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A Novel Quadband Slot Antenna for GPS/WiMAX/WLAN Systems

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ABSTRACT: In this paper, the design of a four-band slot antenna for the global positioning system (GPS), worldwide interoperability for microwave access (WiMAX), and wireless area network (WLAN) is presented. The antenna consists of a rectangular slot, a T-shaped feed patch, an inverted T-shaped stub, and two E-shaped stubs to generate four frequency bands. The radiating portion and total size of the antenna are less than those of the tri-band antennas studied in literature. The multiband slot antenna is studied and designed using CST. The simulated return losses, radiation patterns, directivity of the antenna are presented. Simulated results show that the antenna can be designed to cover the frequency bands from 1.55 to 1.65 GHz for the GPS system, 2.4–2.65 GHz for the IEEE 802.11b&g WLAN systems, 3– 3.75 GHz for the WiMAX system, and 4.9–5.8 GHz for the IEEE 802.11a WLAN system.

KEYWORDS: CST, Global positioning system (GPS), multiband antenna, slot antenna, wireless area network (WLAN), worldwide interoperability for microwave access (WiMAX).

I.INTRODUCTION

With the developments of many different wireless communications standards, it is desirable to integrate as many standards such as the global positioning system (GPS), worldwide interoperability for microwave access (WiMAX), and wireless area network (WLAN) standards as possible into a single wireless device. For this reason, different multiband antennas have been studied, e.g., the dual-band monopole antenna for the WiMAX systems in [1], the multiband planar inverted-F antenna (PIFA) for the wireless wide area network (WWAN) system in [2], the multiband patch antenna having varied polarization states in [3], and the dual-band loop antenna for the 2.4/5.2/5.8 GHz bands in [4]. Slot antenna, with the advantages of compact size, wide bandwidth, and easy integration with other devices is a good candidate for the design of multiband antennas. In the past years, different designs of multiband slot antennas have been proposed [5]–[13]. The dual- band characteristics of the slot antennas in [5], [6], and [7], [8] were generated by etching several narrow slots on the ground planes or several stubs on the large slots, respectively. The tri-band antennas in [9], [10] and [11], [12] were achieved using three folded slots etched on the ground planes or several stubs on the slots, respectively.

In this paper, we present the design of a four-band slot antenna for the GPS/WiMAX/WLAN systems. The antenna consists of a rectangular slot, a T-shaped feed patch, an inverted T-shaped stub, and two E-shaped stubs to generate four frequency bands at about 1.575, 2.45, 3.5, and 5.4 GHz for the GPS, IEEE 802.11b&g, WiMAX, and IEEE 802.11a systems, respectively. It should be noted that since each frequency band is generated using only one antenna element, the proposed antenna cannot support the optional MIMO feature specified in the WiMAX standard. Unlike previous tri-band designs [9]–[12], in which each frequency band was generated using a strip/slot, in the proposed four-band antenna, we use the harmonics of the T -shaped feed patch to generate two frequency bands. Then using a double-folded stub in the T-shaped feed patch, the two harmonic resonant frequency can be tuned independently. With this method, the slot antenna can have four operating bands and a size smaller than those of the tri-band antennas studied in [9]–[12].

The gains of the antenna in the four frequency bands are much higher gains than those of the four-band antenna in [13]. The proposed multiband antenna is studied and designed using the electromagnetic (EM) simulation tool CST. The methodology used to design the antenna for other frequency bands is also proposed. The results on reflection coefficient S11, radiation pattern, realized peak gain, and efficiency are presented.

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II. ANTENNA DESIGN METHODOLOGY

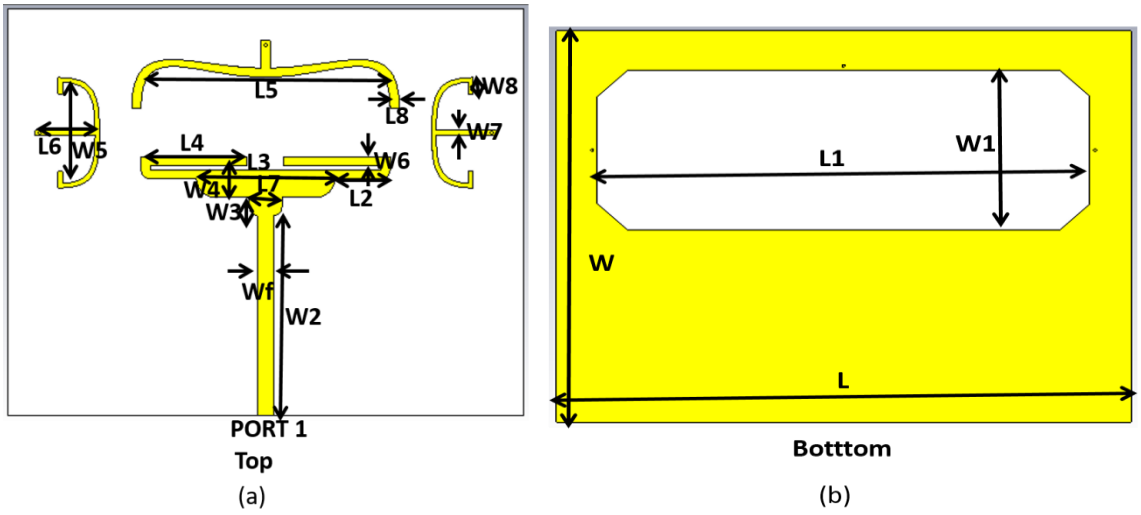

Figure 1. Proposed Structure of the Multiband Antenna

The multiband antenna for GPS, WLAN and WiMAX Applications is proposed is shown in Figure 1. Which consists of a rectangular slot with chamfered at each every corner with a dimension of L1 X W1 on the backside of the substrate plane i.e. ground plane. The Inverted T-shaped stub with bending on both the sides, and two E-shaped stubs with bending on the right hand and left hand side placed on the top plane of the substrate and connected with via to ground plane such that it will get the proper impedance matching at desired frequency. The T shaped feed patch with micro strip fed on the top plane of the substrate is used to feed the rectangular slot with chamfered at each and every corner. The proposed antenna can generate the four frequency bands at about 1.57, 2.5, 3.5 and 5.3 GHz denoted 1,2,3 and 4, respectively.

The rectangular slot with chamfered edges with T-shaped stub with bending generate band 1 at about 1.57 GHz. The 2-E shaped stubs with bending operating as monopole radiators generate band 2 at about 2.5 GHz .for the IEEE standard 802.11 b &g Wireless LAN Systems. Due to coupling of the T-Shaped feed patch and T-shaped stub with bending generate band 3 at about 3.5 GHz for WiMAX Applications. The T-shaped feed patch in the higher order mode generates band 4 at 5.3 GHz for the IEEE Standard 802.11a for Wireless LAN Applications. The proposed multiband antenna is studied and designed on a substrate with a relative permittivity of 4.4, a thickness of 0.8 mm, and a loss tangent of 0.025.The final dimensions of the proposed multiband antenna is depicted in Table.I.

Table 1. Dimensions of the Proposed Antenna (mm)

Parameters	L	L1	L2	L3	L4	L5	L6	L7	L8	W
Unit (mm)	56	48	6	15	12.5	29	5.5	3.6	1	44
Parameters	W1	W2	W3	W4	W5	W6	W7	W8	h	Wf
Unit (mm)	18	21.6	2	2	12	1	0.5	1.3	0.8	.1.76

III. RESULTS AND DISCUSSION

The proposed antenna for multiband applications has been studied using computer simulation technology microwave studio 2019. The simulated reflection coefficient (S11) is depicted from Figure 2. It can be observed that it has four frequency bands (S11 < -10 dB) are 1.55 -1.65 GHz (bandwidth of 100 MHz) for the global system positioning

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applications, 2.4 – 2.65 GHz for the IEEE 802.11 b &g WLAN Systems (bandwidth of 155 MHz) , 3 – 3.75 GHz for the WiMAX systems (bandwidth of 0.75 GHz) and 4.9 – 5.8 GHz for the IEEE standard 802.11a WLAN Systems.

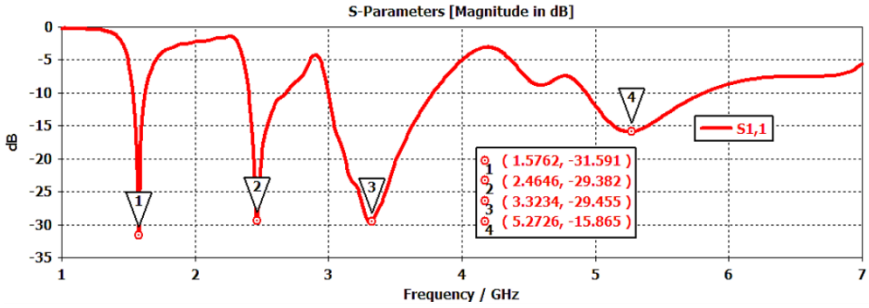

Figure 2. Reflection coefficient (S_{11}) of Multiband Antenna

Figure 3 depicts the VSWR of the proposed multiband antenna which is less than2 for the entire 4 frequency bands. At low frequencies, the ground plane of the antenna becomes electrically small and some currents will flow back from the antenna to the outer surface of the feeding cable. The simulated 2 dimensional and 3 dimensional radiation patterns of E plane and H-plane is shown in Figure 4 and Figure 6 at different frequencies 1.575, 2.5, 3.5 and 5.3 GHz.. It can be seen that the radiation pattern are quite omnidirectional and in other plane it shows the patterns have a “dumb –bell “shape. Figure 5 depicts the directivity of the proposed antenna indicates the directivity is more than 3.4 dBi in the four frequency bands. From the results observed it is suitable of Multiband applications due to better impedance matching.

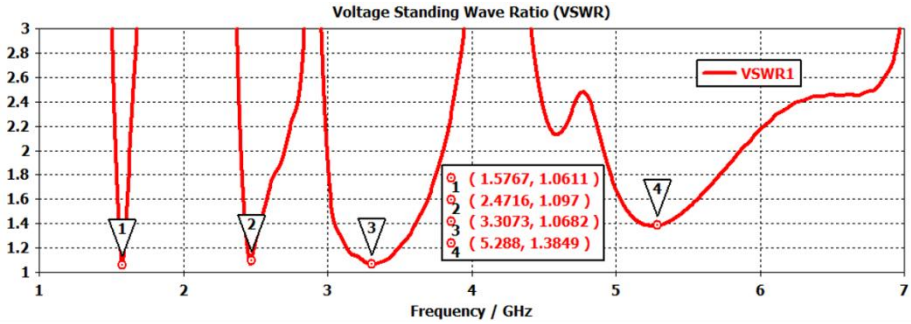

Figure 3. VSWR of the Proposed Multiband Antenna

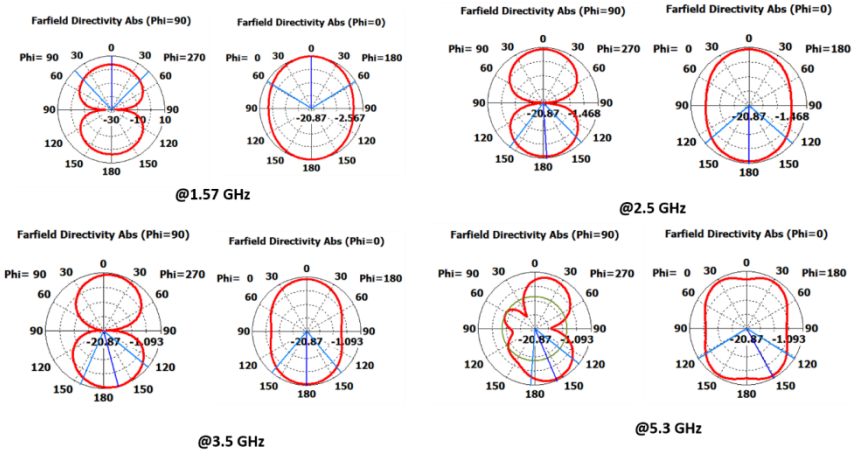

Figure 4. 2D Radiation Pattern of Proposed Multiband Antenna

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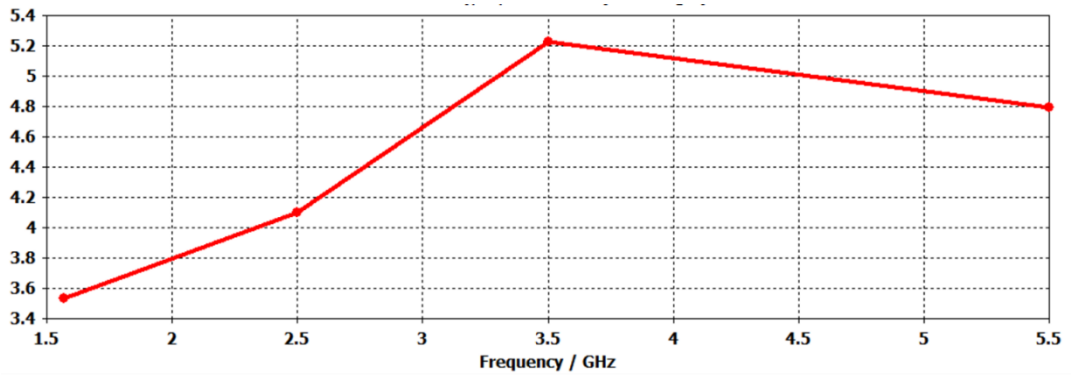

Figure 5. Directivity of the Proposed Multiband Antenna

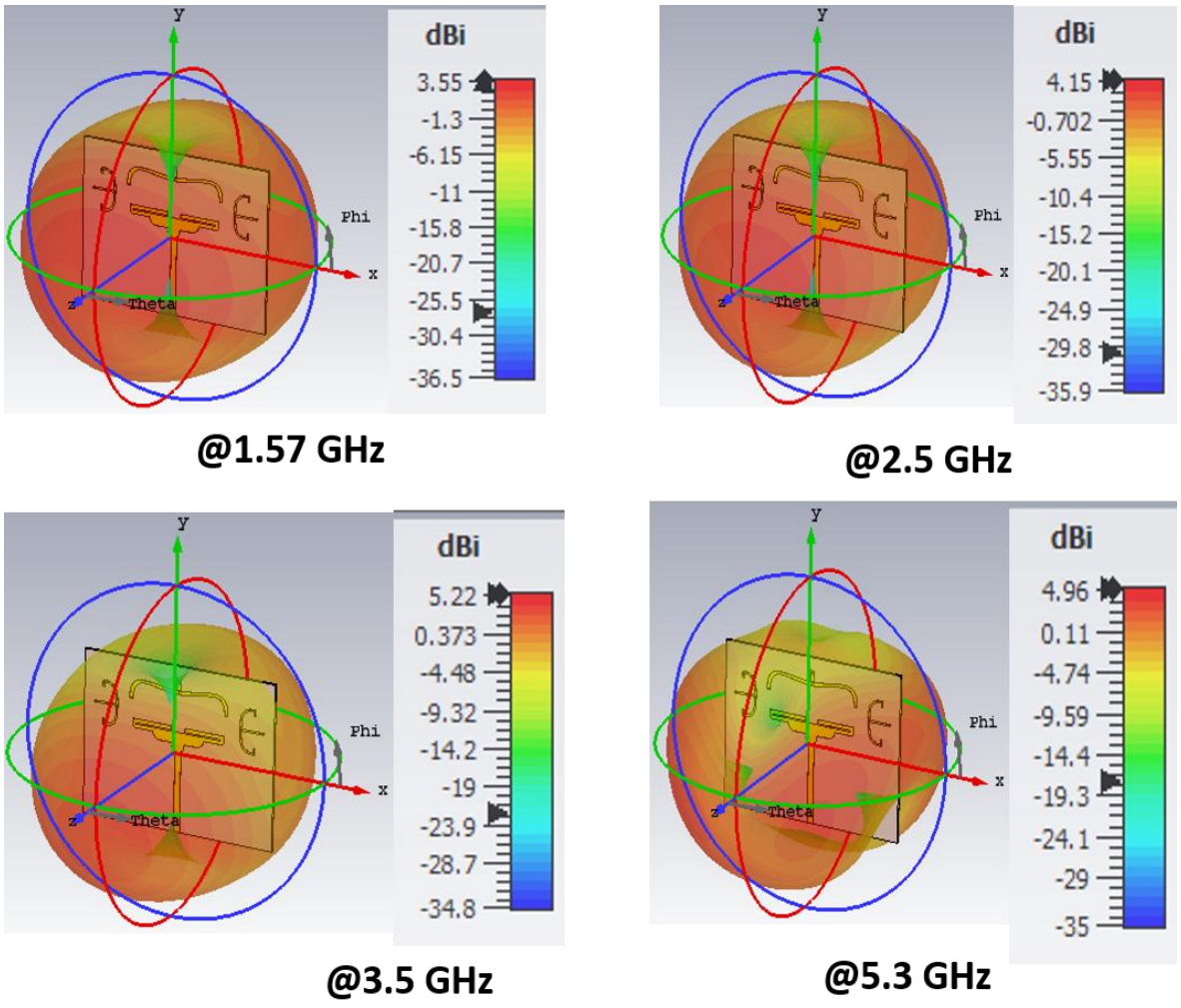

Figure 6. 3D Radiation pattern of proposed Multiband Antenna

IV. CONCLUSION

The design of a planar four-band slot antenna for GPS/WiMAX/WLAN has been presented. The antenna consists of a radiating slot loaded with a T-shaped feed patch, an inverted T -shaped stub, and two E-shaped stubs. Simulation and measurement have been used to study the performance, in terms of return loss, radiation pattern, realized peak gain, and

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efficiency, of the antenna. Results have shown that the antenna has four frequency bands at about 1.575, 2.5, 3.5, and 5.2 GHz, which can be used to cover the GPS, WLAN, and WiMAX systems.

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