**3GPP TSG RAN WG1 #107bis-e R1-200xxxx**

**e-Meeting, January 17th – 25th, 2022**

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

**Title: Session Notes of AI 8.15.1**

**Agenda Item:** **8.15.1**

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



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

[107bis-e-R17-UE-features-MIMO-01] Email discussion UE features for further enhancements on NR-MIMO – Ralf (AT&T)

* 1st check point: January 20
* Final check point: January 25

**Agreement: Adopt the following changes highlighted in green, while keeping the yellow highlighting as shown**

* The following are the components of the feature “joint TCI for intra-cell operation”

1. Joint DL/UL TCI update with their components: (configuration mechanism, ~~[~~QCL rules,~~]~~ applicable source and target signals, ~~MAC-CE -based TCI]~~ ~~activation~~)
2. Common multi-CC TCI update and activation ~~(involving RRC common TCI state pool)~~
3. For PUCCH, PUSCH, and SRS, association between TCI state and UL PC settings except for PL RS ~~[for PUCCH, PUSCH, and SRS]~~
4. Beam misalignment between the DL source RS in the TCI state to provide spatial relation indication and the PL-RS
5. TCI state indication [mode]: update and activation [in case of updates]a) MAC CE based TCI state indication [for one active TCI state]  
   b) ~~[~~MAC-CE+DCI-based TCI state indication (~~including TCI state activation,~~ use of DCI formats 1\_1/1\_2 with ~~and without~~ DL assignment)~~]~~  
   c) MAC-CE+DCI-based TCI state indication (use of DCI formats 1\_1/1\_2 without DL assignment)
6. [TCI states pool for configured reference BWP/CC shared by a set of BWP/CC] FFS: (involving RRC common TCI state pool)
7. [Maximum number of CCs configured with BFR]
8. [R17 mechanism reusing R15/16 signalling to indicate R17 TCI for individual DL channel/RS that cannot share the same unified TCI as UE-dedicated PDCCH/PDSCH]
9. [Configuration of both R17 TCI and R15/16 TCI and spatial relation]
10. The maximum number of configured joint TCI state pools across all BWPs and all CCs in a band [in a band combination]
11. ~~[~~The maximum number of configured joint TCI states across all BWPs and all CCs in a band~~]~~ [in a band combination]
12. ~~[~~The maximum number of configured joint TCI states per CC ~~[~~in a band~~]]~~ [in a band combination]
13. ~~[~~The maximum number of MAC-CE activated joint TCI states ~~[per BWP per CC/~~across ~~all BWPs and~~ all CCs in a band~~]]~~ in a band combination  
    a) The maximum number of MAC-CE activated joint TCI states per CC in a band in a band combination
14. [Whether a particular DL RS that is a valid target DL RS of a Rel-15/16 TCI state based on the Rel-15/16 QCL rules can be configured as a target DL RS of Rel-17 DL TCI (hence the Rel-17 DL TCI state pool)]
15. [The minimum beam application time between PUCCH of ACK and the first slot in Y symbols per SCS]
16. [The minimum time gap between the beam indication PDCCH and first slot where beam is applied]

* This list gives no guidance as to how to group these components into FGs. They may be mapped to one or more FGs and one or more of these FGs may be agreed as basic. Specifically, different FGs can be grouped together through notes “a UE supporting this FG must also support FG 23-x-y”. This allows to create “basic” FGs while allowing, e.g., different types for different components/candidate values.

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* The following are the components of the feature “joint TCI for intra-cell operation”

1. Joint DL/UL TCI update with their components: (configuration mechanism, ~~[~~QCL rules,~~]~~ applicable source and target signals, ~~MAC-CE -based TCI]~~ ~~activation~~)
2. Common multi-CC TCI update and activation ~~(involving RRC common TCI state pool)~~
3. For PUCCH, PUSCH, and SRS, association between TCI state and UL PC settings except for PL RS ~~[for PUCCH, PUSCH, and SRS]~~
4. Beam misalignment between the DL source RS in the TCI state to provide spatial relation indication and the PL-RS
5. TCI state indication [mode]: update and activation [in case of updates]a) MAC CE based TCI state indication [for one active TCI state]  
   b) ~~[~~MAC-CE+DCI-based TCI state indication (~~including TCI state activation,~~ use of DCI formats 1\_1/1\_2 with ~~and without~~ DL assignment)~~]~~  
   c) MAC-CE+DCI-based TCI state indication (use of DCI formats 1\_1/1\_2 without DL assignment)
6. ~~[TCI states pool for configured~~ 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)
7. ~~[~~Maximum number of CCs configured with BFR~~]~~   
   FFS whether this is a component or just a note in the FG to reuse R16 signaling
8. [R17 mechanism reusing R15/16 signalling to indicate R17 TCI for individual DL channel/RS that cannot share the same unified TCI as UE-dedicated PDCCH/PDSCH]
9. ~~[Configuration of both R17 TCI and R15/16 TCI and spatial relation]~~
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 6 a prerequisite or merge with 6
11. [The maximum number of configured joint TCI states across all BWPs and all CCs in a band] [in a band combination]
12. ~~[~~The maximum number of configured joint TCI states [per BWP per CC] [in a band]~~]~~ [in a band combination]
13. ~~[~~The maximum number of MAC-CE activated joint TCI states ~~[per BWP per CC/~~across ~~all BWPs and~~ all CCs [in a band]~~]]~~ [in a band combination]  
    a) The maximum number of MAC-CE activated joint TCI states per CC [in a band] [in a band combination]
14. ~~[Whether a particular DL RS that is a valid target DL RS of a Rel-15/16 TCI state based on the Rel-15/16 QCL rules can be configured as a target DL RS of Rel-17 DL TCI (hence the Rel-17 DL TCI state pool)]~~
15. [The minimum beam application time between PUCCH of ACK and the first slot in Y symbols per SCS]
16. [The minimum time gap between the beam indication PDCCH and first slot where beam is applied]

* This list gives no guidance as to how to group these components into FGs. They may be mapped to one or more FGs and one or more of these FGs may be agreed as basic. Specifically, different FGs can be grouped together through notes “a UE supporting this FG must also support FG 23-x-y”. This allows to create “basic” FGs while allowing, e.g., different types for different components/candidate values.

**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 | 23-2-1 | ~~[Multi-TRP]~~ 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 FR2)] [including PDCCH repetition for Type 3 CSS]  2. Support of reporting one ~~[or more]~~ number~~(s)~~ as required number of BDs for the two PDCCH candidates  ~~3. [If 3 or {2, 3} is reported in component 2,] support of whether the individual candidate is monitored or not when one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET [for the case that the linked PDCCH candidates is 3 BDs] [If 2 or {2,3} is reported in component 2, the individual candidate is monitored when one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET for the case that the linked PDCCH candidates is 2 BDs.]~~  FFS: ~~4~~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 |  |  |  |  |  |  |  |  | ~~Component 1 details FFS~~  Component 2 candidate values: ~~details FFS~~ 2 or 3  ~~Component 3 candidate values: details FFS {monitored, not monitored}~~  Component 4 candidate values: [{0,1,2,3}] ~~details FFS~~  [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 component4, if N PDCCH candidates are overlapped, the number of overlaps is counted as one. | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-2-1a | Monitoring of individual candidates | Support of monitoring of individual candidates when one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET | [23-2-1] |  |  |  |  |  |  |  | [Note: [If 2 is reported in component 2 of FG 23-2-1,] the individual candidate is monitored when one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET for the case that the linked PDCCH candidates is 2 BDs. If 3 is reported in component 2, support of whether the individual candidate is monitored or not when one of the linked PDCCH candidates uses the same set of CCEs as an individual (unlinked) PDCCH candidate, and they both are associated with the same DCI size, scrambling, and CORESET] | Optional with capability signalling |

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| 23. NR\_FeMIMO | 23-3-1 | Multi-TRP PUSCH repetition (type A)[-CB] | 1. Support of multi-TRP PUSCH repetition (based on PUSCH repetition type A) [for CB]  - sequential mapping for repetitions larger than 2  [- cyclic mapping for 2 repetitions]  ~~[2. Support of cyclic mapping when the number of repetitions is larger than 2 for single DCI based M-TRP PUSCH repetition Type A]~~  ~~[3. Support of second TPC field for per TRP closed-loop power control for PUSCH with DCI formats 0\_1 / 0\_2]~~  ~~[4. Support of PHR reporting related to M-TRP PUSCH repetition (calculate two PHRs (at least corresponding to the CC that applies m-TRP PUSCH repetitions), each associated with a first PUSCH occasion to each TRP, and report two PHRs.) ]~~  ~~[5. Support of CG PUSCH transmission towards M-TRPs using a single CG configuration (Use same beam mapping principals as dynamic grant PUSCH repetition scheme.) ]~~  ~~[6. support of sequential mapping for single for single DCI based M-TRP PUSCH repetition Type A]~~  [7. 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)]  ~~[8. Support of A-CSI report on two PUSCH repetitions]~~  ~~[9. Support of SP-CSI report on two PUSCH repetitions]~~  [2. Support dynamic switching between multi-TRP PUSCH scheme and single-TRP PUSCH transmission]  FFS: ~~[11.~~ Support PUSCH operations: CB based and NCB based and corresponding parameters including number of SRS resources~~]~~ |  |  |  |  |  |  |  |  | [Candidate component values: {CB, non-CB, both}] | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-3-1a | Cyclic mapping | Support of cyclic mapping when the number of repetitions is larger than 2 for single DCI based M-TRP PUSCH repetition Type A |  |  |  |  |  |  |  |  |  | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-3-1b | Second TPC field | Support of second TPC field for per TRP closed-loop power control for PUSCH with DCI formats 0\_1 / 0\_2 |  |  |  |  |  |  |  |  |  | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-3-1c | Two PHR reporting | Support of PHR reporting related to M-TRP PUSCH repetition (calculate two PHRs (at least corresponding to the CC that applies m-TRP PUSCH repetitions), each associated with a first PUSCH occasion to each TRP, and report two PHRs.) |  |  |  |  |  |  |  |  |  | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-3-1e | A-CSI report | Support of A-CSI report on two PUSCH repetitions |  |  |  |  |  |  |  |  |  | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-3-1f | SP-CSI report | Support of SP-CSI report on two PUSCH repetitions |  |  |  |  |  |  |  |  |  | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-3-1g | CG PUSCH transmission | Support of CG PUSCH transmission towards M-TRPs using a single CG configuration (Use same beam mapping principals as dynamic grant PUSCH repetition scheme.) |  |  |  |  |  |  |  |  |  | Optional with capability signalling |

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| 23. NR\_FeMIMO | 23-3-1-1 | Multi-TRP PUSCH repetition (type B) [-CB] | 1. Support of multi-TRP PUSCH repetition (based on PUSCH repetition type B) [for CB]  ~~FFS: discuss details (to be discussed after type A is stable~~  FFS: Support PUSCH operations: CB based and NCB based and corresponding parameters including number of SRS resources |  |  |  |  |  |  |  |  | [Candidate component values: {CB, non-CB, both}] | Optional with capability signalling |

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| 23. NR\_FeMIMO | 23-5-1 | Group based L1-RSRP reporting enhancements | 1. Max number N of beam groups (M=2 beams per beam group) in ~~Support~~ a single L1-RSRP reporting instance ~~consisting of N beam groups and M=2 beams per [pair/group]~~ ~~[in one report instance]~~ based on measurement on two CMR resource sets  ~~2. [Support of enhanced group-based reporting for Rel-17 M-TRP]~~  [2~~3.~~ Maximum number of SSB and CSI-RS resources for measurement in both CMR sets within a slot across all CCs]  [3~~4.~~ Maximum number of configured SSB and CSI-RS resources for measurement in both CMR sets across all CCs]  ~~5. [Support beam measurement on two CMR resource sets]~~  ~~6. [Support of enhanced group-based reporting for Rel-17 intra-cell and inter-cell mTRP]~~ |  |  |  |  |  |  |  |  | Component 1 candidate values: {1,2,3,4}  Component 2 candidate values: FFS  Component 3 candidate values: FFS  FFS: If FG 23-5-a is not introduced, the relationship of this FG with FG 16-1g/16-1g-1 needs to be further clarified | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-5-1a | Resources [for beam management , PL measurement, BFD, RLM, and new beam identification] | Note: Strive to align the final implementation of FG 23-5-1a with related R15/16 implementations  If 23-5-1a ends up being identical to one or more of Rel.15/ 16 FGs this row will be deleted |  |  |  |  |  |  |  |  | Component 1 candidate values: FFS | Optional with capability signalling |

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| 23. NR\_FeMIMO | 23-5-2 | MTRP BFR enhancements | 1. Support of the maximum number of BFD-RS resources per set  [2. Support of Rel-17 M-TRP BFR based on two BFD-RS sets]  ~~3. [Maximum number of CSI-RS resources of both BFR-RS sets across all CCs]~~  ~~4. [Maximal number of different SSBs of both BFD-RS sets across all CCs]~~  ~~5. [Maximal number of different CSI-RS and/or SSB resources of both NBI-RS sets across all CCs]~~  [3. [Support of one ~~up to two~~ PUCCH-SR resource~~s~~ for MTRP BFRQ]  4~~7~~. ~~[~~Supported maximum number of BFD-RS resources across two BFD-RS sets per BWP~~]~~  ~~8. [Support of [single DCI/multi-DCI] based BFR enhancement]~~ |  |  |  |  |  |  |  |  | [Candidate values: {1, 2,…}] | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-5-2a | PUCCH-SR resources for MTRP BFRQ | 1. Max number of PUCCH-SR resources for MTRP BFRQ  [2. Association between BFD-RS resource set on sPCell and a PUCCH SR resource (if component candidate value equals 2)] |  |  |  |  |  |  |  |  | Component candidate values: {[0,1], 2} | Optional with capability signalling |

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| 23. NR\_FeMIMO | 23-7-1 | Basic Features of CSI Enhancement for Multi-TRP | 1. Maximum number of NZP CSI-RS resource pairs used as CMR (channel measurement resource) pairs for NCJT measurement hypothesis: Nmax=1 2. ~~FFS:~~ Maximum number of NZP CSI-RS resources in one CSI-RS resource set: Ks,max 3. CSI report mode selection 4. Maximum value of numberOfSingleTRP-CSI-Mode1 5. A list of supported combinations, up to 16, across all CCs simultaneously, where each combination is    * 1. Maximum number of Tx ports in one NZP CSI-RS resource associated with a single-TRP measurement hypothesis      2. Maximum number of Tx ports in one NZP CSI-RS resource associated with an NCJT measurement hypothesis      3. Maximum total number of calculated single-TRP measurement hypotheses      4. Maximum total number of calculated NCJT measurement hypotheses      5. Maximum total number of Tx ports of NZP CSI-RS resources associated with single-TRP measurement hypotheses      6. Maximum total number of Tx ports of NZP CSI-RS resources associated with NCJT measurement hypotheses 6. A list of (Y1,Y2): UE can process Y1 NCJT CSI report(s) and Y2 sTRP CSI report(s) simultaneously in a CC 7. A list of (X1,X2): UE can process X1 NCJT CSI report(s) and X2 sTRP CSI report(s) simultaneously across all CCs   ~~FFS others (supported options; values for X, codebook types, number of ports of CMRs, CMR sharing among NCJT and sTRP measurement hypotheses for FR1, two CMR groups with Ks=K1+K2 CMRs in CSI-RS resource set, reporting of 2 PMIs, 2 RIs and 2 Lis for NCJT measurement hypothesis …)~~ | FFS |  |  |  | ~~[~~Per band and~~/~~ per BC~~]~~ |  |  |  | ~~[~~Component 2 candidate value set: {[2, 3,] 4, 5, 6, 7, 8}~~]~~  Component 3 candidate value set: { mode 1 with X=0, mode 2, both}  Component 4 candidate values: {0, 1, 2}  Component 5 candidate values:   1. {4, 8, 12, 16, 24, 32} 2. {4, 8, 12, 16, 24, 32} 3. {1,2,3,4 … 64} 4. {1,2,3,4 … 16} 5. {4, 8, 12, …, 256} 6. {4, 8, 12, …, 256}   Component 6: The list can have maximum of 16 pairs.  - Y1: {1 to 4}  - Y2: {1 to 8}  Component 7: The list can have maximum of 16 pairs.  - X1: {1 to 16}  - X2: {1 to 32}  Note: ‘NCJT’ is not used in RAN1 specifications and will be aligned with 38.214 | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-7-1a | Additional CSI report mode 1 selection | 1. Support of additional mode 1 |  |  |  |  |  |  |  |  | Component 1 candidate value set: { mode 1 with X=1, mode 1 with X=2} | Optional with capability signalling |

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| 23. NR\_FeMIMO | 23-3-2 | Multi-TRP PUCCH repetition-inter-slot | 1. Support of PUCCH repetition scheme 1 (inter-slot repetition)  ~~2. Support of PUCCH repetition scheme 3 (intra-slot repetition)~~  - sequential mapping for repetitions larger than 2  [- cyclic mapping for 2 repetitions ]  ~~3~~2. Support of cyclic mapping for beam mapping/power control parameter set mapping ~~[when the number of repetitions is larger than 2]~~ for both PUCCH repetitions scheme 1 and 3 when the number of repetitions is larger than 2  43. Support of second TPC field for per TRP closed-loop power control for PUCCH with DCI formats ~~[1\_0 /]~~ 1\_1 / 1\_2 |  |  |  |  |  |  |  |  |  | Optional with capability signalling |
| 23. NR\_FeMIMO | 23-3-2a | Multi-TRP PUCCH repetition-intra-slot | Support of PUCCH repetition scheme 3 (intra-slot repetition)  - sequential mapping for repetitions larger than 2  [- cyclic mapping for 2 repetitions] |  |  |  |  |  |  |  |  |  |  |

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| 23. NR\_FeMIMO | 23-4 | IntCell-mTRP | 1. Support of RRC configuration of additional PCI different from serving cell associated with the TCI state and/or QCL-info  2. The maximum number of configured additional PCIs is X1 when each configuration of SSB time domain positions and periodicity of the additional PCIs is the same as SSB time domain positions and periodicity of the serving cell PCI;  3. The maximum number of configured additional PCIs is X2 when the configurations of SSB time domain positions and periodicity of the additional PCIs is different with SSB time domain positions and periodicity of the serving cell PCI;  ~~[2. Support of X>1 (max number of PCIs different from serving cell)]~~  ~~[3. Supported max number of RRC-configured PCIs different from serving cell PCI for [FR1/case1] (X1)] [SSB time domain positions or periodicity of additional PCIs is not exactly the same as serving cell PCI)]~~  ~~[4. Supported max number of RRC-configured PCIs different from serving cell PCI for [FR2/case2] (X2)] [SSB time domain positions and periodicity are exactly the same among the additional PCIs and the same as serving cell PCI]~~  ~~[5. default case to be supported, e.g., case2 with X2=1]~~ |  |  |  |  |  |  |  |  |  | Optional with capability signalling |

[R1-2200031](../../Docs/R1-2200031.zip) Rel-17 UE features for further NR MIMO enhancements Huawei, HiSilicon

[R1-2200057](../../Docs/R1-2200057.zip) UE features for feMIMO ZTE

[R1-2200098](../../Docs/R1-2200098.zip) Discussion on Rel-17 MIMO UE features vivo

[R1-2200136](../../Docs/R1-2200136.zip) UE features for Rel-17 FeMIMO CATT

[R1-2200216](../../Docs/R1-2200216.zip) UE features for further enhancements on NR-MIMO Samsung

[R1-2200246](../../Docs/R1-2200246.zip) Discussion on Rel.17 FeMIMO UE features NTT DOCOMO, INC.

[R1-2200285](../../Docs/R1-2200285.zip) Discussion on UE features for FeMIMO Spreadtrum Communications

[R1-2200311](../../Docs/R1-2200311.zip) Discussion on FeMIMO UE features Qualcomm Incorporated

[R1-2200341](../../Docs/R1-2200341.zip) UE features for further enhancements on NR-MIMO OPPO

[R1-2200389](../../Docs/R1-2200389.zip) UE Features for FeMIMO Intel Corporation

[R1-2200430](../../Docs/R1-2200430.zip) Views on Rel-17 FeMIMO UE features Apple

[R1-2200445](../../Docs/R1-2200445.zip) MIMO Rel-17 UE features FUTUREWEI

[R1-2200454](../../Docs/R1-2200454.zip) Discussion on UE features for FeMIMO xiaomi

[R1-2200493](../../Docs/R1-2200493.zip) Discussion on Rel-17 UE feature for NR FeMIMO LG Electronics

[R1-2200535](../../Docs/R1-2200535.zip) Discussion on UE features for FeMIMO Lenovo, Motorola Mobility

[R1-2200536](../../Docs/R1-2200536.zip) Discussion on UE features for FeMIMO Ericsson

[R1-2200544](../../Docs/R1-2200544.zip) UE Features for further enhancements on NR MIMO MediaTek Inc.

[R1-2200599](../../Docs/R1-2200599.zip) Discussion on FeMIMO UE features CMCC

[R1-2200622](../../Docs/R1-2200622.zip) On UE features for further enhancements on NR-MIMO Nokia, Nokia Shanghai Bell