Wideband Microstrip Single Patch Antenna

S.Muhamud @ Kayat, M.T.Ali, M. H. M. Zaharuddin, M.N.Md.Tan and A.L.Yusof
Microwave Technology Centre (MTC), Faculty of Electrical Engineering,
Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia,
suzilawati.mkayat@yahoo.com, mizi732002@yahoo.com, hafiz.mazlan@ymail.com, mdnor1408@yahoo.com and azita968@salam.uitm.edu.my

Abstract

This paper presents the design of an E-shaped microstrip single patch antenna with wideband operating frequency. The antenna design is an improvement from a previous research, simulated using CST Microwave Studio 2009 software. The performance of the designed antenna was analyzed in term of bandwidth, gain, return loss, VSWR, and radiation pattern.

Keywords : E-Shaped Microstrip Antenna, Wideband, CST Microwave Studio 2009.

1. Introduction

Microstrip patch antenna has been well known for its advantages. However, narrow bandwidth came as the major disadvantage for this type of antenna [1]. Several techniques have been applied to overcome this problem including modifying the patch shape by designing an E-shaped patch [2],[3] or a U-slot patch antennas [4]-[6]. The basic microstrip patch antenna calculations can be referred in [7]. In this paper, a wideband single patch antenna is proposed as in Figure 1. The design is based on a reconfigurable patch antenna in [8] as a design reference but no switches are incorporated in this design. The objective of this paper is to optimize the base design in [8] to obtain higher bandwidth. This single patch antenna operates at voltage standing wave ratio of less than 2 (VSWR < 2).

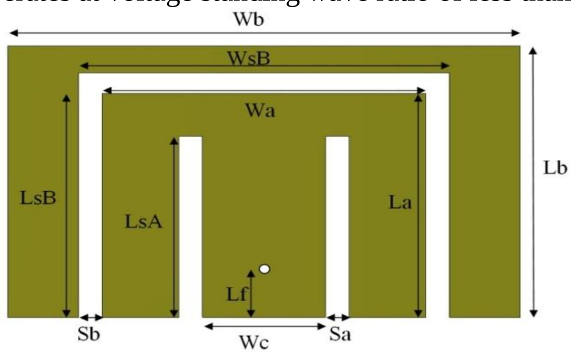

Figure 1: Design geometry of an E-shaped patch antenna

2. Antenna Design

The design geometry of the E-shaped patch antenna is shown in Figure 1. The antenna is fed by a SMA connector positioned at (Wc/2,Lf). The patch and ground are separated by closed-cell low loss foam named PF-2 of thickness 3.2 mm [9]. The dielectric constant for this foam is 1.03 which is very close to air gap, and it benefits to obtain wider bandwidth and higher gain [10]. The SMA connector design is according to specification in [11] using Teflon with dielectric constant of 2.08.

3. Parametric Study

Table 1 presents the default specifications for this antenna. Parameters that are kept constant in this paper are La, Wa, Lb, Wb, LsB and substrate thickness. Other parameters are set as variables. Only one parameter is allowed to change at a time while other variables remain constant as default except for ground and substrate that will be varied accordingly.

Table 1: Default microstrip patch antenna specifications

Parameter	Dimension (mm)	Parameter	Dimension (mm)	Parameter	Dimension (mm)
La	10.9	Sa, Sb	1.0	Lf	1.8
Wa	15.7	LsA	8.4	ε_{rs}	1.03
Lb	13.2	LsB	10.9	Wsub, Lsub, Wg, Lg	60.0
Wb	21.7	Wc	5.2		
WsB	17.7	Wc/2	2.6		

3.1 Changing Air Gap with C-Foam PF-2

An optimization process has been done to determine the best parameters required to achieve targeted performance. As depicted in Figure 2, by using air gap, the frequency band is from 8.76 GHz to 13.58 GHz while when using C-Foam PF-2, the band is from 8.89 GHz to 13.88 GHz, which creates a slightly wider bandwidth. Also, figure 3 shows the S_{11} parameter when the dimensions of substrate are changing whereby Wsub = Lsub = Wg = Lg. These parameters are decreased by 10 mm for each run, starting from 60 mm to 30 mm. The result doesn't show much difference in terms of bandwidth but it slightly affects the magnitude of S_{11}. Figure 4 shows the S_{11} parameter when Wc is varied from 4.2 mm to 6.2 mm by 0.5 mm increment. Figure 5 shows S_{11} magnitude when LsA is varied from 7.6 mm to 9.6 mm with 0.4 mm increment. The final optimized parameters are listed as in Table 2.

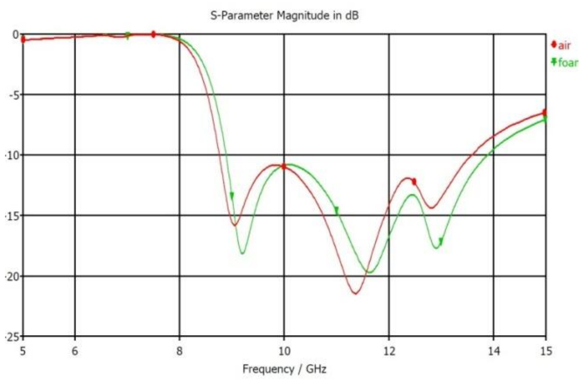

Figure 2: S_{11} for air and foam substrates

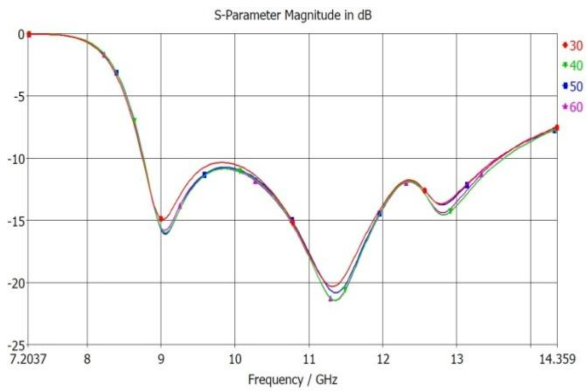

Figure 3: S_{11} for various size of substrate

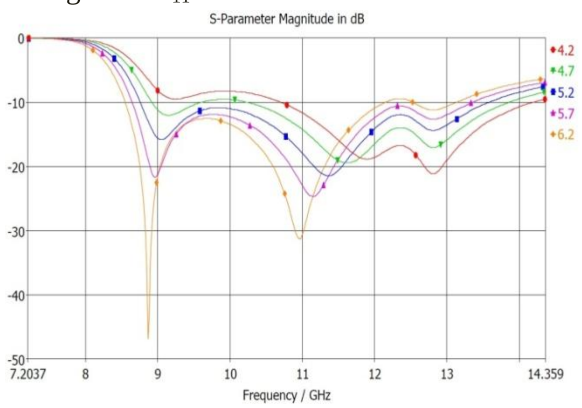

Figure 4: S_{11} for various size of Wc

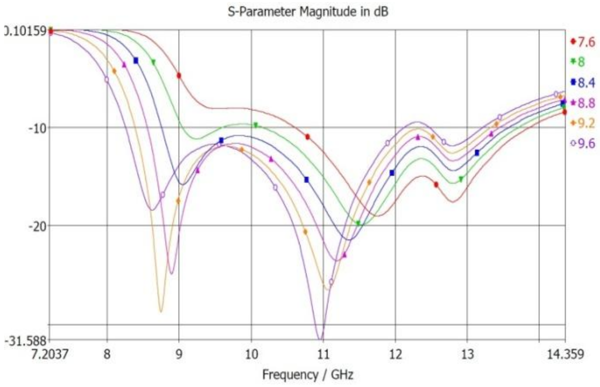

Figure 5: S_{11} for various size of LsA

4. Results And Discussions

The antenna is optimized based on the results obtained in section 3. The aim of optimization is to obtain better gain and bandwidth than in Figure 3. The specification of the varied parameters after optimization is shown in Table 2.

Table 2: Optimized parameters

Parameter	WsB	Sa	Sb	LsA	Wc	Wg	Lg
Dimension (mm)	16.9	1.7	0.6	9.6	2.2	18	18

4.1 Improvement in Bandwidth, Gain, S_{11} and VSWR

Figure 6 shows S_{11} parameters for the original air gap substrate, the original foam substrate, and the optimized wideband antenna. The frequency band for the optimized wideband antenna ranges from 8.35 GHz up to 14.07 GHz, which improves the bandwidth from 4.99 GHz to 5.72 GHz. The antenna operates at 1st resonant frequency (8.73 GHz), 2nd resonant (11.43 GHz) and 3rd resonant (13.1 GHz). The gain measured for default design at 11.355 GHz is 8.698 dB. There is 9.14% of gain improvement when comparing the gain of foam substrate at 8.73 GHz, which is 9.078 dB. In air gap substrate, at 9.15 GHz, S_{11} is measured to be 0.0847 (linear) while in foam substrate, S_{11} is 0.0058 at 8.73 GHz, which indicates smaller amount of signal is reflected back at port 1. Figure 7 shows the VSWR comparison of default specification antenna and the optimized antenna. The line impedance measured in this paper is 49.5139 Ω. For default specification, the lowest VSWR value is 1.185 while the foam substrate acquires the lowest VSWR of 1.0117 at the optimum frequency (8.73 GHz). This VSWR value is close to match perfectly for the antenna. The other VSWR value is less than 2 in the frequency band range.

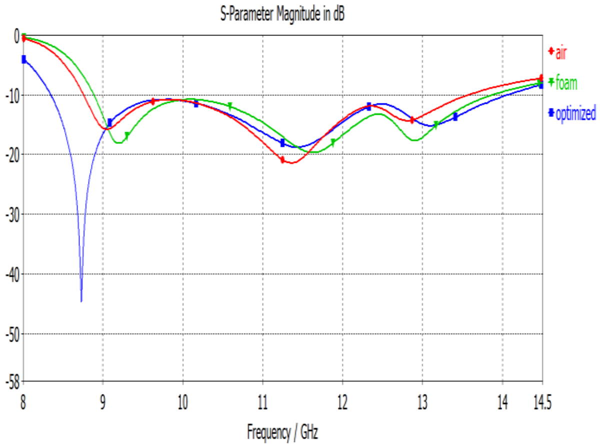

Figure 6: Comparison of three antenna design

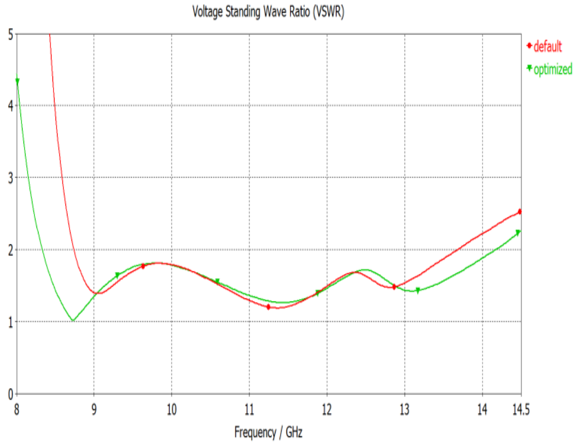

Figure 7: VSWR of optimized wideband antenna

4.2 Radiation Pattern of Optimized Antenna

Figure 8 and Figure 9 show the radiation pattern for the antenna at 8.73 GHz and 11.43 GHz. The parameter values for each figure are listed in Table 3.

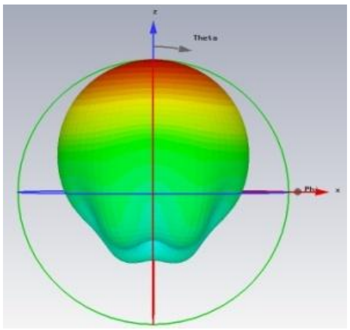

Figure 8: Radiation pattern at 8.73 GHz

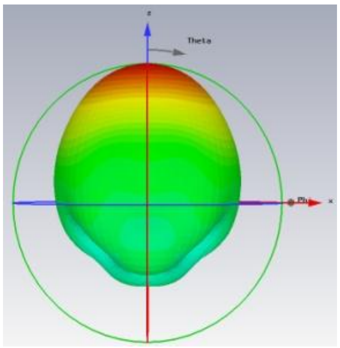

Figure 9: Radiation pattern at 11.43 GHz

Table 3: Values for radiation parameter for each frequency

Frequency (GHz)	8.73	11.43
Gain (dB)	9.078	9.846
Radiation efficiency (dB)	0.03894	-0.006141
Main lobe direction (angle)	0	0
Main lobe magnitude (dB)	9	9.7
Max. back lobe magnitude (dB)	-7.5	-6
Front to back ratio (dB)	16.5	15.7
HPBW (angle, value (dB))	69.2°,6	50.1°,6.69

5. Conclusion

In this paper, an E-shaped wideband microstrip patch antenna using C-Foam PF-2 has been designed, simulated, optimized and analyzed using CST 2009 software. A parametric study is presented with the results showing that the antenna can be operated at 8.34 GHz up to 13.86 GHz frequency band. This result is an improvement to the original specification which saw the bandwidth is expanded from 4.99 GHz to 5.72 GHz. Other parameters such as gain, S_{11} and VSWR have also been improved.

References

[1] Ge, Y.; Esselle, K.P.; Bird, T.S.; , "E-shaped patch antennas for high-speed 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.