**3GPP TSG-RAN WG4 Meeting #114bis R4-2503541**

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Title: Simulation results for Spatial Channel Modeling study

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# 1. Introduction

In RAN4#114 spatial channel model for demodulation requirements was discussed and way forward [1] was approved. In this contribution present simulation results for spatial channel model study.

# 2. Simulation Results

For the initial simulation parameters below, we present our results.

Table : Simulation Parameters for Spatial Channel Model Study

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | | **SU-MIMO PDSCH (FR1)** | **SU-MIMO PMI (FR1)** |
| Duplex mode | | TDD | |
| TDD Slot Configuration Pattern | | 7DS2U | |
| FR / Carrier frequency | | FR1 / 3.5 GHz | |
| UE receiver type | | IRC Baseline | IRC Baseline |
| Number of Tx Ports | | 4 | 8,32 |
| Number of Rx Ports/Antennas | | 4 | 4 |
| Number of layers | | 4 | 4,2 |
| PMI | | Random | Follow, Random |
| Waveform | | CP-OFDM with normal CP | |
| Channel Bandwidth/SCS | | 40MHz/30kHz | |
| MCS | | 13 (64 QAM table) | |
| PDSCH configuration | Mapping type | Type A | |
| k0 | 0 | |
| Starting symbol (S) | 2 | |
| Length (L) | 12 | |
| PDSCH aggregation factor | 1 | |
| Resource allocation type | Type 0 | |
| VRB-to-PRB mapping type | Non-interleaved | |
| VRB-to-PRB mapping interleaver bundle size | N/A | |
| PDSCH DMRS configuration | DMRS Type | Type 1 | |
| Number of additional DMRS | 1 | |
| Maximum number of OFDM symbols for DL front loaded DMRS | 2 (for rank > 4)  1 (for rank <= 4) | |
| Codebook configuration | CodebookType | type-I-SP | type-I-SP, eType-II |
| Codebook configuration | For 4Tx  (N1,N2,O1,O2) = (2,1,4,1) | For 8TX:  (N1,N2,O1,O2) = (4,1,4,1)  For 16 TX:  (N1,N2,O1,O2) = (8,1,4,4)  For 32 TX:  (N1,N2,O1,O2) = (8,2,4,4) |
| PDSCH DMRS Precoding Configuration | | For Random precoding: for every PRB Bundle (size=2) | SB PMI |
| NZP CSI-RS for CSI acquisition | CSI-RS resource Type | Aperiodic | |
| Number of CSI-RS ports (X) | 4 CSI-RS Ports (2,1) for 4 Layer | 8 CSI-RS Ports (4,1)  16 CSI-RS Ports (8,1)  32 CSI-RS Ports (8,2) |
| Density (ρ) | 1 | |
| First OFDM symbol in the PRB used for CSI-RS (l0) | (13) | |
| CQI/RI/PMI delay | | N/A | 7 ms |
| Number of HARQ Processes | | 8 | |
| Maximum HARQ transmissions | | 4 | |

**Channel Models:**

* TDLA30
* TDLC300
* UMa-CDL-C-A1: CDL (TR 38.753) with Table 7.2.1-8 in TR 38.827
* UMa-CDL-C-A2: CDL (TR 38.753) based on untruncated CDL-C from Table 7.7.1-3 in TR 38.901(provided in Appendix)
* UMa-CDL-C-A3: CDL (TR 38.753) based on truncated CDL-C from Table 7.7.1-3 in TR 38.901 (provided in Appendix)

**Doppler/Speed:**

For TDL Models: 10, 100 Hz

For CDL Models: 3, 30 kph

**AAV Configuration**:

AAV with Sub-array AAV 1Y

* + (M,N,P,Ms,Ns) = (8,4,2,8,1) for 4Tx CSI-RS Ports

Pass through – AAV 3

* + (M,N,P,Ms,Ns) = (1,4,2,1,1) for 8Tx CSI-RS Ports
  + (M,N,P,Ms,Ns) = (1,2,2,1,1) for 4Tx CSI-RS Ports
  + (M,N,P,Ms,Ns) = (1,8,2,1,1) for 16Tx CSI-RS Ports
  + (M,N,P,Ms,Ns) = (2,8,2,1,1) for 32Tx CSI-RS Ports

**SU-MIMO PDSCH Performance**

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| --- | --- |
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Figure 1: PDSCH performance for SU-MIMO

From the results above, we don’t observe better performance with CDL channel model compared to TDL with low, XP-Med correlation.

1. *The performance with CDL channel model is not better than existing TDL channel models with Low, Med correlation for 4x4 with 4 layers.*

Performance with Uma-CDLC variants A1/A2/A3 are very similar.

1. *The performance with UMa-CDLC channel model variants – A1/A2/A3 are very similar for PDSCH with random PMI.*

In the table we provide simulation results for alignment.

Table :Simulation results for SU-MIMO PDSCH for alignment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Channel Model w/ Ant Corr** | **Doppler/ Speed** | **AAV** | **SNR @ 70% Max TP** | **SNR @ 30% Max TP** |
| UMa-CDLC-A1 | 3 kph | AAV3 | 15.8 | 8.9 |
| UMa-CDLC-A2 | 3 kph | AAV3 | 16.3 | 9.0 |
| UMa-CDLC-A3 | 3 kph | AAV3 | 16.1 | 9.2 |
| TDLA-30 ULA Low | 10 Hz | N/A | 13.2 | 6.2 |
| TDLA-30 XP Med | 10 Hz | N/A | 14.6 | 7.5 |
| UMa-CDLC-A1 | 30 kph | AAV3 | 16.6 | 8.9 |
| UMa-CDLC-A2 | 30 kph | AAV3 | 16.5 | 8.9 |
| UMa-CDLC-A3 | 30 kph | AAV3 | 16.4 | 9.1 |
| TDLC-300 ULA Low | 100 Hz | N/A | 14.6 | 7.0 |
| TDLC-300 XP Med | 100 Hz | N/A | 16.0 | 7.8 |
| UMa-CDLC-A1 | 3 kph | AAV1Y | 15.4 | 7.3 |
| UMa-CDLC-A2 | 3 kph | AAV1Y | 14.9 | 6.7 |
| UMa-CDLC-A3 | 3 kph | AAV1Y | 14.9 | 7.0 |
| UMa-CDLC-A1 | 30 kph | AAV1Y | 15.7 | 7.0 |
| UMa-CDLC-A2 | 30 kph | AAV1Y | 15.4 | 6.8 |
| UMa-CDLC-A3 | 30 kph | AAV1Y | 15.2 | 6.8 |

**SU-MIMO PMI-PDSCH Performance**

The TP gain with Type I and eType II are presented in the table below. For PMI reporting, only AAV3 is used.

Table : TP Gain with PMI reporting with 8TX

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Channel /MIMO Corr** | **Doppler/Speed** | **Num Layers** | **g Type I** | **g eType II** |
| TDLC300 XP-Low | 10 Hz | 2 | 1.34 | 1.79 |
| TDLC300 XP-Med | 2.77 | 2.66 |
| TDLC300 XP-High | 6.24 | 3.51 |
| UMa-CDL-C-A1 | 3 kph | 1.81 | 1.86 |
| UMa-CDL-C-A2 | 1.82 | 1.86 |
| UMa-CDL-C-A3 | 1.85 | 1.89 |
| TDLC300 XP-Low | 10 Hz | 4 | 1.26 | 1.28 |
| TDLC300 XP-Med | 1.82 | 1.85 |
| TDLC300 XP-High | 1.89 | 2.13 |
| UMa-CDL-C-A1 | 3 kph | 1.75 | 1.50 |
| UMa-CDL-C-A2 | 1.73 | 1.51 |
| UMa-CDL-C-A3 | 1.77 | 1.65 |
| TDLC300 XP-Low | 100 Hz | 2 | 0.94 | 0.98 |
| TDLC300 XP-Med | 2.50 | 2.01 |
| TDLC300 XP-High | 3.27 | 2.82 |
| UMa-CDL-C-A1 | 30 kph | 1.55 | 1.61 |
| UMa-CDL-C-A2 | 1.51 | 1.57 |
| UMa-CDL-C-A3 | 1.63 | 1.71 |
| TDLC300 XP-Low | 100 Hz | 4 | 1.00 | 0.90 |
| TDLC300 XP-Med | 1.81 | 1.80 |
| TDLC300 XP-High | 1.86 | 2.15 |
| UMa-CDL-C-A1 | 30 kph | 1.64 | 1.35 |
| UMa-CDL-C-A2 | 1.62 | 1.23 |
| UMa-CDL-C-A3 | 1.77 | 1.44 |

Table 4: TP Gain with PMI reporting with 16TX

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Channel /MIMO Corr** | **Doppler/Speed** | **Num Layers** | **g Type I** | **g eType II** |
| TDLC300 XP-Low | 10 Hz | 2 | 1.79 | 1.82 |
| TDLC300 XP-Med | 3.84 | 4.60 |
| TDLC300 XP-High | 108.65 | 101.23 |
| UMa-CDL-C-A1 | 3 kph | 3.81 | 4.50 |
| UMa-CDL-C-A2 | 3.43 | 4.82 |
| UMa-CDL-C-A3 | 4.66 | 6.85 |
| TDLC300 XP-Low | 10 Hz | 4 | 1.30 | 1.43 |
| TDLC300 XP-Med | 1.94 | 2.14 |
| TDLC300 XP-High | 3.70 | 5.98 |
| UMa-CDL-C-A1 | 3 kph | 2.06 | 2.76 |
| UMa-CDL-C-A2 | 1.98 | 2.77 |
| UMa-CDL-C-A3 | 1.93 | 4.37 |

Table 5: TP Gain with PMI reporting with 32TX

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Channel /MIMO Corr** | **Doppler/Speed** | **Num Layers** | **g Type I** | **g eType II** |
| TDLC300 XP-Low | 10 Hz | 2 | 1.80 | 1.89 |
| TDLC300 XP-Med | 718.75 | 718.75 |
| TDLC300 XP-High | 958.33 | 958.33 |
| UMa-CDL-C-A1 | 3 kph | 224.21 | 532.80 |
| UMa-CDL-C-A2 | 139.63 | 373.43 |
| UMa-CDL-C-A3 | 245.35 | 671.13 |
| TDLC300 XP-Low | 10 Hz | 4 | 1.37 | 1.78 |
| TDLC300 XP-Med | 137.91 | 452.58 |
| TDLC300 XP-High | Inf | Inf |
| UMa-CDL-C-A1 | 3 kph | 2.84 | 17.19 |
| UMa-CDL-C-A2 | 2.66 | 8.99 |
| UMa-CDL-C-A3 | 2.95 | 18.70 |

|  |  |
| --- | --- |
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Figure 2: UMa-CDL-C variants performance comparison

Based on the results, we have the following observations:

* eType II performance is better than Type I with larger CSI-RS ports even with no AAV
* The performance improvement with eType II can be seen in legacy TDL and well as CDL channel models
* Performance among variants of UMa-CDL-C A1/A2/A3 is similar, but in some cases there is performance delta with A3 compared to A2
* X-pol with Medium / High antenna correlation are not suitable for large number of TX ports/ antenna for > 2layer

1. *eType II performance is better than Type I with larger CSI-RS ports even with no AAV.*
2. *The performance improvement with eType II can be seen in legacy TDL and well as CDL channel models*
3. *Performance with follow PMI with Type I and eType II codebook between variants of UMa-CDL-C A1/A2/A3 is similar, but in some cases there is performance delta with A3 compared to A2*
4. *X-pol with Medium / High antenna correlation are not suitable for large number of TX ports/ antenna for > 2layer*

For eType II we compare performance between different channel models – existing TDL channel models and Uma-CDL-C.

|  |  |
| --- | --- |
|  |  |
|  |  |

Figure : Follow PMI with eType II performance comparison – 8TX

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| --- | --- |
|  |  |
|  |  |

Figure 4: Follow PMI with eType II performance comparison – 16 / 32TX

Based on the results in figure 2, the performance with follow PMI with eType II is not significantly better than existing TDL channel models with/ without correlation.

1. *The performance of follow PMI with eType II is not significantly better than existing TDL channel models.*

# 3. Conclusion

In this paper, we provide our simulation results for study of spatial channel models. Our observations are captured below:

**SU-MIMO PDSCH performance**

1. *The performance with CDL channel model is not better than existing TDL channel models with Low, Med correlation for 4x4 with 4 layers.*
2. *The performance with UMa-CDLC channel model variants – A1/A2/A3 are very similar for PDSCH with random PMI.*

**SU-MIMO PMI PDSCH performance**

1. *eType II performance is better than Type I with larger CSI-RS ports even with no AAV.*
2. *The performance improvement with eType II can be seen in legacy TDL and well as CDL channel models*
3. *Performance with follow PMI with Type I and eType II codebook between variants of UMa-CDL-C A1/A2/A3 is similar, but in some cases there is performance delta with A3 compared to A2*
4. *X-pol with Medium / High antenna correlation is not suitable for large number of TX ports/ antenna for > 2layer*
5. *The performance of follow PMI with eType II is not significantly better than existing TDL channel models.*

# Reference

1. R4-2502378, “Way Forward for [114][322] NR\_SCM”, Nokia.

# Annex A: CDL Tables

Table A-1: UMa-CDLC-A2 without delay quantization

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Cluster #** | **Cluster delay (ns)** | **Power in [dB]** | **AOD in [°]** | **AOA in [°]** | **ZOD in [°]** | **ZOA in [°]** |
| 1 | 0 | -4.4 | -38.2 | -96.9 | 96.8 | 98.1 |
| 2 | 77 | -1.2 | -21.8 | 118.9 | 98.5 | 71.1 |
| 3 | 81 | -3.5 | -21.8 | 118.9 | 98.5 | 71.1 |
| 4 | 85 | -5.2 | -21.8 | 118.9 | 98.5 | 71.1 |
| 5 | 79 | -2.5 | -34.2 | -124.4 | 100.9 | 67.6 |
| 6 | 232 | 0 | -5.9 | 171.2 | 99.2 | 76.6 |
| 7 | 235 | -2.2 | -5.9 | 171.2 | 99.2 | 76.6 |
| 8 | 239 | -3.9 | -5.9 | 171.2 | 99.2 | 76.6 |
| 9 | 240 | -7.4 | 44.2 | 51.9 | 106.4 | 62.8 |
| 10 | 290 | -7.1 | -50.6 | 63.4 | 94.5 | 56.6 |
| 11 | 300 | -10.7 | 49.1 | -42.1 | 107.5 | 69.8 |
| 12 | 341 | -11.1 | -73.0 | 43.1 | 92.3 | 50.8 |
| 13 | 448 | -5.1 | -44.2 | 65.1 | 104.6 | 103.4 |
| 14 | 478 | -6.8 | -50.4 | -63.4 | 105.2 | 50.1 |
| 15 | 792 | -8.7 | -60.2 | 79.0 | 91.7 | 51.7 |
| 16 | 989 | -13.2 | 64.6 | 26.3 | 105.2 | 121.0 |
| 17 | 1554 | -13.9 | 62.2 | -22.6 | 94.0 | 53.9 |
| 18 | 1679 | -13.9 | 55.0 | -1.6 | 91.8 | 61.6 |
| 19 | 2004 | -15.8 | -76.3 | -19.8 | 90.7 | 37.5 |
| 20 | 2047 | -17.1 | 57.4 | 4.5 | 108.2 | 53.1 |
| 21 | 2302 | -16 | 58.1 | 0.2 | 91.7 | 35.8 |
| 22 | 2423 | -15.7 | 67.3 | -4.9 | 91.6 | 52.9 |
| 23 | 2571 | -21.6 | 76.2 | -28.3 | 106.4 | 46.4 |
| 24 | 3158 | -22.8 | -91.4 | 29.3 | 109.5 | 44.7 |
| **Per-Cluster Parameters** | | | | | | |
| *Parameter* | | *c*ASD in [°] | *c*ASA in [°] | *c*ZSD in [°] | *c*ZSA in [°] | XPR in [dB] |
| *Value* | | 1.4 | 15.6 | 3.6 | 12.2 | 7 |

Table A-2: UMa-CDLC-A3 without delay quantization

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Cluster #** | **Cluster delay (ns)** | **Power in [dB]** | **AOD in [°]** | **AOA in [°]** | **ZOD in [°]** | **ZOA in [°]** |
| 1 | 0 | -4.4 | -38.2 | -96.9 | 96.8 | 98.1 |
| 2 | 226 | -1.2 | -21.8 | 118.9 | 98.5 | 71.1 |
| 3 | 238 | -3.5 | -21.8 | 118.9 | 98.5 | 71.1 |
| 4 | 250 | -5.2 | -21.8 | 118.9 | 98.5 | 71.1 |
| 5 | 232 | -2.5 | -34.2 | -124.4 | 100.9 | 67.6 |
| 6 | 682 | 0 | -5.9 | 171.2 | 99.2 | 76.6 |
| 7 | 691 | -2.2 | -5.9 | 171.2 | 99.2 | 76.6 |
| 8 | 702 | -3.9 | -5.9 | 171.2 | 99.2 | 76.6 |
| 9 | 705 | -7.4 | 44.2 | 51.9 | 106.4 | 62.8 |
| 10 | 852 | -7.1 | -50.6 | 63.4 | 94.5 | 56.6 |
| 11 | 1317 | -5.1 | -44.2 | 65.1 | 104.6 | 103.4 |
| 12 | 1405 | -6.8 | -50.4 | -63.4 | 105.2 | 50.1 |
| **Per-Cluster Parameters** | | | | | | |
| *Parameter* | | *c*ASD in [°] | *c*ASA in [°] | *c*ZSD in [°] | *c*ZSA in [°] | XPR in [dB] |
| *Value* | | 1.4 | 15.6 | 3.6 | 12.2 | 7 |