Chapter 2

Survey on Beamforming Techniques for 5G Antennas

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ABSTRACT

Beamforming antennas have become essential for the growth of high-capacity and energy-efficient wireless communication systems, specifically in 5G and future 6G networks. In 5G, hybrid and digital beamforming facilitate the efficient use of millimeter-wave (mmWave) and sub-6 GHz spectrum, in contrast to 6G, advanced

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concepts such as reconfigurable intelligent surfaces (RIS), terahertz (THz) communications, and near-field beamforming are expected to drive unparalleled performance.The present research provides an in-depth review of beamforming techniques employed in both 5G and 6G communication systems. Comparitive analysis are included to show the variations in design, frequency use, performance trade-offs, and developing use cases. The review outlines challenges such as hardware complexity, energy efficiency, and scalability, offering insights into future research areas for achievable beamforming deployment in beyond-5G and 6G systems.

INTRODUCTION

Beamforming has become a cornerstone of wireless communication, which facilitates directed signal transmission and reception, thereby improves spectrum efficiency, energy efficiency, and communication dependability. Beamforming is the method of directing energy over a channel to a certain receiver. With the deployment of 5G New Radio (NR), beamforming—particularly hybrid and digital architectures—is critical in enabling massive MIMO at mmWave frequencies (FR2). As 6G emerges, network aspirations exceed typical 5G ambitions, concentrating on ubiquitous connection, ultra-low latency (<0.1 ms), terabit-per-second data throughput, better energy efficiency, and native AI integration.

Advanced antennas utilize cutting-edge beamforming and MIMO methods, which appear to be efficient approaches for improving user experience, capacity, and coverage. Unlike ordinary antennas, adaptive antennas change their radiation pattern in response to rapidly changing traffic and multi-path radio propagation parameters. Additionally, several signals with unique radiation patterns can be received or delivered at exactly the same time. Constructive augmentation of the matching signals can be accomplished at the User Equipment (UE) receiver by altering the phase and amplitude of the broadcast signals, enhancing the received signal intensity and thereby enhancing throughput, as seen in Figure 1.

Beamforming is an approach to acquire signal energy by employing MIMO antenna. MIMO is meant to increase throughput. MIMO operates on the idea that when the received signal quality is exceptional, receiving many streams of data with lower power streams is efficient. Phased array antenna, reconfigurable antenna with substrate-integrated waveguide (SIW). SIW technology is extensively employed in the development of Beam Forming Network (BFN) antennas (Lu et al.,2020). Antenna in Package (AiP) uses a phased array to regulate the multidimensional stimulation of individual antenna elements (Gao etal.,2021). A reconfigurable array may create stronger beams at multiple locations.