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Adaptive Precoded MIMO for LTE Wireless Communication

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Abstract. Long-Term Evolution (LTE) and Long Term Evolution-Advanced (LTE-A) have provided a major step forward in mobile communication capability. The objectives to be achieved are high peak data rates in high spectrum bandwidth and high spectral efficiencies. Technically, pre-coding means that multiple data streams are emitted from the transmit antenna with independent and appropriate weightings such that the link throughput is maximized at the receiver output thus increasing or equalizing the received signal to interference and noise (SINR) across the multiple receiver terminals. However, it is not reliable enough to fully utilize the information transfer rate to fit the condition of channel according to the bandwidth size. Thus, adaptive pre-coding is proposed. It applies pre-coding matrix indicator (PMI) channel state making it possible to change the pre-coding codebook accordingly thus improving the data rate higher than fixed pre-coding.

1. Introduction
Long Term Evolution (LTE) and LTE-Advanced (LTE-A) are the development of 3GPP that should fulfill the current necessities and to accomplish the global broadband mobile communication [1]. These are

1. Higher data rates
2. Better system capacity and coverage area
3. Superb bandwidth operation
4. Improving spectral efficiency
5. Low latency
6. Low operating cost
7. Supporting multiple antennas
8. Seamless integration with the Internet and existing mobile communication systems

The development of the mobile communication system had come a long way. From 2G mobile standard that support mobile telephony and voice application to 3G system that is the starting point of using packet-based data and Internet application and now the 4G mobile communication system that is based on IP-packet networks and supports the high bandwidth consumption applications.

It has been demonstrated by Shannon’s fundamental work on channel capacity that the data rates are not enough for the existing received signal power. Thus, the usage of orthogonal frequency division multiplexing (OFDM) system and multiple-input multiple-output (MIMO) system that allows the multi-carrier transmission and the usage of multi antennas at transmitter and receiver end are important to increase the data rates and improve the system performance [2]-[4].
With the existence of broadband multi-media services such as smartphones, laptop computers, we currently live in an era where mobile data is very important hence leading to the development of wireless network standard. Telecommunication operators are constrained with limited frequency spectrum purchased from government [5]-[7].

Fixed MIMO modes and fixed precoding cannot adapt to the channel condition to achieve both high data rate and low bit error rate.

In this paper, we are investigating adaptive pre-coder in increasing spectral efficiency.

2. System description

2.1. Adaptive Precoding

Adaptive precoding implements precoding matrix indicator (PMI) channel state and by using PMI the system could modify the precoding matrix index accordingly. A parameter is used to enable the precoding matrix index so that it could be modified according to the channel condition instead of providing a fixed codebook index for the transmission. The PMI index will then be selected at the receiver and is passed to the transmitter to be used at the next step. PMI channel state designated the most suitable precoding matrix codebook for the corresponding frequency unit. This channel state is only available in closed-loop single-user and multi-user spatial multiplexing transmission modes [2].

2.2. Adaptive MIMO

Adaptive MIMO implements rank indicator (RI) channel state and by using RI the system could switch the transmission mode between transmit diversity and spatial multiplexing mode. The system will undergo spatial multiplexing transmission if the RI is equal to the transmitting antennas number and transmit diversity mode if the RI is less than it. The antennas number and data rate remained constant while the manipulated parameter will be the threshold that trigger the switching. Thus, a wideband rank value is used for the simulation. RI channel state designated the number of layers that the spatial multiplexing channel can adapt to [3]. RI channel state does not affect the performance of the system much for the frequency selective thus only one wideband RI is reported for the whole bandwidth [3].

3. Simulation results and discussion

3.1. Adaptive Precoding

This section describes the implementation of PMI and RI in Adaptive Pre-coded MIMO. The PMI channel state designated the most suitable pre-coding matrix codebook for the corresponding frequency unit. RI channel state designates the number of layers that the spatial multiplexing channel can adapt to. RI channel state does not affect the performance of the system much for the frequency selective thus only one wideband RI is reported for the whole bandwidth. For Part A of this section, a comparison between baseline simulation and adaptive pre-coder based on PMI feedback is done to investigate the effect of PMI.

Figure 1 shows the spectrum graph of adaptive precoding with SNR value of 30dBm, coding rate 1/3 for 4x4 antenna configuration with PMI being enabled. The transmitted signal and received signal is shown in it. From the graph, it could be seen that the received signals and transmitted signal are quite similar. The received signal before equalization is showing the effects of frequency selective fading. After equalization, the frequency selective fading effect is equalized by the closed loop spatial multiplexing and is showing a more frequency flat nature that resembles the transmitted signal spectrum. Figure 2 shows the fading channel effect (left) is reduced after the equalization is done. The equalizer compensates the multipath fading effect and rotate and scales back the effected constellation (left) to a constellation symbols can be more easily demodulated (right) as the received signal cluster is closer to the ideal constellation after equalizing.
The average data rate for the baseline simulation with no adaptation is the same as adaptive precoding result albeit with higher BER can be seen in Table 1. Adaptive Precoder and Baseline are simulated with the same modulation rate and coding rate. The table also illustrates that the adaptive precoder index based on PMI feedback simulation has lower bit error rate (BER) compared to the Baseline. This proves that by varying the precoding codebook according to the channel condition, the system will produce less BER, thus improving the transmission of data rate hence improving the system. Hence, it can be concluded that the performance for adaptive precoder index based on PMI feedback simulation is better than the baseline simulation with no adaptation.
Table 1. Adaptive precoding for 4X4 antenna configuration.

| Type of Modulation                          | Average Data Rate (Mbps) | Modulation Rate | Coding Rate | Bit error rate |
|---------------------------------------------|--------------------------|-----------------|-------------|----------------|
| Baseline simulation with no adaptation      | 124.46                   | 6               | 1/3         | 0.151606       |
| Adaptive precoder based on PMI feedback     | 124.46                   | 6               | 1/3         | 0.148546       |

3.2. Adaptive MIMO

For Part B of this section, a comparison between MIMO techniques; transmits diversity and closed-loop spatial multiplexing is done. Next, a closed-loop spatial multiplexing is compared with adaptive MIMO based on RI feedback.

Figure 3 shows the spectrum with SNR value of 30dBm, coding rate 1/3 for 4x4 antenna configuration with PMI being enabled. The received signal and transmitted signal spectrum are quite similar.

![Figure 3](image_url)

Figure 3. Spectrum graph of adaptive MIMO simulation for 4x4 antenna configuration.

The received signal before equalization is showing frequency selective fading. After equalization, the frequency selective fading effect is equalized by spatial multiplexing and is showing a more frequency flat nature that resembles the transmitted signal spectrum. Figure 4 is a constellation diagram. The equalizer mitigates the multipath fading effect and symbols can now be more easily demodulated as the received signal cluster is closer to the constellation after equalizing.
Table 2 shows that the average rate for closed-loop spatial diversity mode is higher than transmit diversity mode. This is because in closed-loop spatial multiplexing, the bit stream is divided into multiple substreams and then modulated separately thus increasing the data rate. Other than that, closed-loop spatial multiplexing mode also has lower BER, which is 0.000631 compared to transmit diversity BER (0.000772). Thus, it could be concluded that the performance for closed-loop spatial multiplexing mode is better than the transmit diversity mode.

**Table 2.** Adaptive MIMO – transmit diversity mode and closed-loop spatial multiplexing mode for 4x4 antenna configuration.

| Type of Modulation | Average Data Rate (Mbps) | Modulation Rate | Coding Rate | Bit error rate |
|--------------------|--------------------------|----------------|-------------|----------------|
| Fixed mode: transmit diversity | 48.06143 | 6 | 1/3 | 0.000772 |
| Fixed mode: closed loop spatial multiplexing | 50.635338 | 6 | 1/3 | 0.000631 |

In Table 3, it could be seen that average data rate for closed-loop spatial multiplexing mode is higher than adaptive MIMO based on RI feedback by 0.39857 Mbps. This is because in spatial multiplexing, the bit stream is divided into multiple substreams and then modulated separately thus increasing the data rate. However, when comparing the BER for closed-loop spatial multiplexing mode and adaptive MIMO based on RI feedback mode, it could be observed that the adaptive MIMO based on RI feedback mode has lower BER which is 0.000612. It is because spatial multiplexing is sensitive to the rank deficiencies of the matrix characterizing the equation of MIMO.
Proportionately, the bit error rate for the adaptive MIMO based on RI feedback mode is

\[
\frac{47.66286}{48.06143} \times 0.000631 = 6.23 \times 10^{-4} \approx 0.000623
\]

The Adaptive mode based on RI feedback has lower BER (0.000612) than pro rata value (0.000623).

### Table 3. Adaptive MIMO –closed-loop spatial multiplexing mode and RI feedback for 4x4 antenna.

| Type of Modulation                              | Average Data Rate (Mbps) | Modulation Rate | Coding Rate | Bit error rate |
|------------------------------------------------|--------------------------|-----------------|-------------|---------------|
| Fixed mode: closed-loop spatial multiplexing   | 48.06143                 | 6               | 1/3         | 0.000631      |
| Adaptive mode based on RI feedback            | 47.66286                 | 6               | 1/3         | 0.000612      |

### 4. Conclusion

By using PMI, adaptive precoding is able to increase spectral efficiencies while keeping the bit error rate at acceptable low value. Adaptive MIMO based on RI can switch between spatial multiplexing and transmit diversity to achieve high data rate at reasonable BER.

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