Design and characterization of a diamond-shaped monopole antenna

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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 characterisation 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.

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 multi-functional 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 paper proposes a novel diamond-shaped monopole antenna to be operated at millimetre wavelengths. It is designed and numerically simulated using the Finite-Difference Time-Domain (FDTD) method [8]. Our design is then fabricated on a RT-Duroid substrate [9] and RF characterised over the frequency range 10 MHz to 20 GHz using a network analyser. The novel diamond-shaped monopole antennas presented in this work are found to be more compact compared their simple monopole counterparts operating at the same resonant frequency, but with higher operational bandwidths. Offering ultra-wideband 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 paper.

Design, simulation and fabrication of a diamond-shaped monopole antenna:

Figure 1 shows a 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 'θ_1'. The corner of the diamond shaped monopole antenna is fed by a 50Ω microstrip-line, which has an inner length of L_2 and sectorial angle of 'θ_2'. The structure is initially analysed by the FDTD method [8]. 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 discretisation on each object. The 50Ω microstrip line were calculated by using the line formula [10]. 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 a RT Duroid laminate with a relative permittivity of 2.22 and a thickness H= 1.6 mm.

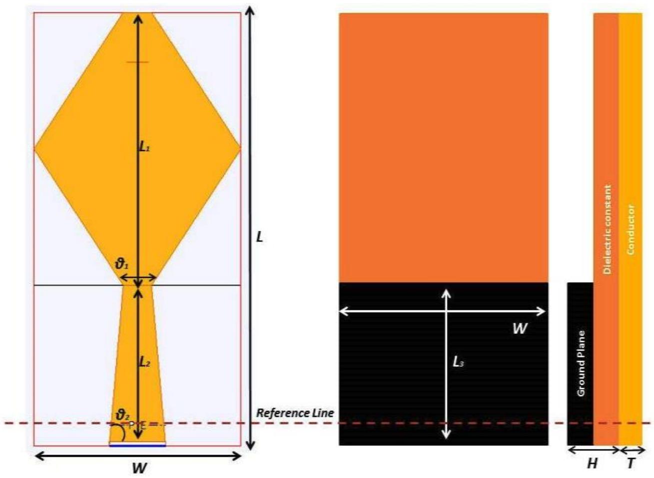

Figure 1 Diamond-shaped monopole antenna

Simulation results of a Diamond shaped monopole antennas:

In [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 [12], [13]. 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 [14]

$$f_0 = -3\times10^{-6}L_1^5 + 5\times10^{-4}\,L_1^4 - 0.0337L_1^3 + 1.0827L_1^2 - 17.29L_1 + 115.89 \quad (1)$$

the polynomial coefficients in (1) are specific adaptations to accommodate different sectorial angles. Figure 2 shows a 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 compare to the simple monopole wire antenna.

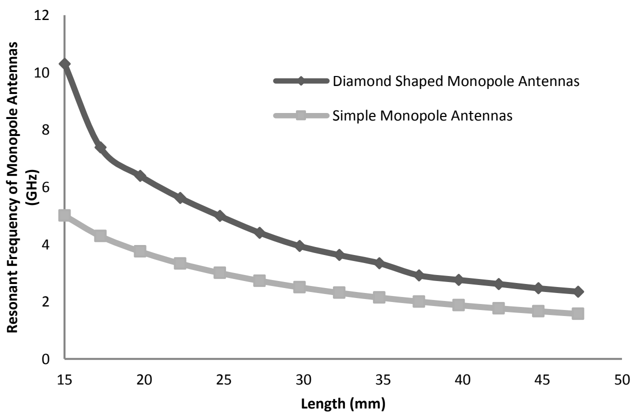

Figure 2. Comparison of the resonant frequency of diamond-shaped monopole antennas as a function of inner length L_1

Experimental Results of a Diamond shaped monopole antennas:

A number of diamond shaped monopole antennas with a sectorial angle (θ_2) of 45º with an inner length L_1 of 15 to 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 μm and the structure is fed by using a 50 Ω 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 analyser [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 agrees with the simulated results for inner length L_1 varying from 4 mm to 44 mm. The quality factor and bandwidth of a diamond shaped monopole antennas are calculated by [16]

$$Q = \frac{Energy\ Stored}{Energy\ dissipated} = \frac{f_o}{\Delta f} \quad (2)$$

where Δf is the 3-dB bandwidth. The 8 mm and θ_2=45º 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 compare to the simple monopole antenna that has a diameter of 1.0 mm.

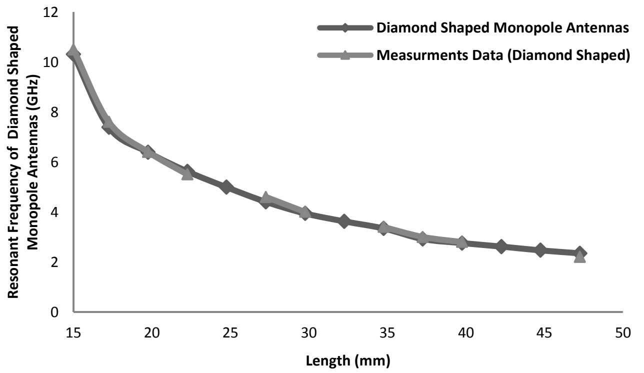

Figure 3. Measured resonant frequency of a diamond-shaped monopole antenna for different inner length L_1 and by fixed sectorial angle

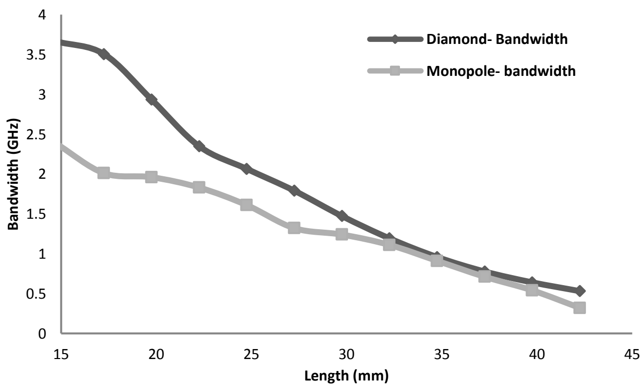

Figure 4. Comparison of the bandwidth of diamond-shaped monopole antennas and simple monopole antennas for different length

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.

Acknowledgement:

The authors would like to acknowledge the European Union Horizon 2020 research and innovation programme under grant no 664828 (NEMF21).

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