Design and characterization of a diamond-shaped monopole antenna

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Abstract
We report a new planar antenna design in the shape of a diamond. The performance of the antenna design is initially obtained through simulation, then fabricated, and its performance evaluated through experiment. Experimental characterization of the diamond-shaped monopole antenna shows good agreement with simulation. In comparison with a simple monopole antenna, our diamond-shaped monopole antenna features smaller geometric footprint and displays a higher bandwidth at millimeteric wave frequencies.

KEYWORDS
diamond shaped, gain, monopole, radiation pattern, return loss

1 | INTRODUCTION

With the rapid development of wireless communication systems, there is an increased demand in antennas whose dimensions are small with respect to their operating wavelengths and those with exceptional and multifunctional performance. Electrically small antennas (ESAs) have therefore gained increasing interest and over the past decades, researchers have proposed many ESA designs, such as the right-/left-hand composite transmission line based antennas,1 near-field resonant parasitic antennas,2 and reactive loaded monopole antennas.3 Furthermore, ESA designs have been proposed that offer physically small antennas with desirable broadband performance.4–6

Moreover, motivated by the demand of a planar antenna design for wireless communications,7 especially in wireless local area network (WLNA), Worldwide Interoperability for Microwave Access (WiMAX), and Long Term Evolution (LTE) applications, this article proposes a novel diamond-shaped monopole antenna to be operated at millimeter wave-lengths. It is designed and numerically simulated using the finite-difference time-domain (FDTD) method.8 Our design is then fabricated on an RT-Duroid substrate9 and RF characterized over the frequency range 10 MHz to 20 GHz using a network analyzer. The novel diamond-shaped monopole antennas presented in this work are found to be more compact compared to their simple monopole counterparts operating at the same resonant frequency, but with higher operational bandwidths. Offering ultrawideband performance alongside a physically small footprint eases the fabrication process and lowers the cost of fabrications.

The antennas presented here are based on a tapered connection between a diamond-shaped patch and a trapezoidal feed line. The ground plane is partial and flushed up to the feed line. The fundamental characteristics of the proposed
design—including simulated and measured return-loss and bandwidth—over the UWB band are presented in this article.

2 | DESIGN, SIMULATION, AND FABRICATION OF A DIAMOND-SHAPED MONOPOLE ANTENNA

Figure 1 shows the schematic view of the diamond-shaped monopole antenna. The monopole antenna has a metalized thickness of “T” and an inner length $L_1$ and a sectorial angle of $\theta_1$. The corner of the diamond-shaped monopole antenna is fed by a 50 $\Omega$ microstrip line, which has an inner length of $L_2$ and sectorial angle of $\theta_2$. The structure is initially analyzed by the FDTD method. In the FDTD simulation, to ensure a fast simulation with a good accuracy, a graded-mesh is used with the maximum mesh parameter of $\lambda_0/25$ with at least five discretization on each object. The 50 $\Omega$ microstrip line was calculated by using the line formula. It is observed that by decreasing the length $L_1$ of the monopole antenna, the resonant frequency of the diamond-shaped monopole antenna is increased. These chosen structures were then fabricated on an RT Duroid laminate with a relative permittivity of 2.22 and a thickness $H = 1.6$ mm.

3 | SIMULATION RESULTS OF A DIAMOND-SHAPED MONOPOLE ANTENNAS

In ref. [11], the resonant frequency of a monopole antenna is calculated using the quarter-wavelength of the resonant frequency. Recently, a new technique has been developed to calculate the resonant frequency of the unstructured resonators. In the present work, a similar approach is adopted to calculate the resonant frequency of the diamond-shaped monopole antennas as a function of inner length at a fixed sectorial angle and is given in a polynomial form as

$$f_0 = -3 \times 10^{-6} L_1^5 + 5 \times 10^{-4} L_1^4 - 0.0337 L_1^3$$

$$+ 1.0827 L_1^2 - 17.29 L_1 + 115.89$$

(1)

the polynomial coefficients in Equation 1 are specific adaptations to accommodate different sectorial angles. Figure 2 shows the comparison of a resonant frequency between the simulated diamonds shaped monopole antenna and a simple monopole wire antenna. The results show that the diamond-shaped monopole antenna resonates at a higher frequency when compared to the simple monopole wire antenna of a comparable length. The plot shows that for a simple monopole wire antenna with an inner length of 15 mm resonates at
a frequency of 5.1 GHz for the diamond-shaped monopole antenna with inner length of 15 mm resonates at a frequency of 10.8 GHz. The diamond-shaped monopole antenna has smaller physical length when compared to the simple monopole wire antenna.

4 | EXPERIMENTAL RESULTS OF A DIAMOND-SHAPED MONOPOLE ANTENNAS

A number of diamond-shaped monopole antennas with a sectorial angle \( \theta_2 \) of \( 45^\circ \) with an inner length \( L_1 \) of 15–48 mm are fabricated on a 1.6-mm-thick RT Duroid material. The thickness of the metallization of the monopole antenna structure is 0.5 \( \mu \)m and the structure is fed by using a 50 \( \Omega \) microstrip line as depicted in Figure 1.

The antennas were characterized by using two-port S-parameter measurements from 10 MHz to 20 GHz using a Keysight (E8362B) network analyzer [15]. The experimental resonant frequency is determined by using the \( S_{11} \) parameter of the monopole antenna.

The measured and simulated resonant frequency of a diamond-shaped monopole antennas with an increasing inner length \( L_1 \) are compared in Figure 3. The plot shows that the measured resonant frequencies agree with the simulated results for inner length \( L_1 \) varying from 4 to 44 mm. The quality factor and bandwidth of a diamond-shaped monopole antenna are calculated by

\[
Q = \frac{\text{Energy Stored}}{\text{Energy dissipated}} = \frac{v_0}{\Delta f}
\]

where \( \Delta f \) is the 3 dB bandwidth. The 8 mm and \( \theta_2 = 45^\circ \) sectorial angle diamond-shaped monopole antenna had a simulated factor of 48; the measured \( Q \)-factor was 42, whereas for the monopole antenna, the simulated \( Q \)-factor was 26. Higher \( Q \)-factor would be possible by increasing the metallization thickness. Figure 4 shows the comparison of a diamond-shaped monopole and simple monopole antenna. It shows that diamond-shaped monopole antenna has a higher bandwidth compared to the simple monopole antenna that has a diameter of 1.0 mm.

5 | CONCLUSION

A novel diamond-shaped monopole antenna has been simulated and fabricated for different inner lengths with very good agreement between the simulation and experimental results. The resonant frequency is approximated as a function of inner length \( L_1 \) in the form of a polynomial equation. We find that the diamond-shaped monopole antenna is more compact (in terms of physical length) compared to a conventional monopole antenna, making it attractive for wireless communication technology applications.

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A novel FSS for gain enhancement of printed antennas in UWB frequency spectrum

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1 | INTRODUCTION

Ultra-wideband (UWB) technology, being low-power and wideband, has found great applications for short-range and high-speed communications such as personal area networks, body area networks, sensor networks, medical imaging, road-safety, search and rescue systems, life-jacket, landmine detection, UWB pulse radars and smart homes,1 to name a few. The very low power spectral density assigned to UWB technology (typically less than $-40$ dBm), where on one side, makes it ideal for short-range communications, on the other side, it needs relatively high gain antennas with very stable radiation characteristics.1

Printed antennas, particularly monopole2 and slot,3 are extensively being used in UWB electronic devices due to their compact size, low profile, low fabrication cost, and ultra-wide impedance bandwidth. However, these antennas, when mounted near metallic surfaces and electronic objects inside handheld communication devices suffer from severe impedance mismatch. Moreover, these low profile antennas inherently exhibit low gain and poor directivity particularly at lower frequencies.4 In certain applications where line-of-sight communication is critical such as microwave medical imaging, see-through-wall radars, and under-rubble radars, UWB antennas with high directivity are required. Properly...