<table>
<thead>
<tr>
<th><strong>Project</strong></th>
<th><strong>IEEE 802.20 Working Group on Mobile Broadband Wireless Access</strong>&lt;br&gt;<a href="http://grouper.ieee.org/groups/802/20/">@http://grouper.ieee.org/groups/802/20/</a></th>
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<tbody>
<tr>
<td><strong>Title</strong></td>
<td><strong>Partial proposal to support flexible, spectrally efficient multi-carrier mode -- Presentation</strong></td>
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<td><strong>Date Submitted</strong></td>
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<tr>
<td><strong>Source(s):</strong></td>
<td><strong>Anna Tee, Zhouyue Pi, Jiann-an Tsai, Cornelius van Rensburg, Yinong Ding, Farooq Khan</strong>&lt;br&gt;Samsung Telecommunications America</td>
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<td><strong>Re:</strong></td>
<td><strong>IEEE 802.20 Call for Proposal</strong></td>
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<tr>
<td><strong>Abstract</strong></td>
<td><strong>This document proposes the support of reduced channel spacing to improve the spectral efficiency of Mobile Broadband Wireless Access Systems in the multicarrier deployment mode.</strong></td>
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<tr>
<td><strong>Purpose</strong></td>
<td><strong>For consideration and adoption as a feature supported by 802.20 standard</strong></td>
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Partial Proposal to Support Flexible, Spectrally Efficient Multi-Carrier Mode

Anna Tee
Zhouyue Pi, Cornelius van Rensburg, Yinong Ding,
Jiann-an Tsai, Farooq Khan
March 13, 2007
Introduction

- Support of spectrally efficient Multi-Carrier Mode
- Previous Letter Ballot 1 and 2 Comments
- Initial Simulation Results discussed in Jan ’07 meeting
- Additional simulation scenarios and results included in the current proposal
- Specific changes to the current standard draft included in the proposal for consideration
Problem Description

- In a conventional Multi-Carrier deployment scenario, Guard bands are used to:
  - Ensure the regulatory requirements on out-of-band emissions are met
  - Performance of adjacent channels (carrier) is not degraded significantly by the interference caused by the out-of-band emissions

- Simulation studies [2] found that the requirements on the number of quasi-guard subcarriers (channel spacing) between adjacent channels in a multi-carrier OFDM/A system is much less stringent than in the conventional system
  - Spectral efficiency in the multi-carrier mode can be improved by using a smaller channel spacing
  - Number of Quasi-Guard subcarriers need not be the same as Guard subcarriers
Multi-Carrier Mode Supported by Current 802.20 Standard Draft

- In the Multi-Carrier mode supported by the current 802.20 standard draft:
  - Number of Quasi-Guard subcarriers is the same as Guard subcarriers

- Multiple values of guard subcarriers are supported
  - For example, in the case of 512 FFT, the number of guard subcarriers in the PHY frame can be 32, 96, 160, ..., or 416
  - MBTDD/FDD proposal was evaluated assuming 32 guard subcarriers
Out-of-Band Emission

- Caused by non-linearity in the transmitter
- Major, dominant source: non-linear power amplifier
- Leads to spectral re-growth of the transmit signal
- This out-of-band emission interferes with the transmission in the adjacent channel
- Adjacent channel interference can be reduced by:
  - PA backoff
  - Sufficient channel spacing or guard bands
Power Amplifier Model for Simulation

- RAPP’s PA model for AM/AM characteristics
- Smoothness factor, $p = 2$
- Output Backoff (OBO) $\sim 5$ dB

\[
V_{\text{out}} = \frac{V_{\text{in}}}{1 + \left(\frac{|V_{\text{in}}|}{V_{\text{sat}}}\right)^{2p}}, \quad p = 2
\]
End-to-end Link Simulation Model

Baseband Equivalent Transmitter model for 1 carrier signal

Non-linearity model

FIR filtering & Down-sampling

Data assembly

Remove Cyclic Prefix

FFT

Symbol De-IFL

Compute average transmit signal power & noise variance for the desired SNR

AWGN generator

Data Symbol Demodulation

(De-Interleaving) & Decoding

BER/BLER/FER computation

Transmitted Random Data
Power Spectrum of Transmit Signal

- Channel spacing:
  - 5 MHz (Δf)

- Cyan curve: Power spectral density of transmit signal at PA input

- Red curve: Transmit signal spectrum at PA output
  - Out-of-band spectral re-growth due to PA nonlinearity
Simulation Results – Uncoded QPSK

- Uncoded QPSK

- Simulated cases:
  - 1 channel
  - 3 channels with channel spacing:
    - 5, 4.6, 4.3 and 4.1MHz

- Includes effects of Power Amplifier nonlinearity
  - RAPP’s model
    - $p = 2$
    - OBO ~ 5 dB

- Error floor for channel spacing $\leq 4.1$ MHz
Simulation Results – Coded QPSK

- Encoded QPSK
- Simulated cases:
  - 1 channel
  - 3 channels with channel spacing:
    - 4.6, 4.3 and 4.1 MHz
- Includes effects of Power Amplifier nonlinearity
  - RAPP’s model
    - \( p = 2 \)
    - OBO \( \sim 5 \text{ dB} \)
- Degradation \( \sim 0.6 \text{ dB} \) at BER\( = 10^{-4} \) for channel spacing at 4.1 MHz
  => Error floor significantly reduced
Simulation Results – Encoded 16-QAM

- Encoded 16-QAM
- Simulated cases:
  - 1 channel
  - 3 channels with channel spacing: 5, 4.3 and 4.1 MHz
- Includes effects of Power Amplifier nonlinearity
  - RAPP’s model
    - $p = 2$
    - OBO $\sim 5$ dB
- Degradation at BER=$10^{-4}$ for channel spacing at 4.1 MHz
  - $\sim 3.0$ dB without PA nonlinearity
  - $\sim 4.0$ dB with PA nonlinearity
  - More significant degradation than QPSK
Performance degradation with respect to single channel

- Reference case: Uncoded QPSK with PA nonlinearity
- 3 channels with channel spacing:
  - $\geq 0.92, 0.86$ and $0.82 \Delta f$ ($\Delta f = 5$ MHz), i.e., $\geq 4.6, 4.3$ and $4.1$ MHz
- RAPP’s PA model with $p = 2$, OBO $\sim 5$ dB

<table>
<thead>
<tr>
<th>BER</th>
<th>Channel Spacing</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{-2}$</td>
<td>$\geq 0.92 \Delta f$</td>
<td>$0.2$ dB</td>
</tr>
<tr>
<td></td>
<td>$= 0.86 \Delta f$</td>
<td>$0.23$ dB</td>
</tr>
<tr>
<td></td>
<td>$= 0.82 \Delta f$</td>
<td>$1.2$ dB</td>
</tr>
<tr>
<td>$10^{-3}$</td>
<td>$0.45$ dB</td>
<td>$0.55$ dB</td>
</tr>
<tr>
<td></td>
<td>0.0$ dB</td>
<td>$&gt;10$ dB</td>
</tr>
</tbody>
</table>

- Encoded QPSK
  - Convolutional code
  - Random symbol interleaving across subcarriers

<table>
<thead>
<tr>
<th>BER</th>
<th>Channel Spacing</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{-3}$</td>
<td>$\geq 0.92 \Delta f$</td>
<td>$0.10$ dB</td>
</tr>
<tr>
<td></td>
<td>$= 0.86 \Delta f$</td>
<td>$0.10$ dB</td>
</tr>
<tr>
<td></td>
<td>$= 0.82 \Delta f$</td>
<td>$0.3$ dB</td>
</tr>
<tr>
<td>$10^{-4}$</td>
<td>$0.10$ dB</td>
<td>$0.12$ dB</td>
</tr>
<tr>
<td></td>
<td>0.0$ dB</td>
<td>$0.46$ dB</td>
</tr>
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</table>
Performance Degradation: 16-QAM

- Encoded 16-QAM
  - Convolutional code
  - Random symbol interleaving across subcarriers
- 3 channels with channel spacing:
  - $\geq 0.86, 0.82 \Delta f$ ($\Delta f = 5$ MHz)
  - i.e., $\geq 4.3, 4.1$MHz

<table>
<thead>
<tr>
<th>BER</th>
<th>1 Channel With PA</th>
<th>Channel Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\geq 0.86 \Delta f$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No PA</td>
</tr>
<tr>
<td>$10^{-3}$</td>
<td>0.3 dB</td>
<td>0.6 dB</td>
</tr>
<tr>
<td>$10^{-4}$</td>
<td>0.4 dB</td>
<td>0.9 dB</td>
</tr>
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</table>
Proposed Changes to the current Standard Draft

- **Changes to Section 8.1.11**
  - To support the proposed feature, a new protocol constant can be added: NQuasiGuard,PR, for use in the MultiCarrier ON mode.

- **Changes to Section 6.5.6.1**
  - A new field can be added to the SystemInfo block: NumQuasiGuardSubcarriers. The new field needs to be transmitted in the SystemInfo block when the number of carriers per sector is greater than one, i.e., in the MultiCarrier ON mode.

- **Changes to Section 9.3.2.2.2**
  - “... The set of quasi-guard subcarriers in the superframe preamble shall be the subcarriers numbered \( N_{\text{carrier size}} \times m - N_{\text{QuasiGuard,PR}} / 2 \) through \( N_{\text{carrier size}} \times m + N_{\text{QuasiGuard,PR}} / 2 - 1 \) where \( m = 1, \ldots, N_{\text{carriers}} - 1 \). The set of quasi-guard subcarriers in each FL shall be the subcarriers numbered \( N_{\text{carrier size}} \times m - N_{\text{QuasiGuard}} / 2 \) to \( N_{\text{carrier size}} \times m + N_{\text{QuasiGuard}} / 2 - 1 \) where \( m = 1, \ldots, N_{\text{carriers}} - 1 \). The quantity \( N_{\text{QuasiGuard}} \) is given by the NumQuasiGuardSubcarriers parameters which is part of the public data of the Overhead Messages Protocol.”

- **Changes to Section 9.4.1.2.2**
  - “... The set of quasi-guard subcarriers in each RL shall be the subcarriers numbered \( N_{\text{carrier size}} \times m - N_{\text{QuasiGuard}} / 2 \) to \( N_{\text{carrier size}} \times m + N_{\text{QuasiGuard}} / 2 - 1 \) where \( m = 1, \ldots, N_{\text{carriers}} - 1 \). The number of quasi-guard subcarriers \( N_{\text{QuasiGuard}} \) for the reverse link shall be the same as the number of quasi-guard subcarriers on the reverse link, as given by NumQuasiGuardSubcarriers, which is part of the public data of the Overhead Messages Protocol for any sector...”
Conclusion

- By allowing the number of quasi-guard subcarriers to be a parameter that is different from the number of guard subcarriers, the standard will be more flexible in supporting various system deployment scenarios so as to achieve higher spectral efficiency in a licensed spectral block.
References

- L. Tee, C. Rensburg, Y. Ding, ‘Performance of a multi-channel OFDM system under the effect of adjacent channel interference’, Proceedings of VTC ’05 Fall conference, September 2005
- A. Tee, J. Cleveland, ‘Evaluation of 802.20 proposals with adjacent channel interference considerations’, C802.20-04/58, April 27, 2004
- A. Tee, ‘Performance degradation caused by adjacent channel interference-simulation results’, March 14, C802.20-05/21, 2005