Optimal Modulation Design for MIMO Communication

Villanova University Investigator

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Background and Unmet Need

Precoding and modulation are important modules in wireless transmissions. Precoding designs improve the spectral efficiency and system performance in multi-input multi-output (MIMO) systems. Modulation is the process of varying one or more properties (amplitude, phase, and/or frequency) of a carrier signal, with information, e.g., bits, to be transmitted.

Existing modulation methods for wireless communication primarily are designed in a complex-valued plane, i.e., focusing on the in-phase and quadrature (I/Q) components. Current communication methods utilizing MIMO systems include separately designed modulations for each sub-channel and provide sub-optimal approaches for symbol error rate (SER) reduction due to independent design and the use of regular structures for symbols. This process introduces novel concepts to improve SER performance and enhance the efficiency of MIMO systems.

Opportunity

Dr. Vaezi has developed an apparatus and method to improve bit error rates within wireless communications. Instead of traditional Euclidean distance, the Vaezi lab has implemented Mahalanobis distance (MD) to separate symbols within the constellation. Dr. Vaezi offers a unified approach that consists of designing constellations and precoding for all antennas simultaneously. Recent experiments conducted by Dr. Vaezi revealed a notable average efficiency improvement of approximately 35% in performance related to bit error rate (BER) across three test cases. This technology will be particularly effective in cases where BER already is skewed high.

The Vaezi system will allow for a hybrid / unified approach that generates constellation and precoding for all antennas of a MIMO system simultaneously. The multiplexing gain of multiple-input and multiple-output systems is used in this technology to enlarge the dimension of the constellation space, significantly improving SER performance on point-to-point transmissions.

The system includes a plurality of antennae and a transmitter communicatively coupled to the plurality of antennae. The transmitter is configured to receive digital data for transmission and to parse the digital data into data groups of a predetermined number of bits. Further, the transmitter is configured to apply joint constellation and precoding process to the data groups and, based on the application of the joint constellation and producing process, generate corresponding transmit symbols.

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The global Massive MIMO market has been valued at $2.8 Bn in 2022 and is projected for significant, rapid growth to $77.1 Bn by 2030 at a Compound Annual Growth Rate (CAGR) of 51.5%.[1] Significant investments in advancing communication technologies such as LTE and 6G drive this growth.

Unique Attributes

- A hybrid or unified approach that includes constellation generation and precoding into a fully integrated MIMO system.
- Multiple-input and multiple-output (MIMO) systems to enlarge dimensions of constellation space, improving symbol error rate and point-to-point transmission performance
- Deployment of Mahalanobis distance to separate symbols within the constellation.

Applications

The technology is applicable for advanced communication technologies to substantially improve bit error rare and transmission performance.

Stage of Development

Prototype and Proof of Concept.

Intellectual Property

US Patent Application published August 2024

Licensing and Collaboration Opportunity

Villanova University is seeking a licensee or collaborators to commercialize the invention.

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[1] Global Massive MIMO Market Analysis Report 2023-2030, Research and Markets, October 2023.