American Journal of Applied Sciences 9 (1): 89-92, 2012
ISSN 1546-9239

Wideband E-Shaped Microstrip Antenna for Wireless Sensor Networks

[1]Elangovan, G. and [2]J. Rajapaul Perinbam
[1]Department of Computer Science and Engineering,
Sakthi Mariamman Engineering College, Thandalam, Chennai 602105, India
[2]Department of Electronics and Communication Engineering,
RMK Engineering College, Kavaraipettai, Tamil Nadu, Chennai 601206, India

Abstract: Problem statement: Wireless Sensor Networks (WSN) is currently receiving significant attention due to their unlimited potential. It is still very early in the lifetime of such systems and many research challenges exist, out of which one of the challenges is sensor processing and fusion under limited capacities, the most important component in sensor is its TX/RX antenna. **Approach:** For high-speed wireless local area networks and other wireless communication systems covering the 5.33-5.71 GHz frequency band. In this frequency band microstrip antennas have attracted with its low-profile in nature. Microstrip antenna was proposed to meet the challenges, which combines the advantages of compactness with the low cost and low profile of a patch antenna. **Results:** The key parameters governing the antenna optimization have been determined with the help of High Frequency Simulation Software (HFSS). As a consequence, 5.5GHz microstrip antenna with size 22×16×3.2 mm had been realized on duroid with 2.2. **Conclusion:** This combination of performance metrics is highly desirable for autonomous distributed sensor network applications where a small sensor node volume and excellent power efficiency are required.

Key words: Broadband, high gain, slotted patch antenna, probe feed

INTRODUCTION

A Wireless Sensor Network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location. The more modern networks are bidirectional, enabling also to control the activity of the sensors (Zhao and Guibas, 2004). The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, environment and habitat monitoring, healthcare applications, home automation and traffic control.

Because of the booming demand in wireless communication system applications, microstrip patch antennas have attracted much interest due to their low profile, light weight, comfortable to planar and non-planar surfaces, simple and inexpensive to manufacture using modern printed circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC designs and when the particular patch shape and mode are selected, they are very versatile in terms of frequency, polarization, pattern and impedance (Balanis, 2005).

However, they also have some drawbacks (Garg, 2001), ranging from narrow bandwidth to low gain. To overcome their inherent limitation of narrow impedance bandwidth and low gain many techniques have been proposed and investigated (Ghorbani *et al*., 2006). However, bandwidth enhancement and size reduction are becoming major design considerations for practical applications of microstrip antennas due to the improvement of one of the characteristics, which normally results in degradation of the other (Xiao *et al*., 2006). In the past few years, new designs arising from the Planar Inverted-F Antenna (PIFA), one of the studies (Ibnyaich *et al*., 2011) focused on the development of wideband planar inverted-F antennas. They used two different studies to obtain the wideband operation. These developed wideband antennas cover the GPS, DCS, IMT-2000, 2.4GHz WLAN and 3.5 GHz WIMAX bands applications. A simple, compact

Corresponding Author: Elangovan, G., Department of Computer Science and Engineering, Sakthi Mariamman Engineering College, Thandalam, Chennai 602105, India

EBG microstrip antenna is proposed to improve the bandwith upto 10.14% (Alam *et al*., 2011). Recently, a microstrip antenna, which is low in cross-polarization level and wide in impedance bandwidth, designated as the suspended probe-fed plate antenna, has been proposed. The antenna has an impedance bandwidth of 20%. However, it was pointed out that using higher patch height cause a higher cross-polarization level. And the antenna gain drops to 5dBi, which is lower than other wideband microstrip antennas (Chair *et al*., 2005). Some other techniques as utilizing the shorting pins or shorting walls (Dargie and Poellabauer, 2010) on the unequal arms of U-shaped patch, U-shaped patch, or L-probe feed patch antennas, investigating the material proprieties (Ismail *et al*., 2010), wideband and dual band impedance bandwidth have been achieved with electrically small size. However the achievable gains of these antennas are below 8.5 dBi. In addition, these techniques result in high crosspolarization radiation. High cross-polarization not only leads to distortion in the co-polarization pattern, but also reduces the gain of the antenna.

In this study a Single layer wideband E-shaped rectangular microstrip antenna for wireless sensor networks is proposed. This type of microstrip antennas can be successfully used to model complex natural objects as galaxies; cloud boundaries, mountain ranges, coastlines, snowflakes, trees, leaves and much more a wide variety of applications. It is designed to cover the 5.33-5.71 GHz frequency band. A comprehensive parametric study has been carried out to understand the effects of various dimensional parameters and to optimize the performance of the final design. The simulations are performed using HFSS software. The proposed antenna structure with its dimesions and the results obtained are discused in the remaining part of this study.

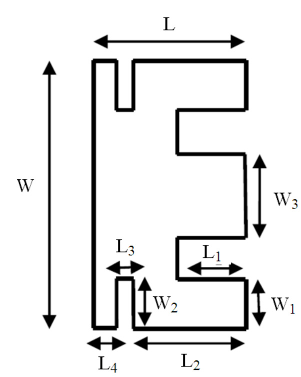
Antenna design: The antenna geometry is shown in Fig. 1a and b first, a rectangular microstrip patch antenna is designed based on the standard design procedure to determine the length (L) and width (W) for resonant frequency at 5.5 GHz. It is fed by a probe at position (x0, y0). In the design, the inverted rectangular patch is supported by a low dielectric substrate with dielectric permittivity εr and thickness h. An air-filled substrate is sandwiched between the substrate and ground plane. The proposed patch slots are on the same radiating element appear like an Eshaped patch. The slots are embedded in parallel on the radiating edge of the patch symmetrically with respect to the x-axis (centerline) of the patch for enhancing the antenna bandwidth. The extra slot is included to reduce the size of the patch. The proposed patch is fed by a probe along the centerline of the patch.

Table 1 shows the optimized design parameters obtained for the proposed patch antenna. A dielectric substrate with dielectric permittivity, εr of 2.2 and thickness, h of 3.2 mm has been used in this research. The thickness of the air-filled substrate h0 is 32 mm. The proposed antenna is designed to operate at 5.33-5.71 GHz region. In this design, the use of thick air-filled substrate in between the radiating patch and the ground plane provides the bandwidth enhancement. The use of probe fed reduces cross-polarization level. The horizontal portions of the probe incorporated with the radiating patch and the ground plane introduce capacitances. These capacitances can suppress some of the inductance contributed by the vertical portions of the probe and hence, achieve low cross-polarization.

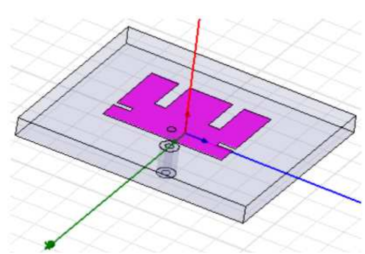
In addition, the presences of slots also restrict the patch currents, at its resonance frequencies that provide lower resonance on the design.

Table 1: Optimized design parameters for E-shaped microstrip antenna

Parameter	Value (mm)	Parameter	Value (mm)
W	22	L2	1.3
L	16	L3	1.0
W1	3	h	3.2
L1	6	fpW	11.0
W2	2	fpL	4.0
W3	6		



(a)



(b)

Fig. 1: (a) Geometry of the proposed microstrip antenna (b) Proposed microstrip antenna in HFSS

MATERIALS AND METHODS

Using the starting conditions and constraints mentioned above, parametric analysis and optimization in Ansoft HFSS was used to find the dimensions to simultaneously maximize factors such as antenna gain, return loss and minimum volume. Duroid was selcted as substrate material and air box is created before simulating the antenna. In the center of the antenna, coaxial probe was used to feed. Frequency sweep analysis was done and far field reports are recorded for the purpose of analyzing the microstrip antenna.

RESULTS

The following figures are optained during the analysis of the designed microstrip antenna

The gain of the proposed patch antenna at various frequencies is shown in Fig. 2. The radiation patterns of the antenna are measured in an anechoic chamber. Figure 3-5 show the radiation results at 5.33 GHz, 5.71 GHz and center frequency 5.5 GHz respectively. Both the E-plane and H-plane have broadside directional radiation patterns similar to a common rectangular patch antenna. The radiation characteristic exhibits little variation at other frequencies over the 380-MHz bandwidth. Figure 6 shows the return loss of the proposed microstrip antenna.

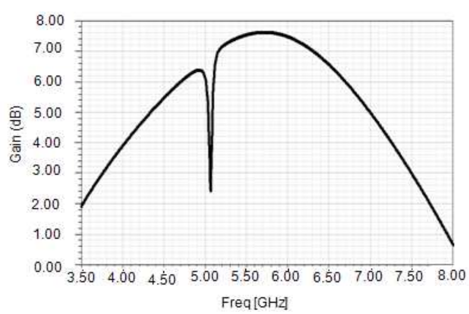


Fig. 2: Radiation pattern gain of E-shaped antenna

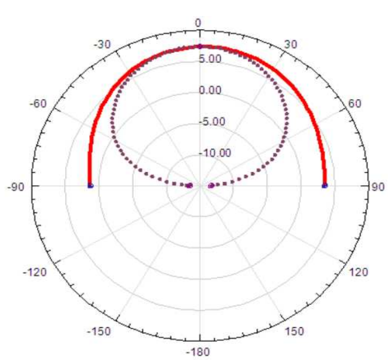


Fig. 3: Measured radiation pattern of E-shaped microstrip antenna at 5.33 GHz

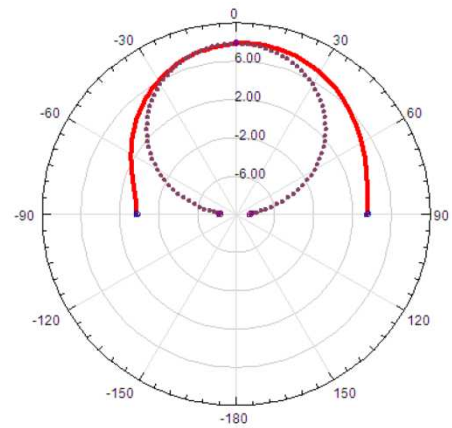


Fig. 4: Measured radiation pattern of E-shaped microstrip antenna at 5.71 GHz

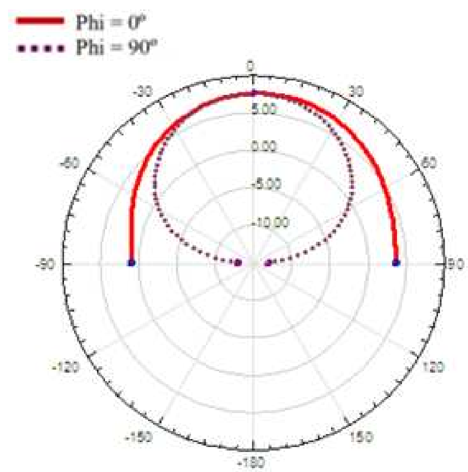


Fig. 5: Measured radiation pattern of E-shaped microstrip antenna at 5.71 GHz

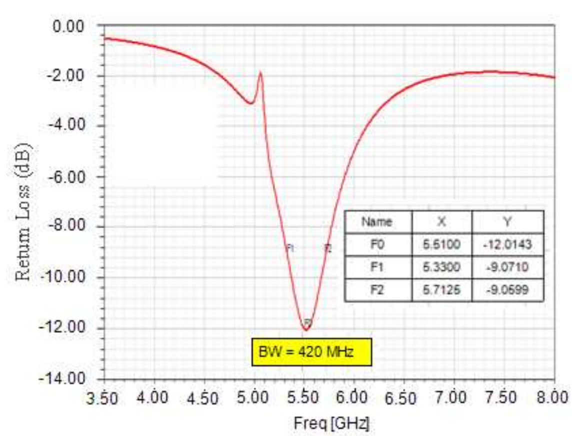


Fig. 6: Return Loss of E-shaped microstrip antenna

DISCUSSION

The impedance bandwidth of 21.6% from 5.33-5.71 GHz is achieved at VSWR $\leq$ 2. The wideband characteristic is due to large separation between the radiating patch and the ground plane and due to the use of low permittivity substrate with the proposed design.

The maximum achievable gain is 7.6 dBi at the frequency of 5.7 GHz and the gain shows stable performance in the entire operating band. The measured total efficiency of the proposed antenna is an average of 90% over the operational frequency. The designed antenna displays good broadband radiation patterns. The antenna shows better cross-polarization. It is notable that the radiation characteristic of the proposed microstrip antenna are better to those of the conventional microstrip antenna due to good cross-polarization level in both planes are achieved over the impedance bandwidth.

CONCLUSION

A wideband E-shaped microstrip patch antenna has been designed for high-speed wireless communication systems. The reflection coefficient is below -10 dB from 5.33-5.71 GHz. The performance is more than meeting the demanding bandwidth specification to cover the 5.33-5.71 GHz frequency band. The measurement results have demonstrated the stability in the radiation performance of the antenna across the entire operating bandwidth. At the same time, the antenna is thin and compact with the use of low dielectric constant substrate material. These features are very useful for worldwide portability of wireless communication equipment. By locating the feed point at the base rather than the tip of the center arm, the resonant frequency of the second resonant mode can be tuned without affecting the resonant frequency of the fundamental resonant mode. The bandwidth can be easily tuned by trimming the length of the center arm. The proposed antenna with enhanced performance will be helpful for antenna engineers to design and optimize the antennas for indoor wireless applications.

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