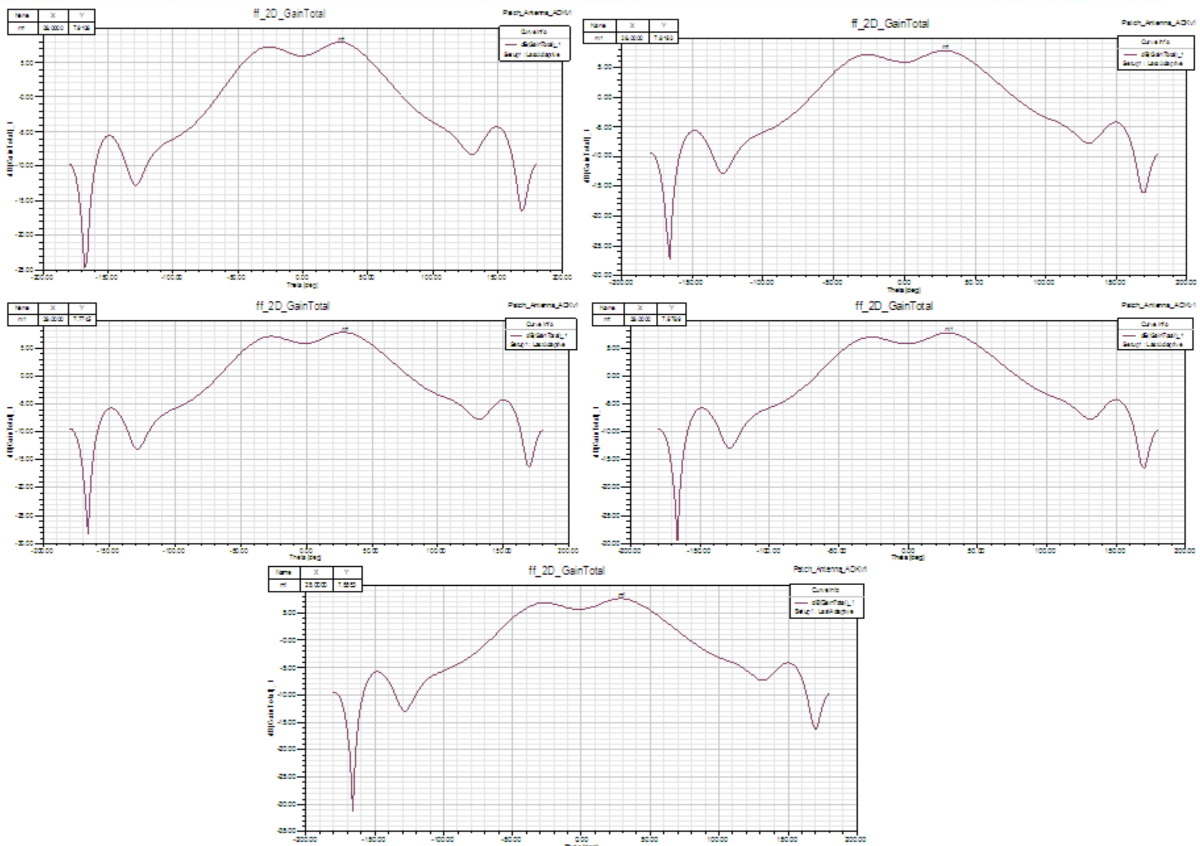

Figure (6) 2D gain

Radiation pattern is a mathematical function or graphical representation of the radiation properties of the antenna as a function of space coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity phase or polarization. In practice, the three dimensional pattern is measured and recorded in a series of two dimensional patterns. However for most practical applications, a few plots of the pattern as a function of θ for some particular values of φ, plus a few plots as a function of φ for some particular values of θ, give most of the useful and needed information.

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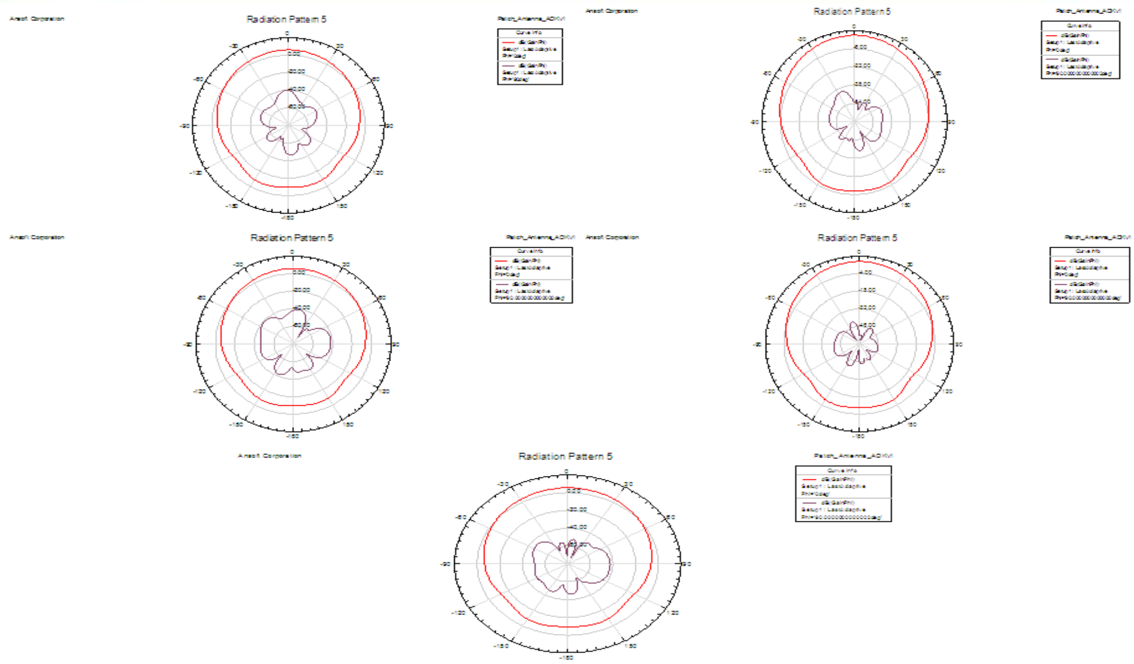

Figure (7) Radiation patterns of gain phi at 0^0 and 90^0

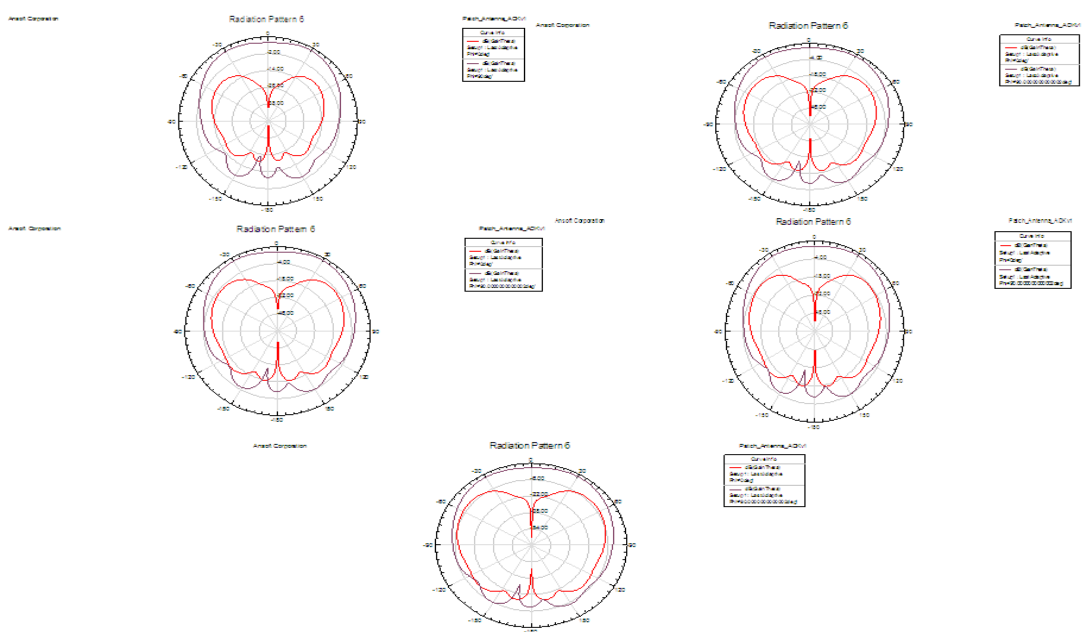

Figure (8) Radiation patterns of gain theta at 0^0 and 90^0

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Antenna parameters and maximum field data are simulated from the Ansoft-HFSS and they are tabulated in table (3) and table (4).

Antenna parameters at 60GHz						
		For ϵ_r=2.2, δ=0.0011	For ϵ_r=2.33, δ=0.0011	For ϵ_r=2.4, δ=0.0010	For ϵ_r=2.5, δ=0.0010	For ϵ_r=2.6, δ=0.0010
1	Max U	0.00648w/sr	0.0070 w/sr	0.0062 w/sr	0.0045 w/sr	0.0031 w/sr
2	Peak Directivity	6.214	6.086	6.013	5.900	5.771
3	Peak gain	6.1814	6.0482	5.9911	5.8621	5.7365
4	Peak realized gain	5.7134	5.7813	5.676	5.336	4.884
5	Radiated power	0.0131 w	0.0146 w	0.0129 w	0.0096 w	0.0069 w
6	Accepted power	0.0131 w	0.0147 w	0.0130 w	0.0097 w	0.0069 w
7	Incident power	0.0142 w	0.0153 w	0.0137 w	0.0106 w	0.0081 w
8	Radiation efficiency	0.9946	0.9937	0.9962	0.9934	0.9939
9	Front to back ratio	23.765	24.085	24.971	24.462	24.51

Table (3) Antenna Parameters

Maximum field data values at 60GHz																
		For ϵ_r=2.2, δ=0.0011			For ϵ_r=2.33, δ=0.0011			For ϵ_r=2.4, δ=0.0010			For ϵ_r=2.5, δ=0.0010			For ϵ_r=2.6, δ=0.0010		
	rE field	Value (v)	At Phi (degrees)	At Theta (degrees)	Value (v)	At Phi (degrees)	At Theta (degrees)	Value (v)	At Phi (degrees)	At Theta (degrees)	Value (v)	At Phi (degrees)	At Theta (degrees)	Value (v)	At Phi (degrees)	At Theta (degrees)
1	Total	2.210	90	28	2.31	90	28	2.164	95	28	1.850	95	28	1.546	85	28
2	X	0.323	115	142	0.363	115	142	0.343	115	144	0.323	25	-40	0.304	20	-42
3	Y	1.995	90	22	2.085	90	22	1.956	90	22	1.669	90	22	1.395	90	22
4	Z	1.325	105	44	1.389	100	44	1.301	80	44	1.117	100	46	0.934	100	46
5	Phi	1.765	180	0	1.844	180	0	1.726	180	0	1.473	180	0	1.230	180	0
6	Theta	2.210	90	28	2.31	90	28	2.164	90	28	1.850	90	28	1.546	90	28
7	LHCP	1.688	65	30	1.764	65	30	1.656	65	30	1.418	65	30	1.190	65	30
8	RHCP	1.688	115	30	1.769	115	30	1.657	115	30	1.422	115	30	1.188	115	30
9	Ludwig3/X dominant	0.495	155	58	0.563	20	58	0.564	160	58	0.520	20	58	0.472	20	58
10	Ludwig 3/Y dominant	2.210	90	28	2.31	90	28	2.164	90	28	1.850	90	28	1.546	90	28

Table (4) Maximum field data

5. CONCLUSION:

Performances of microstrip square patch antenna based on different substrate materials are investigated and their performance characteristics are shown and tabulated in this present work. We observed that the by increasing the dielectric constant of the substrate material the bandwidth is decreasing and gain values are decreased. We also observed that the maximum

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directivity also decreased by increasing the permittivity of the substrate materials. This present work carries the measurement of antenna parameters for different substrate materials. The return loss and VSWR are also showing good agreement with the theoretical values for the proposed model.

6. ACKNOWLEDGMENTS:

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