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Design of Compact Dual F-Slots UWB Monopole Antenna for Wireless Devices

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***Abstract*—In this paper, an Ultra Wideband (UWB) Monopole antenna is proposed for several applications. The size of the antenna is 55mm × 35mm × 1.7mm with dual F-slots in its ground plane and three different pairs of rectangular slots in its upper patch. In order for the antenna to resonate at multiple frequencies or to attain wide impedance bandwidth, the relative lengths, heights and positions of the slots are tuned to the required resonant frequency. The simulation results are obtained using the tool Advanced Design System 2014 (ADS 2014). The -10 dB impedance bandwidth obtained by the proposed antenna at two resonant frequencies 2.5 GHz and 4.9 GHz are 683 MHz (2.280 GHz to 2.963 GHz) and 4.352 GHz (4.667 GHz to 9.019 GHz) respectively.The maximum gain of 3.1 dBi at 2.5 GHz and 2.26 dBi at 5 GHz are also achieved. The antenna will operate for 2.4 GHz ISM band, Bluetooth & Zigbee applications, IEEE 802.11 WiMAX at 5.5 GHz, WLAN (5 GHz) applications of IEEE 802.11a, IEEE 802.11n & IEEE 802.11ac and also covers the part of 4-8 GHz (C-band) satellite frequency band.**

Keywords—Bluetooth, impedance bandwidth, ISM band, monopole antenna, multiband, wideband, Wi-MAX, WLAN, Zigbee.

I. INTRODUCTION

Wireless communication necessitates a broad bandwidth to provide better performance in communication. A wireless terminology used in mobile terminals such as WLAN or Wi-MAX requires the growth of multiband and wideband antennas that are having the ability to operate under different frequency bands of different standards. Multiband antennas have been initiated to support many applications since it can maintain suitable radiation patterns and reasonable gain. Furthermore, multiband antennas should be efficient andcompact in size. In order toincorporate multiband/wideband antennas into modern wireless devices, the dimensions of the antenna should be electrically small.Microstrip antennas are efficient and low profile but it provides narrowband characteristics. Monopole antennas are more suitable for wireless applications.Because the cost and weight of monopole antenna is very low, fabrication is easy and the biggest advantage of using monopole antenna in wireless devices is that the radiation pattern of monopole antenna is omni-directional.

Recently several antennas with wideband and multiband characteristics have been effectively proposed for wireless operations. It includesT-shaped monopole antennafor multiband resonance using horizontal strip resonators [1]Trident shaped Triple-Band Monopole Antenna [2], Multiband monopole antenna with complementary split-ring resonators [3], Monopole antenna using Coplanar Waveguide feed for dual-band WLAN operations [4], Novel design of printed multiband antenna for wireless applications [5], Double-T monopole antenna for 2.4/5.2 GHz WLAN operations [7], Printed monopole antenna for multiband WLAN applications [8], Wideband planar monopole antennas [10] and Modified inverted-L monopole antenna for 2.4/5 GHz operations [11],Compact Multiband and Wideband Monopole Antenna for Wireless Applications [18], etc.,

In [6] rectangular monopole antenna fed withmicrostrip line used a trapezoid conductor to achieve a broad bandwidth. Triple-band omni-directional antenna is developed for WLAN applications in [9]. A printed crescent patch antenna is proposed for Ultra wideband applications with various slots on the patch and on the ground plane [12]. Literature also includes many number of monopole antennas ([1-5], [7-9] and [13-17]) which are either printed or mounted on bulky ground plane. But most of the printed design improves the complexity and cost of the structure.

II. DUAL F-SLOTS UWB MONOPOLE ANTENNA DESIGN

In this paper, a compact dual F-Slots UWB (Ultra Wideband)monopole antenna is constructed with a microstrip feedline for wireless applications. To attain the extreme impedance bandwidth, three separate pairs of rectangular slots are introduced on the upper patch and dual F-slotsareintroduced in the ground plane.

Fig. 1 shows the dimensions of a compact dual F-slots UWB monopole antenna for wireless operations. Multiband performance such as applications in 2.4 GHz ISM band, WLAN, Wi-MAX and C-Band satellite communication can be achieved for the proposed antenna by adjusting the dimensions and positions of the slots on both upper patch and ground plane.

A. Monopole Antenna Geometry

Fig. 2(a) shows the structure of the simple monopole antenna. The antenna is mounted on the Rogers RT_Duroid

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5880 substrate with a permittivity of 2.2 and the thickness of 1.6 mm as indicated in Fig. 1. The proposed antenna is excited with a 50Ω microstrip feed line and with rectangular geometry with dimensions 55mm × 35mm × 1.7mm without introducing any bandwidth enhancement techniques. The relative dimensions of the antenna, slots at corners of the patch, slots in the sides of radiating element and slots in the ground plane are mentioned in Figure 1 and Table I.

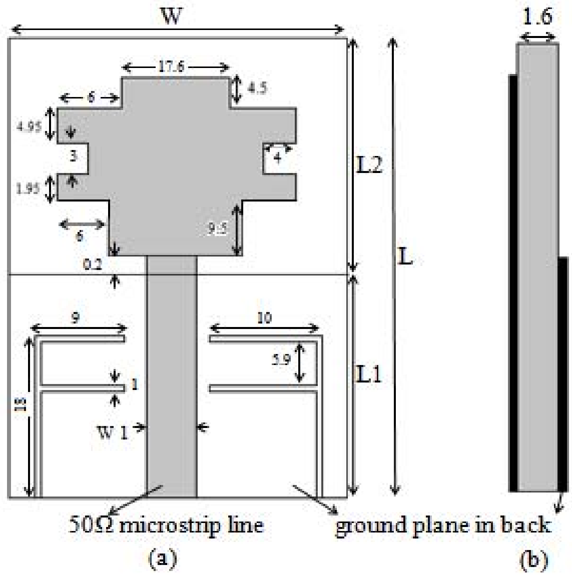

Figure1. Dimensions of the Dual F-slots UWB monopole antenna (a) Top view (b) Side view

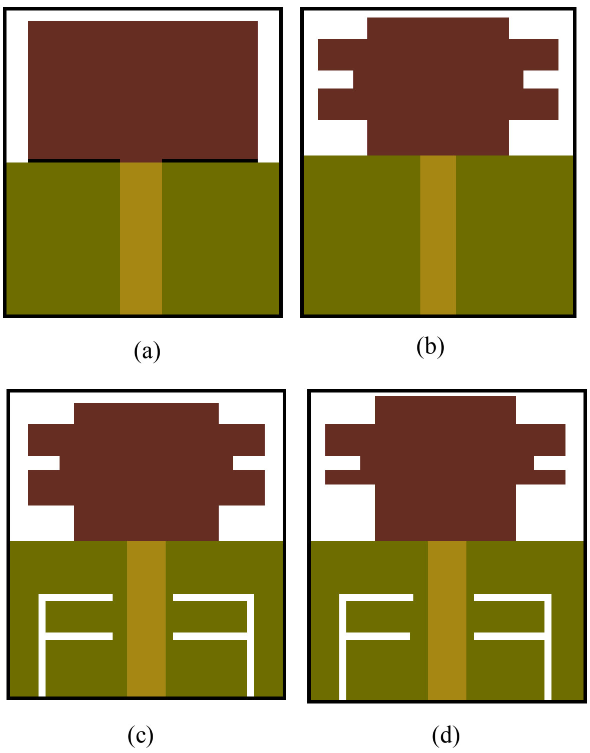

Figure2. Modifications in the antenna geometry (a) simple antenna (b) antenna with slots on upper patch (c) antenna with slots on ground plane (d) Antenna with modified slots

In order to design the relative dimensions of the proposed antenna, first a rectangular monopole antenna is considered (as shown in Fig. 2(a)) with dimensions of Lp × Wp mm^2 operating at the resonant frequency of 5 GHz. The dimension of the monopole patch is Lp = 23.9 mm and Wp = 29.6 mm.

Since the monopole antenna dimensions change the antenna performance at desired frequencies, the study related to the measurement of design parameters of monopole antenna is carried out. In this proposed design, the effects of two antenna design parameters such as the dimensions of rectangular slots anddual F-slots are considered on the antenna impedance bandwidth.

B. Antenna with Slots on upper patch

Two different pairs of rectangular slots with dimensions 4mm×6mm and 3mm × 4mm are made at top two corners and at the middle of the upper patch respectively. A pair of square shaped slots with dimension 6mm × 6mm is then made on the bottom two corners of rectangular monopole patch as shown in Figure 2(b). Simple monopole antenna without any slots produced an impedance bandwidth of 39.4% (2.466 – 3.578 GHz) at 2.8 GHz.

TABLE I. Specifications for the Monopole antenna

Antenna Design Specifications		
S. No.	**Symbol**	**Value (mm)**
1	L	55
2	W	35
3	L1	27
4	W1	4.8
5	L2	28
6	t	0.052
7	h	1.6

But the presence of above slots leads to dual narrowband resonances at 3.9 GHz (10.9%) and 7.1 GHz (7.9%). The simulation results of monopole antenna with and without slots on upper patch are shown in Figures 3(a) and 3(b) respectively.

C. *Antenna with slots on ground plane*

Though the antenna with slots on upper patch produced two operating frequency bands, impedance bandwidth at two resonant frequencies was very low. To improve the Bandwidth of the antenna, dual F-slots are placed on the ground plane leading to exact resonant modes and the multi-band resonance. Introduction of different slots in monopole antenna design changes the direction of current which can lead to the improvement of impedance matching of monopole antenna. This will result in multiband operation. Return loss characteristic of the antenna with slots (two different pairs of

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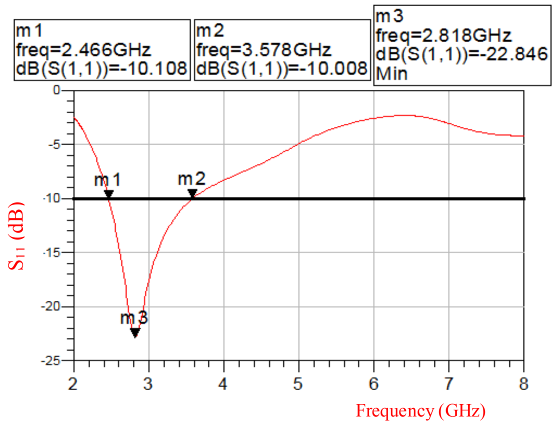
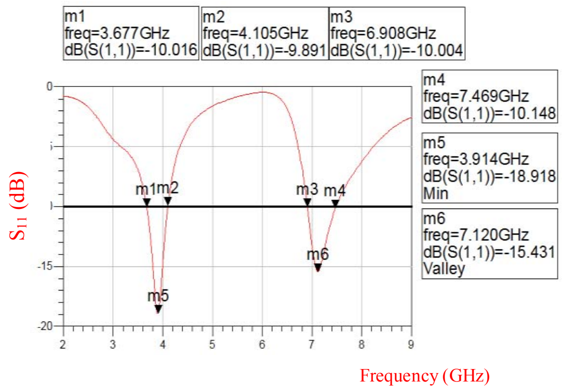
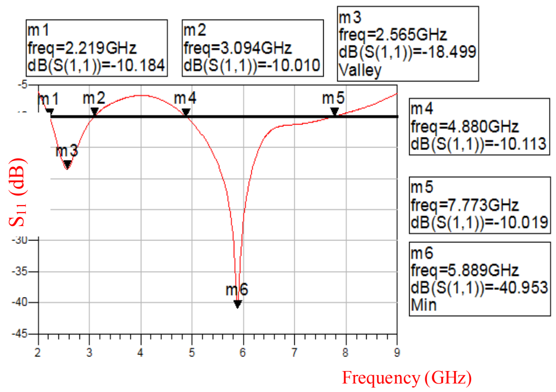
rectangular slots and a pair of square slots) on upper patch and (dual F-slots) on ground plane is shown in Fig. 3(c). Bandwidth at two operating frequencies 2.565 GHz and 5.889 GHz are 875 MHz (2.219 – 3.094 GHz) and 2893 MHz (4.880 GHz – 7.773 GHz) respectively with a return loss of -18.4 dB and -41 dB at corresponding frequencies.



(a) Antenna alone



(b) Antenna with Slots on upper patch



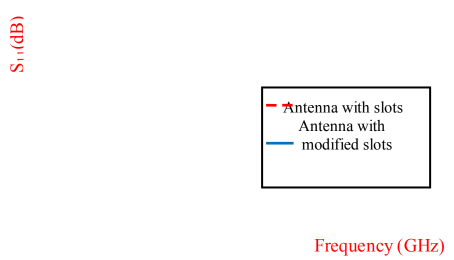
(c) Antenna with slots on ground plane

Figure 3. S_{11} Characteristics of monopole antenna (shown in Figure 2(a), 2(b) and 2(c)) with dimension L_p mm × W_p mm

III. SIMULATION RESULTS AND COMPARISON

A. Reflection Coefficient

Even though the antenna with aforementioned slots produced better bandwidth, further work has been made to improve the impedance bandwidth to utilize the antenna for multi band wireless applications. The dimension of square shaped slots at two bottom corners of upper patch is altered and a pair of rectangular slots with new dimensions 9.5 mm × 6 mm is made. And the dimension of rectangular slots at the top two corners of upper patch is also modified to 4.5 mm × 6 mm. But the geometry of rectangular slots at the middle of two sides of upper patch and the slots on ground plane are unaltered.



The Return loss (-10 dB) characteristics of the proposed antenna structure with slots of new dimensions is obtained using Advanced Design System 2014 (ADS 2014) tool and it is shown in Fig. 4 (given by the solid line). Two separate broadband resonant modes at two different frequencies of 2.54 GHz and 4.97 GHz are clearly excited simultaneously with a proper matching condition. The maximum desired bandwidth at two operating frequencies are 26.8% (683 MHz: 2.280 to 2.963 GHz) and 87.5% (4.667 to 9.019 GHz). From figures 3 and 4, it is obviously noted that the slots made on upper patch and ground plane are responsible for dual band resonances, widening the bandwidth at desired operating frequencies and the improvement of return loss.

Based on the designated dimensions, the return loss characteristics were simulated. The impedance bandwidth of the lower resonant mode covers 2.4 GHz WLAN band (2400-2484 MHz), 2.5 GHz WiMAX band & 2.4 GHz ISM/Bluetooth/Zigbee band and a wide impedance bandwidth is obtained for upper resonant mode, which include the 5 GHz WLAN bands (5.2 GHz/5.8 GHz), 5.5 GHz WiMAX band and also it covers the part of 4-8 GHz satellite frequency band (C-band)

B. Radiation pattern

Radiation patterns are simulated in E (XZ) plane and H (XY) plane for frequencies 2.5 GHz & 5 GHz and shown in

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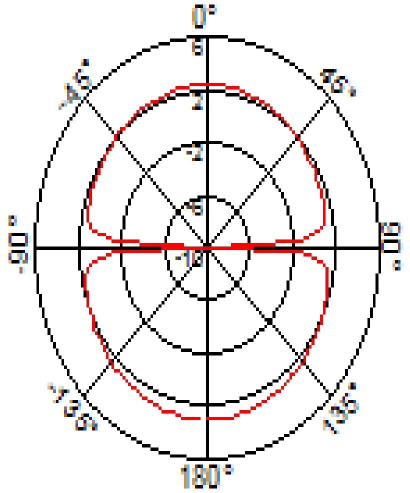
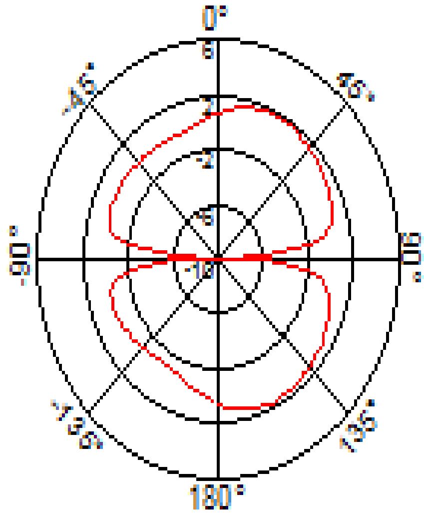
Figures 5 and 6. The maximum possible gain obtained for the above designed antenna is 3.1 dBi and 2.26 dBi at 2.5 GHz and 5 GHz respectively.



(a)

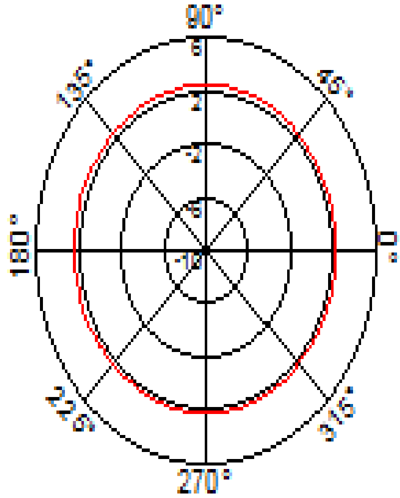


(b)

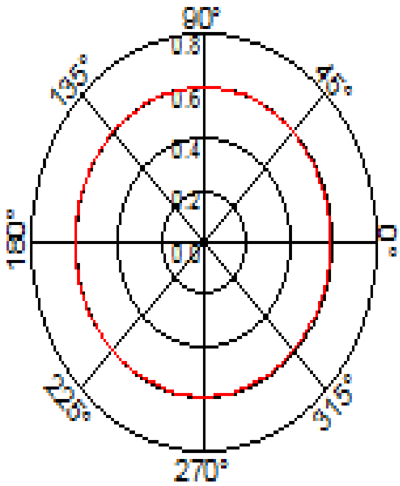
Figure 5. Radiation pattern in E-plane at (a) 2.5 GHz (b) 5GHz

IV. CONCLUSION

Compact dual F-slots UWB monopole antenna is proposed in this paper. It uses different shapes of slots in the upper patch and in the ground plane. The slots introduced in the ground plane reject all undesired bands and the slots in upper patch increases the bandwidth at the desired resonant frequencies. The proposed monopole antenna can offer adequate -10dB bandwidth and almost omni-directional radiation patterns for wireless operations. Two resonant frequencies are obtained at 2.54 GHz and 4.97 GHz with a return loss of -19.8 dB and -25.5 dB respectively for multiband applications. The antenna is suitable for the applications at 2.4 GHz (ISM band, Bluetooth & Zigbee applications), 5 GHz (WLAN applications of IEEE 802.11a, IEEE 802.11n & IEEE 802.11ac) & 5.5 GHz (IEEE 802.11 WiMAX) and also covers the part of 4-8 GHz (C-band) satellite frequency band. Therefore, the proposed design of monopole antenna is a good option for several wireless applications.



(a)



(b)

Figure 6. Radiation pattern in H-plane at (a) 2.5 GHz (b) 5GHz

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