A Compact Planar Wideband Monopole Antenna with dipole like radiation characteristics for Wireless Applications

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Abstract. A planar wideband dipole antenna for wireless application is presented. The antenna consists of a basic dipole like structure with a compact size of $22 \times 12.5 \, \text{mm}^2$. The proposed configuration has a fractional bandwidth of 24% (4.4-5.64 GHz) in simulation and 29% (4.4-5.9 GHz) in measurement and centred at a frequency of 4.9 GHz (WLAN). The antenna analysis is carried out using HFSS v.13.0 on FR4 substrate material with thickness of 1.4 mm, $\delta$ (loss tangent) of 0.02 and dielectric constant ($\varepsilon_r$) of 4.4. The antenna has the advantage of simple configuration, high gain, stable dipole like radiation performances, wide bandwidth and is intended to be used for diverse wireless applications in the range of 4.4-5.9 GHz.

1. Introduction

With the advancement of technology occurring at an exponential rate, the size of electronic equipment is reducing daily. This calls for a more compact antenna design. Hence compact antennas are widespread in use corresponding to the demand of reduced space, size and weight for a wireless portable device[1-6]. The compact size is useful for antennas in cell phones and increases the range of frequency to bands such as HF, VHF, and UHF bands. Communication systems with high reliability and high data transfer are in need more than ever, prompting scientific interest in wideband communications due to their advantage such as low power consumption, high data rate, compact system size. Antenna with a fractional bandwidth greater than 20% of the centre frequency is known as a wideband antenna[7]. Wideband antenna plays a crucial role in wideband communications. These are increasingly used in wireless communication at short range because they can transmit great amount of information across a wide frequency range and low level of signals over a wideband can be sent with less amount of power as it has low interference.

To achieve the above characteristics, in this paper we present a compact, simple configuration, wide bandwidth and high gain antenna. The antenna consists of a basic dipole like structure in radiating and ground plane. The antenna is energized using lumped port excitation to achieve an impedance matching of 50 $\Omega$. The antenna exhibits return loss bandwidth for criteria $S_{11}<-10 \text{dB}$, of about 1.2 GHz (4.4-5.6 GHz) and about 1.5 GHz (4.4-5.9 GHz) in simulation and measurement respectively. The overall analysis of the antenna is performed on HFSS v.13.0 software using FR4 dielectric material. The simple configuration and dipole like radiation performances of the proposed antenna are intended to be used for various wireless applications such as, WLAN, WiMAX, satellite communications.

2. Methodology

An antenna which is compact in size has wider bandwidth, gain and reflection coefficient is beneficial for the present day usage. Therefore, in order to meet the above mentioned antenna, a wideband monopole antenna with radiating and ground patch has been designed. The antenna been
designed with the basic shape of a dipole and the layout of suggested configuration is outlined in Figure 1 and its fabricated prototype is presented in Figure 2.

The substrate on which simulations of the antenna are performed is FR-4 epoxy which has following specifications: $h=1.6\text{mm}$, $\varepsilon_r = 4.4$ and $\delta=0.02$. This structure consists of L shaped monopoles on both sides. This radiating patch produces a resonant frequency of 4.9GHz. For the design, the dimensions are calculated and optimized for setting the respective bands. The strip line patch length (D) and width (C) are calculated as [2].

\[
\frac{C}{h} = \frac{8 \exp(F)}{\exp(2F) - 2}
\]

and,

\[
F = \frac{Z_l}{60} \left[ \frac{\varepsilon_r + \frac{1}{2}}{2} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1} \right] 0.23 + \frac{0.11}{\varepsilon_r}
\]

The resonant frequency of the proposed monopole can be calculated as follows:

\[
\text{MaximumLengthofawidebandmonopole} = \frac{\lambda}{4} = \frac{c}{4f_r}
\]
Thus,

\[ f_0 = \frac{c}{4 \times (\text{maxm. length})} \approx 4.9 \text{ GHz} \]

Where \( c \) represents the velocity of light traveling in free space (\( 3 \times 10^{11} \text{ mm/sec} \)) and \( F \) is a constant. The parameters and the detailed dimensions of the configuration are mentioned in Table.1.

| Parameters           | Dimensions (in mm) |
|----------------------|--------------------|
| Substrate Length (A) | 30                 |
| Substrate Width (B)  | 30                 |
| C                    | 3                  |
| D                    | 12.5               |
| E                    | 22                 |

### 3. Parametric Analysis

To optimize the dimensions of the antenna for proper operational execution, parametric analysis is carried out. The analysis is executed by varying one dimension of the antenna while keeping other dimensions constant. The first dimension that we are going to analyse is the feed line width (C), which is first decreased by 0.5 mm and then increased by 0.5 mm. The results can be visible from the below Figure 3.

![Figure 3](image1)

**Figure 3.** Analysis of Feedline width (F)

Similarly, the next dimension that is analyzed is the feed line length (A). This is also first decreased by 0.5 mm and then increased by 0.5 mm from its optimized value 12.5 mm. The comparison of \( S_{11} \) at different lengths is depicted in the Figure 4, which shows that the optimized length is 12.5 mm.

![Figure 4](image2)

**Figure 4.** Analysis of Feedline length (A)

### 4. Results

The suggested wideband antenna is simulated utilizing HFSS software. The antenna has a fractional bandwidth of 24% (4.4-5.64 GHz) and it has center operating frequency of 4.9GHz. The Simulated \( S_{11} \) result of the proposed configuration is presented in Figure 5.

![Figure 5](image3)
The suggested antenna is inductive in nature as it has the input impedance of $(40.4+j0.11) \ \Omega$ at its operating frequency of 4.9GHz as shown in the below Figure 6.

The peak directivity, gain of the configuration are outlined in Figure 7 and Figure 8, respectively. From graph we can infer that gain increases up to a point and remains almost at a constant value. The peak directivity and gain at the resonant frequency of 4.9GHz is 2.85 dB and 2.49 dB, respectively.
The surface current variation pattern of the proposed configuration at the resonant frequency is shown in the Figure 9. At the dipole arm the current is densely populated.

The radiation pattern for the proposed configuration within the operational bandwidth is shown in Figure 10. We can infer from the plot that there is an omnidirectional pattern at $\phi = 0^\circ$ (H-plane-red) and a bidirectional pattern at $\phi = 90^\circ$ (E-plane-black). The pattern is exactly same as the dipole like radiation characteristics.
After the fabrication of a model of the proposed configuration, the $S_{11}$ of the fabrication is compared with the simulation and is presented in Figure 11. The proposed configuration has a fractional bandwidth of 24% (4.4-5.64 GHz) in simulation and 29% (4.4-5.9 GHz) in measurement. The configuration and the fabrication results are almost similar for the criteria $S_{11}<-10$dB which can be inferred from Figure 11.

![Figure 11. Simulated and measured S11 of the configuration](image)

The suggested wideband configuration’s time domain analysis such as group delay and phase response are also carried out by placing the antennas in side-to-side and face-to-face orientations as outlined in Figure 12.

![Figure 12. (a) Side-to-side and (b) Face-to-Face orientations of antenna setup in HFSS to measure time domain characteristics](image)

The group delay of the proposed configurations for both orientations are presented in Figure 13. A constant group delay (and delay is almost zero nanoseconds) is observed over the entire wide operating bandwidth of the proposed antenna in both the orientations.

![Figure 13. Group delay for both the orientations](image)
The phase response for the proposed configuration for both of the orientations are presented in Figure 14, where it can be observed that the variation of phase angle is constant throughout the operating bandwidth (i.e. 4.4 to 5.64 GHz).

5. Conclusions
A compact simple configuration wideband dipole antenna operating in the range of 4.4 to 5.9 GHz is simulated and the results are validated by fabrication and measurement. The parametric investigations such as the variation of feed width and feedline suggests that the slight variations in the optimized dimensions affect the impedance matching to a greater extent. The acceptable radiation performances such as gain, directivity and impedance bandwidth make the proposed antenna quite attractive for wireless applications such as WLAN (5.2 and 5.8 GHz) and WiMAX (5.5 GHz) applications.

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