**3GPP TSG RAN WG1 #108-e R1-2nnnnn**

**e-Meeting, February 21st – March 3rd, 2022**

**Source: Ad-Hoc Chair (AT&T)**

**Title: Session Notes of AI 8.16.1**

**Agenda Item:** **8.16.1**

**Document for:** **Endorsement**



#### 8.16.1 UE features for further enhancements on NR-MIMO

[108-e-R17-UE-features-MIMO-01] Email discussion on UE features for further enhancements on NR-MIMO – Ralf (AT&T)

* 1st check point: February 25
* Final check point: March 3

**Agreement: Adopt the following changes highlighted in chromatic fonts, while keeping the yellow highlighting, if any, as shown**

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| 23. NR\_FeMIMO | 23-1-1 | Unified TCI ~~[~~with joint DL/UL TCI update~~]~~ for intra- [and inter-cell] beam management | 1. Joint DL/UL TCI update with their components: (configuration mechanism, QCL rules, applicable source and target signals) 2. WA: The maximum number of configured joint TCI states [per BWP per CC] [in a band] [in a band combination] 3. ~~a) The maximum number of~~ One MAC-CE activated joint TCI state~~s~~ per CC [in a band] [in a band combination] 4. TCI state indication [mode]: update and activation [in case of updates]a) MAC CE based TCI state indication [for one active TCI state]   FFS: whether to include the following components ~~2-14~~ into this FG or one or more separate FGs  FFS: Whether basic FGs are defined, and if so, which components are basic FGs, i.e., a UE that supports FG 23-1-1 must also support said basic FGs  ~~FFS: basic FGs for UEs supporting CA~~  FFS: separate FGs for inter/intra/joint/separate   1. For PUCCH, PUSCH, and SRS, association between TCI state and UL PC settings except for PL RS 2. The maximum number of MAC-CE activated joint TCI states across all CCs [in a band] [in a band combination] 3. Common multi-CC TCI state ID update and activation 4. ~~[The minimum beam application time between PUCCH of ACK and the first slot in Y symbols per SCS]~~ 5. Beam misalignment between the DL source RS in the TCI state to provide spatial relation indication and the PL-RS 6. ~~TCI state indication [mode]: update and activation [in case of updates]~~ ~~b) MAC-CE+DCI-based TCI state indication (use of DCI formats 1\_1/1\_2 with DL assignment) c) MAC-CE+DCI-based TCI state indication (use of DCI formats 1\_1/1\_2 without DL assignment)~~ 7. Reference BWP/CC configured with reference TCI state pool shared by a set of BWP/CC Note: agree component, final wording may change (e.g., when this is merged with other components/FGs) 8. Maximum number of CCs configured with BFR  FFS whether this is a component or just a note in the FG to reuse R16 signaling 9. Support of indication/configuration of R17 TCI states for aperiodic CSI-RS, PDCCH, PDSCH, and SRS reusing the Rel-15/16 signaling/configuration design(s) Note: This has no impact on detail signaling design for SRS TCI indication 10. The maximum number of configured joint TCI state pools across all BWPs and all CCs in a band [in a band combination]  ~~FFS: Whether to make component 9 a prerequisite or merge with 9~~ 11. [Alt. 1: [The maximum number of PDSCH-Configs containing TCI states that can referred to from a PDSCH-Config without TCI states Alt. 2: Support PDSCH-Config which contains a reference to another CC/BWP, in which the PDSCH-Config contains the TCI state list]   [16. The minimum time gap between the beam indication PDCCH and first slot where beam is applied] |  |  |  |  |  |  |  |  |  | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-1-1b | Unified TCI with joint DL/UL TCI update for intra- [and inter-cell] beam management with more than one MAC-CE activated joint TCI state | 1. TCI state indication [mode]: update and activation [in case of updates] b) MAC-CE+DCI-based TCI state indication (use of DCI formats 1\_1/1\_2 with DL assignment) c) MAC-CE+DCI-based TCI state indication (use of DCI formats 1\_1/1\_2 without DL assignment) 2. [The minimum beam application time between PUCCH of ACK and the first slot in Y symbols per SCS] 3. The maximum number of MAC-CE activated joint TCI states per CC [in a band] [in a band combination] | 23-1-1 |  |  |  |  |  |  |  | Component 3 candidate values: {2, …} | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-1-1c | Unified TCI with joint DL/UL TCI update for intra- [and inter-cell] beam management with carrier aggregation | Per CC configuration of TCI state pools | 23-1-1 |  |  |  |  |  |  |  |  | Optional with capability signalling |

* Note: There will not be a component to signal the maximum number of configured joint TCI states across all BWPs and all CCs

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| 23. NR\_FeMIMO | 23-1-1 | Unified TCI ~~[~~with joint DL/UL TCI update~~]~~ for intra- [and inter-cell] beam management | 1. Joint DL/UL TCI update with their components: (configuration mechanism, QCL rules, applicable source and target signals) 2. WA: The maximum number of configured joint TCI states [per BWP per CC] [in a band] [in a band combination] 3. One MAC-CE activated joint TCI state per CC [in a band] [in a band combination] 4. TCI state indication [mode]: update and activation [in case of updates]a) MAC CE based TCI state indication [for one active TCI state] 5. One MAC-CE activated joint TCI state across all CC(s) in a band |  |  |  |  |  |  |  |  | Note: Activated joint TCI state(s) include those activated by R17 signaling as well as by reusing R15/16 signaling | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-1-1b | Unified TCI with joint DL/UL TCI update for intra- [and inter-cell] beam management with more than one MAC-CE activated joint TCI state | 1. TCI state indication [mode]: update and activation [in case of updates] b) MAC-CE+DCI-based TCI state indication (use of DCI formats 1\_1/1\_2 with DL assignment) c) MAC-CE+DCI-based TCI state indication (use of DCI formats 1\_1/1\_2 without DL assignment) 2. [The minimum beam application time between PUCCH of ACK and the first slot in Y symbols per SCS] 3. The maximum number of MAC-CE activated joint TCI states per CC [in a band] [in a band combination] 4. The maximum number of MAC-CE activated joint TCI states across all CC(s) in a band | 23-1-1 |  |  |  |  |  |  |  | Component 3 candidate values: {2, …}  Note: Activated joint TCI state(s) include those activated by R17 signaling as well as by reusing R15/16 signaling | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-1-1c | Unified TCI with joint DL/UL TCI update for intra- [and inter-cell] beam management with carrier aggregation | 1. Per CC configuration of TCI state pools | 23-1-1 |  |  |  |  |  |  |  |  | Optional with capability signaling |
| 23. NR\_FeMIMO | 23-1-1d | Reference BWP /CC configured with reference TCI state pool shared by a set of BWP /CC | 1. Reference BWP /CC configured with reference TCI state pool shared by a set of BWP /CC  2. The maximum number of configured joint TCI state pools across all BWPs and all CCs in a band [in a band combination]  [Alt. 1: ~~[~~The maximum number of PDSCH -Configs containing TCI states that can referred to from a PDSCH -Config without TCI states  Alt . 2: Support PDSCH -Config which contains a reference to another CC/BWP , in which the PDSCH -Config contains the TCI state list] | 23-1-1 |  |  |  |  |  |  |  |  | Optional with capability signaling |

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| 23. NR\_FeMIMO | 23-1-1g | Unified TCI with separate DL/UL TCI update for intra- [and inter-] cell beam management | 1. Separate DL/UL TCI update with their components: (configuration mechanism, QCL rules, applicable source and target signals, beam misalignment)  2. The maximum number of configured DL TCI states per BWP per CC  3. The maximum number of configured UL TCI states per BWP per CC  4. The maximum number of RRC configured UL TCI states across all CCs  5. The maximum number of MAC-CE activated DL TCI states for all PDCCH/PDSCH receptions across all CCs in a band  6. The maximum number of MAC-CE activated UL TCI states for all PUSCH/PUCCH receptions across all CCs in a band  7. The maximum number of MAC-CE activated DL TCI states for all PDCCH/PDSCH receptions per CC  8. The maximum number of MAC-CE activated UL TCI states for all PUSCH/PUCCH receptions per CC | 23-1-1 |  |  |  |  |  |  |  |  | Optional with capability signalling |

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| 23. NR\_FeMIMO | 23-1-2 | Inter-cell beam measurement and reporting [(for inter-cell BM [and mTRP])] | 1. Support of L1-RSRP measurement and reporting on SSB(s) with PCI(s) different from serving cell PCI  FFS: whether to include the following components 2-13 into this FG or one or more separate FGs  FFS: Whether basic FGs are defined, and if so, which components are basic FGs, i.e., a UE that supports FG 23-1-2 must also support said basic FGs  [==============================]  2. Support of up to K[=4] SSBRI-RSRP [pairs/beams] in one report [where at least one [pair/beam] associated with a PCI different from serving cell PCI can be reported] (FFS: if K is a component candidate value)  **Basic**  3. The maximum number of [RRC-configured] PCI(s) different from serving cell PCI for L1-RSRP measurement] (FFS: whether to split this for FR1 and FR2) (FFS: whether/how to capture different values/behaviors for periodic/aperiodic/semi-persistent L1-RSRP measurement)  **Basic**  [==============================]  ~~[~~4. The max number of SSB resources configured to measure L1-RSRP within a slot with PCI(s) same as or different from serving cell PCI [across all CC]~~]~~  **Basic**  ~~[~~5. The max number of SSB resources configured to measure L1-RSRP with PCI(s) same as or different from serving cell PCI [across all CC]~~]~~  **Basic**  [==============================]  ~~[~~6. Support on that SSB(s) with PCI(s) different from serving cell PCI configured for L1 beam measurement and report are not included in SSBs with PCIs configured for L3 mobility measurement~~]~~ **New FG or Basic**  [==============================]  ~~[~~7. The maximum number of configured additional PCIs is X1 when time domain positions and periodicity of configured SSBs with additional PCIs are the same as time domain positions and periodicity of the serving cell SSBs~~]~~  **Basic**  ~~[~~8. The maximum number of configured additional PCIs is X2 when time domain positions and periodicity of configured SSBs with additional PCIs are different with time domain positions and periodicity of the serving cell SSBs~~]~~  **Basic**  [==============================]  [9. Supported mode inter-cell measurement: {inside SMTC, both inside and outside SMTC}]  **New FG or Basic**  [10. Supported mode of measurement over overlapped SSBs: {overlapped, both overlapped and non-overlapped}]  **New FG or Basic**  [==============================]  ~~[~~11. Maximum number of overlapped SSBs in one SSB resource for L1-RSRP measurement~~]~~  **New FG or Basic**  [==============================]  ~~[~~12. The maximum total number of SSB/CSI-RS/CSI-IM resources configured to measure within a slot across all CCs in one frequency range for any of L1-RSRP measurement, L1-SINR measurement, pathloss measurement, BFD, RLM and new beam identification for both intra-cell and inter-cell measurement (Similar to FG 16-1g)~~]~~  **New FG**  ~~[~~13.[The maximum total number of SSB/CSI-RS/CSI-IM resources configured across all CCs in one frequency range for any of L1-RSRP measurement, L1-SINR measurement, pathloss measurement, BFD, RLM and new beam identification for both intra-cell and inter-cell measurement (Similar to FG 16-1g)~~]~~  **New FG** | [2-24, 2-29] |  |  |  | [per band] |  |  |  |  | Optional with capability signalling |

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| 23. NR\_FeMIMO | 23-2-1 | PDCCH repetition | 1. Support of intra-slot PDCCH repetition based on two linked SS sets associated with corresponding CORESETs [with [non-SFN scheme] TDM and FDM [(except FDM based PDCCH repetition for FR2)] ~~[~~including PDCCH repetition for Type 3 CSS~~]~~  2. ~~Support of reporting one number as~~ Required number of BDs for the two PDCCH candidates  ~~FFS:~~ 3. Support max number of overlaps when one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate per scheduled component carrier per slot |  |  |  |  |  |  |  |  | Component 2 candidate values: ~~details~~ 2 or 3  Component 3~~4~~ candidate values: ~~[~~{~~0,~~1,2,3, FFS more}~~]~~  ~~[~~Note: UE supports PDCCH repetition for the following (basic) PDCCH monitoring capability: For type 1 CSS with dedicated RRC configuration, type 3 CSS, and UE-SS, the monitoring occasion is within the first 3 OFDM symbols of a slot~~]~~  ~~[~~Note: for component 3, ~~if N PDCCH candidates are overlapped, the number of overlaps~~ each unique pair of overlaps is counted as one.~~]~~ | Optional with capability signalling |

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| 23. NR\_FeMIMO | 23-2-1b | PDCCH inter-span repetition | 1. Support of inter-span repetition for PDCCH | 23-2-1 |  |  |  |  |  |  |  |  | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-2-1c | PDCCH repetition with PDCCH  monitoring on any span of up to 3 consecutive OFDM symbols of a slot | Support of PDCCH repetition for PDCCH monitoring on any span of up to 3 consecutive OFDM symbols of a slot | 3-2  23-2-1 |  |  |  | Per Band |  |  | FR1 only |  | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-2-1d | PDCCH repetition for Case 2 PDCCH monitoring with a span gap | 1. Support of PDCCH repetition for PDCCH monitoring of any occasions with span gap as defined in FG 3-5b.  2. Supported mode of PDCCH repetition  3. X per CC  4. X across all CCs | 3-5b  23-2-1 |  |  |  | Per FS |  |  |  | This capability is necessary for each SCS.  Component2: {intra-span, inter-span, both}  Component3: FFS candidate values  Component 4: FFS candidate values  Note:   * Components 3 and 4 are reported only if UE supports inter-span PDCCH repetition. * The limit (X) is associated with the total number of linked candidates of which the first candidate is received and the second one has not been received at any given span, where “received” and “not been received” is wrt the end of the corresponding span of PDCCH candidate.   The limit X is indicated as a total count assuming count 1 for AL=1; 2 for AL=2; 4 for AL=4 or 8 or 16. | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-2-1e | PDCCH repetition for Rel-16 PDCCH monitoring | 1. Support of PDCCH repetition with Rel-16 PDCCH monitoring capability as defined in FG 11-2 family.  2. Supported mode of PDCCH repetition  3. X per CC  4. X across all CCs  5. Supported max number of overlaps when one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate per scheduled component carrier per span | 11-2  23-2-1 |  |  |  | Per FS |  |  |  | This capability is signalled for SCS 15 kHz and 30 kHz.  Component2: {intra-span, inter-span, both}  Component3: FFS candidate values  Component 4: FFS candidate values  Note:   * Components 3 and 4 are reported only if UE supports inter-span PDCCH repetition. * The limit X is associated with the total number of linked candidates of which the first candidate is received and the second one has not been received at any given span, where “received” and “not been received” is wrt the end of the corresponding span of PDCCH candidate. * The limit X is indicated as a total count assuming count 1 for AL=1; 2 for AL=2; 4 for AL=4 or 8 or 16.   Component5: {1,2,3,5,10,20} | Optional with capability signalling |

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| 23. NR\_FeMIMO | 23-3-1 | Multi-TRP PUSCH repetition (type A) ~~[~~-~~CB]~~ codebook based | 1. Support of multi-TRP PUSCH repetition (based on PUSCH repetition type A) ~~[for CB]~~  - sequential mapping for repetitions equal to or larger than 2  ~~[~~- cyclic mapping for 2 repetitions~~]~~  ~~[2. The maximum number of PHR reporting across all CCs (including those related to M-TRP PUSCH repetition and the legacy Rel-15/16 PUSCH transmission)]~~  ~~[~~3. Support dynamic switching between multi-TRP PUSCH scheme and single-TRP PUSCH transmission~~]~~  4. Support of two SRS resource sets with usage set to 'codebook'  5. Supported number of SRS resources in one SRS resource set  ~~FFS: Support PUSCH operations: CB based and NCB based and corresponding parameters including number of SRS resources~~ |  |  |  |  |  |  |  |  | ~~[Candidate component values: {CB, non-CB, both}]~~  Component 5 candidate values: {1,2,4} | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-3-1-2 | Multi-TRP PUSCH repetition (type A) - non-codebook based | 1. Support of multi-TRP PUSCH repetition for non-codebook based PUSCH (based on PUSCH repetition type A)  2. Support of two SRS resource sets with usage set to 'nonCodebook'  3. Supported number of SRS resources in one SRS resource set | 2-15 |  |  |  | Per FSPC |  |  |  | Component 3: {1,2,3,4} | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-3-1-2a | Two associated CSI-RS resources | Support of up to two CSI-RS resources associated with the two SRS resource sets for non-codebook-based mTRP PUSCH | 2-15a  23-3-1-2 |  |  |  | Per Band |  |  |  |  | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-3-1-2b | CSI-RS processing framework for SRS with two associated CSI-RS resources | 1. Maximum number of periodic SRS resources associated with first or second CSI-RS per BWP  2. Maximum number of aperiodic SRS resources associated with first or second CSI-RS per BWP  3. Maximum number of semi-persistent SRS resources associated with first or second CSI-RS per BWP  4. UE can process Y SRS resources associated with first or second CSI-RS resources simultaneously in a CC. Includes P/SP/A SRS. | 23-3-1-2a |  |  |  | Per Band |  |  |  | Component 1: {1 to 8}  Component 2: {1 to 8}  Component 3: {1 to 8}  Component 4: {1 to 16} | Optional with capability signalling |

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| 23. NR\_FeMIMO | 23-7-1 | Basic Features of CSI Enhancement for Multi-TRP | 1. Support of NZP CSI-RS resource pairs used as CMR (channel measurement resource) pairs for NCJT measurement hypothesis: Support of N=1 2. Maximum number of NZP CSI-RS resources in one CSI-RS resource set: Ks,max 3. CSI report mode ~~[~~selection~~]~~ of mode 1 with X=0 ~~[~~and/or~~]~~ mode 2 4. A list of ~~[~~supported combinations, up to 16, across all CCs simultaneously, where each combination is~~]~~ 5. ~~[Maximum number of Tx ports in one NZP CSI-RS resource associated with a single-TRP measurement hypothesis]~~ 6. Maximum number of Tx ports in one NZP CSI-RS resource associated with an NCJT measurement hypothesis 7. ~~[Maximum total number of CMRs for single-TRP measurement] [per CC/across all CCs]~~ 8. Maximum total number of CMRs for NCJT measurement ~~[per CC/across all CCs]~~ 9. ~~[Maximum total number of Tx ports of NZP CSI-RS resources associated with single-TRP measurement hypotheses] [per CC/across all CCs]~~ 10. Maximum total number of Tx ports of NZP CSI-RS resources associated with NCJT measurement hypotheses ~~[per CC/across all CCs]~~ 11. ~~[Maximum total number of Tx ports of NZP CSI-RS resources associated with one NCJT measurement]~~ 12. ~~[A list of (Y1,Y2):~~ UE can process Y~~1~~ NCJT CSI ~~and Y2 sTRP CSI~~ measurement hypothesis simultaneously in a CC~~]~~ 13. ~~[A list of (X1,X2):~~ UE can process X~~1~~ NCJT CSI ~~and X2 sTRP CSI~~ measurement hypothesis simultaneously across all CCs~~]~~ 14. Supported codebook modes for NCJT CSI 15. Timing restriction for a CMR pair | ~~FFS~~ |  |  |  | ~~[~~Per band and per BC~~]~~ |  |  |  | ~~[~~Component 2 candidate value set: {~~[0~~, 2, 3,~~]~~ 4, 5, 6, 7, 8}~~]~~  ~~[~~Component 3 candidate value set: { mode 1 with X=0, mode 2, both}~~]~~  Component ~~5~~ 4 candidate values:   1. ~~[{2, 4, 8, 12, 16, 24, 32}]~~ 2. {2, 4, 8, 12, 16~~[~~, 24, 32~~]~~} 3. ~~[{1,2,3,4 … 64}]~~ 4. {2,3,4 … 64} 5. ~~[{4,5,6, …, 256}]~~ 6. {2,3,4, …, 256}   ~~[~~Component ~~6~~ 5: ~~The list can have maximum of 16 pairs.~~  - Y~~1~~: {1 to 4}  ~~- Y2: {1 to 8}]~~  ~~[~~Component ~~7~~ 6: ~~The list can have maximum of 16 pairs.~~  - X~~1~~: {1 to 16}  ~~- X2: {1 to 32}]~~  Component 7:{ mode 1, both mode 1 and mode 2}  Component 8: {X=1,X=2}  Note: ‘NCJT’ is not used in RAN1 specifications and will be aligned with 38.214 | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-7-1b | Active CSI-RS resources and ports in the presence of multi-TRP CSI | 1. List of codebook combinations 2. List of {max number of ports per resource, max number of resources, max number of total ports} for each codebook combination | 23-7-1 |  |  |  | Per band and per BC |  |  |  | Component 1 candidate values:  Codebook 1 = {NCJT+Type 1 SP (for sTRP)}  {Codebook 2, Codebook 3} = {(NULL, NULL}), {“Rel 16 combinations in FG 16-8”}, {“New Rel17 combinations in FG 23-9-5”}}  Component 2 candidate values:  - Maximum 16 triplets for each codebook combination  - Max # of Tx ports in one resource: {2, 4,8,12,16,24,32}  - Max # resources: {1 to 64}  - Max # total ports: {4 to 256}  Note 1: A CMR pair configured for NCJT will be counted as two activated resources, a CMR configured for sTRP will be counted as one activated resource for a triplet.  Note2: This capability is relevant only when UE is configured with NCJT CSI in at least one CSI report setting in at least one CC in the band and/or band combination. | Optional with capability signalling |

[R1-2200936](../../Docs/R1-2200936.zip) Rel-17 UE features for further NR MIMO enhancements Huawei, HiSilicon

[R1-2201120](../../Docs/R1-2201120.zip) Discussion on remaining issues of FeMIMO features vivo

[R1-2201199](../../Docs/R1-2201199.zip) UE features for feMIMO ZTE

[R1-2201230](../../Docs/R1-2201230.zip) UE features for further enhancements on NR-MIMO OPPO

[R1-2201344](../../Docs/R1-2201344.zip) On UE features for Rel-17 feMIMO CATT

[R1-2201408](../../Docs/R1-2201408.zip) On UE features for further enhancements on NR-MIMO Nokia, Nokia Shanghai Bell

[R1-2201501](../../Docs/R1-2201501.zip) Discussion on Rel.17 FeMIMO UE features NTT DOCOMO, INC.

[R1-2201562](../../Docs/R1-2201562.zip) Discussion on UE features for FeMIMO Spreadtrum Communications

[R1-2201574](../../Docs/R1-2201574.zip) Discussion on Rel-17 UE feature for NR FeMIMO LG Electronics

[R1-2201723](../../Docs/R1-2201723.zip) On UE features for feMIMO Intel Corporation

[R1-2201791](../../Docs/R1-2201791.zip) Views on Rel-17 FeMIMO UE features Apple

[R1-2201882](../../Docs/R1-2201882.zip) Discussion on UE features for FeMIMO CMCC

[R1-2201952](../../Docs/R1-2201952.zip) Discussion on UE features for FeMIMO Xiaomi

[R1-2202038](../../Docs/R1-2202038.zip) Views on UE features for Rel-17 NR FeMIMO Samsung

[R1-2202058](../../Docs/R1-2202058.zip) UE Features for further enhancements on NR MIMO MediaTek Inc.

[R1-2202092](../../Docs/R1-2202092.zip) Discussion on UE features for FeMIMO Lenovo

[R1-2202165](../../Docs/R1-2202165.zip) Discussion on FeMIMO UE features Qualcomm Incorporated

[R1-2202282](../../Docs/R1-2202282.zip) Discussion on UE features for FeMIMO Ericsson