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Investigation on Wideband E-Shaped Microstrip Patch Antenna with Dielectric Superstrate

V. Saidulu, K. Srinivasa Rao, P. V. D. Somasekhar Rao

Abstract—This paper describes the effect of the superstrates on bandwidth and gain of E-shaped microstrip patch antenna without superstrate and loaded with dielectric superstrates. It is found that there is a degradation in the performance of the antenna when the superstrate is touching the patch antenna i.e its height above the patch antenna (H) =0 mm. Further, it is also observed that the degraded performance characteristics of the patch antenna can be improved by placing the superstrates at optimum height (H) =H_{opt}. The microstrip patch antenna without dielectric superstrate has an impedance bandwidth of 0.17GHz (SWR ≤ 2) at 2.04 GHz, gain is 8.67 dB and return-loss is -19.95 dB. When the superstrate is placed touching the patch antenna, the resonant frequency is reduced to 1.59 GHz from 2.04 GHz and bandwidth is reduced 0.15 GHz (SWR ≤ 2) at 1.59 GHz, gain is decreased by about 0.92% (0.08 dB) for ε_r= 2.2 to 39.5% (3.47 dB) for ε_r= 10.2. As the height of the superstrate is increased, the performance of the patch antenna improves and at a particular optimum height the gain for all the superstrates will be closer to the free space radiation conditions of the patch antenna without superstate. But the resonant frequency decreases with increase in ε_{r2}. The variation in the return-loss for H = H_{opt}. is within ± 1.5 dB of the free space radiation condition for all the dielectric constant of the superstrate and it is within acceptable limits. The bandwidth improves (12%) for ε_{r2} up to 4.8. However, the bandwidth decreases for ε_{r2}= 10.2. There is a good agreement between simulated and measured results.

Index Terms—E-shaped patch antenna, Superstrate, bandwidth and axial ratio etc.

I. INTRODUCTION

The characteristics of E-and U- slot microstrip patch antennas have been studied by simulation and experiments by various authors [1-4]. The attention of the most of the researchers [4-6] has been on the evaluation of radiation characteristics of simple E-shaped patch antennas without any superstrate loading. Such an attempt is made in the present work in which all the performance characteristics of superstrate loaded E –shaped patch antenna have been evaluated. It would be of particular interest to realize the advantages associated with superstrate loaded E- shaped patch antenna.

This paper presents effect of the superstrate on the characteristics of E-shaped microstrip patch antenna. The schematic diagram of the patch antenna loaded with superstrate is shown in Fig. 1. The dielectric superstrates of different dielectric constants are used to study the effect on the performance of the patch antenna. The height of the superstrate is varied and the effect of the height is investigated. The simulation method using High Frequency Structure Simulator (HFSS), version 13.0, is employed to obtain the simulated results of performance characteristics without superstrate and loaded with superstrates as a function of dielectric constant and height of the superstrate. The experimental results are obtained with the help of Precision Network Analyzer (Agilent E8363B) and anechoic chamber.

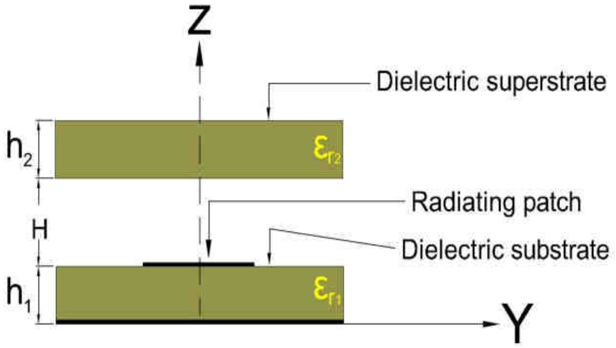

Fig. 1 The schematic of a patch antenna loaded with a superstrate at height H above the patch (side view).

II. SPECIFICATIONS

The specifications of suitable dielectric substrate and superstrate [7-10] are shown in Table 1 and Table 2 respectively. A thicker substrate is mechanically strong with improved impedance bandwidth [10]. However it will increase weight and surface wave losses. The substrates dielectric constant ε_r plays an important role similar to that of the substrate thickness. A low value of ε_r for the substrate will increase the dielectric loss and therefore reduces the antenna efficiency [10, 11].

TABLE 1: Specifications of dielectric substrate (ε_{r1}) material used in the design of patch antennas

Substrate material	Dielectric constant (ε_{r1})	Loss tangent (Tanδ)	Substrate thickness (h_1)mm
Arlon diclad 880	2.2	0.0009	1.6

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V. Saidulu, Department of Electronics and Communication, MGIT,Hyderabad, T.S, India.
K. Srinivasa Rao, Department of Electronics and Communication, VIFCET, Hyderabad, T.S, India.
P. V. D. Somasekhar Rao, Department of Electronics and Communication, JNTUH, Hyderabad,T.S, India.

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TABLE 2: Specifications of dielectric superstrate (ε_{r2}) materials used to study the effect of the superstrate on the performance of the antenna:

Superstrate Materials	Dielectric Constant (ε_{r2})	Loss Tangent (Tanδ)	Thickness of the superstrates (h_2)mm
Air	1.0	0.00009	-
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

III. E- SHAPED PATCH ANTENNA DESIGN AND ITS GEOMETRY

The E-shaped patch antenna produces a wideband beam. The E-shaped microstrip patch antenna is designed at 2.0 GHz on Arlon diclad 880 substrate (ε_{r1}=2.2, h_1=1.6 mm), using expressions available in the standard literature [1, 2, 5, 6]. The designed dimensions of E-shaped patch antenna are given in Table 3.

The patch antenna is fed with coaxial probe at point where the input impedance of the patch is 50 Ω. The geometry of the E-shaped microstrip patch antenna is shown in Fig.2, where W_s = Substrate width, L_s= Substrate length, W_p= Patch width, L_p= Patch length, S_{1L}= Length of the top slot, S_{2L}=Length of the bottom slot, S_{1W}, S_{2W} are the width of both top and bottom slot and (f_x , f_y) are co-ordinates of the feed point.

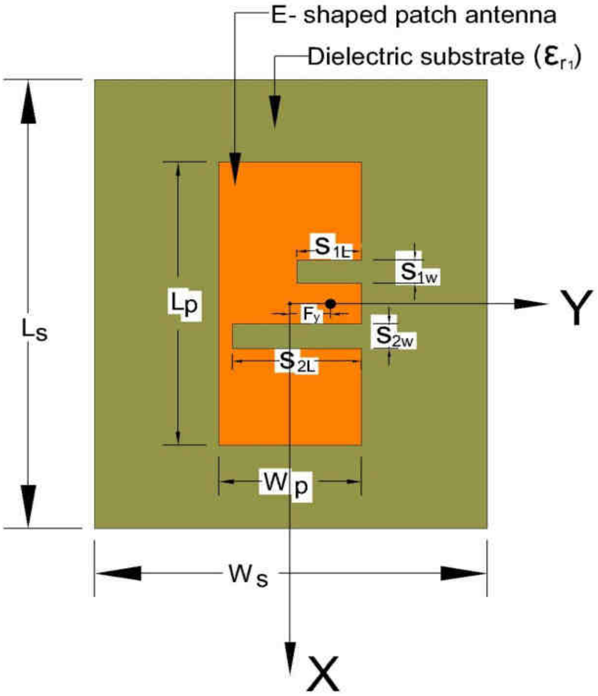


Fig. 2 The top view of E-shaped microstrip patch antenna.

TABLE3: The dimensions of E-shaped patch antenna

Frequency (f_r)	2.0GHz
Dielectric constant (ε_r)	2.2
Thickness (h)	1.6 mm
Substrate ground width (W_S)	150 mm
Substrate ground length (L_S)	150 mm
Patch width (W_P)	55 mm
Patch length (L_P)	55 mm
Top slot length (S_{1L})	25 mm
Top Slot width (S_{1W})	8 mm
Bottom slot length (S_{2L})	50 mm
Bottom Slot width (S_{2W})	8 mm
Feed point location	f_x=0 mm and f_y=9.5 mm

IV. EFFECT OF SUPERSTRATE ON E-SHAPED PATCH ANTENNA

The microstrip patch antenna is covered with the dielectric superstrate as shown in Fig.3. When superstrate is placed above the patch (H = 0 mm) the resonant frequency is shifted to lower side and other parameters are adversely affected.

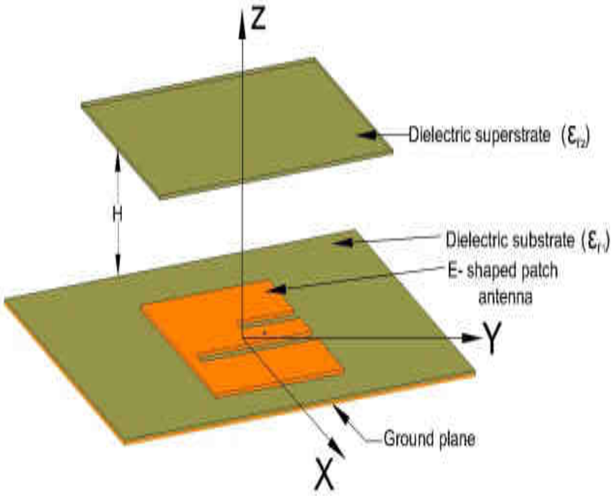


Fig. 3 The schematic of E-shaped microstrip patch antennas with dielectric superstrate.

V. SIMULATED AND EXPERIMENTAL RESULTS

The performance characteristics of the E-shaped patch antenna are evaluated without dielectric superstrate using commercial electromagnetic software such as High Frequency Structure Simulator (HFSS) version 13.0. Then the change in performance of the antenna is studied with dielectric superstrate of different dielectric materials as mentioned in Table 2. The effect of the height of the superstrate above the patch (H) is also studied by simulation. The height at which the performance of the patch is optimum is also found by simulation using HFSS version 13.0. The measurements were carried out by using

i. Precision Network Analyzer (Agilent E8364B) to measure the return-loss (VSWR), center frequency and bandwidth and

ii. 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 (0.5-6GHz).

The antenna measurements were carried out in Anechoic chamber having dimensions (30×20×15) feets.The distance between transmitting and receiving antennas is kept as 5.3mts. The radiation pattern measurements were carried out at 2.0GHz.

VI. RESULTS AND DISCUSSION

As in the case of other patch antennas [10, 11], it is observed that there is a slight degradation in the performance of the antenna when the superstrate is touching the E-shaped patch antenna (H =0 mm). The simulated results show that the center frequency is decreased to 1.59 GHz from 2.04 GHz, bandwidth is decreased to 0.15 GHz from 0.17 GHz, gain is decreased to 5.10 dB from 8.67 dB. The change in the return-loss with increase in dielectric constant is within acceptable limits. The geometry of the patch antenna with dielectric superstrate at a height (H) is shown in Fig.3. A dielectric constant ε_{r2}=1 (air), implies that the patch antenna is without superstrate. The dielectric superstrates with ε_{r2}= 2.2, 3.2, 4.8, 10.2 and thicknesses (h_2)=1.6 mm, 3.2 mm, 1.6 mm, 0.8 mm respectively are employed. The return-loss as a function of frequency for patch antenna without superstrate (free-space condition) is shown in Fig.4. The return-loss as a function of frequency, for particular case, ε_{r2}=3.2 in Fig.5. The overall typical results for the E-shaped patch antenna are given in Table 4, for ε_{r2}=1.0, 2.2, 3.2, 4.8, 10.2 for, H =0 mm and H =H_{opt}. The E-plane and H-plane radiation pattern for particular case, ε_{r2}=3.2 is shown in Figs.6 and 7. The gain of the patch antenna is observed to be decreasing with increase in the dielectric constant of the superstrate for H=0.

As the height of the superstrate is increased, the performance of the E-shaped patch antenna improves and at a particular optimum height the gain for all the superstrates will be closer to the free space radiation conditions of the patch antenna without superstrate. But the resonant frequency decreases with increase in ε_{r2}.The variation in the return-loss is within ± 1.5 dB of the free space radiation condition for all the dielectric constant of the superstrate and it is within acceptable limits. The bandwidth improves (12%) for ε_{r2} up to 4.8. However, the bandwidth decreases for ε_{r2}= 10.2. The E-shaped patch antenna produces nearly circularly polarization (AR ≤ 3dB) over the operating frequencies. The simulated and measured axial ratio versus frequency plot for various dielectric constants is shown in Fig. 8 and Fig. 9. There is good agreement between simulated and measured results.

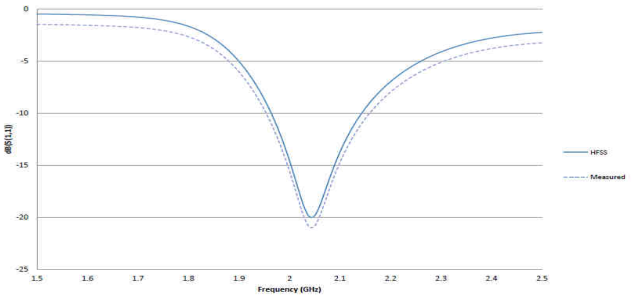


Fig. 4 Comparison of measured and simulated results of return-loss for E-shaped patch antenna without a dielectric superstrate, (ε_{r1} = 2.2, h_1=1.6 mm) .

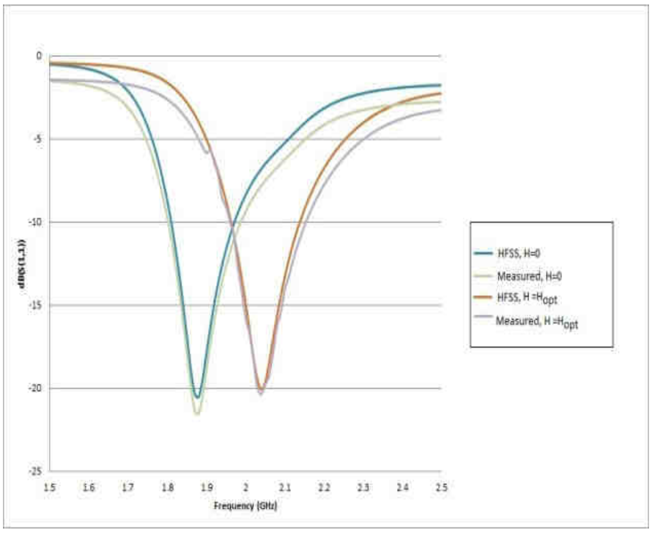
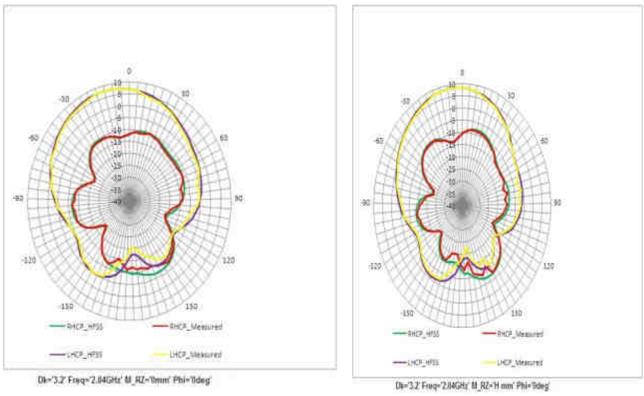
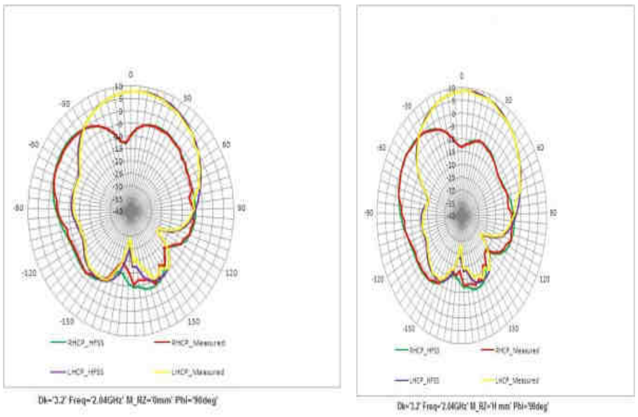


Fig. 5 Comparison of measured and simulated results of return-loss for E-shaped patch antenna loaded with a dielectric superstrate, (ε_{r2} = 3.2, h_2=3.2 mm) for H=0 and H=H_{opt}.



(a) H = 0 mm **(b) H = 17.46 mm**

Fig. 6 Comparison of measured and simulated radiation patterns for (a) H = 0 mm, phi =0^0 (b) H = 17.46 mm, phi =0^0 for E- Shaped patch microstrip antenna (ε_{r2}) =3.2 in E-Plane at 2.0GHz.



(a) H = 0 mm **(b) H = 17.46 mm**

Fig. 7 Comparison of measured and simulated radiation patterns for (a) H = 0 mm, phi = 90^0 (b) H = 17.46 mm, phi =90^0 for E- Shaped patch microstrip antenna (ε_{r2}) = 3.2 in H- Plane at 2.0GHz

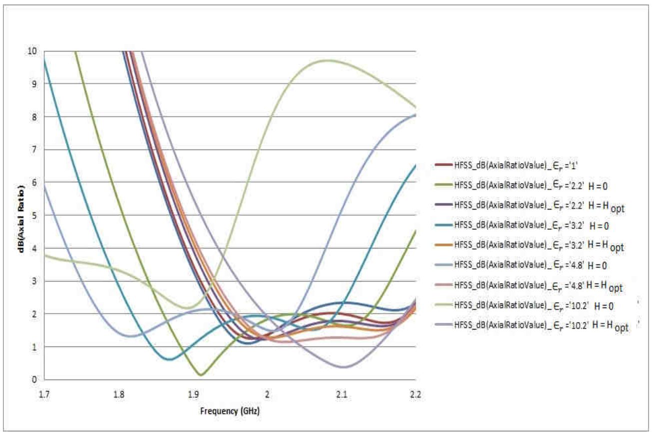


Fig. 8 Comparison of simulated results of axial ratio versus frequency plot for E-shaped patch antenna without superstrate and loaded with a dielectric superstrate for H=0 and H= H_{opt}.

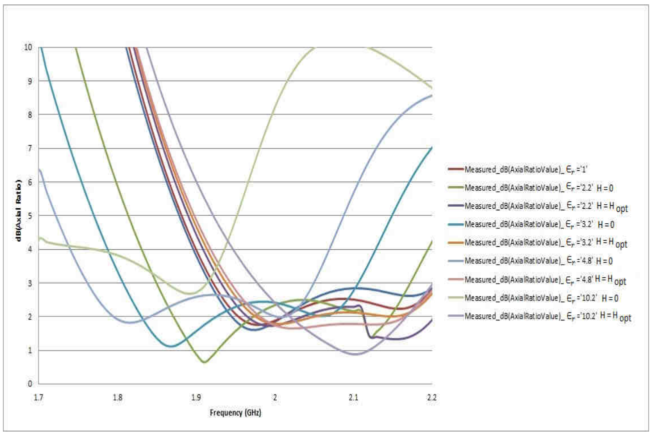


Fig. 9 Comparison of measured results of axial ratio versus frequency plot for E-shaped patch antenna without superstrate and loaded with a dielectric superstrate for H=0 and H= H_{opt}.

TABLE 4: Comparison of simulated and measured results of resonant frequency, return-loss, bandwidth and gain of E-shaped microstrip patch antenna without superstrate and loaded with superstrates for H =0 and H = H_{opt}.

ε_{r2}	Height (H) mm	FREQUENCY (GHz)		RETURN LOSS (dB)		BANDWIDTH (GHz)		GAIN (dB)	
		Simulated	Measured	Simulated	Measured	Simulated	Measured	Simulated	Measured
1.0*	**-**	**2.04**	**2.04**	**-19.95**	**-17.90**	**0.17**	**0.17**	**8.67**	**8.60**
2.2	**0**	**1.94**	**1.94**	**-20.34**	**-19.00**	**0.16**	**0.16**	**8.75**	**8.70**
	21.07 (H_{opt})	**1.99**	**1.99**	**-20.40**	**-21.40**	**0.29**	**0.29**	**8.50**	**8.40**
3.2	**0**	**1.88**	**1.88**	**-20.53**	**-20.00**	**0.16**	**0.16**	**7.82**	**7.70**
	17.46 (H_{opt})	**1.96**	**2.96**	**-20.07**	**-22.10**	**0.21**	**0.22**	**8.48**	**8.40**
4.8	**0**	**1.79**	**1.79**	**-23.62**	**-22.50**	**0.15**	**0.14**	**7.52**	**7.45**
	14.26 (H_{opt})	**1.85**	**1.92**	**-19.62**	**-20.40**	**0.24**	**0.24**	**8.48**	**8.40**
10.2	**0**	**1.59**	**1.59**	**-22.18**	**-21.60**	**0.15**	**0.18**	**5.10**	**5.20**
	9.78 (H_{opt})	**1.76**	**1.76**	**-18.61**	**-18.00**	**0.14**	**0.14**	**8.36**	**8.40**

***without dielectric superstrate**

VII. CONCLUSIONS

E-shaped microstrip patch antenna has been designed and fabricated at 2.0 GHz with Arlon diclad 880 substrate having $\varepsilon_{r1}=2.2$. The effect of the superstrate with different dielectric materials having $\varepsilon_{r2}=2.2$, 3.2, 4.8 and 10.2 has been investigated. The simulation and measurements have been carried out for studying the effect of superstrates on various parameters like resonant frequency, bandwidth, gain and return-loss. It has been observed that there is a degradation in the performance of the antenna when the superstrate is touching the patch antenna (H=0 mm). The center frequency is decreased to 1.59 GHz from 2.04 GHz, bandwidth is decreased to 0.15 GHz from 0.17 GHz and gain is decreased to 5.10 dB from 8.67 dB. As the height of the superstrate is increased the performance of the patch antenna improves and at the gain for all the superstrates will be closer to the free space radiation conditions of the patch antenna without superstate. But the resonant frequency decreases with increase in ε_{r2}. The variation in the return-loss is within ± 1.5 dB of the free space radiation condition for all the dielectric constant of the superstrate and it is within acceptable limits. The bandwidth improves (12%) for ε_{r2} up to 4.8. However, the bandwidth decreases for ε_{r2}= 10.2. The simulated and measured results are in good agreement is shown in Table 4.

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V. Saidulu was born in india, T.S, in 1974. He received the B.Tech in Electronics and Communication Engineering from Nagarjuna university in 1998 and M.Tech in Electronics Engineering (Microwave) from Banaras Hindu University (B.H.U), Varanasi, U.P in 2001 and pursuing Ph.D in Microstrip Antennas. He worked as Assistant Professor from June 2001 to November 2006. Presently he is working as Associate Professor from November 2006 to till date at MGIT, Hyderabad, in Electronics and Communication Engineering. He has published 12 papers in Journals and Conference. His research interests Microstrip antennas, Wireless Communication and Mobile Communication.

Dr. K. Srinivasa Rao, was born in Hyderabad, T.S, INDIA, in 1948. He received his B.E in ECE in the year 1973 from college of Engineering, Osmania University, Hyderabad, T.S. He worked as senior scientist in Defence Electronics Research Laboratory, Hyderabad from 1974-78 and as Lecturer in ECE Dept. college of Engineering, O.U. from 1978 -83. He worked as Associate Professor in ECE Dept. CBIT, O.U. from 1983-88. He worked as Senior Scientist in NERTU, O.U. from 1988-90 and carried out his research work in the area of Microwaves. He received his Ph.D. degree in the year 1995. He was promoted as Professor, ECE in CBIT in 1995 and worked there from 1995-97 and 2000-2008. He worked as Professor and Head, Dept. of VNRVJIET, Hyderabad, T.S. from 1977-2000. After receiving as Professor, ECE in CBIT in 2008, he has been working in various Private Engineering Colleges and presently he is working as Professor in ECE, VIFCET, JNTUH, Hyderabad.