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Research On Method Of PUCCH Channel Estimation Based On UCI Separate Coding

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Abstract. channel quality indicator and hybrid automatic repeat –request acknowledgement are important feedback information in system of 3GPP LTE, adopted joint or separate coding when transmitted via Physical uplink control channel. When uplink control information adopted type of joint coding, performance of channel estimation will decline and the number of reference signal will decrease because the ACK/NAK bits are embedded in one of the CQI reference signals. A program for uplink channel estimation is proposed for this issue. Simulation results show the effectiveness of the algorithm, which has been applied to TD-LTE wireless integrated test instrument.

Keywords: UCI; reference signal; channel estimation; Physical uplink control channel

1. Introduction

Along with the 3G technology appearance, for improve transmission speed, the 3rd generation mobile communication–the long term evolution(LTE) is researched and standardized by 3GPP organization. The target peak data rates for downlink and uplink in the LTE system set at 100Mbps and 50Mbps respectively within a 20MHz bandwidth, corresponding to respective peak spectral efficiencies of 5and 2.5bps/Hz.for low Peak-to-Average Power Ratio(PAPR) and reducing cost , size and power consumption of UE Power Amplifier, Single-Carrier Frequency Division Multiple Access(SC-FDMA) were used in Uplink[1].

In OFDM system , The Channel Estimation algorithm based on reference signal were used widely[2].The reference signal were insert into the resource grid in fixed position, however, In the receiver, the reference signal channel impulse response can be obtain by reference signal with local and received data, and then, All the impulse response of resource grid will be gained via interpolation. The channel estimation of OFDM system can be based on Least Square (LS)[3]or Minimum Mean-Square (MMSE).The MMSE estimate has been shown to give 10–15 dB gain in signal-to-noise ratio (SNR) for the same mean square error of channel estimation over LS estimate. a low-rank approximation is applied to linear MMSE by using the frequency correlation of the channel to eliminate the major drawback of MMSE, which is complexity. The interpolation of the channel can depend on linear interpolation, second order interpolation, low-pass interpolation, splice cubic interpolation, and time domain interpolation. second-order interpolation has been shown to perform better than the linear interpolation. In [4], time-domain interpolation has been proven to give lower bit-error rate (BER) compared to linear interpolation.

When transmitting a channel quality indicator at the same time as a hybrid-ARQ acknowledgement (ACK), for normal cyclic prefix, the second reference symbol in each slot is modulated by ACK/NAK symbols. However, the ACK/NAK symbols on the reference signal are unknown to eNodeB. so, if only one reference signal was used and then the performance of channel estimation became poor.

The paper is organized as follows. In Section II, the generation of reference signal in physical uplink control channel is described. In Section III, the Channel Estimation and interpolation algorithm is detailed. Simulations results and analysis are provided in section IV and the paper is concluded in section V

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2. Reference Signals

2.1. Generation of the Reference Signal

The uplink reference signals in LTE are mostly based on Zadoff-Chu(ZC)sequence. These sequences satisfy the desirable properties for RS mentioned above, exhibiting 0 dB CM, ideal cyclic autocorrelation, and optimal cross-correlation. The cross-correlation property results in the impact of an interfering signal being spread evenly in the time domain after time-domain correlation of the received signal with the desired sequence; this results in more reliable detection of the significant channel taps[5].

The sequence-group number u and sequence hopping number v can be calculated by user equipment with parameters through broadcast messages, and then The definition of the base sequence depends on the sequence length M_{sc}^{RS} [6].

a) For $M_{sc}^{RS} < 3N_{sc}^{RB}$,the base sequence are QPSK RS sequences which are obtained form computer searches so as to have constant modulus in the frequency-domain, low CM, low memory/complexity requirements, and good cross-correlation properties.

$$\overline{r}_{u,v}(n) = e^{j\varphi(n)\pi/4}, \quad 0 \le n \le M_{\text{sc}}^{\text{RS}} - 1 \tag{1}$$

$\varphi(n)$ can be obtained by n and u, defined in [6],table5.5.1.2-1 and 5.5.1.2-2.

b) For $M_{\text{sc}}^{\text{RS}} \ge 3N_{\text{sc}}^{\text{RB}}$,the base sequence is given by

$$\overline{r}_{u,v}(n) = x_q(n \bmod N_{\text{ZC}}^{\text{RS}}), \quad 0 \le n < M_{\text{sc}}^{\text{RS}} \tag{2}$$

Where the Zadoff-Chu sequence is defined by

$$x_q(m) = e^{-j\frac{\pi q m(m+1)}{N_{\text{ZC}}^{\text{RS}}}}, \quad 0 \le m \le N_{\text{ZC}}^{\text{RS}} - 1, \quad q = \lfloor \overline{q} + 1/2 \rfloor + v \cdot (-1)^{\lfloor 2\overline{q} \rfloor}, \quad \overline{q} = N_{\text{ZC}}^{\text{RS}} \cdot (u+1)/31$$

The length $N_{\text{ZC}}^{\text{RS}}$ of the Zadoff-Chu sequence is the largest prime number such that $N_{\text{ZC}}^{\text{RS}} < M_{sc}^{RS}$ .The DMRS on the PUCCH is obtained by multiplied base sequence and cyclic shift. number of cyclic shift α is provide by higher layers. Reference signal sequence $r_{u,v}^{(\alpha)}(n)$ is according to

$$r_{u,v}^{(\alpha)}(n) = e^{j\alpha n}\overline{r}_{u,v}(n), \quad 0 \le n < M_{\text{sc}}^{\text{RS}} \tag{3}$$

The demodulation reference signal sequence is defined by

$$r^{\text{PUCCH}}\left(m' N_{\text{RS}}^{\text{PUCCH}} M_{\text{sc}}^{\text{RS}} + m M_{\text{sc}}^{\text{RS}} + n\right) = \overline{w}(m) z(m) r_{u,v}^{(\alpha)}(n) \tag{4}$$

Where $m' = 0,1$; $m = 0,..., N_{\text{RS}}^{\text{PUCCH}} - 1$; $n = 0,..., M_{\text{sc}}^{\text{RS}} - 1$; $N_{\text{RS}}^{\text{PUCCH}}$ is the number of reference symbols per slot and the sequence $\overline{w}(n)$ are given by[6].

For PUCCH formats 2a and 2b, $z(m)$ equals $d(10)$ for $m = 1$,For all other cases, $z(m) = 1$. $d(10)$ is 1-or 2-bit HARQ ACK/NACK modulation symbol, and used to modulate the second RS symbol.

2.2. Resources Mapping of Reference Signal

In LTE system, the uplink channel estimation is based on block structure[7] of Reference Signal which is insert into time domain periodicity, but all the subcarrier is used as Reference Signal in frequency domain. This structure is suitable for slow fading channel. In this paper, Demodulation reference signal(DMRS) is used for channel estimation.

Cycle prefix(CP) is add to the Each SC-FDMA symbols in uplink for ensuring robustness against ISI. The frequency domain of PUCCH DMRS is the same as PUCCH data signal. And defined as follow in TABLE I.

TABLE I. Demodulation reference signal location for PUCCH

PUCCH format	Normal CP	Extended CP
1,1a,1b	2, 3, 4	2, 3
2	1, 5	3
2a/ab	1, 5	N/A

Position of PUCCH resource[8] is defined：

$$n_{\text{PRB}} = \begin{cases} \left\lfloor \frac{m}{2} \right\rfloor & \text{if } (m + n_s \bmod 2) \bmod 2 = 0 \\ N_{\text{RB}}^{\text{UL}} - 1 - \left\lfloor \frac{m}{2} \right\rfloor & \text{if } (m + n_s \bmod 2) \bmod 2 = 1 \end{cases} \tag{5}$$

Where in（5） $m = \left\lfloor n_{\text{PUCCH}}^{(2)} / N_{\text{sc}}^{\text{RB}} \right\rfloor$，In order to minimize the resources needed for transmission of control signaling, the PUCCH in LTE is designed to exploit frequency diversity: each PUCCH transmission in one subframe is comprised of a single (0.5 ms) RB at or near one edge of the system bandwidth, followed (in the second slot of the subframe) by a second RB at or near the opposite edge of the system bandwidth, as shown in Figure 1; together, the two RBs are referred to as a PUCCH region. This design can achieve a frequency diversity benefit of approximately 2 dB compared to transmission in the same RB throughout the subframe. In the case of ACK and CQI

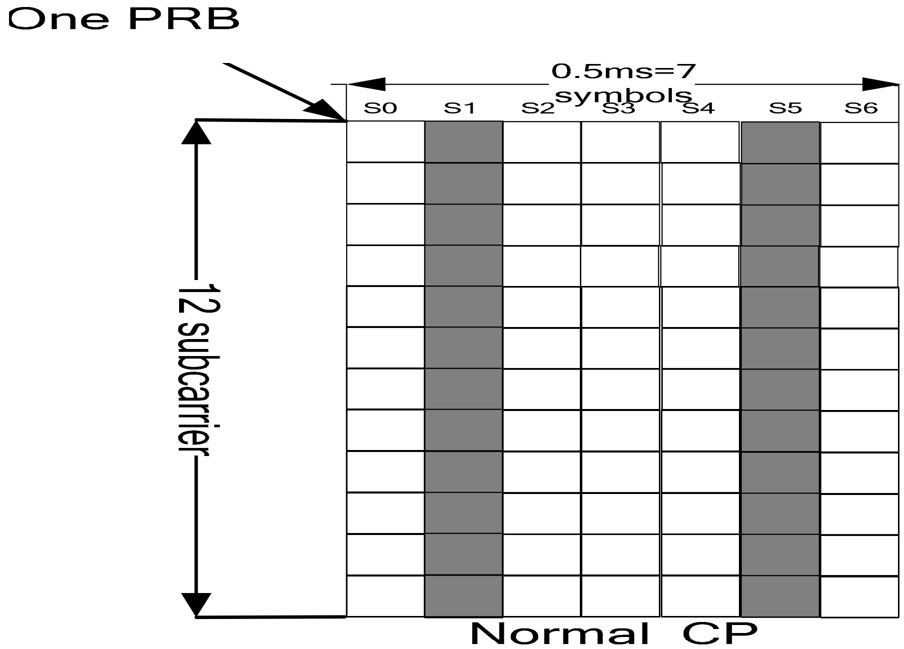

Figure 1. Demodulation reference signal mapping of type 2a/b

3. Channel Estimation Model

3.1.Channel Estimation and Interpolation Algorithm

a) Considering the complexity of the engineering implementation, this paper adopts low complexity and easy to the realization of LS of channel algorithm[3]

$$f = (Y - XFh)^H (Y - XFh) \tag{6}$$

The LS estimate is minimizes (6)。Where，$Y = [Y(0)Y(1)\cdots Y(N-1)]^T$，$X = diag\{X(0), X(1), \cdots, X(N-1)\}$，F is DFT matrix

$$F = \begin{bmatrix} W_N^{00} & \cdots & W_N^{0(N-1)} \\ \vdots & \ddots & \vdots \\ W_N^{(N-1)0} & \cdots & W_N^{(N-1)(N-1)} \end{bmatrix}, \quad W_N^{NK} = \frac{1}{N} e^{-j2\pi(n/N)k}$$ 。

The LS estimate is represented by:

$$H_{LS} = Fh_{LS} = FQ_{LS} F^H X^H Y \tag{7}$$

Where $Q_{LS} = \left(F^H X^H XF\right)^{-1}$,so $H_{LS} = X^{-1}Y$.

b) Considering the RS structure of format 2a/2b, In this paper, linear interpolation is adopted which is defined as follow:

$$H(k,l)=\frac{l_2-l}{l_2-l_1}\times H(k,l_1)+\frac{l-l_1}{l_2-l_1}\times H(k,l_2) \quad (8)$$

Where l_1,l_2 represent the position of RS, $H(k,l_1),H(k,l_2)$ represent the impulse response for two RS. H(k,l) is unknown impulse response for estimate.

3.2.Channel Estimation Process

This paper mainly focus on PUCCH format 2a/2b(see chart 1), In the case of normal CP, There are 7 SC-FDMA symbols in a slot, and symbol S1 and S5 are reference signal, however , reference signal S5 which is modulated by information of ACK is unknown for receiver, so , the reference signal S5 can not be generated by the receiver. The performance of channel estimation which is based on only one DMRS is poor. In this paper, a coherent demodulation algorithm is proposed for estimated symbol S5, and then , two symbols S1and S5 which has been demodulated are used for channel estimation.

a) Parameter Description

Symbol R1 and R5 are represent reference signals 1 and 5 in receiver; Symbol r1 and r5 are represent reference signals 1 and 5 in transmitter; Data symbol of CQI is represent by symbol Y, and H is impulse response of resources grid.

b) Algorithm flow

The algorithm is suitable for PUCCH format 2a/2b and can be summarized as follows:

step 1) The receive data $y(t)$ which has removed CP is changed into complex symbols by FFT in time domain, and then, reference signal R1 and R5 is extracted from symbol 1 and 5 in resources grid.

step 2) Impulse response H1 can be obtained by channel estimation with input of reference r1 and R1,Where $H1=r1^{-1}R1$.

step 3) The second reference signal r5 is generated by reference signal R5 which is modulated by information of ACK and impulse response H1.where $r5=[\alpha_1,\alpha_2,\cdots,\alpha_N]$, N=12, α_i is subcarrier which is include complex symbols, and then coherent with reference signal r which is not include the ACK information ,where $S_r=\sum_{i=1}^{N} r_i r5_i^*$.

step 4) S_r will be dispose with special QPSK demodulation by PUCCH, specific reference table 2, and original ACK bit is obtained. Reference signal $r5$ can be generated by original ACK bit.

step 5) The second Impulse response $H5$ is obtained by channel estimation with RS $R5$ and RS $r5$ which regenerate in local, where $H5=r5^{-1}R5$

step 6) All Impulse response H in resources grid is obtained by linear interpolation with two Impulse response $H1,H5$ of reference signal, and then extract symbol Y which include CQI information from resources grid and signal detection. The program is over.

TABLE II. Chart of PUCCH ACK demodulation

PUCCH format	Modulated symbol	Demodulated bits
2a	1	0
	-1	1
2b	1	00
	$-j$	01
	j	10
	-1	11

The process is showed in detail with Fig 2：

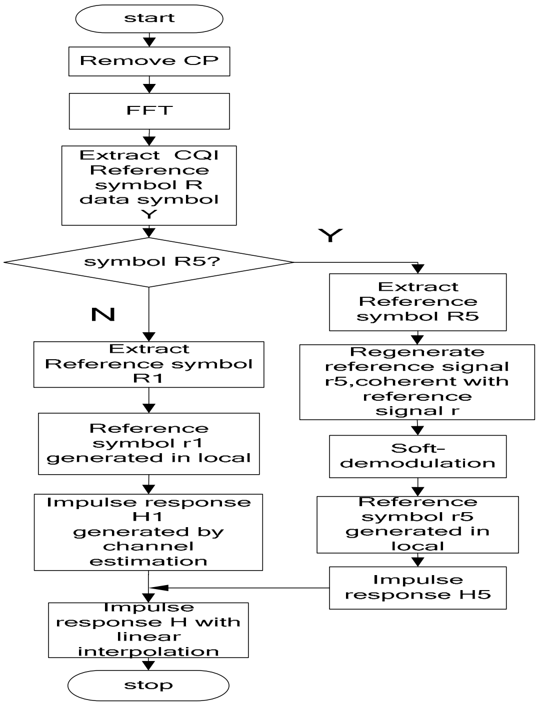

Figure 2. Framework of channel estimation

4. Computer Simulations

To demonstrate the effectiveness of our proposals, computer simulations will be provided in this section. The simulation is based on PUCCH uplink and The performance of Receiver are measured by BLER, we denote x label as SNR and y label as BLER. In LTE system, there are three type of channel[9]: EPA， EVA， ETU, but in this paper, the extended typical urban model (ETU) which has the large multi-path delay is used. The simulation parameters are listed in Table III, Furthermore, we consider two Doppler frequency cases with Fd = 200, 300HZ, respectively, and corresponding speed are $v \approx 105km/h$ 、 $v \approx 160km/h$ 。 In our simulations, length of CQI and ACK/NAK are 12 and 2 bits or 9 and 1.

TABLE III. SIMULATION PARAMETERS

Parameters	Values
Carrier frequency	2GHz
Bandwidth	5MHz
FFT size	2048
Cyclic prefix	Normal
MIMO configuration	1T2R
Modulation	QPSK
Channel model	ETU
Mobile speed	105/160 Km/h
Length of CQI/ACK bits	12/2,9/1
Number of simulation	5000

The algorithm reduce the multipath effect and BLER because CQI reference signal with ACK information is obtained by impulse response of reference signal r1. In Figure 3, the CQI data are obtained by channel estimation with DMRS which include ACK information, and number of CQI is more than that of ACK, as a result , BLER of CQI is higher than that of ACK. as the signal-to-noise ratio increases, the performance of CQI become well and approach to ACK, the performance of one ACK bit is better than that of two ACK bits. In the case of -5dB, BLER of ACK and CQI is under 10^{-3}; Figure 4 is performance of Doppler frequency 300HZ, In the case of -3dB, BLER of ACK and CQI is under 10^{-3}. The algorithm has well performance in high speed environment by comparing Fig 3 with Fig 4. Consequently, performance of algorithm is suitable for engineer realization.

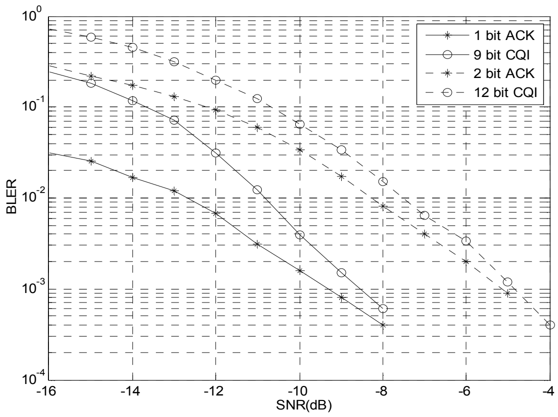

Figure 3. Simulation performance of Doppler frequency 200HZ

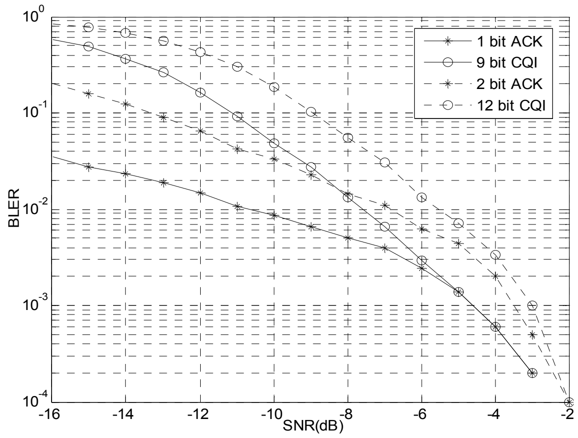

Figure 4. Simulation performance of Doppler frequency 200HZ

5. Conclusions

In this paper, generation of PUCCH DMRS and Resources Mapping in LTE system is introduced in detail. An algorithm based on LS channel estimation and linear interpolation is proposed for PUCCH format 2a/2b, and it can resolve problem of reduced reference signal. Simulation is under the different channel condition and input bit. Our simulation results indicate that the algorithm can provide a well performance and suitable for engineer realization.

6. Acknowledgment

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