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AN EFFICIENT POWER CONTROL DETECTION SCHEME FOR MIMO TRANSMISSION IN LTE

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ABSTRACT

In this paper author's proposed an efficient ordering scheme for interference cancellation, which is determined for multiple antenna systems using transmission power control. Based on this approach, the fixed ordering algorithm is first designed, for which the geometric mean is used for channel gain coverage. Simulation results shows that proposed ordering schemes using QR-decomposition require a reduced computational complexity results with improved error performance. In this article an overview of power control in LTE uplink MIMO schemes including receivers suitable for uplink MIMO are also presented, and their link performances are compared.

Keywords: detection ordering, MIMO, OSIC, power allocation, QR-decomposition.

INTRODUCTION

Global System for Mobile Communications (GSM) has evolved into Enhanced Data Rates for GSM Evolution (EDGE), while on top of these Wideband Code Division Multiple Access (WCDMA) technology is introduced, evolving into networks such as High Speed Packet Access (HSPA).

Long Term Evolution (LTE) is a system currently under standardization. It has the goals of achieving peak data rates of 100 Mbps in downlink (DL) and 50 Mbps in uplink (UL). The ambitious data rate target of the 4th generation mobile communication systems can only be achieved by using an efficient air interface advanced Multiple Input Multiple Output (MIMO) antenna techniques, and wide spectrum allocation for high data rate transmissions. The goal of power control is to transmit at the right amount of power needed to support certain data rate. Too much power generates unnecessary interference, while too little power results in an increased error rate resulting in larger transmission delays and lower throughputs. MIMO system is practical transreceiver implementation for their great potential of enhancing the system performance. Data stream with smallest SINR (Signal to Interference Noise Ratio) degrades the overall error performance so an attractive system is designed for enhancing the system performance is B-OSIC (BLAST Ordered Successive Interference Cancellation). The computational complexity and feed back overhead is decreased by adopting the PA (Power Allocation) scheme with B-OSIC receiver. In this paper BER (Bit Error Rate) minimization condition is derived from the convexity of the Q-function in the PA scheme. This scheme is adaptively updates the threshold to conform the superiority of the adaptive design. The performance of a number of receivers for UL data channel is evaluated using link simulations, which shows that significant performance gain is achievable when an advanced receiver such as the turbo equalization receiver is used at the eNB (eNodeB).

This paper investigates in detail about how the power control detection scheme in MIMO based systems support certain data rate. Section II describes the average interference level received at eNB is reduced by performing slow power control in UE Uplink transmission. The PA scheme for average BER minimization can be obtained from QR decomposition is explained Section III, Performance evaluation is discussed in section IV, simulation results have been shown in V, and finally section VI provides conclusion for this paper. [1-3]

LTE-Uplink power control

The cellular systems are generally coverage limited in the uplink due to limited UE transmit power. The LTE uplink uses orthogonal (Single Carrier-Frequency Division Multiple Access) SC-FDMA high levels of interference from neighbouring cells can limit the uplink coverage if UEs in the neighbouring cells are not power controlled. Power control is responsible for managing the transmitting (Power Spectral Density) PSD of each user. By performing the slow power control scheme on each UE uplink transmission power, the average inter-cell interference level received at the eNodeB is effectively reduced.

Uplink power control for LTE is the set of algorithms and tools by which the transmit power for different uplink physical channels and signals are controlled are received at the cell site with appropriate power. This means that the transmission should be received with sufficient power to allow for proper demodulation of the corresponding information. Power control is responsible for managing the transmitting PSD of each user.

In LTE-UL SC-FDMA introduces (Inter Symbol Interference) ISI in dispersive channels. Thus, a desired MIMO receiver should address both ISI and spatial-multiplexing interference. Link simulation results are provided to demonstrate the performance of UL data channel and also compare the

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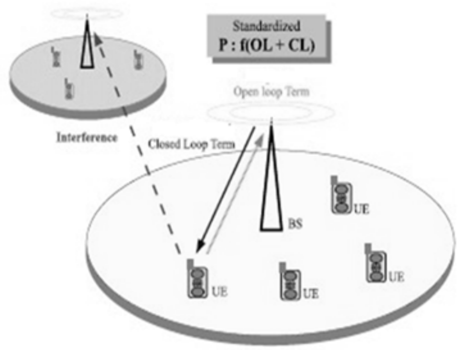

Figure-1. Power Control Working Scenario - Standardized PC includes an open loop and a closed loop term.

performance among these different receivers including linear minimum mean square estimation (MMSE) equalization, successive interference cancellation SIC), and turbo equalization receivers. Minimum BER is employed as the optimization criterion, an approximate power control strategy is proposed for above mentioned receivers to improve performance which has been shown both analytically and by simulation. Uplink power control for LTE is the set of algorithms and tools by which the transmit power for different uplink physical channels and signals are controlled at the cell site with appropriate power. [7]

At the same time, the transmit power should not be unnecessarily high as that would cause unnecessary interference to other cells. The transmit power will thus depend on the channel properties, including the channel attenuation and the noise and interference level at the receiver side, if the received power is too low by increase the transmit power or reduce the data rate by use of rate control. However, due to the difference in transmit power between the cells of the different cell layers there is an area where the pico cell is selected while, at the same time, the downlink transmission from the macro cell is received with substantially higher power than the actual desired downlink transmission from the pico- cell. Within this area, there is thus potential for severe downlink inter-cell interference from the macro cell to pico-cell terminals, interference that may require special means to handle.

To evaluate the performance of the proposed system, key performance indicators (cell throughput, outage throughput, IoT) gives qualitative measure of the gain of a specific PC scheme in terms of system as well as user performance. There are three types of uplink power control in UTRA-LTE.

- Fractional power control.
- Interference based power control.
- Cell-Interference based power control.

The open loop functioning as shown in Figure-1, is based on the Fractional Power Control technique which is designed to allow for full or partial compensation for the path loss. The FPC and IPC techniques are designed to set the user transmitted power spectral density based on its interference and signal. The best performance cases were achieved by targeting the (User Equipment) UE's with good trade off of signal and interference to experience a higher SINR.

In Cell interference based, power control user throughput is a function of the allocated bandwidth, and the band width efficiency experienced in the transmission. To distribute the power among UE's a special criteria is used based on some power control considerations. [3] These are assigned iteratively to the best candidate until the target interference is achieved. This technique is mainly based on estimating a gain and cost, where the gain is measured directly in throughput rather than SINR. [8]

Downink power control

In the downlink LTE uses dedicated control signalling with some degree of link adaptation for uplink and downlink scheduling assignments. The power levels on the dedicated control channels can also be adjusted based on the channel conditions of the UE addressed in the scheduling grant. In the downlink, dynamic power control is applied to dedicated control channels addressed to a single UE or a group of UEs. No feedback of TPC commands is provided on the uplink and power allocation is based on the downlink channel quality feedback from the UEs. Different power levels can be allocated to different resource blocks used for data transmission in a semi-static way to support (Inter-Cell Interference Coordination) ICIC. For LTE power control is slow for the uplink direction. Where as in downlink direction there is no power control. The key motivation for the power control is to reduce terminal power consumption and to avoid an overly large dynamic range in the eNB receiver, rather to mitigate interference.

System model with detection ordering scheme

In this paper we examine a multi antenna fitted with a QR based successive cancellation receiver. A MIMO system with N_t transmit antennas and N_r receiving antennas, the MIMO channel matrix H with the element h_{ij} is channel gain from i_{th} transmitting antenna to j_{th} receiving antenna. The $N_{r\times 1}$ received signal vector is written as,

$$y = \sqrt{\frac{E_s}{N_t}} HPx + n \tag{1}$$

Where x= $[x_1 \; ...x_{Nt}]^T$ denotes the transmitted signal vector and 'n' is the noise vector having elements with complex zero mean Gaussian distribution variance 'σ_{n^2}' and E_s is the total

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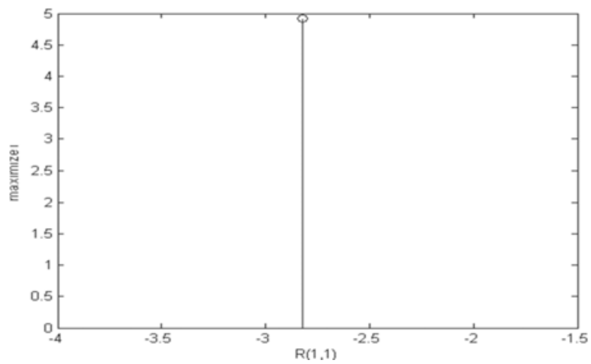

Figure-2. Graphical Output (QR-Fixed), μ=√det(R).

transmitted signal energy on N_t transmit antennas and $P = \sqrt{N_t}.diag(p_1, p_2 .... p_{N_t})$ denotes the diagonal PA precoding matrix. An (Nr+Nt)×Nt augmented channel matrix $\overline{H}$, (Nr+Nt)×1 extended receive vector $\overline{y}$ and an Nt ×1zero matrix 0Nt,1 can be used to express the signal model for the MMSE-QR detector is written as,

$$\overline{H} = \begin{bmatrix} H \\ \sigma_n \boldsymbol{I}_{N_t} \end{bmatrix} \xleftrightarrow{ordering} \overline{Q}\overline{R} \quad \overline{y} = \begin{bmatrix} y \\ 0_{N_{t,1}} \end{bmatrix} \tag{2}$$

The upper triangular matrix $\overline{R}$ which is differently defined by the detection order determines the Signal to Noise interference ratio. The post detection SINR ρ_k of the k_{th} data stream is given by

$$\rho_k = \frac{E_s}{\sigma_n^2} P_k^2 \overline{R}_{k,k}^2 - 1 \tag{3}$$

The QR-OSIC receiver detects the transmitted symbols sequentially in accordance with the designated detection-order, with this BER is minimized and PA transmission can be performed. An efficient detection ordering strategy is derived from the properties of Q-function because in the post detection SINR, the error rate is effected by the channel gain and transmitted power. So the PA scheme for the average BER minimization can be obtained under the assumptions of no error propagation in cancellation of data and QR decomposition of the channel matrix. The PA scheme for BPSK modulation is given by

$$\frac{1}{N_t}\sum_{k=1}^{N_t} Q\left(\sqrt{2\gamma_s} P_K \overline{R}_{k,k}\right) \approx \frac{1}{N_t}\sum_{k=1}^{N_t} Q\left(\sqrt{2\rho_k}\right) \quad \sum_{k=1}^{N_t} P_k^2 = 1$$

$$\overline{R}_{k,k} \geq 0 \qquad Q(x) = \sqrt{\frac{1}{2\Pi}} \int_x^{\infty} e^{(-t^2/2)} dt \quad \gamma_s = \sqrt{\frac{E_s}{\sigma_{n^2}}} \tag{4}$$

The average BER and Post detection SINR ρ_k is determined by the allocated power P_k, and channel gain $\overline{R}_{k,k}$, with convexity property of the Q-function, the BER is minimized by equating all the diagonal elements of the matrix $\overline{R}$ are equal to their geometric average is given by,

$$\mu = N_t \sqrt{\det(\overline{R})} = N_t \sqrt{\prod_{k=1}^{N_t} \overline{R_{k,k}}} \tag{5}$$

The feedback information of the diagonal elements with different detection order leads to different $\overline{R}_{k,k}$ and transmitted power P_k assigned to each data stream. This depicts that an appropriate detection ordering strategy incorporates with the PA scheme can achieve the better BER performance. [3][4]

The ordering strategy that makes $\overline{R}_{k,k}$ converge to μ achieves higher post detection SINR, which also further improves the overall BER performance. The adaptive ordering algorithm can be considered as the reduced sized fixed ordering process can extract the already decided gains for balancing among ordering results.

The detection ordering algorithm, Q-function properties defined in [2], the cumulative distributions of $\overline{R}_{k,k}$ -μ with four transmit and receive antennas are shown in figure 5. It has been observed that the small gap between two similar schemes in the adaptive algorithm is equivalent to the fixed one for slight differences in $\left|\overline{R_{k,k} - \mu}\right|$.

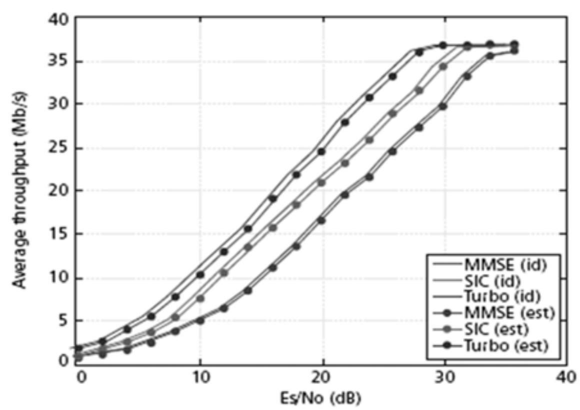

Figure-3. Performance of UL-MIMO, 2 transmit and 2 receive antennas (EVA channel, 5 MHz).

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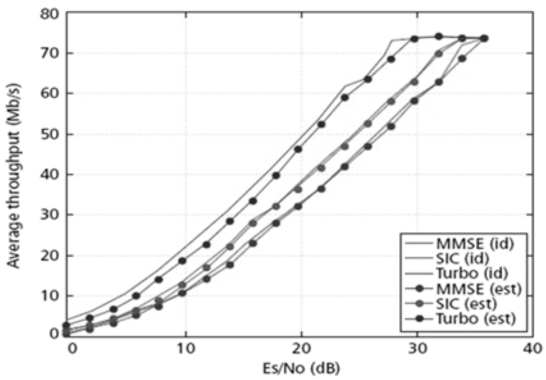

Figure-4. Performance of UL-MIMO, 4 transmit and 4 receive antennas.

PERFORMANCE EVALUATION

The performance of UL-MIMO in an LTE system, the link performance is simulated in the Extended Vehicular A (EVA) channel. In this scenario where 25 resource blocks (5 MHz) are allocated to a user. For each SNR, the average throughput performance over 500 sub frames is evaluated, performance of 2×2 MIMO is shown in Figure-3, for the MMSE, SIC, and turbo equalization receivers, from above figures it has been observed that the turbo equalization offers significant performance gain over both MMSE and SIC, that is 4–5 dB gain over MMSE and 2-3 dB gain over SIC at a medium to high SNR. Furthermore, all the receivers suffer similar degradation when practical channel estimation is considered. Performance of 4×4 MIMO is shown in Figure-4. The gain of the turbo equalization receiver over SIC increases, compared to the 2×2 case. The 4×4 case has the larger gain here is due to better cancellation of intra-channel interference. [5] [9]

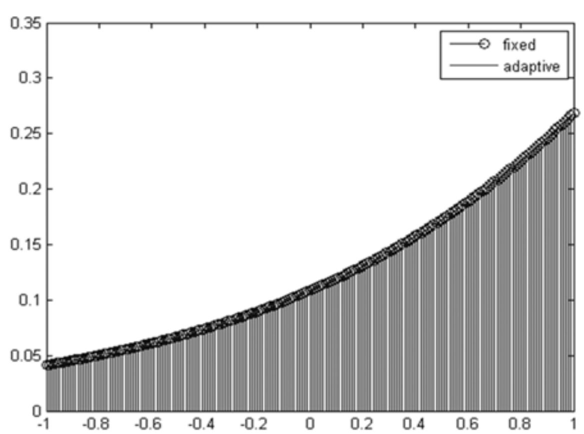

Figure-5. QR ADAPTIVE, comparison of cumulative distribution of $\overline{R_{k,k}} - \mu$.

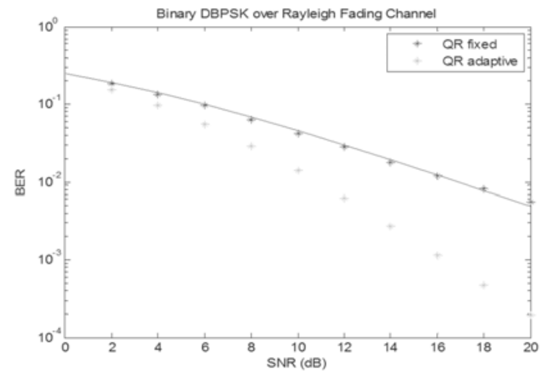

Figure-6. Average BER performance of MIMO systems with four transmit/receive antennas.

SIMULATION RESULTS

Simulation results have been shown in this paper for MIMO system with 4×4 transmit and receive antenna configuration. The average BER performance for the 4×4 MIMO shown in Figure-6. The solid line in above figure indicates the system with BER minimized without PA scheme. Where as dotted line indicates a BER system with PA scheme. From above results it is observed that the power controlled detection scheme attained the improved error performance. It also demonstrated that the importance of the detection order for successive detection. In future for further performance improvement high SNR region need to be designed in terms of the the error propagation because the QR-OSIC with PA scheme receiver is designed with error-free detection process.

CONCLUSIONS

In this paper author's have been investigated the QR-OSIC receiver design for the transmitter-side power allocated MIMO system. Based on the properties of the function and ordering results, we developed the efficient ordering algorithms in combination with the PA scheme. This paper presents design guidelines for optimization of MIMO receiver circuit complexity with respect to performance loss. In spite of less computational effort, the proposed ordering schemes decrease the overall BER in comparison with the previously derived B-OSIC scheme. Because of the post-detection SINR increment, the coded systems with the derived approach can also be expected to achieve the performance improvement. The error detection scheme using QR decomposition improves BER performance compared to conventional.

In future this approach can be used in the coded systems to achieve better performance improvement. The performance of a number of receivers for UL data channel is evaluated using link simulations, which show that significant performance gain is achievable when an advanced receiver such as the turbo equalization receiver is used at the eNodeB.

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