
S-Shaped Microstrip Patch Antenna for Wearable Applications

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Abstract: It is great effort to be in touch wherever we are .This concept of being connected anywhere and everywhere is the main driving force for developing and researching the potential Wireless Body Area Networks operated in WLAN and HiperLAN bands. This paper gives a compact analysis and design of S-shaped microstrip patch antenna by means of inserting two slots into a rectangular patch which is best suited for wearable applications in WLAN band. The analysis and design is simulated over EMCoS Antenna Virtual Lab version 5.0.11. A finite ground plane of 65x70 mm and patch size of 48x57 mm were considered. The substrate height is taken as 2.85mm , dielectric constant of 1.44 and loss tangent of 0.01. The proposed antenna is operating at centre frequency of 2.4GHz. The simulated result shows that the obtained bandwidth is 3.2% for $|S11| \leq 10$ dB ranging from 2.358 to 2.435 GHz. The obtained gain is 7.11 dB , return loss -30.156 dB and the VSWR of this antenna is 1.064 which is within the range of 1-2 at resonant frequency 2.4GHz.

I- INTRODUCTION

The rapid development of wireless communication urges the need of wide and dual band antennas. Microstrip Patch Antennas (MSA) are widely used in wireless communications industry due to their various advantages such as low cost, ease fabrication, low profile, less weight, ease of integration with microstrip circuits, linearly and circularly polarization. Due to these advantages, many researchers worked on MSA. In spite of all these advantages this antenna has some disadvantages also like narrow bandwidth and gain, poor polarization etc. For enhancing the bandwidth and gain many methods have been proposed in the literature like using different patch shape, varying patch size, changing substrate thickness, using different dielectric substrate [1], using array configuration and stack configuration[2],[3] etc.The most proposed patch shapes investigated in literature are E-shaped MSA [4][5][6] [7], C and double C-shaped microstrip patch investigated by [8][9], H-shaped microstrip patch antenna [10][11],experimental study of L-shaped microstrip patch [12],S-shaped microstrip patch [13] [14][15] and simulation & experimental studies of U-shaped microstrip patch [16].

The applications of compact small antennas have been receiving an increasing attention in the past few years for the convenience of integrating them with any small handheld or body-worn communication devices. The radio system components, including the antenna to be used in Wireless Body Area Network (WBAN) and accepted by the majority of consumers , need to be some how hidden , compact and low weight. This requires the possible integration of these systems within clothing . In the recent times, research projects have been initiated, under the concept of smart clothing or electrotextiles, to integrate antennas and RF systems into clothes with regard to size reduction and cost effectiveness, so the wearer will not even notice that these sub-systems exist.

This paper presents design and evaluation of S-shaped microstrip patch antenna for wearable applications in WLAN band.

II-ANTENNA CONFIGURATION

The design of proposed S-shaped microstrip antenna developed for body wearable applications with the coordinate system used is depicted in Figure 1. Substrate properties used for patch are Polyester fabric with substrate thickness of 2.85 mm, dielectric constant of 1.44 and loss tangent factor of 0.01 at resonant frequency 2.4 GHz . Two slots with rectangular shape are embedded on the patch in opposite position, which form the S-shape of the patch. The two slots in the rectangular patch can reduce the area of the patch. This means the space required for antenna fabrication is less than the conventional rectangular patch antenna dedicated for wideband operation usage at a fixed operating frequency. By adding the two slots, the area of the rectangular patch can be reduced to 10.526%, which is from conventional rectangular patch area of 2736mm^2 to 2448mm^2 for the rectangular patch with two slots.The parameters that characterize the antenna are the patch length (Lp) and width (Wp), the width of slot (Ws), the length of slot (Ls) and the distance between the slots (Ps). Those three slot parameters are important in controlling the achievable bandwidth. A rectangular patch size of 57 mm × 48 mm is implemented on this layer and two slots of 24 mm × 6 mm are inserted into the patch. The coaxial feeding system is used here for excitation at position (-.0134, 0.0285). The ground plane size of 70 mm × 65 mm is chosen for this design .

III-SIMULATION SOFTWARE

The antenna is designed and simulated using EMCoS Antenna Virtual Lab version 5.0.11 [17]. EMCoS (Electro-Magnetic Consulting and Software) Antenna Virtual Lab is designed for analysis of linear electromagnetic field and current coupling problems in frequency and time domain. Application of electrical field integral equation for harmonic excitation is performed and resulting equation system is solved. The calculation core of EMCoS Antenna Virtual Lab is Tri-Dimensional solver program (TriD) .This program is a user-oriented computer program for the smart analysis of electromagnetic response of complicated structures placed in free space, into dielectric media or over ground plane. Both metal structures consisting of arbitrary shape wires and surfaces (both open and closed), and dielectric bodies, including embedded ones and coated by metal traces, are handled in the current version of TriD. The program allows for finite conductivity to be accounted for wire segments and free metal triangles by specifying their circuit or material parameters. Different types of excitation are available in TriD including the incident plane wave, voltage or current source at a wire segment, external current excitation, edge voltage source on triangle edge, electric and magnetic dipoles, near field sources, radiation pattern sources, and their combinations. Perfectly electrically conducting (PEC) ground and realistic ground with specifying material parameters are also available .

A core of TriD is based on use of the Method of Moments (MoM) to numerically solve the Electric Field Integral Equations (EFIE) for the induced electric currents on metallic surfaces and wires, and the Combined Field Integral Equations (CFIE) for the equivalent electric and magnetic currents on dielectric interfaces. The well-known triangular basis functions for the surface and segment currents, and special basis functions for the junction currents, have been applied and developed in TriD to properly approximate the induced electric and equivalent electric and magnetic currents on the whole structure.

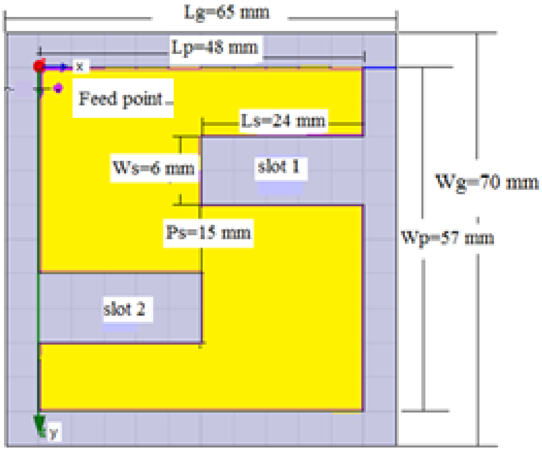

Figure 1. Top view of the S-shaped microstrip patch antenna .

IV- DESIGN CONSIDERATIONS

There are three important parameters which are to be considered carefully for the designing a rectangular microstrip patch antenna for wireless communication.

- *Frequency of operation* f_0*:*

The Mobile Communication Systems (Wi-MAX) uses the frequency range from 2100-5600 MHz. Hence the antenna designed must be able to operate for this frequency range. The default resonant frequency chosen for this research design simulation is 2.4 GHz.

- *Dielectric constant of the substrate* ε_r *:*

The dielectric material chosen for this design is Polyester fabric which has dielectric constant of 1.44 and loss tangent 0.01.

- *Height of dielectric substrate h:*

For the microstrip patch antenna to be used in cellular phones, it is essential that the antenna are kept light and compact. Hence, the height of the dielectric substrate is usually $0.003\lambda o \leq h \leq 0.05\lambda o$ .The height was selected to be $0.0228\lambda o$ which equals to 2.85 mm.

V-DESIGN PROCEDURE

In this section, the design of the proposed antenna will be introduced. Firstly the conventional patch length and width is designed. After designing the patch, two slots have taken out from the patch to make it S-shape patch. Basic width and length is designed with the use of following equations [18].

$$W = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}} \qquad (1)$$

$$L = L_{eff} - 2\Delta L \qquad (2)$$

Where,

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \qquad (3)$$

$$\Delta L = .412h\frac{(\varepsilon_{reff}+.3)\left(\frac{W}{h}+.264\right)}{(\varepsilon_{reff}-.258)\left(\frac{W}{h}+.8\right)} \qquad (4)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}} \text{ for } w/h \geq 1 \qquad (5)$$

Width and length of the patch can be designed by using the equations (1-5). The design specifications are summarized in table 1.

Table 1: Design specifications for the proposed S- shaped MSA.

Length of the rectangular patch (Lp)	48 mm
Width of the rectangular patch (Wp)	57 mm
Substrate height (h)	2.85 mm
Length of the slot (Ls)	24 mm
Width of the slot (Ws)	6 mm
Distance between the slots (Ps)	15 mm
Dielectric constant of the Substrate (ε_r)	1.44
Feed point location (x_f,y_f)	(-.0134,.0285)

VI- SIMULATION RESULTS AND DISCUSSION

Simulations are done for a range of frequencies from 2.3 GHz to 2.5 GHz with a frequency step size of 10 MHz in order to find the antenna parameters like return loss, input impedance, VSWR and gain.
Adding S-slots in the radiator element has made significant effect on the result. The slot and its dimensions plays an important role to control the behavior and the overall performance of the S-shaped patch antenna [19].
Simulation result of the antenna in Figure 2 shows that the return loss of the antenna has its minimum of -30.156 dB at 2.4GHz. Bandwidth of return loss is 77 MHz which is over 3.2% for │S11│ ≤10 dB ranging from 2.358 to 2.435GHz.

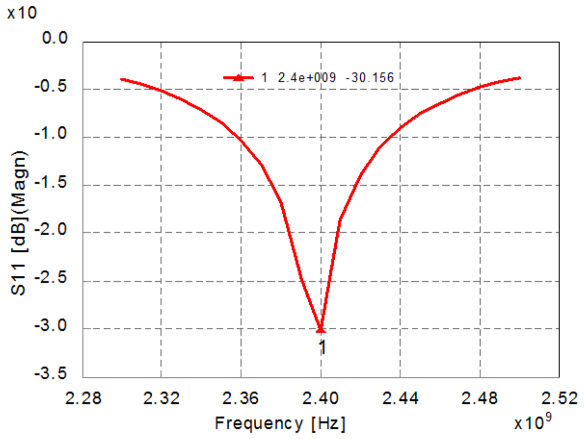

Figure 2. Return loss plot of the S- shaped microstrip patch antenna.

The VSWR plot for coaxial feed antenna is shown in Figure 3. The value of VSWR is 1:1.064 which is lie in the range of 1-2 at the operating frequency.

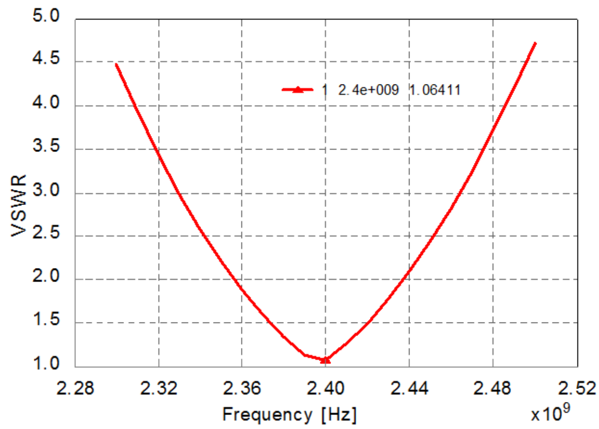

Figure 3. Plot showing variations of VSWR as functions of frequency.

Variations of simulated gain as functions of frequency for the investigated antenna are plotted in Figure 4. At the resonant frequency, the respective predicted value of gain of the antenna is 7.11 dB.

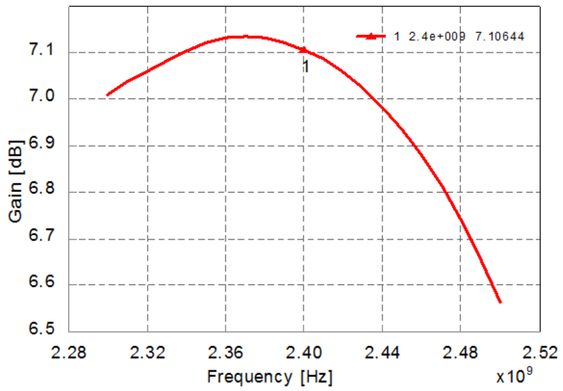

Figure 4. Plot showing variations of gain as functions of frequency.

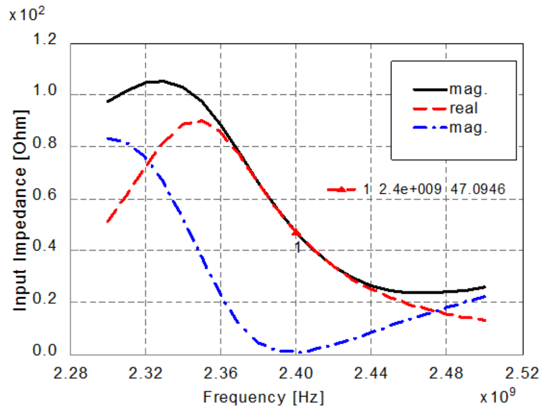

Figure 5. Plot of input impedance variations vs. frequency.

The impedance plot represents how the antenna impedance varies with frequency. The value of impedance should lie near 50Ω in order to perfectly match the port with the antenna. As shown in Figure 5 the impedance for this antenna is 47.09Ω which provides a good match for a feed system. Changing the physical parameters of the patch or slot dimensions can have a multiple effect on the operation of the antenna i.e adjusting height and length of the patch or slot length or width would change the resonance frequency , the return loss and the input impedance [19].The results obtained in this paper for return loss, gain, VSWR and input impedance are comparable with those obtained by [20] for annular ring microstrip patch antenna for the same design specifications.

Figure 6 shows the 3D radiation pattern of the proposed design providing a gain of 7.11 dB.The designed antenna is radiating most of its power in one direction with sufficiently small back lobe which found to be -22 dB. This low back lobe radiation is an added advantage for using this antenna in wearable applications or cellular phone, since it reduces the amount of electromagnetic radiation which travels towards the users body or head.

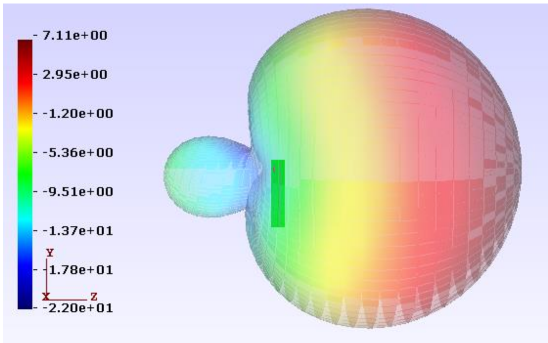

Figure 6. 3D radiation pattern plot of proposed antenna at 2.4 GHz

VII-CONCLUSION

From the obtained results it may be concluded that the S-shaped microstrip patch antenna is a suitable candidate for wearable applications, as it can be built using fabric substrate materials. In this paper, an S-shaped patch antenna covering the 2.3 – 2.5GHz frequency spectrum has been designed and simulated in order to get its impedance and radiation characteristics. It has been clearly seen that the presented antenna provides a bandwidth of 77MHz or 3.2%. It shows a good impedance matching of approximately 47.09Ω at the resonant frequency 2.4GHz. The simple coaxial feeding technique used for excitation of this antenna. This antenna is best applicable to modern communication devices and wireless communication frequencies operating at 2.4GHz and it may eventually replace microstrip patch antennas on standard PCB substrates for various applications.

هوائي الرقعة الشريطي الدقيقِ على شكل S للتطبيقات الممكن ارتداؤها

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الملخص: انه لمسعى عظيم أن نكون على اتصال أينما نحن و حيثما كنا وان هذا المفهوم يعتبر مصدر القوة الدفعة الرئيسية لتطوير البحوث و الدراسات لشبكات الاتصالات اللاسلكية التي تعمل في النطاق الترددي WLAN and HiperLAN .

تقدم هذه الورقة تصميم و دراسة لهوائي رقعة شريطي دقيق على شكل الحرف اللاتيني S وذلك من خلال ادخال شقين في الرقعة المستطيلة مما يجعلها مناسبة جدا في تطبيقات الهوائيات المدمجة مع أي اجهزة صغيرة محمولة او حاجيات ممكن ارتداؤها تعمل في النطاق WLAN band . لقد تمت المحاكاة باستخدام برنامج EMCoS Antenna Virtual Lab version 5.0.11 حيث كانت إبعاد الرقعة الشريطية 48x57 mm , ارتفاع الطبقة العازلة 2.85mm بثابت عزل 1.44 بينما كانت إبعاد المستوى الأرضي 65x70 mm .

نسبة موجة مستقرة , 7.11 dB معامل كسب ,MHz177 لقد أظهرت النتائج المتحصل عليها نطاق ترددي للهوائي مما يجعلها مناسبة جدا للتطبيقات 2.4GHz عند تردد رنين return loss -30.156 dB و معامل فقد VSWR 1.064 المشار إليها آنفا .

VIII-References

[1] Linxi Zhang, Zhang Qi, Chufeng Hu, "The Influence of Dielectric Constant on Bandwidth of U-notch Microstrip Patch Antenna," Proceedings of 2010 IEEE International Conference on Ultra-Wideband (ICUWB2010).

[2] Kaushik Malakar, Danish Abbas S . M. , Sudipta Chattopadhyay, " Stacked Stair-case patch antenna for High Gain and Ultra Wideband Applications," IJECT Vol. 2, Issue 1, p.p.7-9, March 2011.

[3**]** Nishiyama E., Aikawa M. and Egashira S., " Stacked microstrip antenna for wideband and high gain," IEE Proc.-Microw. Antennas Propag., Vol. 151, No. 2, p.p.143-148, April 2004

[4] Elangovan, G. And Rajapaul Perinbam J., " Wideband E-Shaped Microstrip Antenna for Wireless Sensor Networks," American Journal of Applied Sciences, ISSN 1546-9239, p.p.89-92, 2012.

[5] Hoseini Izadi O., Mehrparvar M.," A compact microstrip slot antenna with novel E-shaped coupling aperture," *5th International Symposium on Telecommunications(IST)*, pp 110 – 114, 2010.

[6] Amit Kumar Gupta, Prasad R.K. and Srivastava D.K.,"Design and Development of Dual E-shaped Microstrip patch antenna for bandwidth and gain enhancement," IJECET, ISSN: 0976-6464, Volume3, Issue3, Oct-Dec 2012.

[7] Ang B.K and chung B.K, " A Wideband E-shaped Microstrip Patch Antenna for 5-6 GHz Wireless communication," Progress in Electromagnetics Research, Vol.75, p.p.397-407, 2007.

[8] Srivastava D. K., Diwakar Singh, Amit Kumar Gupta and Prasad R.K.,

" Design and Analysis Of Extended C-Shaped Microstrip Patch Antenna For Wideband Application, " Conference on Advances in Communication and Control Systems 2013 (CAC2S 2013)

[9] Sanad M., " Double C-patch antennas having di®erent aperture shapes, " Proc. IEEE AP-S. Symp., 2116{2119, Newport Beach, CA, June 1995 .

[10] Gao S. C., L. W. Li, Leongand M. S. and Yeo T. S. ,"FDTD analysis of a compact H-shaped microstrip patch antenna," IEEE Trans Antenna Propogation , pp 494 – 497,Vol.1, 2001.

[11] Ali M. T., Nordin N., Pasya I., Md Tan M. N.,"H-shaped microstrip patch antenna using L-probe fed for wideband applications", *6th European Conference on Antennas and Propagation (EUCAP)*, pp. 2827 – 2831, 2012.

[12] Mak C. L., Luk K. M., Lee K. F., Chow Y. L.,"Experimental study of a microstrip patch antenna with an L-shaped probe" *IEEE Trans. Antennas Propagation*,Vol. 48, Issue 5, pp. 777 – 783, 2000.

[13] Diwakar Singh, Amit Kumar Gupta, Prasad R.K., " Analysis and Design of S-shaped Microstrip Patch Antenna ," IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) ,e-ISSN: 2278-2834,p- ISSN: 2278-8735. Volume 7, Issue 4 (Sep. - Oct. 2013), PP 18-22 .

[14] Fitri Yuli Zulkifli, Faisal Narpati, and Eko Tjipto Rahardjo, "S-shaped Patch Antenna Fed by Dual Offset Electromagnetically Coupled for 5-6GHz High Speed Network ,"PIERS ONLINE, VOL. 3, NO. 2, 2007 ,PP 163-166 .

[15] Naresh Kumar Joshi , Anoop Singh Poonia , Piyush Choudhary , "Broadband Microstrip S-shaped Patch Antenna for Wireless Communication,"*International Journal of Computer Applications (0975 – 8887) Volume 57– No.17, November 2012* .

[16] Lee, K. F., Luk K. M., Tong K. F., Shum S. M., Huynh T. and R. Q., "Experimental and simulation studies of the coaxially fed U-slot, " Proc. Inst. Elec. Eng., pt. H, Vol. 144,PP 354-358,Oct.1997.

[17] EMCoS Antenna Virtual Lab 5.0.11 version , http://www.emcos.com

[18] C.A. Balanis, ''Antenna Theory Analysis and Design, ''John Wiley & Sons, Inc, 1997.

[19] Mohammad Aneesh, J.A Ansari, Ashish Singh, Kamakshi, S.S Sayeed, " Analysis of S-shape Microstrip Patch Antenna for Bluetooth application, " *International Journal of Scientific and Research Publications, Volume 3, Issue 11, November 2013 ISSN 2250-3153.*

[20] Sankaralingam S., Kaushik Mohanty and Bhaskar Gupta, "Annular Ring Patch Antenna for Wearable Applications," IEMCON 2011 organised by IEM in collaboration with IEEE on 5th & 6th of Jan,2011.PP 267-270