Indonesian Journal of Electrical Engineering and Computer Science
Vol. 1, No. 2, February 2016, pp. 365 ~ 370
DOI: 10.11591/ijeecs.v1.i2.pp365-370

Inset Feed Toppled H-Shaped Microstrip Patch Antenna for PCS/WiMAX Application

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Abstract

In this paper, an inset feed toppled H-shaped microstrip patch antenna with grounded plane is investigated for triple band operation. The simulation of proposed antenna geometry has been performed using IE3D simulation software based on method of moment. The prototype of the proposed antenna has been fabricated and tested to validate the simulation work. The measured results indicate that the reflection coefficient is better than -10dB for 1.8 GHz (PCS), 3.5 GHz (WiMAX), and 5.5 GHz (WiMAX) frequencies.

***Keywords**: Inset feed, Toppled, Personal communication Systems, Multiband*

1. Introduction

With the blooming of recent communication systems, microstrip patch antennas (MSAs) gained utmost attention of antenna developers because of its striking features such as low cost, easy integration, easy fabrication, light weight and omni directional radiation pattern. These antennas are in massive demand due to its applications in several fields such as personal communication systems (PCS), and worldwide interoperability for microwave access (WiMAX) etc. [1-3]. MSAs become more admired when a single antenna can be used to operate the signals for dual and triple frequency bands. These remarkable features of antennas persuade the researchers to design MSAs for multiband operation so that a single MSA can be used for multiple frequency bands.

Numerous literatures are presented on the design of MSA for dual and triple frequency bands [4-12]. Subsequently, plethoras of multiband MSAs have been reported [13-26] due to recent advancement in these antennas. In [15], a review has been reported for dual and multiband designs of MSAs. In [16-17], stacked and fractal patch antennas were proposed and they obtained triple band for application of cellular phone, GPS, satellite communication. Two integrated patch antennas was investigated in [18] with resonating frequencies 2.45 GHz (WLAN), 3.5 GHz (WiMAX) and 5.5 GHz (WiMAX) applications using glass epoxy substrate. Few other techniques such as using metamaterial [19], defected ground plane [20], parasitic elements [21], and varacter diodes [22] were implemented on the design of MSAs for achieving multi band frequencies for different valuable applications. Thereafter a crescent-shaped was reported by See et al. [23] and they achieved multiband response of proposed antenna geometry for mobile wireless applications. A triple band solar cell stacked MSA loaded with multiple L-slot was reported by Yurduseven et al [24] and this antenna was resonating at frequencies 2.5/3.3/5.8 GHz. Further few more patch antennas based on single feed stacked patch antenna [25], and C-slot patch antenna [26] were reported. Most of the above reported patch antennas operate in dual and triple band frequency operation and lack better efficiency and frequency ratio. This work is highly motivated from the above reported literature and devoted to design a triple band patch antenna for PCS and WiMAX applications so that a single antenna can operate for multiband frequencies with better efficiency and frequency ratio.

In this paper, an inset feed toppled H-shaped microstrip patch antenna with grounded plane is proposed for triple bands frequencies. The proposed antenna operates at 1.8, 3.5, and

Received October 4, 2015; Revised January 11, 2016; Accepted January 29, 2016

5.5 GHz frequencies. The novelty of this work is that, we have achieved triple frequency bands with sufficient bandwidth without using any, thick substrate such as foam, shorting pin, stacked patch or without modification in the feed. The proposed antenna is designed with thin inexpensive, low dielectric constant FR4 substrate.

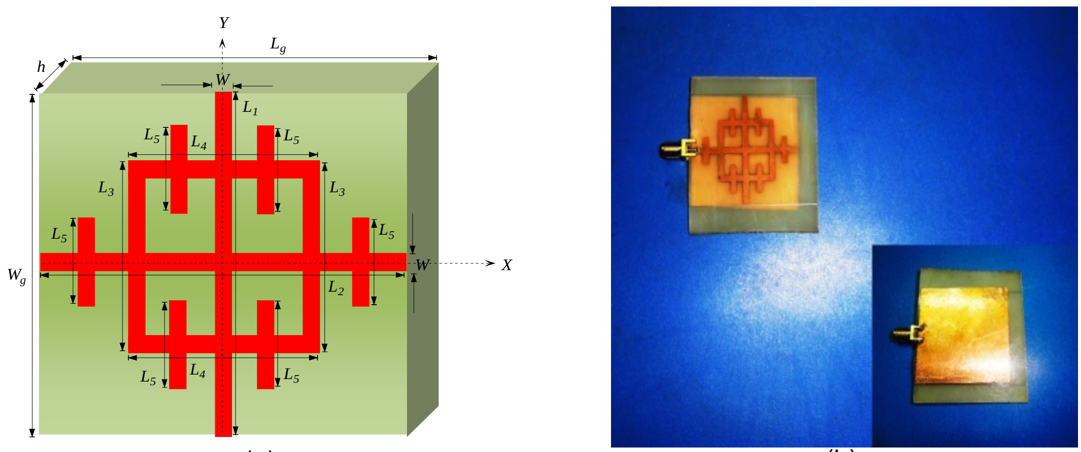
This paper is organized as follows; Section 2 deals with design of proposed antenna geometry and its fabrication. Section 3 holds the result and discussion; and finally Section 4 puts the conclusion of entire study.

2. Antenna Design

This section shows the geometry formation process of proposed antenna. The proposed antenna of dimension L_g×W_g is designed on FR4 substrate with dielectric constant ε_r= 4.4 and height h = 1.60 mm as shown in Figure 1(a). For the formation of proposed antenna geometry, firstly two strips of dimensions L_1×W and L_2×W are etched on the upper side of the rectangular patch at coordinate (0, 0). Further, two vertical strips of dimension L_3×W and two horizontal strips of dimension L_4×W are etched at the coordinate (+10, 0), (-10, 0) and (0, +10), (0, -10) respectively. In the next step, six vertical strips of dimension L_5×W are etched at coordinates (5, 10), (-5, 10), (5, -10), (-5, -10), (15, 0) and (-15, 0) respectively on the upper side of the patch. Although the lower portion of the patch is fully grounded and covers dimensions of L_g×W_g, the microstrip line feed is used for the excitation of the proposed antenna. The necessary numerical analysis and suitable geometrical parameters of the proposed antenna are obtained with the aid of the electromagnetic simulation software IE3D, and the best design parameters are revealed in Table 1. The fabricated design of proposed antenna is shown in Figure 1(b).

Table 1. Design specifications

Parameter	Value	Parameter	Value
L_g	40 mm	L_5	10 mm
W_g	40 mm	W	2 mm
L_1	40 mm	h	1.60 mm
L_2	40 mm	ε_r	4.4
L_3	20 mm	$tan\partial$	0.002
L_4	20 mm		



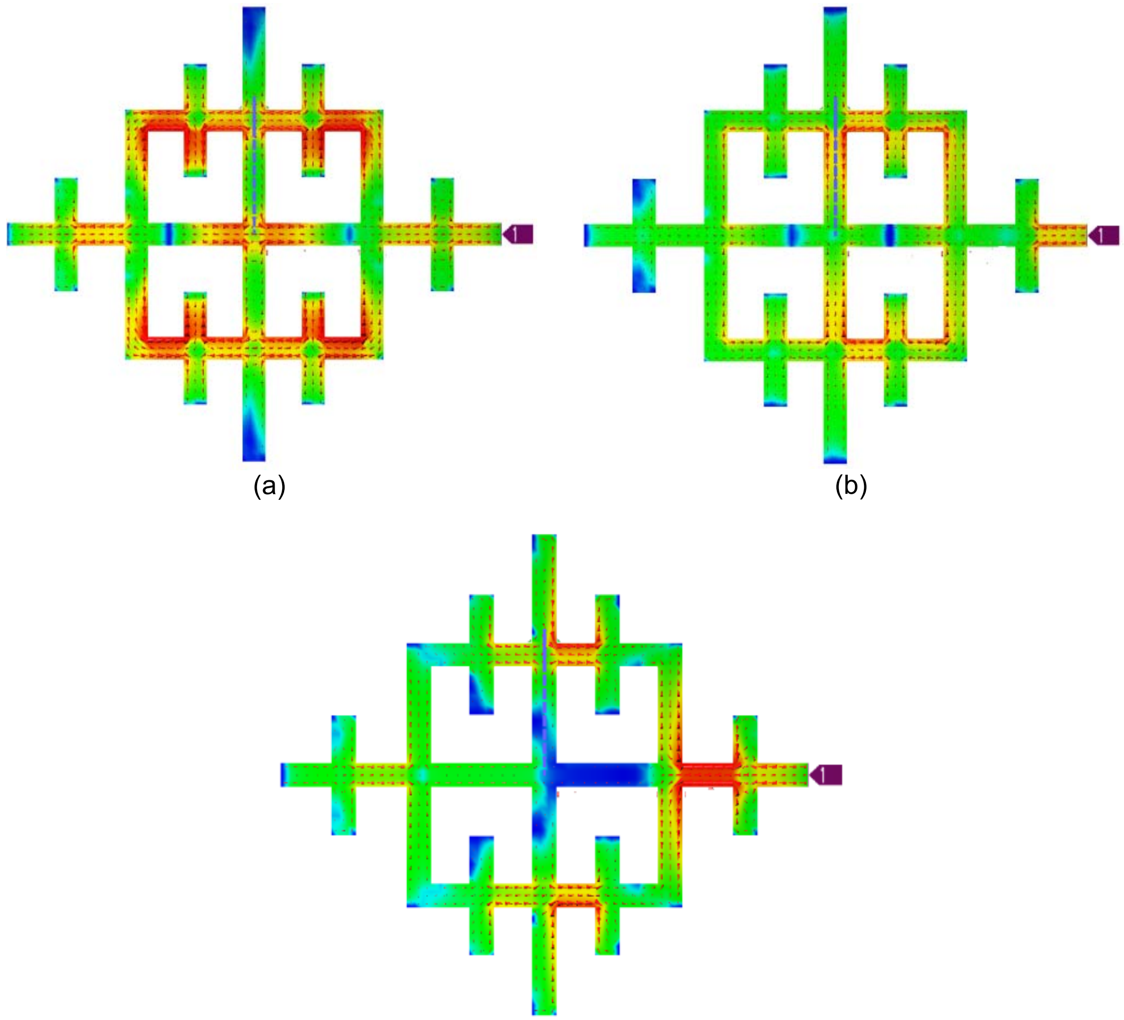
(a) (b)

Figure 1. (a) Inset feed toppled H-shaped microstrip patch antenna structure; (b) Fabricated inset feed toppled H-shaped microstrip patch antenna

3. Results and Discussion

For triple band operation, the proposed antenna is fed by inset feeding. The simulation of proposed antenna has been performed using method of moment based IE3D simulation software [27]. The proposed antenna design has been fabricated for the validation of simulation work. An SMA connector of 50 ohm impedance is connected for the excitation of the proposed antenna geometry. The reflection coefficient of proposed antenna has been measured using N5230 network analyzer. The detail information about designed antenna characteristics are discussed in this section.

The current distribution of the proposed antenna is shown in Figures 2(a)-(b) and (c) at frequencies 1.8 GHz, 3.5 GHz, and 5.5 GHz respectively. From these Figures, it is observed that a good amount of current with different length appears on the patch of the proposed geometry. This different length of currents is responsible for generating triple band resonance frequencies. The current flowing in three directions on the patch due to which antenna characteristics improves in good radiation mode.



(a) (b)

(c)

Figure 2. Simulated current distribution at (a) 1.8 GHz (b) 3.5 GHz (c) 5.5 GHz

Figure 3 shows the variation of reflection coefficient for different dielectric materials. It is observed that with decreasing the value of dielectric substrate from FR4 to foam, the resonant frequencies are shifted towards higher resonance side and the value of reflection coefficients increases. This happens because the dielectric constant of the substrate is directly proportional to the resonant frequency of patch antenna.

Figure 4 shows the variation in reflection coefficient for different heights of the material. It reveals that, with decreasing the height from h=1.60 mm to h=0.13 mm, second, and third band are shifted toward the higher resonance side whereas first band is shifted towards lower resonance side.

Figure 5 shows the comparison of simulated and measured reflection coefficients at various frequencies. It is observed that the proposed antenna operates in triple frequency bands at 1.8 GHz (1.743 GHz – 1.857 GHz), 3.5 GHz (3.294 GHz – 3.7 GHz), and 5.5 GHz (5.205 GHz – 5.94 GHz) and this happens because the adding of ground plane on proposed antenna, a coupling capacitance is generated between the upper patch and ground plane since radiating structure improves. These operating frequency bands meet the demands for PCS and WiMAX applications. From this figure it also reveals that the simulated and measured reflection coefficients ($S_{11} \leq$ -10 dB) of proposed antenna are in good agreement, only minor discrepancy occurs because of the irregular fabrication and soldering joint losses which was not included during simulation.

Figure 6 shows the plot for measured gain and efficiency of proposed antenna at various frequencies. The gain of the proposed antenna at operating frequencies 1.8, 3.5, and 5.5 GHz are found 4.44, 6.15, and 6.57 dBi respectively. The efficiency of proposed antenna is found 69.53%, 95%, and 88.15% at resonating frequencies 1.8, 3.5, and 5.5 GHz respectively.

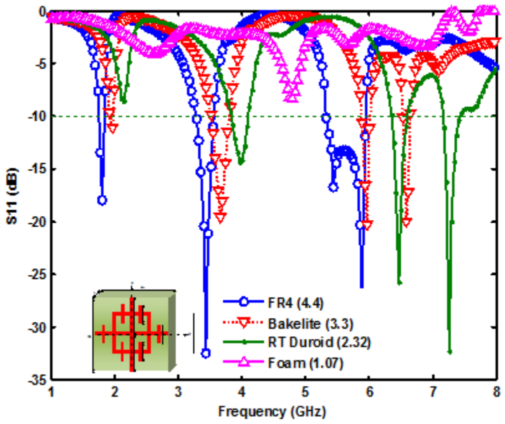


Figure 3. Reflection coefficient variation for several dielectric materials

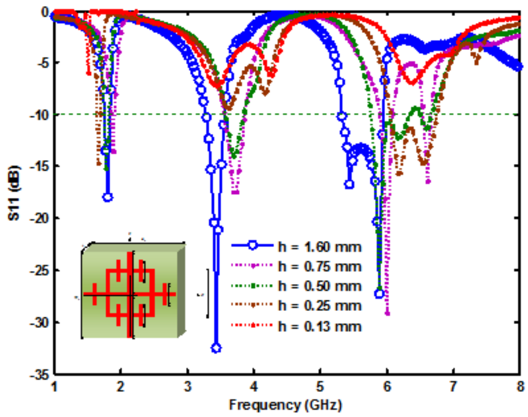


Figure 4. Reflection coefficient variation for several heights of dielectric material

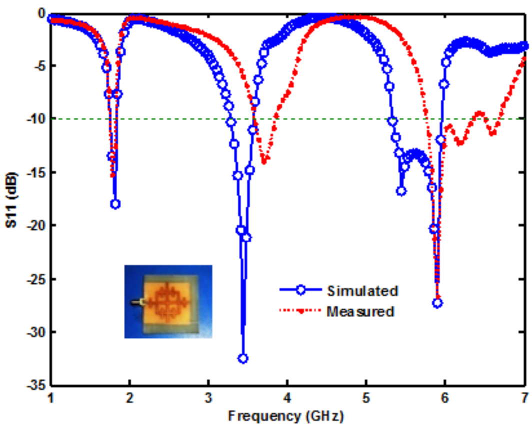


Figure 5. Comparison ofsimulated and measuredreflection coefficient variation at various frequencies

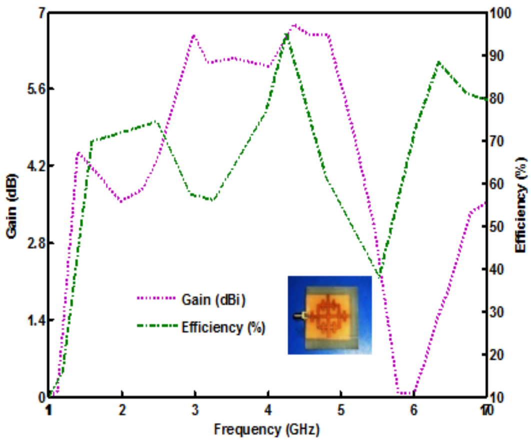


Figure 6. Measured gain and efficiency of proposed antenna at various frequencies

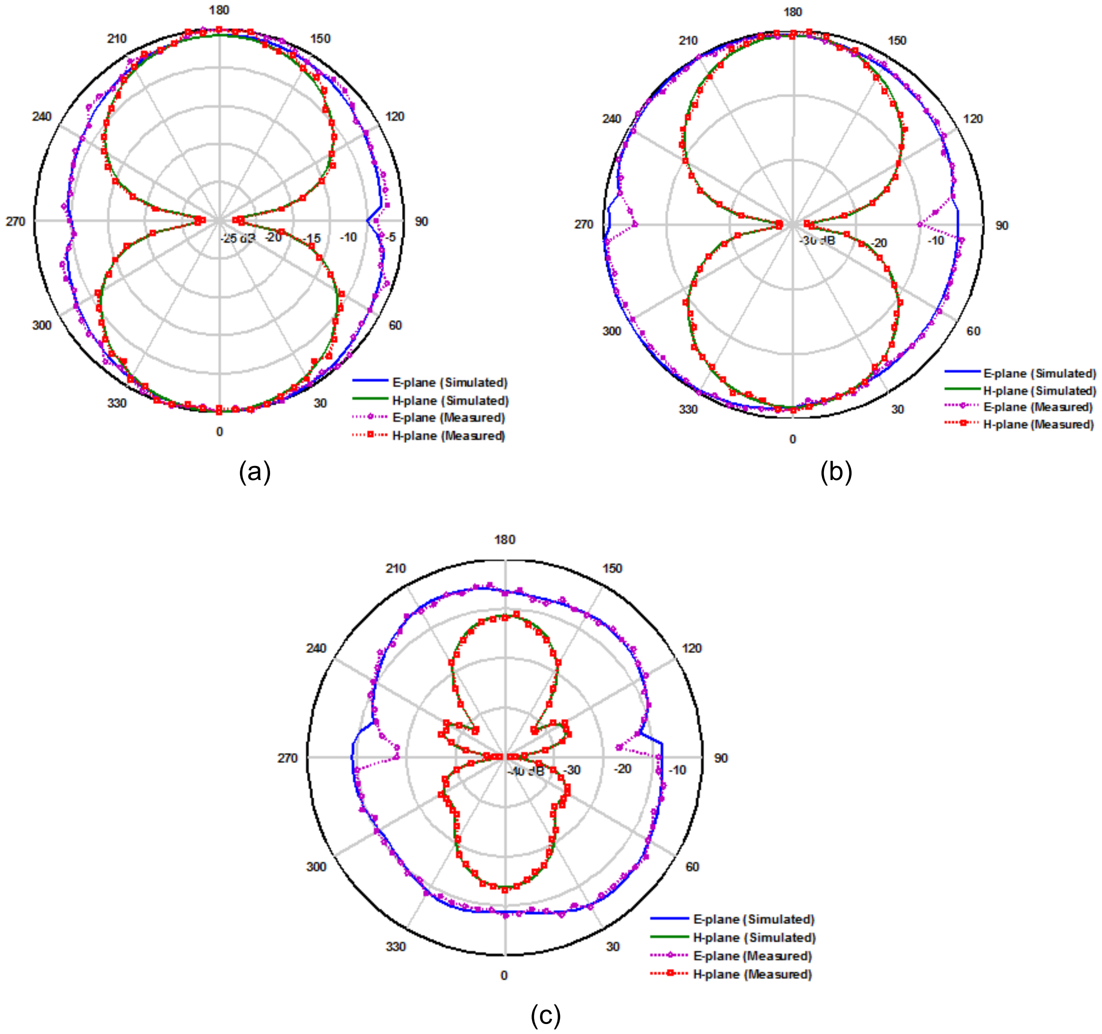


Figure 7. Comparative plot for radiation pattern at frequencies (a) 1.8 GHz (b) 3.5 GHz (c) 5.5 GHz

Radiation pattern of proposed antenna is shown in Figure 7 (a)-(b) and (c). It shows the comparative plot for *E-H* plane radiation pattern of proposed antenna at frequencies 1.8, 3.5, and 5.5 GHz respectively. From these figures, it is observed that the proposed antenna is radiating maximum power in broadside direction within the operating bands. The 3 dB beamwidth of proposed antenna are calculated as 58˚, 58.3˚, 52.7˚ for *E*-plane ($E\text{-}\theta, \varphi=0^{\circ}$) and 48˚, 49˚, 45˚ for *H*-plane ($E\text{-}\theta, \varphi=90^{\circ}$) at frequencies 1.8, 3.5, and 5.5 GHz respectively. It means that, at 1.8, 3.5, and 5.5 GHz, antenna radiates most of the power at these specified beamwidths.

4. Conclusion

An inset feed toppled H-shaped microstrip patch antenna have been presented. The proposed antenna has three different resonant frequencies which offer at 1.8/3.5/5.5 GHz for triple band operation with the center frequency ratios of F_{c2}/F_{c1}=1.94, and F_{c3}/F_{c2}=1.57 which provides less interference with other coexisting application bands. The proposed antenna is expected to be a good candidate for PCS/WiMAX applications due to its higher gain, better efficiency, and good radiation characteristics.

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