A Modified E-Shaped Microstrip Antenna for Ultra Wideband and ISM band applications

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Summary
In this paper, the analysis of a modified E-shaped patch antenna is presented. The purpose of the modification over the original E-shaped structure is to accommodate the operating frequency band and signal bandwidth requirements of the Ultra Wideband (UWB) wireless system. Simulation results show that the modified E-shaped has fulfilled the frequency band and signal bandwidth requirements of the UWB system. A resonance frequency of 3.5 GHz and signal bandwidth of 29.3% is achieved for the presented structure. The radiation pattern for these antennas is almost omnidirectional. For the applications of ISM (industrial, scientific, and medical) band where directive antennas are needed, multi-reflectors are used with the E-shaped antenna. The analysis of the proposed antenna has been done using the Finite Difference Time Domain (FDTD) with Perfect Matched layer (PML) approach in addition to numerical package based on the method of moment (MOM). Results have been compared with published data and good agreements are found.

Key words:
Antenna, Microstrip, Bluetooth, WLAN, HIPERLAN, FDTD, PML, radiation pattern, ISM.

1. Introduction

Recently, the Federal Communication Commission (FCC) has allocated 7.5 GHz of spectrum for unlicensed use of the Ultra Wideband devices in the 3.1 to 10.6 GHz frequency band. The FCC defined the UWB as any signal that occupies more that 500 MHz bandwidth in the 3.1 to 10.6 GHz. An EIRP emission level has to be less than -40 dBm in the entire band [1]. UWB is expected to be the solution for the IEEE 802.15.3a (TG3a) standard. The standard specifications are low cost, low power consumption, low complexity, and high data rate wireless connectivity for devices in a personal operating area. The targeted bit rate is expected to be higher than 110 Mb/s and the desired range is 30 ft.
Several techniques have been presented for extending the bandwidth. The conventional method for increasing the bandwidth is obtained by using a parasitic patches. These patches may be in the same plane or aperture-coupled with the main patch [2,3]. In [4], the authors presented a U-shaped patch antenna while in [5], an E-shaped patch antenna is presented. For the suppression of the back lobes of the radiation pattern to gat a directive antenna for the application of the ISM band, multi-reflectors are used [7].
In this paper, we present a new modified E-shaped patch antenna for UWB and ISM bands wireless communication systems. The analysis is carried out using the finite difference time domain (FDTD) method [7,8]. The perfect matched layer (PML) is used to terminate the unbounded structure [9,10]. The obtained results are verified by using of a numerical package based on the MOM. The obtained results are compared with the available published data and good agreements are found.

2. Basic Formulations

2.1 Antenna Geometry

In the present work, two different structures are studied. The first one is the conventional E-shaped antenna geometry shown in Fig. 1. While the second one is the modified E-shaped patch antenna shown in Fig. 2. For the two cases, the dimensions of the patch are given by (L,W,h) as shown in Fig.1. The patch is fed by a coaxial probe at the position (x_f , y_f). The parallel slots are taken of width Ws. The values of these dimensions are taken as: L=70 mm, W=50 mm, h=15mm, x_f =35 mm,Ws=6 mm, Ls=40 mm, and Ps=10mm. The y_f is taken of different values to avoid the middle slot in the modified E-shaped.

2.2 Finite Difference Time Domain (FDTD) and Perfect Matched Layer (PML)

One can use the FDTD to discretize the differential equations of Maxwell. This is carried out by using of a central difference approximation in both time and space first-order partial differentiations. One can arrange the spatial nodal points where the different components of E and H are to be determined. This leads to the discretized the differential equations of Maxwell for homogeneous regions as given in [7-8]. To ensure that the numerical error generated in one calculation step does not

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accumulate and grow, the stability criterion of Yee's algorithm is applied [7],

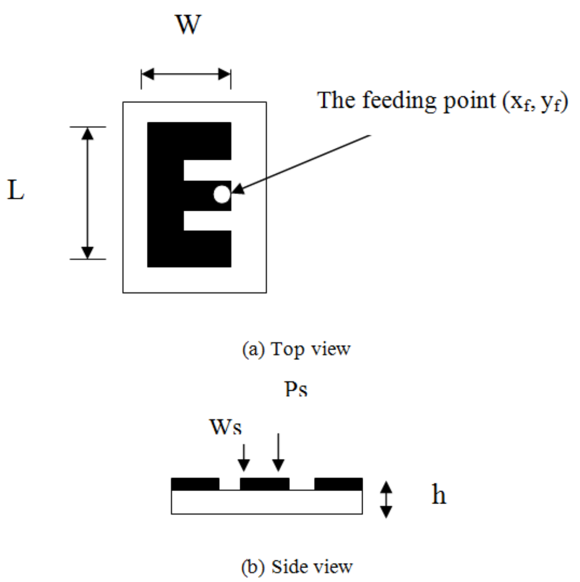

Fig. 1. The E-shaped patch antenna

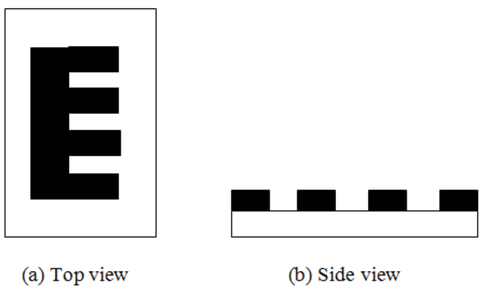

Fig. 2. The Modified E-shaped patch antenna

The PML is a nonphysical absorber adjacent to the outer boundary of the open structure computational domain. The PML ensures that a plane wave incident at any arbitrary angle or frequency from the free-space upon a PML region is totally transmitted into PLM region with a negligible reflections toward the inner structure [9-10]; i.e. total absorption for the outgoing waves. This is carried out by introducing an additional degree of freedom by splitting the field components with anisotropic material properties in the PML region [10].

3. Numerical Results and Discussions

As mentioned in section II, two structures are studied which are the conventional and modified E-shaped antennas, shown in Fig. 1, and Fig.2, respectively. The finite difference time domain (FDTD) With PML is used for the analysis of the proposed structures.

Fig. 3 shows the current distribution for the E-shaped antenna given in Fig. 1. This current are computed at the two resonance frequency which are 1.8 GHz and 2.4 GHz. The corresponding return loss of this antenna is given in Fig. 4. The obtained results are compared with that published in [5] by using of the moment of method (MOM). From Fig. 4, one can observe the good agreements between the present results and that of [5]. The return loss shows that the E-shaped antenna resonates at 1.9 and 2.4 GHz.

Fig. 5 shows that the input impedance of the E-shaped antenna at the resonance frequencies can be considered pure real as its imaginary part tends to be zero.

In Fig. 6, the return loss of the modified E-shaped patch is presented. The same dimensions of the conventional E-shaped are taken for the modified case. The effect of the middle slot width is considered. Four different values for the middle slot width are taken which are 0,2,4, and 6 mm. From this figure, one can see that the antenna resonates at higher frequencies as the slot width increases. This is useful for the UWB wireless communications systems that need to operate at C, and KU bands. For less than 10dB, the modified E-shaped antenna of middle slot of width equal to 2 mm has a wide bandwidth of 29.3% and operating frequency equal 3.5 GHz. While at middle slot width equal to 4mm, the operating frequency is equal 3.75 GHz and bandwidth 25%.

The effect of the middle slot position is shown in Fig. 7. Three different cases are studied. These cases are obtained by adjusting the distance between the middle slot and the left one to be equal to 1,3, and 5 mm. The middle slot is taken of width equal 2 mm. It can be observed from this figure that the increasing of the distance between the two slots leads to get more higher resonance frequency of the antenna. In all cases, a wide bandwidth of more than 23% is obtained. The corresponding input impedance is shown in Fig. 8, which is pure real at the resonance frequencies.

Fig. 9. shows the radiation of the E-shaped patch antenna at 3.5 Ghz. The radiation pattern exhibits a behavior that is suitable for WLAN communication systems; quasi-omnidirectional radiation pattern.

Fig. 10. shows the E-shaped antenna with multi-reflectors to obtain a directive antenna for the applications of the ISM (industrial, scientific, and medical) band at 2.4 GHz [11]. Three different reflectors are considered as shown in Fig. 10. The width of the reflectors are equal 2 mm, where

its length is 76, 78, 80 mm with gaps between them equal 2 mm. The radiation pattern of this antenna is shown in Fig. 11. The effect one, two, and three reflectors are given in Fig. 11 b, c, and d, respectively. The third reflector has approximately no effect on the directivity of the antenna.

4. Conclusion

This paper presents the analysis of a modified E-shaped patch antenna. With this modification, one can increase the antenna operating frequency and bandwidth to meet the requirements of the UWB signal frequency and bandwidth. In the present work, antennas of operating frequency at 3.5, 3.75, and 4.1 GHz with bandwidth of 29.3%, 23%, 24% are presented, respectively. The bandwidth is measured for a return loss less that 10 dB. Results for the antenna input impedance and radiation pattern are obtained. The input impedances are pure real at the resonance frequencies while the radiation is quasi-omnidirectional. A directive antenna for the ISM application is obtained by the adding of multi-reflectors for the E-shaped antenna. The analysis is based on the finite difference time domain (FDTD) with the perfect matched layer (PML) and verified by a numerical package based on the MOM. The obtained results are compared with the available published data and good agreements are found.

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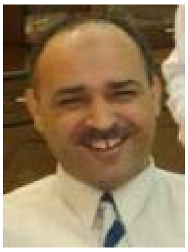

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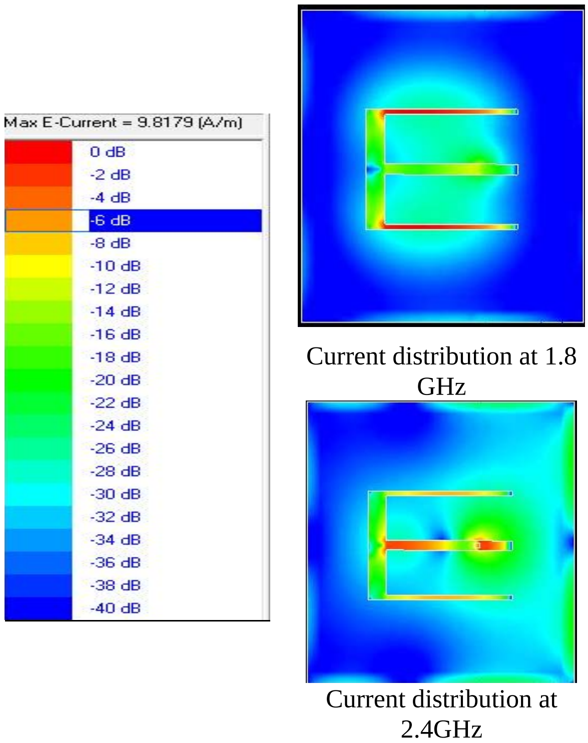


Fig. 3. The Current distribution of E-shaped antenna shown in Fig. 1.

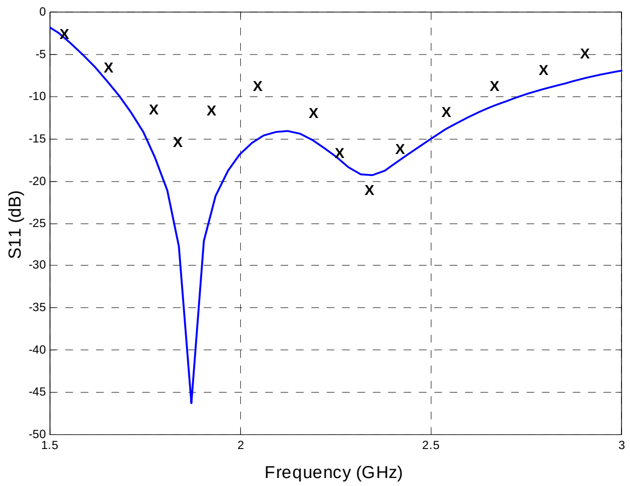


Fig. 4. S11 of the E-shaped patch antenna
(x x x [5], ------ the present work)

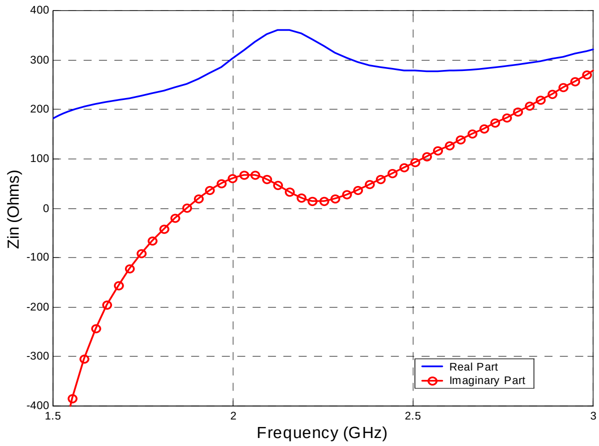


Fig. 5. The input impedance of the E-shaped patch antenna.

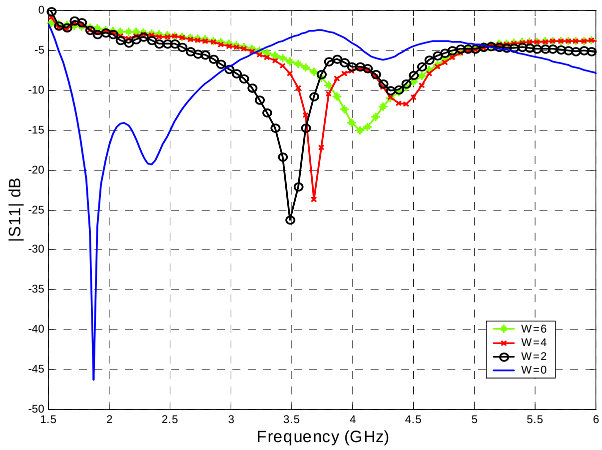


Fig. 6. The effect of the middle slot on the scattering parameters.

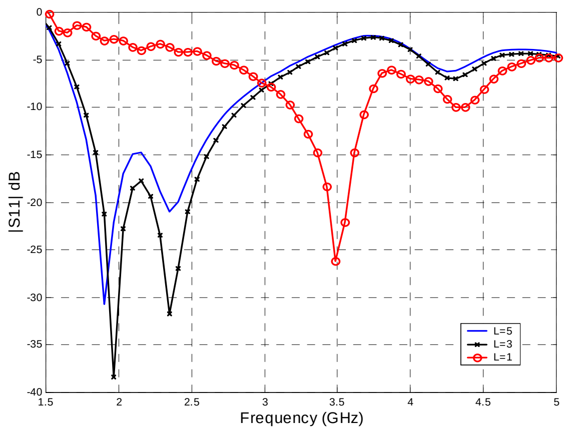


Fig. 7 The effect of the middle slot position on the scattering parameters of the patch shown in Fig. (L: is the distance between the middle slot and the left one, WS2=2)

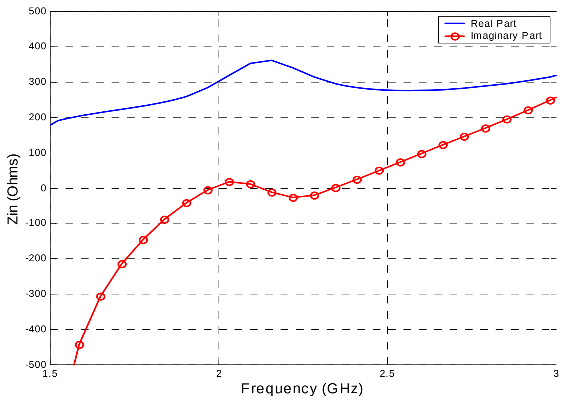


Fig. 8. The input impedance of the modified E-Shaped patch antenna of Ws2=2.

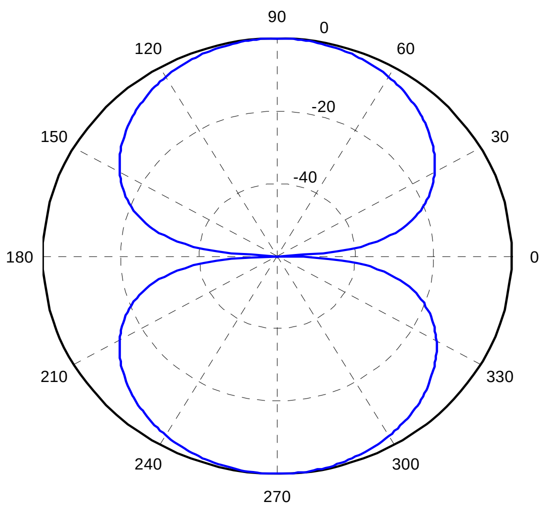


Fig. 9. The radiation pattern of the modified E-shaped antenna at 3.5 GHz.

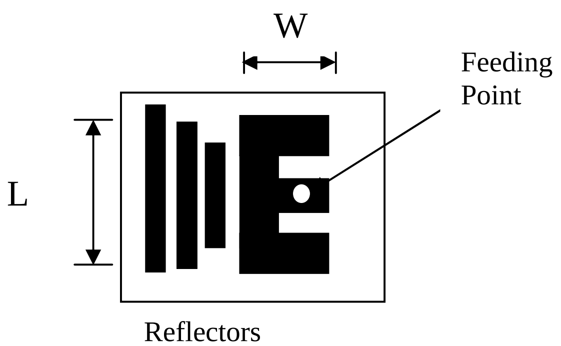
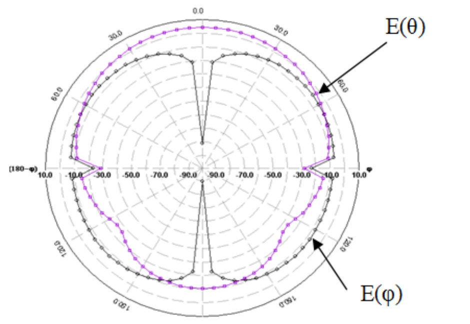
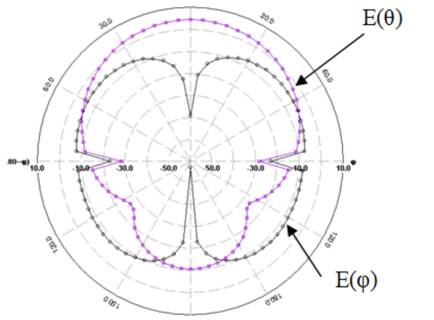


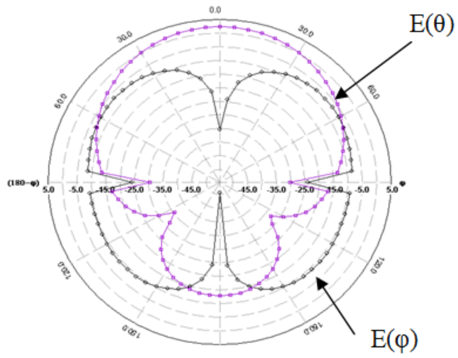
Fig. 10 E-shaped antenna with multi-reflectors



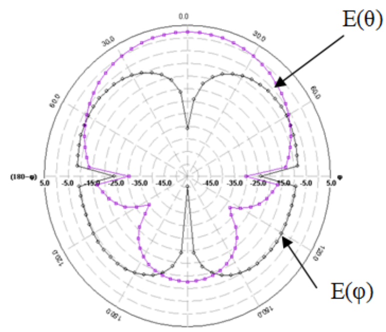
(a) The radiation pattern Without reflectors



(b) The radiation pattern With 1 reflector



(c) The radiation pattern With 2 reflectors



(d) The radiation pattern With 3 reflector

Fig. 11. shows the E-shaped antenna with multi-reflectors