Performance Enhancement of Dual Polarized Array Antenna for Modern Wireless Applications

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Abstract: This paper presents a performance-enhanced of dual-polarized array antenna designed for modern wireless communications covering 2G, 3G, and LTE frequency bands. The proposed antenna employs orthogonally arranged Y-shaped dipole elements combined with structural miniaturization and multi-resonant techniques to achieve wide impedance bandwidth, high port isolation, and stable radiation characteristics. Bandwidth enhancement is realized through bent dipole arms and shorting stubs, which collectively introduce multiple resonant modes across the operating band. A reflector with sidewalls is incorporated to suppress back radiation and improve forward gain. In addition, a director is used to further enhance the overall gain of the antenna. Simulation results demonstrate an impedance bandwidth of approximately 1.68–2.69 GHz with isolation better than 25dB, array gain around 18.6-20.2dBi, and port to port tracking less than 1dB. This proposed antenna offers a compact, broadband, and high-performance solution for modern wireless communication systems.

Keywords: Array antenna, Beam width, Dual polarized, Isolation, Modern wireless communications,

Abstract: Dual-polarized antennas are widely employed in modern wireless communication systems due to their ability to mitigate multipath fading, improve channel capacity, and enhance spectral efficiency [1], [2]. With the rapid expansion of 2G, 3G, and LTE services, base station antennas are required to support wide impedance bandwidths, high port isolation, stable radiation patterns, and compact physical dimensions. Achieving all these requirements simultaneously remains a challenging task in antenna design. Conventional dual-polarized antennas, such as crossed dipoles, patch antennas, and slot-based structures, have been extensively investigated. Crossed dipole antennas provide good polarization diversity but often suffer from large size and limited bandwidth [3]. Patch-based dual-polarized antennas offer low profiles; however, their impedance bandwidth is generally narrow and insufficient for wideband base station applications [4], [5]. Slot and magneto-electric dipole antennas can achieve wide bandwidth and high isolation, but they usually involve complex three-dimensional or heavy metallic structures, making them unsuitable for large-scale deployment [6].

To overcome these limitations, several bandwidth enhancement techniques have been proposed, including parasitic loading, dipole bending, and the introduction of multi-resonant structures [7], [8]. Inspired by these approaches, this work presents a performance-enhanced dual-polarized antenna that combines bent dipole elements and impedance-matching stubs. In addition, a director is used above the radiating element to enhance the overall gain of the MIMO antenna. The proposed design achieves wide bandwidth, high isolation, and stable radiation characteristics while maintaining a compact and practical structure suitable for modern wireless communications.

Antenna Design

The proposed dual-polarized antenna consists of two orthogonally arranged Y-shaped dipole radiators printed on an FR-4 substrate with a relative permittivity of 4.4 and a thickness of 0.8 mm. Each dipole is excited independently through a microstrip feeding network, enabling ±45° dual-polarization operation. The feeding lines are arranged in a crossed or Y-shaped configuration to ensure balanced excitation and high port isolation.

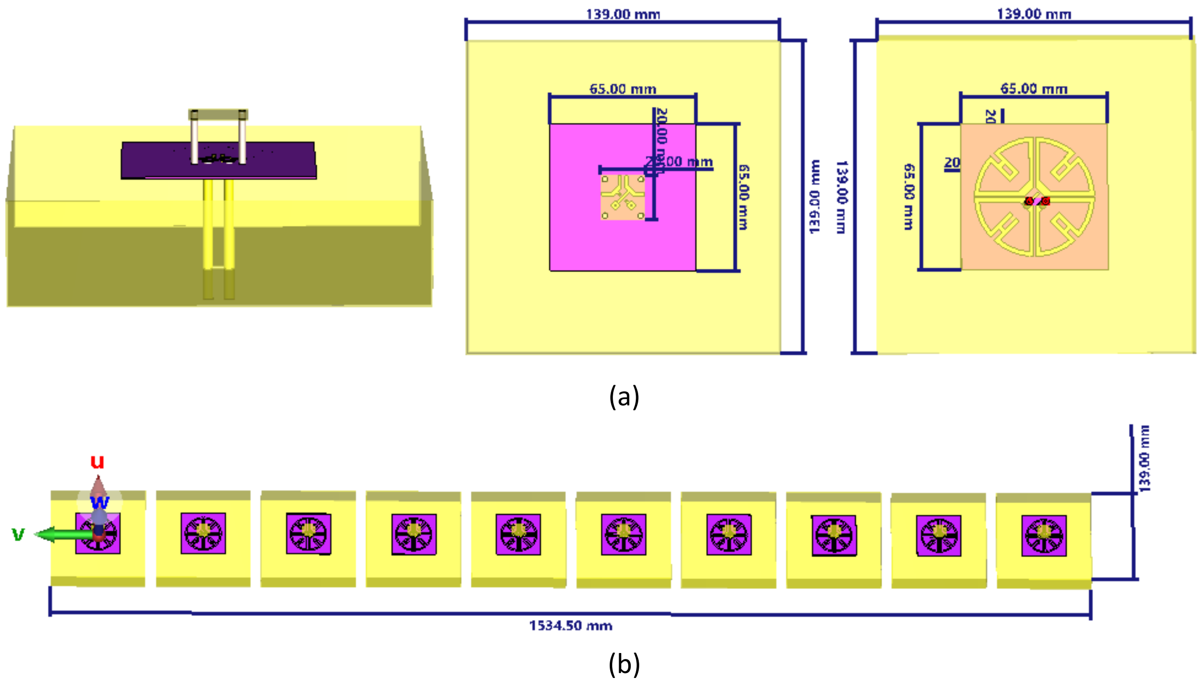


Figure 1. Proposed dual polarized MIMO antenna (a) Single antenna element (b) Array antenna

To reduce the overall antenna size and improve bandwidth performance, the dipole arms are bent and loaded with shorting stubs. The bending of the dipole arms effectively increases the electrical path length without increasing the physical footprint, while also introducing an additional resonant mode at higher frequencies [9], [10], [11]. Shorting stubs and metallic vias are incorporated to improve impedance matching across the entire operating band. These elements help stabilize the input impedance by controlling the current distribution at higher frequencies, thereby merging multiple resonant modes into a single wide operating band. In addition, a director is used above the radiating element to enhance the overall gain of the proposed MIMO antenna.

A metallic reflector with sidewalls is placed beneath the radiating structure to achieve unidirectional radiation, suppress back lobes, and enhance antenna gain. The overall antenna height is maintained for making the design compact and suitable for installations.

Simulation Results and Discussion

The antenna performance is evaluated using full-wave electromagnetic simulations. The simulated reflection coefficients show that the proposed antenna achieves a wide impedance bandwidth from approximately 1.68–2.69 GHz for $|S_{11}| < -10$ dB (or VSWR < 1.5), fully covering the operational bands required for 2G, 3G, and LTE systems as shown in figure 2. The simulated port isolation between the two orthogonal polarizations and same polarization better than 24 dB across the entire operating band which indicating excellent polarization purity and minimal mutual coupling. This high isolation is mainly attributed to the orthogonal dipole arrangement and the optimized feeding structure as shown in Figures 3 and 4. Port to port isolation between polarization lies less than 1dB which is good for the modern wireless communications MIMO antenna.

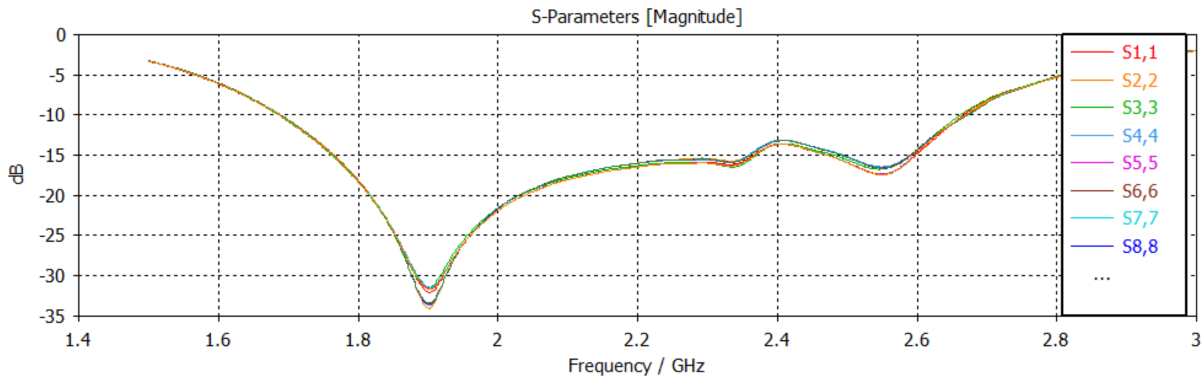


Figure 2. Return Loss with respect to frequency

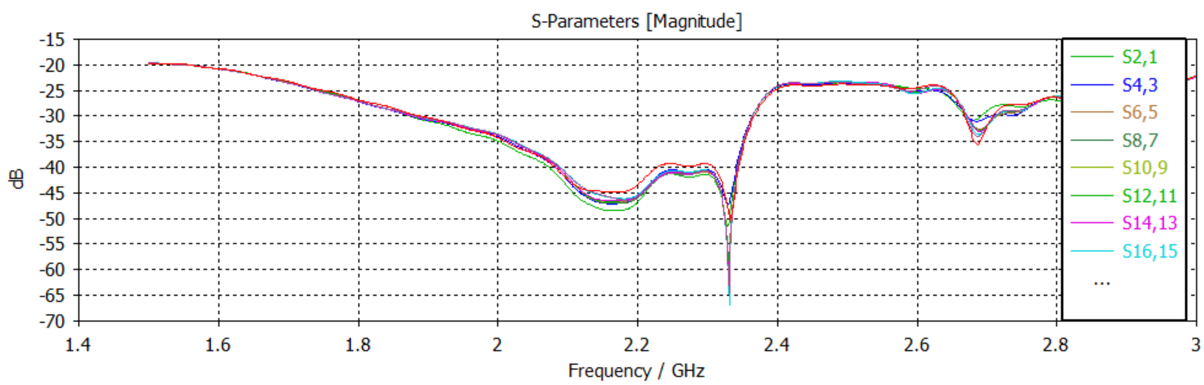


Figure 3. Isolation with respect to frequency (Between Polarizations)

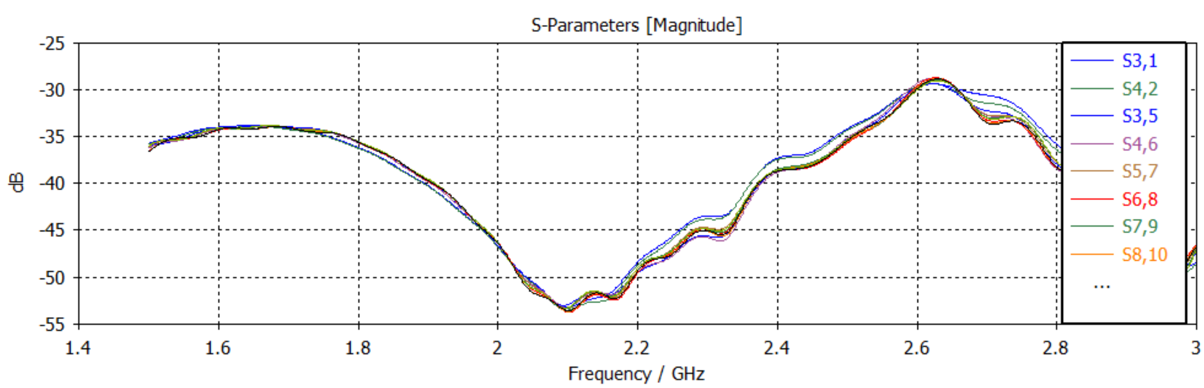


Figure 4. Isolation between same polarizations (Same Polarizations)

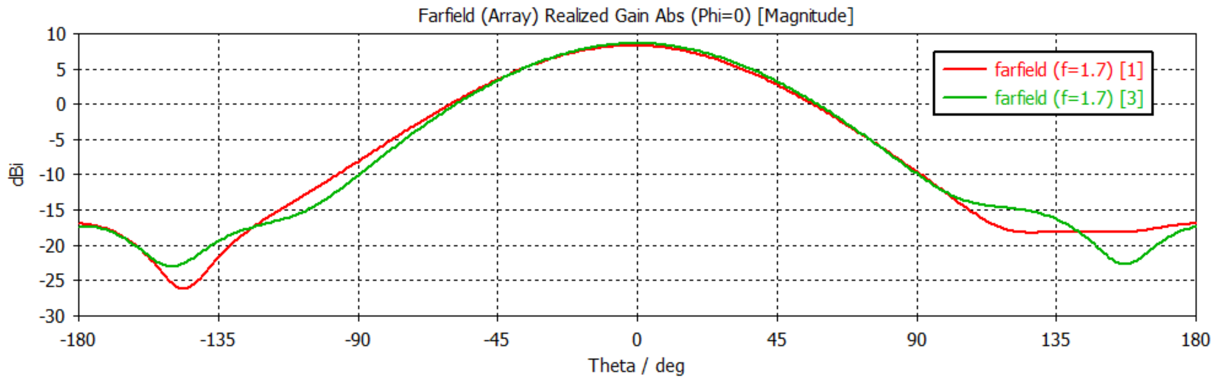
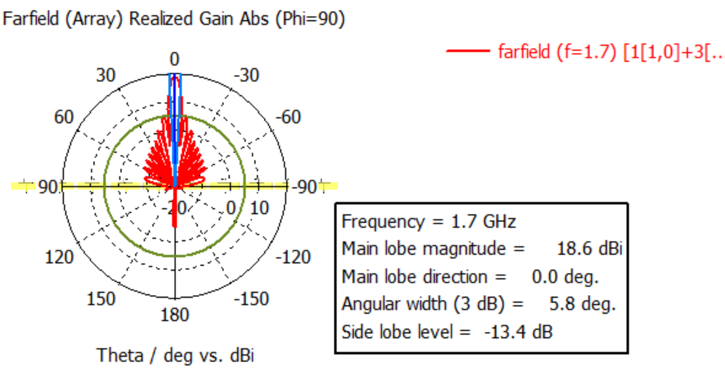
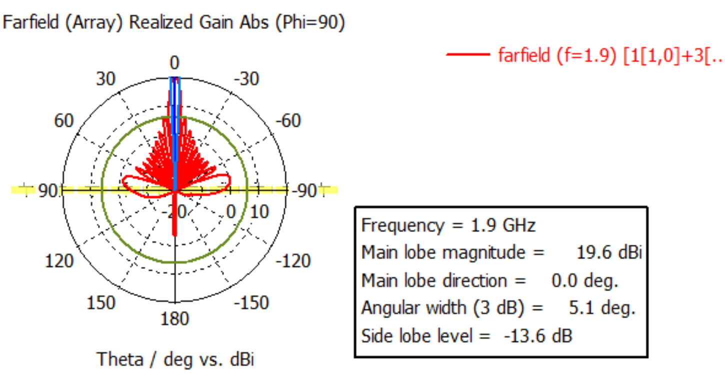


Figure 5. Port to Port Tracking



(a)



(b)

Figure 6. Radiation pattern of the proposed MIMO antenna (a) 1.7GHz (b) 1.9GHz

The Radiation pattern analysis demonstrates stable and symmetrical patterns for ±45° polarizations. The antenna exhibits a consistent horizontal half-power beamwidth of approximately 65°-70° and vertical half-power beamwidth of approximately 5°-5.8°, which is well suited for sectorized base station antenna coverage. The realized gain remains stable across the band, with values around 18.6-20.2dBi. In addition, the presence of the metallic reflector significantly suppresses back radiation, achieving back lobe levels below −20 dB and improving the front-to-back ratio. These results confirm that the proposed antenna provides a balanced combination of wide bandwidth, high gain, and stable radiation performance as shown in figure 6. Detailed comparison with previous works and proposed work are presented in table 1.

Table 1. Compares this work with the related work or previous research by other researchers

Ref	Geometry	Dimension (mm)	Frequency (GHz)	Isolation (dB)	Gain (dBi)	Array Gain (dBi)
[9]	Crossed Dipole	100×100	1.65-2.73	26	9	NO
[10]	Crossed Dipole	140×140	1.65-2.84	26	7.9	NO
[11]	Crossed Dipole	139×139	1.68–2.69	25	9	NO
This work	Crossed Dipole	139×139	1.68–2.69	25	9	18.6-20.2 (Array Gain)

Conclusions

A performance-enhanced dual-polarized MIMO antenna for modern wireless communications has been presented. By integrating bent dipole elements, shorting stubs, and a director, wide impedance bandwidth, high port isolation, high gain and stable radiation characteristics are successfully achieved. The proposed antenna operates over the 1.68–2.69 GHz frequency range, provides isolation better than 25 dB, and maintains a stable array gain. Due to its compact structure, broadband performance, and reliable radiation behavior, the proposed antenna is well suited for 2G, 3G, and LTE base station deployments. The design methodology can also be extended to future wireless systems with minor structural modifications.

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