SC-FDE System Capacity and Modulation Efficiency

IEEE 802.16 Presentation Submission Template (Rev. 8.2)

Document Number: IEEE 802.16abp-01/47

Date Submitted:
2001-11-15

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Venue: IEEE 802.16 Session #16

Base Document:
IEEE 802.16abc-01/47

Purpose:
This contribution is presented to the Task Group in Session #16 to update the Single Carrier PHY throughput and channel efficiency clause of the IEEE802.16ab-01/r2 document.

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SC-FDE System Capacity and Modulation Efficiency

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Contribution

• Incorporate provided text as revision of Section 8.3.4.15 of document 80216ab-01_01r2.

• This contribution completely simplifies and merges two subsections into one with more accurate results.
Continuous transmission Format:

- Frame Preamble
- Transported Frame
- Frame Preamble
- Transported Frame

- H_{symb} \quad \text{Interval between Preambles} \quad (I \text{ symb}) \quad \text{H}_{symb} \quad \text{Interval between Preambles} \quad (I \text{ symb})

- Frame Preamble
- Transported Frame

- H_{symb} \quad I_{symb}

- Frame Preamble
- Transported Frame

- MAC Frame Control (Broadcast)
- User Data

User Data Sequenced in Decreasing order of 'modulation type' robustness (e.g., QPSK, 16-QAM, 64-QAM; or 1.5 bits/symb, 2 bits/symb, etc.)

Most Robust Modulation Type (Rate 1/2 QPSK)
Burst transmissions Frame Format

Burst Preamble

Payload (& Optional Pilot Words)

Rx

Interval for Ramp Down and Delay Spread to Clear Receiver

Ramp Down (clear TX filter with zeros)

TX filter input initialized with zeros and driven by Preamble
Overlap Save Scheme of Arbitrary Continuous Payload

Continuous Payload (\& Optional Pilot Words)
Overlap Save Scheme of Arbitrary Bursty Payload

- Burst Preamble
- Burst Payload (\& Optional Pilot Words)
- RxDs
- UW
- Rx Zero pad
# Parameters and Values Defining Operating Modes for SC Systems

<table>
<thead>
<tr>
<th>Selection Level</th>
<th>Parameter</th>
<th>Symbol</th>
<th>Set of Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>System-Dependent Parameters</td>
<td>Channel Bandwidth (MHz)</td>
<td>W</td>
<td>1.75, 3.5, 7, 14, 1.5, 3, 6, 12</td>
</tr>
<tr>
<td></td>
<td>Design Maximum Delay Spread (μsec)</td>
<td>d</td>
<td>4, 10, 20</td>
</tr>
<tr>
<td></td>
<td>Spectral Guard Factor</td>
<td>γ</td>
<td>0.18, 0.25</td>
</tr>
<tr>
<td></td>
<td>Symbol Rate (MSymb/sec)</td>
<td>R</td>
<td>$R = (1 + \gamma)W$</td>
</tr>
<tr>
<td>Link-Dependent Parameters</td>
<td>Number of Constellation States</td>
<td>M</td>
<td>4, 16, 64</td>
</tr>
<tr>
<td></td>
<td>Convolutional (Inner) Code Rate</td>
<td>rI</td>
<td>1/2, 2/3, 3/4, 7/8</td>
</tr>
<tr>
<td></td>
<td>Reed-Solomon (Outer) Code Rate</td>
<td>rO</td>
<td>$239 / 255 = 0.937$</td>
</tr>
<tr>
<td>Traffic-Dependent Parameter</td>
<td>Burst Data Payload Size for uplink (in Bytes)</td>
<td>P</td>
<td>239, 717, 1195, 1673</td>
</tr>
<tr>
<td>Traffic-Dependent Parameter</td>
<td>Continuous Data Payload Size for downlink (in Bytes)</td>
<td>P</td>
<td>1673, 2151, 2629, 3585</td>
</tr>
</tbody>
</table>
System throughput for the burst transmission modes

\[ U = R \cdot d, \text{ rounded up to the nearest power of 2.} \]

\[ T_{\text{burst}} = \frac{8PR \log_2 (M)}{\left( \frac{8P}{\kappa_1 r_0} + (A + U) \log_2 (M) \right)} \]
System throughput for the continuous transmission modes

\[ T_{\text{cont}} = \frac{8PR \log_2 (M)}{\left(\frac{8P}{r_I r_O} + A \log_2 (M)\right)} \]

P is the burst data size and A is used as the average frame preamble size (in symbols).

The choice of A=2U for the uplink and the choice of A=4U for the downlink.
SC Channel Efficiency

\[ E_{\text{burst}} = \frac{T_{\text{burst}}}{W} = \frac{T_{\text{burst}}}{(1 + \gamma)R} = \frac{8P \log_2(M)}{(1 + \gamma) \left( \frac{8P}{r_I r_O} + (A + U) \log_2(M) \right)} \]

\[ E_{\text{cont}} = \frac{T_{\text{cont}}}{W} = \frac{T_{\text{cont}}}{(1 + \gamma)R} = \frac{8P \log_2(M)}{(1 + \gamma) \left( \frac{8P}{r_I r_O} + A \log_2(M) \right)} \]
## Throughput for various Models in 1.75 MHz Channels (Uplink Burst)

### System Throughput for Overlap Save Technique

(for Single Carrier Burst Mode U/L with $W = 1.75$ MHz bandwidth)

<table>
<thead>
<tr>
<th>Symbol Rate (MS/sec)</th>
<th>Symbol Design (Sample Rate)</th>
<th>Convolutional Code (Number of States)</th>
<th>System Throughput (in Mbits/sec)</th>
<th>System Efficiency (in MBits/sec/Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>239</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>717</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1195</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1673</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( $P = 1673$ )</td>
<td></td>
</tr>
<tr>
<td>1/2</td>
<td>4</td>
<td>1/2</td>
<td>1.37</td>
<td>1.39</td>
</tr>
<tr>
<td>2/3</td>
<td>7/8</td>
<td>1.82</td>
<td>1.84</td>
<td>1.85</td>
</tr>
<tr>
<td>3/4</td>
<td>2/3</td>
<td>2.05</td>
<td>2.07</td>
<td>2.08</td>
</tr>
<tr>
<td>1/2</td>
<td>2/3</td>
<td>2.38</td>
<td>2.42</td>
<td>2.43</td>
</tr>
<tr>
<td>2/3</td>
<td>5/6</td>
<td>2.72</td>
<td>2.76</td>
<td>2.77</td>
</tr>
<tr>
<td>3/4</td>
<td>7/8</td>
<td>4.03</td>
<td>4.12</td>
<td>4.14</td>
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<tr>
<td>2/3</td>
<td>5/6</td>
<td>5.31</td>
<td>5.47</td>
<td>5.51</td>
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<tr>
<td>3/4</td>
<td>1/2</td>
<td>6.56</td>
<td>6.82</td>
<td>6.87</td>
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<tr>
<td>2/3</td>
<td>5/6</td>
<td>1.36</td>
<td>1.38</td>
<td>1.38</td>
</tr>
<tr>
<td>3/4</td>
<td>2/3</td>
<td>1.80</td>
<td>1.83</td>
<td>1.84</td>
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<tr>
<td>2/3</td>
<td>5/6</td>
<td>2.01</td>
<td>2.06</td>
<td>2.07</td>
</tr>
<tr>
<td>3/4</td>
<td>7/8</td>
<td>2.34</td>
<td>2.40</td>
<td>2.41</td>
</tr>
<tr>
<td>2/3</td>
<td>5/6</td>
<td>6.22</td>
<td>6.69</td>
<td>6.79</td>
</tr>
<tr>
<td>3/4</td>
<td>1/2</td>
<td>1.33</td>
<td>1.37</td>
<td>1.38</td>
</tr>
<tr>
<td>2/3</td>
<td>7/8</td>
<td>1.74</td>
<td>1.82</td>
<td>1.83</td>
</tr>
<tr>
<td>3/4</td>
<td>5/6</td>
<td>1.95</td>
<td>2.04</td>
<td>2.06</td>
</tr>
<tr>
<td>2/3</td>
<td>1/2</td>
<td>2.25</td>
<td>2.37</td>
<td>2.39</td>
</tr>
<tr>
<td>3/4</td>
<td>7/8</td>
<td>2.54</td>
<td>2.70</td>
<td>2.73</td>
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<tr>
<td>2/3</td>
<td>5/6</td>
<td>3.65</td>
<td>3.98</td>
<td>4.06</td>
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<tr>
<td>3/4</td>
<td>1/2</td>
<td>4.68</td>
<td>5.23</td>
<td>5.36</td>
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<tr>
<td>2/3</td>
<td>7/8</td>
<td>5.63</td>
<td>6.44</td>
<td>6.64</td>
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<tr>
<td>3/4</td>
<td>5/6</td>
<td>6.72</td>
<td>6.72</td>
<td>6.72</td>
</tr>
</tbody>
</table>

### System Efficiency

- **Packet Size (P in Bytes)**: 239, 717, 1195, 1673
- **System Efficiency (in MBits/sec/Hz)**: ( $P = 1673$ )

### Link-Dependent Parameters

- **Symbol Rate (MS/sec)**
- **Symbol Design (Sample Rate)**
- **Convolutional Code (Number of States)**

### System-Dependent Parameters

- **Convolutional Code (Number of States)**
- **Packet Size (P in Bytes)**
### Throughput for various Models in 6 MHz Channels

**Downlink Continuous**

<table>
<thead>
<tr>
<th>Symbol Design</th>
<th>Convolutional Rate Spread Number of States QAM States QAM Code (MS/sec) (U in Symbols)</th>
<th>Packet Size (P in Bytes)</th>
<th>System Efficiency (in MBits/sec/Hz)</th>
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<tbody>
<tr>
<td>1/2</td>
<td>4.69</td>
<td>2151</td>
<td>6.02</td>
</tr>
<tr>
<td>2/3</td>
<td>6.22</td>
<td>2629</td>
<td>6.69</td>
</tr>
<tr>
<td>3/4</td>
<td>6.98</td>
<td>3585</td>
<td>7.53</td>
</tr>
<tr>
<td>7/8</td>
<td>8.12</td>
<td>12.03</td>
<td>7.88</td>
</tr>
<tr>
<td>1/2</td>
<td>9.24</td>
<td>14.00</td>
<td>10.03</td>
</tr>
<tr>
<td>3/4</td>
<td>13.65</td>
<td>14.48</td>
<td>15.00</td>
</tr>
<tr>
<td>2/3</td>
<td>17.94</td>
<td>14.81</td>
<td>19.96</td>
</tr>
<tr>
<td>64</td>
<td>22.10</td>
<td>19.47</td>
<td>24.89</td>
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<tr>
<td>1/2</td>
<td>4.62</td>
<td>4.92</td>
<td>5.01</td>
</tr>
<tr>
<td>2/3</td>
<td>6.10</td>
<td>6.54</td>
<td>6.67</td>
</tr>
<tr>
<td>3/4</td>
<td>6.83</td>
<td>7.34</td>
<td>7.50</td>
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<tr>
<td>7/8</td>
<td>7.91</td>
<td>8.54</td>
<td>8.74</td>
</tr>
<tr>
<td>1/2</td>
<td>8.97</td>
<td>9.74</td>
<td>9.98</td>
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<tr>
<td>16</td>
<td>13.07</td>
<td>14.45</td>
<td>14.90</td>
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<tr>
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<td>16.94</td>
<td>19.06</td>
<td>19.77</td>
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<tr>
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<td>20.60</td>
<td>23.58</td>
<td>24.60</td>
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<tr>
<td>1/2</td>
<td>4.48</td>
<td>4.87</td>
<td>4.95</td>
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<tr>
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<td>5.86</td>
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<td>7.45</td>
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<td>7/8</td>
<td>7.51</td>
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<td>8.67</td>
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<td>9.89</td>
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<td>12.03</td>
<td>14.00</td>
<td>14.69</td>
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<tr>
<td>2/3</td>
<td>15.24</td>
<td>18.30</td>
<td>19.41</td>
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<tr>
<td>64</td>
<td>18.14</td>
<td>22.42</td>
<td>24.04</td>
</tr>
</tbody>
</table>

**System Throughput for Overlap Save Technique**

(Single Carrier Continuous Mode D/L with W = 6 MHz bandwidth)

<table>
<thead>
<tr>
<th>Packet Size (P in Bytes)</th>
<th>(in MBits/sec/Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1673</td>
<td>4.69</td>
</tr>
<tr>
<td>2151</td>
<td>4.95</td>
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<tr>
<td>2629</td>
<td>5.00</td>
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<td>12.03</td>
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