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Design & Simulation of E-Shaped Micro Strip Patch Antenna for GPS Application

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ABSTRACT
Micro strip antennas are widely used in many applications due to their low Profile, low cost and ease of fabrication. In some applications it is desired to have a dual band or multiband characteristics. This paper presents the design and simulation of E-shape micro strip patch antenna with wideband operating frequency for wireless application. The shape will provide the broad bandwidth which is required in various application like remote sensing, biomedical application, mobile radio, satellite communication etc. The antenna design is an improvement from previous research and it is simulated using HFSS (High Frequency Structure Simulator) version 13.0 software.

GPS provides specially coded satellite signals that can be processed with a GPS receiver enabling the receiver to compute position, velocity and time. Coaxial feed or probe feed technique is used. Parametric study was included to determine affect of design towards the antenna performance. Radiation performance of the designed antenna is simulated using the HFSS software version 13.0. The performance of the designed antenna was analyzed in term of bandwidth, gain, return loss, VSWR, and radiation pattern. The design was optimized to meet the best possible result. Substrate used was air which has a dielectric constant of 1.0006. The results show the wideband antenna is able to operate from 8.80 GHz to 13.49 GHz frequency band with optimum frequency at 8.73 GHz. Due to the compact area occupied. The pro-posed antenna is promising to be embedded within the different portable devices employing GPS applications.

Keywords-E-shaped slot microstrip,Rectangular Patch,Co-axial probe, GPS, HFSS Software

I. INTRODUCTION

A simple GPS repeater consists of an outdoor antenna, narrow band pass filter and low noise amplifier and a reradiating indoor antenna. Figure 1 shows the block diagram of a simple GPS repeater. The outdoor antenna picks the GPS signal from the satellite. This antenna should be wide beam and circular polarized to acquire more satellites. Micro strip circular polarized patch antenna and helical antenna are two suitable choices for this application. The GPS signal received by the outdoor antenna is fed to the input of a narrow band ceramic band pass filter. The filtered signal is then provided to a multi stage low noise amplifier. The amplifier provides the necessary gain so that the signal can be retransmitted inside the building. With the help of indoor reradiating antenna the GPS signal is transmitted inside the buildings. As GPS receiver can be placed any where inside the building, so a wide beam and circular polarized antenna is required. Micro strip patch antenna is a suitable choice.

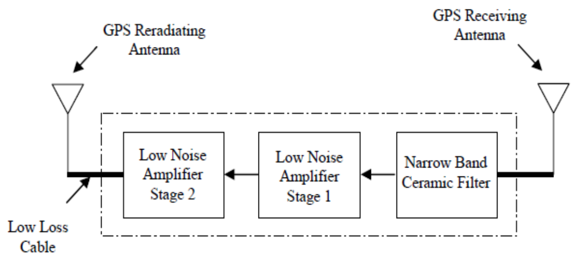

Figure 1: Block diagram of a simple GPS repeater.

II. METHODOLOGY

A. Design of E-Shaped Slot

General Design of Patch Antennas

In this section there is presented a design with the use of –Microwave HFSS simulation software.

First of all we have to choose a dielectric constant and substrate height to design an antenna as these are the basics for the design an antenna. They were chosen according to the design frequency (8.83GHz). There was chosen substrate material is air with dielectric constant.

1. Substrate Height =3.2 mm
2. Dielectric Constant=1.0006

B. Designing parameters:

* Calculation of the Width (W)

- * Calculation of Effective dielectric constant (ε_{reff})
- * Calculation of the Effective length (L_{reff})
- * Calculation of the length extension (ΔL)
- * Calculation of actual length of patch (L).

C. Designing Equations

The below equations are used to find out the length and width of patch.The width of the patch is found by

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

Where the v_0 is the free-space of velocity of light

The effective dielectric constant can then found by

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-0.5} \qquad (2)$$

Where the dimensions of the patch along its length have been extended on each end by a distance ΔL, which is a function of the effective dielectric constant εreff and the width to- height ratio (W/h), and the normalized extension of the length, is

The extension length has been adapted into the form

$$\Delta L = 0.412\, h\frac{(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \qquad (3)$$

The actual length of patch(L) can be determined as

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L \qquad (4)$$

D. Antenna Configuration

The configuration of the proposed antenna is shown in Figure2. The substrate used for this design is air with relative permittivity of 1.0006 and thickness of 3.2 mm. Dimensions of the ground plane are also 60mm *X* 60 mm.

Parameter		**Label**	**Dimension (mm)**
Main Patch	Length	La	10.9
	Width	Wa	15.7
Outer Patch	Length	La	13.2
	Width	Wb	21.7
Slot	Main slot width	WsB	17.7
	Slot width	Sa,Sb	1.0
	Slot A length	LsA	8.4
	Slot B length	LsB	10.9
Centre Arm	Width	Wc	5.2
Feed Point	Width	Wc/2	2.6
	Length	Lf	1.8
Substrate Air	Thickness	H	3.2
	Dielectric Constant	ε_{rs}	1.0006
Substrate and Ground	Width and Length	Wsub,Lsub, Wg,Lg	60
SMA	Core Diameter	Dc	1.275
	Teflon Diameter	Dt	4.17
	Teflon Dielectric constant	ε_{rt}	2.08

Table1: Micro Strip Patch Antenna Specifications

By using the above configuration the proposed antenna is like as the figure 2, the total view of a simple E-slot patch antenna is designed by using HFSS software. In this we use a coaxial feeding with aperture type. The aperture slab is at the height of 3.2mm from the ground. The main purpose of this is to improve the matching between the feeding and the radiating element.

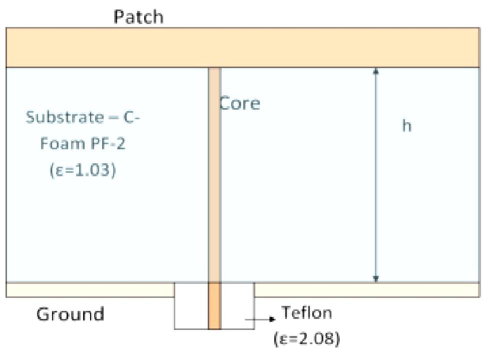

Figure 2: Cut plane view of antenna

E. Simulation Setup

The antenna's resonant properties were predicted and optimized using High Structure simulation software Ansoft version 11. The design procedure begins with determining the length, width and the type of dielectric substance for the given operating frequency. Then using the measurements obtained above simulation has been setup for the basic rectangular micro strip antenna and the parameters are optimized for the best impedance matching. Furthermore two parallel slots are incorporated and optimized such that it closely resembles E shape; this increases the gain of the antenna. After that two more parallel slots and one perpendicular slot are incorporated and optimized such that it closely resembles U shape. Then dielectric substrate of dielectric constant of 1.0006 introduces to decrease the size of the antenna and to further enhance the bandwidth. At last the probe feeding is introduced for attaining a required bandwidth, resonating frequency and gain value.

F. Geometry of Antenna

The geometry of the designed antenna is shown in the Figure 3.The antenna is made of a single patch on top, one layers of dielectric (air) and a vertical probe connected from ground to the upper patch.

The main E shaped patch has Wa x La dimension while the outer patch has Wb x Lb dimension. The antenna is fed by a SMA connector positioned at the center arm. The center of probe is positioned at (Wc/2,Lf).

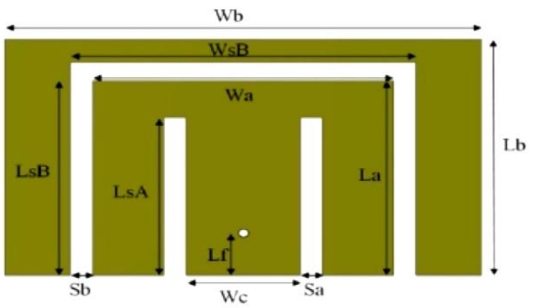

Figure3: Design geometry of the E-shape micro strip patch.

Parallel slots in this design are responsible for the excitation of next resonant mode i.e. main parallel slot excite 2nd resonant frequency while outer slot excite 3rd resonant frequency. Slots length (LsA and LsB), slot width (S), main slot width (WsB) and center arm (Wc) controls the frequency of the next resonant mode. Figure 2 shows the cut plane view of the antenna. The patch and ground are separated by closed-cell low loss air of thickness 3.2 mm. Dielectric constant for this foam is 1.0006, and it benefits to obtain wider bandwidth and higher gain. Air gap was used as substrate and infinite ground was assumed. This paper design a finite set of ground dimension which is defined by Wg x Lg. SMA connector design is according to specification in using Teflon of dielectric constant = 2.08.

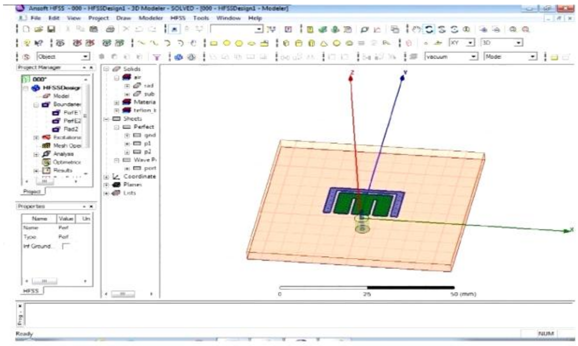

Figure 4: Design of E-shape micro strip patch in HFSS software

III. III.RESULTS AND EXPLANATIONS

A. Return Losses

Figure 5 illustrates both the simulated and experimental results of the antenna return loss. Here, return loss is defined as

R =20log10 | □| (5)

where Γ is the reflection coefficient. As shown in this figure, simulated values of the first and second resonant frequencies are 2.31 GHz and 3.78 GHz, respectively. Current paths of the 1st and2nd modes are shown. Dash-dot lines show the average length of current paths for each mode. The resonant frequencies can be calculated approximately as follows:

$$f_1 = \frac{c}{2\sqrt{\varepsilon_{eff}}L1} \quad (6)$$

$$f_1 = \frac{c}{2\sqrt{\varepsilon_{eff}}L2} \quad (7)$$

Where $L1$ and $L2$ are the average lengths for current paths of the 1st and 2nd resonant modes and c is the free space velocity of light. The effective permittivity is also given by

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{10h}{W}\right)^{-0.555} \quad (8)$$

Where $\boldsymbol{h}$ and Ware height of the substrate and width of the patch, respectively. The above equation, which is given in, is valid for single layer substrates. However, while the effect of L-shaped feed system is negligible, this equation can be used for two-layered substrates provided that the parameter h is substituted by the total height of $h1 + h2$.The average lengths for current paths of the 1st and 2nd resonant modes can be obtained by using the following approximate relations:

$$L1 = \alpha_1 ls + \alpha_2 ws + \alpha_3 w \quad (9)$$

$$L2 = \beta_1 d1 + \beta_2 d2 + \beta_3 ls + \beta_4 ws \quad (10)$$

Based on results of several simulations, optimum values of α_i and β_i in the above equations are obtained as follows.

α_1= 0:385;α_2= 0:445; α_3= 1:000
β_1= 1:097β_2= 0:630; β_3= 0:876; β_4= 1:412

The return losses are shown in the below figure.

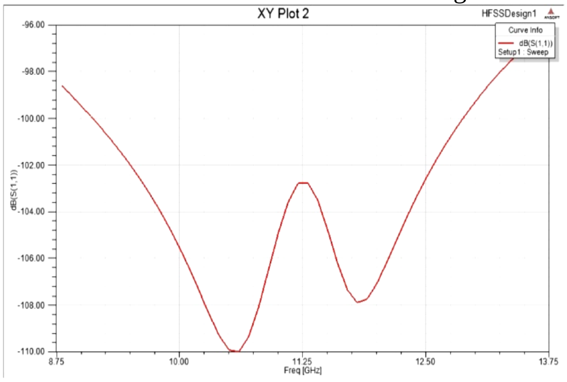

Figure 5: Return losses

B. Radiation Pattern

The radiation field of the micro strip antenna may be determined using either an electric current model or a magnetic current model. In the electric current model, the current is used directly to find the far-field radiation pattern. The electric current for the (1,0) patch mode. If the substrate is neglected (replaced by air) for the calculation of the radiation pattern, the pattern may be found directly from image theory. If the substrate is accounted for, and is assumed infinite, the reciprocity method may be used to determine the far-field pattern. In the magnetic current model, the equivalence principle is used to replace the patch by a magnetic surface current that flows on the perimeter of the patch.

The radiation Pattern of antenna is shown in below figures 6,7

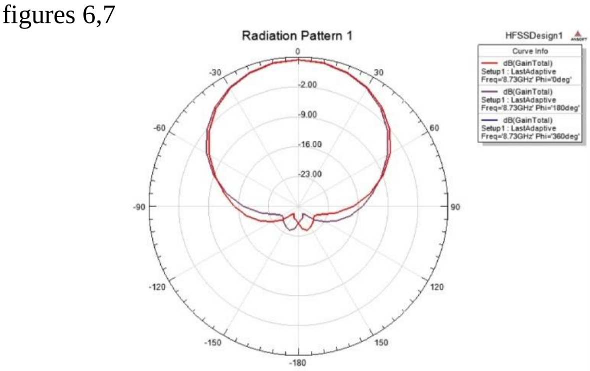

Figure6: Radiation pattern

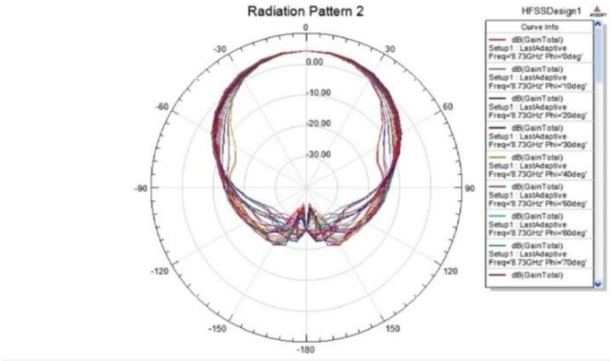

Figure7 Radiation pattern

C. 3-D View of Radiation Pattern

The radiation pattern is main concentration for the wide band application. For wide band application the effect of the radiation up to 30 miles. The gain must be high for this type of application the radiation pattern for E-shape is

The Figure 6 and 7 show the radiation pattern for the antenna at 8.73GHz. HPBW is the angular separation which the magnitude of the radiation pattern from the peak of the main beam decreases by 50% or -3 dB. HPBW (angle) is 70˚ for Optimum Frequency of 8.73 GHz.

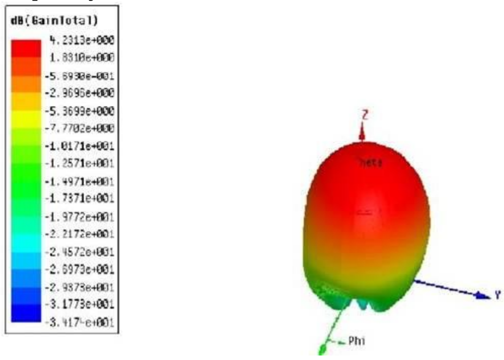

Figure9: 3D-view

D. Field Distribution

The E-field distribution and H-Field distribution for E-shape design is

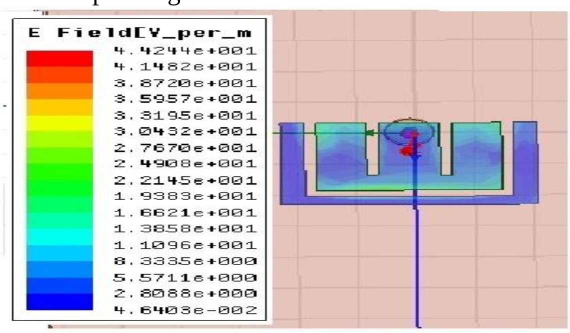

Figure 9: E-field distribution for E-shape micro strip patch antenna

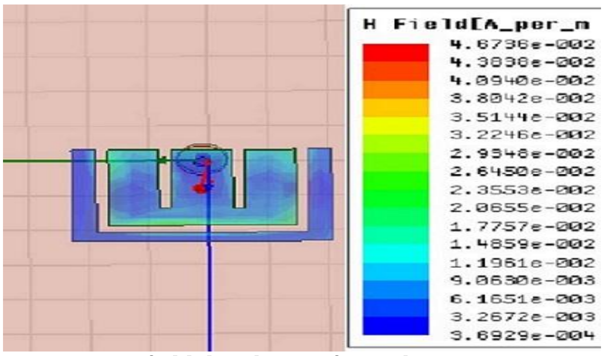

Figure 10: H-field distribution for E-shape micro strip patch antenna

For the view of field distribution there is no uniform distribution in the single u-slot patch antenna. For non-uniform distribution of these fields the return losses are somewhat high. For decrease the return losses there must perfect matching between coaxial system and the radiating element then we can easily remove the return losses.

E. VSWR

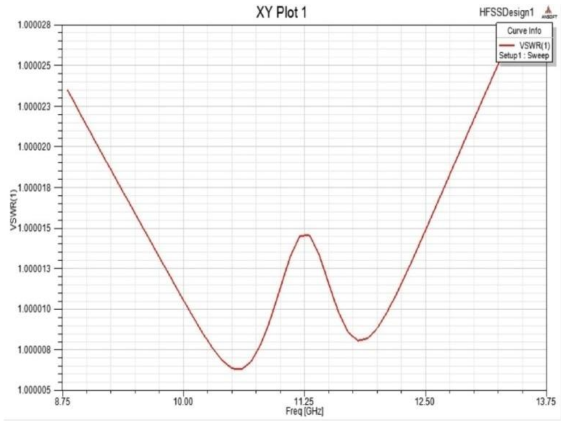

Figure 11: VSWR for E-shape patch antenna

F. GAIN

Another useful measure describing the performance of an antenna is the gain. Although the gain of the antenna is closely related to the directivity, it is a measure that takes into account the efficiency of the antenna as well as its directional capabilities. Remember that directivity is a measure that describes only the directional properties of the antenna, and it is therefore controlled only by the pattern. Gain of an antenna (in a given direction) is defined as "the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically. The radiation intensity corresponding to the isotropically radiated power is equal to the power accepted (input) by the antenna divided by 4π." In equation form this can be expressed as

$$Gain = 4\pi \frac{radiation\ \ intensity}{total\ \ input\ \ power} = 4\pi \frac{U(\theta,\varphi)}{p_{in}} \qquad (11)$$

The result of gain is shown in below figure12

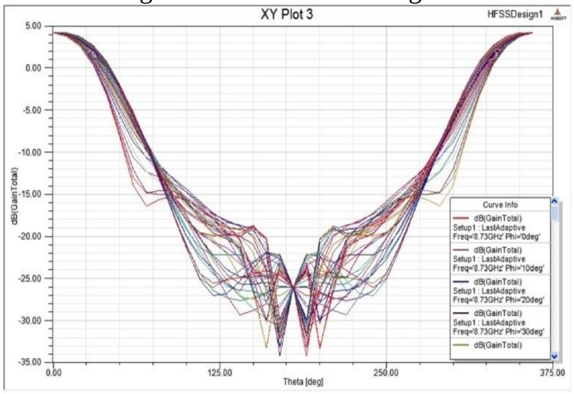

Figure12. Gain

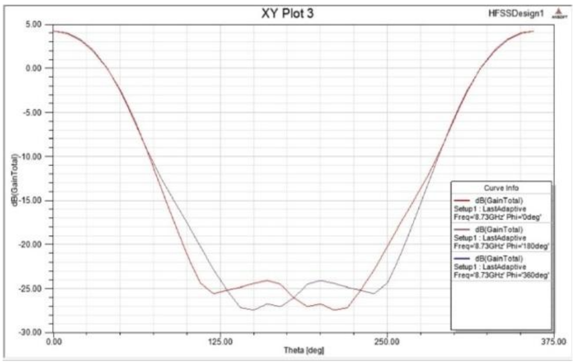

Figure13: Gain

G. Different Antenna Parameters at Different Frequencies

Frequency(GHz)	8.73	11.45	13.15
Gain (dB)	4.33	5.43	4.79
Radiation Efficiency(dB)	5.142	7.254	9.6069
Front to back Ratio (dB)	30.3170	23.8817	13.0879
Max U(W/Sr)	0.000010	0.000008	0.000001
Peak Directivity	8.8615	7.6318	1.17309
Radiated Power(W)	0.000014	0.000014	0.000010
Accepted Power(W)	0.000046	0.000073	0.000092
Incident Power(W)	0.000033	0.000060	0.000083

Table 2: Values for radiation parameters for each frequency

H. Different Antenna Parameters at Different Thickness of Substrate

ANTENNA PARAMETER	AT t=3.0mm	At t=3.2mm	At t=3.4mm
Gain (dB)	0.9211	4.33	0.8251
Radiation Efficiency(dB)	9.0420	5.142	8.9193
Front to back Ratio (dB)	27.6243	30.3170	30.1303
Max U(W/Sr)	0.000004	0.000010	0.000003
Peak Directivity	9.4868	8.8615	9.1721
Radiated Power(W)	0.000005	0.000014	0.000005
Accepted Power(W)	0.000038	0.000046	0.000038
Incident Power(W)	0.000063	0.000033	0.000030

Table 3: Values for radiation parameters for different thickness

I. Different Antenna Parameters at Different Main Arm Widths

ANTENNA PARAMETER	AT Wc=4.2mm	At Wc=5.2mm	At Wc=6.2mm
Gain (dB)	3.33	4.33	5.12
Radiation Efficiency(dB)	5.02	5.142	5.08
Front to back Ratio (dB)	27.3125	30.3170	28.2537
Max U (W/Sr)	0.00002	0.000010	0.000012
Peak Directivity	7.9852	8.8615	9.1256
Radiated Power(W)	0.00001	0.000014	0.000012
Accepted Power(W)	0.000045	0.000046	0.000043
Incident Power(W)	0.00003	0.000033	0.000033

Table 4: Values for radiation parameters for different main arm widths

J. Different antenna Parameters at Changing Air Gap with C-Foam

Antenna Parameter	Substrate with material Air(□ =1.0006)	Substrate with material C-Foam(□ =1.03)
Gain (dB)	4.33	4.230
Radiation Efficiency(dB)	5.142	5.2076
Front to back Ratio (dB)	30.3170	30.0728
Max U (W/Sr)	0.000010	0.000010
Peak Directivity	8.8615	8.7857
Radiated Power(W)	0.000014	0.000014
Accepted Power(W)	0.000046	0.000046
Incident Power(W)	0.000033	0.000033

Table 5: Values for radiation parameters for different substrate materials

IV. CONCLUSION

In this paper, an E-shaped wideband microstrip patch antenna using Air substrate has been designed, simulated, optimized and analyzed using HFSS (High Frequency Structure Simulator) software version 13.0. The performance of the designed antenna was analyzed in term of bandwidth, gain, return loss, VSWR, and radiation pattern. The design was optimized to meet the best possible result. Substrate used was air which has a dielectric constant of 1.0006. The results show the wideband antenna is able to operate from 8.80 GHz to 13.49 GHz frequency band with optimum frequency at 8.73 GHz. Due to the compact area occupied. The proposed antenna is promising to be embedded within the different portable devices employing GPS applications.

REFERENCES

[1] Ge, Y.; Esselle, K.P.; Bird, T.S.; , "*E-shaped patch antennas for highspeed wireless networks*," *Antennas and Propagation, IEEE Transactions on* , vol.52, no.12, pp. 3213-3219, Dec. 2004

[2] B.-K. Ang and B.-K. Chung, "*A wideband e-shaped microstrip patch antenna for 5 - 6 GHz wireless communications*," *Progress In Electromagnetics Research*, Vol. 75, 397-407, 2007.

[3] Yang, F.; Xue-Xia Zhang; Xiaoning Ye; Rahmat-Samii, Y.; "*Wide-band E-shaped patch antennas for wireless communications*," *Antennas and Propagation, IEEE Transactions on* , vol.49, no.7, pp.1094-1100, Jul 2001

[4] Hadian, A.M.; Hassani, H.R.; , "*Wideband Rectangular Microstrip Patch Antenna with U-Slot*," *Antennas and Propagation, 2007. EuCAP 2007. The Second European Conference on* , vol., no., pp.1-5, 11-16 Nov. 2007

[5] Vedaprabhu, B.; Vinoy, K.J.; , "*A double U-slot patch antenna* with dual Wideband characteristics," *Communications (NCC), 2010 National Conference on* , vol., no., pp.1-4, 29-31 Jan. 2010

[6] Weigand, S.; Huff, G.H.; Pan, K.H.; Bernhard, J.T.; , "*Analysis and design of broad-band single-layer rectangular U-slot microstrip patch antennas*," *Antennas and Propagation, IEEE Transactions on* , vol.51, no.3, pp. 457- 468, March 2003

[7] Verma, M.K.; Verma, S.; Dhubkarya, D.C.; , "*Analysis and designing of E-shape microstrip patch antenna for the wireless communication systems," Emerging Trends in Electronic and Photonic Devices & Systems, 2009. ELECTRO '09. International Conference on* , vol., no., pp.324-327, 22-24 Dec. 2009

[8] Wang, B.-Z.; Xiao, S.; Wang, J.; , "*Reconfigurable patch-antenna design for wideband wireless communication systems*," *Microwaves, Antennas & Propagation, IET* , vol.1, no.2, pp.414-419, April 2007

[9] Cuming Microwave, "*Flexible, Low Loss Foam*," C-Foam PF-2 and PF-4 datasheet, 2011.

[10] Kumar, G., and K. P. Ray. *Broadband Microstrip Antennas*. Boston: Artech House, 2003.

[11] Micro Lambda, "*E+ SMA connectors & Hermetic Seals*," SMA connectors datasheet, 2011.