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Performance Analysis and Comparison of Zero Forcing and MMSE Precoding and Detectors for 5G MIMO

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ABSTRACT: Wireless transmission is affected by fading and interference effects which can be combated with equalizer. Non-linear precoding for the downlink of a multiuser MISO (multiple-input single-output) communication system inthe presence of imperfect channel state information (CSI) is considered. The use of MIMO system promises good improvement in terms of spectral efficiency, link reliability and Signal to Noise Ratio (SNR). The Bit Error Rate (BER) characteristics for the various transmitting and receiveing antennna are simulated in Matlab tool box and many advantages and disadvantages ofthe system is described. The simulation results show that the equalizer based zero forcing receivers is good for noise free channel and is successfulin removing ISI, but MMSE is a better choice than ZF in terms of BER charateristics and under Noise performance.

KEYWORDS: MIMO, Zero forcing Equalizer, ISI, BER, linear equalization, MMSE

I. INTRODUCTION

As of now future wireless networks will should address a sizableincrease of data transmission due to some of risingapplications that include gadget-to-machine communicationsand video streaming [1]- [4]. This very big amount of statisticsalternate is anticipated to hold and upward thrust inside the subsequent decoder so, presenting a totally huge challenge to designers offifth-generation (5G) wireless communications systems [4].Amongst the main problems are how to make the fine useof the available spectrum and a way to growth the power performance in the transmission and reception of each informationunit. 5G communications will should rely on technologies that can provide a chief growth in transmission capacity asmeasured in bits/Hz/location but do now not require increased spectrum bandwidth or strength intake.Multiple-antenna or multi-user multi-output (MIMO) wireless communication devices that employ antenna arrays witha very massive variety of antenna elements that are called enormous MIMO systems have the ability to conquer the ones challenges and deliver the specified statistics rates, representing akey allowing era for 5G [5]- [8]. Among the devices of big MIMO networks are person terminals, medicines, technologies and base stations which can be equipped with a range of antenna elements with orders of value higher thanmodern devices. Massive MIMO networks could be structured by way ofthe subsequent key elements: antennas, network architectures, protocols and signal processing.The idea behind massive MU-MIMO is to equip the base-station (BS) with hundreds of antennas while serving tens of users in thesame time-frequency resource. This approach enables extremely fine-grained beamforming in the uplink(users transmit to the BS) and in the downlink (BS transmits to the users), and hence improved spectral efficiency compared to traditional, small-scale MIMO systems. Linear data detection algorithms, e.g.,minimum-mean square error (MMSE) equalization or zero-forcing (ZF) equalization, are known to achievenear-optimal performance in realistic massive MIMO systems with a finite number of transmit antennas in the [9]–[11]. Non-linear data detection algorithms [12]–[15] have recently been shown to outperform linear methodsin massive MU-MIMO systems with a similar number of users and BS antennas. Most of these linear and non-linear algorithms, however, entail high computational complexity, mainly caused by the computationof the Gram matrix $G = H^H H$ [9], where $H \in C^{B\times U}$ is the (uplink) channel matrix, B the number ofBS antennas, and U the number of (single-antenna) users.While some equalization and precoding algorithms have been proposed that avoid thecomputation of the Gram matrix altogether. Hence, such algorithms inevitably perform redundant computations which increases the total complexity of equalization and precoding.

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II. RELATED WORK

In such multiuser MISO systems, multiuser interference at the receiver is a crucial issue. One way to deal with this interference issue is to use multiuser detection [17] at the receivers, which increases the receiver complexity. As an alternate way, transmit side processing in the form of precoding is being studied widely [16], [18]. Several
linear precoders such as transmit zero-forcing (ZF) and minimum mean square error (MMSE) filters, and non-linear precoders including Tomlinson-Harashima precoder (THP) have been proposed and widely investigated in the literature [19],[20].Non-linear precoding strategies, though more complex thanthe linear strategies, result in improved performance compared to linear pre-processing. Transmit side precoding techniques, linear or non-linear, can render the receiver side processing at the user terminal simpler. However, transmit sideprecoding techniques require channel state information (CSI)at the transmitter.The model describes the downlink of a system in which each user is equipped with number of antennas and the access point has antennas. The network has K users.
Several studies on transmit precoding assume perfect knowledge of CSI at the transmitter. However, in practice, CSI atthe transmitter suffers from inaccuracies caused by errors inchannel estimation and/or limited, delayed or erroneous feedback. The performance of precoding schemes is sensitive tosuch inaccuracies [21]. Several papers in the literature have proposed precoder designs, both linear and non-linear, whichare robust in the presence of channel estimation errors [22],[23].

III. SYSTEM ARCHITECTURE

Precoding and detection algorithms are fundamental approaches to mitigating interference at the transmitter and receiver of modern wireless communication systems. In 5G systems, the heterogeneity and architecture of networks and the increasing levels of interference pose challenges for the design precoding and detection algorithms.

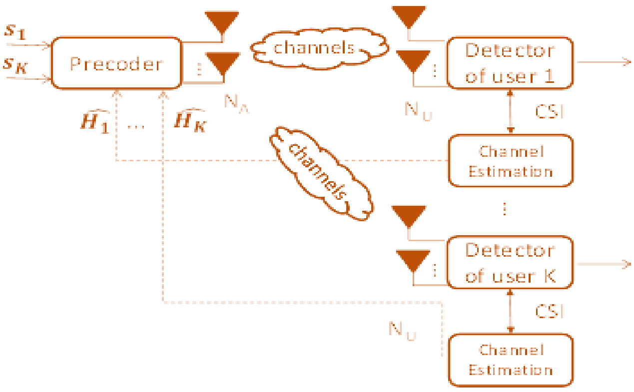

Fig-1 Block diagram of Precoding System

In particular, precoding algorithms must have access to the channels of all users in the system in order to perform interference mitigation, which is often carried out with the help of signal processing transformations. Among the existing precoders are vector perturbation, Tomlinson-Harashima and linear techniques, which exhibit different performance complexity trade-offs. Key problems in the design of precoders for 5G networks include the limitation of existing signal processing algorithms which are not scalable, the hardware impairments, inaccurate channel state information across networks with small cells, network MIMO concepts and users with mobility. In our 5G lab, we look at innovative solutions to the problems encountered in the design of precoders, namely:

- Low-complexity precoding strategies
- Robust precoding algorithms
- RF-aware precoding designs
- Pilot contamination

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In the case of detection algorithms, the receiver must perform synchronization, channel estimation prior interference mitigation, which is often carried out with the help of either lattice searches or receive filters. Among the most effective detection algorithms are maximum likelihood detectors, sphere decoders, lattice-reduction techniques, decision-feedback schemes, successive interference cancellation and linear techniques, which exhibit different performance complexity trade-offs.

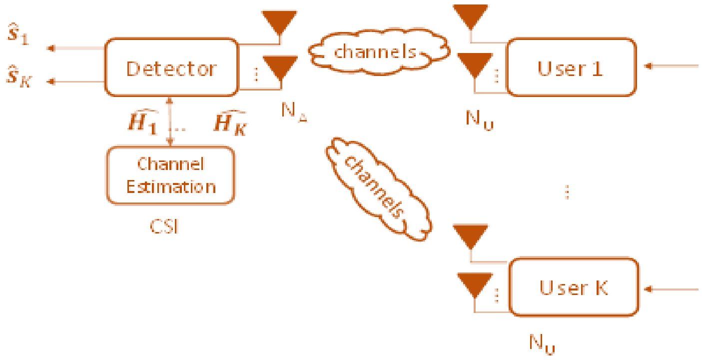

Fig-2 Block diagram of detector System

Key problems in the design of detectors for 5G networks include the limitation of existing signal processing algorithms which are not scalable to large-scale systems, hardware impairments, inaccurate channel state information across networks with small cells, network MIMO concepts and users with mobility and decoding delay when iterative detection and decoding algorithms are employed. In our 5G lab, we look at innovative solutions to the problems in the design of detectors, namely:

- Low-complexity detection algorithms
- Low-delay iterative detection and decoding techniques
- RF-aware detection algorithms

We consider an uncoded MU-MIMO downlink channel, with N_T transmit antennas at the base station (BS) and Ni receive antennas at the i[th] user equipment (UE). With K users in the system, the total number of receive antennas is NR $=\sum_{i=1}^{k} N_i$. A block diagram of such a system is illustrated in Fig. 1.From the system model, the combined channel matrix H and the joint precoding matrix P are given by

$$H = [H_1^T H_2^T \ldots\ldots H_K^T]^T \in \mathbb{C}^{N_R \times N_T}, \quad (1)$$

$$P = [P_1 P_2 \ldots\ldots P_K] \in \mathbb{C}^{N_R \times N_T}, \quad (2)$$

Where$H_i \in \mathbb{C}^{N_i \times N_T}$ is the ith user's channel matrix. The quantity $P_i \in \mathbb{C}^{N_T \times N_i}$ is the ith user's precoding matrix. We assume a flat fading MIMO channel and the received signal $y_i \in \mathbb{C}^{N_i}$ at the ith user is given by

$y_i = H_i x_i + H_i \sum_{j=1, j\neq i}^{K} x_j + n_i (3)$

Zero Forcing Equalizer: Zero Forcing Equalizer is a linear equalization algorithmused in communication systems, it inverts the frequencyresponse of the channel. The name Zero forcing corresponds to bringing down the Inter Symbol Interference (ISI) to zero in a noise free case. For a channel with frequency response F (f) the zero forcing equalizer C (f) is constructed by C (f) = 1 / F(f). Thus the combination of channel and equalizer gives a flat frequency response and linear phase F(f)C(f) = 1.

MMSE Equalizer Mathematics:A Minimum Mean Square Error (MMSE) estimatordescribes the approach which minimizes the mean squareerror (MSE), which is a common measure of estimator quality.The main feature of MMSE equalizer is that it does notusually eliminate ISI completely but, minimizes the total powerof the noise and ISI components in the output.The linear MMSE estimator is theestimator achieving minimum Mean square error among allestimators of the form AY + b. If the measurement Y is arandom vector, A is a matrix and b is a vector.

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Pseudo code for Precoder

Get Signal-to-noise ratio (SNR) manipulation
- Finding Signal square root power and Conversion from dB
- Noise standard deviation

Finding the requirement for ZF and MMSE precoders
Acquire linear filter for linear detector and K users
Acquire linear filter for SIC detector and K users

```
% Counters for Bit errors
 Channel Matrix
% channel power standard deviation
 % Precoders
% Normalization to ensure that the precoded signal energy is the same as  before precoding-

for l = 1:N
    QPSK symbols
      Scaling
       Noise
 Received vector with normalization
    Slicer for QPSK

    Error counting
    ZF
      % MMSE
    end
```

IV. SIMULATION RESULTS

In this section, we assess the performance of the proposedMB-THP algorithms. A system with $N_t = 8$ transmit antennasand $K = 3$ users each equipped with $N_k = 2$ receive antennasis considered; this scenario is denoted as the (2, 2, 2, 2) × 8case.We compare this performance with other precoders inthe literature. The comparison is based on the average uncoded bit error rate (BER) versus the average signal-to-noiseratio (SNR). The modulationscheme used is QPSK. The elements of the estimation error matrix, E, are generated independently from zero-meanGaussian distribution of variance σ2E. We compare the BERperformance of the proposed robust MMSE-THP with that ofi) the robust linear MMSE precoder in [8], and ii) the robust ZF-THP in [9]. Figure 4 shows the BER performanceof the various precoders in a system with two transmit antennas ($N_t = 2$) at the BS, three users ($N_u = 3$) with onereceive antenna each, and channel estimation error with variance $\sigma^2_E = 0.05$.

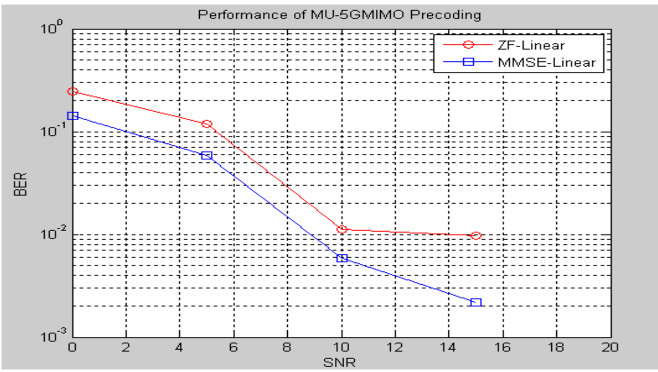

Fig.3 BER versus average SNR performance for different precoders

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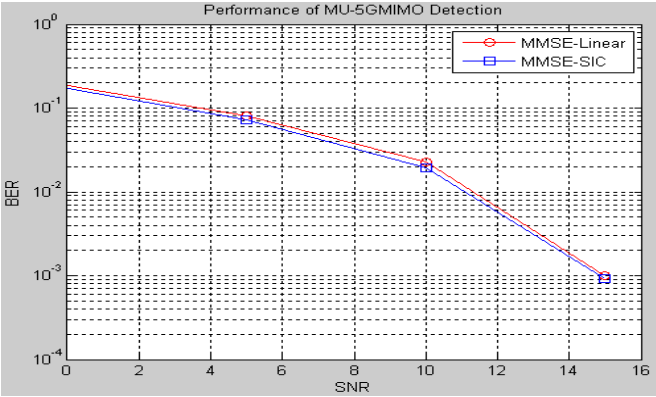

Fig.4BER versus average SNR performance for different detectors

V. CONCLUSION& FUTURE SCOPE

We addressed the problem of designing a robust linear precoder and detectors for Multi user MIMO systems with imperfect channel state information. Among two linear algorithms i.e. ZF and MMSE, it has been found that MMSE is having better performance than the ZF in the ill condition SNR regime.

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BIOGRAPHY

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