PAPR Reduction for Single Carrier FDMA LTE Systems using Frequency Domain Spectral Shaping

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Presentation Outline

✓ 3GPP LTE uplink transmission – Single-Carrier Frequency Division Multiple Access (SC-FDMA).

✓ PAPR comparison of SC-FDMA with distributed and localized subcarrier mapping schemes.

✓ Investigate the impact of PAPR through frequency domain spectral shaping with localized sub-carrier mapping.
Introduction

✓ Generations of Mobile Networks
  • 1G, 2G, 3G → 4G (are currently in development around the world)
  • Mobile phone plays an important roles – business or social networking
  • ‘smartphone’

✓ Limitations – network coverage, capacity...
  • Battery life – a key parameter that affects all mobile handsets.
  • Even though the battery technology is improving
    – To ensure that mobiles phone use as little energy as possible
4G- Wireless & Mobile Technology

Wired communication

1G (Analog) 2G (Digital) 3G (W-CDMA)

Orthogonal frequency-division multiplexing (OFDM)

• OFDMA
• SC-FDMA

PAPR ???
3GPP LTE (Long-Term Evolution)

Scalable Transmission Bandwidth (MHz)
1.4, 3, 5, 10, 15 & 20

Adaptive Modulation
QPSK, 16QAM & 64QAM

Duplexing
FDD and TDD

Multiplexing
SC-FDMA

Scalable Transmission Bandwidth (MHz)
1.4, 3, 5, 10, 15 & 20

Adaptive Modulation
QPSK, 16QAM & 64QAM

Duplexing
FDD and TDD

Multiplexing
OFDMA
SC-FDMA vs OFDMA

Data symbols occupy M*15 kHz for 1/M SC-FDMA symbol periods

Data symbols occupy 15 kHz for one OFDMA symbol period

✓ shows how a sequence of eight QPSK symbols is presented in frequency and time domain
SC-FDMA Transmitter System

$$\text{FFT}\{x_m\} = X_m^{(k)} = \frac{1}{\sqrt{M}} \sum_{n=0}^{M-1} x_m e^{-\frac{j2\pi nm}{M}}$$
PAPR and Power Amplifier Constraints

• Peak-to-average power ratio (PAPR) problems occur in broadband communications causing power amplifier distortion issues.
• It also results in received errors as well as reducing power efficiency and battery life.
• Amplifiers must be specifically designed to cope with this problem, and this increases their cost.
PAPR

- Peak-to-average-power ratio (PAPR) is a performance measurement to indicate the power efficiency of the transmitter.
- Figure shows the theoretical efficiency limits of linear amplifier.
- High PAPR degrades the transmit power efficiency performance.

\[
P_{\text{PAPR}}(i) = 10 \log \left( \frac{\max_t \{|x_{tx}(t,i)|^2\}}{E[|x_{tx}(t,i)|^2]} \right)
\]
SC-FDMA Subcarrier Mapping Schemes

- LFDMA, DFDMA and IFDMA demonstrating that signals of the four (4) different terminals arriving at a base station occupy mutually exclusive sets of subcarriers.
- \( M \) symbols per block, \( N \) subcarriers and \( Q \) users.

![Diagrams of LFDMA, DFDMA, and IFDMA subcarrier mapping schemes](Image)
## Simulation Parameters/Assumptions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier Frequency</td>
<td>2 GHz</td>
</tr>
<tr>
<td>System bandwidth</td>
<td>5 MHz</td>
</tr>
<tr>
<td>$N$-size IFFT</td>
<td>512</td>
</tr>
<tr>
<td>$M$-size FFT</td>
<td>128</td>
</tr>
<tr>
<td>Modulation scheme</td>
<td>QPSK, 16QAM</td>
</tr>
<tr>
<td>Cyclic prefix</td>
<td>32 samples (6.4 μs)</td>
</tr>
<tr>
<td>Antenna scheme</td>
<td>SISO</td>
</tr>
</tbody>
</table>
LFDMA and IFDMA both have significant PAPR improvement compared to OFDMA.

OFDMA exhibits a higher PAPR compared to LFDMA and IFDMA.

SC-FDMA exhibits a lower PAPR compared to OFDMA because of its single carrier structure.
The Impact of Pulse Shaping on the PAPR of SC-FDMA signals

- QPSK

✓ PAPR decreases as roll-off-factor ($\alpha$) increases.
Frequency Domain Spectral Shaping (1)

✓ What is the difference between the time domain pulse shaping used in traditional single carrier systems and the frequency domain spectral shaping used in SC-FDMA?
  • A traditional time domain pulse shaping filter is used to band limit the transmit signal.
  • However, the frequency domain spectral shaping process is applied to reduce PAPR.

✓ The PAPR of SC-FDMA signals with RC frequency domain spectral shaping is now further investigated.
PAPR Reduction via Spectral Shaping

The SC-FDMA uplink requires pulse shaping to limit the inter-symbol interference (ISI) between neighboring time symbols.

Frequency domain spectral shaping can be used in SC-FDMA to achieve PAPR reduction.
The number of transmit data symbols, $M_{data} = 100, 110$ and $128$. The PAPR of SC-FDMA signals can be reduced at the cost of degraded bandwidth efficiency.
PAPR Reduction

✓ PAPR of SC-FDMA for LFDMA employed RC frequency domain spectrum shaping and time domain pulse shaping with QPSK signaling at $\alpha = 0.22$.

✓ Results show that a PAPR reduction of 1.3 dB can be achieved for QPSK when RC frequency domain spectral shaping is used with roll-off factor of 0.22.

✓ Compared to the unfiltered version, the bandwidth efficiency is reduced to 78.1%.
Conclusions

SC-FDMA is suitable for uplink transmissions as it has a lower PAPR than OFDMA (since it improves the power efficiency of the mobile transmitter).

In this paper we have shown that by applying a frequency domain spectral shaping filter, the PAPR of a localized FDMA (LFDMA) signal can be further reduced (1.3 dB) at the expense of degraded bandwidth efficiency (78.1%).

The resulting PAPR reduction can be used to enhance handset power efficiency, or alternatively to improve uplink throughput and/or operating range.
Thank You

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