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Using turbo iterative receiver to mitigate RPI effect in MIMO OFDM communication system

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Abstract: The received power imbalance (RPI) effect exists in multiple antennas wireless communications system due to design flaw, operator's negligence etc. The range of RPI can be from −10 dB to 0 dB and if the RPI information is not available at the receiver terminal, it can implement turbo iterative receiver by concatenating multi-input and multi-output (MIMO) orthogonal frequency division multiplexing (OFDM) demodulation (MIMO OFDM demodulation, MOD) serially by channel decoder such as low density parity check (LDPC) decoder or Convolution code (CC) decoder to mitigate the RPI effect and to maintain the system performance at certain acceptable level.

Keywords: array antenna, received power imbalance (RPI), turbo iterative receiver, low density parity check (LDPC), convolution code (CC)

Classification: Microwave and millimeter wave devices, circuits, and systems

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1 Introduction

For a wideband transmission, the combination of multi-input and multi-output (MIMO) [1] and orthogonal frequency division multiplexing (OFDM) [1, 2] can achieve very high data rate such as in 1 Giga bits/s. However according to literature [3, 4], the received power imbalance (RPI) effect, which is caused by design flaw or user's negligence, may exist at the multiple antennas receiver in MIMO wireless communication. This RPI effect can vary in a wide range from −10 dB to 0 dB and its effect may exhibit in burst pattern; and consequently when it occurs the channel estimator may not have the capability to mitigate or conquer this effect and the system performance may be degraded seriously. For this reason we propose a way to mitigate RPI effect by using iterative operations between MIMO OFDM demodulation (MOD) and channel decoder [1].

2 A Turbo iterative receiver implemented communication system

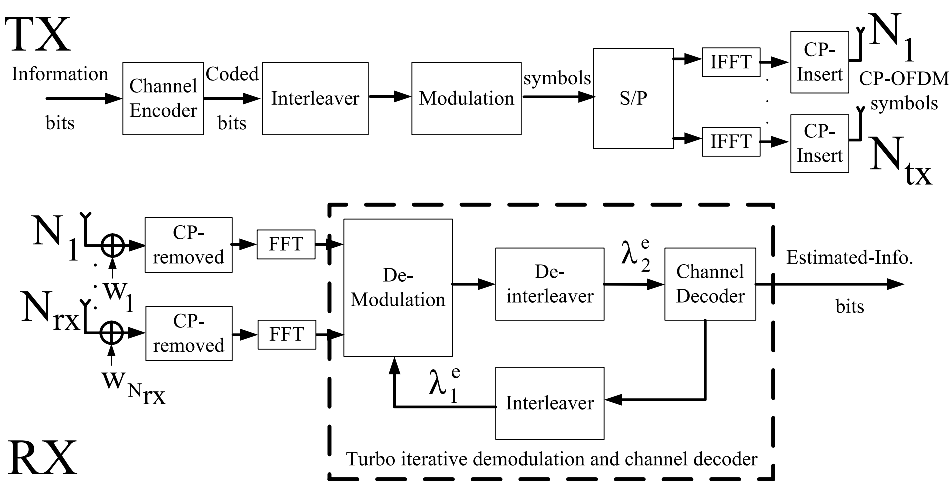

Fig. 1. An MIMO OFDM Turbo iterative receiver suffers from RPI effect

For a transmitter structure as shown in Fig. 1 and bases on the available LTE system bandwidth, we consider the MIMO OFDM system with K subcarriers and having N_{tx} transmitter antennas, and N_{rx} receiver antennas. In the transmitter of Fig. 1, a block of information bits m is passed to the channel encoder and encoded at a rate $r = m/n$. Then n coded bits are passed to the interleaver so as to decrease the correlations among coded bits and to eliminate the possible burst errors, they are afterwards passed to modulator to form modulated symbols with format of QPSK, 16QAM or 64QAM; the transmitter then bases on the channel condition to select an appropriate

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modulation format. They are then sent to serial to parallel (S/P) block and perform the inverse fast Fourier transform (IFFT) to formulate OFDM signals. There are $\mathrm{q} = (\mathrm{n}/\log_2|\Omega|)/\mathrm{KN_{tx}}$ OFDM symbols; these symbols are added by proper cyclic prefixes (CP) [2] and transmitted through the antennas to the communication channel, where Ω is the set of modulation constellations and K is the number of subcarriers in the OFDM symbol. In this paper we adopt the extended pedestrian A (EPA) scenario [5] in LTE specification as the multipath signal propagation model.

In Eq. (1) the relation between the received signal $\mathbf{y}[p,k] \in C^{N_{rx}}$ that is resulted from removing the CP and passing through the fast Fourier transform (FFT) block and the transmitted signal $\mathbf{x}[p,k] \in \Omega^{N_{tx}}$ for the pth OFDM symbol and kth subcarrier, the matrix of the channel frequency response $\mathbf{H}[p,k] \in C^{N_{rx}N_{tx}}$ [1, 5] and the RPI effect, denoted as $\Delta\mathbf{G}$ [3, 4] can be expressed as in Eq. (1)

$$
\begin{aligned}
&\mathbf{y}[p,k] = \sqrt{\frac{SNR}{N_{tx}}}\Delta\mathbf{G}\mathbf{H}[p,k]\mathbf{x}[p,k] + \mathbf{w}[p,k], \text{ where} \\
&\Delta\mathbf{G} = \begin{bmatrix} 1 & 0 \\ 0 & \alpha \end{bmatrix}, \ -10\,\mathrm{dB} \le \alpha \le 0\,\mathrm{dB} \\
&\mathbf{H}[p,k] = \sum_{l=0}^{L-1} \mathbf{H}_l[p] \exp\left(\frac{-j2\pi lk}{K}\right), \\
&0 \le k \le K-1, \ 0 \le p \le q-1
\end{aligned} \tag{1}
$$

It is assumed that the channel frequency response $\mathbf{H}[p,k]$ in Eq. (1) is a quasi-static fading channel with L totally resolvable multipath that in path l the OFDM with symbol index p and subcarrier index k has fading characteristic independently from other symbols and subcarriers in different paths; in addition, the power of all resolvable path is normalized to 1 and each path is an independent and identity distributed (i.i.d.) circularly symmetric complex Gaussian with mean 0 and variance 1. An additive white Gaussian noise (AWGN), $\mathbf{w}[p,k] \in C^{N_{rx}}$, with i.i.d. of mean 0 and variance 1 is considered.

We define SNR is the average received signal to noise ratio at each received antenna without considering RPI and is equal to $\mathrm{E_b{*}R{*}M/N_0}$ where $\mathrm{E_b}$ is the information bit energy, R and M stand for the code rate and the modulation order respectively, it assumes that transmitted power is normalize to one and the two antennas at the transmitter and the receiver terminal are synchronized and without any correlation among antennas. At the transmitter terminal it is assumed that there is no link to know the channel state information (CSI) however it is assumed that at the receiver terminal it is able to acquire the CSI information. The turbo iterative receiver at the receiver terminal includes the MIMO OFDM demodulation (MOD), deinterleaver, channel decoder and the feedback path from the channel decoder through the interleaver to the MOD and in Fig. 1 λ_1^e and λ_2^e are the extrinsic information conveyed from the MOD to the channel decoder and from the channel decoder to the MOD respectively [1]. From iterative operations of the turbo receiver it not only performs interferences cancellation to remove

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interferences from the desired signal and it also improves the error correction efficiency of the decoder through these extrinsic information exchanges.

3 System performance simulation

The system parameters such as the system bandwidth, number of subcarriers in an OFDM symbol [2], cyclic prefix values [2] and the channel model EPA implemented in the system performance simulation are specified in LTE specifications [5]. System bandwidth of 1.4 MHz is adopted in the simulation. When the system suffers various levels of RPI effect then a LDPC code with code rate 1/2 or a (2, 1, 6) Convolution code (CC216) with code rate 1/2 is used as the channel coding, and also in LDPC decoding it performs 16 iterative operations within the LDPC channel decoder [3].

Table I. Simulation Result when MOD Concatenates Serially with LDPC or with CC216

BER $\leq 10^{-3}$								
Turbo iteration	**Without Turbo iteration**		**Turbo iteration=1**		**Turbo iteration=2**		**Turbo iteration=3**	
channel coder	**LDPC**	**CC216**	**LDPC**	**CC216**	**LDPC**	**CC216**	**LDPC**	**CC216**
RPI=0dB	~5.15dB	~14dB	~3.92dB	~10dB	~3.4dB	~9.2dB	~3.01dB	~9.1dB
RPI=-1dB	~5.57dB	~14.8dB	~4.46dB	~10.6dB	~4.3dB	~10dB	~3.9dB	~10dB
RPI=-2dB	~6.3dB	~16.3dB	~5.01dB	~11.8dB	~4.47dB	~11dB	~4.01dB	~11dB
RPI=-3dB	~7.2dB	╳	~5.8dB	~13dB	~5.47dB	~12.6dB	~5.47dB	~12.6dB
RPI=-4dB	~8.18dB	╳	~6.7dB	~17dB	~6.37dB	~15.6dB	~6.3dB	~15.6dB
RPI=-5dB	~9.4dB	╳	~7.92dB	╳	~7.4dB	╳	~7.4dB	╳
RPI=-6dB	~11.6dB	╳	~9.4dB	╳	~8.65dB	╳	~8.6dB	╳
RPI=-7dB	~14dB	╳	~11.4dB	╳	~10.6dB	╳	~10.4dB	╳
RPI=-8dB	╳	╳	~14.3dB	╳	~13.2dB	╳	~12.6dB	╳
RPI=-9dB	╳	╳	╳	╳	╳	╳	~18.1dB	╳
RPI=-10dB	╳	╳	╳	╳	╳	╳	╳	╳

When the allowable BER in the system is set less than 10^{-3}, the simulation results are listed in Table I for the required SNR in our proposed turbo iterative receiver with either LDPC or CC216 decoder is cascaded with the MOD and the turbo iteration number between MOD and channel decoder varies from 0 to 3 for the RPI effect in the MIMO OFDM communication system has the range from -10 dB to 0 dB. For any entry in the table with the symbol '╳' it represents that in the considered RPI effect the resulting system BER curve has reached the error floor and the performance is worse than the set requirement 10^{-3} even SNR is operated at very good channel condition.

From this table it finds that when we use turbo iterative receiver it can mitigate RPI effect no matter which channel decoder is cascaded with the MOD, especially it reveals that when the MOD is concatenated by the CC216 it can mitigate the RPI effect only if its range lies between -4 dB and 0 dB. And in all simulations it has the results that the data are convergent when the iteration is larger than two times, hence even we set the turbo iteration

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number larger than 2 the resulting system gain would not be increased further. On the other hand when we use powerful error correction code like the LDPC code, the performance converges when RPI varies from −7 dB to 0 dB and the iterative times of the turbo receiver is larger than 2; however if the magnitude of RPI is larger than 7 dB but smaller than 10 dB, it also observes that by using turbo iterative receiver it can improve system performance significantly when we increase the turbo receiver iterative times. Therefore if the magnitude of RPI is lower than 10 dB and the system BER is set better than 10^{-3}, as opposed to the situation when it does not implement any iteration between the MOD and the channel decoder (the results as listed in the column 'Without Turbo iteration' in the table), the MOD cascades with CC216 is insensitive to the variation of RPI when its magnitude is lower than 5 dB, while when the MOD is concatenated by a LDPC it reveals that it makes the gradient of SNR is not sensitive to RPI effect when the magnitude of RPI is lower than 10 dB therefore even the system suffers from RPI effect it is still possible to provide acceptable quality of service by implementing turbo iterative receiver.

4 Conclusion

If the RPI information is not available at the receiver terminal, we can implement turbo iterative receiver to mitigate this RPI effect no matter whether a LDPC or a CC216 is cascaded with MOD, however the capability of turbo iterative receiver to relieve RPI effect depends on the error correction capability of the channel coding. If a channel coding, such as CC216, does not have strong error correction capability then although the turbo iterative receiver implemented with this decoder can sooth RPI effect but the capability of its mitigation is not quite satisfactory; however when RPI magnitude is lower than 5 dB it can reduce the RPI effect by increasing the turbo iteration times. However if the MOD is concatenated serially by a powerful error correction decoder like LDPC the resulting decoder can make the BER insensitive to the variation of RPI effect when the magnitude of RPI is lower than 10 dB comparing with the results obtained from the system without implementing the turbo iterative receiver, and in this situation we can even improve the system performance by increasing the iteration numbers. Consequently it concludes even if the system suffers from RPI effect we still can implement the system with turbo iterative receiver to reduce this RPI effect and to maintain the system performance at certain acceptable level.

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