PERFORMANCE ANALYSIS OF PCFICH LTE CONTROL CHANNEL

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Abstract: Control channels play a key role in the evaluation of mobile system performance. The purpose of our paper is to evaluate the performance of control channel implementation in a Long Term Evolution (LTE) system. The paper deals with the simulation of the complete signal processing chain for Physical Control Format Indicator Channel (PCFICH) in a LTE system. We implemented a complete signal processing chain for downlink control channels as an extension of the existing MATLAB LTE downlink simulator. The paper presents results of PCFICH control channel performance analysis in various channel conditions, the results can be compared with the performance of data channels.

Keywords: Long Term Evolution, Control Channels, Physical Control Format Indicator Channel, Bit Error Rate, MATLAB

1 INTRODUCTION

Link level simulators are typically involved in the processing of traffic channels. For an overall system performance and comparison with real network deployment it is necessary to include control channels in the simulations. Control channels are typically designed with more robust forward error correction and modulation. In the case of the Third Generation Partnership Project (3GPP) LTE system uses a combination of the OFDMA (Orthogonal Frequency Division Multiple Access) access method and robust scrambling of control channel information. We base our work on the MATLAB simulator developed at Technical University Vienna [2]. The missing control channels for downlink were implemented in the above-mentioned simulator.

The next evolution step in the high data-rate packet mobile systems is 3GPP Long Term Evolution. LTE still belongs to the third generation of mobile systems. It directly follows up on the UMTS (Universal Mobile Telecommunication System) and HSPA (High-speed Packet Access) systems. LTE supports variable bandwidths in a range from 1.4 MHz to 20 MHz. The RAN Round-trip time is less than 10 ms. LTE also supports Frequency Division Duplex (FDD) and Time Division Duplex (TDD). The theoretical peak data rate in downlink is 172.8 Mbps, in uplink 57.6 Mbps. This article deals with the downlink part only.

The physical Layer of LTE system uses different modulating and accessing techniques in downlink and uplink. In downlink OFDMA was chosen the. It is a multiuser version of OFDM, a combination of Frequency Division Multiple Access (FDMA) and the OFDM modulation technique. It is the best-quality subcarriers that are assigned to individual users.

The paper is organized as follows. First the LTE system is described briefly. The next part brings a detail description of the signal processing chain of PCFICH control channel. Simulations and their results are mentioned in the third part and summarized in the conclusion.

2 PHYSICAL CONTROL FORMAT INDICATOR CHANNEL - PCFICH

This article deals with signal processing and bit error rate in the Physical Control Format Indicator Channel. Via this channel CFI (Control Format Indicator) information is transmitted. The value stored in CFI determines the timing span of OFDM symbols carrying the data of PDCCH control channel – it determines the control area in each subframe in downlink. The block diagram of PCFICH signal processing is shown in Figure 1.

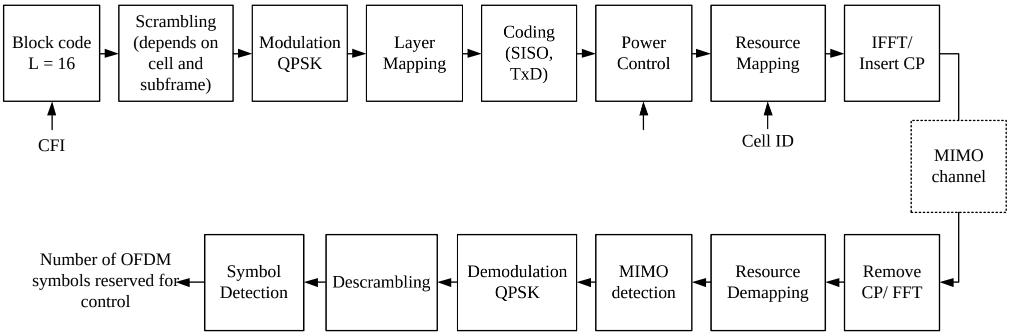

Figure 1: Block scheme of signal processing in the PCFICH [6].

2.1 CFI - CONTROL FORMAT INDICATOR

The Control Format Indicator (CFI) takes values 1, 2 or 3 only. The value CFI = 4 is reserved. For a bandwidth which is defined by more than 10 RB (Resource Blocks [4]), the number of OFDM symbols used for transmitting control information is the same as the value stored in CFI. Otherwise the value is CFI+1. The first operation in the signal processing chain is channel coding. A bit sequence of 32 bits in length is assigned to each value in CFI, see Table 1.

CFI	CFI codeword $[b_0, b_1, \cdots, b_{31}]$
1	[01101101101101101101101101101101]
2	[10110110110110110110110110110110]
3	[11011011011011011011011011011011]
4 (reserved)	[00000000000000000000000000000000]

Table 1: Channel coding PCFICH.

2.2 TRANSMITTER

The first operation on the physical layer is scrambling. A codeword of 32 bits in length is scrambled with a scrambling sequence which is unique for each cell. Scrambling sequences are pseudo-random sequences created by the generator of Gold Sequences of 31 bits in length [4]. At the beginning of every subframe this generator is initialized using the slot number in radio frame n_s and the cell indetification number N_{ID}^{cell}. The scrambling sequence, which is unique for each cell in the system, is a means of supressioning intercell interference. Interference received together with the correct data stream will be descrambled incorrectly and they will be decoded only as a non-corelated noise.

The scrambled bits are modulated by QPSK modulation and then form a block of complex-value symbols [4]. Next, complex symbols are mapped into one, two or four layers, depend on the number of transmitting antennas. Complex, modulated symbols denoted $d^{(0)}(i)$ are mapped into ν-layers $x^{(0)}(i), x^{(1)}(i), \ldots, x^{(\nu-1)}(i)$. In the case of one transmitting port, layer mapping is not used, thus

$x^{(0)}(i) = d^{(0)}(i)$. In the case of two or four tranmitting ports, layer mapping and symbol selection are provided sequentially.

The block of layer-mapped symbols goes into the coder, from which a data sequence is generated for every transmitting antenna port y^p, where p is the number of antenna ports. If only one antenna is used for transmitting (SISO), coding is not implemented. Coding for Transmit Divesity (TxD) is available only for two or four antenna ports. The Alamouti scheme for transmit diversity is defined by an exact relationship between input and output [4].

The Resource Mapping is the last operation in the PCFICH channel processing chain. Complex symbols for each transmit antenna are grouped to quaternary symbols, so-called symbol quadruplets, which are mapped to resource elements. Resource element is the smallest unit in the time-frequency resource grid. Altogether there are 16 complex symbols (i.e. 4 quadruplets) and they are mapped into the first OFDM symbol in the radioframe slot.

2.3 RECEIVING SIDE

When the signal passes through the channel (here signed as MIMO channel), first the cyclic prefix (CP) of OFDM symbol is removed and FFT is performed. After that, resource demapping and selection of symbols corresponding with PCFICH from the resource (time-frequency) grid take place. In the MIMO detection block, decoding and symbol combination (in the case of transmission using multiple antennas) are performed. Symbols are demodulated and descrambled. The last block in the signal chain is a block that detects two-bit CFI codewords.

3 SIMULATIONS

Within the scope of the PCFICH control channel analysis, simulations of Bit error rate were performed with different parameter. The main common parameter for all simulations are the number of transmitted subframes for each value of SNR, $N_{\text{subf}} = 2000$ and the system bandwidth $\text{BW} = 1.4$ MHz. All available MIMO antenna configurations were also used.

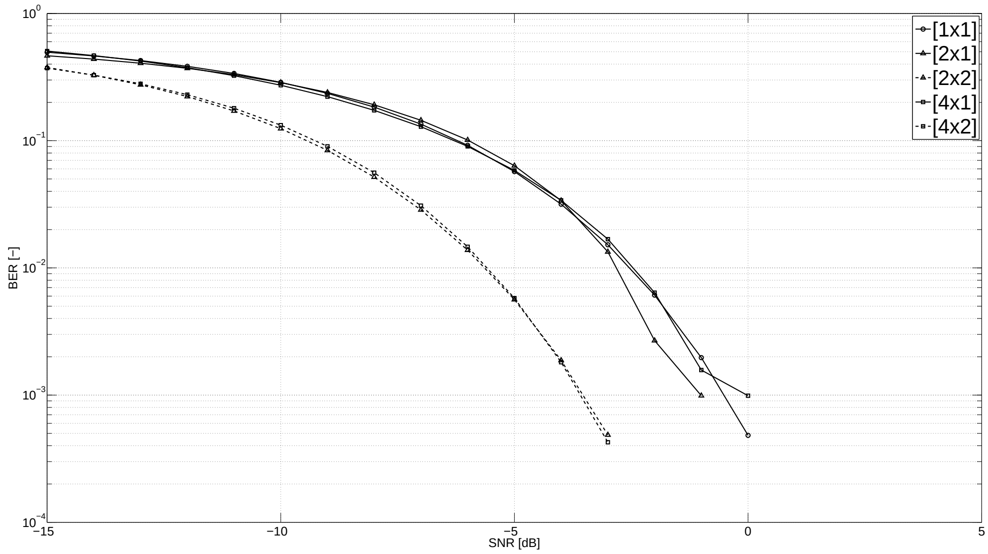

Figure 2: Bit error rate PCFICH in AWGN channel, $N_{\text{subf}} = 2000$.

Bit error rate in PCFICH for AWGN and Pedestrian B channel are shown in Figure 2 and 3. It is obvious that receiving diversity by two receiving antennas provides a lower BER.

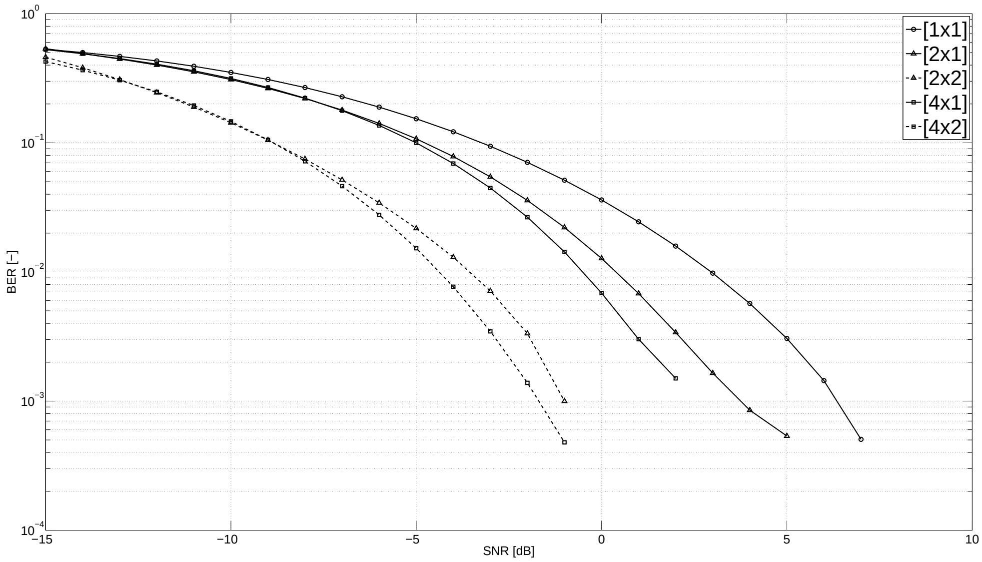

Figure 3: Bit error rate PCFICH in Pedestrian B channel, $N_{\text{subf}} = 2000$.

Bit error rate in urban environment, Typical Urban channel, is shown in Figure 4. This graph shows analogous results as to those of Pedestrian B channel. Receiving diversity markedly improves receiving conditions.

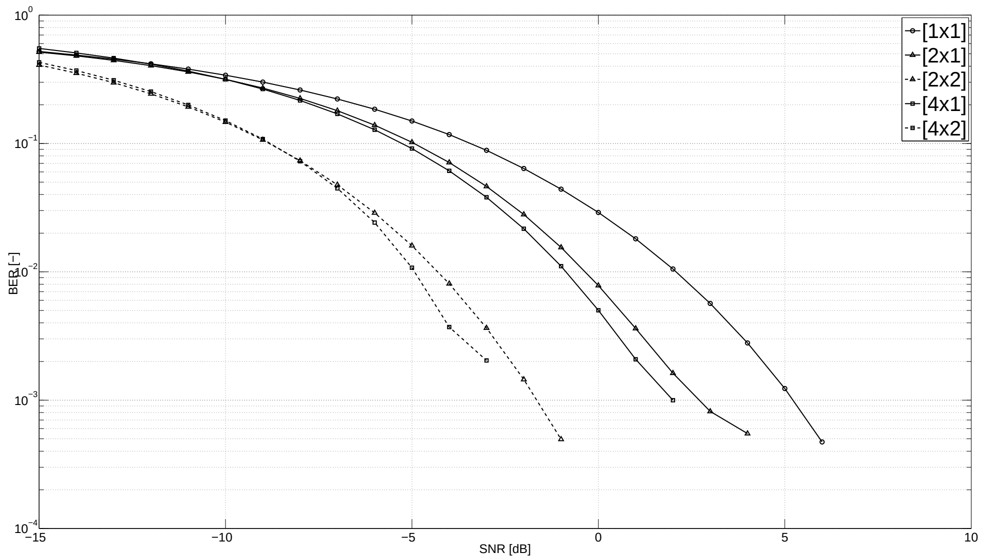

Figure 4: Bit error rate PCFICH in Typical Urban channel, $N_{\text{subf}} = 2000$.

In Figure 5, BER in Vehicular A channel is shown. It is evident that for objects moving with a high velocity using the SISO mode is not suitable.

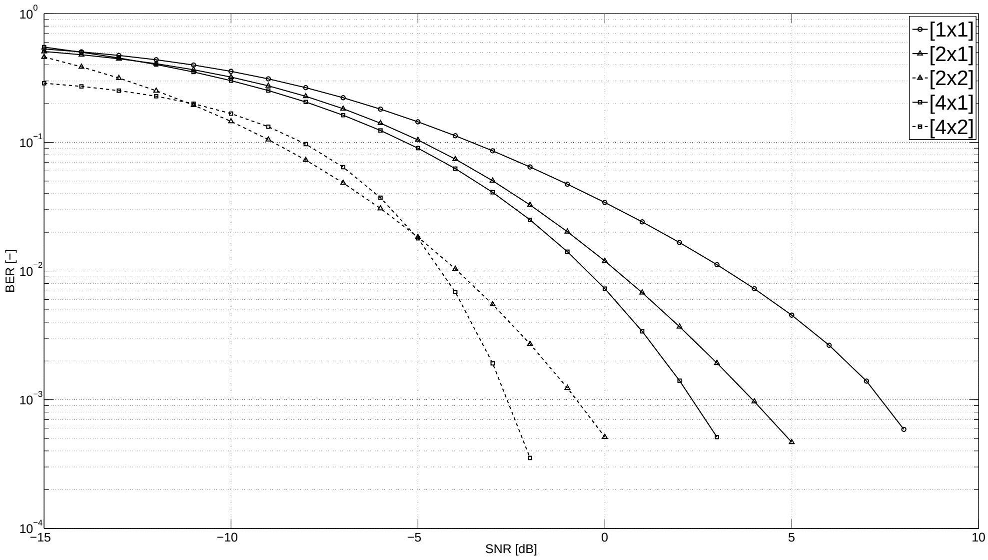

Figure 5: Bit error rate PCFICH in Vehicular A channel, $N_{\text{subf}} = 2000$.

4 CONCLUSION

Signal processing in the LTE PCFICH channel and bit error rate simulation results are presented. As shown in the results, using the SISO mode in some types of radio channel is not suitable. Most markedly, we can see it in the case of Vehicular A model. In this case, it is strongly recommended to use receiving diversity with two receiving antennas. For further research activity would be appropriate to examine the possibility of changing the method of processing the PCFICH signal and the channel coding of CFI.

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