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Study of the Dielectric Superstrate Thickness Effects on Microstrip Patch Antennas

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Abstract: *Adielectric superstrate is touching the patch antennas has remarkable effects on antenna parameters. This paper experimentally studiesthesuperstrate thickness effectson the patch antennas parameters and compared their performances with without dielectricsuperstrate.The coaxial probe fed of rectangular, circular and square patch antennas were designed with 2.4 GHz and fabricated on Arlondiclad 880 substrate.The superstrate materials is also used same specifications ofsubstrate material for designing of the patch antennas. It is found that there is a slight degradation in the performance of the antennas when the superstrate thickness is touching the above the patch antennas. In particular, the resonant frequency will be shifted lower side, while other parameters have slight variation in their values. In addition, it has also been observed that return loss and VSWR increases, however bandwidth and gain decreases with the dielectric constant of the superstrate thickness. This type of antennas were used for wireless, Wi-Fi and Blue-tooth applications*

Index Terms: *Rectangular patch antenna, circular patch antenna, square patch antenna, dielectric superstrate (radome), resonate frequency, gain etc.*

I. Introduction

A microstrip antenna consists of a radiating patch on one side of a dielectric substrate, which has a ground plane on the other side. The patch conductors are normally copper or gold, can assume virtually any shape, but regular shapes are generally used to simplify analysis and performance prediction. Ideally, the dielectric constant of the substrate should be low ($\in_r < 2.5$) to enhance the fringing fields that account for the radiation [1-3].Microstrip antennas have been employed in the airborne and spacecraft system because of their low profile and conformal nature. Many of these applications require a dielectric cover over the radiating element to provide protection against heat, physical damage and other environmental hazards [2, 3, 6-22]. The effect of the superstrate used on the patch antenna to provide protection from heat and environmental hazards etc., results in change of important parameters like impedance, bandwidth (frequency range for SWR ≤ 2), gain, resonant frequency etc. This geometry of microstrip patch with dielectric superstrate can form part of a specific high performance airborne system. In view of this, it becomes imperative to investigate the effect of superstrates on the performance of the microstrip patch antennas.

II. Antenna Specifications And Selection Of Substrate Material

The dielectric constants, loss tangents and thicknesses of the dielectric materials used in the investigations are given in Table 1 and Table 2. Dielectric substrate of appropriate thickness and loss tangent is chosen for designing the rectangular, square and circular MPAs. A thicker substrate is mechanically strong with improved impedance bandwidth and gain. However it also increases weight and surface wave losses. The dielectric constant ($\in_r$) plays an important role similar to that of the thickness of the substrate. A low value of $\in_r$ for the substrate will increase the fringing field of the patch and thus the radiated power. A high loss tangent ($\tan\delta$) increases the dielectric loss and therefore reduces the antenna performance. The low dielectric constant materials increase efficiency, bandwidth and radiation [1-3, 6].

Keeping these aspects in mind, the rectangular, square and circular MPAs are fabricated on Arlondiclad 880 dielectric substrate, whose dielectric constant ($\in_{r1}$) is 2.2, loss tangent ($\tan\delta$) is 0.0009, thickness (h_1) is 1.6 mm and appropriate substrate dimensions.

Table 1: Specification of dielectric substrate($\in_{r1}$) material used in the design of patch antennas

Substrate material	Dielectric constant ($\in_{r1}$)	Loss tangent ($Tan\delta$)	Thickness of the substrate (h_1), mm
Arlondiclad 880	2.2	0.0009	1.6

Table 2: Specification of dielectric superstrate($\in_{r2}$) materials used to study the effect of the superstrate thickness on the performance of the patch antennas

Superstrate materials	Dielectric constant ($\in_{r2}$)	Loss tangent ($Tan\delta$)	Thickness of the superstrates (h_2),mm
Arlondiclad 880	2.2	0.0009	1.6

III. Design Formulae

(A) Effective Dielectric Constant:

The effective dielectric constant has values in the range of $1 < \in_{reff} < \in_r$. For most applications where the dielectric constant of the substrate is much greater than the unity ($\in_r \gg 1$), the value of $\in_{reff}$ will be closer to the value of the actual dielectric constant $\in_r$ of the substrate. The expression for $\in_{reff}$ is given by [2]

$$\in_{reff} = \frac{\in_r+1}{2} + \frac{\in_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}, \text{ for } \quad W/h > 1 \qquad .....(1)$$

(B) Effective Length and Effective Width:

The dimensions of the patch along its length have been extended on each end by a distanceΔL, which is a function of the effective dielectric constant $\in_{reff}$ and the width-to-height ratio [2]

$$\frac{\Delta L}{h} = 0.412\frac{(\in_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\in_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \ldots (2)$$

The effective length of the patch is now [2]

$$L_{eff} = L + 2\Delta L \ldots..(3)$$

For an efficient radiator, a practical width that leads to good radiation efficiencies is [2]

$$W = \frac{1}{2f_r\sqrt{\mu_0\in_0}}\sqrt{\frac{2}{\in_r+1}} = \frac{\vartheta_0}{2f_r}\sqrt{\frac{2}{\epsilon_{r+1}}} \ldots. (4)$$

The actual length of the patch can now be determined L[2]

$$L = \frac{1}{2f_r\sqrt{\in_{reff}}\sqrt{\mu_0\in_0}} - 2\Delta L \ldots(5)$$

(C) Circular Patch Radius and Effective Radius:

The dimension of the patch is treated a circular loop, the actual radius of the circular patch antenna is given by [2]

$$a = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_r F}\left[ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}} \qquad \ldots. (6)$$

Where $F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}}$

Equation (1) does not take into considerations the fringing effect. Since fringing makes the patch electrically larger, the effective radius of patch is used and is given by [2]

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

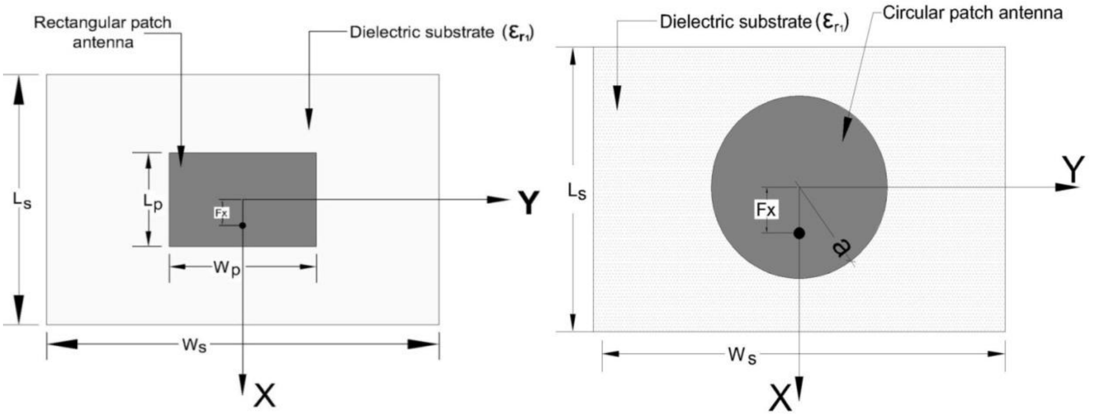
Hence, the resonant frequency for the dominant TM_{110}^{Z} is given by [2]

$$(f_r)_{110} = \frac{1.8412v_o}{2\pi a_e\sqrt{\varepsilon_r}} \ldots. (8)$$

Where $v_0$is the velocity of light

IV. Design Of Patch Antennas And Thier Geometry

The rectangular, square and circular microstrip patch antennas are designed at the center frequency of 2.4 GHz on Arlondiclad 880 substrate ($\in_{r1}$=2.2, h_1=1.6 mm), using expressions available in the standard literature [2-21] and given by equations (4), (5) and (6). The designed dimensions of rectangular, square and circular patch antennas are given in Table 3 and Table 4 respectively. The patch antennas are fed with coaxial probe feed at a point where the input impedance of the patch is 50 Ω. The location co-ordinates (F_X, F_Y) are found by simulation. The geometries of the rectangular, square andcircular patch antennas are shown in Fig.1 and Fig.2. In the geometry shown, W_s = Substrate width, L_s= Substrate length, W_P= Patch width, L_P = Patch length, a =Patch radius, D =Diameter of circular patch and(F_x,F_y) are the co-ordinates of the feed point.



(a) (b)

Fig. 1(a) Geometry of rectangularmicrostrip patch antenna and (b) Geometry of circular microstrip patch antenna (Top view)

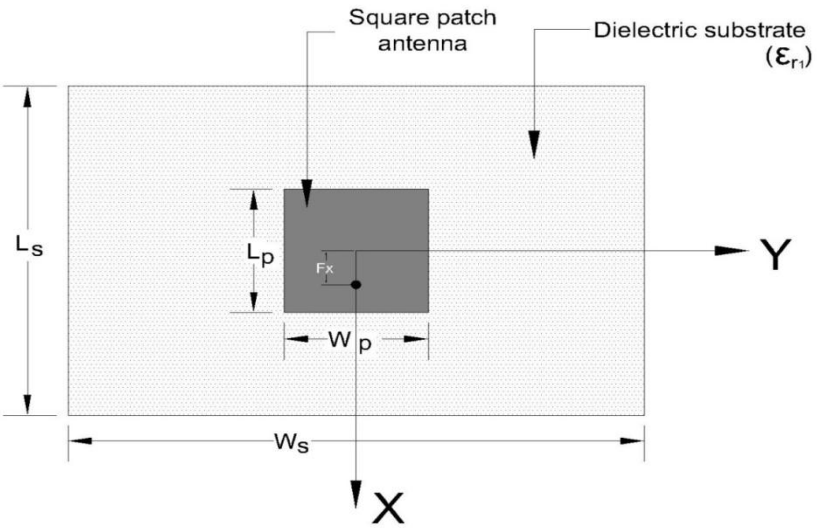


Fig. 2 Geometry ofsquare microstrip patch antenna (Top view)

Table 3: TheDimensions of the Rectangular and Square Patch Microstrip Antenna in mm

Type of Patch	f_r	$\in_{r1}$	h_1	W_s	L_s	W_p	L_p	F_X, F_Y
Rectangular patch antenna	2.4 GHz	2.2	1.6	100	100	49.40	40.30	10.5,0
Square patch antenna	2.4GHz	2.2	1.6	100	100	33.60	33.60	10.0,0

Table 4: The Dimensions of the Circular Microstrip Patch Antenna in mm.

f_r	$\in_{r1}$	h_1	W_s	L_s	D	F_X, F_Y
2.4 GHz	2.2	1.60	100	100	47.10	5.5,0

V. Dielectric Superstrateeffects

When microstrip antennas are covered with protective dielectric superstrate, the antenna resonant frequency, bandwidth, gain and other parameters are altered, resulting in detuning, which may seriously degrade the system performance. As the bandwidth of microstrip antennas is inherently low, it is important to determine the effect of the dielectric layer on the resonant frequency and other parameters of patch antennas in order to introduce appropriate corrections in the design of antenna. The change in the resonant frequency by placing the dielectric superstrate can be calculated using the following the expression [1-3].

$$\frac{\nabla f_r}{f_r} = \frac{\sqrt{\in_e} - \sqrt{\in_{eo}}}{\sqrt{\in_e}} \ldots .(9)$$

If $\in_e = \in_{eo} + \nabla \in_e$ and $\nabla \in_e \leq 0.1 \in_{eo}$,

$$\frac{\Delta f_r}{f_r} = {}^1/_2 \frac{\Delta\epsilon_e/_{\epsilon e_o}}{1+{}^1/_2 {}^{\Delta\epsilon_e}/_{\epsilon e_o}} \qquad \text{…. (10)}$$

Where,
ϵ_e = Effective dielectric constant with dielectric superstrate
$\epsilon\ e_o$ =Effective dielectric constant without dielectric superstrate
$\Delta\epsilon_e$ = Change in dielectric constant due to dielectric superstrate
Δf_r =Fractional change in resonance frequency
f_r =Resonce frequency

VI. Experimental Results

The performance of the antenna is evaluated without dielectric superstrate using commercial electromagnetic software such as High Frequency Structure Simulator (HFSS). Then the change in performance of the antenna is studied with dielectric superstrate thickness as mentioned in Table 2. The measurements were carried out by using

- Network Analyzer (HP E5071C) to measure the return-loss (VSWR), Center frequency and Bandwidth and
- Anechoic chamber to measure the radiation characteristics. The antenna under test (patch antenna with and without dielectric superstrate) is used as receiving antenna and the transmitting antenna is a pyramidal horn antenna (1-50 GHz). The radiation pattern measurements were carried out at 2.43GHz. The photograph of fabricated rectangular and circular microstrip patch antennas without superstrates are shown in Figs 3 to 4 and with superstrate for measurement of return loss setup is shown in Fig.5

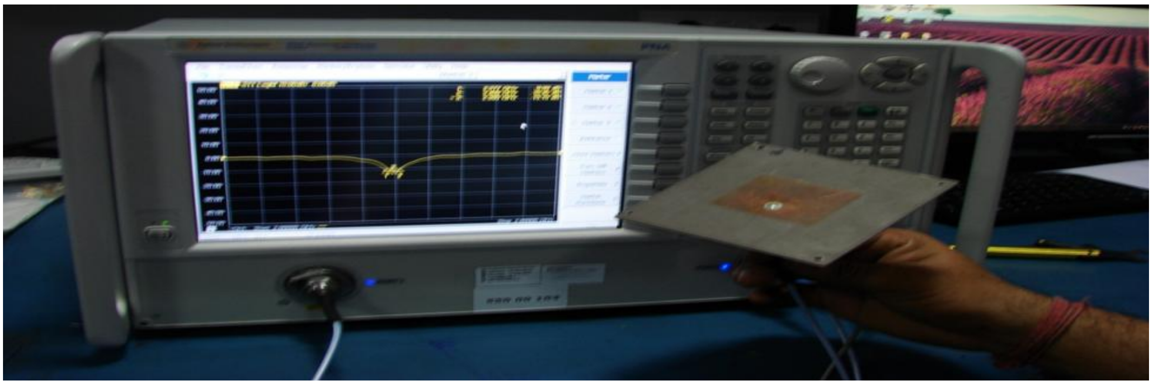


Fig. 3 Measurement set up for fabricated rectangular microstrip patch antenna without dielectric superstrate for measurement of return loss (Free space radiation conditions).

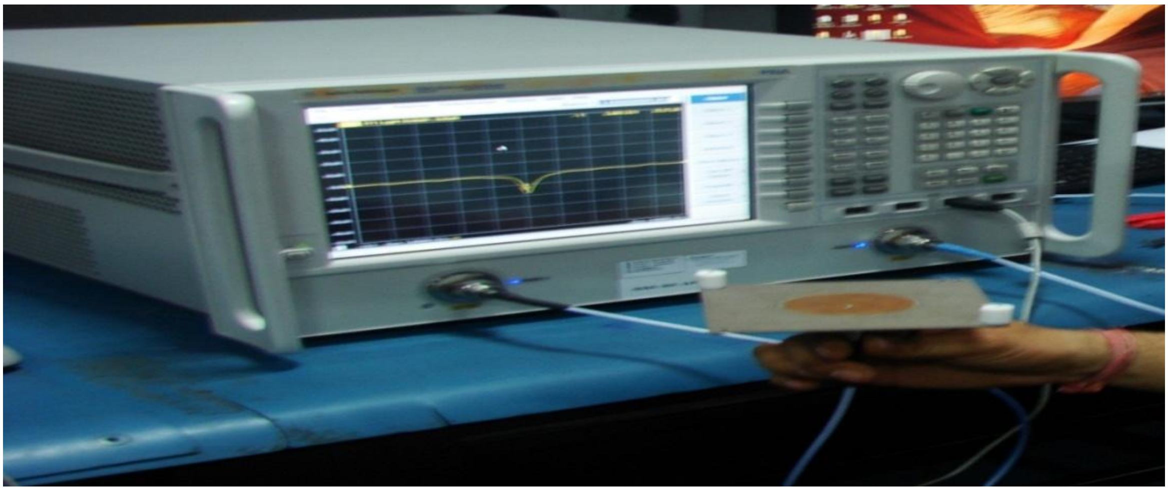


Fig.4 Measurement set up for fabricated circular patch antenna without dielectric superstrate for measurement of return loss (Free space radiation conditions).

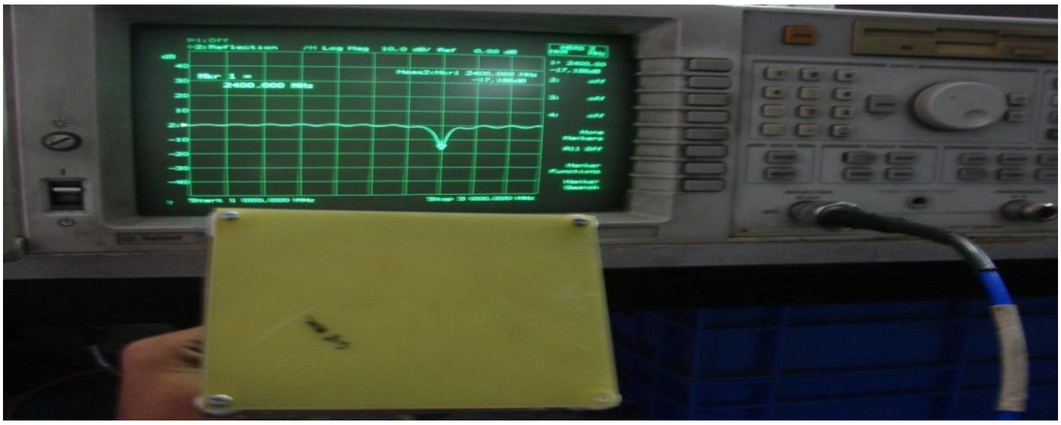
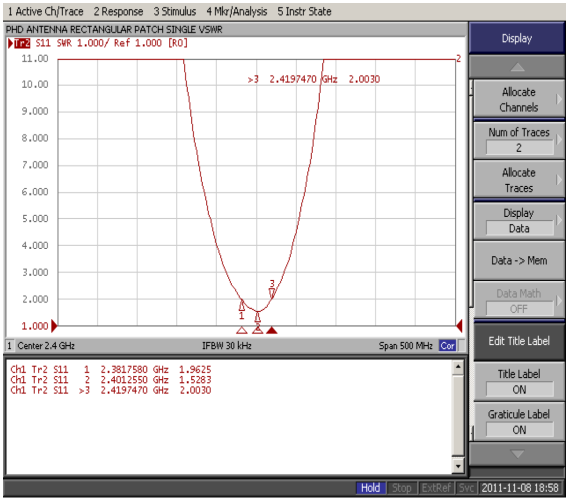


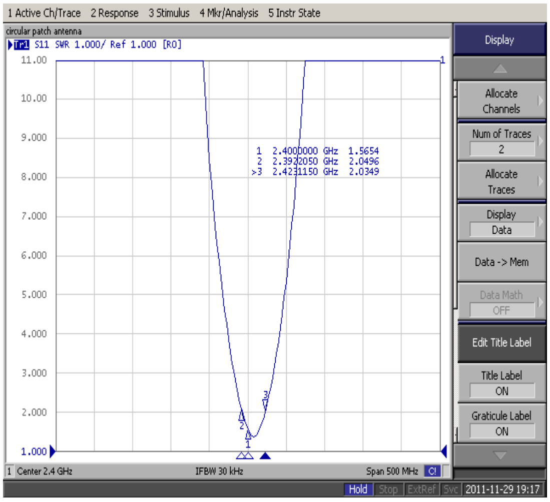
Fig.5 Measurement set up for fabricated microstrip patch antenna with dielectric superstratefor measurement of return loss

A. Rectangular, Square and Circular MPA under Free Space Radiation Conditions (Without Superstrate)

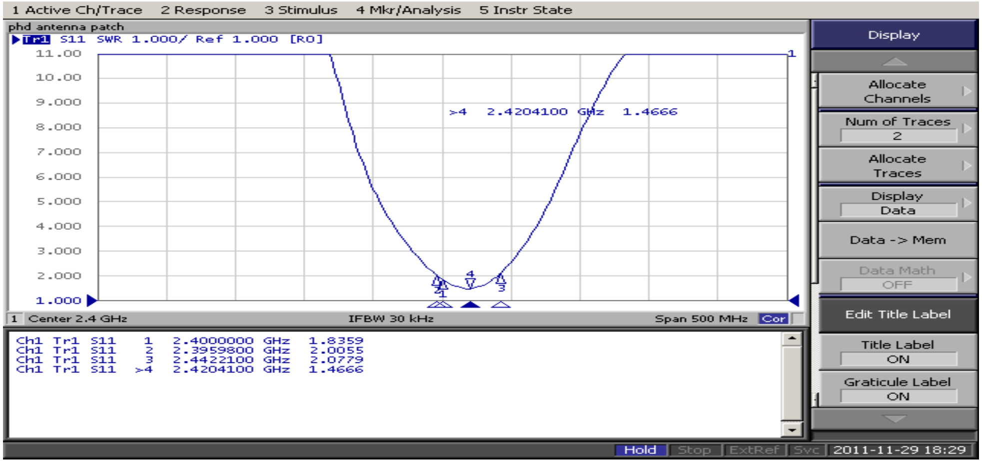
The experimental measured results of VSWR, radiation patterns for the rectangular patch antenna under free space radiation conditions i.e., withoutsuperstrate are shown in Figs.6, 7, 8 and 9 given below.

The resonant frequency is 2.40 GHz, same as the design frequency, the experimental measured results of rectangular patch antenna bandwidth is 0.02 GHz (VSWR ≤ 2), and gain is 7.3dB. For circular patch antenna bandwidth is 0.030 GHz (VSWR≤ 2) and gain is 6.7dB, whereas square patch antenna bandwidth is 0.046 GHz (VSWR ≤ 2) and gain is 4.8dB. Radiation pattern simulation and measurements are carried out at the center frequency for the case under consideration. The center frequency is found from return-loss measurements. For free space radiation condition i.e., without superstrate the center frequency is occurring at 2.40 GHz and hence, the radiation pattern measurements are carried out at this frequency i.e. at 2.40 GHz.





(a) Rectangular patch antenna (0.2mm) (b) Square patch antenna (0.2mm)



(c) Circular patch antenna (0.2mm)

Fig 5: Comparison of experimentally measured VSWR plot of (a) rectangular (b) circular and (c) square microstrip patch antenna for$\in_{r1} = 2.2$without dielectric superstrates (Free space radiation conditions) at 2.4GHz.

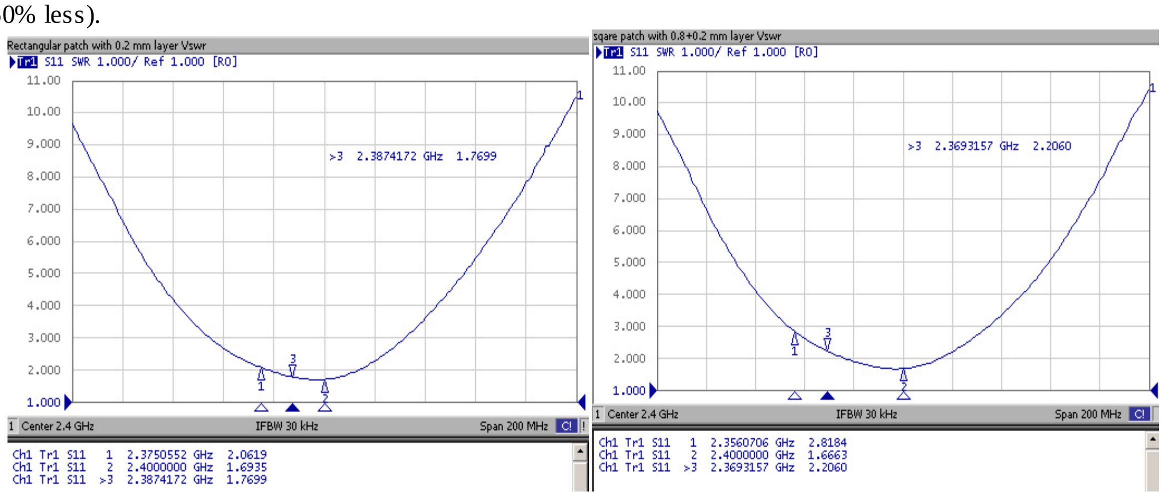
B. Effect of the Superstrate on the Performance Characteristics of Rectangular, Square and Circular Microstrip Patch Antenna

The effect of the superstrates with different thicknesses as mentioned in Tables 6 to 14 isexperimentally investigated on the performance characteristics of rectangular, circular and square microstrip patch antenna, the measurements have been carried out for typical cases. The results are discussed below.

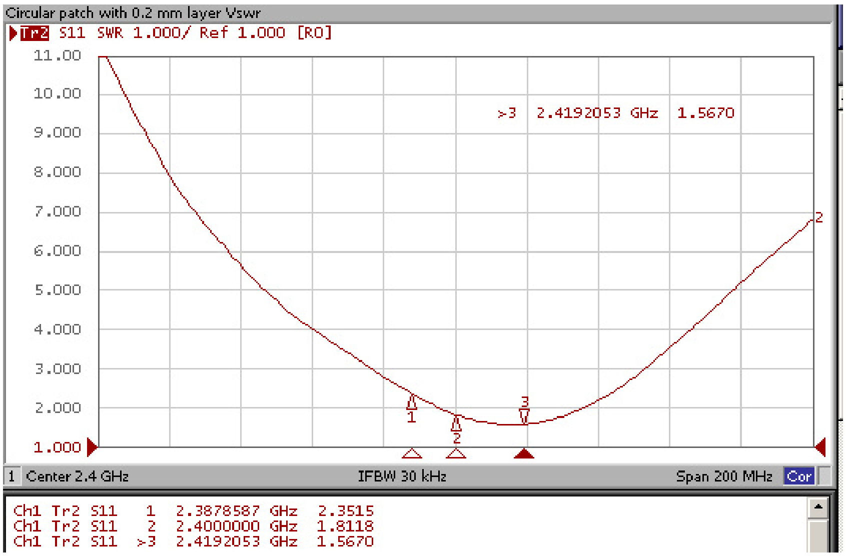
Superstrate with $\in_{r2} = 2.2$ *and* h_2 *=0.2 mm.*

The effect of the superstrate having $\in_{r2} = 2.2$, h_2 =0.2 mm on the performance characteristics of the rectangular, circular and square patch is evaluated experimentally which are given in Table 6, from the results it can be observed that the resonant frequency, gain and bandwidth will deteriorate when the superstrate is touching the patch antenna. The measurements are carried out for with and without superstrate. The measured results are shown in Figs6 to 8.The VSWR plot as a function of frequency is shown in Fig6. The impedance and the radiation patterns plots are shown in Figs 7 and 8. The radiation patterns are measured at the resonant frequency for the case under consideration. For the rectangular patch antennathe measured resonant frequency is decreased to 2.38 GHz, thebandwidth is decreased to 0.024 GHz and gain is decreased to 4.29dB. For square patch antennathe measured resonant frequency is decreased to 2.41 GHz, the bandwidth is decreased to 0.012 GHz and gain is decreased to 3.92dB. For circular patch antenna the measured resonant frequency is same as designed frequency, the bandwidth is increased to 0.267GHz and gain is decreased to 1.42dB.

As compared to free space radiation conditions i.e without superstrate, for rectangular patch antenna, the resonant frequency (f_r) is 0.013 GHz (0.541% less), bandwidth is 0.003 GHz (19.5% less) and gain is 3.01dB (41.23% less). For square patch antenna, the resonant frequency (f_r) is same as designed frequency, bandwidth is 0.221 GHz (22.1% more) and gain is 3.38 dB (70.41% less). For circular patch antenna, the resonant frequency (f_r) is 0.01 GHz (0.833% more), bandwidth is 0.018 GHz (2.17 % less) and gain is 2.78dB (60% less).



(a) Rectangular patch antenna (0.2mm) (b) Square patch antenna (0.2mm)



(c) Circular patch antenna (0.2mm)

Fig 6: Comparison of experimental measured VSWR plot of (a) rectangular (b) Square and (c)Circularmicrostrip patch antenna for 0.2mm thickness for superstrate dielectric constant (ϵ_{r2}= 2.2) at 2.4 GHz.

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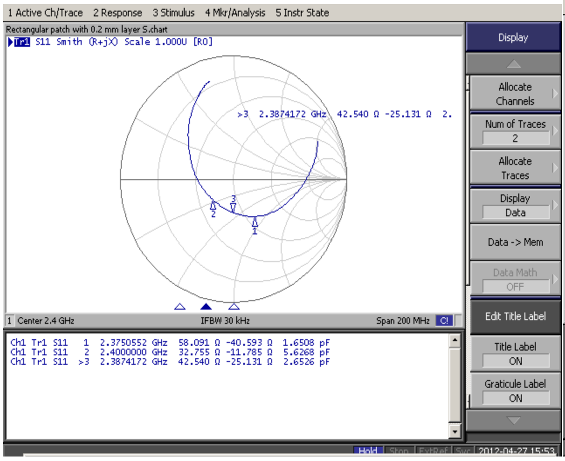
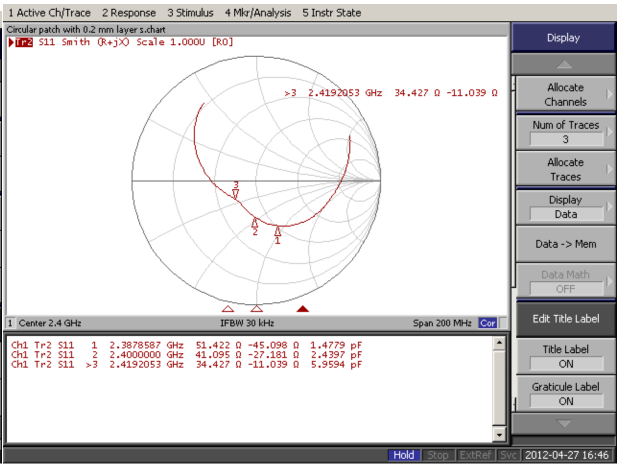
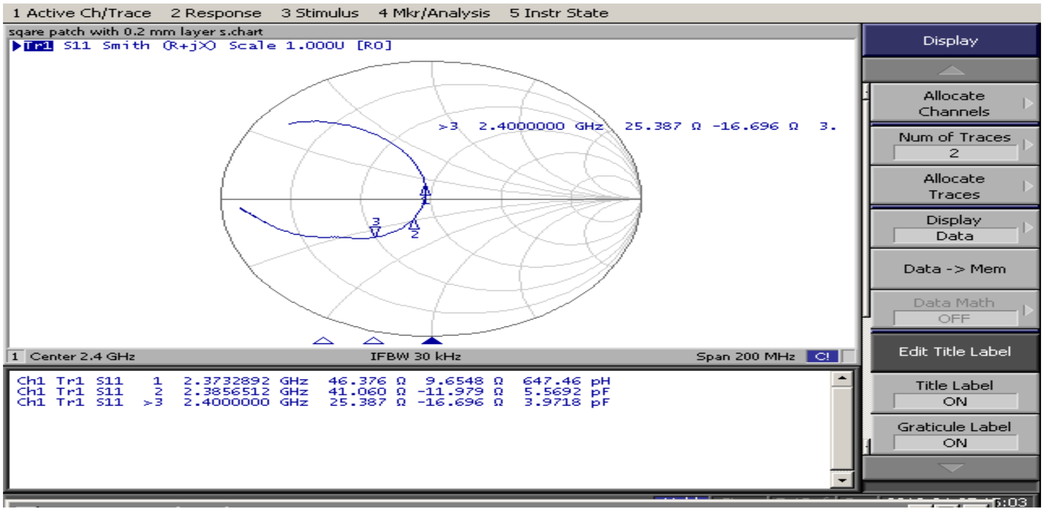


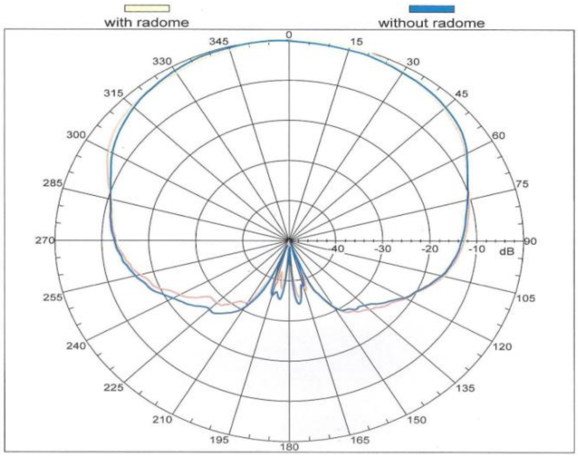


(a) Rectangular patch antenna (0.2mm) (b) Square patch antenna (0.2mm)

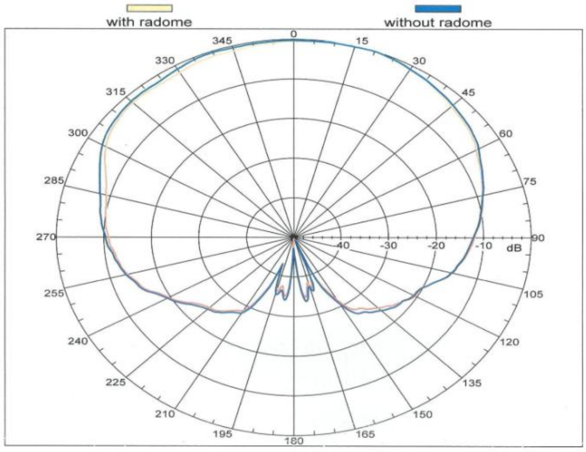


(c) Circular patch antenna (0.2mm)

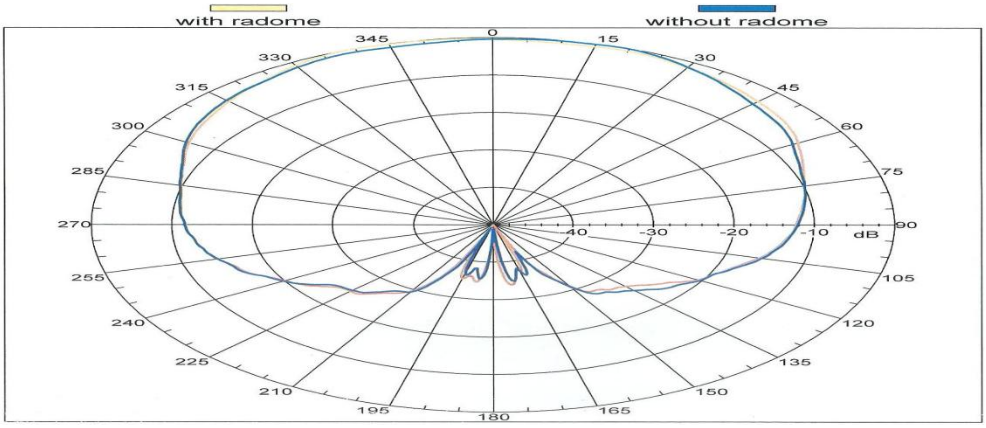
Fig 7: Experimental measured results of impedance plot for (a) Rectangular patch (b) Square patch and (c) Circular patch for 0.2mm thickness for superstrate dielectric constant (ϵ_{r2}= 2.2)at 2.4 GHz.



(a) Rectangular patch antenna (0.2mm)



(b) Square patch antenna (0.2mm)



(c) Circular patch antenna (0.2mm)

Fig 8: Experimental measured results of VSWR for (a) Rectangular (b) Squareand (c) Circular patch antennas for 0.2mm thickness for superstrate dielectric constant $(\epsilon_{r2} = 2.2)$in HP at 2.4GHz.

Table 5: Comparison of experimental result for rectangular, circular and square microstrip patch antennas without dielectric superstrateϵ_{r1}=2.2 (Free space radiation conditions)

	Characteristics	Rectangular patch antenna	Circular patch antenna	Square patch antenna
2.2	*Resonant frequency (f*	2.40	2.40	2.40
	Gain(dB)	7.3	6.7	4.8
	BW(GHz)	0.0201	0.030	0.046
	HPBW(HP),Deg	88.36	98.77	108.1
	HPBW(VP),Deg	90.20	90.01	105.4
	Impedance (Ω)	35.79-j10.952	35.75+j2 3.955	36.24-j8.9070
	Return-loss(dB)	-13.63	-15.55	-10.08
	VSWR	1.998	2.034	1.466

Table 6: Comparison of experimental measured results for rectangular, circular and squaremicrostrip patch antennas with dielectricsuperstrate thickness 0.2mm$(\epsilon_{r2} = 2.2)$

	Characteristics	Rectangular patch antenna	Circular patch antenna	Square patch antenna
0.2mm	$\Delta f_r / f_r$ *(GHz)*	2.387	2.41	2.40
	Gain(dB)	4.29	3.92	1.42
	BW(GHz)	0.024	0.012	0.267
	HPBW(HP),Deg	90.94	84.26	98.16
	HPBW(VP),Deg	70.71	77.47	90.20
	Impedance (Ω)	42.540-j25.131	34.427-j11.039	25.387-j16.690
	Return-loss(dB)	-11.560	-12.857	-8.286
	VSWR	1.769	1.567	2.253

Table 7: Comparison of experimental measured results for rectangular, circular and square microstrip patch antennas with superstrate thickness 0.5mm (ϵ_{r2}= 2.2)

	Characteristics	Rectangular patch antenna	Circular patch antenna	Square patch antenna
0.5mm	$\Delta f_r/f_r$ (GHz)	2.40	2.419	2.40
	Gain(dB)	3.97	4.01	0.93
	BW(GHz)	0.0033	0.0313	0.015
	HPBW(HP),Deg	89.80	85.70	99.15
	HPBW(VP),Deg	73.21	73.02	74.86
	Impedance (Ω)	24.622+J2.938 7	27.784-J7.3993	35.833-J17.566
	Return-loss(dB)	-9.0884	-10.423	-12.142
	VSWR	2.077	1.846	1.656

Table 8: Comparison of experimental measured results for rectangular, circular and squaremicrostrip patch antennas with dielectric superstrate thickness 0.8mm (ϵ_{r2}= 2.2)

	Characteristics	Rectangular patch antenna	Circular patch antenna	Square patch antenna
0.8mm	$\Delta f_r/f_r$ (GHz)	2.36	2.41	2.38
	Gain(dB)	3.85	3.64	1.63
	BW(GHz)	0.039	0.012	0.158
	HPBW(HP),Deg	84.77	84.32	95.41
	HPBW(VP),Deg	76.88	76.99	77.56
	Impedance (Ω)	47.950-j32.106	21.980-j12.968	31.468-j19.960
	Return-loss(dB)	-10.518	-9.956	-10.054
	VSWR	1.879	5.581	1.916

Table 9: Comparison of experimental measured results for rectangular, circular and squaremicrostrip patch antennas with dielectric superstrate thickness at 1.0mm(ϵ_{r2}= 2.2)

	Characteristics	Rectangular patch antenna	Circular patch antenna	Square patch antenna
1.0mm	$\Delta f_r/f_r$ (GHz)	2.380	2.419	2.369
	Gain(dB)	5.75	5.88	4.28
	BW(GHz)	0.054	0.012	0.158
	HPBW(HP),Deg	88.40	88.33	88.27
	HPBW(VP),Deg	77.63	75.49	78.20
	Impedance (Ω)	31.542-j11.772	24.635-2.850	53.759-j45.307
	Return-loss(dB)	-11.214	-9.11	-10.233
	VSWR	1.758	2.021	2.206

Table 10: Comparison of experimental measured results for rectangular, circular and square microstrippatch antennas with dielectric superstrate thickness at 1.3mm(ϵ_{r2}= 2.2)

	Characteristics	Rectangular patch antenna	Circular patch antenna	Square patch antenna
1.3mm	$\Delta f_r/f_r$ (GHz)	2.380	2.419	2.87
	Gain(dB)	6.12	5.29	1.83
	BW(GHz)	0.0054	0.003	0.0158
	HPBW(HP),Deg	84.69	90.0	105.33
	HPBW(VP),Deg	67.91	76.84	79.72
	Impedance (Ω)	24.370-J785.85mΩ	21.982+j1.3726	29.987-j10.869
	Return-loss(dB)	-9.785	-10.75	-12.066
	VSWR	1.899	2.355	1.670

Table 11: Comparison of experimental measured results for rectangular, circular and squaremicrostrippatch antennas with dielectric superstrate thickness 1.5mm(ϵ_{r2}= 2.2)

	Characteristics	Rectangular patch antenna	Circular patch antenna	Square patch antenna
1.5mm	$\Delta f_r/f_r$ (GHz)	2.380	2.419	2.40
	Gain(dB)	4.99	5.21	4.98
	BW(GHz)	0.0054	0.0121	0.0024
	HPBW(HP),Deg	89.20	90.0	88.40
	HPBW(VP),Deg	89.20	76.80	88.40
	Impedance (Ω)	26.099-j3.3584	21.248+j3.7056	36.166-j15.292
	Return-loss(dB)	-9.205	-7.673	-10.991
	VSWR	3.076	2.497	1.786

Table 12: Comparison of experimentalmeasured results for rectangular, circular and squaremicrostrippatch antennas with dielectric superstrate thickness at 2.2mm(ϵ_{r2}= 2.2)

	Characteristics	Rectangular patch antenna	Circular patch antenna	Square patch antenna
2.2mm	$\Delta f_r/f_r$ (GHz)	2.117	2.394	2.173
	Gain(dB)	3.30	2.87	3.43
	BW(GHz)	0.0023	0.0033	0.0034
	HPBW(HP),Deg	91.50	89.06	98.55
	HPBW(VP),Deg	71.80	74.51	81.07
	Impedance (Ω)	26.099-j3.3584	21.248+j3.7056	36.166-j15.292
	Return-loss(dB)	-9.205	-7.673	-10.991
	VSWR	3.076	2.497	1.786

Table 13: Comparison of experimental measured results for rectangular, circular and squaremicrostrip patch antennas with dielectric Superstrate thickness at 2.4mm(ϵ_{r2}= 2.2)

	Characteristics	Rectangular patch antenna	Circular patch antenna	Square patch antenna
2.4mm	$\Delta f_r/f_r$ (GHz)	2.136	2.394	2.123
	Gain(dB)	3.31	2.87	3.43
	BW(GHz)	0.021	0.033	0.021
	HPBW(HP),Deg	91.50	89.06	98.55
	HPBW(VP),Deg	71.80	74.51	78.20
	Impedance (Ω)	26.099-j3.3584	21.248+j3.7056	36.166-j15.292
	Return-loss(dB)	-9.205	-7.673	-10.991
	VSWR	3.076	2.497	1.786

Table 14: Comparison of experimental measured results for rectangular, circular and squaremicrostrip patch antennas with dielectric Superstrate thickness at 3.2mm(ϵ_{r2}= 2.2)

	Characteristics	Rectangular patch	Circular patch	Square patch
3.2mm	$\Delta f_r/f_r$ (GHz)	2.174	2.394	2.145
	Gain(dB)	4.47	3.29	0.47
	BW(GHz)	0.0031	0.0033	0.0023
	HPBW(HP),Deg	91.50	92.78	102.25
	HPBW(VP),Deg	71.80	79.34	83.61
	Impedance (Ω)	26.099-j3.3584	21.248+j3.7056	36.166-j15.292
	Return-loss(dB)	-9.205	-7.673	-10.991
	VSWR	3.076	2.497	1.786

VI. Results And Discussion

It is found there is degradation in the performance of the antenna when the superstrate is touching the patch antenna. As compared to the with the free space radiation conditions (without superstrate),the experimental results show that for rectangular patch antenna the measured resonant frequency is decreased to

2.387 GHz, thebandwidth is decreased to 0.024 GHz and gain is decreased to 4.29dB. For square patch antennathe measured resonant frequency is same as designed frequency, the bandwidth is increased to 0.267 GHz and gain is decreased to 1.42 dB. For circular patch antenna the measured resonant frequency is 2.41 GHz, the bandwidth is decreased to 0.012 GHz and gain is decreased to 3.92 dB.The return-loss and VSWR increases as superstrate dielectric constant thickness increases. Measurements have been carried out for the above mentioned superstrate using dielectric constant $\in_{r2}=$ 2.2 and h_2 =0.2 mm. The VSWR as a function of frequency and radiation patterns at center frequency are shown for superstrate$\in_{r2}=$ 2.2 andh_2 =0.2 mm is shown in Figs 6 to 8.The optimum gain is obtained at 1.0mm which is 5.75dB for rectangular patch antenna, 5.88dB for circular patch antenna and 4.28dB for square patch antenna. The overall typical results for the rectangular, circular and square patch antennas are given in Tables 6 to 14.

VII. Conclusion

The effect of dielectric superstrate thickness effects on the behavior of rectangular, circular and square patch of microstrip antennas reveals that the superstrate thickness affects not only the resonance frequency but also effects on other parameters such as gain, bandwidth, beam width, VSWR and return-loss. In particular, the resonance frequency is shifted to lower side. The obtained results indicate that return loss and VSWR increases, BW decreases with the different dielectric constant of the superstrates. The value of impedance, return loss and VSWR are minimum, whereas BW is maximum for superstrate having dielectric constant$(\in_{r2})$ is 2.2, h_2 =2.4 mm.

As compared to free space radiation conditions i.e without superstrate, for rectangular patch antenna, the resonant frequency (f_r) is 0.013 GHz (0.541 % less), bandwidth is 0.003 GHz (19.5 % less) and gain is 3.01 dB (41.23 % less). For square patch antenna, the resonant frequency (f_r) is same as designed frequency, bandwidth is 0.221 GHz (22.1 % more) and gain is 3.38 dB (70.41 % less). For circular patch antenna, the resonant frequency (f_r) is 0.01 GHz (0.833% more), bandwidth is 0.018 GHz (2.17 % less) and gain is 2.78 dB (60 % less).

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