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Multiband antenna for WLAN, WiMAX and future wireless applications

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Abstract

A novel multiband microstrip patch antenna suitable for WLAN and WiMAX applications is proposed in this paper. The antenna primarily comprises of a defected ground plane and an inverted, upright chair type patch. The antenna resonates at four frequencies, 3, 3.5, 4.1 and 5.3 GHz with bandwidths of 640, 420, 620 and 150 MHz respectively, which makes it suitable to use for WLAN, WiMAX, and other RF communications. The miniature size of 25×19×1.53 mm^3 gives this antenna a cut above the rest, which is available in larger sizes. To evaluate the performance of the proposed antenna, CST Microwave studio has been used. The return loss, gain, radiation pattern, the surface current has also been analyzed here.

1. Introduction

In the present era of wireless communication, where everyone is not only connected to one another through various means like the mobile network, internet, but also, gives a user power to remotely operate various businesses, handle various applications, from driving unmanned aerial vehicles, unmanned cars, smart homes/ offices. As the world would have noticed, how the ever-increasing demand for information has made the communication world take a grand leap, from the pre-industrial age, when communication was done over the line of sight, further replaced by the telegraph network system in the late eighteen hundred, followed by the radio transmission giving better quality with less power consumption, later advancing from the analog to digital [1,2]. Then came the 1G, used for long-range communication, using advanced mobile phone system technology, using frequencies around 800 MHz, followed by 2G, which further gave the facility of SMS with network ranges from 800 to 1900 MHz, followed by the 3G, in which wideband network was used, thus giving clarity in conversation, including the data services, access to the television and video calling etc., operating at a range of 2100 MHz, further came the 4G (fourth generation), which provided downloading speeds up to 100 Mbps in addition to above said 3G services. There is another wireless network, which has improved a significant name for themselves in the field of communication, i.e., the Wireless Local Area Network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) and are significantly been used in the mobile networks.

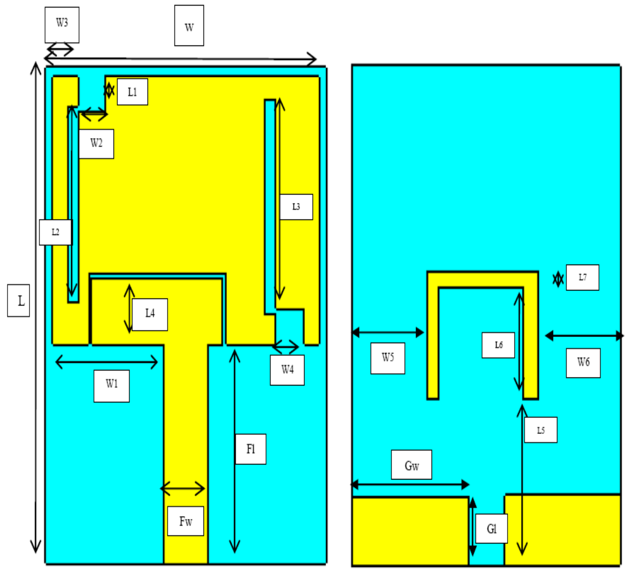


Fig. 1. Schematic configuration of the proposed antenna. (a) Top and (b) Bottom view.

The allocated frequency spectrum for WLAN systems is centered at 2.4GHz (2.4-2.484 GHz), 5.2 GHz (5.15-5.35 GHz), 5.8GHz (5.725-5.825 GHz). For WiMAX, there is no unified standard of frequency division around the Globe. The frequency spectrum for WiMAX is centered at 2.3 GHz (2.3-2.4 GHz), 2.5 GHz (2.5-2.69 GHz), 3.5 GHz (3.3-3.7 GHz), 5.8 GHz (5.725-5.85 GHz) [4].

In the field of RF, one of the most important things which makes the various communication protocols running in various applications is the antenna, which plays a vital role of transmitting the signal from one place to another. With the very fast development of wireless communication systems, WLAN and WiMAX technologies, the demand for a single antenna covering several wireless communication channels are growing high. Simple structure, multiple bands, compact size, and low-cost antennas are highly desired for such communication standards. There are many antennas designs on hand in the literature that are having very good performance. Though many of them have major drawbacks such as their bulky size, especially for portable devices. A number of microstrip antennas with different geometries have been realized to reduce the size and enhance the bandwidth for WLAN/WiMAX applications [2]– [12].

TABLE I: DIMENSIONS OF PROPOSED ANTENNA

Parameters	Size (mm)	Parameters	Size (mm)
L_1	1.8	W_3	0.7
L_2	9.6	W_4	1.9
L_3	10.6	W_5	5.3
L_4	3.4	W_6	6
L_5	8.3	F_w	3
L_6	5.6	F_1	11
L_7	0.8	G_w	8.2
W	19	G_1	3.4
W_1	7.5	L	25
W_2	1.8	h	1.53

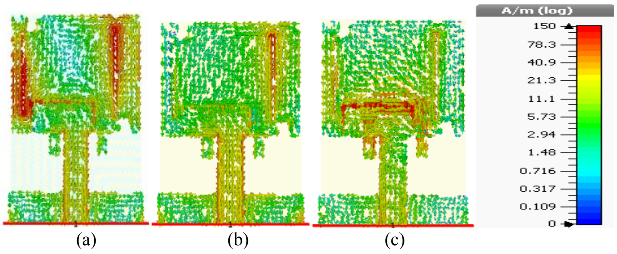


Fig .2. Surface current at various frequencies

In [2], an antenna is designed from the conventional patch antenna structure. In the radiating patch, double L-slots and a modified M-slot are etched which help in achieving the multi-band operation. In [3], patches are introduced in the radiating patch in the form of inverted H-letter. In [4], three arms radiating element with various arms lengths are used to create three different resonances. The three arms radiating element with different length excites three distinguishable resonances which are separate from each other in frequency. An asymmetric M-shaped patch is used to design a triple-band antenna in [5]. Inverted L-slot patch with a defected ground plane is used for triple-band operation in [6]. A monopole antenna with two rectangular corners cut off and two inverted-L slots are etched to achieve three resonant modes for tri-band operation is presented in [7].

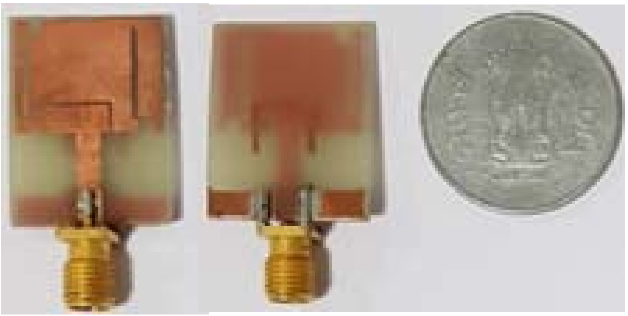
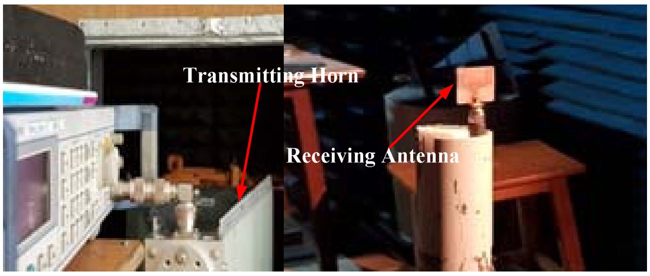
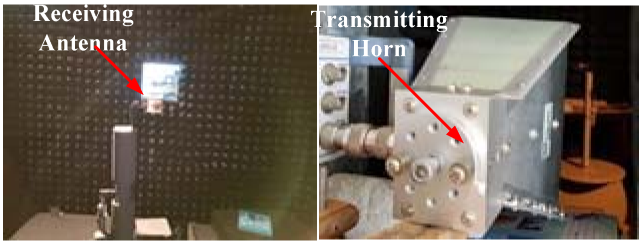


Fig .3. The fabrication prototype of proposed antenna top and bottom view.

Fig .4. Antenna under test using VNA



(a)



(b)

Fig. 5. E and H – field antenna set up in anechoic chamber

In this paper, a compact, upright chair-shaped planar antenna is proposed and designed for wireless communication systems that can support the multi-band WLAN/ WiMAX applications. The proposed antenna consists of two upright chairs like shaped slots of the same size that are etched on a rectangular patch to achieve multiband operation along with a defected ground plane with a ring-shaped slot in the center of the ground, to activate resonance at higher frequencies. In this design, the simulation results of proposed antenna show four distinct resonances with impedance bandwidths of 2.63-3.3 (670 MHz), 3.3-3.72 (415 MHz), 3.96-4.58 (600 MHz) and 5.29-5.43 GHz (150 MHz), respectively. The antenna configuration has a compact size of 19 × 25 mm^2. Since the chair-shaped slots are etched on the left and right sides of the radiator for multiband operation, the antenna is very compact in size and simple in structure. To validate the proposed design, an experimental prototype has been fabricated and tested. Details of antenna design and the simulated and measured results are presented and discussed in the following sections.

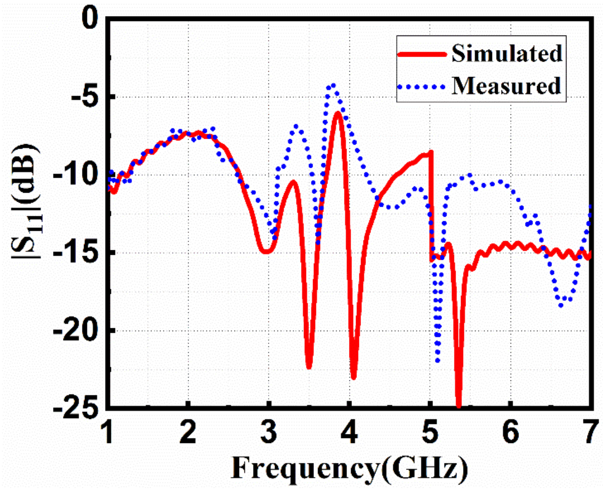


Fig. 6. Measured and simulated reflection coefficient

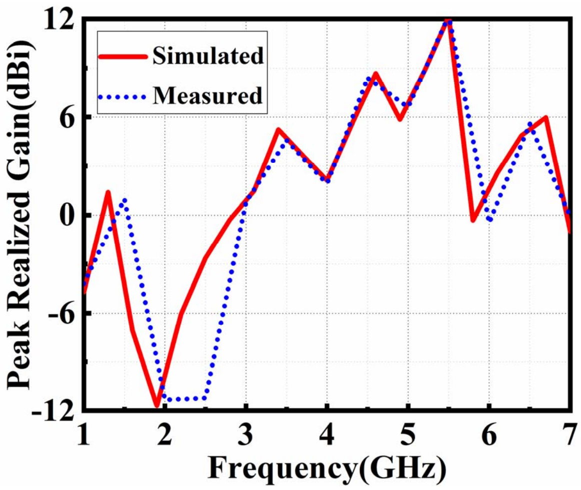


Fig .7. Measured and simulated peak realized gain

2.Antenna Configuration and Design Approach

Fig.1. shows the geometry and dimensions of the proposed multiband antenna for WLAN and WiMAX triple-band operation. The proposed antenna is fabricated on the FR4 dielectric substrate of the thickness of 1.53 mm, the relative permittivity of 4.4, and dielectric loss tangent of 0.02. The overall size of the proposed antenna is 19×25 mm^2. The antenna is composed of a rectangular-shaped radiator with two upright chair-shaped slots which are etched on the left and right side of the radiator. A defected ground plane, with a ring in the center of the ground on the backside of the dielectric substrate, is given to resonate at higher frequencies. Computer simulation technology (CST), microwave studio (MWS) is used to optimize parameters for triple- band operation of the proposed compact antenna, and the all dimensions are given in Table I.

3. Antenna Performance Analysis

The surface current distribution at various resonant frequencies, i.e. at 3.5, 4.1 and 5.3 GHz can be seen in figure 2. The first resonant frequency occurs at 3.5 GHz due to the surface current maximum at the right and left side of the radiating patch, at ends of the two slot arms, more towards the bottom left of the patch is shown in Fig 2. (a). Next resonant frequency, i.e., 4.1 GHz occurs due to surface current maximum at the center middle portion and the upper right side of the patch is shown in Fig 2. (b). Further, the next resonant frequency, at 5.3 GHz occurs due to the modified ground, ring-like structure below the substrate as seen in Fig. 2 (c).

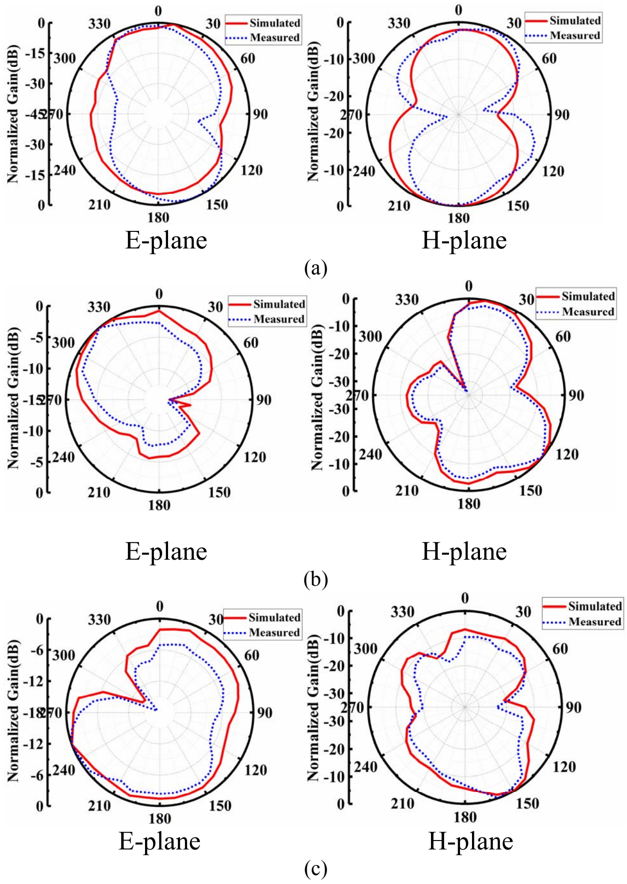


Fig.8. Simulated and measured normalized radiation pattern of proposed antenna at the frequencies of (a) 3.55, (b) 5.1 and (c) 6.68 GHz

4. Results and Discussion

The antenna as shown in fig. 3 (a and b) show the top and bottom view of the antenna been realized in the microwave lab as per the dimensions listed and described in Table I. Also, the antenna has been put under test in the microwave lab for validation of the simulated results. As seen in fig. 4, the antenna is connected to the vector network analyzer (VNA) for calculation of the return loss. For calculation of various parameters like return loss, the E and H-field radiation pattern, gain, the fabricated antenna was subjected to tests in the anechoic chamber as shown in fig. 5 (a and b respectively).

4.1 Reflection Coefficient

The simulated and measured return loss can be seen in fig 6. It is seen that the measured return loss almost matches the simulated return loss, with a shift in the measured return loss to a slightly higher frequency as compared to the simulated results. This shift in the simulated and measured results is due to the losses incurred due to the outer environment, the various interferences while in the making of the antenna and losses incurred while taking measurements in the lab. At four prominent places, a dip below -10 dB can be noticed at 3.1, 3.55, 5.1 and 6.68 GHz.

4.2 Peak Realized Gain

The measured and simulated gain of the proposed antenna as shown in fig 7. The both almost overlapped, and the result is in accordance with the simulated results. It can be seen that the gain of the antenna is almost above 3dBi for major required frequencies and meets our requirements. The simulation and measurement results slightly shifted, and it can be seen as in Table II below for the required resonant frequencies.

TABLE II: GAIN OF ANTENNA

Frequency (GHz) Simu. /Meas.	3/3.1	3.5/3.55	4.1/5.1	5.3/6.68
Gain(dBi) Simu. /Meas.	2/2.1	5.8/5.2	2.9/8.2	11.8/4.2

4.3 Normalized Radiation Pattern

Fig.8. (a) to (c) are showing both, measured and simulated E and H-field antenna normalized radiation pattern at various resonant frequencies. Fig. 8 (a) show the E and H- plane radiation pattern respectively at 3.55 GHz. Fig. 8 (b) show the E and H-plane radiation pattern respectively at 5.1 GHz and fig. 8 (c) show the E and H-plane radiation pattern respectively at 6.68 GHz. The measured results are good agreement with simulation results and same is verified from Fig. 8 (a), (b) and (c)

5. Conclusion

Due to the number of wireless users increasing day by day, the wireless network has spread to such an extent, that the spectrum has become congested and overloaded and thus there is a shortage of the spectrum. Future communication networks such as 5G and beyond will most likely use millimeter wave frequencies. Thus, we need antenna systems, which are not only able to access the internet with fast speed but also can deal with wireless communication below and above 6 GHz. In this paper, various methods have been projected to achieve multiband characteristics of UWB (Ultra Wide Band) microstrip antenna. The antennas proposed in this paper are specially designed for multi-band applications. The antenna is of compact size so that it can be easily integrated with or mounted onto miniature devices. The simulation of the antennas is performed in CST micro studio software. Finally, the experimental results and the simulated results are verified. The designed antennas can be used in various applications like WLAN, WiMAX and microwave applications covering from 1 to 6 GHz frequency range.

6. References

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