

Design and Implementation of Reconfigurable Intelligent Surfaces with Active Devices

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The rapid development of wireless communication technologies is driven by the need for faster data speeds, lower latency, and better spectral efficiency, especially with the rollout of 5G and the upcoming 6G networks. As these networks evolve, they face new challenges like higher path loss, signal blockages, and limited coverage, which make it clear that innovative solutions are needed. Reconfigurable intelligent surfaces (RIS) are gaining attention for their ability to dynamically manipulate electromagnetic waves. By improving coverage and addressing signal issues, RIS offer a cost-effective and energy-efficient way to boost wireless communication performance, making them a key solution for overcoming the challenges in next-generation networks.

This paper presents the design, simulation, and implementation of a reconfigurable intelligent surface (RIS) aimed at enhancing beamforming and beam steering capabilities for future 5G and 6G mobile communication systems. The RIS incorporates a split-ring resonator (SRR) unit cell with a single varactor diode, which enables precise capacitance tuning and generates four distinct phase states, forming a 2-bit unit cell. Operating at 23.8 GHz within the 5G New Radio (NR) frequency range 2 (FR2), the design supports dynamic beam steering over a broad azimuth range of -60° to 60° , which is crucial for improving coverage in the demanding mm-wave spectrum. Simulation results using the CST 3D electromagnetic (EM) simulator demonstrate effective beam steering from -10° to -60° and 10° to 60° , with a minimal scan loss of approximately 3 dB. The layout of the simulated unit cell is shown in Fig. 1, and the implemented prototype is depicted in Fig. 2. A comparison between the simulation and measured results at the resonant frequency confirms their consistency, as shown in Fig. 3. Phase control for RIS beam steering at 23.8 GHz, including both continuous and 2-bit cases, is presented in Fig. 4.

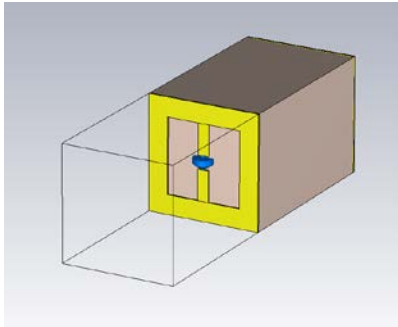


Figure 1: Layout of the proposed 2-bit unit cell.

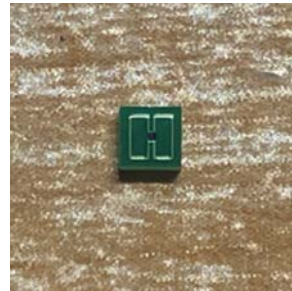


Figure 2: Prototype of the proposed 2-bit unit cell.

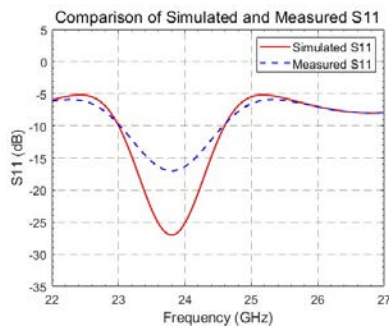


Figure 3: Comparison of simulation and measurement results

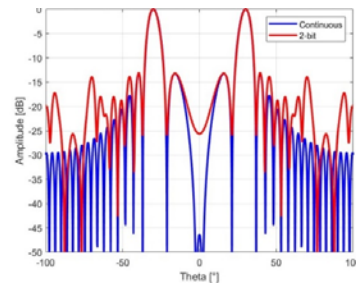


Figure 4: RIS Beam Steering at 23.8 GHz