Design, Simulation and Experimental Analysis of Square Microstrip Patch Antenna with Superstrates at 2.4GHz

V. Saidulu

Abstract*: Microstrip antenna is used in wide area of applications such as high speed vehicles, missiles, tanks and satellite communications. In these applications dielectric superstrate (or cover) is used above the square patch antenna for providing the protections from severe environmental conditions such as rain, snow, heat, and damage etc. The proposed square microstrip patch antenna is designed using coaxial probe feed technique and transmission line model and operated at center frequency of 2.40 GHz, which is lying in the S-band region. The proposed model is used in linear polarization applications. The square patch is fabricated on low loss dielectric substrate material having dielectric constant is 2.2 and loss tangent of the substrate material is 0.0009. Ansoft electromagnetic simulator software such as HFSS is used for simulating proposed model and studied the effect cover or superstrate on different parameters of square patch antenna. This paper mainly focuses on the performance of square patch antenna without superstrate, and with superstrate at different height of dielectric superstrate above the patch antenna. The result found of patch antenna without superstrate the bandwidth is 0.04GHz and gain is obtained 8.9 dB and 7.51 dB in azimuth and elevation respectively. The result observed of patch antenna with dielectric cover (or superstrate) at height H =0, the antenna performance characteristics are slightly degraded and also comparing the antenna with the bandwidth is decreased to 0.02GHz from 0.04 GHz and gain is decreases to 6.44 dB and 6.6 dB from 8.9 dB and 7.51 dB in both azimuth and elevation plane respectively. The decreased performance characteristics of antenna will be improved by varying height of the superstrate above the patch antenna.. At particular optimum height, the performance characteristics patch antenna will be almost same as the patch antenna without superstrates. The obtained simulated results good match with measurement results.

***Keywords:* Dielectric superstrates, bandwidth, beam-width, gain, resonant frequency.**

I. INTRODUCTION

Microstrip patch antennas have several advantages such as light weight, low volume, and low profile over conventional microwave antennas [1]. Because of the low profile characteristics of microstrip antenna is most widely used defense, aerospace, military, and satellite communication applications [2]. The antenna is also having the limitations such as low gain due to loss, low efficiency and low power handling capacity. These limitations can overcome by taking care of antenna designing. Multi layer and stacking method is improved the gain and efficiency of the antenna [3]-[11]. In this paper the coaxial probe feed of square microstrip patch antenna is operated in S-band region at the frequency of 2.40GHz and used in linear polarization applications.

II. ANTENNA SPECIFICATIONS

The low loss and low dielectric constant of substrate and superstrate materials is used for improving the performance characteristics of microstrip patch. The higher dielectric constant materials give losses and reduce the efficiency [1]. The low dielectric constant materials is ideal suitable for reducing the losses and increasing the efficiency. The substrate material is Arlon diclad 880 substrate, having dielectric constant (ϵ_{r1}) = 2.2, thickness of the substrate (h_1) =1.6mm, loss tangent is 0.0009. The superstrate materials such Arlon diclad, 880, Arlon Ad 320, FR4 and Arlon Ad 1000, having the dielectric constant (ϵ_{r2}) = 2.2, 3.2, 4.8 and 10.2 respectively and also their thickness (h_2) = 1.6mm, 3.2 mm, 1.6 mm and 0.8 mm. Air (vacuum) is also used as substrate whose dielectric constant (ϵ_{r2}) = 1.0. It is considered as antenna without superstrate.

III. GEOMETRY

The geometry square microstrip patch antenna is shown in Fig. 1 (a). The designed dimensions of proposed square patch antenna are shown in Table1.

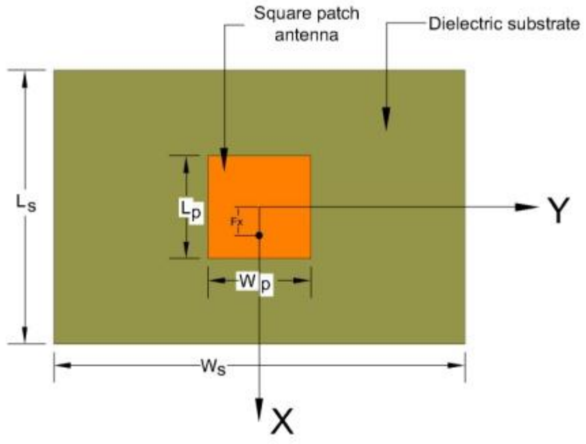
Table I: The designed dimension of square microstrip patch antenna

f_r (GHz)	ϵ_{r1}	H (mm)	Tanδ	W_S (mm)	L_S (mm)	W_P (mm)	L_P (mm)
2.4	2.2	1.6	0.0009	81.3	72.3	40.3	40.3

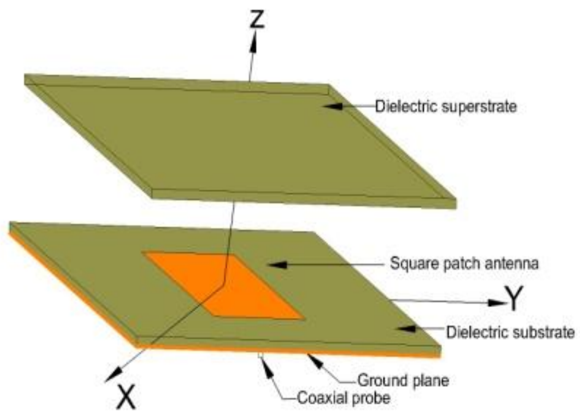
The feed point location (f_x, f_y) = (10.5mm, 0mm) is calculated at which the antenna impedance match with free space impedance.

Revised Manuscript Received on April 15, 2020.

Saidulu, Assistant Professor, ECE DepartmentMahatma Gandhi Institute of TechnologyGandipet, Hyderabad.



(a)



(b)

Fig1: Geometry of proposed square patch (a) without superstrate (b) With superstrate

IV. SUPERSTRATES EFFECTS ON PATCH ANTENNA

The change of resonant frequency can be calculated using the following expression [1], [2].

$$\frac{\Delta f_r}{f_r} = \frac{\sqrt{\epsilon_e}-\sqrt{\epsilon_{eo}}}{\sqrt{\epsilon_e}} \qquad (1)$$

If $\epsilon_e = \epsilon_{eo} + \Delta\epsilon_e$ and $\Delta\epsilon_e \leq 0.1\ \epsilon_{eo}$, then

$$\frac{\Delta f_r}{f_r} = {}^{1}/_{2}\,\frac{\Delta\epsilon_e/\epsilon_{eo}}{1+{}^{1}/_{2}\,\Delta\epsilon_e/\epsilon_{eo}} \qquad (2)$$

Where,

ϵ_e= Effective dielectric constant with dielectric superstrate

ϵ_{eo} =Effective dielectric constant without dielectric Superstrate

$\Delta\epsilon_e$= Change in dielectric constant due to dielectric superstrate

Δf_r = Change in resonance frequency

f_r =Resonant frequency

V. SIMULATION AND MEASUREMENT RESULTS

The simulation and measurement results of square patch antenna with and without superstrate, the return loss, and the radiation patter plot is shown in Fig. 2 to 6 and corresponding data is tabulated in Tables II to V. Superstrate ϵ_{r2} =1 is considered as vaccum or air (without superstrate) is shown in Fig.1 and Fig. 2 and with superstrate dielectric constant ϵ_{r2} =2.2, 3.2, 4.8 and 10.2 is shown in Fig. 3 to Fig.4. The gain, bandwidth and beam width is measured from the radiation pattern is shown Fig.5 and Fig.6.

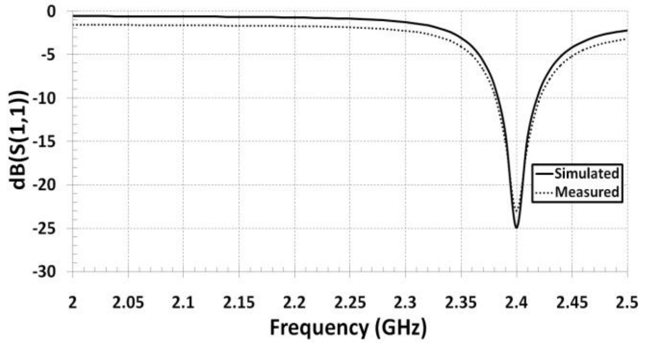


Fig.2 The return loss plot of square patch antenna without superstrate for dielectric constant (ϵ_{r1}) =1.0

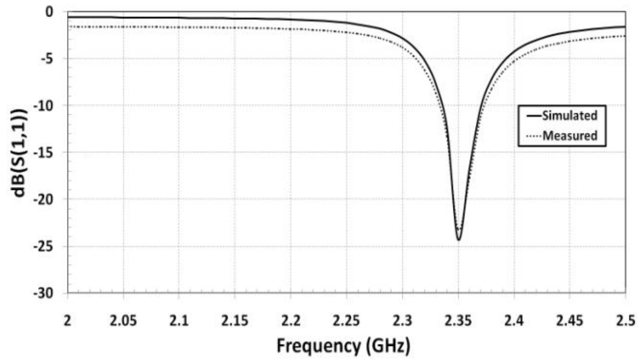


Fig.3 The return loss plot at H =0mm for dielectric constant (ϵ_{r2}) =2.2

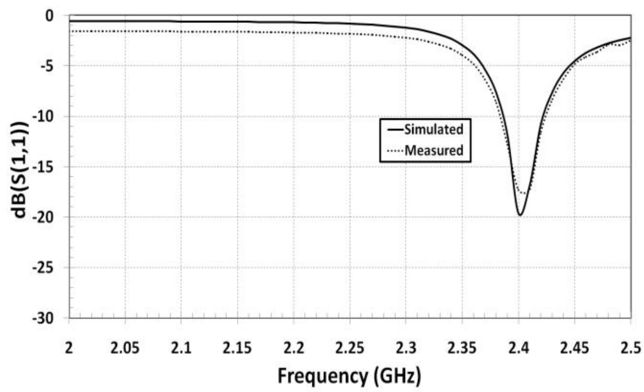
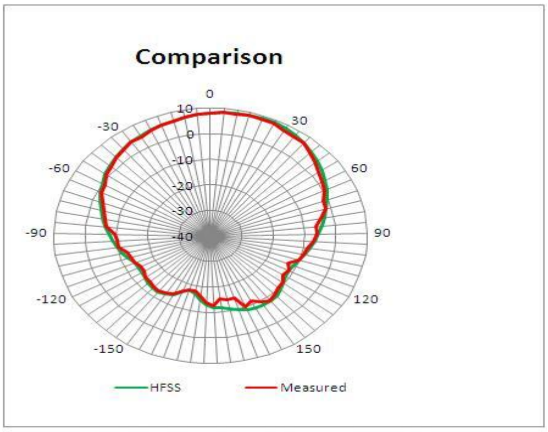
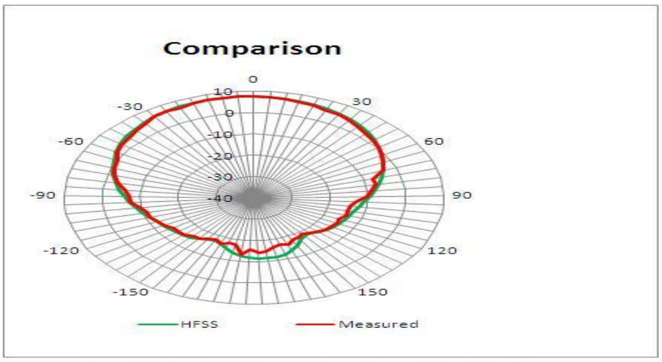


Fig.4 The return loss plot at optimum height(H) =Hopt for dielectric constant (ϵ_{r2}) = 2.2



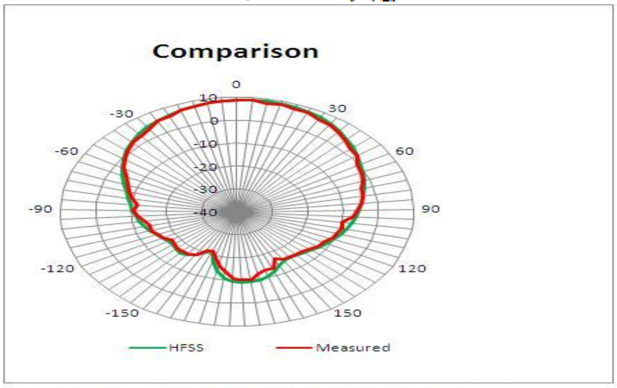
Dk='1' Freq='2.41GHz' M_RZ='0mm' Phi='0deg'



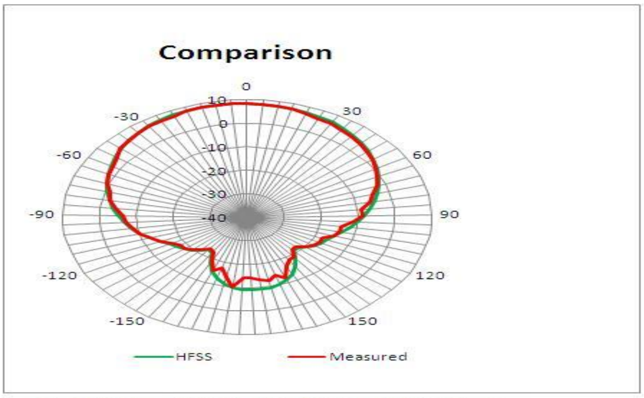
Dk='1' Freq='2.41GHz' M_RZ='0mm' Phi='90deg'

(a) H = 0
(b) H =31.5mm

Fig.5 Comparison of simulated and measured result of radiation pattern plot (a) H = 0mm, phi = 90degree (b) H = 31.25mm, phi = 90degree for (ϵ_{r2}) = 1 in H- Plane.



Dk='10.2' Freq='2.41GHz' M_RZ='25mm' Phi='0deg'



Dk='10.2' Freq='2.41GHz' M_RZ='25mm' Phi='90deg'

(a) H = 0
(b) H =9.78mm

Fig 6: Comparison of simulated and measured result of radiation pattern plot (a) H = 0mm, phi = 0degree (b) H = 9.78mm, phi = 0degree for (ϵ_{r2}) = 10.2 in E- Plane.

Table II: Comparison of simulated and measured result of center frequency, bandwidth and return loss with and without dielectric superstates at H =0mm

Parameters		1*	2.2	3.2	4.8	10.2
Optimum distance (H),mm		31.25	21.07	17.46	14.26	9.78
Center frequency(fo),GHz	Simulated	2.40	2.35	2.32	2.27	2.12
	Measured	2.4	2.34	2.31	2.27	2.12
Band width(GHz)	Simulated	0.04	0.03	0.03	0.03	0.02
	Measured	0.04	0.03	0.03	0.03	0.02
Return loss(dB)	Simulated	-24.94	-24.3	-26.77	-25.12	-21.34
	Measured	-23	-23.2	-25	-23.6	-20.5

*without dielectric superstrate

Table III: Comparison of simulated and measured result of gain, bandwidth with and without dielectric superstates at H =0mm

Dielectric constant	**HPBW(deg.)**				**Gain(dB)**			
	Simulated		***Measured***		***Simulated***		***Measured***	
	Azimuth	***Elevation***	***Azimuth***	***Elevation***	***Azimuth***	***Elevation***	***Azimuth***	***Elevation***
1*	70.9	70.8	71.86	71.28	8.9	7.51	8.9	7.60
2.2	53.8	87.7	53.91	87.94	8.74	7.07	8.60	7
3.2	50.6	99.40	51.58	100.14	8.32	6.88	8.3	6.75
4.8	47.7	110	48.83	110.29	7.67	6.76	7.6	7.6
10.2	57	112	57	112.78	6.44	6.6	6.4	6.50

***without dielectric superstrate**

Table IV: Measured and simulated result of center frequency, bandwidth and return-loss at optimum height

Parameters		1*	2.2	3.2	4.8	10.2
Optimum height (H),mm		31.25	21.07	17.46	14.26	9.78
Center frequency(fo),GHz	Simulated	2.41	2.4	2.41	2.41	2.41
	Measured	2.41	2.4	2.41	2.41	2.41
Band width(GHz)	Simulated	0.04	0.04	0.04	0.04	0.04
	Measured	0.04	0.04	0.03	0.04	0.04
Return loss(dB)	Simulated	-22.1	-19.61	-16.9	-15.64	-12.24
	Measured	-23.1	-20.4	-17.3	-16.4	-11.7

***without dielectric superstrate**

Table V: Measured and simulated result of half power beam-width and gain in elevation and azimuth plane at optimum height

Dielectric constant	**HPBW(deg.)**				**Gain(dB)**			
	Simulated		***Measured***		***Simulated***		***Measured***	
	Azimuth	***Elevation***	***Azimuth***	***Elevation***	***Azimuth***	***Elevation***	***Azimuth***	***Elevation***
1*	71.5	71.4	72	72.06	8.95	7.53	8.95	7.55
2.2	71	71.8	71.93	72.38	8.77	7.36	8.65	7.25
3.2	70.9	70	71.13	70.86	8.66	7.8	8.60	7.7
4.8	69.9	71.2	70.06	71.49	8.71	7.95	8.7	8
10.2	71.3	71.5	72.17	71.95	8.8	8.33	8.8	8.40

***without dielectric superstrate**

VI. RESULTS AND DISCUSSION

The simulated and measured plot of return loss, radiation pattern in E-plane and H-Plane is shown in Figs. 3 to 6 and data is tabulated in corresponding Table II to V, it is observed that the antenna without superstrate, the resonant frequency is 2.4GHz, BW is 0.04GHz, gain is 8.9dB and 7.51dB in elevation and azimuth plane respectively, HPBW is 70.9 degree and 70.8 degree in azimuth plane and elevation plane, at which the return loss is obtained -24.94dB. The antenna with superstrate, the antenna resonant frequency is decreased to 2.12 GHz from 2.4 GHz. BW is decreased to 0.02GHz from 0.04GHz at which the return loss is found -21.34dB. As dielectric constant increases the height of the superstrate is decreased. The height of the superstrate is varying from 31.25 mm to 9.78 mm. At Particularly optimum height the performance characteristics are improved which is almost same as the patch antenna without superstate.

VII. CONCLUSION

The different superstrate dielectric constant effects have been studied on square patch antenna. it has been observed that the HPBW is decreases in azimuth plane and increases in elevation plane. Whereas gain is decreased in azimuth plane and increased in elevation plane at H =0mm. As height is increased from H =0mm to optimum height, the antenna gain is increased in elevation and slightly decreased in azimuth plane. Whereas HPBW is decreased in azimuth plane and increased in elevation plane. The gain and BW is decreasing as increasing dielectric constant of superstrates. VSWR and return loss increases as increasing dielectric constant of the superstrates.

ACKNOWLEDGMENT

The author expresses his deep gratitude to the Department of ECE, MGIT, for their encouragement during this work.

REFERENCES

1. I J Bhal and P Bhartia, "Microstrip antennas", Artech house, 1980.
2. Balanis, C.A., Antenna Theory: Analysis and Design, John Wiley& Sons.
3. Hussain, A. Hammus, " Radiation performance evaluation of microstrip antenna covered with a dielectric layer", Eng& Tech Journal, vol.27, 2009.
4. P. Malathi and Rajkumar" Design of multilayer rectangular microstrip antenna using artificial neural networks" International journal of recent trends in Engineering, vol.2, no.5, Nov. 2009.
5. Christopher J Meagher and Satish kumar Sharm " A wide band aperture- coupled microstrip patch antennas employing space & dielectric cover for enhanced gain performance, IEEE Transaction on antenna and propagation, Vol.58, No.9, Sep. 2010
6. R.K.Yadav,R.L.Yadava "Performance Analysis of superstrate loaded patch antenna and Abstain from environmental Effects"International Journal of Engineering science and Tech., vol.3, no.8, p.p.6582-6591, Aug. 2011
7. H.Attia, L.Yousefi and O.M.Ramahi" Analytical model for calculating the radiation fields of MSA with artificial maganetic superstrates: Theory and experiment. IEEE Tranc. Antennas and wave progation, vol.59,2011
8. M..Younssi,A.Jaoujal" Study of MSA with and without superstrate for Terahz frequency', ISSR Journal, 2013
9. Chirag Arora, Shyam S.Pattnaik and R.N. Baral, "Multiple Split Ring Resonator Inspired Dual Band Microstrip Patch Antenna Array" Microwave Review in June, 2019.
10. Harshit Srivastava and Usha Tiwari "Design, Simulation & Analysis of Rectangular & Circular Microstrip patch antenna for Wireless Applications, International Journal of Recent Technology and Engineering, ISSN. 2277-3878, Volume.8, Issue. 4, November 2019.
11. V. Saidulu, "Design of Inset Feed Rectangular Microstrip Patch Antenna with Different Dielectric Substrates" IJITEE, ISSN. 2278-3075, March 2020.

AUTHOR'S PROFILE

Dr V. Saidulu received B.Tech and M.Tech degree from Nagarjuna University, A.P and Banaras Hindu University, U.P.respectively. He received his Ph.D degree from JNTUH, Hyderabad. Currently he is working as Associate Prof. in ECE Department, MGIT, Hyderabad. His research area is antennas and mobile communications. He has more than 25 papers published to his credit