# Design of a Small Printed Monopole Antenna for Ultra-wideband Applications

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## Abstract

**In this paper, a small-size low-cost printed monopole antenna for ultra-wideband operation is presented. The proposed antenna, which was designed and simulated using the FEM-based HFSS, is based on a 20 mm × 40 mm × 1.6 mm FR4-epoxy dielectric, is microstrip-line fed and has a partial ground plane flushed with the feed line. To verify its frequency response, the antenna is also simulated using CST Microwave Studio, and a prototype is fabricated and the return loss is measured. A credible analogy between computed and measured return loss data is witnessed. Furthermore, the antenna shows acceptable peak gain figures, good radiation efficiency values and omnidirectional radiation patterns over its band of operation.**

## 1. Introduction

Since the Federal Communications Commission declaration of the 3.1–10.6 GHz frequency band for use in commercial communication applications in 2002 [1], many researchers focused on pioneering novel antenna designs suitable for ultra-wideband operation. Several PCB antenna designs, employing various procedural facets to achieve a 3.1–10.6 GHz impedance bandwidth, have been proposed. However, low cost, small size and ease of fabrication, while still maintaining good radiation properties over the 3.1–10.6 GHz frequency band, are challenging key points in these designs.

Two interesting methodologies for the design of UWB microstrip antennas were looked into. The 3 cm × 3 cm monopole-type PCB antenna discussed in [2] operates over the 3.4–11 GHz frequency band, taken for $S_{11} \leq -10$ dB. Therein, three design guidelines were used to perform good impedance matching. These are incorporating dual slots on the rectangular patch, introducing a tapered connection between the rectangular patch and the feed line, and flushing the ground plane with the feed line. On the other hand, a 3.3 cm × 3.3 cm dipole-type microstrip antenna, with a 3.15–12.03 GHz impedance bandwidth for VSWR $< 2$ , was proposed in [3]. Here, the authors built an UWB operating antenna by employing a feed line with a sectored end and readjusting the sizes of two semi-elliptical radiating patches, leading to a tapered slot in between, whose major and minor axes were initially interchanged. Although both approaches demonstrated two well-suited antenna designs for UWB operation in wireless communications, it's worth mentioning that the former revealed a satisfactory performance while using the low-cost FR4-epoxy material.

The design presented in this work provides a comparable ultra-wide performance for a smaller PCB antenna size, while maintaining the low cost and ease of fabrication properties. Here, we propose a low-cost compact PCB antenna based on a on a tapered connection between a semi-elliptical patch and a trapezoidal feed line. The ground plane is partial and is flushed with the feed line. The fundamental characteristics of the proposed design, including simulated and measured return loss, computed gain, radiation efficiency, and radiation patterns, over the UWB band, are illustrated herein.

## 2. Antenna Configuration and Design Guidelines

The geometrical structure and dimensions of the proposed printed monopole antenna are detailed in Fig. 1. The proposed microstrip-line-fed antenna is based on a 20 mm × 40 mm, 1.6 mm-thick FR4-epoxy substrate. The feed line has the shape of an isosceles trapezoid. The patch comprises a trapezoidal part, similar to the arm of a bowtie, and a semi-elliptical part. The ground plane is partial, rectangular in shape and flushed with the feed line.

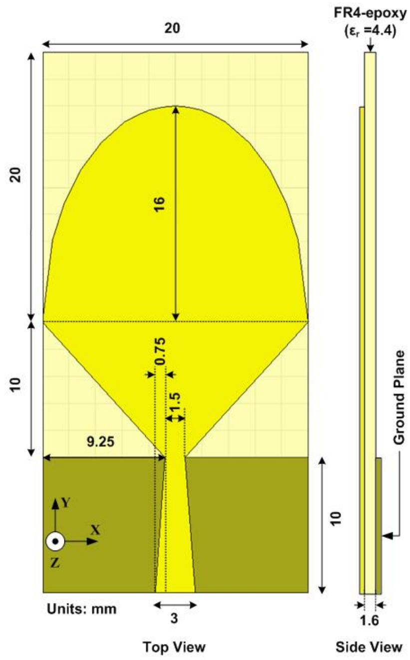


**Fig. 1.** Geometry of the proposed antenna

In the proposed design, the width (x-dimension of the substrate) was selected smaller than the length (y-dimension of the substrate) to keep better omnidirectional properties at high frequencies. As the width of a planar monopole antenna decreases, it operates more similar to a printed thin monopole, and thus has an improved ability to retain the omnidirectional horizontal patterns over its band of operation. A smaller width also makes the antenna easier for integration in communications devices.

To achieve an ultrawideband operation for the above small-sized antenna, the following techniques were used:

1) A partial ground plane flushed with an isosceles trapezoid-shaped feed line was utilized. Compared to rectangular feed lines, this configuration contributes better impedance matching for the above antenna structure. As mentioned in [4], ground plane effects on antenna impedance matching and radiation patterns can be suppressed by concentrating the majority of current on the upper radiating patch of a monopole-type PCB antenna.

2) A trapezoidal connection, between the feed line and the antenna’s patch, was brought in to improve the antenna performance for UWB operation. Tapered connections between the feed line and the main patch are known and applied to smooth the current’s path, thus providing wider impedance bandwidth.

## 3. Results and Discussion

The antenna was designed and simulated using Ansoft HFSS [5], an EM simulator based on the Finite-Element Method (FEM). The return loss was verified using CST Microwave Studio [6], which is based on the Finite Integration Method (FIM). HFSS revealed a 2.8–10.6 GHz impedance bandwidth for $S_{11} \le -10$ dB. A 2.6–10.2 GHz bandwidth is obtained for $S_{11} \le -10$ dB using CST MWS. The return loss plots from both simulators are shown superimposed in Fig. 2, in the 2–10.6 GHz frequency range.

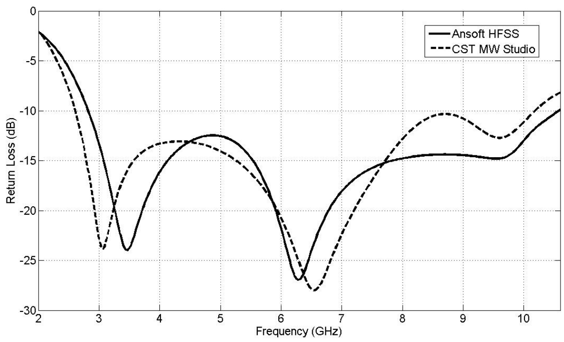


**Fig. 2.** FEM-based and MoM-based return loss

A photo of a fabricated prototype is shown in Fig. 3. The actual return loss is measured using Agilent’s E5071B network analyzer, which operates in the 300 KHz–8.5 GHz frequency range. A comparison between computed and measured $S_{11}$ in the 2–8.5 GHz frequency span is depicted in Fig. 4. Good agreement is witnessed between simulated and measured $S_{11}$ plots.

**Fig. 3.** Photograph of the fabricated prototype

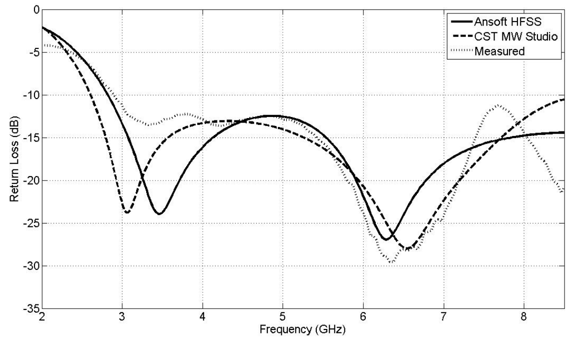


**Fig. 4.** Measured and simulated $S_{11}$ plots superimposed

The HFSS-computed peak gain and radiation efficiency of the antenna over the UWB frequency band are displayed in Fig. 5 and Fig. 6, respectively. The antenna's peak gain shows acceptable figures over the frequency span of interest. The average maximum gain in the 3.1–10.6 GHz frequency range is 3.8 dB. The radiation efficiency is 98.66% at 3.1 GHz and smoothly decays to 87.12% at 10.6 GHz due to more losses in the FR4-epoxy substrate at high frequencies.

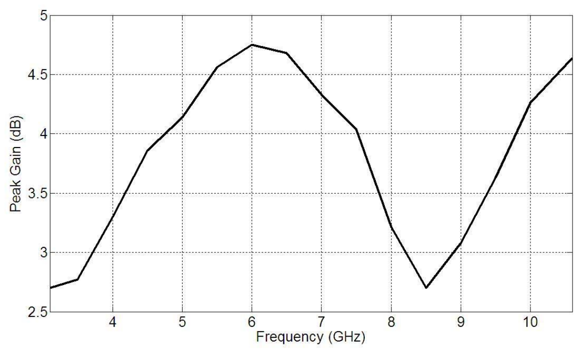


**Fig. 5.** Peak gain of the antenna over the 3.1–10.6 GHz frequency band

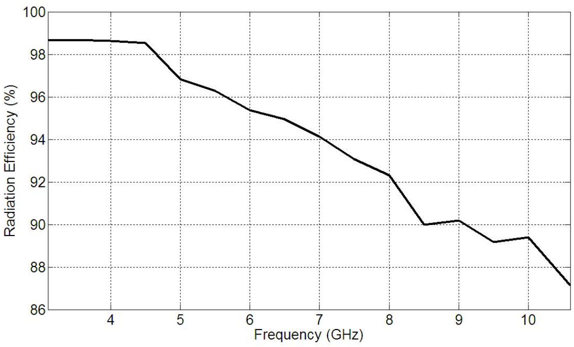


**Fig. 6.** Radiation efficiency of the antenna over the 3.1–10.6 GHz frequency span

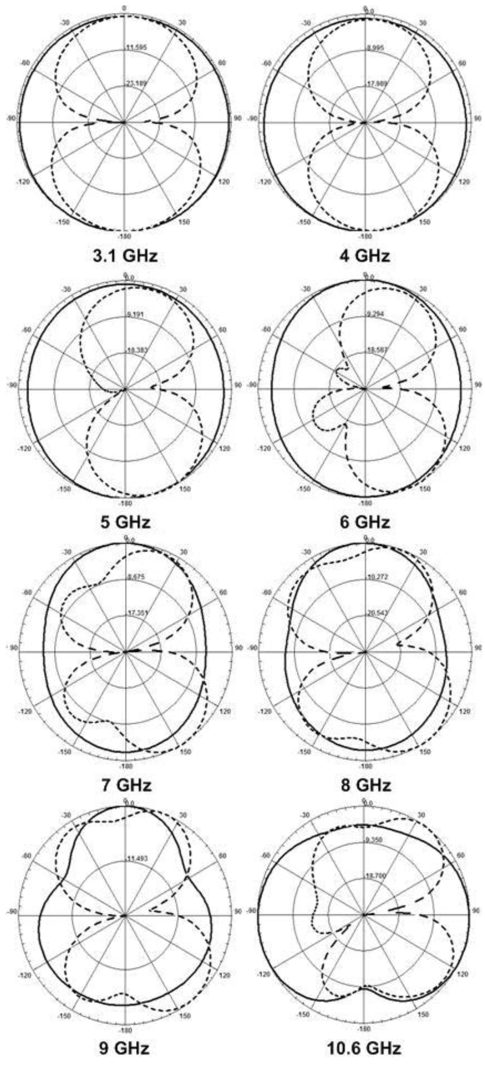


**Fig. 7.** FEM-computed radiation patterns in the X–Z plane (solid line) and Y–Z plane (dotted line)

The HFSS-computed radiation patterns are illustrated in Fig. 7. Satisfactorily omni-directional patterns are obtained. The improved ability to retain the omni-directional characteristics of the antenna over its band of operation is assisted by the proper choice of the antenna's dimensions. The smaller the width of the monopole antenna compared to its length, the more it operates similar to a thin monopole characterized by its stable omni-directional patterns. The patterns in the Y–Z plane have the shape of an '8', corresponding to a 3D shape of a donut. However, side lobes start to appear at higher frequencies, as expected in the patterns of a printed monopole. For thin monopoles (very small widths), side lobes appear when the length is close or larger than one-half a wavelength.

## 4. Conclusion

A novel low-profile, low-cost and easy-to-fabricate monopole-type microstrip antenna for UWB operation was presented in this paper. The antenna uses a combination of techniques to achieve UWB behavior. The antenna was fabricated on a 1.6 mm-thick FR4-epoxy substrate with dimensions 2 cm × 4 cm. A good analogy between simulated and measured return loss results was obtained. The antenna possessed stably omnidirectional patterns, good gain figures and acceptable radiation efficiency values over the whole UWB range.

## 5. Acknowledgment

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## 6. References


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