Link-level calibration results

The following document provides the specific calibration results that were performed for the link-level simulator. It describes the calibration procedure performed to demonstrate the correct operation of the link-level simulator employed in the Evaluation Report from the 5G Infrastructure Association on the IMT-2020 proposal.

The calibration results are obtained for 5G New Radio PDSCH (Physical Downlink Shared Channel) and PUSCH (Physical Uplink Shared Channel).

I PDSCH methodology and parameter configuration

The calibration procedure is fully aligned with the evaluation process followed in 3GPP RAN WG4. As described in [1], 3GPP calibrates the PDSCH performance by evaluating the maximum throughput provided for FR1 and FR2 scenarios and FDD and TDD techniques. For each frequency range and duplexing technique, a specific set of cases is described. Calibration is here performed for FR1 and FDD.

As shown in Table 1, 3GPP defines up to fourteen different evaluation cases for this combination. Different channel models, MCS indexes and MIMO configurations are considered. For the sake of simplicity, the calibration is here provided for cases 4 and 5.

<table>
<thead>
<tr>
<th>Case Number</th>
<th>BW/SCS</th>
<th>MIMO</th>
<th>PDSCH mapping and MCS</th>
<th>Layers</th>
<th>Channel Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10MHz/15kHz</td>
<td>2Tx 2Rx ULA Low</td>
<td>Type A QPSK MCS 4</td>
<td>1</td>
<td>TDL-B 100ns, 400Hz</td>
</tr>
<tr>
<td>2</td>
<td>10MHz/15kHz</td>
<td>2Tx 2Rx ULA Low</td>
<td>Type A QPSK MCS 4</td>
<td>1</td>
<td>TDL-C 300ns, 100Hz</td>
</tr>
<tr>
<td>3</td>
<td>10MHz/15kHz</td>
<td>2Tx 2Rx ULA Low</td>
<td>Type A 256QAM MCS 24</td>
<td>1</td>
<td>TD-L-A 30ns, 10Hz</td>
</tr>
<tr>
<td>4</td>
<td>10MHz/15kHz</td>
<td>2Tx 2Rx ULA Low</td>
<td>Type A 16QAM MCS 13</td>
<td>2</td>
<td>TDL-C 300ns, 100Hz</td>
</tr>
<tr>
<td>5</td>
<td>10MHz/15kHz</td>
<td>2Tx 2Rx ULA Low</td>
<td>Type A 64QAM MCS 19</td>
<td>2</td>
<td>TD-L-A 30ns, 10Hz</td>
</tr>
<tr>
<td>6</td>
<td>10MHz/15kHz</td>
<td>4Tx 4Rx ULA Low</td>
<td>Type A 16QAM MCS 13</td>
<td>3</td>
<td>TD-L-A 30ns, 10Hz</td>
</tr>
<tr>
<td>7</td>
<td>10MHz/15kHz</td>
<td>4Tx 4Rx ULA Low</td>
<td>Type A 16QAM MCS 13</td>
<td>4</td>
<td>TD-L-A 30ns, 10Hz</td>
</tr>
<tr>
<td>8</td>
<td>10MHz/15kHz</td>
<td>2Tx 2Rx ULA Med</td>
<td>Type A 16QAM MCS 13</td>
<td>2</td>
<td>TD-L-A 30ns, 10Hz</td>
</tr>
<tr>
<td>9</td>
<td>10MHz/15kHz</td>
<td>4Tx 4RX ULA Med A</td>
<td>Type A 16QAM MCS 13</td>
<td>3</td>
<td>TD-L-A 30ns, 10Hz</td>
</tr>
<tr>
<td>10</td>
<td>10MHz/15kHz</td>
<td>2Tx 2Rx ULA Low</td>
<td>Type A 16QAM MCS 13</td>
<td>1</td>
<td>TDL-C 300ns, 100Hz</td>
</tr>
<tr>
<td>11</td>
<td>10MHz/15kHz</td>
<td>2Tx 2Rx ULA Low</td>
<td>Type B QPSK MCS 2</td>
<td>1</td>
<td>TD-L-A 30ns, 10Hz</td>
</tr>
<tr>
<td>12 (LTE-NR #1)</td>
<td>10MHz/15kHz</td>
<td>4Tx 2Rx ULA Low</td>
<td>Type A QPSK, MCS 4</td>
<td>1</td>
<td>TD-L-A 30ns, 10Hz</td>
</tr>
<tr>
<td>13 (LTE-NR #2)</td>
<td>10MHz/15kHz</td>
<td>4Tx 2Rx ULA Low</td>
<td>Type A QPSK, MCS 4</td>
<td>1</td>
<td>TD-L-A 30ns, 10Hz</td>
</tr>
<tr>
<td>14 (LTE-NR #3)</td>
<td>10MHz/15kHz</td>
<td>4Tx 2Rx ULA Low</td>
<td>Type B QPSK, MCS 4</td>
<td>1</td>
<td>TD-L-A 30ns, 10Hz</td>
</tr>
</tbody>
</table>

Table 1 Evaluation cases considered in 3GPP for FR1 and FDD configuration.
The following 3GPP parameters and configurations are assumed:

- **SSB/PBCH**: Allocation in slot 0 in each second frame. 1 slot per 20 ms.
- **CORESET configuration**: Full BW allocation, 2 control symbols.
- **PDSCH configuration**:
  - Time domain: mapping type A (starting symbol 2, duration of 12 symbols).
  - Frequency domain: full bandwidth allocation.
- **Scheduling in all slots but SSB/PBCH** (19 out of every 20 subframes carry data).
- **HARQ assumptions**: RV sequence {0, 2, 3, 1}, 4 HARQ processes.
- **DMRS configuration** of 2 DMRS symbols.

**II PDSCH calibration results**

Throughput results are obtained in this section and compared against the calibration results provided by specific companies in different 3GPP contributions [1-4].

![Figure 1](image1.png)

**Figure 1** Throughput calibration results, case 4.

![Figure 2](image2.png)

**Figure 2** Throughput calibration results, case 5.
III PUSCH methodology and parameter configuration

The methodology in this case is aligned with the evaluation process followed in [5]. The 3GPP technical specifications TS 38.104 [6] and TS 38.141-1 [7] are used as a reference. 3GPP calibrated PUSCH results are obtained by different companies by measuring the SNR at the 70% of the maximum throughput. 3GPP defines different simulation cases with multiple antenna configurations, MCS, channel models, etc.

The selected parameter configuration for this calibration is:

- CP-OFDM without precoding and normal cyclic prefix.
- DMRS configuration: 1+1
- Minimum mean-squared error (MMSE) equalizer.
- Ideal estimation conditions.
- Channel models simulated with different sub-carrier spacing (SCS), MCS and bandwidth combinations, as shown in Table 2:

<table>
<thead>
<tr>
<th>Evaluation case</th>
<th>Bandwidth (MHz)</th>
<th>SCS (kHz)</th>
<th>Antenna Configuration</th>
<th>Channel model</th>
<th>Delay spread (ns)</th>
<th>MCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>15</td>
<td>SIMO 1x2</td>
<td>TDL-B</td>
<td>100-400</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>15</td>
<td>SIMO 1x2</td>
<td>TDL-C</td>
<td>300-100</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>15</td>
<td>SIMO 1x2</td>
<td>TDL-A</td>
<td>30-10</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>30</td>
<td>MIMO 2x2</td>
<td>TDL-B</td>
<td>100-400</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>30</td>
<td>MIMO 2x2</td>
<td>TDL-C</td>
<td>300-100</td>
<td>16</td>
</tr>
<tr>
<td>6</td>
<td>40</td>
<td>30</td>
<td>SIMO 1x2</td>
<td>TDL-B</td>
<td>100-400</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>40</td>
<td>30</td>
<td>SIMO 1x2</td>
<td>TDL-C</td>
<td>300-100</td>
<td>16</td>
</tr>
<tr>
<td>8</td>
<td>40</td>
<td>30</td>
<td>MIMO 2x2</td>
<td>TDL-A</td>
<td>30-10</td>
<td>20</td>
</tr>
<tr>
<td>9</td>
<td>40</td>
<td>30</td>
<td>MIMO 2x2</td>
<td>TDL-B</td>
<td>100-400</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 2 Evaluation cases considered in 3GPP for FR1 and FDD configuration.

II PUSCH calibration results

Throughput results are obtained for the 9 selected evaluation cases and compared against the calibration results provided by specific companies. Figure 3 depicts an example of the calibration results for the evaluation case 1.

Table 3 shows all results provided by the companies as well as those obtained in this report. The difference between the average of them and these results is additionally shown.

Figure 3 Example of calibration PUSCH results, case 1.
Table 3  SNR (dB) at 70% of throughput. Evaluation cases 1 to 9.

<table>
<thead>
<tr>
<th>Company</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung</td>
<td>-2.9</td>
<td>8.53</td>
<td>10.89</td>
<td>1.01</td>
<td>10.6</td>
<td>3.99</td>
<td>8.5</td>
<td>10.37</td>
<td>-0.35</td>
</tr>
<tr>
<td>ZTE</td>
<td>-5.04</td>
<td>9.19</td>
<td>11.43</td>
<td>1.16</td>
<td>17.24</td>
<td>3.92</td>
<td>9.54</td>
<td>10.51</td>
<td>-0.94</td>
</tr>
<tr>
<td>CMCC</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>6.8</td>
<td>6.8</td>
<td>10</td>
<td>X</td>
</tr>
<tr>
<td>Nokia</td>
<td>-4.68</td>
<td>7.81</td>
<td>9.77</td>
<td>-0.09</td>
<td>16.94</td>
<td>-4.84</td>
<td>7.62</td>
<td>9.54</td>
<td>-1.04</td>
</tr>
<tr>
<td>Huawei</td>
<td>-4.6</td>
<td>8.2</td>
<td>10.5</td>
<td>-1.24</td>
<td>15.94</td>
<td>-4.7</td>
<td>7.9</td>
<td>10.5</td>
<td>-1.23</td>
</tr>
<tr>
<td>Ericsson</td>
<td>-5.1</td>
<td>8.1</td>
<td>9.6</td>
<td>-0.9</td>
<td>15.8</td>
<td>-5</td>
<td>7.9</td>
<td>9.5</td>
<td>-1.1</td>
</tr>
<tr>
<td>China Telecom</td>
<td>-5.45</td>
<td>7.97</td>
<td>11.62</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>7.9</td>
<td>10.43</td>
<td>X</td>
</tr>
<tr>
<td>CATT</td>
<td>-5.02</td>
<td>7.89</td>
<td>9.53</td>
<td>-1.13</td>
<td>15.31</td>
<td>-4.72</td>
<td>7.62</td>
<td>10.07</td>
<td>-1.08</td>
</tr>
<tr>
<td>Average</td>
<td>-4.68</td>
<td>8.24</td>
<td>10.48</td>
<td>-0.59</td>
<td>16.31</td>
<td>-4.68</td>
<td>7.97</td>
<td>10.12</td>
<td>-0.96</td>
</tr>
<tr>
<td>5G-PPP WG</td>
<td>-4.15</td>
<td>8.6</td>
<td>10.2</td>
<td>-0.45</td>
<td>15.45</td>
<td>-4.15</td>
<td>8.4</td>
<td>9.7</td>
<td>-0.1</td>
</tr>
<tr>
<td>Difference</td>
<td>0.53</td>
<td>0.36</td>
<td>0.28</td>
<td>0.14</td>
<td>0.86</td>
<td>0.53</td>
<td>0.43</td>
<td>0.41</td>
<td>0.86</td>
</tr>
</tbody>
</table>

References