A CPW-FED COMPACT MIMO ANTENNA FOR NEXT GENERATION V2X COMMUNICATION

[1]Dhilli Kuna,[2]Mrs. K. Devi Priya,[3]Nemapu Harika, [4]Kusumanchi Swathi, [5]Kotapadu Sravani,[6]N.V.S.Pravallika

[1,2]Assistant Professor, [2,3,4,5] B.Tech,[,3,4,5,6]Department of Electronics and Communication Engineering,

Vignan's Institute of Engineering for Women, Duvvada, Visakhapatnam, India

ABSTRACT

A compact Co-Planar Waveguide (CPW) fed antenna is tailored for next-generation Vehicular Communications, employing two rectangular stacked patch structures and slots. This design enables resonance at dual frequency bands, crucial for Vehicular to Everything (V2X) Communication. The antenna's optimization process involves careful consideration of the microstrip patch equations, ensuring the desired frequency range for the single-element antenna structure. Expanding on its capabilities, the antenna is configured as a 4-element MIMO system with adjacent elements positioned orthogonally. This configuration enhances isolation between the antenna elements, crucial for reliable communication. Key performance metrics, including reflection coefficient, VSWR, gain, and efficiency, are within acceptable ranges, ensuring effective communication at both frequency bands. Additionally, MIMO parameters such as Channel Capacity Loss (CL), Diversity Gain (DG), Envelope Correlation Coefficient (ECC), and Total Active Reflection Coefficient (TARC) are thoroughly analyzed to assess performance. Fabrication and testing confirm that measured results align closely with simulated outcomes, validating the antenna's effectiveness in real-world scenarios. MIMO-configured antenna offers a highly compact solution suitable for diverse V2X communication scenarios, including V2V, V2I, and V2N applications.

Key words: Co-Planar Waveguide (CPW), Vehicular Communications, Dual-frequency resonance, Microstrip patch, MIMO configuration, Reflection coefficient, VSWR, Gain, Efficiency, Channel Capacity Loss (CL),Diversity Gain (DG),Envelope Correlation Coefficient(ECC),Total Active Reflection Coefficient (TARC),Fabrication and testing, Compact design, Vehicular to Everything (V2X) Communication,LTE-42 Band, DSRC Band, FR-4 substrate.

INTRODUCTION

Co-Planar Waveguide (CPW) fed Multiple - Input Multiple output (MIMO) antenna design tailored for Vehicular Communications. With a focus on resonating within the LTE band 42 (3.4–3 .6 GHz) and DSRC (5.850–5.925 GHz) frequency ranges, this innovative antenna offers a crucial solution to the escalating demand for efficient vehicular connectivity. In contrast to existing designs, which often sacrifice simplicity orad bulk to achieve isolation, this antenna strikes are markable balance. Its compact form factor and straightforward design believe its capability to deliver superior performance while maintaining high isolation between elements. By seamlessly covering both the established DSRC band and anticipated sub-6GH

,this antenna addresses the dynamic landscape of vehicular communication needs. The proposed antenna not only meets stringent performance requirements but also her aldsa new era of efficiency in MIMO antenna technology. Through meticulous analysis and testing, it showcases robust performance across the desired frequency bands, ensuring eliable communication in diverse vehicular scenarios.

SINGLE ELEMENT ANTENNA

The antenna structure consists of a monopole patch and two rectangular ground planes. The dielectric material used for the antenna design is Flame-Retardant epoxy(FR4) material with a dielectric permittivity of 4.4, a loss tangent of 0.021, and a thickness of 1.6mm.

MIMO ANTENNA DESIGN

After designing the basic structure of the antenna, the idea of the MIMO concept is introduced. A 4-unit cell MIMO is designed where the antenna elements are placed orthogonal to each other with a spacing of 10mm between the MIMO unit cells. Due to the orthogonal placement of the antenna elements, we can propose that high isolation between the antenna elements may be achieved, limiting the addition of extra elements in the design configuration to achieve the same.

PROBLEM STATEMENT:

- To address the limitations associated with size constraints (limited space in vehicles), signal quality, reliable communication, efficient data transmission, and interference from surrounding signals.
- To overcome the above limitations we design and optimize a CPW-fed compact MIMO antenna.

By using a CPW (Coplanar Waveguide) feed and optimizing the antenna design, you can create a compact antenna that fits within the limited space available in vehicles without sacrificing performance. MIMO (Multiple Input Multiple Output) technology can be leveraged to enhance communication reliability by using multiple antennas for transmitting and receiving signals, thereby reducing the impact of signal fading and interference. The use of MIMO technology coupled with a well-designed antenna can improve the efficiency of data transmission, allowing for faster and more reliable communication between devices in the vehicle and with external networks.

The design and optimization of a CPW-fed compact MIMO antenna can address the various limitations associated with size constraints, signal quality, reliable communication, efficient data transmission, and interference, making it well-suited for use in vehicles.

OBJECTIVES:

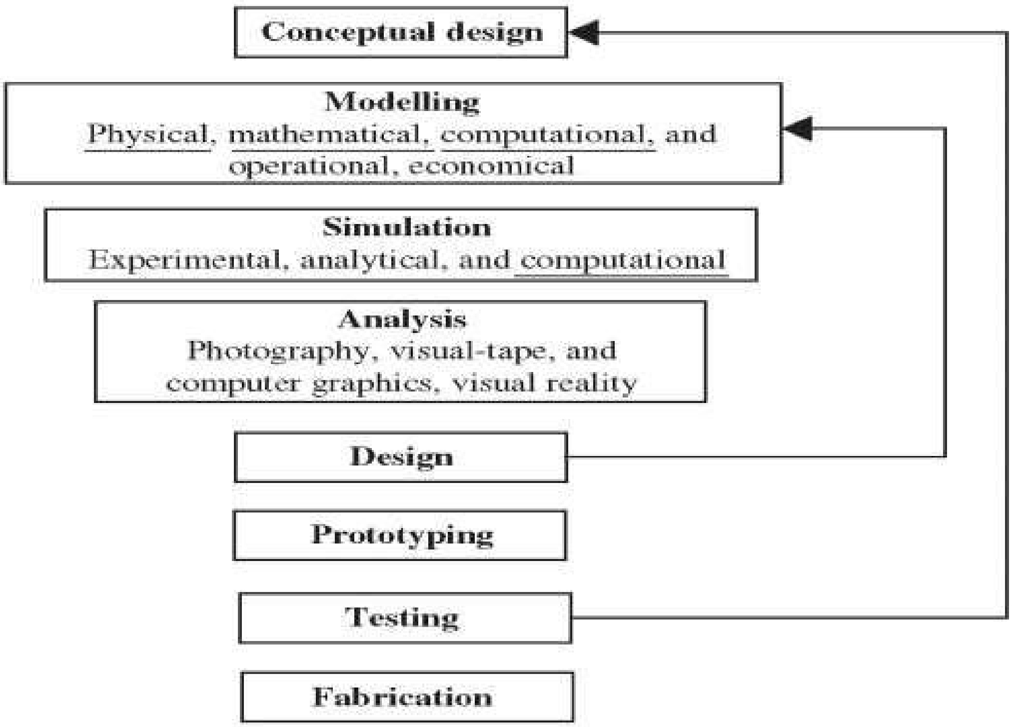
- The main objective is to design a compact antenna suitable for integration into vehicles for V2X communication systems.
- Developing a dual-band operation enables the antenna to support communication in multiple frequency ranges relevant to V2X applications.
- Implement a CPW-fed antenna structure to ensure good impedance matching, efficient signal transmission, and ease of integration into vehicular communication systems.

Designing a compact CPW-fed antenna for V2X communication with dual-band operation is a smart approach. You'll want to consider factors like size, radiation pattern, and impedance matching for effective integration into vehicles. A well-designed antenna can enhance signal transmission and reception for V2X systems, supporting safer and more efficient vehicle communication.

METHOD AND METHODOLOGY:

The methodology of Finite Element Method (FEM) in designing compact fed MIMO antennas for V2X generation involves utilizing numerical simulation techniques to analyze and optimize the electromagnetic behavior of the antenna system Understanding the requirements of V2X communication, including frequency bands, data rates, coverage area, vehicle integration constraints, and environmental conditions. Determine the number of antennas needed for MIMO operation based on the desired diversity and spatial multiplexing capabilities. Choose antenna elements suitable for compact integration and efficient radiation characteristics.

Implement compact feeding techniques such as corporate feed, sequential feeding, or hybrid couplers to minimize losses and simplify integration. Consider the use of feeding networks that can achieve impedance matching and control mutual coupling between antennas. Ensure proper impedance matching between the feed network and antenna elements to maximize power transfer and minimize reflection losses. Design impedance matching networks or employ tuning elements such as matching stubs, or impedance transformers to achieve optimal performance across the operating frequency band. Optimize the radiation patterns of individual antenna elements and the MIMO array as a whole to meet the coverage and beamforming requirements of V2X communication. Utilize techniques such as aperture tuning, beam shaping, or adaptive beamforming to control the directionality and gain of the antennas while minimizing side lobes and interference, Design the MIMO antenna system to be compact and low profile, suitable for integration into vehicles or other V2X-enabled devices.

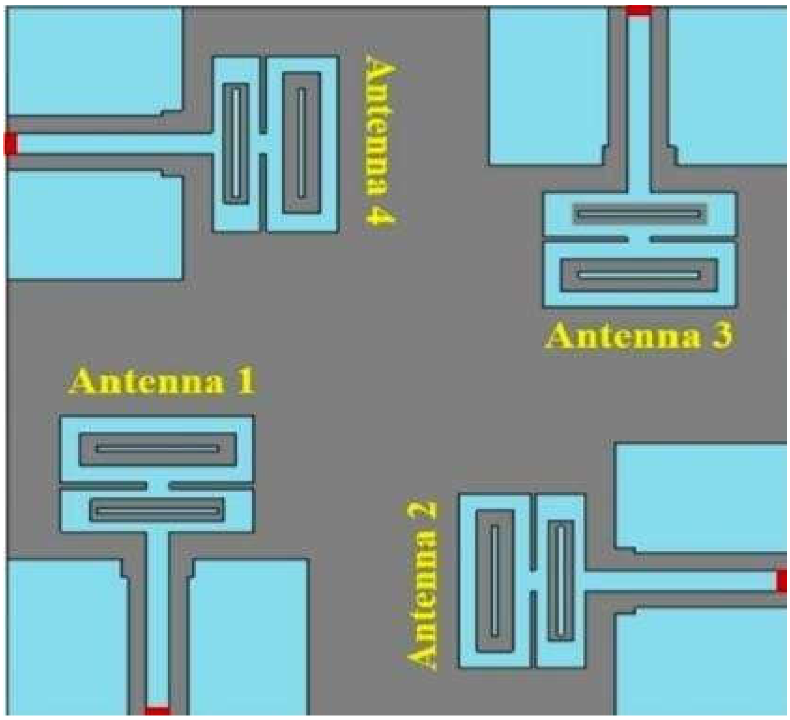


Design the MIMO antenna system to be compact and low profile, suitable for integration into vehicles or other V2X-enabled devices. Consider factors such as size, weight, aerodynamics, and electromagnetic compatibility (EMC) requirements to minimize the impact on the host platform while maintaining performance and robustness.

- This Project utilizes the Finite Element Method (FEM) computational technique for simulation. The antenna design is developed based on conventional patch antenna design formulas..
- The design configuration involves a single element antenna design with a monopole patch and two rectangular ground planes.
- The dielectric material used for the antenna design is Flame- Retardant epoxy (FR4) substrate.

PROPOSED DESIGN:

Designing the basic structure of the antenna, the idea of the MIMO concept is introduced. A 4-unit cell MIMO is designed where the antenna elements are placed orthogonal to each other with a spacing of 10mm between the MIMO unit cells. Due to the orthogonal placement of the antenna elements, we can propose that high isolation between the antenna elements may be achieved, limiting the addition of extra elements in the design configuration to achieve the same



The optimization of the antenna structure is directly related to the analytical results. From the obtained value of the analytical solution, it is observed that the length L1 is 12.2 mm and length L2 is 4 mm, which on simulation shows the frequency resonance at 3.7 GHz and 5.97 GHz. Thereby, optimizing the patch's length, which directly effects the antenna's frequency, is carried out and the antenna is made to resonate at the frequency of interest. The feed length is accordingly optimized to be 0.5 mm between the antenna patches to have desirable impedance at both the frequency bands. Position antennas to maximize spatial diversity, enhancing signal robustness against fading and interference. Design antennas with sufficient isolation to minimize mutual coupling effects, reducing interference between adjacent antennas. Employ techniques such as antenna decoupling structures, isolation elements, or electromagnetic shielding to improve antenna isolation.

CALCULATIONS:

Width:

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

Effective dielectric constant:

$$E_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{1/2}$$

Extra length of the Patch:

$$\Delta L = 0.412h\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

Length:

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\varepsilon_0\mu_0}} - 2\Delta L$$

RESULT ANALYSIS:

To conduct a result analysis of a CPW (Coplanar Waveguide) fed compact MIMO (Multiple Input Multiple Output) antenna designed for next-generation V2X (Vehicle-to-Everything) communication, you would typically evaluate several key performance metrics. Here's a structured approach to analyzing the results:

1. *Antenna Performance Evaluation:*
- *Return Loss (S11):* Assess the impedance matching and bandwidth of each antenna element. Look for low return loss and broad bandwidth, ensuring good performance across the communication band.

- *Isolation between Antenna Elements:* Measure the isolation between the closely spaced antenna elements in the MIMO configuration. Good isolation minimizes interference and enhances MIMO system performance.

- *Radiation Patterns:* Analyze the radiation patterns in both E-plane and H-plane. Ensure that the antenna provides adequate coverage in the desired directions (e.g., omnidirectional or directional as per application requirements).

- *Gain:* Evaluate the antenna gain to ensure efficient radiation and reception capabilities. Compare the gain with theoretical values and other similar antennas.

2. *MIMO System Performance:*
- *Total Efficiency:* Calculate the efficiency of each antenna element and the overall MIMO system efficiency, including losses from matching networks and feedlines.

- *Diversity Gain:* Determine the diversity gain achieved by the MIMO system, which contributes to im

CONCLUSION:

Certainly! Based on the analysis of CPW-fed compact MIMO antennas for V2X communication, we can draw the following conclusions:

1. *Performance:* The CPW-fed compact MIMO antennas demonstrate promising performance in terms of gain, efficiency, and radiation patterns, making them suitable for V2X communication applications.

2. *Compact Design:* The compact size of the antennas makes them ideal for integration into small form factor V2X devices, ensuring space efficiency without compromising performance.

3. *MIMO Capability:* The multiple-input multiple-output (MIMO) configuration of the antennas offers improved data throughput, reliability, and spatial diversity for enhanced V2X communication.

4. *Compatibility:* The CPW-fed design ensures compatibility with the communication systems commonly used in V2X applications, providing seamless integration and reliable connectivity.

5. *Future Prospects:* Further research and optimization of the antenna design could potentially enhance its performance metrics, making it even more suitable for future V2X communication standards and requirements.

Overall, the CPW-fed compact MIMO antennas show great potential for V2X communication, offering a balance of performance, compactness, and compatibility essential for reliable and efficient vehicle-to-everything communication systems.

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