Design of a Novel falcate-shape Broadband printed monopole antenna for UWB application

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***Abstract*—a novel falcate-shape broadband printed monopole antenna for UWB application is proposed. The falcate shaped printed antenna has two arc lengths and is constructed from the intersection of two different size circular shaped patches. The arc lengths that determine the resonant frequency of the antenna can be obtained through recursive equations. The antenna is fed through a microstrip feed line and is backed by a finite ground plane. The return loss of the antenna is less than 10dB over a bandwidth of 3.1-10.6 GHz. The antenna also provides a good omni-directional radiation pattern, ±1dB, over this bandwidth. The measured and simulated results show good agreement between them.**

I. Introduction

The allocation of the frequency range 3.1-10.6GHz to the Ultra wideband (UWB) communication system has led to substantial number of researches and developments of the UWB antenna suitable for high data transmission rate, low cost, and simple hardware configuration in communication applications such as radio frequency identification devices, sensor networks, radar, and location tracking.

Consequently a lot of research has taken place to design ultra-wideband (UWB) antennas which have small size, wide bandwidth, and omnidirectional pattern. However, the radiation patterns of the antennas reported in the literature show degradation in omnidirectional pattern as frequency increases. In [1], square slot used as monopole radiator to provide wide impedance bandwidth. Similarly, in [2] a printed monopole with two steps and circular slot provides good impedance bandwidth over the UWB band with notch behaviour. In [3-5] elliptical shaped monopole antenna is used. In [3] the monopole radiator is used with either rectangular or elliptical shaped ground plane to achieve omnidirectional pattern. In [4] monopole antenna is used with two slots cut along the edge of the ellipse to provide wide impedance bandwidth and omnidirectional pattern. In [5] modified elliptical monopole with modified elliptical ground plane shape is employed to produce omnidirectional pattern in UWB band. In all these reported UWB antennas good impedance bandwidth are reported but the patterns are not stable omnidirectional patterns over the bandwidth.

In this paper we present a novel printed monopole antenna which is suitable for UWB applications. The proposed antenna is in the shape of a falcate produced from the intersection of two circular patches. The falcate-shape monopole antenna shows wide impedance bandwidth over the 3.1-10.6 GHz. Due to its shape, the antenna has multi resonance characteristics. Two similar antenna designs are provided. In the first the falcate shaped antenna covers the UWB bandwidth with very good stable omnidirectional pattern, ±1dB variations. In the second design, a falcate shaped antenna that covers both UWB and the UMTS (1.92–2.17 GHz) band is reported. In the latter, the variation in the omnidirectional pattern is within ±3dB. The simulated results as obtained through software package, HFSS, and through measurement are provided and discussed.

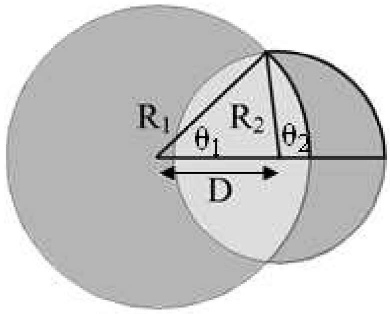

Fig. 1 Construction of the falcate-shape geometry

II. Antenna Design

To have an antenna that can operate over a large frequency bandwidth requires a geometry in which multi resonances can be created. Planar antennas with curved radiating surface can provide such requirement. The design principle behind the proposed falcate-shape antenna is shown in Fig. 1. The geometry of the falcate is created by cutting the section of a larger circle which overlaps another smaller circle. The radii of the circles are assumed R1 and R2. The distance between the centres is D. Fig. 2 shows the final design of the proposed antenna.

Based on the geometry shown in Fig. 1 we have

$$L1 = 2 \times R1 \times \theta 1 \quad (1)$$

$$L2 = 2 \times R2 \times \theta 2 \quad (2)$$

And

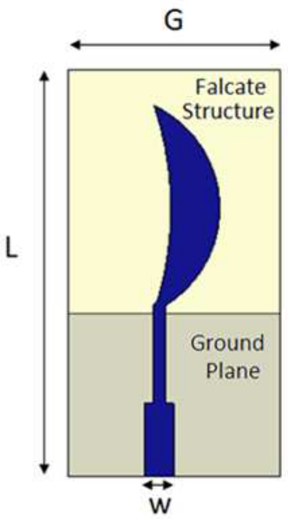

Fig. 2 The proposed falcate-shape monopole antena

$$\cos(\theta_1)=\left(\frac{R_1^2-R_2^2+D^2}{2\times R_1\times D}\right) \qquad (3)$$

$$\cos(\theta_2)=\left(\frac{R_1^2-R_2^2-D^2}{2\times R_2\times D}\right) \qquad (4)$$

To design a falcate-shape monopole antenna at first one should select the lower resonant frequency. The resonant lengths, L1 and L2, can be obtained through the following formula, (5), where ε_{eff} is given in equation (6).

$$f_r=\frac{c}{4\sqrt{\varepsilon_{eff}}L} \qquad (5)$$

where

$$\varepsilon_{eff}=\frac{\varepsilon_r+1}{2} \qquad (6)$$

Error! Reference source not found. We can start firstly by designing the antenna for UWB application only. For the lower frequency limit to be 3.5GHz, and with $\varepsilon_r=2.33$, *L2* is found to be about 16mm while for the upper resonant frequency we choose a value e.g. 4.5 GHz, leads to a value for *L1*=13 mm. If we select *R2*, through equation (2) one obtains θ2. From equation (1) one can obtain θ1 in terms of *R1*, which can then be placed in equation (3). We then have two equations, (3) and (4) which are functions of *R1* and *D*, which can be solved. The solution gives: *R1*=20.2mm, *R2*=7.1mm and *D*= 16.5mm. Dimension of the antenna would be *G*×*L*=13mm×25mm and width of the feed line *w* is 2mm. The narrower section of feed line is set at 1mm.

Another design of falcate shape antenna is also done to include both the UWB and the UMTS bands. The value for *L1* and *L2* for the frequencies 2 and 3.1 GHz would be 30mm and 19mm. From these values of resonances the lengths of *R1, R2* and *D* would be 35 mm, 12.5 mm, and 30 mm, respectively. Thus, dimension of the antenna would be *G*×*L*=19mm×36mm and width of the feed line *w* is 2mm. The narrower section of feed line is 1mm. As would be shown in the next section, although this second design provides higher impedance bandwidth, the radiation pattern stability for the upper end of the band is not as well as those of the first design for the UWB case.

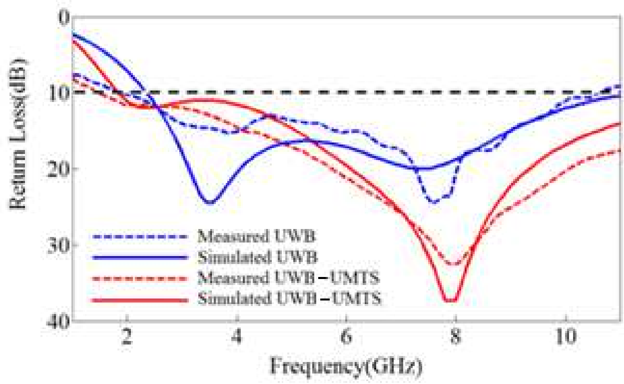

Fig. 3 Return loss of falcate-shape monopole antenna for UWB application and UWB - UMTS application

It should be pointed out that the value given for the upper resonant frequency is obtained through optimization that results in a better radiation pattern from the antenna.

III. Results

Figure 3 shows the measured and simulated return loss of the falcate shape antenna for two design cases; the design that covers the UWB band and the design that covers both UWB and UMTS bands. As can be observed the antenna for the first design shows a good match across the 3.1-10.6 GHz bandwidth which is proper for UWB application. Also the measured and simulated return loss of the second antenna for the UWB and UMTS applications is shown in Fig. 3. This result shows that with the proper dimensions for the falcate antenna, the lower frequency limit of the antenna can be reduced down to 1.5GHz. Also it can be seen that the bandwidth of this antenna is quite high.

Figure 4 shows the E and H-plane radiation pattern of the first antenna for the frequencies 3.5GHz, 5.5GHz, 7.5GHz and 9.5GHz. As can be seen the pattern are quite stable over the bandwidth, with maximum variation being within ±1dB. Radiation pattern of the second antenna is shown in Fig. 5. Figure 5(a) shows the radiation pattern at 2GHz which can be used for UMTS application. This pattern is completely omnidirectional. Figure 5 (b)-(e) shows the radiation pattern at frequencies 3.5GHz, 5.5GHz, 7.5GHz and 9.5GHz, respectively, which also covers the UWB band. The radiation pattern varies within ±3dB while frequency increases.

From Figs. 4 and 5, it can be seen that the E-plane radiation pattern of the proposed antenna is very similar to the usual printed monopole antenna pattern and that with change in frequency the beam peak rotates very slightly.

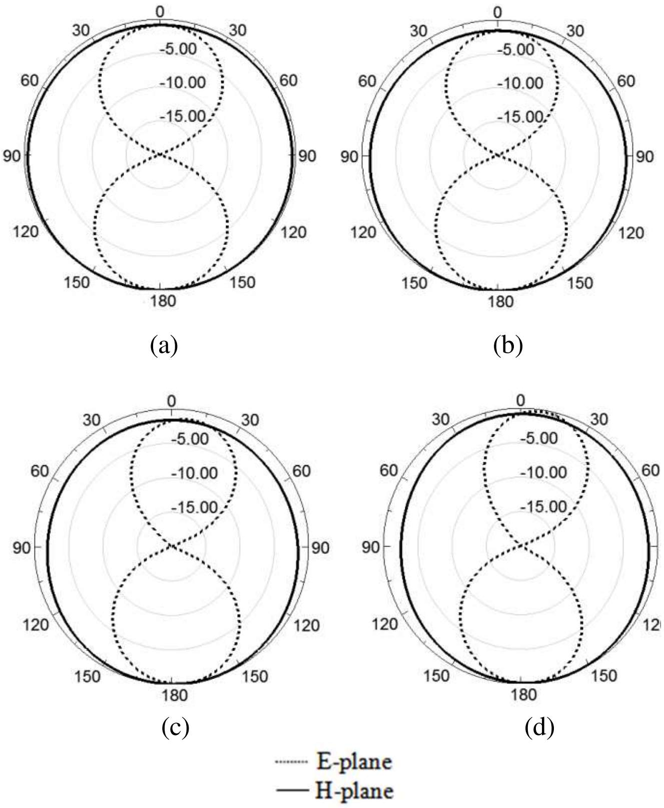

Fig. 4 Radiation pattern of the falcate shape antenna for UWB application at (a) 3.5GHz, (b) 5.5GHz, (c) 7.5GHz and (d) 9.5GHz

IV. CONCLUSIONS

The design of a novel broadband falcate shape monopole antenna covering UWB (3.1-10.6 GHz) or UWB-UMTS (1.92-10.6 GHz) bands has been presented. Iterative formulas for the resonance frequencies are provided. The antenna provides a good impedance match over the wide bandwidth and has a very good, stable omnidirectional radiation pattern over the bandwidth.

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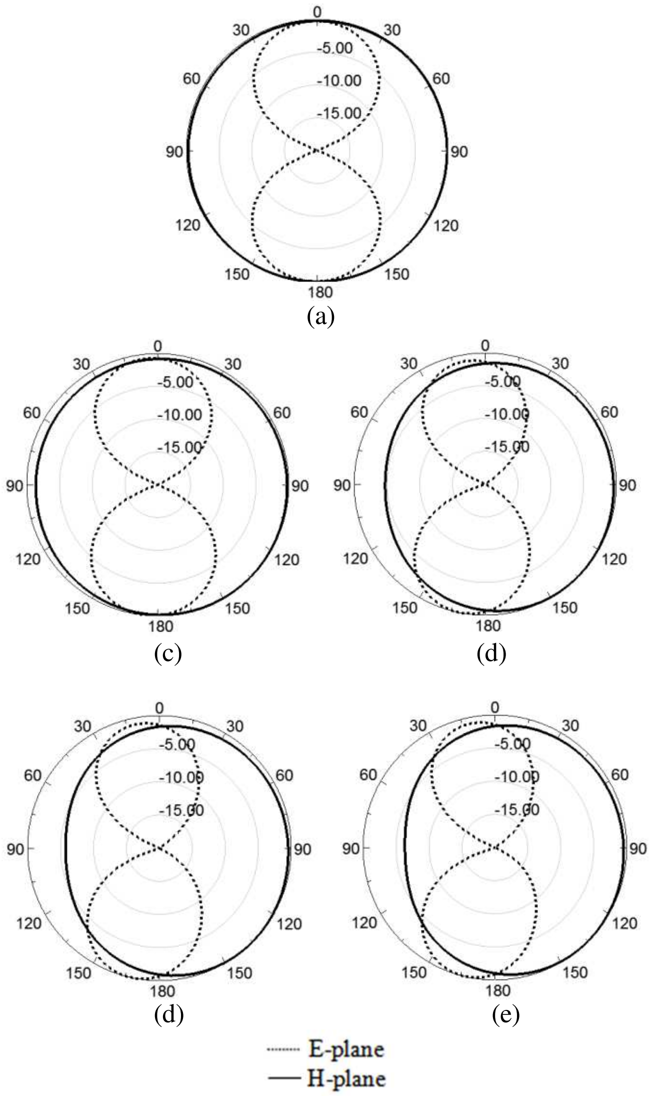

Fig. 5 Radiation pattern of the falcate shape antenna for UWB-UMTS application at (a) 2GHz, (b) 3.5GHz, (c) 5.5GHz, (d) 7.5GHz and (e) 9.5GHz