Design Implementation of Trapezoidal Notch Band Monopole Antenna for LTE, ISM, Wi-MAX and WLAN Communication Applications †

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Abstract: This article analyses & describes a trapezoidal dual-band monopole antenna. The notch band monopole disables 4.4–5.7 GHz commercial communication equipment. The basic type operates at 2.5–4.4 GHz with a 500 MHz marginal bandwidth and 5.7–7 GHz with a 1000 MHz bandwidth. Present research optimises multiband trapezoidal antennas. Trapezoidal antennas improve multiband wireless antennas. GSM, LTE, Wi-Fi, and 5G frequency bands start design. Inefficient and space-wasting, traditional antennas lack frequency range. Benefits of trapezoids: changing trapezoidal element sizes and angles enables the antenna to transmit many frequencies, sloping trapezium sides allow impedance changes without networks or tuning, numerical calculation and electromagnetic modelling optimise the trapezoidal antenna’s performance throughout the communication band, impedance matching, gain, and radiation efficiency provide transmission reliability, and broadband trapezoidal forms eliminate band-specific antennas & switches. Simplified antenna integration makes modern devices cheaper and simpler. In multiband applications, trapezoidal antennas outperform normal antennas. The antenna fits numerous wireless communication devices and systems due to its modest size and wide band coverage. The redesigned structure with notch increases operating band bandwidth and notches application bands between 4.4–5.7 GHz. By modifying trapezoidal geometry, we generate selective impedance transition notches to target crucial interference frequencies. Modern wireless communication systems with complicated interference situations can trust its careful engineering to provide good efficiency and radiation patterns across a wide frequency band while actively rejecting interfering signal. The peak realized gains obtained at 2.5 GHz is 2.4 dB, at 3.4 GHz it is 3.5 GHz and at 5.8 GHz it is 4.7 dB.

Keywords: monopole antenna; communication applications; trapezoidal shape; notch band design; dual-band frequency

1. Introduction

There is a rising demand for microwave devices and antennas in various fields for their usage in the wide range of commercial communication applications, providing opportunities to engineers for the design of compact and novel models. The design specifications and parameters as per the future communication requirements need to be considered while developing such products. The demand for notch band antennas to restrict the operating band as per the specification is gaining its own advantage in communication fields. In the defence sector and in military communication especially, the demand for notch band antennas is to have more control on the spectrum.

The S-band rejection-based trapezoidal notch band antenna has been designed by Kaza [1]. The designed antenna model is blocking s-band and allowing L-band with ejection ratio of 36%. Ajay [2] produced a V-shaped metamaterial-based antenna with a
flared element for notching 1.2–3.2 GHz and 4.2–4.8 GHz with a rejection ratio of 38% and 32%. Mohan [3] designed a wideband antenna which operates in the range of 3.1 to 8.4 GHz with notching from 5.6 to 5.9 GHz. Kosuru [4] developed a PIN diode-based notch band antenna with reconfigurable nature to block WLAN/IEEE-802 (WLAN-Wireless Local Area Network). In total, there are 11 n bands in switching conditions. A split ring model-based structure has been used to design a metamaterial-based antenna by Venkateswara Rao [5]. The designed notch antenna structure is constituted on a conformal dielectric and the flexible characteristics are studied and found satisfactory in simulation and prototype measurement.


Antenna Modelling: A trapezoidal shaped monopole antenna is modelled into a notch band monopole with the placement of U-slot on the radiating structure [18]. Figure 1 projects the trapezoidal monopole and Figure 2 projects the notch band monopole. The dimensional view and side view of the trapezoidal monopole and the notch band monopole with coplanar waveguide feeding is presented [19]. The antenna is compact in dimensions and fabricated on the FR4 dielectric of thickness \( h \) is 1.65 mm.

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h > 0.06 \lambda_g \tag{1}
\]

where \( \lambda_g \) is the guided wavelength. The coplanar waveguide feeding with 50-ohm impedance and ground gap with of 0.2 mm is used in this model. A U-shaped lot is placed in the radiating structure to attain the band notch parameter in the initial design [20]. The notch band antenna showing band rejection from 4.4–5.7 GHz and attained the bandwidth value of 1.3 GHz.

![Figure 1. Trapezoidal Monopole Structure Antenna, (a) Dimensional View, (b) Side View.](image-url)
1.1. Benefits of Incorporating Notch Structure

The performance of an antenna and its ability to suppress interference in the 4.4–5.7 GHz band can be greatly improved by incorporating a notch structure. This is especially true in terms of bandwidth augmentation. Enhanced Bandwidth: a notch structure can reduce undesired frequencies in an antenna’s operational spectrum. This suppression allows the antenna to operate over a wider bandwidth, making it more versatile and adaptable to different communication needs. Adding a notch structure improves antenna gain, radiation pattern, and impedance matching [21]. The notch reduces resonances and standing waves, making the antenna more stable and efficient. Interference mitigation: multiple wireless communication systems coexist in the 4.4–5.7 GHz region, making interference difficult. The notch structure can target specific interfering frequencies to reduce interference and improve the antenna’s capacity to receive and transmit signals in noisy environments. Notch structures can dynamically target different interfering frequencies, allowing frequency reconfigurability. This versatility is crucial when the interference landscape changes or numerous frequency bands are needed.

1.2. The Antenna’s Frequency

The antenna’s broad frequency coverage, spanning 2.5–4.4 GHz and 5.7–7 GHz, holds significant practical implications for diverse communication systems. It finds application in 4G LTE and Wi-Fi (2.5–4.4 GHz) for improved data rates, and in 5G networks (5.7–7 GHz) for robust connectivity. Its versatility extends to IoT and various devices, offering a compact, high-performance solution for the evolving landscape of wireless technology.

2. Results and Analysis

Figure 3 elevates the structural view of the proposed antenna, impedance smith chart plot and prototyped antenna on FR4 substrate material. An impedance value of 50 ohm is attained at resonant frequencies from Figure 3b and the dimensions of the prototyped antenna in millimetre.

Figure 4 projects the scattering parameter S11 result of the designed antenna and the working range. Antenna resonating between 2.5–4.4 GHz with a 500 MHz bandwidth and 5.7–7 GHz with a bandwidth of 1000 MHz. A clear notching can be observed from 4.4–5.7 GHz with 1300 MHz bandwidth. Figure 5 shows the impedance plot of the antenna model with respect to the working and notch band. It projects the obtained impedance value of very high in the notch band.
Figure 3. Notch band Monopole, (a) Side View, (b) Smith Chart.

Figure 4. Reflection coefficient of notch band monopole.

Figure 5. Impedance plot with Frequency in GHz.

Figure 6 shows the simulated VSWR-Voltage standing wave ratio plot from the EM-tool and obtained measurement results of VSWR on an anritsu combinational device analyser. The ratio of 2:1 is perfectly aligned in the operating region and in good matching with the simulation. Dotted line is idle impedance for reference and solid line is the original result which is attained from proposed method.
The Peak Realized Gains at Different Frequencies

Different Frequency Peak Realised Gains: 2.5 GHz. At 2.5 GHz, the antenna has [Peak Gain Value] dBi. This gain number shows the antenna’s ability to focus and radiate signals at this frequency. An antenna with a higher gain at 2.5 GHz is well-optimized for this frequency and can provide improved coverage and signal propagation in this band. The solid line in above Figure 6 explains about VSWR variations at different frequencies.

3.4 GHz: The antenna’s peak gain is [Peak Gain Value] dBi at 3.4 GHz. Antenna efficiency in emitting 3.4 GHz signals is shown by this gain level. The antenna’s 3.4 GHz gain implies it can transmit and receive signals in this frequency band.

5.8 GHz: At 5.8 GHz, the antenna has [Peak Gain Value] dBi. The antenna’s 5.8 GHz performance and propagation are shown by this gain test. A high gain at 5.8 GHz indicates that the antenna can cover this spectrum well and communicate reliably.

Analysis: Peak realised gains at different frequencies demonstrate the antenna’s versatility and efficiency in processing signals across frequencies. A well-matched and optimised antenna with a high peak gain at a given frequency is useful for applications targeting that band. In modern wireless systems that operate in many frequency bands, the antenna’s ability to sustain reasonable gain values across different frequencies shows its versatility in multi-band communication settings. These gain values indicate the antenna’s radiation efficiency and signal propagation. Higher gains increase communication quality and coverage by strengthening, transmitting, and receiving signals. While the chosen keywords (ISM, LTE, Wi-MAX, WLAN) aptly reflect the antenna’s relevance, consider providing a context within the abstract about how the antenna aligns with and addresses the challenges in these communication technologies.

Radiation Analysis: Figure 7 projects the obtained radiation parameters of the antenna at three different operating bands collected from CST tool. Antenna showing 2.4 dB, 4.7 dB and 5.1 dB gain at 2.5, 3.4 and 4 GHz, respectively.

Figure 8 projects the radioactivity performance features of the proposed model at 3 different working groups that are taken from the Antenna magus tool. Antenna showing 2.4 dB, 3.5 dB and 4.7 dB gain at 2.5, 2.8 and 3.4 GHz, respectively. The polar as well as three dimensional representations are presented here for azimuthal and elevation angles.
Figure 7. Notch antenna 3D-Radiation at three bands, (a) 2.5 GHz, (b) 3.4 GHz, (c) 4 GHz.

Figure 8. Trapezoidal Notch Monopole Antenna: (a) gain ranges from 2.407 to −27.28 dB; (b) model exhibits a gain of 3.564 to −20.48 dB; (c) gain ranges from 4.749 to −23.58 dB.
3. Conclusions

A trapezoidal notch band monopole model projection is considered, analysed and articulated clearly. The designed antenna model is working at two operating bands and notching 4.4 to 5.7 GHz with 1.3 GHz bandwidth. The modelled antenna exhibit excellent impedance parameter characteristics at the operating frequencies with the nearest value to 50 ohm and high impedance values in notch band. The radiation characteristics are analysed from CST and the Antenna magus tool and presented the same with gain values. A maximum gain of 5.1 dB is attained in the operating band with directive pattern. The simulation-based results exhibit good matching with the measured parameter results on a combinational analyser in the chamber.

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References


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