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EFFECTS OF SUPERSTRATE ON MICROSTRIP ANTENNA WITH COAXIAL PROBE FEED

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Abstract: This paper presents an analysis of rectangular and square patch microstrip antennas with and with sutsuperstate. The effect of the superstate on the radiation pattern,, input impedance, bandwidth, beamwidth, gain and VSWR examined. In this work, the pattern of designs of the microstrip patch antenna have been analyzed and studied experimentally. Both the antennas were designed with 2.4GHz and simulated using HFSS simulation software. The low dielectric constant substrate and superstrate materials are used for designing and fabrication of these antennas. This paper mainly focuses on comparison of antenna performance characteristics. These antennas are used in wireless communications.

Keywords: Dielectric superstrate, Radiation pattern, Return loss, Beam-width etc.

I. INTRODUCTION

Microstrip antenna consists of radiating patch on the one side of the substrate having the ground plane on other side. The major advantages are light weight, low profile, conformable to planar and non planar surfaces and easy to fabricate. The microstrip antenna are suitable for high speed vehicles, aircraft's, space crafts and missiles because of low profile and conformal nature of characteristics [2]. Microstrip antenna has inherent limitation of narrow bandwidth. So, superstrate is used on a microstrip antenna as a cover to protect the antenna from external environmental conditions like temperature, pressure etc. When microstrip antenna covered with a dielectric superstrateits properties like resonance frequency, gain, bandwidth and beam width are changed which may seriously degrading the antenna performance[1-4]. By choosing the thickness of the substrate superstrate layer, a very large gain can be achieved [5-9]. Coaxial probe fed rectangular and square microstrip antenna characteristics have been investigated using HFSS software and measured experimentally. The variation of some selected antenna characteristics has been studied using with and without dielectric superstrate. When microstrip antennas are covered with protective dielectric superstrates, are subjected to icing conditions, or come into contact with plasma, the resonant frequency is altered and shifted to lower sides, causing detuning which may seriously degrading the antenna performance. As the bandwidth and gain of microstrip antennas is inherently low, typically of the order of 1-2%[1]. It is important to determine the effect of dielectric superstrate on the resonant frequency of the microstrip antennas and in order introduce appropriate corrections in the design of microstrip antennas[10-14]. In this paper experimentally measured the effect of dielectric superstrates on the antenna parameters such as bandwidth, beam-width, gain, resonant frequency radiation pattern are studied at various thicknesses. This paper mainly focused on comparison of antenna performance. These antennas are used in wireless communication. The geometrical structure of rectangular and square patch antennas are shown in Figs. 1 and 2.

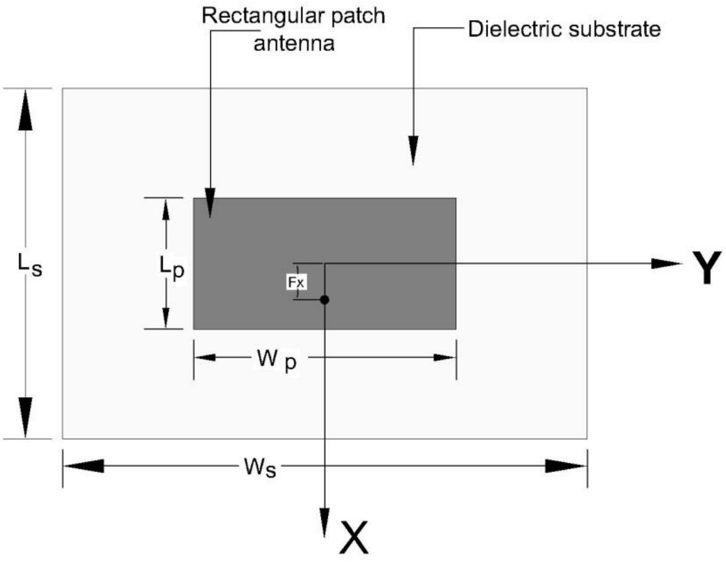


Fig.1 Rectangular patch antenna

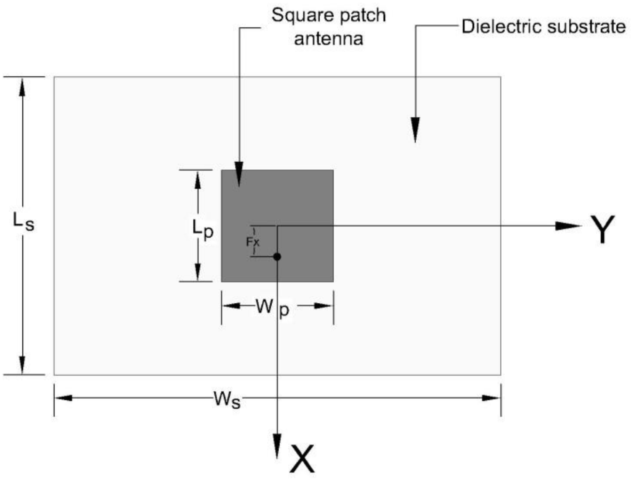


Fig.2. Square patch antenna

II. ANTENNA DESIGN

The designing of the rectangular and square microstrip patch antenna, the transmission-line model and cavity model is used, because easy to analysis andgood physical insight. Basically the transmission –line model represents the microstrip antenna by two slots. The amount of fringing is a function of the dimentions of the patch and the height of the substrate.. Since for microstrip antennasL/h≫ 1, fringing is reduced; however, it must be taken into account because it influences the resonant frequency of the antenna. 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.

$$W/h > 1$$

$$\in_{reff} = \frac{\in_r + 1}{2} + \frac{\in_r - 1}{2}\left[1 + 12\frac{h}{W}\right] - 1/2$$

1. For an efficient radiator, a practical width that leads to good radiation efficiencies is

$$W = \frac{1}{2f_r\sqrt{\mu_0}\in_0}\sqrt{\frac{2}{\in_r + 1}} = \frac{\vartheta_0}{2f_r}\sqrt{\frac{2}{\epsilon_{r+1}}}$$

2. The actual length of the patch can now be determined

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

Table 1: Antenna design dimensions

Type of Patch	Width (W),mm	Length (L),mm	Feed Point (F),mm
Rectangular Patch Antenna	49.4	40.3	X=0, Y=10.5
Square patch antenna	33.6	33.6	X=0, Y=10.0

III. SPECIFICATIONS

The geometry of a probe fed rectangular microstrip patch antenna is shown in Figs1 and 2. The antenna under investigation is a patch of width(W) is 49.4mm, length(L) is 40.3mm where as square patch width (W) is 33.6mm and length (L) is 33.6mm. The same substrate and superstrates materials are used for designing both patches and are fabricated on Arlondiclad 880 dielectric substrate, whose dielectric constant($\in_{r1}$) is 2.2, loss tangent(tanδ) is 0.0009, thickness(h) is 1.6mm and substrate dimension is 100mm×100mm. The dielectric superstrate is Arlon diclad 880 dielectric substrate ,whose dielectric constant($\in_{r2}$) is 2.2, loss tangent(tanδ) is 0.0009, thickness(h) is 1.6mm and substrate dimension is 100mm×100mm. The antenna center frequency is 2.4GHz(ISM band) and corresponding feed location is X=0 and Y=10.5 is shown in Figs.1 and 2. The ground plane is perfectly conducting. Antenna geometry, material properties and boundary conditions are considered and simulated using HFSS. The variation of superstrate thickness above the substrate studied experimentally for various parameters such as bandwidth, gain, beamwidth, resonant frequency, radiation pattern etc. The specifications of substrate and superstrate materials are shown in Tables 2 and 3.

Table 2: Dielectric substrate specifications

Substrate Material	Dielectric Constant ($\in_{r1}$)	Loss Tangent ($Tan\delta$)	Tickness of the Substrate(h_1),mm
Arlondiclad 880	2.2	0.0009	1.6

Table 3: Dielectric superstrate specifications

Superstrate Material	Dielectric Constant ($\in_{r2}$)	Loss Tangent ($Tan\delta$)	Thickness of Superstrates (h_2), mm
Arlondiclad 880	2.2	0.0009	1.6

IV. DIELECTRIC SUPERSTRATES EFFECTS

The change of the resonant frequency by placing the dielectric superstrate has been calculated using the following the expression.

$$\frac{\nabla f_r}{f_r} = \frac{\sqrt{\in_e}-\sqrt{\in_{eo}}}{\sqrt{\in_e}}$$

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

$$\frac{\Delta f_r}{f_r} = {}^1/_2 \frac{{}^{\Delta\in_e}/_{\in e_o}}{1+{}^1/_2\,{}^{\Delta\in_e}/_{\in e_o}}$$

Where,

$\in_e$= Effective dielectric constant with dielectric superstrte

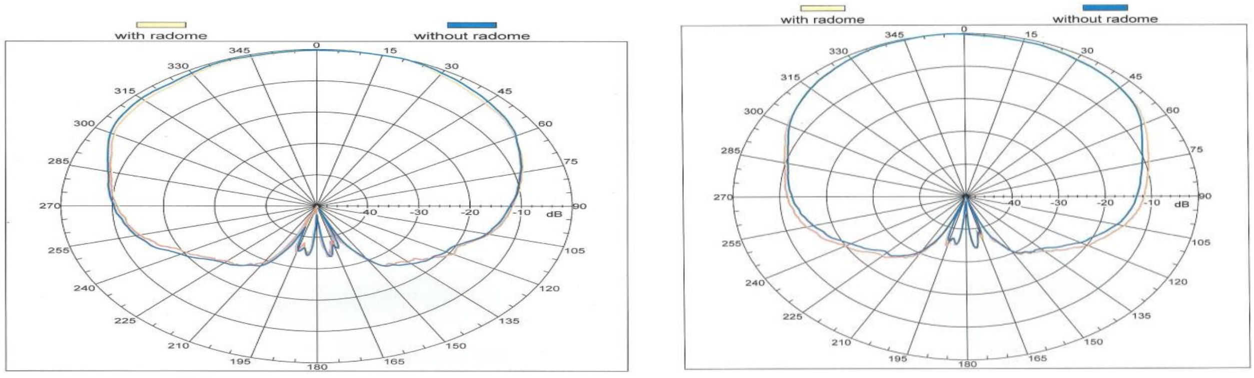
$\in e_o$=Effective dielectric constant without dielectric superstrate

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

Δf_r =Fractional change in resonance frequency

f_r =Resonce frequency

V. EXPERIMENTAL RESULTS AND DISCUSSION



(a) (b)

Fig 3. Far field radiation pattern with and without superstate in horizontal plane (a) Square patch at superstrate thickness1.0mm (b) Rectangular patch at superstrate thickness 2.4mm

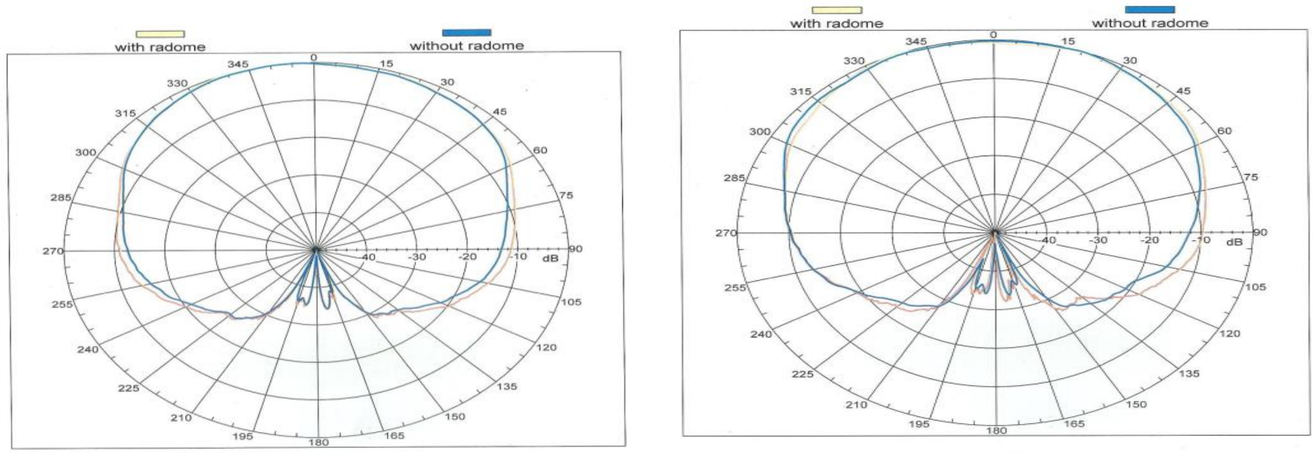
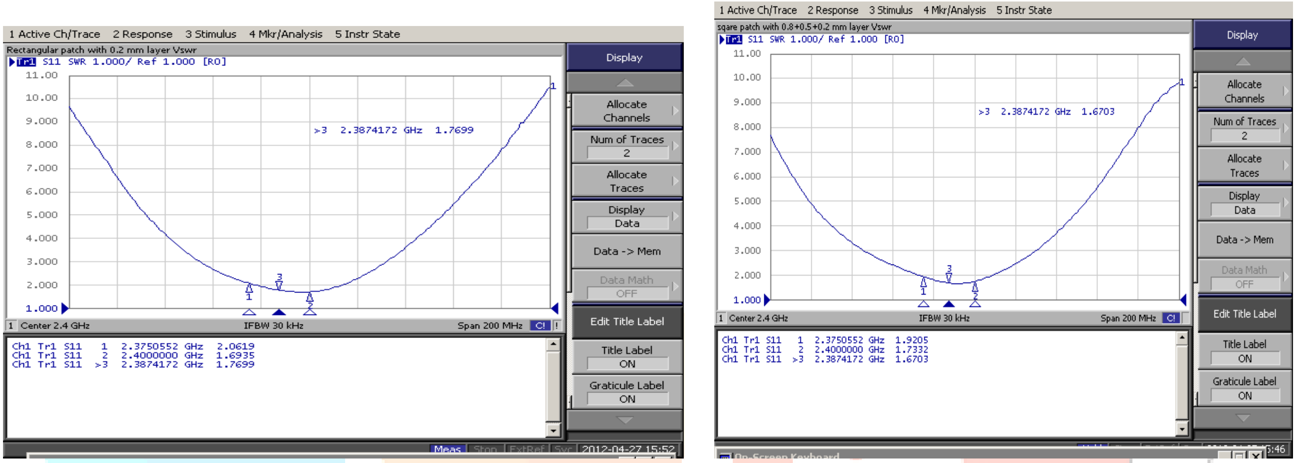


Fig 4. Far field radiation pattern with and without superstate in horizontal plane (a) Square patch at superstrate thickness 3.2mm (b) Rectangular patch at superstrate thickness 3.2mm



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Rectangular patch with 0.2 mm layer Vswr
Tr1 S11 SWR 1.000/ Ref 1.000 [R0]
>3  2.3874172 GHz  1.7699
1  Center 2.4 GHz          IFBW 30 kHz          Span 200 MHz
Ch1 Tr1 S11   1  2.3750552 GHz  2.0619
Ch1 Tr1 S11   2  2.4000000 GHz  1.6935
Ch1 Tr1 S11  >3  2.3874172 GHz  1.7699
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sqare patch with 0.8+0.5+0.2 mm layer Vswr
Tr1 S11 SWR 1.000/ Ref 1.000 [R0]
>3  2.3874172 GHz  1.6703
1  Center 2.4 GHz          IFBW 30 kHz          Span 200 MHz
Ch1 Tr1 S11   1  2.3750552 GHz  1.9205
Ch1 Tr1 S11   2  2.4000000 GHz  1.7332
Ch1 Tr1 S11  >3  2.3874172 GHz  1.6703
```

(a) (b)

Fig. 5. VSWR plot (a) Rectangular patch at superstrate thickness 0.2mm (b) Square patch at superstrate thickness 1.5mm

Table 4: Experimental data for without superstrate (single patch)

Patch Antennas	Dielectric Constant ($\in_{r1}$)	Center Frequency (f_0) in GHz	Band –Width (BW) in GHz	Gain (G) in db	HPBW (HP) in Degree	HPBW (VP) in Degree
Rectangular patch	2.2	2.410	0.203	7.3	88.36	90.0
Square patch	2.2	2.410	0.046	4.8	108.16	90.20

Table 5: Experimental data for rectangular patch antenna with different superstrates

Thickness of Superstrate Dielectric ($\in_{r2}$) in mm	Center Frequency (f_0),GHz	Band-Width (BW),dB	Gain (G),dB	HPBW (HP),Deg	HPBW (VP),Deg
0.2	2.3875276	0.0249448	4.29	90.94	70.71
0.5	2.3833334	0.0333333	3.97	89.80	73.29
0.8	2.3804636	0.0390728	3.85	84.77	76.88
1.0	2.3727373	0.0545254	5.75	88.40	77.63
1.3	2.3727373	0.0545254	6.12	84.69	67.91
1.5	2.3727573	0.0545254	6.0	84.20	73.20
2.2	2.37273	0.03213	3.3	91.50	71.80
2.4	2.3372345	0.02234	4.99	90.23	74.20
3.2	2.3372732	0.02121	4.47	91.20	76.34

Table 6: Experimental data for rectangular patch antenna with superstrates

Thickness of dielectric superstrates	Frequency(GHz)	VSWR
0.8	2.360927 2.4 2.387417	1.8791 2.2373 1.8534
1.3	2.345475 2.4 2.380353	1.94184 2.9168 2.076
1.5	2.345475 2.4 2.380353	1.9904 2.7226 1.8992
1.0	2.345475 2.4 2.380353	2.437 2.278 1.758
0.5	2.366 2.4 2.387	1.810 1.6935 1.7699
0.2	2.375055 2.4 2.387417	2.0619 1.6935 1.7699

Table 7: Experimental data for square patch antenna with different superstrates

Thickness of Superstrate Dielectric $(\in_{r2})$ in mm	Center Frequency (f_0),GHz	Band-Width (BW),dB	Gain (G),dB	HPBW (HP),Deg	HPBW (VP),Deg
0.2	2.3866446	0.02671108	1.42	98.16	80.20
0.5	2.3953643	0.0158941	0.93	99.15	74.86
0.8	2.3953643	0.0158941	1.63	95.41	77.56
1.3	2.3953643	0.0158941	1.83	105.33	79.72
1.5	2.3875276	0.0249448	1.81	95.20	79.24
2.2	2.354321	0.02431	3.43	98.55	81.07
2.4	2.323423	0.02413	0.74	98.01	77.30
3.2	2.33421	0.02131	0.47	102.25	83.61
0.2	2.3866446	0.02671108	1.42	98.16	80.20

Table 8: Experimental data for square patch antenna with superstrate

superstrates, mm	Frequency(GHZ)	VSWR
0.8	2.387417 2.4 2.403311	1.8655 1.6451 1.6367
1.3	2.387417 2.4 2.403311	1.7067 1.786 1.8429
1.5	2.37555 2.4 2.387417	1.9205 1.7332 1.6703
1.0	2.356071 2.4 2.369316	2.8184 1.6663 2.206
0.2	2.373289 2.4 2.387417	1.238 2.253 1.389
0.5	2.387417 2.4 2.403311	1.9083 1.6564 1.6457

We observed from rectangular microstrip patch, the resonating frequency is shifting to lower side 2.40 GHz to 2.33GHz, while other parameters have slight variation in their values. The gain of single patch antenna without dielectric superstrate is 7.3 dB and the microstrip patch with dielectric superstre is 3.3dB to 6.0dB. The bandwidth of microstrip single patch without dielectric superstrate is 2% and the microstrip patch with dielectric superstrte is 2.% to 5.0% based upon the thickness of the dielectric superstrtes. The beamwidth for single patch without dielectric superstrte in E-Plane is 88.36^0 and in H-Plane is 90.2^0. The beamwdth with dielectric superstre in E-Plane is $84.20^0$to 9.94^0 and in H-Plane is $67.91^0$to 77.63^0. The value of VSWR is from 1.6935 to 2.2373 based upon the thickness of the dielectric superstrates. The variation of VSWR with different dielectric superstrate thickness, as dielectric superstrate thickness increases, VSWR increases. The variation of gain at different dielectric superstrate thickness, as dielectric superstrate thickness increases, gain decreses. The beamwidth in E-Plane decreases from 90.94 degree to 90.50 degree and in H-Plane increases from 70.71 degree to 71.80 degree. The bandwidth of microstrip antenna is increases with increasing thickness of dielectric superstrates for low dielectric constant and decreases for high dielectric constant.The experimental measured results is shown in tables 4 to 8 and corresponding measured VSWR and radiation pattern plot for various thickness is shown in Fig 3 to Fig 5.The discussion we conclude that in the following points square patch microstrip antennas.

1. Variation of VSWR with different dielectric superstrate (radome) thickness, as dielctricsuperstrate thickness increases, VSWR increases.
2.Variation of gain at different dielectric superstrate(radome) thickness as dielectric superstrate thickness increase, the gain decreases.
3. The antenna beamwith in E-Plane increases from 95.20 degree to 105.33dregree and the antenna Beam width in H-Plane increases from 74.86 degree to 83.61 degrees.
4. The return loss first increases with increasing thickness of dielectric superstrates and then decreases.
5. The bandwidth of the microstrip antennas also increases with increasing thickness of dielectric superstrate for low dielectric constant materials, and decreases for high dielectric constant of the materials.

V CONCLUSION

The design of rectangular microstrip antennas with and without dielectric superstrates has been presented. The resonant frequency of a microstrip covered with dielectric superstrates can be predicted accurately if the effective dielectric constant of the structure is known. The effective dielectric constant can be calculated using transmission line. The experimentally results shows that the variation of VSWR with different dielectric superstrate thickness, as dielectric superstrate thickness increases, VSWR increases. The variation of the antenna gain at different dielectric superstrate thickness as dielectric superstrate thickness increases, the gain decreases. The bandwidth of the microstrip antennas can also increases with increasing thickness of the dielectric superstrate for low dielectric constant materials, and decreases for high dielectric constant of the substrate materials. Initially the return loss increases with increasing thickness of dielectric superstrates and then decreases. The antenna beamwidth in E-Plane increases from 84.20 degree to 9.94 degree and beamwidth in H-Plane is increases from 67.91 degree to 77.63 degree.The among variouethickness at 1.3mm thicknes will give higher gain 6.0Db and higher BW 5%. Observed from the square patch, antenna beamwidth in E-Plane increases from 95.2 degree to105.33 degree and beamwidth in H-Plane increase from 95.20 degree to 105.33 degree and among various thickness 2.2mm thicknes is best for higher gain 3.43dB and 0.2mm thicknes is best for higher BW is 2%

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