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## Massive MIMO Precoding and Beamforming Techniques for Future Generation Communication System



**Abstract:** - Massive MIMO, which was initially suggested, is a critical technique for meeting the rapidly growing data demand of 5G networks. MIMO technology may provide the propagation channel with a greater degree of flexibility in terms of multiplexing gain or diversity gain. New disruptive technologies have been developed in response to the large increase in data traffic that the forthcoming 5G mobile communication system. This is a critical research area for 5G wireless communication since massive MIMO has the possible system to significantly boost throughput and data transmission charges, as well as residual energy and energy efficiency. As a result of three years of fast development in massive MIMO technology, spectrum efficiency has been enhanced to an unprecedented level by the combination of growing antennas and adopting an extremely duplex communication mechanism. It is achieved by modeling the interference signal first and then constructing an exactly opposite signal added to a pre-distorted signal to cancel it. Additionally, this article discusses precoding methods and energy efficiency.

**Keywords:** 5G, massive MIMO, precoding, beamforming, BER

### I.INTRODUCTION

This article proposes a technique for reducing interference between antennas operating at various frequencies [1-5]. An FSS (Frequency Spread Spectrum) is sandwiched between two different antennas. Allowing electromagnetic waves to pass through the FSS and radiate into the surrounding environment is the primary function of the antenna. Two neighboring antennas may keep their distinct performance features, such as their emission patterns if they use this design. As an aside, it's worth mentioning that, although the FSS has been used in many applications. An FSS structure is established because of the closeness of two antennas operating in different 5G bands. Over its entire working range, it seems that the antenna's overall electrical and radiation properties are better.

5G Massive MIMO applications appear to gain greatly from this decoupling technique beam shaping is critical to the transmission of energy in millimeter-wave MIMO systems [6-12]. To find a compromise between low-cost but inaccurate analog approaches and energy-intensive, high-cost fully digital systems, hybrid beam formation frequently incorporates analog wideband and digital sub-band components[13-15]. Based on the Zero Forcing of the channel matrix, we construct and evaluate dual-stage hybrid beam formation approaches for the 5G New Radio (NR) simulator, which maintains an entirely digital foundation. Based on throughput and block error rate, it is feasible to compare the benefits of partly and completely linked topologies, as well as various numbers of Radio Frequency chains and transmit antennas, and to draw conclusions BER. By altering the number of phase shifters employed in the experiment, we examine the performance-complexity trade-off for phase shifter resolution. The simulations were conducted using the Clustered Delay Line CDL-A channel model with angle scaling since it correctly depicts the propagation environment. It is one of the most exciting air interface technologies for next generation communications, with the potential to completely transform the industry as shown in figure 1. The majority of prior studies demonstrated various advantages of large MIMO systems, but only for co-located deployment scenarios. Co-location and distributed deployment scenarios are compared in terms of the trade- Closed-form expressions may be generated to aid in the For large antenna , it is desirable to send a low-distortion signal to maintain a tightly regulated spectral mask.. When there are more carriers, OFDM systems have a hard

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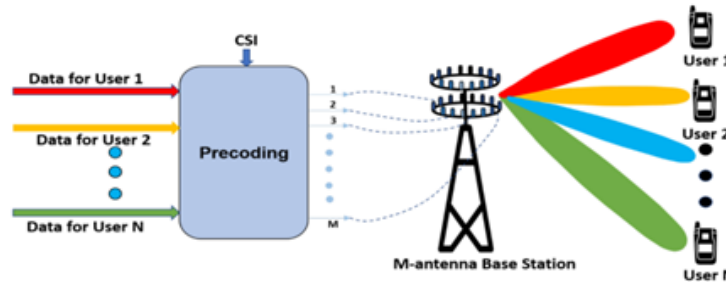
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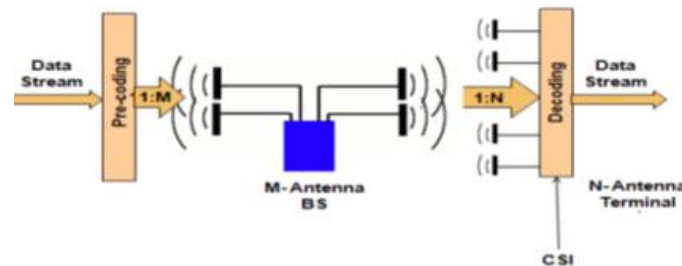
time dealing with them discovery of critical design principles. A Significant example is that, whereas great antenna dispersion often benefits ASE, it has little effect on AEE. Collaboration between cells is not always desirable in all deployment scenarios, and effective use cases are highly dependent on system characteristics like the number and location of transmit antennas, given the massive number of available transmit antennas and the actual cost of channel estimation [27-30].



**Figure 1: Massive MIMO Base Station to all users using precoding technique**

Equalization in an OFDM system using one-tap equalization would be simpler in the case of a Rayleigh fading channel. Single-carrier approaches employing a cyclic prefix and frequency domain equalization have been the subject of several investigation systems.

It has provided an overview of single-carrier systems. With the inclusion of MIMO techniques into real-world wireless systems, such as LTE and 4G, it has been able to increase connection dependability and deliver a larger capacity, all while maximizing spectral efficiency. Using a pre coding approach that is compatible with the frequency selective channel, the base station transmitter utilizes single-carrier approach; it's fascinating to see how it affects PAPR. Millimeter-wave massive MIMO systems rely on beam forming techniques to work effectively.



**Figure 2: Massive MIMO System with more users and BS antenna selection**

## II. MASSIVE MIMO TECHNOLOGY

The massive MIMO pre-coding technique is critical in reducing the system's capacity. For this will be needed to convey the complexity of a large MIMO system from a terminal to a base station.

The most often used precoding methods are zero-forcing (ZF), matched filtering, MRC, MMSE, Matched filter precoding, Peak to average power precoding, and all nonlinear methods that may be used to solve problems. To address fundamental technical concerns, we must first understand the activities of Massive MIMO communication systems. This contributes to the creation of a broader stage for the next-generation system.

As a consequence, it also aids in the understanding and development of the smart sensing system's many applications and services. Below, we've listed some of the primary goals of M-MIMO technology in 5G networks. Although linear precoders exhibit performance degradation in some cases, their relative simplicity allows them to play a critical role in transmitter design. Linear pre-coders are compared in this article in detail, along with their performance-complexity profile.

Non-linear pre-coders are also reviewed. Despite their considerable computational complexity, non-linear precoders may achieve acceptable performance. Additionally, this research looked at whether or not machine learning may be used in precoding methods.

The MIMO model, which has hundreds or more antennas at the transmitter and receiver, will assist to boost the system's capacity. Due to the implementation of improved water filling is known CSI. The system capacity is increased at a lower SNR than with unknown CSI. Using linear detectors at the base station (BS) with perfect CSI for FBMC and OFDM signals, a technique for analyzing the spectral efficiency (SE) of the Massive MIMO system uplink in a single cell environment is examined. In the case of Massive MIMO, where the base station (BS) comprises a high number of antenna components and serves hundreds of mobile terminals (MT), linear receivers function well. Massive quantities of antennas at BS will aid in lowering the symbol error rate (SER) for the ZF and MRC detectors. AAS are now a viable solution for sweeping deployments in current 4G and impending 5G mobile networks, thanks to recent technological advancements. In addition to beamforming and MIMO, AAS provides cutting-edge techniques for boosting user experience, capacity, and coverage [65-70].

Figure 3 shows Bit Error Rate for Massive MIMO with Signal to Noise Ratio (dB). New Radio (NR) is the fifth-generation (5G) standard, and millimeter wave (mmWave) technology enables low latency and multi-gigabit transmission rates.

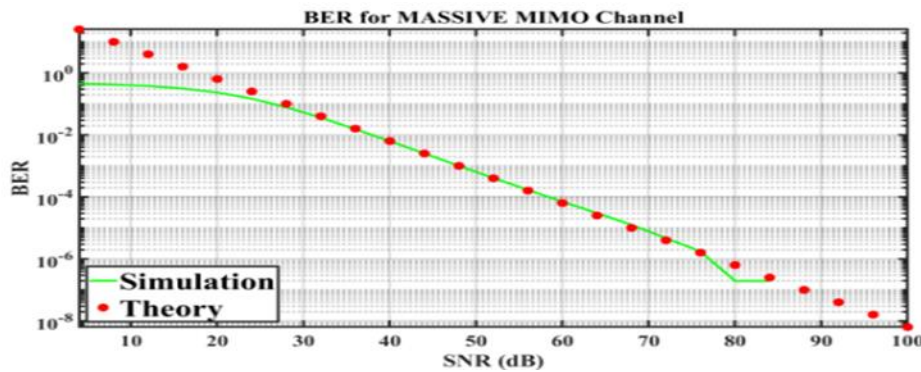


Figure 3: Bit Error Rate for Massive MIMO system with Signal to Noise Ratio (dB).

### III. LINEAR PRECODING TYPES

There has been substantial research into both linear and non-linear pre-coding approaches, which has enabled massive MIMO pre-coding technology to be used to enhance system performance when pilot pollution is present. In the next section, go through non linear precoding approach. Even with a wide antenna array and low SNR, the MRC receiver may perform as well as or better than an optimal linear receiver when SNR is low enough. If there is significant interference, even at higher SNRs, the OLR receiver system still outperforms the standard MMSE system, even when the SNR is higher.

#### 1) ZF precoding:

A spatial signal processing approach known as zero-forcing (also known as null-steering) may be used in a MIMO wireless communication system to eliminate multiuser interference. When a transmitter is certain in its knowledge of a channel's current condition before broadcasting, it uses the pseudo-inverse of the channel matrix.

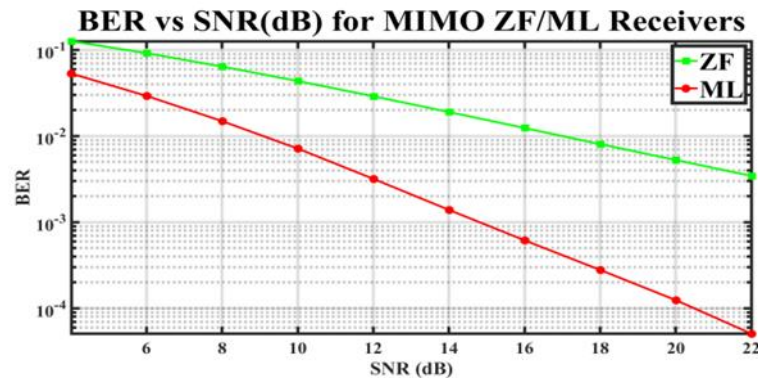


Figure 4: SNR versus BER for ZF/ML receivers

An N transmit antenna access point and M users with single receive antennas form a multi-antenna downlink system, where  $M \leq N$ , the received signal of user u is defined as

$$y_u = h_u^T x + n_u \quad (3)$$

where  $u=1,2,\dots,M$

$$\text{and } x = \sum_{i=1}^M \sqrt{P_i} S_i W_i \quad (4)$$

is the  $N \times 1$  vector of transmitted symbols,  $n_u$  is the noise signal, is the  $h_u^T$  channel vector and  $w_i$  is some  $N \times 1$  linear precoding vector. Here  $(.^T)$  is the matrix transpose,  $\sqrt{P_i}$  is the square root of transmit power, and  $S_i$  is the message signal with zero mean and variance 1.

The signal model described above may be rewritten in a more compact manner as

$$y = H^T W D_s + n \quad (5)$$

where y is the  $M \times 1$  received signal vector,

$H = [h_1, h_2, \dots, h_k]$  is  $N \times K$  channel matrix

$W = [w_1, w_2, \dots, w_k]$  is the  $N \times K$  precoding

Matrix and D is the diagonal of square of power P is a  $M \times M$  diagonal power matrix, and

$s = [s_1, \dots, s_k]^T$  is the  $M \times 1$  transmit signal.

Figure 6 shows the SNR verses BER for ZF/ML precoding techniques.

When a large number of users are present and the transmitter has extensive knowledge of the downlink Channel State Information, the use of ZF-precoding may enable the system to operate at nearly full capacity (CSI). When the CSI at the transmitter (CSIT) is limited, the accuracy of the ZF-performance precoding decreases proportionally to the CSI at the transmitter's accuracy. ZF-precoding demands a large amount of feedback overhead to get the highest multiplexing gain achievable in terms of signal-to-noise (SNR). Due to residual multiuser interferences, inaccuracies in CSIT result in considerable throughput loss. Multiuser interferences persist because they cannot be eliminated with poor CSIT-generated beams. This article aims to produce a mathematical large MIMO 5G system that consumes less energy when utilized with a ZF receiver. A signal-to-noise ratio (SNR) comparison of co-located and distributed MIMO systems and hybrid MIMO systems were conducted.

In terms of signal-to-noise ratio, gain, and antenna count, combination MIMO, such as hybrid MIMO, has the highest energy efficiency among the three types of MIMO, according to the performance research. On the other hand, co-located and hybrid MIMO have worse energy efficiency in terms of spectrum efficiency than dispersed MIMO. Dispersed MIMO is always more energy efficient than co-located MIMO. Our future study will focus on developing an energy-efficient system that is also spectrum-efficient.

**2) MRC precoding:** Maximum Ratio Combining is a telecommunications integration method: Each channel's signals are combined.

Gain for each channel is adjusted to be inversely proportional to the mean square signal level and proportionate to the mean square noise level for that channel and each channel is assigned a unique set of proportionality constants. Pre-detection combining and ratio-squared combining are two more names for the same technique. When combining several white Gaussian noise channels, the most successful approach is maximum-ratio combining. MRC is capable of regenerating a signal to its original state.

Let's assume the receiver has M antennas, as shown in the following example. The y-coordinate obtained in this case is

$$y = hs + n \quad (6)$$

On a small scale, assuming Rayleigh fading, the channel's impulse response with variance  $\sigma^2$

As a result, the instantaneous channel power is dispersed exponentially.

$$p^2 = (1/\sigma^2) \exp(-(\sigma^2/h^2)) \quad (7)$$

MRC Beamformer is  $\mathbf{w} = \frac{\mathbf{h}}{\|\mathbf{h}\|}$  (8) where

$$\|\mathbf{h}\| = \sqrt{h_1^2 + h_2^2} \quad (9)$$

**3) MMSE Precoding:** When constructing a pre-coding approach for a multi-cell massive MIMO system, it is critical to take into account the difficulty of allocating the training sequence to the system's cells. The research suggests that the minimum mean square error estimate precoding (MMSE) technique may help decrease pilot contamination.

**4) Matched Filtering Precoding:** Modern MIMO spatial multiplexing systems employ the matched-filter (MF) detector, which is the simplest basic linear detector available to users. Finally, we wish to expand the scope of our study to include more realistic systems with erroneous channel estimations.

**5) PAPR (Peak-To-Average Power Ratio) precoding:**

Using high-end linear power amplifiers in a massively multi-antenna MIMO system almost invariably results in higher hardware costs as well as higher energy consumption. As a result, a feasible method for implementing huge MIMO systems was required. Massive MIMO systems may be implemented practically using efficient non-linear power amplifiers. Thus, the PAPR should be kept as low as possible to mitigate the influence of amplifier nonlinearity. This section will discuss precoding techniques that try to lower the PAPR. The presence of a large PAPR results in inband distortion and spectral spreading. There are several approaches to resolving the PAPR issue. Amplitude clipping, filtering, coding, partial transmit sequences, selective mapping (SLM), and partially transmit sequences are only a few of them (PTS). BER performance is determined using a sixteen-path channel model. There are sixteen possible pathways between each user and each antenna owing to channel fading.

$$BER = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) = Q(\sqrt{SNR}) \quad (9) \text{ where } Q \text{ is a function}$$

$$BER = Q(\sqrt{SNR}) \quad (10)$$

**6) Continuous Envelope (CE) Precoding:** In MU-MIMO systems, the constant envelope (CE) precoding approach are employed to lower the peak amplitude per repeat (PAPR) of the broadcast signal. To fulfill its objectives, the CE algorithm takes advantage of readily available, low-cost, high-efficiency amplifiers. As a certain sum rate and a big M are employed, the total transmits power may be reduced by around 4 decibels (dB) when compared to a system that utilizes very linear and inefficient amplifiers (such as those used in satellite communications). It is feasible that the CE technique may still result in an array power increase under certain mild channel circumstances, and that this capacity will be provided by the average only total transmit power-constrained channel.

**7) Approximate Message Passing (AMP):** It is computationally demanding to tackle the non-convex NLS issue posed by the CE approaches utilizing Approximate Message Passing (AMP). Compressed sensing-related inference tasks are the driving force behind [12]'s development of the AMP precoding technique. Rather than relying on a global solution to a non-convex issue through a computationally intensive approach, it aims to give an effective solution to the CE precoding challenge. The AMP technique allows you to establish a balance between computational requirements and achievable performance.

**8) Quantized Precoding (QP):** It is critical to weigh the advantages and disadvantages of using more antennas at the base station when designing these systems. To avoid inefficiency, the system must be restructured. The BS has become much more complicated, costlier, and power-hungry due to the introduction of several RF chains. The

data converters at the transmitter are a significant source of power consumption in huge MIMO systems. Generally, direct caring for methods, exhaustive of zero-forcing (ZF) taking care of approach, had been certified to help the plausible data transmission worth or organizations limitation concerning the multiuser MIMO frameworks. In any case, contemplating the staggering surveyed remarks overhead and inordinate truly worth of the enormous amount of RF chains/radio wires needed via the use of ZF precoding, the summed-up ZF approach can't be almost done for our proposed mmWave m-MIMO plans. As of late unexamined half strain taking care of advancement can avoid huge proportions of iterative procedures added through the normal multiuser m-MIMO associations.

#### IV. NONLINEAR PRECODING

VP, DPC, and auxiliary network approaches are only a few of the nonlinear precoding techniques at one's disposal. When the cells  $M$  and  $K$  aren't too large, nonlinear precoding may have some advantages. The SNR estimate in the VP of complete CSI is given in the literature. DPC is a coding technique that pre-cancels known interference without incurring a power consumption penalty. While just the transmitter requires knowledge of this interference, complete CSI is needed everywhere to achieve weighted sum capacity. Costa precoding, Tomlinson-Harashima precoding, and the vector perturbation approach all fall under this group.

There are many well-known nonlinear detection methods, such as Sphere decoding (SD), which uses a maximum likelihood (ML) decoder. To find any signaling points, the SD algorithm only evaluates a certain radius point. The low complexity of TB can be efficiently reduced by extending the search radius. This approach is known as Random Steps (RS). Here's a breakdown of the underlying theory: choose an initial vector, assess its peripheral vector that requires MSE, and choose MSE as the smallest vector.

#### V. CONCLUSION

Massive MIMO significantly enhances user experience and mobile services. It will continue to be available for a while. But it's expected that the transmitter's design would draw the most attention. For extremely large MIMO systems, this study studied linear and nonlinear precoding methods. The new method outperforms the old one when computing average power allocation. Under the premise that each user's minimum communication rate will be met, we proposed a method based on maximizing harvested energy to estimate the proper power splitting factor for each user. With the aid of this technology, the system can collect more energy while maintaining a minimal communication speed for the user, leading to energy recycling and environmentally responsible communication.

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