**Rel-17 Type II PS codebook**

**Min Zhang (Moderator)**

# **Agreements in RAN1 108**

**Agreement**

The UE is not expected to be configured with allowed ranks 3 and/or 4 only via RI-restriction-r17, when α=1/2 (i.e., *paramCombination-r17*=5) and PCSIRS=4.

**Agreement**

Text Proposal in Section 2 in R1-2202771 for FeType II for 38.214 is agreed to be included in editor’s CR.

**Agreement**

* Text Proposal in Section 2 in R1-2202647 for 38.212 is agreed to be included in editor’s CR.
* Text Proposal in Section 2 in R1-2202648 for 38.214 is agreed to be included in editor’s CR.

# **Agreements in RAN1 107**

**Agreement**

The window size is min(N,N3).

* Note: the UCI payload of i1,6 is ceiling(log2(N-1)) bits regardless of values of N3

**Agreement**

Support to report Port indicator, SCI, and FD indicator in Group 0

* FFS (to be concluded in RAN1 107): Report bitmap in Group 0 or Group 1 without bitmap partition
* FFS (to be concluded in RAN1 107): whether/how to deal with coefficients partition issue when ceil(KNZ/2-v) < 0 or report coefficients together without partitioning
* Note: It is RAN1 common understanding that when UCI omission occurs for Rel-17 PS codebook, the associated CQI does not have to be recalculated conditioned on the PMI after omission.

**Agreement**

For Rel-17 PS codebook:

* Alt 2(updated #2): UCI Group 1 includes the $max(0, \left⌈\frac{K^{NZ}}{2}\right⌉-υ) $ highest priority elements of $i\_{2,4,l}$ and the $max(0, \left⌈\frac{K^{NZ}}{2}\right⌉-υ)$ highest priority elements of $i\_{2,5,l}$ ($l=1,…,υ$). UCI Group 2 includes the $min(K^{NZ}-v, \left⌊\frac{K^{NZ}}{2}\right⌋)$ $ $lowest priority elements of $i\_{2,4,l}$ and the $min(K^{NZ}-v, \left⌊\frac{K^{NZ}}{2}\right⌋)$ lowest priority elements of $i\_{2,5,l}$ ($l=1,…,υ$)

**Agreement**

In Rel-17, the priority value is given by $Pri\left(l,i,f\right)=v⋅K\_{1}⋅f+v⋅ψ(i)+l$ whereas for $ψ(i)$,

* Alt 2: Support non-interleaving between polarization, $ψ\left(i\right)=$i

**Conclusion**

Excepting for reporting port indicator, SCI, and FD indicator in Group 0, the remaining indicators are mapped to reporting Groups 1 and 2 same as Rel-16 eType-II PS codebook with updated the priority value of Phi(i).

**Agreement**

Regarding to codebook parameters for Rel-17 PS codebook, (Alt-1) alpha =3/4 is not applicable to 4 and 12 CSI-RS ports.

**Agreement**

Regarding to the restriction applying to parameter combination for Rel-17 PS codebook:

* Alt 3: {M, alpha, beta ={2,1,3/4} and {2, 1, 1/2} are only applicable to P <= 24 ports

# **Summary of Agreements:**

**Agreement**

For PS codebook enhancements utilization DL/UL reciprocity of angle and/or delay, support codebook structure **W=W1W2 WfH** where

* **W1** is a free selection matrix, with identity matrix as special configuration
	+ FFS polarization-common/specific selection
* **Wf** is a DFT based compression matrix in which N3 = NCQISubband\*R and Mv>=1
	+ At least one value of Mv>1 is supported
		- Decide on the value(s) of Mv, e.g. Mv=2,  in RAN1# 104bis-e
	+ Working assumption:  Support of Mv>1 is a UE optional feature if the UE supports Rel-17 PS codebook enhancement, taking into account UE complexity related to codebook parameters
	+ FFS candidate value(s)  of R, mechanism for configuring/indicating to the UE and/or mechanism for selecting/reporting by UE for **Wf**
* **Wf** can be turned off by gNB. When turned off, **Wf**is an all-one vector (FFS; the length of all-one vector)
* FFS other signaling/CSI reporting mechanism for trade-off among signaling overhead, UE complexity and UPT gain

**Agreement**

For Rel-17 port selection codebook, study following Alternatives and down-select in RAN1 106e:

* Alt 1: Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length N3. Wf as an all-one vector of length 1 is not needed
* Alt 2: Wf OFF and Wf ON with Mv=1 are same, and Wf is an all-one vector of length 1, i.e., a scalar. Wf as an all-one vector of length N3 is not needed.
* Alt 3: Keep both Wf OFF and Wf ON with Mv=1.
	+ If PMI format is SB, Wf is an all-one vector of length N3
		- Informative note: this case is considered as “Wf ON with Mv=1” in the agreement in RAN1 104e
	+ If PMI format is WB, Wf is an all-one vector of length 1, i.e., a scalar
		- Informative note: this case is considered as “Wf OFF” in the agreement in RAN1 104e
* Note: N3 = NCQISubband\*R.
* FFS: the case when no SB size is configured.

**Agreement**

For Rel-17 PS codebook,

* ***pmi-FormatIndicator* is not needed for Rel-17 PS codebook**
* A CSI Reporting Setting is said to have a wideband frequency-granularity if "*codebookType*" is set to "*typeII-PortSelection-r17*" with M=1 **and *cqiFormat* = WB**.
	+ **To be captured in 5.2.1.4 of 38.214**
* **A unified codebook formula is used for M=1 and M=2 in 38.214**

**Agreement**

Further reduction for possible parameter combinations among codebook parameters of Rel-17 port selection codebook, e.g. {K1, Mv, Beta}, will be discussed jointly once candidate values are determined

* based on trade-off among UPT performance, feedback overhead, and complexity
* based on all supported ranks
* Limit total number of parameter combinations comparable to Rel-16 eType II
* Exact parameters (e.g. with 2 or 3 parameters) within each combination are FFS
* Other parameterizations of codebook parameter (e.g. alpha with K1= Alpha\*# of CSI-RS ports and Alpha <=1) are not excluded

**Agreement**

Support parameter combinations represented by (alpha, Mv, beta) with K1 = alpha\*P for Rel-17 PS codebook

* The candidate values of alpha are {1/2, 3/4, 1}
* Note that exact parameter combination will be discussed from RAN1 106bis:
	+ based on trade-off among UPT performance, feedback overhead, and complexity
	+ based on all supported ranks
	+ Limit total number of parameter combinations comparable to Rel-16 eType II
* Mv={1, 2} and beta = {[1/4], 1/2, 3/4, 1} are from previous agreements

**Agreement**

With regarding to parameter combinations, following 8 parameter combinations are supported in Rel-17 PS codebook:

|  |  |  |
| --- | --- | --- |
| M | Alpha | Beta |
| 1 | 1 | 1 |
| 1 | 1 | 3/4 |
| 1 | 1 | 1/2 |
| 1 | 3/4 | 1/2 |
| 2 | 1 | 3/4 |
| 2 | 1 | 1/2 |
| 2 | 3/4 | 1/2 |
| 2 | 1/2 | 1/2 |

FFS: whether further restrictions/dependences for given parameter combination(s) are needed

**Agreement**

Support rank 2 for Rel-17 codebook

**Agreement**

Support rank 3 and 4 for Rel-17 PS codebook with following:

* Supporting ranks 3 and 4 is optional with separate UE capability (same as Rel-16 PS codebook)
* The maximal CSI overhead of rank 3 and 4 is comparable to rank 2
	+ FFS: use a smaller K1 (or alpha) or beta for ranks 3 and 4, or limit the maximum number of non-zero coefficients across all layers to 2K0 and per layer to K0 with the same beta
* FFS: limit Mv=1 for ranks 3 and 4 PMI

**Agreement**

For the priority of mapping coefficients for Rel17 PS codebook, study the following alternatives and down-select one or more alternatives in RAN1#107-e:

* Alt 1: Support mapping coefficients firstly across port indices, secondly across FD basis indices, and thirdly across layers, i.e. priority value is given by the priority value $Pri\left(l,i,f\right)=K\_{1}⋅M⋅l+K\_{1}⋅f+i$
* Alt 2: Support mapping coefficients firstly across layers, secondly across port indices, and thirdly across FD basis indices, i.e., the priority value is given by $Pri\left(l,i,f\right)=v⋅K\_{1}⋅f+v⋅i+l$
* Alt 3: Support mapping coefficients firstly across layers, secondly across port indices, and thirdly across FD basis indices, i.e., the priority value is given by $Pri\left(l,i,f\right)=v⋅K\_{1}⋅f+v⋅ψ(i)+l$
	+ FFS port permutation function $ψ(i)$

Note that other solutions are not excluded.

**Agreement**

For Rel-17 PS codebook, support RI restriction which is the same with Rel-16 PS codebook, i.e., 4 bits are used to indicate the applicable ranks separately.

**Conclusion**

For Rel-17 PS codebook, CBSR to restrict port and corresponding amplitude is not needed

# **W1 Design**

**Agreement**

For PS codebook enhancements utilization DL/UL reciprocity of angle and/or delay,

* W1 ∈ N^{P×K1} (K1≤P) is a port selection matrix in order to freely select K1 ports out of P CSI-RS ports or K1/2 ports out of P /2 CSI-RS ports
* Note that P is the number of CSI-RS ports for port selection (whose value depends on the outcome of the CSI-RS related study).

**Agreement**

For rank=1, polarization-common based free-selection should be supported for *W1*$W\_{1}$.

* FFS: Whether there is a need to restrict the number of CSI-RS ports for which this is supported

**Agreement**

At least for rank 1, combinatorial coefficient is used for port selection for W1.

* FFS when *Wf* is turned off

**Agreement**

For Rel-17 port selection codebook, the maximal value of CSI-RS port number P as Pmax is 32.

Agreement

At least for rank 1, **candidate** values of K1 for port selection matrix W1 in NP\*K1 are {**2,** 4, 8, 12, 16, 24, 32}.

* **Note: for polarization-common based free-selection, it means to select the same L=K1/2 ports out of P/2 ports for both polarizations**

**Conclusion**

At least for rank 1, no further restriction or condition is applied for polarization-common based free-selection and combinatorial coefficient based port selection for W1.

**Agreement**

For Rel-17 PS codebook, support layer-common port selection for rank 2.

**Agreement**

For Rel-17 PS codebook for rank 3 and 4, support layer-common port selection

# **W2 Design**

**Agreement**

A bitmap for indication non-zero coefficients should be supported for W2 with a compression coefficient beta<=1 whereas

* FFS values of beta < =1, e.g. 1/8, 1/4, 1/2, 3/4, 1
* FFS: whether/how such a bitmap can be absent for specific codebook configuration parameters
* FFS: whether a bitmap is polarization-common or polarization-specific whereas polarization-specific bitmap is the baseline
* FFS: possible parameter combinations/dependence for beta with other PS CB parameters

**Agreement**

A polarization-specific bitmap for indication non-zero coefficients should be supported for W2.

**Agreement**

For the quantization of W2 coefficient, reusing following Rel-16 quantization mechanism for Rank1 at least:

* Two polarization-specific reference amplitudes:
	+ for the polarization associated with the strongest coefficient, the reference amplitude is not reported
	+ for the other polarization, reference amplitude is quantized to 4 bits
		- The alphabet is{1, 1/2)^(1/4), (1/4)^(1/4), (1/8)^(1/4), …, (1/2^14)^(1/4), [Reserved]} (-1.5dB step size)
* For coefficients other than the strongest coefficient
	+ differential amplitude is calculated relative to the associated polarization-specific reference amplitude and quantized to 3 bits
		- The alphabet is {1, 1/sqrt(2), 1/2, 1/(2\*sqrt(2)), 1/4, 1/(4\*sqrt(2)), 1/8, 1/(8\*sqrt(2))} (-3dB step size)
	+ phase is quantized to 16PSK
* For the reserved state for reference amplitude, down-select one Alt
	+ Alt 1: it is kept to be reserved
	+ Alt 2: it is replaced as (1/2)^(15/4)
	+ Alt 3: it is replaced as (1/2)^(3/8)

Note: whether/how SCI is supported for R17 codebook will be discussed separately

**Agreement**

For Rel-17 PS codebook, the reserved state for reference amplitude is to be reserved as Rel-16 PS codebook.

Agreement

**At least for rank 1 and 2,** for the compression coefficient Beta for non-zero coefficients of W2, values of Beta are {[1/4], 1/2, 3/4, 1}

* Note: [1/4] means that 1/4 is also a candidate value for the discussion on reduction of parameter combinations, but has a lower priority compared to other beta values

**Agreement**

For Rel-17 PS codebook with Rank 2, support layer-specific bitmap for indicating non-zero coefficient selection of W2.

**Agreement**

For Rel-17 PS codebook rank 3-4, support layer-specific non-zero coefficient selection (bitmap) of W2.

**Agreement**

To mitigate CSI overhead of Rel-17 PS codebook rank 3~4, the value of beta for rank 3 and 4 is the same with that for rank 1 and 2

* Limit the maximum number of non-zero coefficients across all layers to 2K1\*Mv\*beta and per layer to K1\*Mv\*beta

**For future RAN1 meeting:**

Study whether/how the bitmap for indicating non-zero coefficients for W2 can be absent for CSI reporting

* FFS: applicable conditions of being absent, .e.g. Mv=1 and Beta =1 for rank 1 or higher ranks
* FFS: additional impact for reporting mechanism when/how the bitmap is absent
* Note: The principle of UE determining the real number of NZC (same as Rel-15 and Rel-16) is unchanged in Rel-17
* based on trade-off among UPT performance, feedback overhead and complexity

**Agreement**

If a bitmap for indicating non-zero coefficients can be absent, down-select one Alt from the following for Rel-17 PS codebook:

* Alt 1: At least for rank 1 PMI, the bitmap of indicating non-zero coefficients is not needed if Mv=1 and Beta=1.
	+ FFS the need for Mv>1 and/or Beta<1
* Alt 2: For rank 1 /2 PMI, the bitmap(s) of indicating non-zero coefficients for corresponding layer(s) is absent if reported KNZ=K1\*Mv\*rank
	+ Where KNZ is the number of non-zero coefficients
* Alt 3: In addition to Alt 2, additional field is reported by UE to inform whether the bitmap of indicating non-zero coefficients for specific layer is absent if rank>1.
* Alt 4: The bitmap of indicating non-zero coefficients is not needed if the number of coefficients is sufficiently small, i.e. K1Mv ≤ δ

Note: If none of above Alternative is agreed in RAN1#106bis-e, the bitmap for indicating non-zero coefficient is always present by default.

**Agreement**

For Rel-17 PS codebook rank 1~2 PMI, the bitmap(s) of indicating non-zero coefficients for corresponding layer(s) is absent if reported KNZ=K1\*M\*rank

* Where KNZ is the number of non-zero coefficients reported by UE

**Agreement**

For UCI part II of Rel-17 PS codebook, **study the following** alternatives and down-select one or more alternatives in RAN1 107

* Alt 1: Report Port indicator, SCI, and FD indicator in Group 0
* Alt 2: Report bitmap in Group 0 or Group 1 without bitmap partition
* Alt 3: Three groups of UCI Part 2 for Rel-16 PS codebook is reused for Rel-17 PS codebook enhancement except that the starting position of the FD basis window is not needed

**Note that other solutions of UCI part II design are not excluded.**

# **Wf Design**

**Agreement**

Confirm following working assumption of *Wf* for R17 PS CB

* Support of *Mv*>1 is a UE optional feature if the UE supports Rel-17 PS codebook enhancement, taking into account UE complexity related to codebook parameters.

Agreement

For **W**f in CN3\*Mv, Mv=2 is supported for R17 PS codebook

* FFS: whether further dependence/restriction, i.e. conditioned on the number of CSI-RS ports, can be applied to Mv=2
* FFS: Whether Mv=4 can be supported for # of CSI-RS ports, e.g. 4 or 8

**Conclusion**

For Rel-17 PS codebook, there is no consensus on the support of Mv>2 for Wf.

**Working Assumption**

At least for rank 1, FD bases used for Wf quantization are limited within a single window with size N configured to the UE whereas FD bases in the window must be consecutive from an orthogonal DFT matrix, i.e. Alt 1

* FFS: Further dependence/restriction, e.g. conditioned on N3 or the number of CSI-RS ports, can be applied to above design. If does, how to support a non-consecutive FD bases used for Wf quantization
* FFS: Whether to introduce thresholds for N3 and/or P

**Agreement**

Following working assumption is confirmed (with revision in RED):

* At least for rank 1 and 2, FD bases used for Wf quantization are limited within a single window with size N configured to the UE whereas FD bases in the window must be consecutive from an orthogonal DFT matrix, i.e. Alt 1.
* FFS other restrictions, e.g. value(s) of N, if the value of N3 is small
* FFS other restrictions, e.g. when the number of CSI-RS ports is small

**Agreement**

* At least for rank 1 and for Mv>1, Minit for the single window with size N is fixed to be 0

**Agreement**

At least for rank 1 and 2 and Mv > 1, for relationship between N and Mv, study and down-select one alternative from following in RAN1#106-e

* Alt 1: N= Mv always, no UE reporting of Wf
* Alt 2-1: N >= Mv, Wf is layer-common and reported by UE for N>Mv.
* Alt 2-2: N >= Mv, Wf is layer-specific and reported by UE for N>Mv.

Note: Wf is layer-common for N=Mv

Note: For all alternatives, a layer-common window/set of size N is configured.

**Agreement**

At least for rank 1/2 and Mv > 1, for relationship between N and Mv, support following alternative

* Alt 2-1: N >= Mv, Wf is layer-common and reported by UE for N>Mv.
	+ For Mv=2, N=2 and one value from {3, 4, 5}
		- RAN1 to select one value from {3, 4, 5} in RAN1#106bis-e
	+ FFS: how to report Wf in terms of reporting mechanism and associated bits when Mv=2 and N=one value from {3, 4, 5}

Note: Wf is layer-common for N=Mv

Note: For all alternatives, a layer-common window/set of size N is configured.

**Agreement**

For Rel-17 PS codebook for rank 3/4 and M> 1,

* Support M=2, **which is rank-common**
* When N >= M, Wf is layer-common and reported by UE for N>M
* Note: Wf is layer-common for N=M

**Agreement**

In addition to N=2, N=4 is supported when M=2 for rank 1/2

* **For rank 3/4, when M=2, N = 2 or 4 is supported and same with the value of N configured for rank 1/2**
	+ FFS how to handle N3=3 case

**Agreement**

If M=2 and N>M, **the non-zero offset between the lower and higher FD indices of Wf is reported by using ceiling(log2(N-1)) bits, assuming that the lower FD index (reference for the offset) of Wf is 0.**

* Note: The phase shift/remapping of FD basis is up to UE implementation which may remap M FD components so that the lower FD index of Wf is assumed to be 0.

**Agreement**

**At least for rank 1,** regarding the value(s) of R for Rel-17 PS codebook enhancement, study and down-select one or more than one Alternative (or a subset of corresponding values) in RAN1 105e:

* Alt 0:  R < 1 (e.g. 1/4, 1/2)
* Alt 1: R=1
* Alt 2: R=1 and 2
* Alt 3: R=1,2, 4, and 8
* Alt 4: R= {1,2,…, D\*NPRBSB} whereas D is the density of CSI-RS in frequency domain
* **FFS: applicable conditions: e.g. Wf turned ON/OFF and/or associated value of Mv**
* **FFS: Whether this applies when Wf is turned OFF**

**Note that “at least for rank 1” does not imply for the support of rank 1 only in Rel-17 or restrictions of supporting/not supporting additional alternatives for higher rank.**

**Agreement**

**For Rel-17 PS codebook, following values of R are supported:**

* **R = 1 and**
* **At most one value from {2, D\* NPRBSB}**
	+ **FFS: which one is to be decided in RAN1#106bis if support, and applicable conditions, e.g. whether the support of this feature when Mv=1**
	+ **D is the density of CSI-RS in frequency domain and NPRBSB is the subband size in PRBs**
	+ **Note that this R is optional if supported**

**Agreement**

For Rel-17 PS codebook, support R=2 when M=2

* Note that this R is optional, whereas how to support R=2 in Rel-17 UE capability signalling is FFS, e.g. similar with Rel-16 eType II codebook.

**Agreement**

For Rel-17 PS codebook, support reporting of the position, [il\*, fl\*], of the strongest coefficient (SCI) of layer l, using ceil(log2(K1\*Mv)) bits