LTE Antenna Port Number Detection Algorithm Based on Channel Estimation and Piecewise Linear Regression

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Abstract. In LTE system, blind detection of traditional antenna port number detection generated a lot of computational redundancy and delay. To solve this problem, an improved detection algorithm based on channel estimation and piecewise linear regression is proposed. This algorithm fits the phase information of channel state and determines the number of antenna ports. The problem of decision error caused by phase jump is solved by piecewise. The theoretical analysis and simulation results show that the proposed algorithm has the advantages of low complexity and delay.

Keywords: LTE system · Antenna port number detection · Cell reference signal · Channel state information · Piecewise linear regression

1 Introduction

Long Term Evolution (LTE), compared with the previous generation communication system, it has the significant increase of data transmission rate and system capacity is largely due to the adoption of Multiple Input Multiple Output (MIMO) technology [1]. The transmitting end can choose to use 1, 2, or 4 antennas to send Physical Broadcast Channel (PBCH) system messages. The User Equipment (UE) performs the PBCH message decoding after the cell search and downlink synchronization operations are conducted [2]. The PBCH system message can be successfully decoded only if the correct antenna port number configuration information is obtained.

The traditional antenna port number blind detection algorithm repeats PBCH decoding by traversing all possible antenna ports. This method requires up to three complete decoding, so the calculation amount is large and the delay is high. In [3], the authors propose a power detection algorithm that estimates the signal-to-noise ratio of possible antenna ports using the antenna reference signal and secondary synchronization code power of each antenna port, and then uses the signal-to-noise ratio to perform threshold decision to obtain the number of antenna ports. However, when the channel signal-to-noise ratio is relatively poor, the performance of the algorithm drops sharply. The correlation detection algorithm proposed by the authors in [4] is based on the repeatable correlation properties of cell reference signals of different antenna ports and extract the data related to the reference signal position corresponding to the antenna

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port, then determining whether to use the antenna port to transmit data according to the size of the correlation value.

This paper presents an antenna port number detection algorithm based on channel estimation and piecewise linear regression. This algorithm obtains the possible channel state information (CSI) for sending PBCH messages using different antenna ports based on the reference signal. The phase diagram of CSI is fitted by piecewise linear regression algorithm, and then the number of antenna ports used at the sending end is determined.

2 Channel Status Information Extraction

CRS maps the time-frequency resource map according to the antenna port number used to transmit data [5]. When the antenna port $p = 0$ or 1, CRS is located on the first or penultimate OFDM symbol of each slot; when the antenna port $p = 2$ or 3, CRS is located on the second OFDM symbol of each slot.

Channel estimation by comparing the locally generated reference signal with the received reference signal [6]. We assume that the frequency domain information of transmitting end which are not undergone OFDM modulation is $S(\mathrm{j}\omega)$ and the base-band signal information is $s(t)$. After $s(t)$ transmitted by the transmitting end, and receiving by the receiving end, the received signal $r(t)$ is obtained as

$$r(t) = A \cdot s(t + \Delta t)e^{\mathrm{j}\Delta\omega t} + n \tag{1}$$

where A is the amplitude gain during channel transmission, Δt is transmission delay, $\Delta\omega$ is frequency offset, n is Gaussian white noise, which is ignored for simplicity. By the OFDM demodulation [7], $r(t)$ can be transformed into

$$\mathrm{R}(\mathrm{j}\omega) = A \cdot e^{\mathrm{j}(\omega - \Delta\omega)\Delta t} S[\mathrm{j}(\omega - \Delta\omega)] \tag{2}$$

Then, the channel estimation [8] is obtained as

$$H(\mathrm{j}\omega) = R(\mathrm{j}\omega)/S(\mathrm{j}\omega) \ = \frac{A \cdot e^{\mathrm{j}(\omega - \Delta\omega)\Delta t} S[\mathrm{j}(\omega - \Delta\omega)]}{S(\mathrm{j}\omega)} \tag{3}$$

3 Piecewise Linear Regression Algorithm

The theoretical regression model [9] of the linear regression equation is:

$$Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i \tag{4}$$

where i is the sample point sequence, Y_i is the explained variable, X_i is the explanatory variable, ε_i is the random error term, β_0 and β_1 are the regression coefficients.

Define N as the number of sample points, $\bar{X}$ as the average of X_i and $\bar{Y}$ as the average of Y_i. Obtain the regression coefficient solution expression as:

$$\beta_1 = \frac{\sum_{i=1}^{N}(X_i - \bar{X})(Y_i - \bar{Y})}{\sum_{i=1}^{N}(X_i - \bar{X})^2} = \frac{\sum_{i=1}^{N} X_i Y_i - \mathrm{N}\overline{XY}}{\sum_{i=1}^{N} X_i^2 - n\overline{X}^2} \tag{5}$$

$$\beta_0 = \bar{Y} - \beta_1 \bar{X} \tag{6}$$

The absolute average error is:

$$\overline{\varepsilon} = \frac{\sum_{i=1}^{N} |\varepsilon_i|}{N} = \frac{\sum_{i=1}^{N} |\beta_0 + \beta_1 X_i - Y_i|}{N} \tag{7}$$

According to the linear regression equation, the random error ε_i can be calculated, and the mean of the absolute error $\overline{\varepsilon}$ can be obtained. After threshold γ decision, whether the antenna port is equipped with CRS or not can be determined, and finally the number of antenna ports can be determined.

$Y(k)$ represents the estimated phase value of the channel at sampling point k. In this paper, by comparing the average error $\overline{\varepsilon}$ of different antenna ports with the size of the preset threshold γ, we determine whether the current antenna ports are equipped with CRS. The four antenna ports are judged in the order given in Fig. 1, and finally the number of antenna ports used at the transmitter is determined. The specific processing steps of the whole decision process are as Fig. 1.

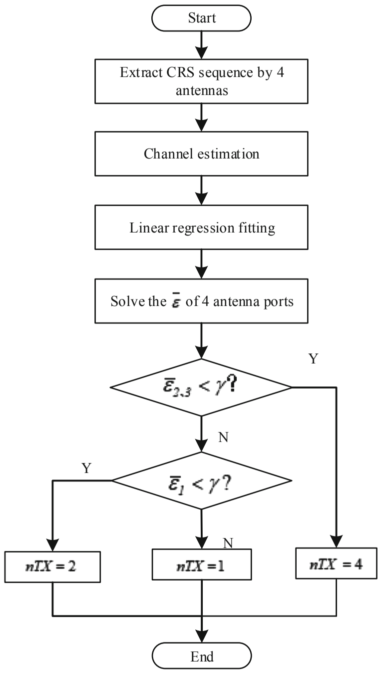


Fig. 1. Flow chart of antenna port number decision

4 Piecewise Linear Regression Algorithm

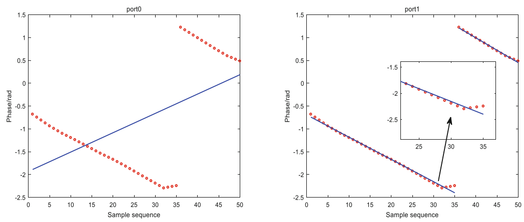
4.1 Verify Piecewise Linear Regression Fit Performance

This section simulates the generation of LTE downlink signals according to specific signal parameters. The specific parameters are shown in Table 1:

Table 1. Simulation parameter settings.

System parameters	Parameter value
Number of transmit antenna ports	1/2/4
Number of receiving antenna ports	1
bandwidth/MHz	20
Frequency offset/Hz	100
Delay/Ts	0.5
Signal to noise ratio/dB	0
Channel model	AWGN

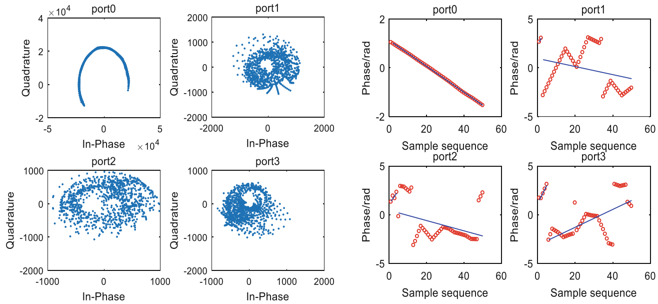
In the process of simulation verification, a decision error occurs due to a large phase jump of the discrete point, as shown in the left subgraph of Fig. 2. It is necessary to add a mutation decision, when the different of phase value which between the current sampling point and the next sampling point reaches a certain threshold, the second stage of fitting is performed, as shown in the right subgraph of Fig. 2.



(a) Unsegmented detection (b) Segmented detection

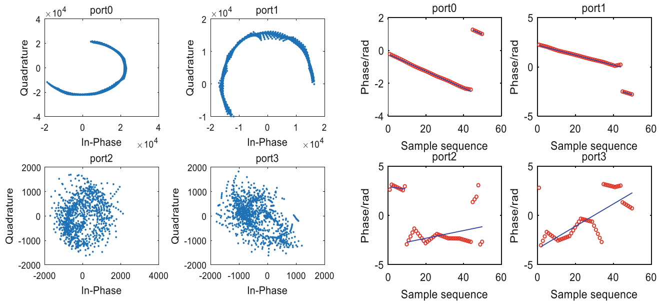
Fig. 2. Unsegmented/segmented detection comparison chart

Figures 3, 4 and 5 shows the case where the sender uses single antenna and two antennas and four antennas to transmit data. When channel estimation is performed using the correct antenna port, the phase value of the channel estimation will form a relatively concentrated arc under the action of frequency offset and phase offset, as shown in the port 0 subgraph of Fig. 4(a). In Fig. 4(b), the red discrete point represents the phase value of the received signal, and the blue line represents the fitted line of the discrete point phase after piecewise linear filter. The phase dispersion point can be well matched when the phase changes regularly. After the simulation test, the threshold γ is generally in the range of 0.2 to 0.6. In this paper, the value of γ is 0.4.



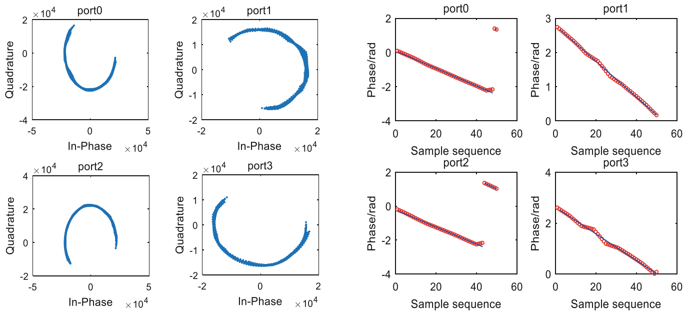
(a) Constellation diagram (b) Piecewise linear regression

Fig. 3. Single antenna constellation and phase fitting diagram



(a) Constellation diagram (b) Piecewise linear regression

Fig. 4. Two antenna constellation and phase fitting diagram (Color figure online)



(a) Constellation diagram (b) Piecewise linear regression

Fig. 5. Four antenna constellation and phase fitting diagram

According to the measured data sent by two antenna ports, verification can be obtained that $\bar{\varepsilon}_0 = 0.0624$, $\bar{\varepsilon}_1 = 0.0763$, $\bar{\varepsilon}_2 = 0.6445$, $\bar{\varepsilon}_3 = 0.7247$. According to the process of Fig. 1, the threshold decision is made, and the number of antenna ports can be correctly solved as two.

4.2 Algorithm Detection Performance Comparison

Section 4.1 has verified the availability of the algorithm when the frequency offset is 100 Hz. This section adds the power detection algorithm and the correlation detection algorithm to the comparison, and adds the frequency offset to 500 Hz and 1000 Hz. If the PBCH message can pass the CRC check, it is determined that the antenna port detection is successful. The detection success rate is shown in Fig. 6.

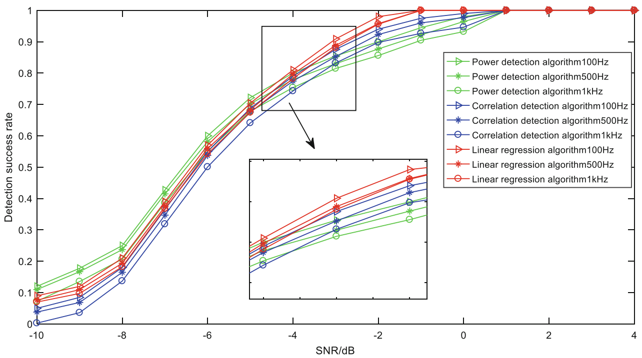


Fig. 6. Comparison of success rates under different frequency offsets

Taking the case of SNR of −3 dB as an example, after the frequency offset is increased from 100 Hz to 500 Hz, the detection success rate of this algorithm is reduced by 1.1%, and the correlation and power detection are reduced by 1.78% and 1.81%, respectively. So the proposed algorithm is more robust. Success rate of piecewise linear regression algorithm detection is always higher than the others. Therefore, the piecewise linear regression algorithm in this paper has more resistance to frequency deviation, better robustness and higher detection success rate than the other two algorithms.

5 Piecewise Linear Regression Algorithm

This paper proposes an antenna port number detection algorithm based on linear regression of channel estimation values. The algorithm uses the channel estimation value through the linear regression equation matching method to determine the number of antenna ports, which solves the problem of the antenna port number decision error caused by the phase mutation of the sampling point of the channel estimation value for fitting. Theoretical and simulation results prove the detection algorithm based on channel estimation has lower complexity performance and better anti-frequency offset performance. The detection of antenna port number directly affects channel estimation and channel decoding, so it is of great significance to study it in detail.

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