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Study of Superstrate Effects on Patch Antenna for WiMax/WLAN Applications

KEYWORDS: Rectangular patch, Superstrate, bandwidth etc.

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ABSTRACT *This paper describes the effect of the superstrates on bandwidth, beam-width, gain and radiation pattern of rectangular microstrip patch antenna with and without dielectric superstrates. It is found that there is a slight degradation in the performance of the antenna when the superstrate is touching the patch antenna (H =0mm). Further, it is also observed that the degraded performance characteristics of the rectangular microstrip patch antenna can be improved by placing the dielectric superstates at optimum height H (mm). The microstrip patch antenna without dielectric superstrate achieves an impedance bandwidth of 0.04GHz (SWR 2) at 2.40 GHz, and patch antenna with dielectric superstrates which shows that the resonate frequency is decreased and achieved impedance bandwidth is 0.030 GHz (SWR 2) at 2.30 GHz. As the dielectric constant of the superstrate increases, it has been observed that the center frequency varies from 2.34GHz to 2.08GHz. For superstrates of different dielectric constants, it has been observed that the HPBW decreases in azimuth plane where as it increases in the elevation plane. The center frequency is decreased to 2.30 GHz from 2.40 GHz, bandwidth is decreased to 0.030 GHz (SWR 2) from 0.040 GHz and gain is decreased to 6.0 dB from8.75dB. As the height of the superstrate is increased the performance of the patch antenna improves and at particular optimum height the performance characteristics will almost be same as that of the patch antenna without superstrate. The antenna is mainly intended to be used for WiMax (2.2 -3.4 GHz) and WLAN (2.40 -2.48 GHz) applications.*

INTRODUCTION

Rectangular microstrip antenna is widely used in wireless communication because of light weight and smaller size and low profile [1]. In many applications require dielectric superstrate above the radiating elements to provide protection from environmental hazards and improve the performance of antenna. When microstrip patch antenna covered with dielectric superstrate the antenna resonant frequency is decreased and other parameters are slightly degraded. The rectangular microstrip antenna is designed at 2.4GHz for wireless application. This paper is mainly focused on the effect of the superstrate on the characteristics of rectangular microstrip patch antenna. An antenna with superstrate height H=0mm, the resonant frequency is shifted to lower side because of dielectric loaded. Due to this loading effect the antenna performance characteristics are degraded [1-22]. Degraded the antenna performance characteristics such as gain and bandwidth can be improved by placing the Superstrate at optimum height H mm for various dielectric constants of the Superstrates.The geometry of the rectangular patch antenna is shown in Fig.1

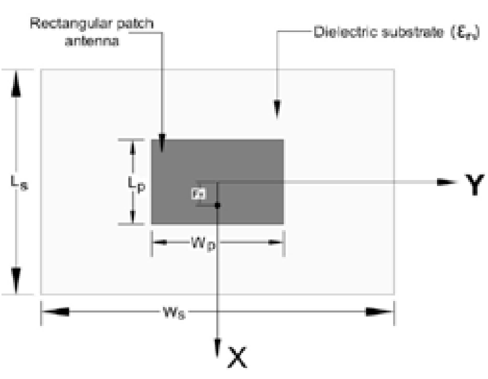

Fig1: Geometry of patch antenna with superstrtae

DESIGN SPECIFICATIONS OF SUBSTRATE AND SUPERSTRATE MATERIALS

The specification of substrate and superstrate materials is used in the designing of rectangular microstrip patch antenna with and without superstrates which is shown in Tables 1 and 2.

TABLE- 1
SPECIFICATION OF SUBSTRATE MATERIALS

Substrate Material	Dielectric Constant (εr1)	Loss Tangent (Tan ε)	Tickness of the Substrate (h1) ,mm
Arlon diclad 880	2.2	0.0009	1.6

TABLE- 2
SPECIFICATION OF DIELECTRIC SUPERSTRATE:

Superstrate Materials	Dielectric Constant (εr2)	Loss Tangent (Tanε)	Thickness of the superstrates (h2), mm
Arlon diclad 880	2.2	0.0009	1.6
Arlon Ad 320	3.2	0.003	3.2
FR4	4.8	0.02	1.6
Arlon Ad 1000	10.2	0.0035	0.8

ANTENNA DESCRIPTION AND DESIGN GEOMETRY

The geometry of the rectangular microstrip patch with detailed dimensions is shown in Fig1. The antenna designed at operating frequency of 2.4GHz and designed dimension is shown in Table 3.

TABLE-3
DESIGNED DIMENSION OF PATCH ANTENNA (MM)

Width (W)	Length (L)	Feed point (Fx, Fy)
81.23	70.43	(10.5,0)

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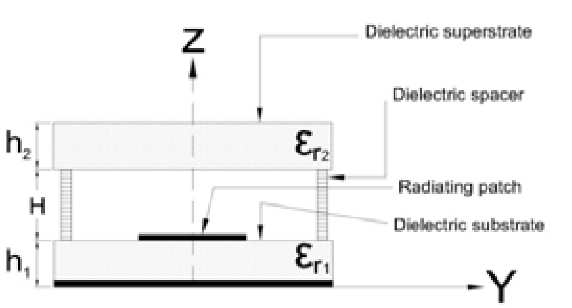


Fig: 2 The schematic of a patch antenna loaded with a superstrate at height H above the patch (side view).

ANTENNA PERFORMANCES WITH AND WITHOUT DIELECTRIC SUPERSTRATE USING SIMULATION AND MEASUREMENTS

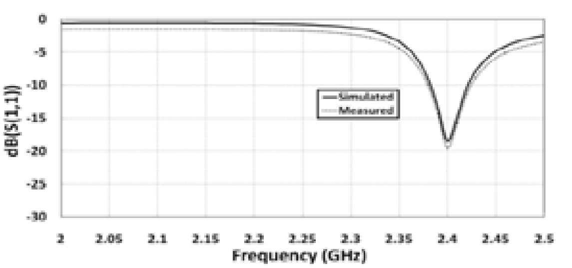


Fig: 3 Comparison of measured and simulated results of return-loss for rectangular microstrip patch antenna without dielectric superstrate (ε r1)= (ϵ_{r1}) = 2.2(free space radiation conditions).

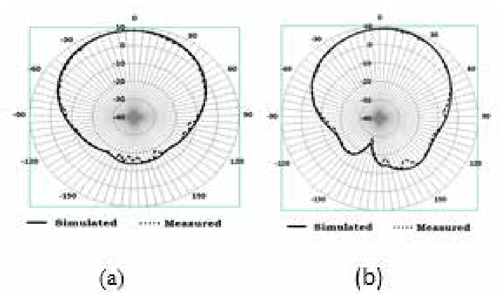
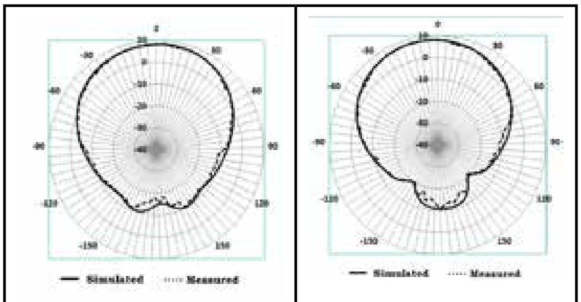
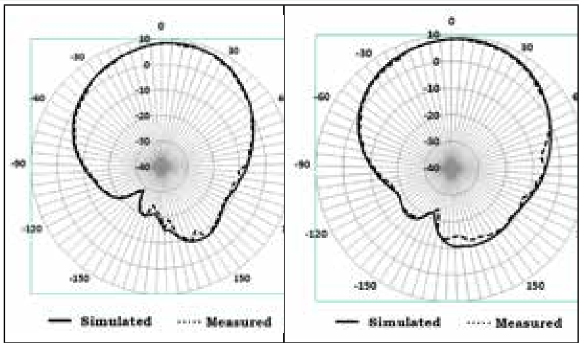


Fig:4 Comparison of measured and simulated results of radiation patterns for rectangular microstrip patch antenna in (a) E-plane and (b)H-planefor ϵ_{r1}=(ε r1) = 2.2 without dielectric superstrate (free space radiation conditions) at 2.40 GHz



(a) Φ=0^0, H=0 (b) Φ=0^0, H=H_{opt}

Fig:5 Measured and simulated radiation patterns of rectangular patch antenna in E-plane for εr2= ϵ_{r2}= 2.2, ε=0^0 (a) H=0, f_r = f_r =2.34 GHz (b) H=H_{opt}, f_r = f_r =2.38 GHz.



(a) ε=90^0, H=0 (b) ε=90^0, H=H_{opt}

Fig:6 Measured and simulated radiation patterns of rectangular patch antenna in H- Plane for ϵ_{r2}= εr2= 2.2, ε=90^0 (a) H=0, f_r =f_r = 2.34 GHz, (b) H=H_{opt}, f_r =, f_r = 2.38 GHz.

TABLE -4
SIMULATED AND MEASURED RESULT OF GAIN, BANDWIDTH AND RETURN- LOSS OF RECTANGULAR MICROSTRIP PATCH ANTENNA WITH DIELECTRIC SUPERSTATES AT HEIGHT H =0 (mm)

Dielectric constant (εr2)		1	2.2	3.2	4.8	10.2
Optimum Height (H),mm		-	21.07	17.46	14.26	9.78
Center frequency(fo),GHz	Simulated	2.40	2.34	2.31	2.26	2.08
	Measured	2.40	2.34	2.31	2.26	2.08
Band width(GHz)	Simulated	0.040	0.030	0.030	0.030	0.030
	Measured	0.040	0.030	0.030	0.030	0.030
Return loss(dB)	Simulated	-18.51	-19.91	-20.46	-21.29	-25.64
	Measured	-19.00	-17.80	-22.00	-21.00	-26.64

TABLE- 5
SIMULATED AND MEASURED RESULT OF GAIN, BANDWIDTH OF RECTANGULAR MICROSTRIP PATCH ANTENNA WITH DIELECTRIC SUPERSTATES AT HEIGHT H =0 (mm)

Dielectric constant (εr2)	HPBW(deg.)				Gain(dB)			
	Simulated		Measured		Simulated		Measured	
	Azimuth	Elevation	Azimuth	Elevation	Azimuth	Elevation	Azimuth	Elevation
1	70.8	71.1	71.27	71.23	8.77	8.16	8.75	8.1
2.2	60.7	85.4	61.52	85.8	8.67	7.85	8.6	7.90
3.2	57.4	95.8	57.89	95.81	8.26	7.34	8.3	7.3
4.8	53.8	101.5	54.5	101.7	7.76	7.06	7.77	7.00
10.2	49.1	112.0	49.35	112.67	6.02	6.59	6.00	6.50

TABLE -6
SIMULATED AND MEASURED RESULT OF BANDWIDTH AND RETURN LOSS OF RECTANGULAR MICROSTRIP PATCH ANTENNA WITH AND WITHOUT DIELECTRIC SUPERSTATES AT OPTIMUM HEIGHT (H) =Hopt (MM)

Dielectric constant (ϵ_rεr2)		1	2.2	3.2	4.8	10.2
Optimum Height (H),mm		-	21.07	17.46	14.26	9.78
Center frequency(fo),GHz	Simulated	2.40	2.38	2.39	2.4	2.4
	Measured	2.4	2.38	2.39	2.4	2.4

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Band width(GHz)	Simulated	0.040	0.040	0.040	0.040	0.040
	Measured	0.040	0.040	0.040	0.040	0.040
Return loss(dB)	Simulated	-17.52	-17.46	-16.44	-14.6	-11.15
	Measured	-20.40	-18.80	-15.80	-14.00	-12.15

TABLE -7
SIMULATED AND MEASURED RESULT OF BEAM WIDTH AND GAIN OF RECTANGULAR MICROSTRIP PATCH ANTENNA WITH DIELECTRIC SUPERSTATES AT OPTIMUM HEIGHT (H) =Hopt (MM)

Dielectric constant (εr2)	HPBW(deg.)				Gain(dB)			
	Simulated		Measured		Simulated		Measured	
	Azimuth	Elevation	Azimuth	Elevation	Azimuth	Elevation	Azimuth	Elevation
1	71.1	71.5	71.43	71.94	8.8	8.2	8.8	8.1
2.2	70.1	71.5	71	71.53	8.7	8.08	8.65	8.0
3.2	69.9	71.2	70.72	72.14	8.65	8.17	8.6	8.20
4.8	69.5	71	70.24	71.62	8.7	8.28	8.6	8.3
10.2	68.5	73	68.51	73.85	8.88	8.59	8.75	8.55

RESULTS AND DISCUSSION

Coaxial probe fed rectangular microstrip antenna is designed to operate at 2.4GHz and behavior is explained through parameter study using Finite Element Method based on EM-simulator such as HFSS (High Frequency Structure Simulator). Geometry of the proposed rectangular microstrip patch antenna is shown in Fig.1 and Fig.2. Dielectric constant (εr2)ϵ_{r2}) =1 is considered as antenna without dielectric superstrate and dielectric constant (εr2) ϵ_{r2}) =2.2, 3.2, 4.8 and 10.2 considered as antenna with dielectric superstrates at H= 0 (mm) and optimum height with superstrate H mm. The geometry of the patch antenna with dielectric superstrate at a optimum height Hmm is shown in Fig.2. The simulation result have been carried out for superstrates of various dielectric constants of εr2 =2.2, 3.2, 4.8 and 10.2. For superstrates of different dielectric constants, it is observed that the center frequency is decreased to 2.30 GHz from 2.40 GHz, bandwidth is decreased to 0.030 GHz (SWR<<2) from0.040 GHz and gain is decreased to 6.0 dB from 8.75 dB. As the height of the superstrate is increased the performance of the patch antenna improves and at particular optimum height is shown in Table 6 and 7, the performance characteristics will almost be same as that of the patch antenna without superstrate. Further, it has been also observed that the HPBW decreases in azimuth plane where as it increases in the elevation plane. The gain of the patch antenna is decreased with increasing dielectric constant of the superstrates. The return-loss as a function of frequency and radiation patterns at the center frequency are shown in Fig.6 and Fig. 7 for ϵ_{r2} εr2 =2.2. It is observed that the impedance bandwidth without superstrates is 0.04 GHz and with superstrate 0.030 GHz (SWR≤2). The overall results are given in Tables 4 to 7 for ϵ_{r2} εr2 =2.2, 3.2, 4.8 and 10.2 at optimum heights. As the height of the superstrate is increased the performance of the patch antenna improves and at particular optimum height the performance characteristics will almost same as that of the patch antenna without superstrate

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