IMPROVING THE EFFICIENCY OF WIRELESS COMMUNICATION SYSTEMS BASED ON MIMO AND MU-MIMO TECHNOLOGIES

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Abstract: *Modern wireless communication systems require high data rates, reliable connectivity, and the ability to serve multiple users simultaneously. In this context, multi-antenna transmission technologies have become one of the most effective solutions for improving system performance. This paper discusses the fundamental principles of MIMO (Multiple-Input Multiple-Output) and MU-MIMO (Multi-User MIMO) technologies and their role in enhancing the efficiency of wireless communication systems. The advantages of using multiple antennas at the transmitter and receiver sides are analyzed, with particular emphasis on spatial transmission and beamforming techniques. It is shown that MU-MIMO technology enables simultaneous data transmission to multiple users within the same frequency spectrum by exploiting spatial separation, thereby increasing system throughput and reducing inter-user interference. The importance of beamforming and antenna arrays in improving signal quality through coherent signal combining is also highlighted. In addition, practical applications of MIMO and MU-MIMO technologies in modern wireless systems such as 4G, 5G, Wi-Fi, IoT, and smart city infrastructures are discussed.*

Keywords: *MIMO, MU-MIMO, beamforming, antenna arrays, wireless communication systems, spatial transmission.*

In modern wireless communication systems, high data rates, reliable connectivity, and the ability to serve a large number of users simultaneously are among the most important challenges. The continuous increase in the number of users and the sharp growth in the volume of transmitted information require efficient utilization of the available frequency resources. For this reason, approaches based on multi-antenna transmission technologies have been widely developed in recent years [1]. One such technology is MIMO (Multiple-Input Multiple-Output), which is based on the use of multiple antennas at both the transmitter and the receiver. This approach enables an increase in the throughput and reliability of communication systems by exploiting the spatial dimension. An advanced form of MIMO technology, known as MU-MIMO (Multi-User MIMO), provides the capability to transmit information to multiple users simultaneously. In conventional SISO (Single-Input Single-Output) systems, transmission and reception are carried out using a single antenna. In such systems, signal fading and noise have a significant impact on communication quality. In contrast,

MIMO technology employs multiple transmit and receive antennas, making it possible to transmit multiple signal streams at the same time. The main difference between MIMO and SISO systems lies in the use of multiple antennas Fig.1 [1].

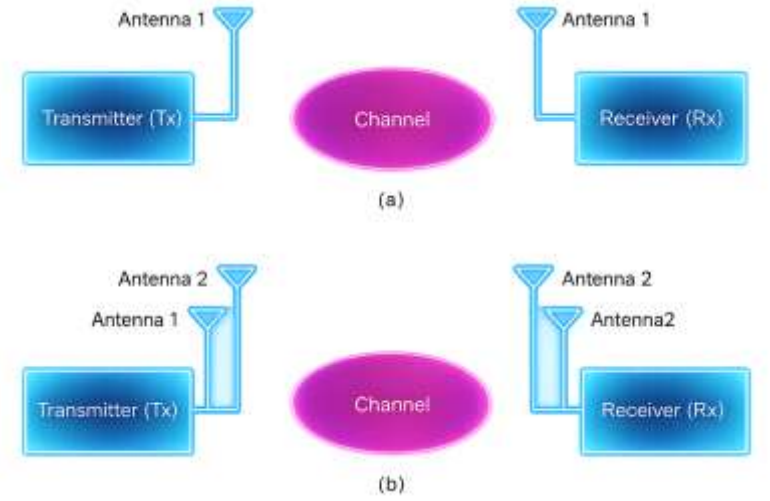

Figure 1. General structure of SISO and MIMO technologies:

(a) Single transmitting and receiving antenna (b) Spatial transmission through multiple transmitting and receiving antennas.

In MU-MIMO technology, the transmitter serves several independent users simultaneously. In this case, the signal for each user is formed in a separate spatial direction, while a common frequency spectrum is shared. This approach makes it possible to increase the overall system throughput and reduce inter-user interference (Fig. 2) [3, 4]. The performance of MIMO and MU-MIMO systems largely depends on beamforming technology, that is, the formation of directional radiation patterns. In the beamforming process, high-frequency signals transmitted from multiple antennas are radiated with specific phase and amplitude shifts.

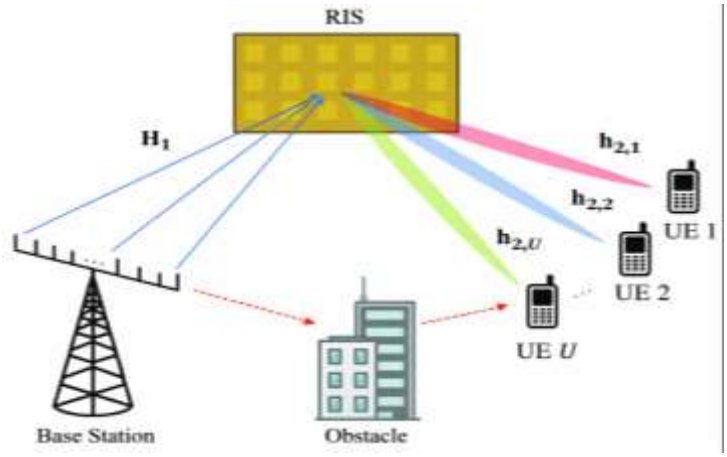

Figure 2. Spatial transmission by users in MU-MIMO technology.

If the transmitted signals combine in phase at the location of the receiver, constructive interference occurs. As a result, the received signal power increases coherently and communication quality improves. At the same time, signal strength in undesired directions is reduced, leading to a decrease in noise and interference Fig.3 [2, 5]. Today, MIMO and MU-MIMO technologies are widely used in many modern wireless

communication systems. In mobile communication networks (4G LTE and 5G), these technologies provide high data rates and reliable connectivity. In Wi-Fi technologies, they enable efficient simultaneous service to multiple devices [4].

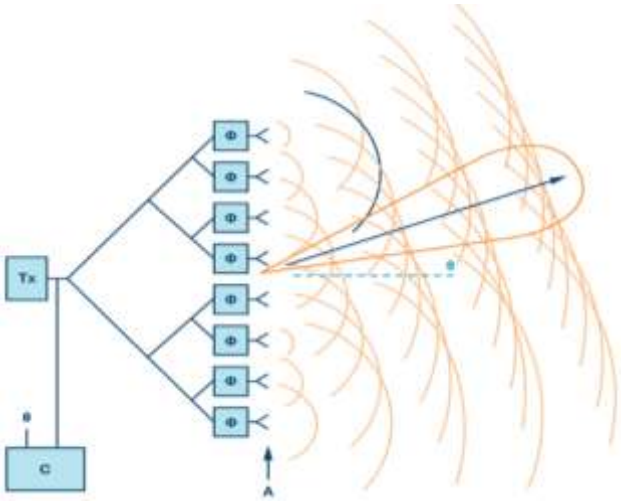

Figure 3. Synchronous coherent addition of signals using antenna arrays.

In addition, MIMO technologies play an important role in enhancing communication reliability in wireless sensor networks, Internet of Things (IoT) systems, and smart city infrastructures [4, 5].

Conclusion. MIMO and MU-MIMO technologies are important solutions that significantly enhance the efficiency of modern wireless communication systems. By utilizing multiple antennas and spatial transmission principles, data transmission rates and communication quality are improved. Beamforming technology further increases system performance by concentrating signal power in desired directions. In the future, the increase in the number of antenna elements and the development of signal processing algorithms are expected to lead to even wider adoption of MIMO technologies.

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