Design of Multiband/Wideband E-shaped Microstrip Patch Antenna for Modern Wireless Communications Systems

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Abstract- A simple E-shaped microstrip patch antenna model for multiband/wideband operation is proposed to be used in modern wireless communications. The antenna is fed by a microstrip line. By modifying the antenna parameters, the proposed antenna provides three operating bands covering all the desired operation intervals for WLAN/ WiMAX devices. Also the model can be developed to increase the bandwidth of a rectangular microstrip patch antenna. Extensive simulation are done using WIPL-D software package and results of the return loss, VSWR and radiation pattern of the proposed antennas are presented. The WIPL-D software package is based on method of moment solution and the obtained results show the capability of WIPL-D package in designing microstrip patch antennas.

Keywords: Microstrip Patch Antenna (MPA), E-Shaped, WLAN/WiMAX Operation.

1. Introduction

The microstrip patch antennas are widely used in modern wireless communication systems and airborne applications due to their compact size, ease of fabrication, conformal properties, light weight, precise reproduction through photolithographic techniques, and low cost. Therefore they are preferred and have great potential for usage in the aforementioned type of applications [1, 2]. The inherently narrow impedance bandwidth is the major disadvantage of microstrip antennas for applications in wireless communications. Moreover in many of these mentioned applications, quite a number of systems require multi-frequency operation. So, the enhancement of the bandwidth and the achievement of multi-frequency operation ability caused considerable research activity for the antenna designer and many techniques have been investigated in past decades for this purpose [2-6].

Internal wireless local area network (WLAN) antennas operating in the 2.4/5.2/5.8 GHz bands have become a standard embedded element in the laptop computers for wireless internet access. The IEEE 802.16 working group has established WiMAX (worldwide interoperability for microwave access) standard which can cover a much wider range than the WLAN system does, which is limited to be about 100 meters. The covering range of WiMAX is the bands (2500–2700/3300–3800/5250–5850 MHz)[3,7]. WIMAX theoretically can have coverage up to 50 km radius [8]. In this paper considering the WLAN/WiMAX operation range, we present a simple E-shaped MPA. The antenna parameters have been investigated and parameters giving the best possible width and length of the slots are searched in order to achieve best antenna performance. The simulation results obtained at the end of this extensive search is reported in this study and these results show that the E-shaped microstrip patch antennas can be used in WLAN/WiMAX range. In order to obtain results, WIPL-D software package is used.

2. Multiband Antenna Design and Modeling

The proposed MPA geometry is shown in Figure 1. The patch size is characterized by patch width W_2 and patch length L_2, and it is fed by a microstrip line, that is connected to the microstrip and has a width W_1 and length L_3. Two parallel slots with slot width W_3 and slot length L_1 are inserted into this patch and placed symmetrically with respect to the microstrip line feed point. The parameter W_4 in this model identified as $W_4=(W_2\text{-}2W_3\text{-}W_1)/2$. Due to the shape structure of the patch the geometry resembles the letter "E,", and is called E-shaped MPA. The slot length L_1 and width W_3 are important parameters in adjusting resonant frequencies and controlling the bandwidth of the E-shaped MPA. The model has a finite substrate and it is over finite ground plane. The dielectric material selected for this design is a 60 mil RO4003 substrate from Rogers-Corp with dielectric constant of 3.4 and loss tangent of 0.002. WIPL-D Model of E-shaped MPA is shown in Fig. 2.

We analyzed E-shaped MPA using WIPL-D software package [9]. The electromagnetic computation application WIPL-D (Wires, Plates, and Dielectrics) is a commercially available analysis tool based on the method of moment (MoM), which is faster and more accurate method for electromagnetic computat-ion than other existing methods. Its most outstanding advantage is reducing the computation time [9-11]. For each simulation 21 different data points are considered.

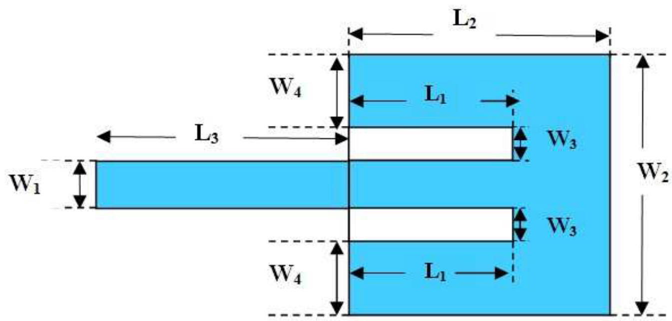


Fig. 1. The geometry of E-shaped MPA.

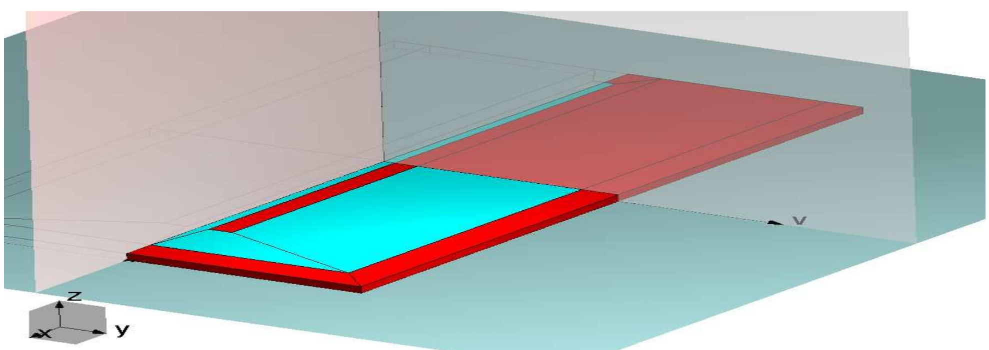
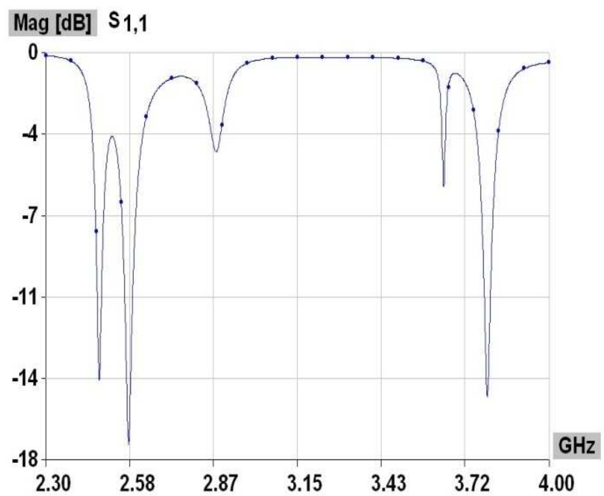


Fig. 2. WIPL-D Model of E-shaped MPA.

3. Multiband Antenna Simulation Results

The simulation process started with the MPA model shown in Fig 2. The dimensions of the MPA model are W_2 = 67.1 *mm* and length L_2 = 63.1 *mm*. A microstrip line feed is connected to the microstrip and has a width W_1 and length L_3 with W_1 =2.75 *mm*, W_3=2.75 *mm*, L_1 =50 *mm*, L_3 = 49 *mm*, ε_r = 3.4, h_{sub}=1.524*mm* and $W_4=(W_2\text{-}2\ W_3\text{-}\ W_1)/2$. The resonances of the antenna occur at three different frequencies 2.4GHz, 2.58GHz and 3.79GHz. The first and second cover 2.4 GHz WLAN and 2.5 GHz WiMAX operation range, respectively. The third one covers 3.8 GHz WiMAX operation range. All these are in the expected range and seem to be suitable for the envisaged applications, as can be followed in Fig.3.

The proposed antenna structure can be easily constructed on any other band by choosing the appropriate width and length of the slots. For example we proposed the second MPA with dimension of W_1 =2.99 *mm*, W_2=50.25*mm*, W_3=3.95*mm*, L_1 =35.75 *mm*, L_2 = 45 *mm*, L_3 = 42.51 *mm*, W4= $(W_2-2W_3-W_1)/2$ and ε_r = 3.4 and h_{sub}=1.524*mm.* Fig.4 shows simulated return loss for the second proposed MPA. The resonances of the antenna occur at three different frequencies 3.7GHz, 4GHz and5.3GHz. Finally the third MPA with dimension of W_1 =2.75 *mm*, W2=60*mm*, W_3=1.99 *mm*, L_1 =24.9 *mm*, L_2 = 50 *mm*, W_4= $(W_2-2W_3-W_1)/2$, L_3 = 20.01 *mm* , ε_r = 3.4 and h_{sub}=1.524*mm* is presented. Fig. 5 shows simulated return loss for the third proposed MPA with resonances 2.7GHz, 3.2/3.5GHz and 5.3GHz. The all bands satisfied the bandwidth of the WiMAX technology. All the impedance matching of the frequencies over the operating bands is better than 10-dB return loss, which result is in good agreement with U-slots patch antenna reported in [7].



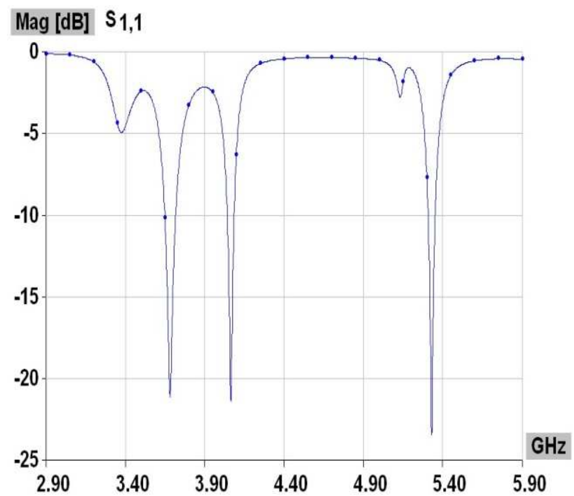


Fig 3. Magnitude of S_{11} of the first proposed MPA   Fig 4. Magnitude of S_{11} of the second proposed MPA

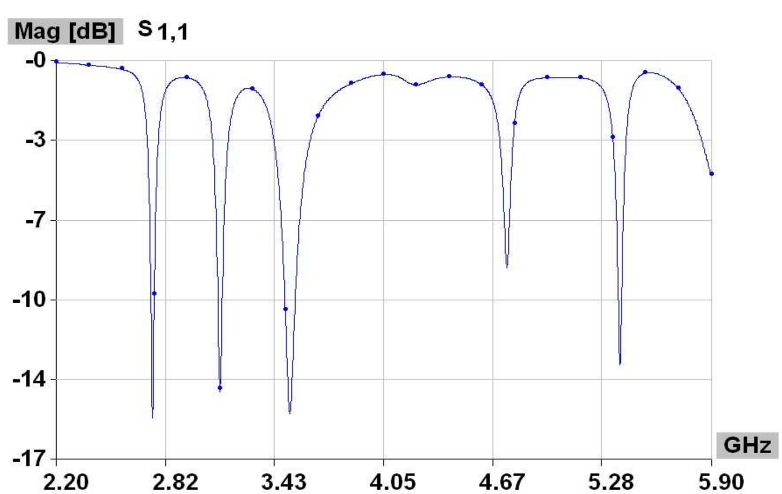


Fig. 5. Magnitude of S_{11} of the third proposed MPA.

4. Wideband Antenna Simulation Results

In order to investigate, the wideband application of patch antenna, it is implemented on microwave substrate (ε_r= 3.4, h = 1.524 mm, tan σ = 0.002) and suspended above the ground plane using a foam substrate (ε_r= 1, h = 5.5 mm, tan σ = 0.0002) [12]. The E-shaped microstrip patch antenna model is reconsidered for this application with following dimensions: W_2 = 40 *mm* and length L_2 =30 *mm*. A microstrip line feed which has a width W_1 and length L_3, with following parameter values: W_1 =5 *mm*, W_3=5 *mm*, L_1 =25 *mm*, L_3 = 19.75 *mm*, $h=h_{sub}+h_{foam}$, h_{sub}= 1.524, $\varepsilon_{r\ sub}$= 3.4, h_{foam}=5.5 *mm*, $\varepsilon_{r\ foam} \approx 1$, $W_4=(W_2-2W_3-W_1)/2$ is connected to the microstrip and the return loss of this MPA is given in Fig.6. The simulation results of E-shaped MPA for a VSWR (voltage standing wave ratio) is shown in Fig.7, and as it can be followed from the figure it has a VSWR= 1.009 at the resonant frequency f = 5.232 GHz. This antenna is applicable at modern wireless communication frequencies of 4.352 to 5.510 GHz. The impedance bandwidth, defined from a 10-dB return loss, is 1158 MHz or about 24.8% with respect to the center frequency at 4.931 MHz. This center frequency corresponds to the average of the lower and higher frequencies with a 10-dB return loss. The radiation characteristics for this antenna are shown in Fig. 8 illustrating 7.69 dB gain at 5.232 GHz.

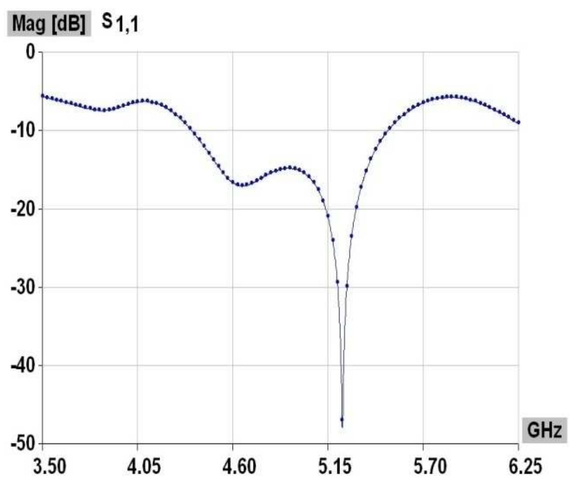


Fig. 6. Magnitude of S_{11} of the fourth proposed MPA.

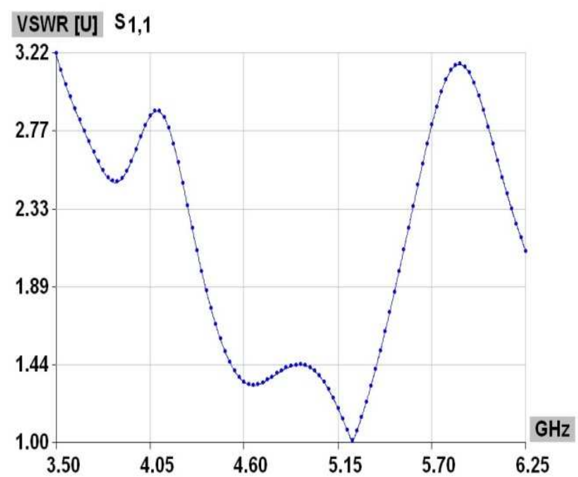


Fig. 7. VSWR of the fourth proposed MPA.

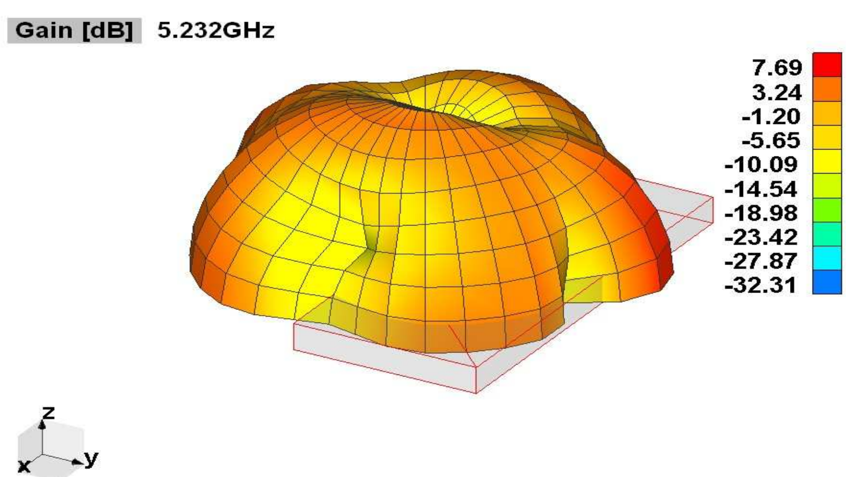


Fig. 8. Radiation pattern of the fourth proposed MPA.

5. Conclusions

In this paper a simple multiband/wideband E-shaped MPA model is designed for possible use in modern wireless communications systems. This structure is easily constructed on WLAN/ WiMAX bands by choosing the appropriate width and length of the slots. Also the multiband/wideband characteristic of microstrip patch antenna with E-shaped has been illustrated. The simulation results show that the bandwidth of microstrip patch antenna increased significantly and well enhanced from narrow band to wideband. Good radiation characteristics and return loss for frequencies over the operating bands have been achieved. With the achieved results, the proposed E-shaped MPA is adequate for practical WLAN/WiMAX operations in the wireless devices.

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