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Analysis of Single Slot on Microstrip Patch Antenna for Frequency Miniaturization

A. Beno

Associate Professor, ECE Department, Dr. Sivanthi Aditanar College of Engineering, Tiruchendur, Tamilnadu, India.

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Abstract

The design of microstrip patch antenna with a dimension of 27.1 mm × 37.9 mm with single slots for miniaturization is presented. The antenna is designed on a FR4 dielectric substrate for 2.4 GHz. The antenna inserted with slot is designed to analyze the effect of surface current distribution and frequency miniaturization. The antenna with slots with variable length and width helps to achieve a frequency miniaturization of 30.41 % with reduced operating frequency of 1.67 GHz. The antenna has multiband operation covering major wireless bands with a maximum impedance bandwidth. The antenna exhibits good radiation characteristics gain. The antenna operates in the bands of WLAN, Bluetooth, GSM, ISM and GPS bands.

Keywords: Miniaturized, Microstrip, Slot, Slit, Patch.

Introduction

The concept of reducing the size of the consumer electronics has increased the demand on communication modules considerably reducing the antenna dimensions. To reduce the size of the antenna at the required application band the electrical length of the antenna need to be increased. To decrease the size of the antenna, the concept of miniaturization been introduced using various techniques like using high dielectric substrate, folding of the patch, use of shorting post, using EBG, PBG materials, slots, slits and meta-materials [1-6]. The concept of miniaturization helps to increase the electrical length on the radiating antenna structure enabling the antenna to operate at lower frequency from its designed operating frequency. The simplest approach broadly used in miniaturization is using slots and slits on the radiating patch. A good frequency tuning characteristics can be achieved using suitable shape of slots in a specific position on the radiating element. The various types of slots like E, U, V, H-Shaped antennas are widely used in the literature [7-9]. Another method of reducing the size of the antenna for miniaturization is using meandering. It is achieved by inserting narrow slits in the non radiating edges of the patch. It helps to achieve miniaturization in a particular operating frequency [10, 11]. The effect of L shaped slots and strips on the radiating patch in various shapes and structures are given by researchers [12-14]. The effect of slot loaded antennas for dual and multiband applications has good attraction in various wireless applications [15-19]. This work is intended to broadly show the effects of slots on radiating patch with variable length and width. Also the design work focuses in the effect of increasing the number of slots and slits on the radiating patch towards achieving miniaturization.

Correspondence
A.Beno,
E-mail: beno_csi@yahoo.com, Ph. +9194434 53030

Antenna Design

The antenna basic design formulae for a rectangular microstrip antenna are used to calculate the dimensions and feed position of the antenna for a fixed operating frequency of 2.4 GHz using FR4 substrate with a height of 2.4 mm [20]. The basic structure of the antenna is given in the Figure 1 and the dimensions of the antenna are given in Table 1.

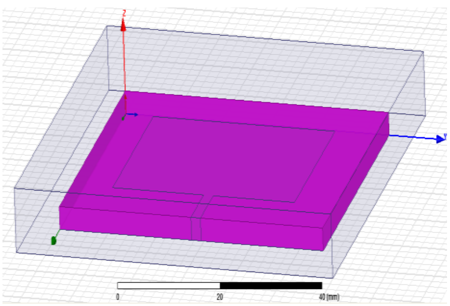


Figure 1. Basic Rectangular Microstrip Patch Antenna

Table 1: Dimension of Basic Patch

Sl.No	Parameter	Dimension (mm)
1	*W*	37.9
2	*L*	27.1
3	*H*	2.4
4	$\mathcal{E}_r$	4.4
5	*Lg*	44.1
6	*Wg*	54.9

The basic structure is designed using ANSOFT HFSS. The basic structure resonates with a frequency of 2.4 GHz having S_{11} of -25.17 dB achieving an impedance bandwidth of 12% as given in Figure 2.

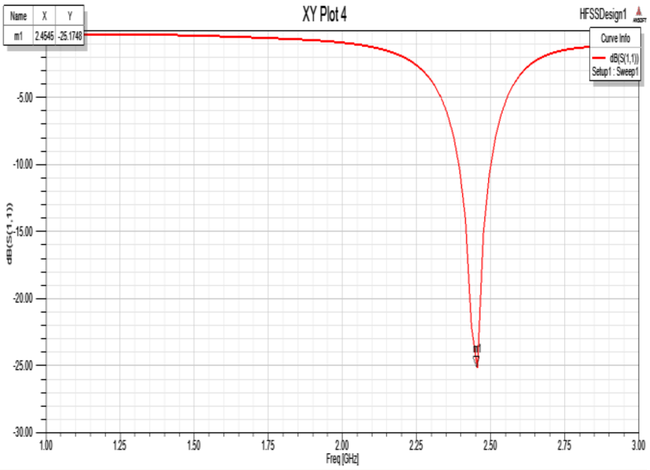


Figure 2: S_{11} vs Frequency of Basic RMSA

Single Slot Microstrip Antenna

To achieve miniaturization on the basic design slots is introduced on the radiating patch. The effect of the slot on the radiating patch is observed by introducing a single slot along the length of the radiating patch. The dimension of the slot is so chosen that it matches with the electrical length λ/4 of the patch antenna that helps to create inductive effect in the equivalent circuit of the patch antenna creating an influence on the resonant frequency of the antenna. The dimension of the slot is designed with a length of S_{L1} = 10mm and width S_{W1} = 0.5mm parallel to the radiating edge of the patch antenna as shown in the Figure 3.

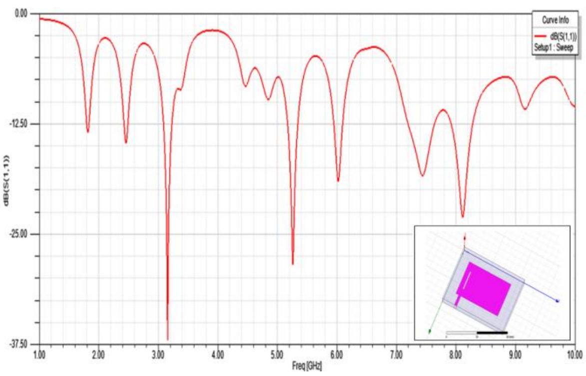


Figure 3. Radiating patch with single slot

The slot has an intense effect based on the length and width of the slot. The slot creates variation in the fundamental resonant frequency of the basic antenna. The S_{11} against frequency characteristics for various slot lengths S_{L1} = 5mm, 10mm, 15mm, 20mm and width S_{W1} = 0.5mm, 1mm, 1.5mm and 2mm for the single slot is analyzed. The antenna with a slot width S_{W1} = 2.5 mm and S_{L1} = 15 mm is given in the Figure 4. The change in resonant frequency for the variations created on the radiating patch is given in the Table 2.

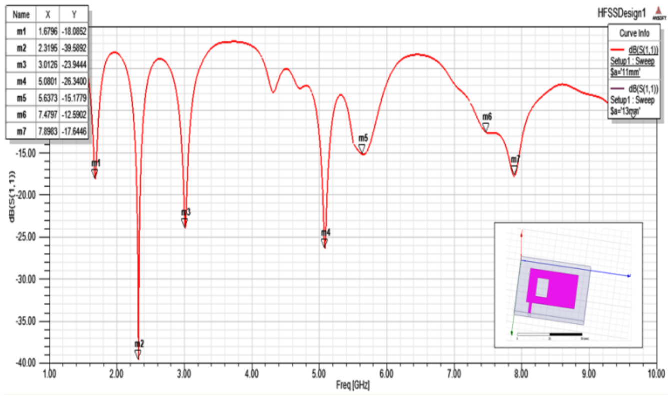


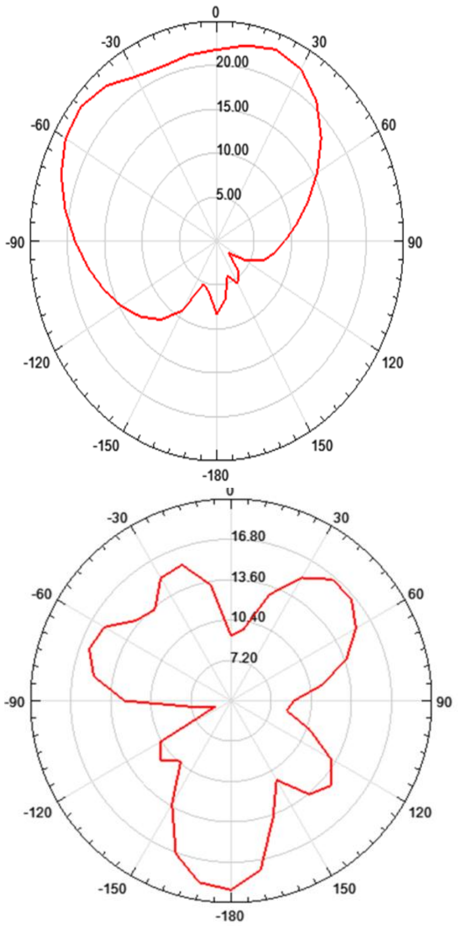
Figure 4. Radiating patch with single wide slot

Table 2. Variation in Slot Length and Width on Resonant Frequency

Sl.No	*Slot Length (S_L in mm)*	*Slot Width (S_W in mm)*	*Lower Resonant Frequency (GHz)*
1	4	0.5	2.4
2	8	0.5	2.35
3	8	1.0	2.38
4	8	1.5	2.24
5	8	2.0	2.2
6	15	0.5	2.1
7	15	1.0	1.9
8	15	1.5	1.82
9	15	2.0	1.75
10	15	2.5	1.67

The microstrip antenna is designed with the specified length and width to observe the change in resonant frequencies. The antenna is fed in the edge of the patch to counteract the impedance mismatch generated due to the insertion of the slots. The slot inside the antenna alters the surface current flow. The change in surface current path increases the electrical length of the antenna. The fundamental design frequency of the antenna starts shifting from 2.4 GHz to lower frequency while increasing the slot length. The slot length is varied from S_L 4 mm to 8 mm where the frequency shifted down to 2.2 GHz. This helps to achieve a frequency miniaturization of 8.33%.

To further increase the frequency miniaturization the antenna slot length is increased to 15 mm. This with variable slot width is used to analyze the change in resonant frequency. The different frequencies achieved at 15mm with a maximum slot width of 2.5 mm helps to increase the electrical path and reducing the operating frequency to 1.67 GHz. This has achieved a frequency miniaturization of 30.41%.



(a) **(b)**

Figure 5: Simulated a). E-Field Radiation Pattern b). H-Field Radiation Pattern

The E-plane and H-plane radiation pattern is shown in the figure 5 (a) and Figure 5 (b). The frequency miniaturization of the antenna is achieved whereas the antenna is not able to achieve the best radiation characteristics. The radiation pattern has achieved good gain in the operating frequency of interest.

Conclusion

The work analysis performed on the effect of slot length and width is completed with a edge fed microstrip antenna. The effect of slot on the surface current distribution and reducing the operating frequency is observed for the slot length and width. An optimum slot width and length is achieved with good gain for S_L 15mm and S_W 2.5mm with a lower operating frequency of 1.67 GHz. This makes the antenna to achieve a frequency miniaturization of 30.41%.

References

1. David M.Pozar, Daniel H.Schoubert "Microstrip Antennas, The Analysis and Design of Microstrip Antennas and Arrays", John Wiley & Sons, 15 May 1995.
2. R. Garg, P. Bhartia, I. Bahl, and A. Ittipiboon, *Microstrip Antenna Design Handbook*, Artech House, London, 2001.
3. R. Chair, C.-L. Mak, K.-F. Lee, K.-M. Luk, and A. A. Kishk, "Miniature wide-and half U-Slot and half E-Shaped patch antennas," *IEEE Trans. Antennas Propag.*, Vol. 53, No. 8, pp. 2645–2652, 1983.
4. C. Y. Chiu, C. H. Chan, and K. M. Luk, "Study of a small wide-band patch antenna with double shorting walls", *IEEE Antennas Wireless Propag. Lett.*, Vol. 3, pp. 230–231, 2004.
5. A. K. Shackelford, K. F. Lee, K. M. Luk, and R. Chair, "U-Slot patch antenna with shorting pin," *Electron Lett.*,Vol. 37, No. 12, pp. 729–730, 2001.
6. K. L. Lau, K. C. Kong, and K. M. Luk, "A miniature folded shorted patch antenna for dual-band operation," *IEEE Trans. Antennas Propag.*, Vol. 55, No. 8, 2007.
7. M. T. Islam, M. N. Shakib and N. Misran, "Broadband E-H Shaped Microstrip Patch Antenna For Wireless Systems", Progress In Electromagnetics Research, PIER 98, 163-173, 2009
8. Wang Ren, Zhiguo Shi*,Yu Li,and Kangsheng Chen, "Compact Dual-Band T-Slot Antenna for 2.4/5GHz Wireless Applications", Page No.2493-2497, IEEE 2006.
9. G.F.Khodaei, J.Nourinia, and C.Ghobadi, "A Practical Miniaturized U-Slot Patch Antenna with Enhanced Bandwidth", Progress in Electromagnetic Research B, Vol.3, 47-62, 2008.
10. Prabhakar H.V., U.K. Kummuri, R.M. Yadahalli and V. Munnappa, "Effect of various meandering slots in rectangular microstrip antenna ground plane for compact broadband operation", Electronics Letters, Vol. 43 No. 16, 2nd August 2007
11. A. Kaya, "Meandered Slot And Slit Loaded Compact Microstrip Antenna With Integrated Impedance Tuning Network", *Progress In Electromagnetics Research B, Vol. 1, 219–235, 2008*
12. W. Hu, Y.-Z. Yin, X. Yang, K. Song, Z.-Y. Liu and L.-H. Wen, "A Wide Open U-Slot Antenna with a Pair Of Symmetrical L-Strips For WLAN Applications", *Progress In Electromagnetics Research Letters, Vol. 16, 141-149, 2010*
13. Lin Peng · Cheng-Li Ruan, "A Microstrip Fed Patch Antenna with Two Parasitic

Invert L Stubs for Dual-Band WLAN Applications, Wireless Personnel Communication, Nov 2009.

14. C.-J. Wang, Y.-J. Lee, and K.-C. Lee, "A Dual-Band CPW-Fed L-Slot Antenna With Both Linear And Circular Polarizations, *Progress In Electromagnetics Research C, Vol. 21, 229-241, 2011*.
15. Y.-C. Lee and J.-S. Sun, "Compact Printed Slot Antennas for Wireless Dual and Multi-Band Operations, *Progress In Electromagnetics Research, PIER 88, 289–305, 2008.*
16. Heng-Tung Hsu, Fang-Yao Kuo, and Ping-Hung Lu, "Design Of Wi-Fi/Wi-MAX Dual-Band E-Shaped Patch Antennas Through Cavity Model Approach", Microwave And Optical Technology Letters, Vol. 52, No. 2, pp-471-474, February 2010.
17. Mudar A. Al-Joumayly, Suzette M. Aguilar,Nader Behdad, and Susan C. Hagness, "Dual-Band Miniaturized Patch Antennas for Microwave Breast Imaging", IEEE Antennas And Wireless Propagation Letters, Vol. 9, 2010.
18. A. Beno, D. S. Emmanuel, "Diamond Shaped Symmetrical Slotted Miniaturized Microstrip Patch Antenna for Wireless Applications" Journal of Theoretical and Information Technology, Vol. 48, February 2013.
19. A. Beno, D. S. Emmanuel, ""High Gain Inverted U Shaped Miniaturized Patch Antenna for Multiband Wireless Applications" Microwave and Optical Technology Letters , Vol. 55, No. 1, pp**.** 27-31, January 2013
20. Vidya Sagar Chintakindi, Shyam.S.Pattnaik, O.P.Bajpal, Swapna Devi, Sastry V. R. S. Gollapudi and Patra.K.Pradyumna, "Parameters Calculations of Rectangular Microstrip Patch Antenna Using Particle Swarm Optimization Technique," IEEE, 2007.