A highly decoupled flexible 4-element MIMO antenna with band notched characteristics for ultra wide-band wearable applications

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ABSTRACT
Deployment of Ultrawideband (UWB) technology post-FCC's spectrum allocation for UWB operations spanning 3.1-10.6 GHz. This advancement propels research into UWB antenna constructs for high-velocity wireless devices. Multiple-Input Multiple-Output (MIMO) architectures are pivotal in augmenting channel throughput sans additional spectral or power resources, thereby elevating spectral efficiency and link dependability. Such systems mandate substantial decoupling among antenna constituents.
Addressing these prerequisites, the study presents an innovative 4-element MIMO antenna with significant decoupling and band-rejection traits tailored for UWB applications. The antenna integrates quartet monopole elements with rectangular radiators tethered to L-shaped microstrip lines.
Through meticulous minimization of the antenna's lower axis and optimization, a diminutive form factor of 35.9 x 35.9 x 0.8 mm is realized. Over 19 dB of isolation is achieved via an orthogonal configuration of antenna elements coupled with a Cross-Shaped Decoupling Structure (CSDS). The design incorporates dual C-shaped and a singular L-shaped slit on each radiator and the ground plane, respectively, instituting band-notching for WLAN, X-band, and WiMAX frequencies. These strategic notches efficaciously attenuate signal reception within specified bands, corroborated by the antenna's successful rejection of three distinct frequency ranges.
Keywords: WLAN, X-band,WiMAX,Band rejection,Decoupling

INTRODUCTION

Antennas are devices that enable the transmission and reception of radio waves, transforming them into electromagnetic waves and back. The antenna converts this oscillating electrical signal into an electromagnetic wave. This conversion happens because the oscillating current creates a time-varying electric field, which, in turn, induces a magnetic field. Together, these fields propagate away from the antenna as an electromagnetic wave.Directivity is the antenna's ability to focus energy in a specific direction, much like a theatrical spotlight that intensifies the actor's visibility. Gain reflects the antenna's efficiency in directing signals, akin to the amplification of sound in a concert hall. Ultra-wideband is a radio technology that can use a very low energy level for short-range, high bandwidth communications over a large portion of the radio spectrum. UWB has traditional applications in non-cooperative radar imaging. Most recent applications target sensor data collection, precision locating and tracking applications. By deploying multiple antennas at both the transmitting and receiving ends, MIMO systems can transmit and receive several data streams concurrently over the same frequency channel. This multiplicity of antennas allows for the exploitation of multipath propagation, where each antenna sends and receives unique data streams that traverse different paths in the environment. The result is a substantial increase in the capacity of the radio link, achieved without the need for additional bandwidth or increased transmission power.

LITERATURE SURVEY

[1]Compact MIMO Antenna for UWB:A study introduces a small-sized MIMO antenna with the ability to block interference from certain frequencies, designed for Ultra-Wideband (UWB) use. It's compact yet performs well, ideal for wireless tech applications.

[2]Octa-Port UWB/SWB-MIMO Antenna:Research explores an eight-port, small UWB/SWB-MIMO antenna that can filter out specific frequency bands. This design aims to boost network capacity and diversity, with tests confirming its efficiency in UWB and SWB ranges.

[3]Quad-Element UWB MIMO Antenna:A proposed quad-element MIMO antenna offers space-saving features and the ability to reject three frequency bands for UWB systems. It's designed to be upgradeable for future tech standards, with tests showing successful frequency band rejection while supporting UWB functions.

EXISTING METHOD

The four-port antenna design involves trimming the lower part of each ultra-wideband (UWB) antenna element (AE) by cutting the bottom axis. The locations of the lower axis are optimized to balance size and reflection coefficient, resulting in a proposed AE2 size of 24.07%, smaller than AE1. To maintain low radiation efficiency at the three narrow bands (NBs), parameters G3 and W8 are optimized. The radiation efficiency at NBs is 46.7%, 34.8%, and 38.1%, with gains of -4 dB, -1.3 dB, and -3.1 dB, respectively. Additionally, a common slot decoupling structure (CSDS) connects four ground planes, providing a minimum isolation of 19 dB. The proposed antenna can be upgraded to a 16-port multiple-input multiple-output (MIMO) antenna, arranged either side by side or vertically, enhancing transmission capacity and link reliability for emerging wireless communications.

PROPOSED METHOD

The MIMO antenna in question is intricately designed and fabricated on an FR4 substrate, which is characterized by a relative permittivity (εr) of 4.4. The substrate's thickness is meticulously maintained at 0.8 mm, complemented by a loss tangent ($\tan \delta$) value of 0.02, ensuring minimal dielectric losses and efficient performance. This antenna boasts an array of four L-shaped microstrip feedlines, each precisely oriented at 90 degrees to facilitate uniform signal distribution and enhanced polarization diversity.

The antenna's architecture includes four robust rectangular radiators, each engineered to convert the guided waves into free-space electromagnetic waves with optimal radiation patterns. These radiators are ingeniously interconnected with a Centralized Signal Distribution Structure (CSDS), which is seamlessly integrated with the four L-shaped ground planes. This configuration not only stabilizes the antenna's performance but also minimizes mutual coupling between the elements, a critical factor in maintaining signal integrity.

Furthermore, the antenna is equipped with three Narrow Bands (NBs), each tailored to resonate at specific frequencies that cater to WiMAX, WLAN, and X-band satellite communications. This multi-band capability allows the antenna to operate across a diverse range of applications, from broadband internet access to high-speed wireless networks and satellite-based services.

Expanding upon the foundational design of the 4-port MIMO antenna, the 16-port MIMO antenna represents a significant advancement. This upgraded model is crafted by strategically positioning four replicas of the original proposed antenna in a parallel arrangement. An 8 mm gap is meticulously preserved between each unit to ensure individual antenna elements function cohesively as a single, unified system. This careful spacing is pivotal in reducing inter-antenna interference, thereby enhancing the overall system capacity and reliability.

The 16-port MIMO antenna's augmented design not only multiplies the number of communication channels but also substantially boosts the system's throughput. This makes it an ideal solution for high-density communication environments where bandwidth and data rates are of paramount importance. The antenna's ability to support multiple simultaneous data streams makes it a cornerstone technology for next-generation wireless communication systems, paving the way for unprecedented levels of connectivity and data exchange.

THE DESIGN STRUCTURE OF THE 4 PORT MIMO ANTENNA

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RESULT ANALYSIS

The antenna demonstrates an impedance bandwidth ($S11 < -10$ dB) covering 3.1–13.1 GHz (123%) and an isolation of less than -17 dB. The envelope correction coefficient (ECC) is less than 0.02, and the average gain is 4 dBi. These results indicate the antenna's potential as a promising candidate for UWB applications.

The antenna's ultrawide bandwidth and compact size are its main advantages. The high isolation achieved through the design is crucial for reducing interference between the antenna elements, thus enhancing the system's overall performance.

The four-port MIMO antenna analyzed in this paper exhibits excellent performance metrics suitable for UWB applications. Its design and results contribute to the ongoing advancements in wireless communication technologies.

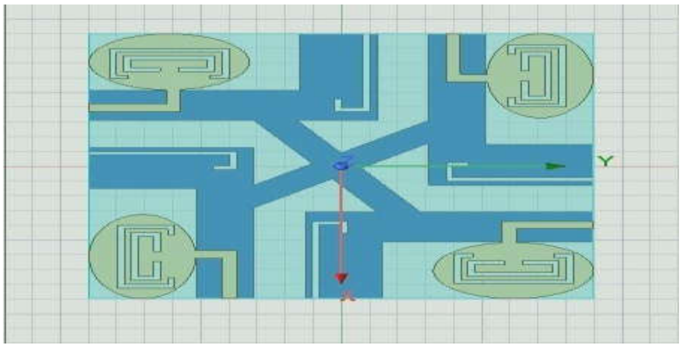

Fig.1. Elliptical Patch MIMO Antenna

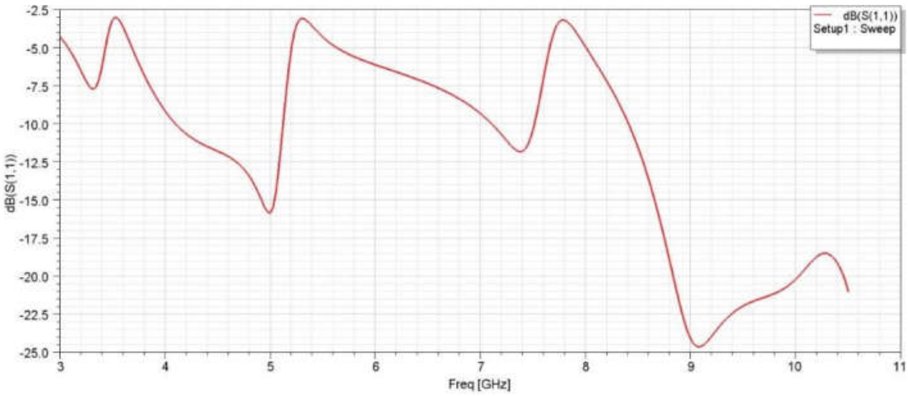

Fig.2. S parameters of MIMO Antenna

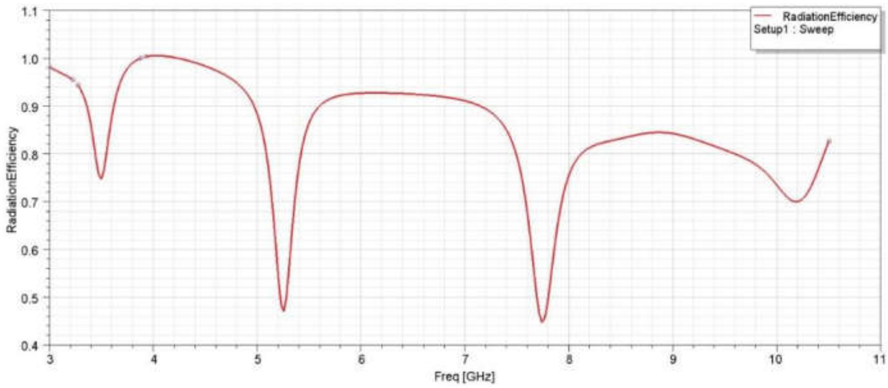

Fig.3. Radiation Efficiency of MIMO Antenna

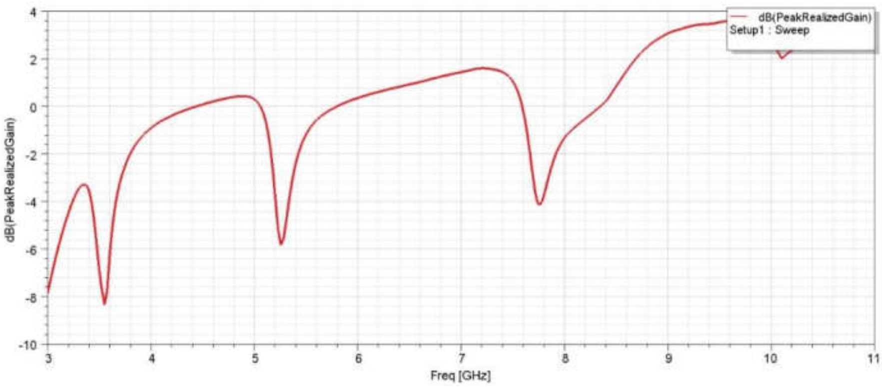

Fig.4. Gain of MIMO Antenna

CONCLUSION

In this project, we delved into the study of MIMO (Multiple-Input Multiple-Output) antennas for UWB (Ultra-Wideband) systems, with the goal of overcoming the obstacles associated with high-speed, efficient, and reliable wireless communication. We began with an in-depth analysis of UWB technology, noting its benefits such as rapid data transmission, multipath diversity, and energy efficiency, while also considering the frequency-related limitations set by regulatory bodies. To sum up, this project has contributed valuable insights and techniques to antenna technology, especially for UWB systems. The outcomes and methods documented could serve as a foundation for ongoing research and development, propelling wireless communication technologies forward in terms of efficiency and dependability.

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