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NOVEL SUPER WIDE BAND ANTENNA WITH WLAN/WiMAX BAND REJECTION AND COMPACT SIZE

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Abstract

A 25×25×1.6mm^3 implementation of a microstrip-fed printed monopole antenna for the future UWB wireless systems application is presented. It has features of possesses band notched function (from 4.88 to 6.07GHz), extremely wide impedance bandwidth (from 2.58 to 18GHz) and its compact size. By using a smooth tapering between the semi fractal-shaped patch and the half ellipse-shaped defected ground plane, the wide impedance bandwidth is achieved with ratio bandwidth larger than 6.97:1. Numerical and experimental results are in good agreement and they indicate that the proposed antenna has a measured 2:1 VSWR bandwidth of 149.8%, except the rejected WLAN band.

1. Introduction

Development of ultra-wideband (UWB) systems has increased the demand for compact antennas that can be economically manufactured and possess omnidirectional radiation patterns. It is well known that printed monopole antennas have attractive features, namely: (i) large impedance bandwidth; (ii) ease of fabrication using conventional MIC technology; (iii) acceptable radiation properties; and (iv) light weight. Consequently such antennas have received great attention for UWB applications. In fact, since the Federal Communications Commission (FCC) launched the bandwidth defined between 3.1–10.6 GHz [1] for commercial use, UWB technology has now become the favored choice for short-range and High-speed indoor data communications. Several printed monopole antennas with different geometries have been reported recently [2]–[17]. Unfortunately UWB systems have to operate in an electromagnetic spectrum occupied by several narrow band signals used by wireless communication systems such as wireless local area network (WLAN) IEEE802.11a and HIPERLAN/2 WLAN operating in 5–6 GHz band. This necessitates the use of filters to suppress these much stronger interfering signals that would otherwise degrade the operation of UWB systems. However, this requirement would unnecessarily increase the complexity, weight and volume of the UWB systems. Hence additional functionality is required from UWB antennas. Over the recent years numerous antennas have been developed to eradicate electromagnetic interference between the UWB and other narrowband systems such as WLAN. Over recent years various printed antennas have been reported for application in UWB systems using different structures and feed methods such as coplanar waveguide, coaxial, and microstrip. H.-H. Xian et al. used proximity coupled resonator [6], Y. L. Zhao et al. proposed a slotted planar antenna using π-shaped slot [7]. In reference [8] band notch function based on slot type electric LC resonator on patch has been presented. Sung-Jung Wu et al. Described applying an open looped resonator [9], and Young Jun Cho et al. in reference [10] proposed a U-shaped filter in radiating element. For WLAN notched operation, a slot with semi rectangular shape has been used in [11]. Segmenting a circular patch to create a stop band is presented in [12]. To realize the rejection band inverted U-shaped slot is added in the hexagonal patch in [13]. Other techniques include: slotted arc-shaped edge rectangular antenna [14], and utilizing a pair of inverted-L-shaped slots on the ground plane.

This design that not only demonstrate a very large impedance bandwidth of 149.8%, but also exhibits a band notched characteristic that is vital to eradicate interference from WLAN systems. The evolution of the proposed SWB antenna design, its simulated and measured results and comparison with other similar works are presented and discussed in the next sections.

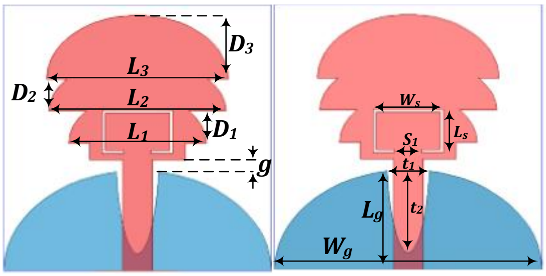

Fig. 1. Antenna configuration (L_1=13mm, L_2=16.5mm, L_3=17.75mm, W_g=25mm, h=1.5mm, W_f=1.875mm, D2=3mm, D3=6mm, D1=3mm, L_g=9.375mm, g=1.14mm)

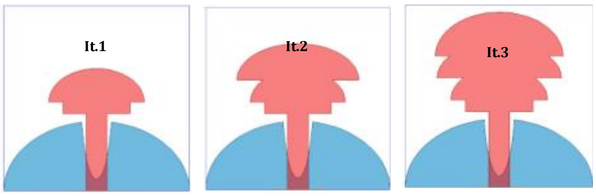

Fig. 2. Three supplementary antenna designing steps

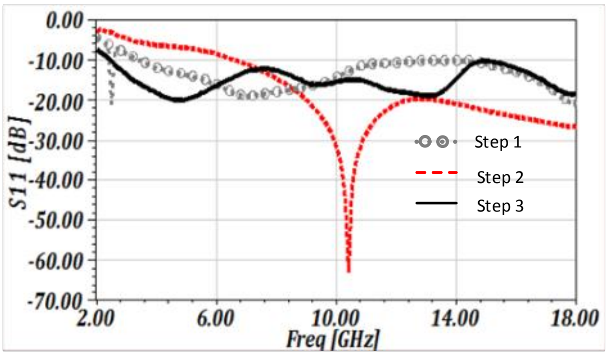

Fig. 3. Simulated return losses of the three designing steps of the antenna

2. Antenna design

Fig.1 displays the geometry of the proposed antenna structure. It is printed on a FR4 substrate with relative permittivity 4.4, lass tangent 0.02 and thickness of 1.6mm. The total dimension of this compact structure is approximately 25(0.206λₒ) ×25(0.206λₒ) mm^2, where the λₒ is the lower-end frequency of the band wavelength that with comparison to the recent antenna structures is admirable. As illustrated in the figure, the antenna consists of a semi fractal-shaped patch that includes a rectangular stub loaded sequentially three unequal elliptical metal elements to the top side of the stub in three steps .For achieving 50 impedance matching, the antenna is fed by a microstrip line with width and length of 2.8mm and 10.4mm respectively, that soldered to an SMA connector serves as antenna port. Two goals are considered for proposed antenna in this design. First, widening the bandwidth to satisfy the UWB antennas requirements and second achieving a band-notched function in WLAN band. Fig.2 shows the three steps employed to attain these two goals. It is seen that by increasing the size of the radiation element by addition of the three unequal trapezoidal metal elements to the stub and providing a smooth tapering between the semi-fractal-shaped patch.

In the three steps (i.e., step 1, 2 and 3) the UWB antenna is realized and in the step-4 by carving on the patch, a band notched characteristic is obtained.

3. Simulation results

Explanation about aforementioned antenna performance the fig.4 is plotted. It shows the current density distribution and electric fields over the patch at the notch frequency (5.3GHz). In this frequency the electric fields are more dominant around semi elliptical patch. The current vectors around the slot are in opposite directions resulting in cancellation of signals predominately at or very close to a specific frequency determined by slot length. The length of slot is nearly equal to quarter wavelength at the center frequency of the notched band. The guided wavelength is given by [15]:

$$L_{slot} = \frac{\lambda_g}{4} = \frac{c}{4f\sqrt{\varepsilon_{eff}}} \tag{1}$$

$$\varepsilon_{\mathrm{eff}} = \frac{1+\varepsilon_r}{2\varepsilon_r} \tag{2}$$

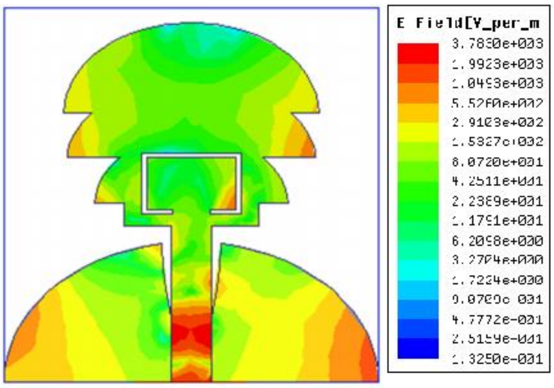

Fig. 4 Current density distribution and electric field over the patch at the notch frequency (5.3 GHz)

Where c is the speed of light in vacuum, f (notch center frequency) =5.3GHz, ε_{eff} (effective dielectric constant) = 0.61, and ε_r (relative permittivity) = 4.4. The length of the slot (Lslot) in this study is 16mm.

As shown in Fig. 5, the Lslot plays an important role in the position of the notch center frequency. When Lslot is increased from 18mm to 21.5mm the position of notch frequency is reversely changed, approximately from 5.6GHz to 4.4GHz. The optimal dimension of the slot length is Lslot=18.5mm, whereas it is nearly, equal to the quarter wavelength at center frequency of the notch band (i.e., 5.3GHz).

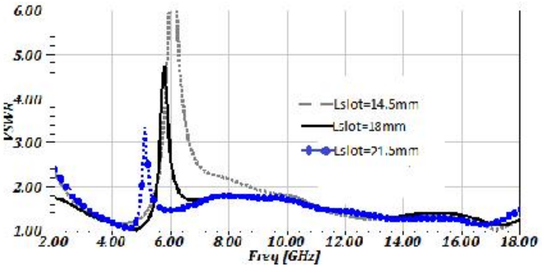

Fig.5 Simulated VSWR characteristics of the proposed antenna for various Lslot lengths

4. *Experiments and results*

Radiation patterns of the antenna with the co- and cross-polarizations in the H-plane (x–z plane) and E-plane (y–z plane), at low frequencies (i.e. 3.5, 7.5 and 10.5GHz) and at high frequencies (i.e.12), are plotted in fig.7.

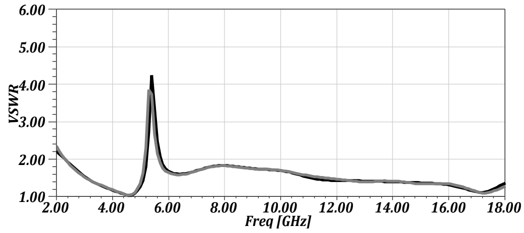

Fig.6 Measured and simulated VSWR of the proposed antenna

In fig.7, it is observed that the radiation patterns in H-plane and E-plane are approximately omnidirectional and monopole-like, respectively in low frequencies but in fig.7 it can be seen that at higher frequencies the cross-polarization level rises due to the increasing orthogonal surface currents. Also, a few nulls are observed at higher frequencies.

measured gain abruptly drops to -6 dB in the vicinity of the notch bands, and it is around 2-4 dB till 18GHz while gain decreases after 18GHz. Fig.6 shows the measured and simulated VSWR characteristics of the proposed antenna. The fabricated antenna has a frequency band from 2.58GHz to 40GHz with a rejection band around 4.88GHz - 6.07GHz. Any discrepancy is attributed to fabrication tolerance and the effect of the SMA port of the prototype. The antenna was analyzed and optimized using a commercial electromagnetic (EM) simulation tool (HFSS 11) and the final optimized UWB structure has been fabricated. The fabricated antenna is also shown in fig. 8. The measured results of the proposed SWB antenna are attained using the Agilent E8363CPNA network analyzer.

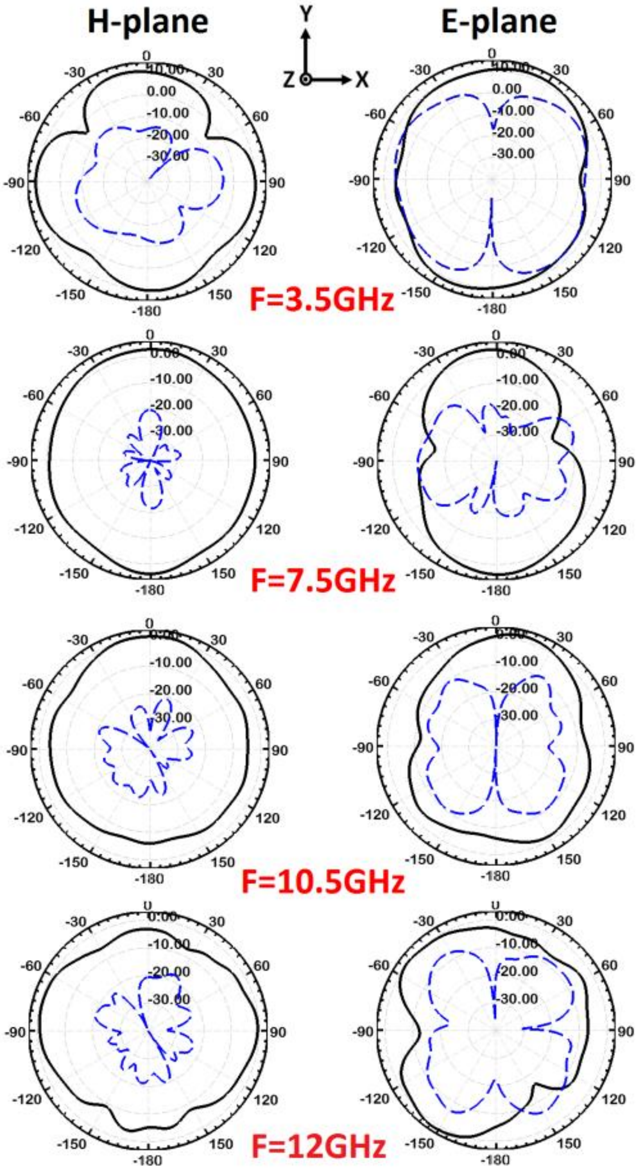

Fig. 7. The measured pattern of proposed antenna at a) 3.5GHz, b) 7.5GHz, c) 10.5GHz and d) 12GHz

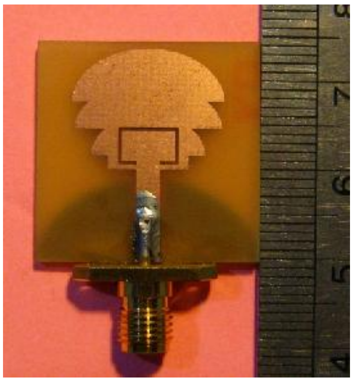

Fig. 8 Photograph of proposed fabricated antenna

5. Conclusion

In this paper a compact UWB antenna with a band notched function has been designed and tested. By generating a semi fractal-shaped patch by addition of the unequal elliptical metal elements to the stub and increasing the size of the patch leads to a smooth tapering between the patch and the ground plane, the super wide IBW can be achieved. With a measured 2:1 VSWR bandwidth of 149.8%, with 6.97:1 ratio bandwidth (from 2.58 to 18GHz), except the rejected WLAN band, this antenna can operate over a large frequency range to support multiple wireless communication services.

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