Investigation into a Folded Wideband Monopole Antenna for Use in Portable Devices

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Abstract—**This paper presents investigations into a compact antenna for use in portable devices to access almost all modern wireless services from about 800MHz to 6GHz. Initially, a microstrip-fed planar monopole of quarter-elliptical shape on FR-4 substrate is designed to generate a wide impedance bandwidth. This radiating element is augmented with a parasitic microstrip stub and a ground-plane cut to improve wideband performance. To reduce its projection area, the planar monopole is folded. The folded antenna occupies a volume of 13mm x 50mm x 5.6mm. It operates over two wide bands between 0.85 and 3.8GHz, and 4.9 and 6GHz, with reference to 6dB return loss (VSWR 3:1). Its radiation patterns are omnidirectional in the lower band and deteriorate at higher frequencies. The corresponding gain varies between 1.5 and 7dBi.**

Keywords-Fold; GSM; GPS; PCS; Quarter-elliptical; UMTS; Wideband; WiMAX; WLAN;

I. INTRODUCTION

With the expansion of wireless communications, there has been a growing interest in the design of compact multi-band and wideband antennas. Such antennas are required for portable devices to access various wireless services which are predominantly available in the 880MHz to 5.85GHz frequency band. These include GSM, GPS, DCS, PCS, UMTS, WLAN and WiMAX. As the commercial market demands portable RF transceivers with a compact single-feed antenna to cover these service bands, the antenna design becomes very challenging.

To answer these challenges, many antennas with wideband performance have been published in open literature. However most of them concentrate on higher frequency bands such as UWB which spans across 3.1-10.6GHz. In [1] and [2], wideband antennas serving lower microwave frequencies have been reported. The CPW-fed antenna in [1] achieves a wideband performance at as low as 800 MHz (at 9.5dB return loss) but is of large size and thus is not practical for use in portable devices. A quarter-ellipse wideband monopole antenna reported in [2] is of smaller size and thus is suitable for use in portable devices. It generates a wideband operation. However for the chosen size it is unable to operate at low frequencies around 1GHz.

This paper presents a logical expansion of antenna design reported in [2]. In order to meet the requirement of operation at low microwave frequencies the size of quarter ellipse monopole is increased and then the element is folded to meet the requirement of compact size. The second-order folding gives the reduction of projection area to 57% of the original size while the thickness is increased to about 4mm. Apart from folding the radiator a parasitic element is introduced for tuning purposes. Also, the top corner of the quarter ellipse is curved to modify the current path and thus improve the overall return loss performance. To meet a very large operational bandwidth, the finite size ground plane is utilized in the design process. A ground-cut close to the main radiator is made to enhance the bandwidth. The size of the ground-cut is then decreased to limit the dependency of resulting impedance bandwidth from the ground plane structure. The final antenna configuration is capable to achieve wide bandwidth from 850MHz to 3.78GHz and 4.87GHz to 6GHz at 6dB return loss. Here 6dB rather than 10dB is used as return loss reference for an antenna aimed for operation in an ultra wideband portable device.

This paper is arranged as follows. Firstly, the configuration of the unfolded antenna is introduced. Then the folding is applied to miniaturize the antenna size. Its effect is simulated and discussed. Next, the effects of ground-cut and parasitic element assisting the antenna tuning are investigated. Finally, the antenna return loss, radiation patterns and gain at the bands of interest are presented and discussed.

II. ATENNA DESIGN

A. Unfolded Geometry

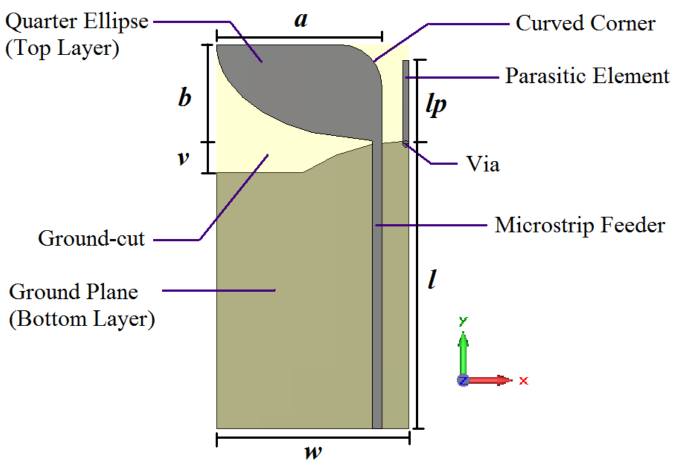
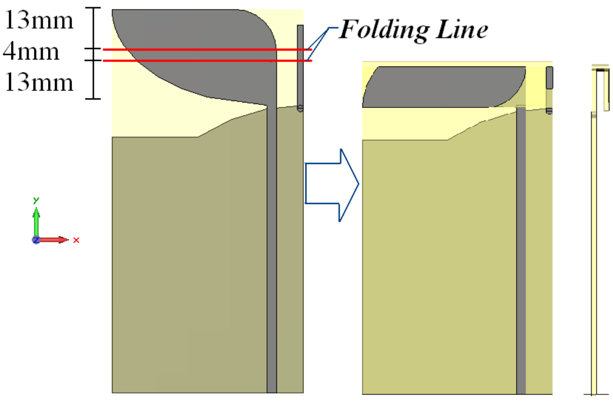
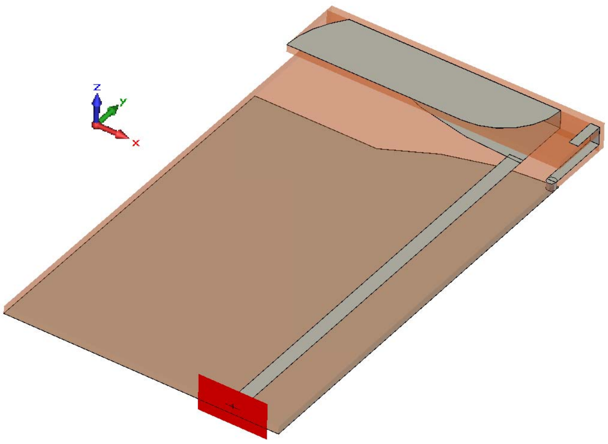


Figure 1: Unfolded configuration of the proposed antenna.



(a) (b) (c)



(d)

Figure 2: Folded configuration of proposed antenna (a) Folding location; (b) Front view; (c) Side view; (d) 3D view.

Initially, the unfolded antenna is designed with the use of CST Microwave Studio v2009. A quarter-ellipse planar monopole with major radius of a = 50mm and minor radius b = 30 mm is designed on the top layer of a 1.6mm FR4. The substrate has a dielectric constant of 4.4 and the radiator is fed by a microstripline of width w_f = 3mm. In practice, the position of the feed point of the microstripline can be made arbitrary depending on the location of the RF feed-point circuitry. The main radiator is placed on the top left corner of the substrate and supported by a w = 60mm x l = 90mm ground plane on the bottom layer as shown in Fig. 1. An open circuited at one end microstripline of width w_p = 2mm and length l_p = 24mm is placed parallel with the edge of the quarter ellipse and shorted to the ground via a shorting pin, as shown in Fig. 1. It acts as a parasitic element to tune the antenna input impedance and hence the impedance bandwidth. Next, the top edge corner of the radiator is curved with a 13mm radius circular curvature to improve the bandwidth.

The ground plane modification includes a cut beginning with a 60mm radius circular curvature on the top left corner of the ground plane as shown in Fig. 1. In the next step, the cut is minimized by reducing the gap v between the main radiator and the ground.

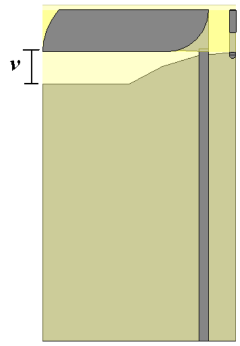
B. Folded Geometry

To accomplish the antenna size reduction, the main radiator is folded twice (second-order folding technique). Fig. 2 shows the folding location followed by the final configuration of the folded antenna. The folding takes place at the 30mm minor axis of the quarter ellipse at the ratio 13:4:13. Because the antenna is initially designed on an FR4, the folding considers the substrate as part of the folded element, as seen in Fig.2.

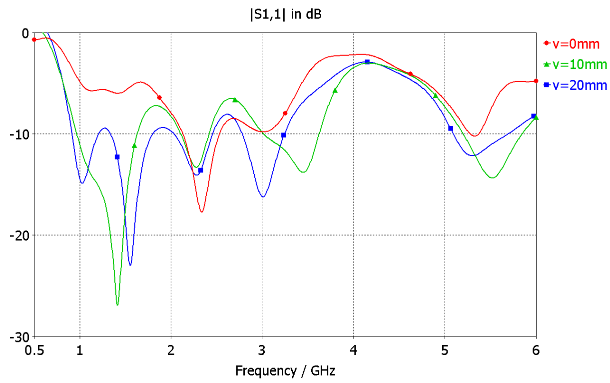
III. Results and Discussion

During the design of the folded monopole antenna two investigations, one concerning the size of the ground-cut and the other one regarding the total length of the parasitic element have been performed.

Fig.3 shows the effect of ground-cut size on return loss characteristics of the folded antenna. As observed from the results presented in Fig.3, a larger cut reduces the overall resonance frequency much below 3GHz. In particular, a cut with v=20mm results in a fine quality antenna return loss characteristic from about 850MHz to 3.3GHz.



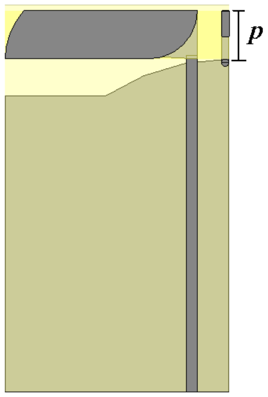
(a)



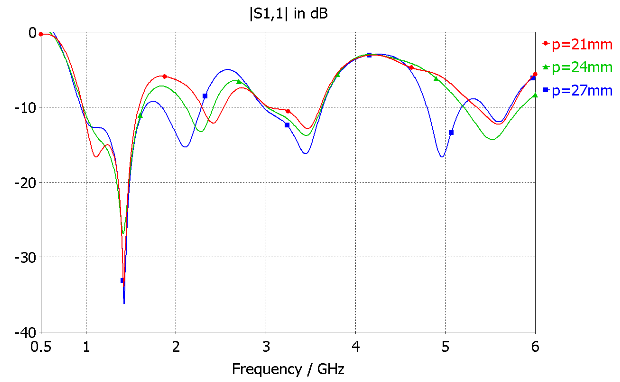
(b)

Figure 3: (a) Variation of the ground-cut size; (b) The return loss performance

Fig. 4 presents another result from the folded antenna parametric analysis. In this case, the length of the parasitic element is adjusted to improve the return loss performance. From results shown in Fig.4 it is apparent that the longer length (p = 27mm) weakens the resonance at around 2.5GHz but widens the upper band width. For a shorter length (p = 21mm), the resonance quality at around 2GHz is compromised.



(a)



(b)

Figure 4: (a) Parametric element total length variation; (b) Return loss performance.

The simulated return loss for the final design is presented in Fig. 5. This figure reveals a wideband performance of the antenna. First it is from 850MHz to 3.78GHz and then from 4.87GHz to 6GHz at 6dB return loss (or VSWR of 3:1). The resulting wide bandwidths cover all the popular wireless services including GSM, GPS, DCS, PCS, UMTS, WLAN and WiMAX.

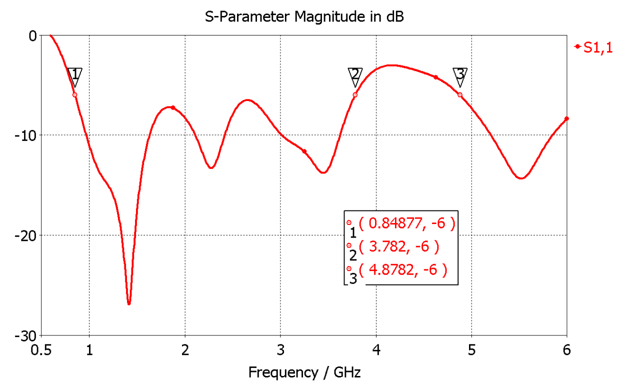


Figure 5: Simulated return loss of the final folded geometry.

Fig. 6 presents the simulated 3-dimensional radiation patterns of the folded antenna at 900MHz, 1.57GHz, 1.8GHz, 2.0GHz, 2.45GHz, 3.5GHz, 5.2GHz and 5.8GHz. Note that these radiation patterns are obtained for the antenna location in the xy plane, as shown in Fig. 2.

On average the patterns are close to omni-directional. A further insight shows that the omnidirectional behaviour depreciates at frequencies above 3.5GHz where the patterns become distorted and directional.

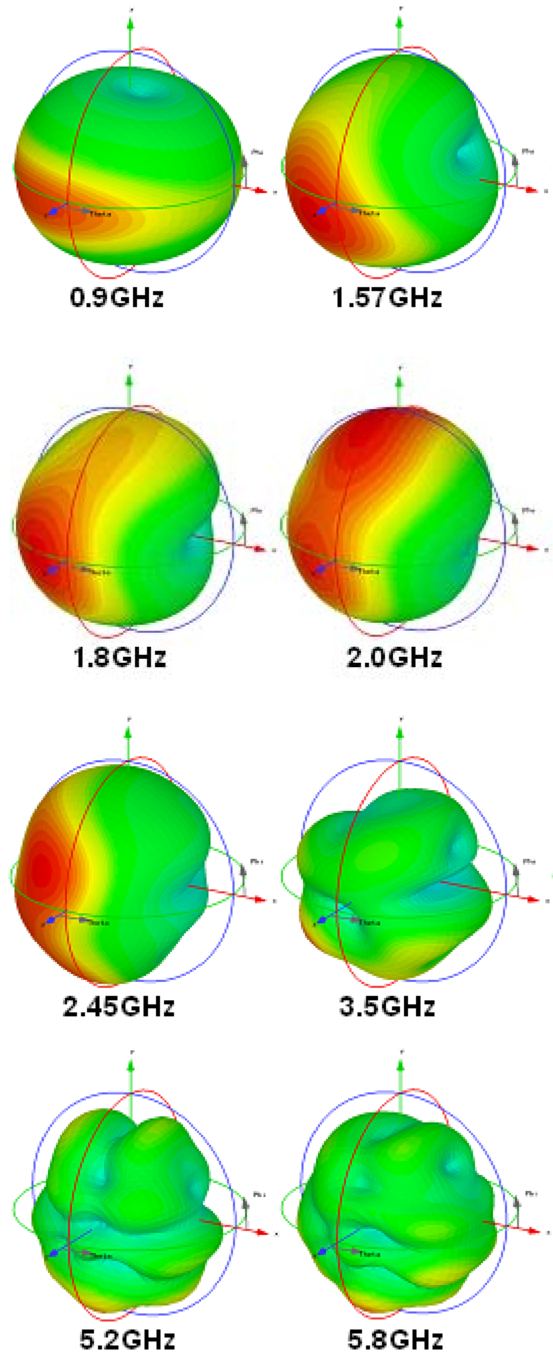


Figure 6: Simulated radiation patterns of the proposed antenna.

Having obtained satisfactory simulation results, the antenna is manufactured and experimentally tested. Photograph of the manufactured antenna is shown in Fig.7.

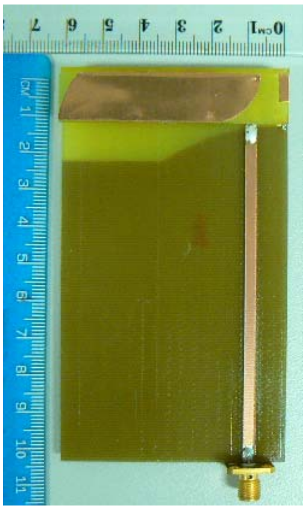


Figure 7: Fabricated prototype of the proposed folded monopole antenna.

The simulated and measured antenna gain is presented in Fig. 8.

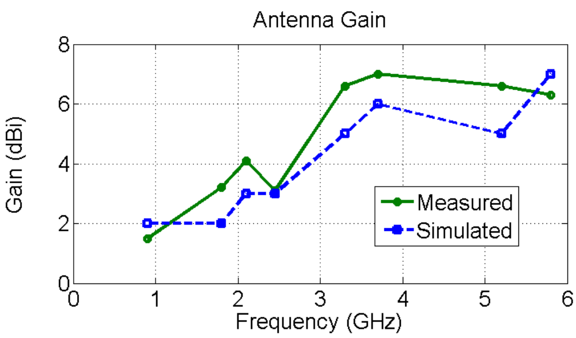


Figure 8: Simulated and measured antenna gain.

From the presented graph, the simulated gain over the band of interest ranges between 1.5dBi and 7dBi while the measured one is between 2dBi and 7dBi. This low and then moderate gain can be considered as acceptable with respect to the application in portable wireless devices. The omnidirectional characteristic depreciation occurs at upper frequencies due to increased directivity observed in the higher frequency radiation patters in Fig. 6.

The trends in the measured and simulated gain results are similar. Discrepancies can be explained by general challenges met in an accurate experimental characterization of this type of antenna that operates with a small ground plane [3].

IV. CONCLUSION

In this paper, a new folded quarter-elliptical wideband monopole antenna for portable wireless applications has been presented. The proposed antenna offers a wideband performance from 850MHz up to 3.78GHz and 4.87GHz to 6GHz (at 6dB return loss or VSWR 3:1) with nearly omni-directional radiation patterns. Therefore, this antenna enables the RF transceiver to access all modern wireless frequency services such as GSM, GPS, PCS, DCS, UMTS, WLAN and WiMAX. Its attractive feature is that it is of compact size and employs only a single feed. Because of these attributes, it has a considerable potential for inclusion in current and new generations of wideband and multiband portable wireless transceivers.

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