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**Chengdu, China, October 8th – 12th, 2018**

Source: ZTE

Title: Email discussion to collect detailed description of the NOMA schemes

Agenda Item: 7.2.1.1

**Document for:** **Discussion and Decision**

# **Introduction**

This document is used to collect more detailed description of the proposed NOMA scheme (to the extent that solid simulations can be performed).

# **Candidate MA signature designs per transmitter design aspect for NOMA**

*Note: Refer to R1-1809974 [1]*

…

# Detailed descriptions of NOMA schemes

*Note: strive to use the MA signatures listed in Section 2 in R1-1809974 to describe the scheme details with additional information associated with each scheme. Whether it is captured in the main text or the appendix of TR is up to the editor.*

### Symbol level processing assisted

#### MUSA

*The MA signatures are described in Section 2.2.1 - 2).*

For the MUSA (Multi-User Shared Access) scheme, the MA signatures are described in *Section 2.2.1 - 2)* with the transmitter procedure shown in Figure 4 in *Section 2*. With regarding to the simulation of MUSA, no UE-specific bit-level processing (e.g., scrambling or interleaving) is considered. In the case of DFT-s-OFDM waveform, symbol-level spreading is performed in time domain per OFDM symbol basis as illustrated in Figure 3.1.1-1. For CP-OFDM, either frequency domain or time domain spreading can be adopted.

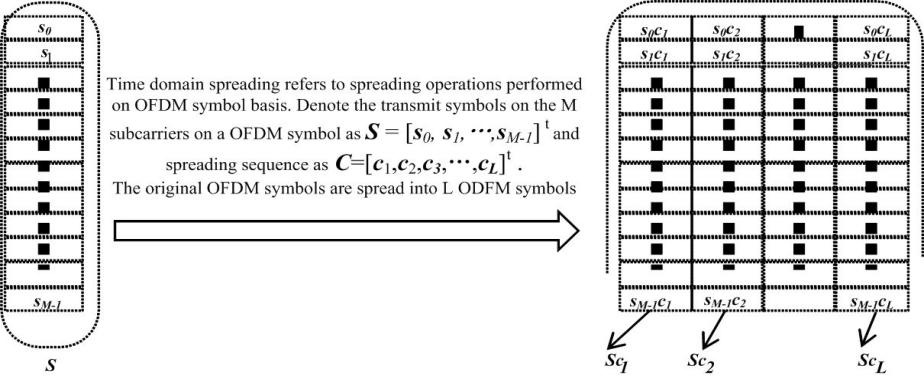


Figure 3.1.1-1 Illustration of time domain spreading for DFT-S-OFDM

For transmission with pre-configured MA signature, the scalable assignment of MA signature for different combination of TBS and UE number is supported. For example, in case of less throughput from network perspective, e.g., higher SE per UE together with less UE number or lower SE per UE together with large UE number, the SF = 2 is considered. In case that the number of UE is larger than the pool size, collision of MA signature/RS via cyclic repetition is considered. Otherwise, MA signatures with SF= {3,4,6} can be selected. In addition to the MA signature listed in *Annex X.3*, more candidates can be considered as listed in Table 3.1.1-1 and Table 3.1.1-2.

For transmission with random selection of MA signature (i.e., Option 1), the configuration can be conducted in a pool-based manner, whose pool size is typically 64 and length of spreading sequence is L= 4 in the LLS simulation. Either RS-assist or data-only based [2] can be used. For example, in case of RS-assist transmission, dedicated channel structure, i.e., 1ms preamble + 1ms data can be considered for large TO (TO = 1.5 NCP).

The corresponding extentsion of RS can be conducted via adopting large comb in frequency domain or different numerologies[3]. Additional, the multi-branch transmission as shown in Figure 11 (c) can be considered as enhanced for MUSA transmission [4]. When the allocation of MA signatures are fixed, this mutli-branch can be done by either opt. 1 - using orthogonal sequences for multi-branch per UE and non-orthogonal sequences across different UEs, opt 2 - using the same sequences for multi-branch per UE with different power ratio, or opt 3 - achieving some “shaping” effect by using the example depicted in Annex X.10.

Table 3.1.1-1 Additional MA signature with SF =3 (before normalization)



Table 3.1.1-2 Additional MA signature with SF =2 (before normalization)

|  |  |  |
| --- | --- | --- |
| No. | c1 | c2 |
| 1 | 1 | 1 |
| 2 | 1 | -1 |
| 3 | 1 | j |
| 4 | 1 | -j |
| 5 | 1 | 0 |
| 6 | 0 | 1 |
| 7 | 1 |  |
| 8 | 1 |  |
| 9 | 1 |  |
| 10 | 1 |  |

#### ML-RSMA

A general framework for multi-layer RSMA (ML-RSMA) transmit side processing is shown in Figure 3.1.2-1. The bit-level processing is the same as in the NR Rel-15 UE transmit chain. The modules unique to a NOMA UE are added after the modulation step.

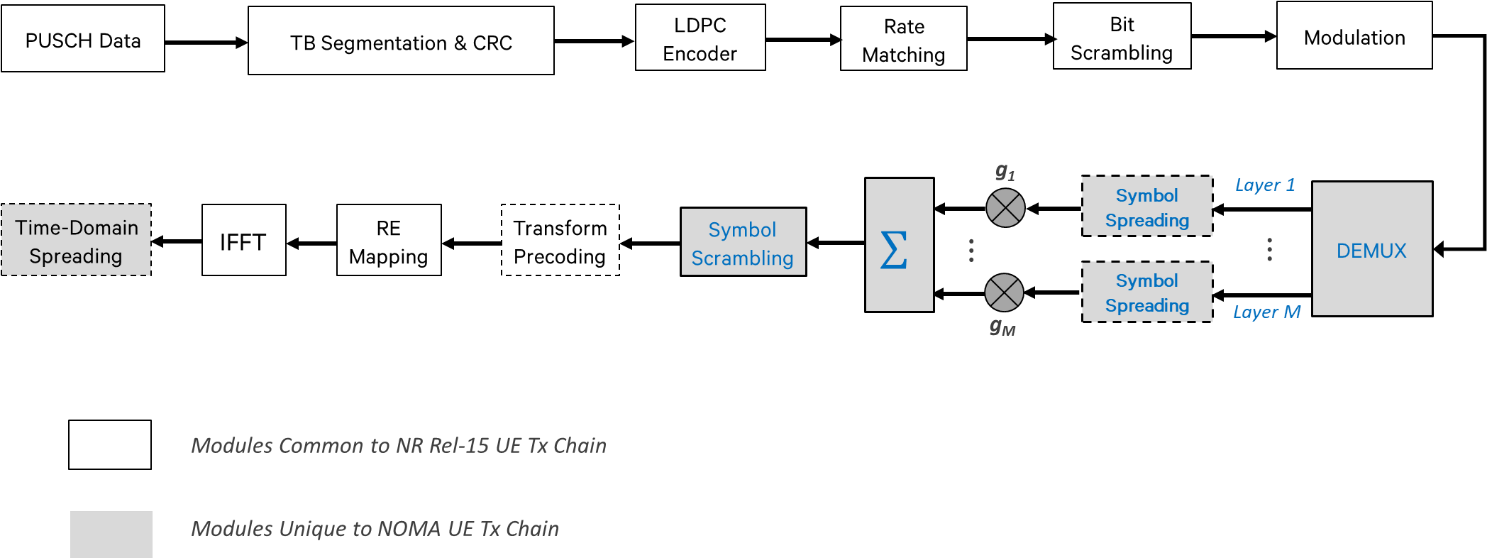


Figure 3.1.2-1: General Framework for ML-RSMA Data Transmit Chain

**MA Signature:**

* In general, the MA signatures of ML-RSMA data transmission are represented jointly by a bit-level scrambing code, one or multiple symbol-level short spreading codes and a symbol-level scrambling code [1].
* Specifically, the use of multiple symbol-level short spreading codes can be considered for the following scenarios:
  + for multi-layer transmission per UE, different short spreading codes can be applied to different layers to reduce the inter-layer interference [5];
  + for single-layer transmission per UE, different short spreading codes can be applied to adjacent symbols to randomize the inter-UE interference [5].

**Bit-level Scrambling:**

* The bit-level scrambling can be reused from existing specification in Subclauses 5.2.1 and 6.3.1.1 of 38.211, which is based on a length-31 Gold sequence.

**Symbol-level Spreading:**

* The symbol-level spreading code is UE specific and is also layer-specfic in multi-layer transmissions. A closed-form description for the modified chirp (MCP) sequences is provided below, which can be proven mathematically to achieve the Welch bound equality (WBE) on sum-squared cross correlations for arbitrary spreading factor and arbitrary codebook size *N* ( [5]. A spreading codeword is generated as follows:

.

One example of closed-form construction would be

;

where can be chosen as an all-one sequence or a DFT sequence of period *K*.

* Each UE can be configured to use one or multiple MCP sequences. For example, UE *n* can be configured to use one MCP sequence (e.g. ) across all PUSCH symbols, or MCP sequences (e.g. . In the latter case, the permutation pattern of MCP sequence index is UE-specific. Within the codebook of MCP, orthogonal or quasi-orthogonal subsets of short spreading code can be constructed for multi-layer transmission to reduce the inter-layer interference. For example,
  + ***M Orthogonal******MCP seqeuences*** can be constructed systematically by choosing a uniformly spaced subset given by for *M*-layer transmission, where .
  + ***M Quasi-orthogonal MCP seqeuences*** can be constructed systematically by choosing another uniformly spaced subset given by for *M*-layer transmission, where and .
* It should be noted that the number of layers (*M*) and the spreading factor (*K*) do not have to be the same.
* By design, the closed-form representation of MCP sequences minimizes the description complexity of MA signatures, and its WBE achieving optimality facilitates flexibile support for different spectral efficiencies and overloading ratios.

**Layer-specific Gain Multiplexing:**

* In multi-layer transmission, a complex gain factor (e.g. *gm* for layer *m* inFig*.* 1) is applied to each layer (. The values of can be optimized using sigma mapping [7], or can be jointly optimized with the layer-specific spreading codes.

**Symbol-level Scrambling:**

* The generation of scrambling sequences can be UE-group and/or cell specific, wherein the sequence ID of scrambling code is a function of cell ID and UE-group ID and the cell can have one or multiple UE groups.
* Scrambling codes can be designed to reduce PAPR and inter-cell interference [6].
* The sequences used for scrambling code can be Gold sequences, Zadoff-Chu sequences, or a combination of the two, according to 3GPP TS 38.211.
* The length of scrambling codes in each slot can be made equal to the number of PUSCH data REs. When Zadoff-Chu sequence is used for symbol-level scrambling, the root index and cyclic shifts can be optimized to reduce PAPR of CP-OFDM waveform and DFT-s-OFDM waveform.
* With the help of group-specific symbol level scrambling, the same set of spreading codes can be reused by different UE groups within the same cell, and the inter-group interference can be reduced. This leads to scalable extension of MA signatures.

**Different Waveform Support:**

* ML-RSMA supports both CP-OFDM waveform and DFT-s-OFDM waveform.
* For CP-OFDM waveform, spreading can be performed in the per-layer spreading step and no time-domain spreading is needed.
* For DFT-s-OFDM waveform, spreading can be conducted before or after the IFFT, denoted “symbol spreading” and “OFDM-symbol spreading” in Figure 3.1.2-1, respectively. The following are possible alternatives:
  + The per-layer spreading factor for symbol spreading can be 1.
  + All spreading can be performed in the per-layer spreading step.
  + Both per-layer symbol-spreading and OFDM-symbol spreading can be applied.

**DMRS Extension:**

* For grant-based or configured-grant NOMA, the UL DMRS transmission is synchronized. The DMRS sequences can be orthogonal or non-orthogonal. To support large overloading ratio (more thn 12 UEs), an extension of DMRS ports can consider OFDM-symbol scrambling, comb-based RE mapping, orthogonal or quasi-orthogonal base sequences with different cyclic shifting. As a result, at least 24 DMRS sequences can be supported by two DMRS symbols within a slot.

For asynchronous NOMA operation, joint use of preamble and DMRS can be considered. The preamble can be treated as extended DMRS signal occupying different OFDM symbols and/or subcarriers group. UE detection and channel estimation can be based on the joint processing of preamble and DMRS.

#### SCMA (Sparse Code Multiple Access) [8]

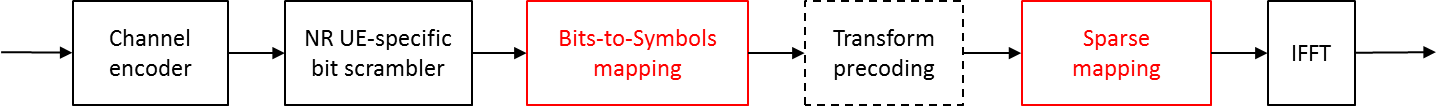
##### ***General description***

An SCMA transmitter follows the bit level processing in NR Rel-15, i.e., UE specific bit scrambling, and employs two mapping functions in the symbol level processing to jointly construct an MA signature: i) *bits-to-symbols* mapping and ii) *sparse* mapping.

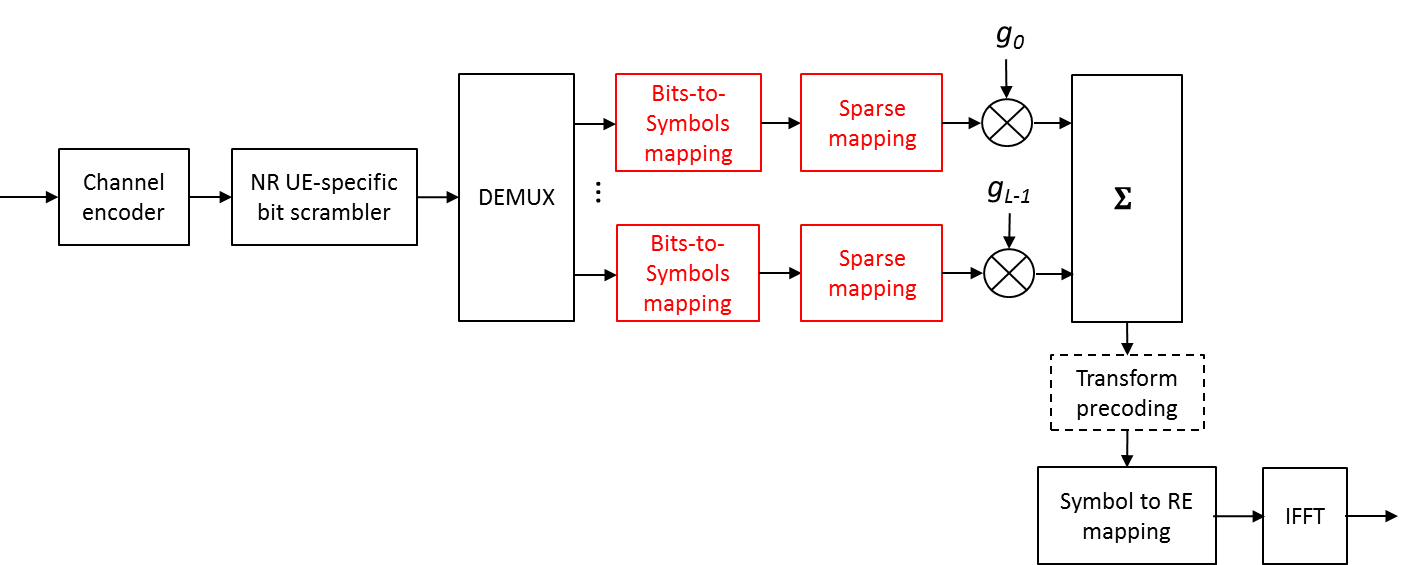
The *bits-to-symbols* mapping first maps *M* bits into *m* symbols (denoted as **x**), which can be represented by a table in which each column represents the symbol sequence in term of an index of the input bit stream. The bits-to-symbols mappings with different input bit lengths can be found in *Annex X.9*. The symbols x is further multiplied by a UE specific transform matrix **G** of size *m-by-m*, to obtain **y**=**Gx**. The transform matrix G is given in section 3.1.3.2.

The *sparse* mapping module maps the symbols **y** onto *m* elements in a block of *N* elements, wherein the rest *(N – m)* elements are of value 0. The corresponding sparsity pattern is described in section 3.1.3.2, as part of MA signature. It is noted that for single branch operation, the *sparse* mapping is performed after the DFT operation (i.e. transform precoding), as shown in Figure 3.1.3-1; for multi-branch operation, the *sparse* mapping is performed before the DFT operation, as shown in Figure 3.1.3-2.

An SCMA transmitter supports both single-branch and multi-branch transmission with both CP-OFDM and DFT-s-OFDM waveforms, as illustrated in Figure 3.1.3-1 and Figure 3.1.3-2 respectively. Note the *symbols-to-REs* mapping given in multi-branch operation after the summation procedure may or may not be sparse, depending on the *sparse mapping* used in each branch.



**Figure 3.1.3-1 SCMA with single-branch operation for CP-OFDM and DFT-s-OFDM waveforms.**



**Figure 3.1.3-2 SCMA with multi-branch operation for CP-OFDM and DFT-s-OFDM waveforms.**

##### ***MA signature pool generation***

The pool size of the SCMA signatures can be flexibly adapted according to number of UEs in different application scenarios. The guideline for designing such flexible signature pool can be described as follows:

* *Using sparsity pattern*: When the size of the mapping block is *N* and the number of non-zero elements is *m*, there are total of distinct sparsity patterns. An example is shown below for and , which gives 6 sparsity patterns as follows

Another example is given below for the case of and , which gives total of 15 sparsity patterns as follows:

* *Using transform matrix*: Transform matrix can be introduced to enlarge the signature pool. When , 2-by-2 transform matrices from the following set can be used:

*.*

The way to construct SCMA signature pool with different sizes are listed in Table 3.1.3-1 and Table 3.1.3-2. Depending on the required number of signatures, the MA signature pool for SCMA could be generated using sparsity patterns and transform matrices on top of the *bits-to-symbols* mapping listed in *Annex X.9* with different input bit lengths. Assume a signature pool with size 12 is expected. In the case of and , the 6 sparsity patterns can be combined with the 2 transform matrices of to generate the desired signature pool. While, in the case of and , there are already 15 sparsity patterns and the signature pool can be generated by using the first 12 sparsity patterns and tranform matrix of .

**Table 3.1.3-1 Generation of SCMA signature pool with different pool sizes (size of mapping block ).**

|  |  |
| --- | --- |
| MA signature pool size | The way of generation |
| 6 | 6 sparsity patterns and 1 transform matrix |
| 12 | 6 sparsity patterns and 2 transform matrices |
| 24 | 6 sparsity patterns and 4 transform matrices |
| 48 | 6 sparsity patterns and 8 transform matrices |

**Table 3.1.3-2 Generation of SCMA signature pool with different pool sizes (size of mapping block).**

|  |  |
| --- | --- |
| MA signature pool size | The way of generation |
| 15 | 15 sparsity patterns and 1 transform matrx |
| 30 | 15 sparsity patterns and 2 transform matrices |
| 60 | 15 sparsity patterns and 4 transform matrices |
| 120 | 15 sparsity patterns and 8 transform matrices |

In particular, the signature index in the pool, , where denotes the signature pool size, can be derived by the sparsity pattern index and the transform matrix index where denotes the total number of sparsity patterns.

##### ***MA signature assignment***

Assume the size of signature pool is with the signature index , for single-branch transmission,

* In the case of grant-based transmission or configured grant with periodic traffics, the MA signatures of active UEs are fixed and known to the network. When the number of active UEs is , the -th UE is assigned with the -th signature, where and .
* In the case of configured grant with sporadic (e.g., Poisson arrival) traffics, the MA signature is pre-assigned for each UE but the set of active UEs is unknown. Assuming there are total potential UEs, the -th UE is pre-assigned with the -th signature, where and .

For multi-brach transmission, non-overlapping (i.e., orthogonal) sparsity patterns can be used to ensure the orthogonality between the branches. For example, in the case of and , the sparsity patterns of and can be assigned to one UE so that the two braches are orthogonal. When the number of braches for each UE is , the -th UE is assigned with signatures and the indices of the signatures are given by

Note that in reality some UEs may perform multiple-branch transmission while others apply single-branch transmission, depending on network configurations.

When the number of branches exceeds the total number of available orthogonal patterns, different power levels between branches can be applied, as descrbed in section 2.4, by adjusting the values of in Figure 3.1.3-2.

In the case of DFT-s-OFDM waveform, different MA signatures can have different CMs/PAPRs [8]. The signature pool can be the same as that for CP-OFDM and the signatures with good CM/PAPR performance can be assigned to the power-limited UEs. In addition, multiplexing of UEs with CP-OFDM and DFT-s-OFDM waveforms is supported.

##### ***Parameter adaptation and configuration***

There are certain parameters in the transmitter side that can be adapted, including:

* *MCS*: modulation size and FEC code rate
* *N*: Size of the mapping block
* *L*: Number of branches

In the case of grant-based transmission or configured grant with periodic traffics, the above parameters can be optimized for each combination of TBS, number of multiplexed UEs, and number of received antennas.

In the case of configured grant with sporadic traffics, the number of multiplexed UEs is random per packet arrival at each slot regardless of the MA selection option, and therefore, the parameters cannot be adapted to the actual number of multiplexed UEs. In the link-level simulations, the performance of multiple configurations of these parameters can be evaluated. However, in the system-level simulations, only one configuration of these parameters is applied to optimize the system performance (depending on the traffic load and the defined KPIs), which should be further notified later on for cross-check.

##### ***DMRS based UE detection***

DMRS based UE detection is applied for the case of configured grant transmission with sporadic traffic. To distinguish the UEs, it is preferred to have the number of DMRS ports larger than or equal to the number of potential UEs so as to avoid DMRS collision. When there are potential UEs and DMRS ports, the -th UE is assigned with the -th DMRS port, where and .

For DMRS pool generation, Rel-15 NR DMRS should be considered as baseline and starting point. However, to improve the UE detection performance in the cases that the number of potential UEs is larger than the number of Rel-15 NR orthogonal DMRS ports, some additional techniques can be considered. These additional techniques include using comb-based RE mapping, orthogonal cover codes (OCCs), and cyclic shifts (CSs). Some examples of how to generate DMRS pool with different sizes are give in Table 3.1.1-3 and Table 3.1.1-4 for CP-OFDM and DFT-s-OFDM, respectively. Also additional DMRS overhead can also be considered, if needed.

**Table 3.1.1-3 Generation of DMRS pool with different pool size (CP-OFDM waveform).**

|  |  |
| --- | --- |
| DMRS pool size | Ways of generation |
| 12 | NR DMRS in Rel-15 with PN sequences |
| 24 | Comb-based RE mapping or more CSs/OCCs |
| 48 and higher | Comb-based RE mapping, more CSs/OCCs or scrambling IDs |

**Table 3.1.1-4 Generation of DMRS pool with different pool size (DFT-s-OFDM waveform).**

|  |  |
| --- | --- |
| DMRS pool size | Ways of generation |
| 8 | NR DMRS in Rel-15 with ZC sequences |
| 16 | Comb-based RE mapping, more CSs/OCCs |
| 24 and higher | Comb-based RE mapping, more CSs/OCCs or base sequences |

#### PDMA

The transmitter side processing of PDMA (Pattern Division Multiple Access) for single branch and multi-branch transmission is shown in Figure 3.1.4-1. The bit-level processing is the same as NR release 15 design. The MA signature for each UE/layer is an *N*×1 vector from a sparse spreading pattern which includes element of ‘0’ where *N* denotes the spreading factor. The example sparse spreading patterns can be found in X.7 in Annex. The sparsity can be achieved by sparse spreading or sparse RE mapping. In addition, distributed RE mapping can be used to achieve frequency diversity gain. A scaling factor ***wk*** is applied after symbol-level spreading to normalize average power per RE [18].



Figure 3.1.4-1: PDMA transmitter side processing

For UL grant-free transmission, NR Rel-15 UL transmission with configured grant can be used. UE detection and identification are based on DMRS. DMRS pool can be extended by comb-based RE mapping, cyclic shifts, OCC and quasi-orthogonal sequences. For the case when the number of UE exceeds the MA signature pool, the same MA signature can be assigned to multiple UEs with different DMRS.

#### UGMA

*The MA signatures of UGMA are described in Section 2.2.1 (4) and Section 2.5* [1]*.* which include target average received powers (corresponds to uplink power control parameters in practical systems) and spreading sequences.

1. Part 1 of MA signature: Multi target average received powers

In UGMA, multi target average received powers are used, where *G* is the number of target average received powers and for . Users are considered as in one user group if the users having same target average received power in one cell or beam. The target average received power of each user is configured dynamically in grant-based transmission, or pre-configured by higher-layer signaling or dynamic signaling in Rel-15 configured-grant transmission, or selected by each user from the pre-defined set of target average received powers based on its estimated RSRP in grant-free transmission.

Uplink power control can be used to realize the target average received powers. Based on TS38.213 [10], the UE determines the PUSCH transmit power in PUSCH transmission occasion as

(3.1.5-1)

where the definitions of variables in (3.1.5-1) can be found in chapter 7.1.1 of TS38.213 [10].

At least following options for uplink power control can be considered:

* Closed-loop power control in grant-based or Rel-15 confirured-grant transmission
  + , and in (3.1.5-1) can be configured dynamically, and and can be obtained by the allocated number of PRB and MCS configured dynamically.
* Open-loop power control in grant-based or Rel-15 configured-grant transmission
  + , and in (3.1.5-1) can be pre-configured, and and in (3.1.5-1) can be obtained by the allocated number of PRB and pre-configured MCS .
* Open-loop power control in grant-free transmission
  + Group-specific nominal power , , and for fixed PRB number and MCS can be obtained by UE according to pre-configured parameters,
    - * , where . The UE determines its nominal power based on the downlink path-loss estimate (*PL*) calculated by the UE using reference signal received power (RSRP). If *PL* of the UE is smaller than , nominal power is used for the UE to achieve target average received power . If *PL* of the UE satisfies for , nominal power is used for the UE to achieve target average received power . If *PL* of the UE is larger than , nominal power is used for the UE to achieve target average received power .
    - The set of target average received powers can be obtained in multiple ways. At least the two options below can be considered.

*Option 1*: Configure/Pre-configure the mean of target average received powers , number of target average received powers *G* and gap between two adjacent target average received powers to UE by higher-layer signaling. The *g*-th target average received power can be calculated as for *G* being even and for *G* being odd.

*Option 2*: Configure/Pre-configure the set of target average received powers by higher-layer signaling. The gaps between any two adjacent target average received powers of a can be same as in option 1 or different.

Some examples for target average received powers are listed in Table 3.1.5-1.

**Table 3.1.5-1 Examples of target average received powers for any**

|  |  |
| --- | --- |
| Index | Target average received powers |
| 0 | , for *G* = 2, |
| 1 | , for *G* = 3, |
| 2 | , for *G* = 2, |
| 3 | , for *G* = 3, |

1. Part 2 of MA signature: Generalized welch-bound equality (GWBE) sequences

Spreading sequences targeting to generalized welch-bound equality, i.e., GWBE sequences, can be generated as described in Section 2.2.1 -4).

* Required information to generate GWBE sequences
  + Size of sequence pool, *K*
  + Spreading factor, *N*
  + Target average received powers for obtaining *K* sequences, . Two cases below shall be considered.
    - Case 1: GWBE sequences are generated independent from the multi target average received powers introduced in Section 3.1.5-1). can be defined directly.
    - Case 2: GWBE sequences are generated based on the multi target average received powers introduced in Section 3.1.5-1). can be obtained based on *G*, and number of sequences for *G* target powers satisfying . Then, the target average received powers for obtaining *K* sequences are generated as .
  + Number of sequences for *G* target powers satisfying
* Required information for sequence grouping
  + Number of sequences for *G* groups satisfying

With above information, GWBE sequences can be generated based on Algorithm in Annex X.5.

* Mapping between power and sequence

The *K* sequences should be divided to *G* sequence groups, where the *g*-th sequences group is used by users with target average received powers .

* + Option 1: The *K* sequences are divided into *G* groups based on the sequence grouping algorithms in Annex X.11.
  + Option 2: The *K* sequences are divided into *G* groups based on the target average received powers for obtaining the K sequences. This is suitable to Case 2. In this case, *K* sequences obtained from target powers are divided into *G* groups, and are allocated for the *g*-th sequences group.
  + Option 3: The *K* sequences are multiplexed in the *G* groups.

**Table 3.1.5-2 Mapping between power and sequences for option 1 and option 2**

|  |  |  |
| --- | --- | --- |
| Sequence for target average received power |  | Sequence for target average received power |
|  |  |  |

**Table 3.1.5-3 Mapping between power and sequences for option 3**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Sequence for target average received power |  | Sequence for target average received power |
| Example 1: 1< *Kb* < *Ka* < *K* |  |  |  |
| Example 2 |  |  |  |

For example, consider GWBE sequences with spreading factor 4 and pool size 16. For two groups each with 8 sequences and 6dB power gap between the two groups, the powers for obtaining 16 sequences in dB are , i.e., for k = 1,2,3,4,5,6,7,8 and for k = 9,10,11,12,13,14,15,16. Then, GWBE sequences can be obtained based on Algorithm in Annex X. 5. It should be noted that the constructed matrix ***Q*** with required diagonal elements and eigenvalues in step 2 of Algorithm in Annex X.5 would be random based on “Generalized Chan-Li” or “Generalized Bendel-Mickey” algorithms in [11]. There would be many choices of GWBE sequences satisfying the same conditions. One example of GWBE sequences is provided in Table X.5-2 and the mapping between power and sequences is provided in Table 3.1.5-4, 5, 6 and 7.

**Table 3.1.5-4-1 Example of target average received powers and GWBE sequences with unit norm before quantization (Spreading factor = 4, User number = 16, Group number = 2, Received power offset = 6dB)**

|  |  |
| --- | --- |
| Sequences for target average received power in dB | Sequences for target average received power in dB |
| 0.5747-0.3408i -0.2554+0.4933i -0.0064-0.3592i 0.1565-0.3023i | -0.5 -0.5 -0.5 -0.5 |
| 0.3786-0.2143i 0.0064-0.5928i -0.4637+0.2793i 0.0282-0.4069i | -0.4321+0.3191i -0.031-0.1271i -0.5079-0.1491i -0.4844-0.4237i |
| -0.0439+0.3734i 0.2209-0.0687i -0.3654+0.7617i 0.1165-0.279i | 0.682+0.3864i -0.4349+0.1979i -0.3113-0.0085i 0.1355+0.2046i |
| 0.2663-0.3807i -0.0548-0.1704i -0.1334+0.6523i 0.527+0.176i | -0.0278+0.654i -0.5421+0.2316i -0.4443+0.0596i 0.1428-0.0523i |
| 0.3714+0.1164i -0.2134+0.3388i 0.1225+0.2758i -0.7398+0.2234i | -0.1467+0.6878i -0.2674+0.1785i -0.1723+0.3663i 0.1277+0.4711i |
| 0.1216-0.537i -0.0764-0.2757i -0.3015+0.0669i -0.7202+0.0299i | 0.4229-0.576i 0.411+0.0295i 0.1824+0.2432i 0.417-0.2307i |
| 0.212+0.2656i -0.633-0.5417i 0.1693-0.398i 0.0549+0.0147i | -0.1062-0.3379i -0.1145-0.1416i 0.7577+0.0774i 0.4096-0.3057i |
| -0.148+0.4161i 0.1072+0.5946i 0.1729+0.301i -0.1189-0.5525i | -0.3009-0.4003i -0.5465+0.6044i 0.1188+0.1732i 0.1014-0.1756i |

**Table 3.1.5-4-2 Example of target average received powers and GWBE sequences with unit norm before quantization (Spreading factor = 4, User number = 20, Group number = 2, Received power offset = 6dB)**

|  |  |
| --- | --- |
| Sequences for target average received power in dB | Sequences for target average received power in dB |
| 0.1218 + 0.2463i -0.6140 - 0.5629i 0.2936 + 0.0003i -0.3742 + 0.0672i | -0.5000 + 0.0000i -0.5000 + 0.0000i 0.5000 - 0.0000i 0.5000 + 0.0000i |
| -0.5184 - 0.3325i 0.0091 + 0.2751i 0.1955 + 0.0752i -0.3716 - 0.6025i | 0.3066 - 0.1079i 0.0999 + 0.0941i -0.0153 - 0.3694i 0.4970 - 0.7013i |
| 0.2927 + 0.7097i 0.2449 + 0.3088i -0.0852 + 0.4384i 0.2142 + 0.1003i | -0.1964 - 0.5502i 0.0447 + 0.1532i -0.2963 + 0.0529i 0.6672 + 0.3124i |
| 0.2874 + 0.6140i 0.0483 + 0.0144i 0.5050 + 0.4866i 0.2119 - 0.0342i | 0.4357 - 0.0664i 0.0651 + 0.4460i -0.3726 - 0.1649i -0.4890 - 0.4443i |
| -0.4111 - 0.0736i 0.3406 + 0.0655i 0.6830 + 0.0412i 0.0511 + 0.4842i | 0.2428 + 0.6867i 0.1435 + 0.3048i -0.1309 + 0.0751i -0.5620 - 0.1320i |
| 0.2096 + 0.0963i -0.5328 + 0.6843i -0.1162 + 0.2054i 0.3716 + 0.0308i | 0.7399 + 0.1685i 0.4459 + 0.4011i -0.0275 - 0.1532i 0.0340 - 0.1977i |
| -0.3948 - 0.1827i -0.5230 + 0.0798i 0.4464 + 0.4974i 0.1970 + 0.2130i | 0.1310 - 0.5608i -0.1306 - 0.0583i 0.5866 - 0.0373i -0.1342 + 0.5332i |
| -0.4321 + 0.2236i 0.1848 - 0.4484i 0.2990 + 0.3632i 0.0073 - 0.5538i | -0.1236 + 0.0220i 0.5561 + 0.3195i 0.7200 - 0.0346i -0.1933 + 0.1263i |
| 0.4280 + 0.0475i -0.3027 - 0.3791i 0.1630 + 0.4655i 0.4086 - 0.4112i | -0.1783 + 0.2854i 0.2806 + 0.3905i 0.6909 + 0.3634i -0.1443 - 0.1595i |
| 0.2735 - 0.1557i 0.1903 + 0.1535i 0.3245 + 0.4166i -0.3770 + 0.6482i | 0.1346 - 0.5058i 0.0701 - 0.6507i -0.0626 + 0.4370i 0.2981 + 0.1186i |

**Table 3.1.5-4-3 Example of target average received powers and GWBE sequences with unit norm before quantization (Spreading factor = 4, User number = 24, Group number = 2, Received power offset = 6dB)**

|  |  |
| --- | --- |
| Sequences for target average received power in dB | Sequences for target average received power in dB |
| 0.2354 + 0.5646i -0.1526 - 0.1296i 0.1781 - 0.3768i -0.6419 + 0.0054i | -0.5000 - 0.0000i 0.5000 + 0.0000i 0.5000 - 0.0000i -0.5000 + 0.0000i |
| -0.1130 + 0.2271i -0.1107 + 0.0689i -0.6977 + 0.2175i 0.2212 + 0.5793i | -0.2099 - 0.1509i -0.8030 - 0.0071i 0.2083 + 0.2336i 0.3498 + 0.2606i |
| 0.6387 - 0.0944i -0.5080 - 0.2692i -0.1998 + 0.2690i -0.3450 - 0.1461i | -0.0383 - 0.3673i -0.0295 + 0.1670i -0.2382 + 0.5494i 0.0230 - 0.6898i |
| -0.1511 - 0.5226i 0.3335 - 0.0764i -0.3400 - 0.1892i 0.4014 - 0.5239i | 0.0073 + 0.4204i -0.7240 - 0.2453i -0.3408 - 0.2421i 0.1700 - 0.1875i |
| 0.3447 + 0.0452i -0.5179 + 0.0485i 0.3942 + 0.6213i -0.0360 - 0.2566i | -0.5153 + 0.2372i -0.5671 - 0.2603i -0.3610 + 0.1357i 0.0472 - 0.3713i |
| -0.6091 - 0.0393i -0.0414 + 0.0553i 0.4453 + 0.1947i -0.3492 + 0.5144i | -0.4472 - 0.4218i -0.1215 + 0.4971i -0.2053 - 0.4673i -0.2348 - 0.2111i |
| -0.3296 + 0.1364i -0.3206 - 0.1189i 0.1847 - 0.4123i 0.6342 + 0.3867i | -0.4905 - 0.1737i 0.7166 + 0.2764i -0.1394 - 0.0096i -0.0484 - 0.3429i |
| -0.5807 + 0.2676i -0.6652 - 0.0127i -0.0572 + 0.0840i 0.3174 - 0.1937i | -0.5033 - 0.3447i -0.1423 + 0.1119i -0.7423 - 0.1501i 0.1301 - 0.0674i |
| 0.4721 + 0.3366i 0.3614 - 0.6634i 0.1651 + 0.0624i -0.2478 + 0.0243i | 0.1888 + 0.1449i -0.0567 + 0.2538i -0.4490 - 0.3448i -0.6379 + 0.3852i |
| -0.0512 - 0.2939i 0.6281 - 0.6941i 0.0877 + 0.1395i 0.0792 + 0.0368i | -0.1148 + 0.2097i 0.2934 - 0.2600i -0.4004 - 0.5754i -0.5238 + 0.1530i |
| 0.5331 - 0.0903i -0.0970 - 0.0078i -0.1863 - 0.7571i -0.0346 - 0.2986i | 0.1984 + 0.4007i 0.2256 - 0.4530i -0.6065 + 0.2636i 0.0895 - 0.3141i |
| 0.0625 + 0.5260i 0.1482 + 0.3417i -0.3494 + 0.3553i -0.1186 + 0.5642i | 0.0269 + 0.0096i -0.0254 + 0.0106i -0.5861 - 0.0994i -0.7554 + 0.2727i |

**Table 3.1.5-4-4 Example of target average received powers and GWBE sequences with unit norm before quantization (Spreading factor = 4, User number = 28, Group number = 2, Received power offset = 6dB)**

|  |  |
| --- | --- |
| Sequences for target average received power in dB | Sequences for target average received power in dB |
| -0.3129 - 0.3679i 0.0409 + 0.1242i -0.7568 - 0.2371i -0.1732 - 0.3012i | -0.5000 - 0.0000i -0.5000 + 0.0000i -0.5000 + 0.0000i -0.5000 + 0.0000i |
| -0.0895 + 0.5975i 0.3032 - 0.4184i -0.2768 - 0.2546i -0.1199 + 0.4605i | -0.2901 + 0.0200i 0.1550 + 0.4067i -0.2642 + 0.2446i -0.3513 - 0.6877i |
| -0.5536 - 0.6892i 0.2261 + 0.1387i 0.3337 - 0.1635i 0.0594 - 0.0809i | -0.2628 + 0.3409i -0.4103 - 0.4017i 0.6048 + 0.3156i 0.1388 - 0.0205i |
| 0.4147 + 0.4577i 0.0025 + 0.5199i -0.3225 - 0.0349i -0.0896 - 0.4848i | -0.5976 + 0.5116i 0.2673 + 0.3955i -0.1199 + 0.2338i -0.2476 + 0.1515i |
| -0.1623 + 0.1711i -0.0588 + 0.4838i 0.6038 + 0.2980i -0.3708 - 0.3405i | -0.0871 - 0.2234i 0.3447 + 0.0147i 0.5023 - 0.2485i 0.0872 - 0.7084i |
| -0.2540 + 0.5352i 0.2165 + 0.4597i 0.3195 - 0.3584i 0.2201 - 0.3344i | 0.6687 + 0.3741i 0.0625 - 0.0637i -0.4653 + 0.3754i -0.2157 + 0.0321i |
| 0.0028 - 0.1480i 0.4983 - 0.3636i -0.2698 + 0.3410i -0.1130 - 0.6291i | 0.6800 + 0.4541i -0.0509 - 0.2585i -0.2266 - 0.1896i 0.3547 + 0.2212i |
| 0.2034 + 0.3090i -0.2627 - 0.5409i 0.4856 + 0.4434i 0.1022 - 0.2424i | 0.3402 + 0.6264i 0.4133 - 0.3559i -0.0148 + 0.0141i -0.0150 + 0.4402i |
| 0.1073 + 0.0496i 0.0472 + 0.2773i 0.7681 - 0.2170i -0.1592 + 0.4944i | -0.1824 + 0.8268i -0.0106 - 0.4239i -0.1359 - 0.1786i 0.1905 - 0.1294i |
| 0.2867 + 0.5395i 0.3543 + 0.5107i 0.2358 + 0.3231i -0.1623 + 0.2325i | 0.1751 - 0.6882i -0.4104 - 0.2509i 0.4669 + 0.1329i -0.0711 + 0.1537i |
| 0.2838 - 0.0551i -0.2357 + 0.5679i 0.0154 - 0.0415i -0.1644 + 0.7137i | 0.0295 - 0.1543i 0.5533 + 0.3745i -0.2279 + 0.2509i 0.1533 + 0.6249i |
| -0.0804 - 0.3854i 0.6584 + 0.3672i 0.1453 + 0.4763i -0.0911 - 0.1427i | -0.1963 - 0.3866i -0.3898 - 0.5801i 0.0013 - 0.3621i -0.4352 + 0.0549i |
| -0.2251 - 0.1936i -0.3679 + 0.2168i -0.5201 - 0.1063i -0.3066 + 0.5948i | -0.0318 + 0.3069i -0.3608 - 0.2711i -0.3418 - 0.2790i 0.0168 + 0.7115i |
| -0.3586 + 0.2798i -0.2636 - 0.0394i 0.3286 + 0.0937i 0.7765 - 0.0479i | -0.0332 - 0.1236i 0.5847 + 0.0816i -0.1955 + 0.0887i -0.4128 + 0.6470i |

**Table 3.1.5-4-5 Example of target average received powers and GWBE sequences with unit norm before quantization (Spreading factor = 4, User number = 32, Group number = 2, Received power offset = 6dB)**

|  |  |
| --- | --- |
| Sequences for target average received power in dB | Sequences for target average received power in dB |
| -0.0787 - 0.3950i -0.3145 - 0.5105i -0.5782 - 0.0536i -0.1018 + 0.3616i | -0.5000 + 0.0000i -0.5000 - 0.0000i -0.5000 - 0.0000i -0.5000 - 0.0000i |
| 0.5704 + 0.5690i -0.1095 + 0.4641i 0.1077 + 0.3041i 0.0521 + 0.1290i | 0.2038 - 0.0838i 0.2965 - 0.3240i -0.1523 - 0.1461i 0.5427 - 0.6477i |
| -0.3635 - 0.2520i 0.1039 + 0.1650i -0.5124 - 0.5516i -0.0458 - 0.4444i | 0.8590 + 0.0654i -0.2932 - 0.0673i -0.3848 - 0.0588i 0.1105 - 0.0598i |
| -0.2514 - 0.1082i -0.2629 + 0.7880i -0.0346 + 0.1381i 0.3142 - 0.3408i | -0.0615 + 0.6871i -0.1724 + 0.4594i -0.1758 - 0.2016i 0.4589 - 0.0352i |
| -0.2813 + 0.2115i 0.5570 - 0.3628i -0.1093 + 0.0482i 0.3734 + 0.5297i | 0.0614 - 0.3241i -0.1737 + 0.4659i 0.6577 + 0.4153i -0.0268 - 0.1953i |
| -0.6081 + 0.2591i -0.3579 + 0.1441i 0.3684 - 0.4736i -0.0213 - 0.2318i | 0.3380 - 0.0760i 0.2235 - 0.1978i 0.5302 + 0.0194i -0.2788 - 0.6571i |
| 0.0248 - 0.3595i 0.0485 + 0.4723i 0.0818 + 0.7279i 0.1657 + 0.2841i | -0.0758 - 0.2996i -0.2885 + 0.2409i 0.4767 - 0.4460i 0.4653 + 0.3471i |
| -0.2448 - 0.0318i 0.0922 + 0.2669i -0.3212 + 0.1695i -0.3145 + 0.7928i | -0.4560 + 0.0893i -0.3434 + 0.2654i 0.3349 + 0.3139i -0.4277 + 0.4496i |
| 0.3150 - 0.1102i 0.2878 + 0.4237i 0.3955 - 0.2388i -0.5735 + 0.2899i | 0.5661 + 0.3037i 0.1847 - 0.1396i 0.2655 - 0.6399i -0.1217 + 0.1973i |
| 0.5276 + 0.1051i 0.5300 - 0.1679i -0.2734 + 0.5377i -0.1737 + 0.0872i | 0.4564 - 0.3599i 0.2391 + 0.0076i -0.0775 - 0.6447i -0.2269 + 0.3632i |
| 0.7080 - 0.3295i -0.1353 + 0.1323i 0.3167 + 0.1070i -0.3828 - 0.3101i | 0.2533 + 0.6262i -0.0324 - 0.2366i -0.4256 + 0.3149i -0.2816 + 0.3565i |
| 0.0711 - 0.3031i -0.0498 + 0.2239i -0.5956 - 0.2668i 0.4576 + 0.4638i | 0.1932 + 0.5035i 0.5886 - 0.5378i 0.1804 - 0.0556i 0.1057 + 0.1634i |
| 0.3005 - 0.1491i -0.2406 + 0.1400i -0.4038 - 0.4311i 0.1837 - 0.6537i | -0.3292 - 0.2536i 0.1340 - 0.2556i 0.3066 + 0.2723i -0.2328 - 0.7223i |
| 0.2040 - 0.3095i 0.4465 + 0.1711i -0.6444 - 0.1057i 0.1707 - 0.4224i | -0.1951 + 0.2425i 0.7777 + 0.4069i -0.2005 - 0.0044i 0.0928 - 0.2897i |
| -0.3657 - 0.3022i 0.0070 + 0.8114i 0.1128 - 0.0401i 0.2729 + 0.1666i | -0.2364 + 0.2214i 0.4901 + 0.3660i 0.5196 - 0.0100i -0.3517 + 0.3566i |
| -0.6434 + 0.3671i -0.2949 - 0.4063i 0.1324 - 0.1324i -0.3377 - 0.2240i | -0.2910 - 0.3572i 0.3328 + 0.2657i 0.3331 + 0.3308i -0.4468 - 0.4317i |

**Table 3.1.5-5-1 Example of target average received powers and GWBE sequences with unit norm before quantization (Spreading factor = 4, User number = 8, Group number = 3, Received power offset = 3dB)**

|  |  |  |
| --- | --- | --- |
| Sequences for target average received power in dB | Sequences for target average received power in dB | Sequences for target average received power in dB |
| -0.0287 + 0.5171i -0.2938 - 0.1434i 0.2452 - 0.3615i -0.6170 - 0.2311i | 0.3736 - 0.5511i -0.0107 - 0.2080i 0.4609 - 0.3894i 0.0675 - 0.3805i | -0.5000 - 0.0000i 0.5000 - 0.0000i 0.5000 + 0.0000i -0.5000 + 0.0000i |
| -0.3974 - 0.3305i -0.2059 + 0.3224i 0.4218 + 0.2844i -0.1877 + 0.5409i | 0.3744 - 0.4263i 0.2687 + 0.1213i 0.1662 - 0.6662i 0.3196 + 0.1325i | -0.3483 + 0.4956i 0.6653 + 0.1076i -0.0146 - 0.0413i -0.3836 + 0.1726i |
| -0.0444 + 0.2862i -0.6517 + 0.4983i -0.1179 + 0.0140i 0.3906 - 0.2765i | -0.0142 + 0.4325i 0.3319 - 0.2355i -0.4210 + 0.6578i 0.0980 + 0.1658i |  |

**Table 3.1.5-5-2 Example of target average received powers and GWBE sequences with unit norm before quantization (Spreading factor = 4, User number = 12, Group number = 3, Received power offset = 3dB)**

|  |  |  |
| --- | --- | --- |
| Sequences for target average received power in dB | Sequences for target average received power in dB | Sequences for target average received power in dB |
| 0.1760 - 0.4531i -0.2837 - 0.0487i -0.5757 + 0.2435i -0.4960 - 0.2098i | 0.4733 - 0.6011i 0.0428 + 0.0304i -0.0707 + 0.1243i 0.4493 + 0.4354i | -0.5000 + 0.0000i -0.5000 + 0.0000i 0.5000 - 0.0000i 0.5000 + 0.0000i |
| 0.0131 + 0.6966i -0.0096 + 0.0533i 0.1189 + 0.3012i -0.0145 - 0.6376i | 0.1821 + 0.3123i 0.6199 + 0.2429i 0.0529 - 0.4771i 0.1381 + 0.4201i | 0.3248 - 0.3739i 0.0621 - 0.0678i -0.5821 + 0.3519i 0.2987 - 0.4409i |
| 0.0115 + 0.0961i 0.7389 - 0.2140i 0.0471 + 0.6214i 0.0668 - 0.0769i | 0.3775 + 0.2532i -0.5215 - 0.1800i -0.3367 + 0.1037i 0.6040 - 0.0139i | 0.2852 + 0.0470i -0.0688 + 0.3992i -0.1853 + 0.0583i 0.7401 - 0.4084i |
| -0.1457 - 0.5634i 0.3483 + 0.2284i 0.2358 - 0.5675i 0.0773 - 0.3228i | -0.0056 - 0.3525i 0.0356 - 0.8402i 0.2932 + 0.1060i 0.2438 - 0.1088i | -0.1450 + 0.1688i -0.1684 - 0.4782i -0.4379 - 0.2632i -0.4683 + 0.4617i |

**Table 3.1.5-5-3 Example of target average received powers and GWBE sequences with unit norm before quantization (Spreading factor = 4, User number = 16, Group number = 3, Received power offset = 3dB)**

|  |  |  |
| --- | --- | --- |
| Sequences for target average received power in dB | Sequences for target average received power in dB | Sequences for target average received power in dB |
| 0.4148 + 0.3311i -0.0217 - 0.5287i 0.3646 - 0.2228i 0.2638 + 0.4314i | 0.2377 - 0.8430i 0.2889 - 0.0984i -0.1272 + 0.0200i 0.1268 + 0.3273i | -0.5000 - 0.0000i 0.5000 + 0.0000i -0.5000 + 0.0000i 0.5000 - 0.0000i |
| 0.5876 - 0.3294i -0.1914 + 0.0851i -0.3122 + 0.4122i 0.4007 + 0.2729i | -0.0321 - 0.0970i -0.0635 - 0.1551i 0.4650 - 0.6824i 0.0652 - 0.5246i | -0.7443 - 0.1195i 0.1120 - 0.3920i 0.0545 - 0.2664i -0.1323 - 0.4172i |
| 0.2359 + 0.4913i 0.0294 - 0.0661i -0.4985 + 0.4163i 0.0973 - 0.5163i | -0.4015 - 0.4750i 0.1487 - 0.4672i 0.3013 - 0.4798i 0.2272 - 0.0109i | -0.4658 - 0.0089i -0.0119 - 0.5839i 0.0204 + 0.0550i 0.6549 - 0.0975i |
| -0.3823 - 0.1460i -0.2851 - 0.1693i -0.0454 + 0.3856i -0.6102 + 0.4466i | 0.3797 - 0.1316i 0.7626 - 0.2398i -0.0971 + 0.2342i -0.2454 - 0.2736i | 0.1807 + 0.1768i -0.6459 - 0.1971i -0.2790 - 0.0637i 0.1942 + 0.6004i |
| 0.1446 + 0.2235i 0.7297 - 0.4349i -0.0809 - 0.1608i 0.3738 + 0.1882i | -0.2720 + 0.2730i 0.6646 + 0.0813i -0.0129 + 0.5290i 0.2607 - 0.2351i | 0.0882 - 0.2567i -0.1094 + 0.2673i -0.5375 - 0.5013i 0.2129 + 0.5073i |
| 0.3432 + 0.1352i 0.0693 + 0.4723i 0.4437 - 0.5164i -0.1325 - 0.3937i |  |  |

**Table 3.1.5-6-1 Example of target average received powers and GWBE sequences with unit norm before quantization (Spreading factor = 4, User number = 8, Group number = 2, Received power offset = 4dB)**

|  |  |
| --- | --- |
| Sequences for target average received power in dB | Sequences for target average received power in dB |
| 0.2257 + 0.5211i 0.2696 - 0.3255i -0.2752 - 0.5089i 0.2209 + 0.3397i | -0.5000 + 0.0000i -0.5000 + 0.0000i 0.5000 + 0.0000i 0.5000 - 0.0000i |
| 0.0748 - 0.0552i -0.7077 - 0.1382i 0.2572 - 0.6156i -0.1551 + 0.0471i | 0.0446 + 0.0166i -0.8755 + 0.0009i 0.2394 + 0.2186i 0.1187 - 0.3347i |
| -0.2328 + 0.0465i 0.0024-0.1999i -0.2202 + 0.1961i -0.8932 - 0.1373i | -0.2280-0.7184i 0.2479 + 0.0181i 0.4200 + 0.0306i 0.3542 + 0.2594i |
| -0.3245 + 0.6473i -0.1682 + 0.2411i -0.0348 + 0.5357i 0.3106-0.0678i | -0.5300 - 0.3472i 0.5834 - 0.1448i 0.1650 - 0.2258i 0.3802 - 0.1204i |

**Table 3.1.5-6-2 Example of target average received powers and GWBE sequences with unit norm before quantization (Spreading factor = 4, User number = 12, Group number = 2, Received power offset = 4dB)**

|  |  |
| --- | --- |
| Sequences for target average received power in dB | Sequences for target average received power in dB |
| -0.1714 - 0.3704i -0.1113 - 0.4602i -0.0034 + 0.5042i 0.5746 + 0.1578i | -0.5000 + 0.0000i 0.5000 + 0.0000i 0.5000 - 0.0000i -0.5000- 0.0000i |
| 0.7510 + 0.2746i 0.2740 - 0.3195i 0.1207 - 0.0617i 0.3160 - 0.2554i | -0.4120 + 0.1535i -0.3278-0.5137i -0.3035 + 0.3476i 0.4715+ 0.0099i |
| -0.0939 + 0.1633i -0.3419 - 0.5622i -0.0445 - 0.1002i -0.5671- 0.4449i | -0.3845 - 0.2948i -0.0755 - 0.3418i 0.4925 + 0.2484i 0.5564- 0.1697i |
| 0.0004 - 0.2263i 0.2462- 0.3349i 0.0634 + 0.6560i -0.5772 + 0.0919i | -0.1783 + 0.7429i 0.1990 +0.3154i -0.2646+0.3739i -0.1612+ 0.2036i |
| 0.1557 + 0.5410i 0.2306-0.5057i 0.3884 + 0.2552i -0.3977 + 0.0061i | 0.2054 - 0.0191i -0.2320 + 0.4063i -0.0619+0.8305i -0.0160+ 0.2116i |
| -0.2528-0.3667i 0.4938 + 0.1734i 0.5075 - 0.4140i -0.2406 + 0.2021i | 0.1925 + 0.6244i -0.2196 + 0.3524i 0.3869+0.1463i 0.4494+ 0.1663i |

**Table 3.1.5-6-3 Example of target average received powers and GWBE sequences with unit norm before quantization (Spreading factor = 4, User number = 16, Group number = 2, Received power offset = 4dB)**

|  |  |
| --- | --- |
| Sequences for target average received power in dB | Sequences for target average received power in dB |
| -0.7111 + 0.1678i -0.4744 - 0.3990i -0.0681 - 0.0096i 0.2295-0.1566i | -0.5000 + 0.0000i 0.5000 + 0.0000i -0.5000+0.0000i 0.5000+ 0.0000i |
| -0.2730 - 0.3839i -0.2635 + 0.1781i 0.3038 -0.0972i -0.7120+ 0.2614i | 0.1775 - 0.3950i 0.2956 - 0.5501i 0.6302 + 0.0961i -0.0166 - 0.1258i |
| 0.5345 - 0.1113i 0.5895 - 0.2662i -0.3567 - 0.1444i -0.2844-0.2334i | 0.2108 + 0.4718i -0.2767 - 0.0497i 0.7416 +0.3029i 0.0000+ 0.1110i |
| 0.4542 - 0.4357i -0.2304 - 0.3411i -0.5339 + 0.3734i 0.0128+0.0987i | 0.3677 + 0.4335i 0.0469 + 0.3400i 0.0714-0.1159i -0.5649 + 0.4706i |
| 0.1649 - 0.1539i -0.2779 + 0.5518i 0.0151 +0.1705i -0.1618- 0.7155i | -0.0855 + 0.5405i 0.3190 - 0.0585i 0.2612+0.1398i -0.5059+ 0.5017i |
| -0.0096 - 0.2009i -0.4641 + 0.2243i -0.4005-0.6475i 0.3359+ 0.0381i | -0.0991 + 0.1776i 0.1391 + 0.2028i 0.2673+0.4930i 0.1110+ 0.7559i |
| 0.5967 + 0.0207i -0.7164 + 0.0672i 0.1332-0.1432i -0.1517+ 0.2539i | 0.0596 + 0.2734i 0.0777 + 0.0801i -0.0688+0.6864i 0.6323+ 0.1829i |
| -0.1756 - 0.4290i 0.2388 - 0.0863i 0.4112 - 0.5355i 0.0865 - 0.5073i | 0.3684-0.3666i -0.3773 + 0.2869i -0.4445+0.3935i -0.2046 + 0.3330i |

**Table 3.1.5-7-1 Example of target average received powers and GWBE sequences with unit norm before quantization (Spreading factor = 4, User number = 8, Group number = 3, Received power offset = 2dB)**

|  |  |  |
| --- | --- | --- |
| Sequences for target average received power in dB | Sequences for target average received power in dB | Sequences for target average received power in dB |
| -0.4673+0.6655i 0.0106-0.2485i -0.2299-0.0762i 0.2772 - 0.3762i | -0.2166 - 0.4917i 0.0684 - 0.2881i -0.1136 - 0.4155i -0.1396 - 0.6470i | -0.5000 - 0.0000i 0.5000 - 0.0000i 0.5000 - 0.0000i -0.5000 - 0.0000i |
| 0.3258-0.1054i 0.5010-0.5612i 0.0925+0.5524i 0.0221+0.0509i | 0.2468 + 0.0315i -0.4760 + 0.5672i 0.0005 + 0.1871i 0.5837 + 0.1186i | 0.2030 - 0.0868i -0.2666 + 0.0362i -0.1156 - 0.5280i 0.6992 - 0.3127i |
| 0.1801+0.2947i 0.2894+0.2958i 0.4345-0.6293i -0.2942+0.1951i | -0.3315 - 0.4271i -0.0745 + 0.3778i -0.3640 + 0.2049i -0.2324 + 0.5753i |  |

**Table 3.1.5-7-2 Example of target average received powers and GWBE sequences with unit norm before quantization (Spreading factor = 4, User number = 12, Group number = 3, Received power offset = 2dB)**

|  |  |  |
| --- | --- | --- |
| Sequences for target average received power in dB | Sequences for target average received power in dB | Sequences for target average received power in dB |
| 0.2158 + 0.0943i -0.4298 - 0.5960i -0.2173 + 0.1849i -0.5671 - 0.0404i | -0.0741 + 0.1956i 0.2986 + 0.6903i -0.5093 - 0.1883i -0.2142 + 0.2232i | -0.5000 + 0.0000i 0.5000 + 0.0000i 0.5000 + 0.0000i -0.5000 - 0.0000i |
| -0.8877 - 0.1477i -0.0813 + 0.1156i -0.0058 - 0.1490i -0.3414 + 0.1769i | 0.6832 - 0.3095i -0.2314 + 0.1718i -0.4251 - 0.1591i -0.3430 + 0.1750i | 0.2473 - 0.3517i -0.3480 + 0.0151i 0.6843 + 0.0194i 0.4646 - 0.0961i |
| -0.1227 - 0.1629i 0.0223 - 0.6154i -0.0907 - 0.1923i -0.3302 + 0.6519i | 0.5276 + 0.3970i -0.0309 + 0.1919i 0.1886 - 0.6522i -0.1354 + 0.2168i | 0.4952 - 0.2471i 0.4805 + 0.2313i -0.0608 - 0.3015i 0.5235 + 0.2018i |
| 0.2396 + 0.1363i 0.1689 + 0.0271i 0.2088 + 0.8722i -0.2888 + 0.0832i | -0.1185 + 0.0606i -0.7370 - 0.1616i -0.3046 + 0.0841i 0.0340 - 0.5586i | -0.1681 - 0.4224i 0.1352 - 0.0033i -0.4534 - 0.0240i -0.1890 + 0.7301i |

**Table 3.1.5-7-3 Example of target average received powers and GWBE sequences with unit norm before quantization (Spreading factor = 4, User number = 16, Group number = 3, Received power offset = 2dB)**

|  |  |  |
| --- | --- | --- |
| Sequences for target average received power in dB | Sequences for target average received power in dB | Sequences for target average received power in dB |
| -0.0107 - 0.1259i 0.0207 + 0.1704i 0.7972 + 0.3467i -0.4262 - 0.1310i | -0.0177 + 0.7145i -0.2907 + 0.1648i -0.3268 + 0.0330i -0.0017 - 0.5193i | -0.5000 - 0.0000i -0.5000 + 0.0000i -0.5000 + 0.0000i -0.5000 + 0.0000i |
| 0.2625 + 0.3032i -0.5057 + 0.2813i -0.0369 - 0.4832i 0.0269 + 0.5185i | -0.0674 + 0.0637i -0.7019 + 0.0504i 0.2722 + 0.2071i 0.5424 - 0.2916i | 0.1735 + 0.0032i 0.7505 + 0.0311i 0.3138 - 0.2625i -0.2967 - 0.3877i |
| -0.4254 + 0.2075i 0.6481 - 0.1628i -0.1137 + 0.3373i 0.3963 + 0.2136i | 0.3082 - 0.6476i -0.6054 - 0.1854i 0.0892 + 0.1690i 0.2149 + 0.0456i | 0.3735 + 0.7299i 0.4336 + 0.1071i -0.0850 + 0.0201i 0.1672 - 0.3045i |
| -0.5285 + 0.3204i -0.2046 - 0.4248i 0.4352 + 0.1559i 0.4090 + 0.1215i | -0.4236 + 0.2885i 0.6069 + 0.1328i -0.0491 + 0.1449i -0.5143 - 0.2520i | -0.5771 + 0.2218i -0.1681 + 0.0901i -0.2131 + 0.3578i -0.3883 + 0.5071i |
| -0.0187 - 0.5003i -0.0099 + 0.2761i 0.7341 + 0.1151i 0.2402 + 0.2515i | -0.1605 - 0.0369i -0.0139 - 0.0137i 0.4786 + 0.4788i -0.3044 - 0.6493i | 0.2905 + 0.5197i 0.0381 + 0.0825i -0.0669 + 0.3121i -0.6431 + 0.3491i |
| 0.2674 - 0.4170i 0.2292 - 0.5687i -0.0603 - 0.3899i 0.0445 - 0.4701i |  |  |

1. Selection/configuration of MA signature

UE can be configured or pre-configured with 1 or multiple target average received powers and 1 or multiple sequences from the corresponding sequences group(s) by dynamic signaling or higher-layer signaling. In addition, UE can determine the target average received power as described in Section 3.1.5-1) based on the estimated RSRP and randomly select the sequence from the sequence group for the trget power in Section 3.1.5-2).

For example, consider the target powers and sequences in Table 3.1.5-4-1,

* in grant-based or Rel-15 configured grant transmission,
  + if the number of users is 8, which is smaller than the number of MA signatures 16, 4 users can be (pre-)configured with target power and the 4 sequences in the first four rows of first column, and the left 4 users can be (pre-)configured with target power and the 4 sequences in the first four rows of second column.
  + if the number of users is 16, 8 users can be (pre-)configured with target power and the 8 sequences in the first column, while the left 8 users can be (pre-)configured with target power and the 8 sequences in the second column.
  + if the number of users is 24, mapping relation between power and sequences defined in Table 3 can be used. Then, 12 users are (pre-)configured with target power and the 8 sequences in the first column and 4 sequences in the first four sequences of the second column, while the left 12 users are (pre-)configured with target power and 8 sequences in the second column and 4 sequences in the first four rows of first column.
* in grant-free transmission, for any number of users, the UE can firstly determine its target sequences based on ite estimated RSRP as described in Section 3.1.5-1) and then select one sequence randomly from all the 16 sequences in Table 3.1.5-4-1, i.e., mapping relation in Table 3.1.5-3 is used.

1. Extended DMRS

In UGMA, DMRS in Rel-15 NR and extended DMRS with more ports are both supported. To keep the backward compatibility, the extended DMRS can be obtained based on the DMRS in NR Rel-15. The basic idea of the proposed method is to sparse the NR DMRS type1 & type 2 under the condition of orthogonal sequence and same overhead with NR [13]. For example, the extended DMRS can be generated as follows.

* Sequence generation for DMRS

The method for sequence generation is identical with NR in TS38.211 [12].

* If transform precoding is not enabled, the sequence r(n) shall be generated according to



where the random pseudo-random seqeuence c(i) is defined in [5.2.1, TS38.211].

* If transform precoding is enabled, the reference-signal sequence *r*(n) shall be generated according to



where  is given by [5.2.2, TS38.211].

* Precoding and mapping to physical resources

The sequence *r*(n) shall be mapped to the intermediate quantity  according to

* If transform precoding is not enabled,



* If transform precoding is enabled,



where , , and  are given by Table 6.4.1.1.3-1, 6.4.1.1.3-2 in [TS38.211], Table 3.1.5-8, Table 3.1.5-9 and Table 3.1.5-10.

The position(s) of the DMRS symbols is given by  and follow the definition in TS38.211.

* Configuration/Selection of DMRS

In UGMA, the mean transmit power over the allocated bandwidth per OFDM symbol carrying data and DMRS can be the same.

UE can be configured or pre-configured or randomly selected with DMRS type and 1 or multiple DMRS ports by dynamic signaling or higher-layer signaling.

For example, DMRS type can be decided based on the number of (potential) users, which supports more DMRS ports than the number of (potential) users.

**Table 3.1.5-8 Parameters for PUSCH DM-RS configuration type 1 + sparser pattern 1**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | CDM group |  |  | |  | |
|  |  |  |  |
| 0 | 0 | 0 | +1 | +1 | +1 | +1 |
| 1 | 0 | 0 | +1 | -1 | +1 | +1 |
| 2 | 1 | 1 | +1 | +1 | +1 | +1 |
| 3 | 1 | 1 | +1 | -1 | +1 | +1 |
| 4 | 2 | 2 | +1 | +1 | +1 | +1 |
| 5 | 2 | 2 | +1 | -1 | +1 | +1 |
| 6 | 3 | 3 | +1 | +1 | +1 | +1 |
| 7 | 3 | 3 | +1 | -1 | +1 | +1 |
| 8 | 0 | 0 | +1 | +1 | +1 | -1 |
| 9 | 0 | 0 | +1 | -1 | +1 | -1 |
| 10 | 1 | 1 | +1 | +1 | +1 | -1 |
| 11 | 1 | 1 | +1 | -1 | +1 | -1 |
| 12 | 2 | 2 | +1 | +1 | +1 | -1 |
| 13 | 2 | 2 | +1 | -1 | +1 | -1 |
| 14 | 3 | 3 | +1 | +1 | +1 | -1 |
| 15 | 3 | 3 | +1 | -1 | +1 | -1 |

**Table 3.1.5-9 Parameters for PUSCH DM-RS configuration type 1 + sparser pattern 2**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | CDM group |  |  | |  | |
|  |  |  |  |
| 0 | 0 | 0 | +1 | +1 | +1 | +1 |
| 1 | 0 | 0 | +1 | -1 | +1 | +1 |
| 2 | 1 | 1 | +1 | +1 | +1 | +1 |
| 3 | 1 | 1 | +1 | -1 | +1 | +1 |
| 4 | 2 | 2 | +1 | +1 | +1 | +1 |
| 5 | 2 | 2 | +1 | -1 | +1 | +1 |
| 6 | 3 | 3 | +1 | +1 | +1 | +1 |
| 7 | 3 | 3 | +1 | -1 | +1 | +1 |
| 8 | 4 | 4 | +1 | +1 | +1 | +1 |
| 9 | 4 | 4 | +1 | -1 | +1 | +1 |
| 10 | 5 | 5 | +1 | +1 | +1 | +1 |
| 11 | 5 | 5 | +1 | -1 | +1 | +1 |
| 12 | 0 | 0 | +1 | +1 | +1 | -1 |
| 13 | 0 | 0 | +1 | -1 | +1 | -1 |
| 14 | 1 | 1 | +1 | +1 | +1 | -1 |
| 15 | 1 | 1 | +1 | -1 | +1 | -1 |
| 17 | 2 | 2 | +1 | +1 | +1 | -1 |
| 18 | 2 | 2 | +1 | -1 | +1 | -1 |
| 19 | 3 | 3 | +1 | +1 | +1 | -1 |
| 20 | 3 | 3 | +1 | -1 | +1 | -1 |
| 21 | 4 | 4 | +1 | +1 | +1 | -1 |
| 22 | 4 | 4 | +1 | -1 | +1 | -1 |
| 23 | 5 | 5 | +1 | +1 | +1 | -1 |

**Table 3.1.5-10 Parameters for PUSCH DM-RS configuration type 2 + sparser**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | CDM group |  |  | |  | |
|  |  |  |  |
| 0 | 0 | 0 | +1 | +1 | +1 | +1 |
| 1 | 0 | 0 | +1 | -1 | +1 | +1 |
| 2 | 1 | 2 | +1 | +1 | +1 | +1 |
| 3 | 1 | 2 | +1 | -1 | +1 | +1 |
| 4 | 2 | 4 | +1 | +1 | +1 | +1 |
| 5 | 2 | 4 | +1 | -1 | +1 | +1 |
| 6 | 3 | 6 | +1 | +1 | +1 | +1 |
| 7 | 3 | 6 | +1 | -1 | +1 | +1 |
| 8 | 4 | 8 | +1 | +1 | +1 | +1 |
| 9 | 4 | 8 | +1 | -1 | +1 | +1 |
| 10 | 5 | 10 | +1 | +1 | +1 | +1 |
| 11 | 5 | 10 | +1 | -1 | +1 | +1 |
| 12 | 0 | 0 | +1 | +1 | +1 | -1 |
| 13 | 0 | 0 | +1 | -1 | +1 | -1 |
| 14 | 1 | 2 | +1 | +1 | +1 | -1 |
| 15 | 1 | 2 | +1 | -1 | +1 | -1 |
| 16 | 2 | 4 | +1 | +1 | +1 | -1 |
| 17 | 2 | 4 | +1 | -1 | +1 | -1 |
| 18 | 3 | 6 | +1 | +1 | +1 | -1 |
| 19 | 3 | 6 | +1 | -1 | +1 | -1 |
| 20 | 4 | 8 | +1 | +1 | +1 | -1 |
| 21 | 4 | 8 | +1 | -1 | +1 | -1 |
| 22 | 5 | 10 | +1 | +1 | +1 | -1 |
| 23 | 5 | 10 | +1 | -1 | +1 | -1 |

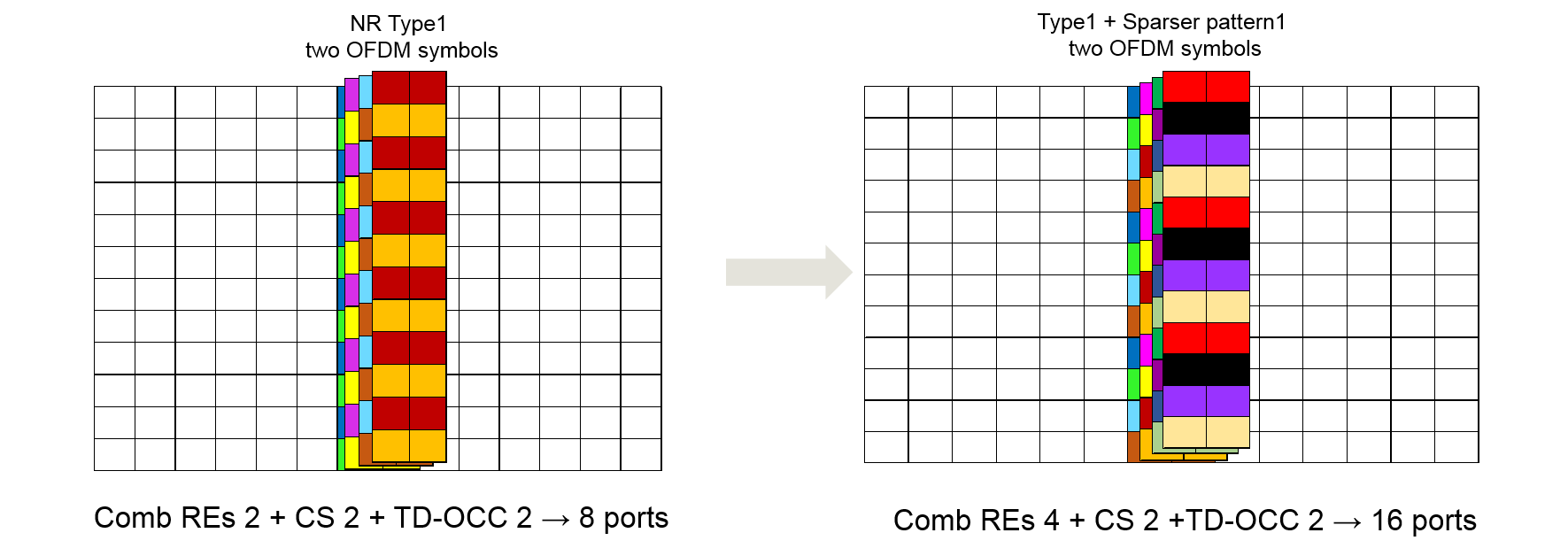
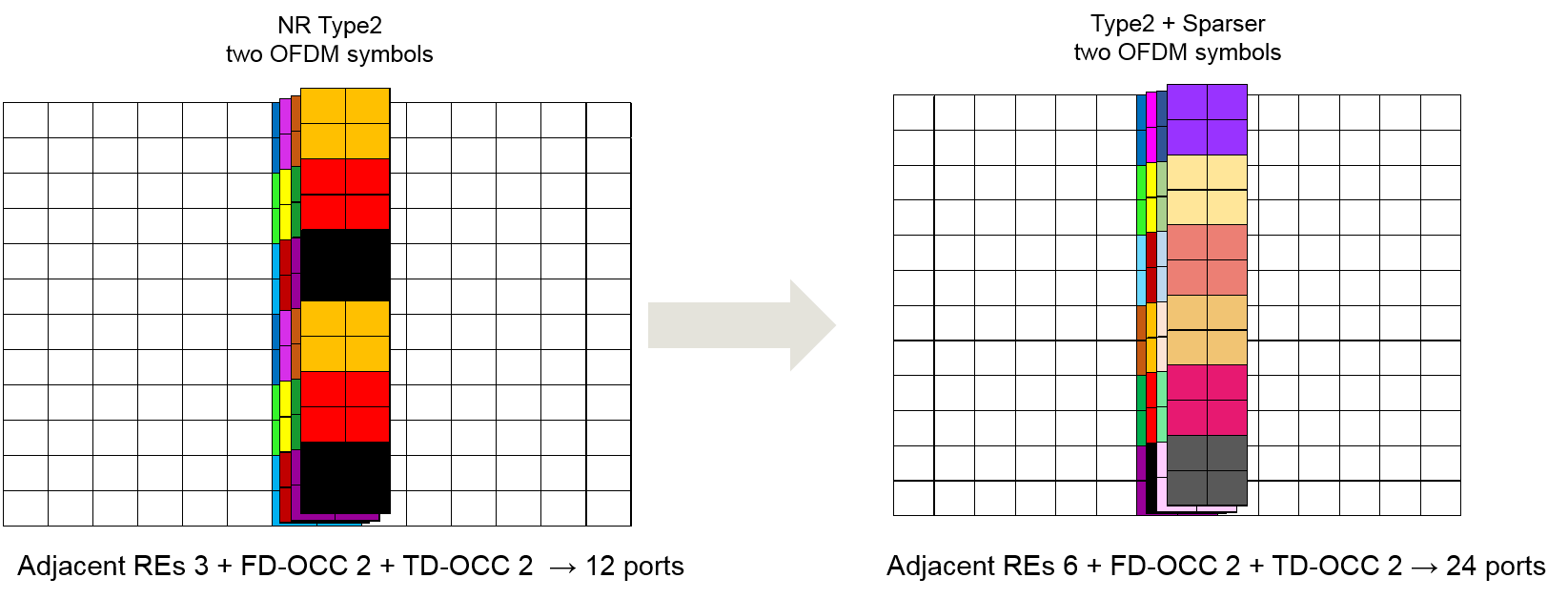
Illustrations of DMRS supporting different number of ports with overhead 1/7 are provided in Figure 3.1.5-1 for CP-OFDM.



(a)﷒NR DMRS type 1 with 4 ports (b) NR DMRS type 1 with 8 ports



(c) NR DMRS type 2 with 6 ports (d) NR DMRS type 2 with 12 ports

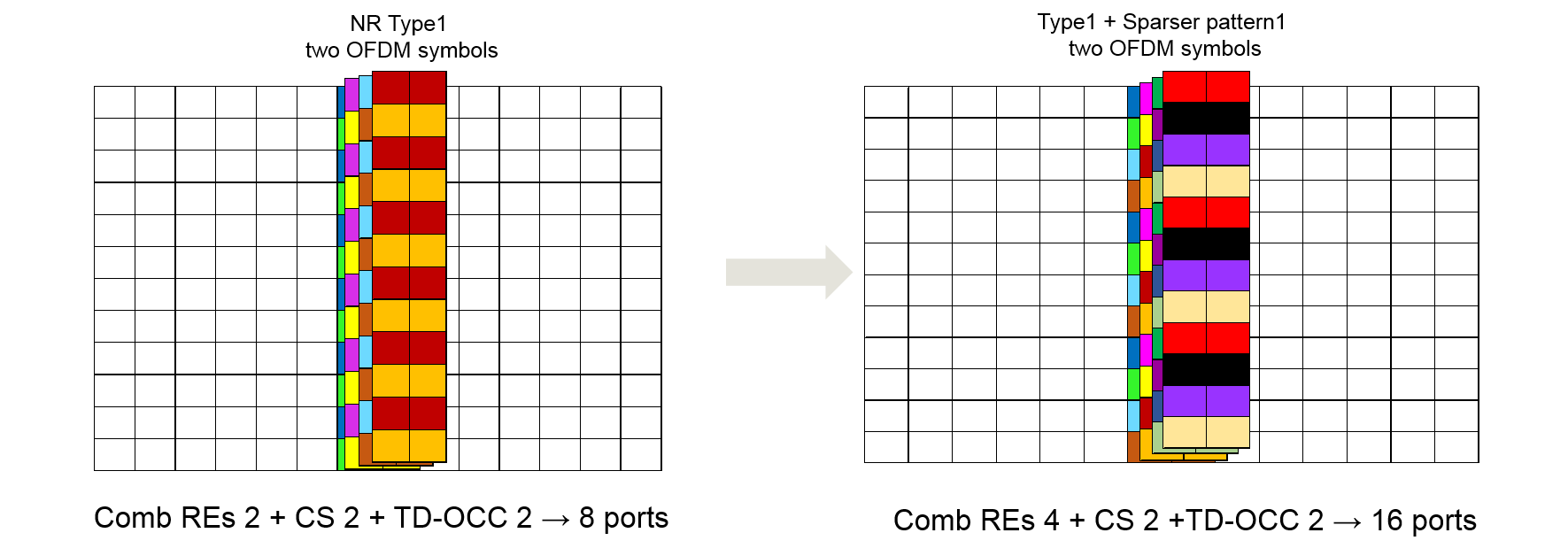
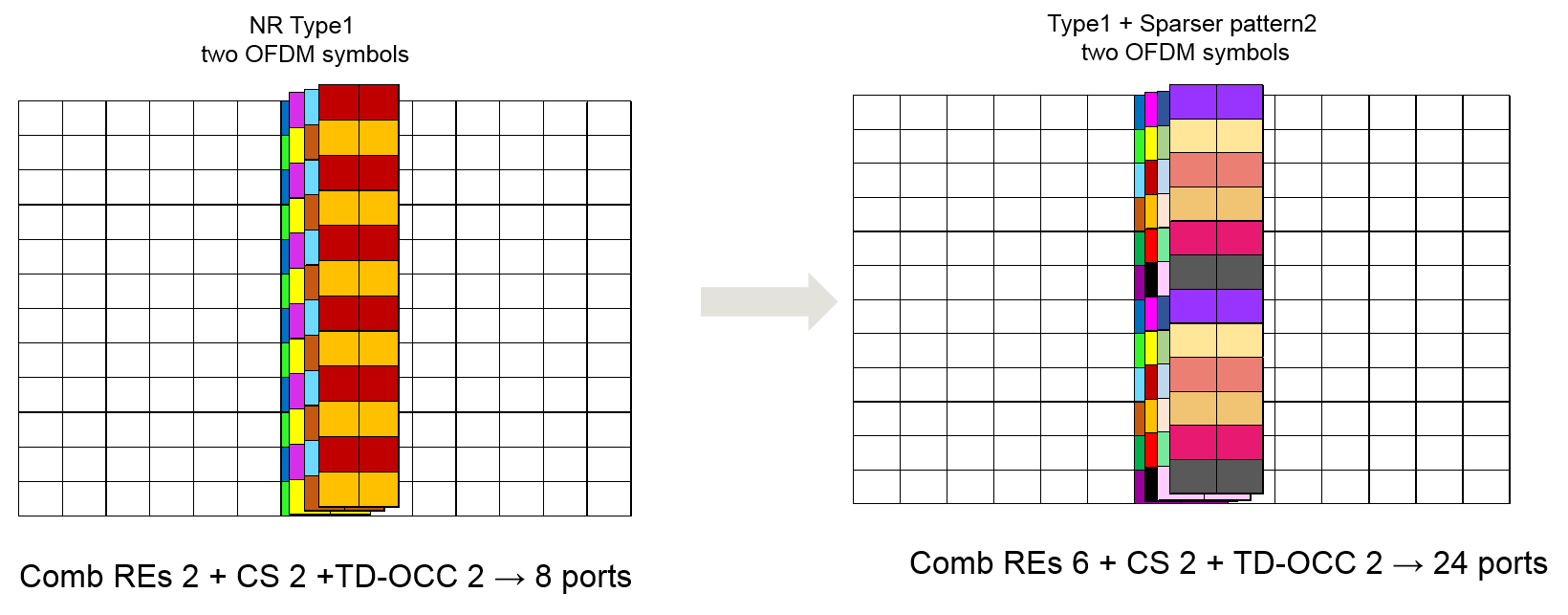
 

(e) DMRS with 16 ports extended from NR type 1 (f) DMRS with 24 ports extended from NR type 2

**Figure 3.1.5-1 Illustration of DMRS supporting 4, 6, 8, 12, 16 and 24 orthogonal DMRS ports for CP-OFDM**



(a)﷒NR DMRS type 1 with 4 ports (b) NR DMRS type 1 with 8 ports

(e) DMRS with 16 ports extended from NR type 1 (f) DMRS with 24 ports extended from NR type 1

**Figure 3.1.5-2 Illustration of DMRS supporting 4, 8, 16 and 24 orthogonal DMRS ports for DFT-s-OFDM**

1. UGMA with DFT-s-OFDM

Three options can be considered for UGMA with DFT-s-OFDM.

* Option 1: Spreading in frequence domain before DFT
* Option 2: Spreading in time domain before DFT
* Option 3: Spreading after DFT



(a) Option 1 for UGMA with DFT-s-OFDM



(b) Option 2 for UGMA with DFT-s-OFDM



(c) Option 3 for UGMA with DFT-s-OFDM

Figure 3.1.5-3 Examples of transmitter structure for UGMA with DFT-s-OFDM

1. Combination of UGMA with multi-branch structure

UGMA can be combined with multi-branch structure defined in Section 2.4, where layer-specific design can be added before UGMA. Three examples of transmitter structure for UGMA with multi-branch structure is provided in Figure 3.1.5-4. In Figure 3.1.5-4(a), layer-specific spreading and power are considered. In Figure 3.1.5-4(b), in additional to layer-specific powers, layer-specific coding rates can be considered, where the demodulation of multiple layers can be carried out jointly at the receiver to eliminate or reduce inter-layer interference in one user.



(a) UGMA with multi-branch structure at symbol-level after FEC



(b) UGMA with multi-branch structure before FEC

Figure 3.1.5-4 Example of transmitter structure for UGMA with multi-branch structure

#### WSMA

*For example, MA signatures are described in Section 2.2.1 (y).*

An update to a portion of R1-1809974 that describes WSMA operation is provided, including example matrices for WSMA as well as some editorial updates. Change marks are relative to the text in Annex X of R1-1809974.

🡨**-------------------------------------------Begin Text Update-----------------------------------------------**🡪

2.1 Symbol level processing

2.1.1 UE-specific symbol-level spreading with NR legacy modulation.

Symbol-level spreading based NOMA schemes use low cross-correlation or low density spreading sequences as the MA signature [1][2][3][9][10][14][17][18][49][58]. Symbols may be drawn from QPSK as well as higher order QAM constellations to adjust spectral efficiency. Schemes typically map spread symbols to adjacent REs in a PRB. The transmitter processing procedure can be found in Figure 4.

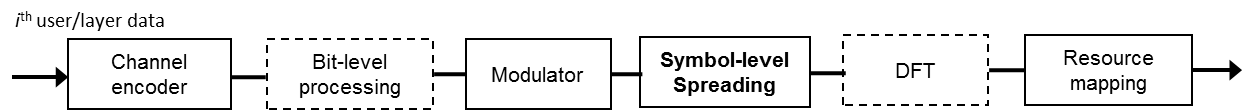


Figure 4 Transmitter procedure for symbol-level spreading with NR legacy modulation

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Annex X: MA signature designs for NOMA schemes

***X.1 Generation method for the construction of WBE spreading sequences [17]***

For a user , let be the transmitted symbol that modulates a unit norm spreading sequence (SS) vector . The Additive White Gaussian Noise (AWGN) signal model may be given as , where is the zero-mean AWGN vector with a covariance matrix , i.e., an Identity matrix. the overall SS matrix with an SS codeword (CW) in each of its columns is , the transmit symbol vector is . The transmit power of each user is set to unity, so the power control problem is not addressed here. A unit norm receive filter , such as a Matched Filter (MF) or a linear Minimum Mean Squared Error (MMSE) filter, may be employed by the receiver to obtain an estimate for the transmitted symbol . The post processed SINR of a user is given as

where is the trace operator, is the noise component in the SINR . The term in the denominator is the total squared correlation (TSC), which also contains the desired unit signal power. So an additional unity term arises in the denominator. If the post processed noise is white, i.e., the noise power of each is the same, then the TSC can directly be used as a performance metric.

From the center part of the SINR equation, let , which is the correlation matrix of the interference plus noise. It can be identified that minimizing the denominator (or equivalently maximizing ) is a well known Rayleigh-Quotient problem. From this, the Eigen vector corresponding to the minimum Eigen value of may be considered as CW for UE , if it is assumed that is matched to .

The fixed-point iterations start from the users choosing a random CW, preferably with a unit norm. In a given sequential user order, say , each user updates its SS by solving the Eigen value problem while other SS, are kept fixed, i.e. After user , the next user updates it’s CW in the same way by assuming the other CWs to be fixed. The iterations progress up to the final user in the given order, such that in each iteration there are updates, one for each CW (a signature vector) in . After the final update in the given iteration, the first user in the order restarts the updates. This repeats until convergence. Note that matrices that minimize the TSC are not unique.

Again, from the center part of the SINR equation, the solution to can also be identified as the well known Generalized Eigen Value Problem (GEVP), i.e., finding a common Eigen value for the matrix pair (). The solution to which is the linear MMSE vector given as , in its normalized form. Sequential iterations as mentioned before can be used, except that instead of solving the Eigen value problem, the normalized linear MMSE expression is used during updates. For this SINR maximization problem (or equivalently a TSC minimization), the obtained solution for from both the MMSE iterations and the Eigen vector iterations is the same fixed-point. These methods are classified as Interference Avoidance (IA) techniques.

The obtained TSC value is bounded from below by the Welch Bound (WB). For theoretically optimal system performance in certain conditions, it is required that the bound be satisfied by equality, in which case it is called the Welch Bound Equality (WBE). At the WBE, various metrics (such as the System Capacity, Sum MSE) in the system are simultaneously optimized. So the main objective of the IA technique here is to obtain a matrix S, such that the TSC from the constituent vectors achieve the WBE.

A Kronecker product based approach may be employed to obtain (or construct) higher dimensional Welch bound equality (WBE) SS, i.e., higher values, from lower dimensional WBE SS.

Table X.1-1. An instance of a (4x8) WSMA spreading matrix (codebook) from an ensemble of (4x8) WBE complex codebooks with spreading factor *L*=4, supporting *K*=8 active users. Overloading factor (*K*/*L*)=2. Each 4x1 column is a unit norm complex vector assigned to a single user. [14]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Sequence #** | **1** | **2** | **3** | **4** |
| **Sequence**  **Sample #** | **1** | -0.6617 + 0.1004i | -0.0912 + 0.4191i | 0.4151 - 0.3329i | 0.2736 - 0.4366i |
| **2** | 0.0953 + 0.4784i | -0.4246 - 0.0859i | 0.2554 - 0.3140i | 0.5452 + 0.2068i |
| **3** | -0.4233 - 0.1399i | -0.4782 + 0.3752i | -0.3808 - 0.1569i | -0.4690 - 0.2225i |
| **4** | -0.1265 + 0.3153i | 0.4936 + 0.1233i | 0.6130 - 0.0873i | -0.3399 + 0.0974i |
|  | **Sequence #** | **5** | **6** | **7** | **8** |
| **Sequence**  **Sample #** | **1** | -0.4727 - 0.1234i | -0.3413 + 0.1257i | 0.4216 + 0.1187i | 0.4603 + 0.2142i |
| **2** | 0.0592 - 0.6432i | 0.3671 - 0.1430i | -0.0241 - 0.5620i | 0.0048 - 0.4244i |
| **3** | 0.3493 - 0.1988i | 0.6514 - 0.0660i | -0.4507 + 0.0958i | 0.4047 + 0.1601i |
| **4** | -0.0975 - 0.4161i | 0.2174 + 0.4864i | -0.5167 + 0.1116i | -0.4908 + 0.3629i |

Table X.1-2. An instance of a (4x12) WSMA spreading matrix (codebook) from an ensemble of (4x12) WBE complex codebooks with spreading factor *L*=4, supporting *K*=12 active users. Overloading factor (*K*/*L*)=3. Each 4x1 column is a unit norm complex vector assigned to a single user. [14]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Sequence #** | **1** | **2** | **3** | **4** |
| **Sequence**  **Sample #** | 1 | -0.2221 + 0.3220i | -0.0690 - 0.5020i | -0.4866 + 0.3090i | 0.4007 - 0.3034i |
| 2 | 0.1709 - 0.3679i | -0.2222 - 0.2729i | -0.4148 - 0.2589i | -0.3206 - 0.0231i |
| 3 | 0.4335 - 0.4253i | 0.0875 - 0.3912i | 0.5181 + 0.0067i | -0.6714 - 0.0514i |
| 4 | -0.2877 + 0.4804i | 0.6669 - 0.1183i | -0.3439 - 0.2048i | -0.2117 - 0.3819i |
|  | **Sequence #** | **5** | **6** | **7** | **8** |
| **Sequence**  **Sample #** | 1 | 0.0525 - 0.6492i | -0.3121 + 0.4136i | 0.1887 - 0.5138i | 0.3628 - 0.5556i |
| 2 | 0.2786 + 0.2173i | -0.5533 + 0.2843i | -0.5603 + 0.0403i | -0.2496 - 0.3482i |
| 3 | 0.4058 - 0.3688i | -0.3497 + 0.2042i | 0.3714 - 0.0660i | 0.4539 - 0.0605i |
| 4 | -0.0586 - 0.3831i | 0.4123 + 0.1027i | 0.3124 + 0.3807i | -0.2014 - 0.3549i |
|  | **Sequence #** | **9** | **10** | **11** | **12** |
| **Sequence**  **Sample #** | 1 | -0.4067 - 0.0166i | -0.2969 - 0.2084i | 0.3160 + 0.0753i | 0.3612 - 0.2061i |
| 2 | 0.5821 - 0.2559i | -0.5414 - 0.1665i | -0.7029 - 0.1267i | 0.3525 - 0.0158i |
| 3 | 0.1316 - 0.2310i | -0.1075 + 0.6412i | 0.3540 - 0.2274i | -0.4880 - 0.1396i |
| 4 | 0.5222 - 0.2944i | 0.2613 - 0.2380i | -0.3490 - 0.2925i | -0.5884 - 0.3142i |

Table X.1-3. An instance of a (6x12) WSMA spreading matrix (codebook) from an ensemble of (6x12) WBE complex codebooks with spreading factor *L*=6, supporting *K*=12 active users. Overloading factor (*K*/*L*)=2. Each 6x1 column is a unit norm complex vector assigned to a single user. [14]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Sequence #** | **1** | **2** | **3** | **4** |
| **Sequence**  **Sample #** | **1** | 0.2077 + 0.3793i | 0.3451 + 0.1338i | 0.2279 - 0.4659i | 0.1552 + 0.3036i |
| **2** | -0.0242 - 0.2918i | 0.1832 + 0.1258i | 0.2007 + 0.0517i | -0.0691 - 0.2333i |
| **3** | 0.0033 + 0.4259i | -0.0068 - 0.5688i | -0.0117 + 0.1839i | 0.3280 - 0.0232i |
| **4** | 0.2805 + 0.2018i | -0.2553 + 0.1472i | -0.3232 - 0.4850i | -0.4418 - 0.1054i |
| **5** | 0.4517 - 0.1700i | -0.4087 + 0.4122i | -0.0183 - 0.2256i | -0.0676 - 0.2340i |
| **6** | -0.1248 + 0.4218i | 0.1703 - 0.1931i | -0.5000 - 0.1145i | -0.4826 - 0.4668i |
|  | **Sequence #** | **5** | **6** | **7** | **8** |
| **Sequence**  **Sample #** | **1** | -0.1673 - 0.3954i | -0.4380 + 0.0177i | -0.4180 + 0.0654i | -0.4587 + 0.0503i |
| **2** | -0.4059 + 0.0635i | 0.3095 + 0.1809i | 0.2950 + 0.0247i | -0.1975 - 0.3656i |
| **3** | 0.3157 - 0.1566i | 0.1062 - 0.1523i | 0.4446 + 0.1407i | -0.4910 - 0.0302i |
| **4** | -0.3762 - 0.0444i | 0.0795 - 0.4774i | -0.2827 + 0.1945i | 0.2100 - 0.4170i |
| **5** | 0.4927 + 0.0365i | -0.0625 + 0.2372i | 0.5409 - 0.1294i | -0.0451 - 0.3571i |
| **6** | 0.1134 + 0.3497i | -0.3099 + 0.5045i | -0.1071 - 0.2781i | -0.0360 - 0.1536i |
|  | **Sequence #** | **9** | **10** | **11** | **12** |
| **Sequence**  **Sample #** | **1** | -0.2025 - 0.2054i | -0.2957 + 0.0742i | 0.4714 - 0.2817i | -0.0674 + 0.1996i |
| **2** | 0.2475 - 0.7093i | 0.1213 - 0.1690i | -0.0943 - 0.5046i | -0.5072 + 0.2784i |
| **3** | 0.2462 - 0.0514i | -0.3848 + 0.5111i | -0.2767 + 0.1296i | -0.3987 - 0.0943i |
| **4** | 0.2286 + 0.2661i | -0.2398 + 0.1706i | -0.4046 + 0.1132i | -0.2844 + 0.2621i |
| **5** | -0.2812 + 0.0005i | -0.5698 + 0.0562i | 0.1131 - 0.2679i | 0.2862 - 0.0408i |
| **6** | -0.2472 - 0.1609i | 0.1745 + 0.0979i | 0.2413 + 0.1491i | -0.3883 - 0.2626i |

Table X.1-4. An instance of a (6x18) WSMA spreading matrix (codebook) from an ensemble of (6x18) WBE complex codebooks with spreading factor *L*=6, supporting *K*=18 active users. Overloading factor (*K*/*L*)=3. Each 6x1 column is a unit norm complex vector assigned to a single user. [14]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Sequence #** | **1** | **2** | **3** | **4** |
| **Sequence**  **Sample #** | **1** | 0.0127 - 0.4081i | 0.4044 + 0.0562i | -0.2851 + 0.2922i | -0.4006 + 0.0789i |
| **2** | -0.3376 + 0.2295i | -0.3739 + 0.1639i | -0.1569 + 0.3769i | -0.2290 + 0.3380i |
| **3** | -0.1792 - 0.3668i | -0.3488 - 0.2121i | -0.2767 + 0.3001i | -0.3467 - 0.2155i |
| **4** | 0.1812 + 0.3658i | -0.1718 - 0.3704i | -0.3815 + 0.1454i | -0.3994 + 0.0846i |
| **5** | 0.2566 + 0.3176i | 0.2490 - 0.3235i | -0.3897 - 0.1217i | 0.3421 + 0.2228i |
| **6** | 0.0764 - 0.4010i | 0.3607 - 0.1912i | -0.2157 - 0.3466i | 0.4079 - 0.0172i |
|  | **Sequence #** | **5** | **6** | **7** | **8** |
| **Sequence**  **Sample #** | **1** | 0.4065 - 0.0374i | 0.2661 + 0.3096i | 0.2941 - 0.2831i | -0.2765 + 0.3003i |
| **2** | 0.4008 + 0.0779i | -0.4068 + 0.0347i | -0.2459 - 0.3259i | -0.3970 - 0.0953i |
| **3** | 0.3497 - 0.2106i | 0.3137 - 0.2613i | -0.2331 + 0.3352i | -0.3400 + 0.2260i |
| **4** | -0.2905 + 0.2869i | 0.3796 + 0.1502i | 0.1112 - 0.3928i | 0.0136 - 0.4080i |
| **5** | 0.4072 + 0.0287i | -0.0430 - 0.4060i | 0.2744 + 0.3023i | -0.0933 - 0.3974i |
| **6** | -0.0089 + 0.4082i | -0.2751 + 0.3017i | 0.1705 + 0.3709i | -0.1029 + 0.3951i |
|  | **Sequence #** | **9** | **10** | **11** | **12** |
| **Sequence**  **Sample #** | **1** | -0.3326 + 0.2367i | -0.3130 - 0.2621i | 0.3478 - 0.2137i | -0.1482 - 0.3804i |
| **2** | 0.3399 - 0.2261i | 0.3567 - 0.1986i | -0.3279 + 0.2432i | 0.3409 + 0.2246i |
| **3** | -0.4045 - 0.0552i | -0.2184 - 0.3449i | -0.3677 - 0.1773i | 0.2542 - 0.3195i |
| **4** | -0.3645 - 0.1839i | -0.0414 + 0.4061i | -0.3691 + 0.1744i | -0.3072 - 0.2688i |
| **5** | 0.3338 - 0.2351i | 0.0992 - 0.3960i | 0.2238 - 0.3414i | -0.3323 - 0.2371i |
| **6** | -0.1345 - 0.3854i | -0.1021 + 0.3953i | -0.4039 + 0.0595i | -0.1442 + 0.3819i |
|  | **Sequence #** | **13** | **14** | **15** | **16** |
| **Sequence**  **Sample #** | **1** | 0.3503 + 0.2097i | 0.3966 + 0.0968i | -0.0718 - 0.4019i | 0.1103 - 0.3931i |
| **2** | 0.2704 + 0.3059i | -0.3121 - 0.2631i | -0.1017 - 0.3954i | 0.3154 + 0.2592i |
| **3** | -0.3382 - 0.2286i | 0.0828 - 0.3998i | -0.3402 + 0.2257i | 0.3827 - 0.1420i |
| **4** | 0.2216 - 0.3429i | -0.3867 - 0.1310i | -0.4068 - 0.0340i | -0.0265 - 0.4074i |
| **5** | -0.2380 - 0.3317i | -0.3579 + 0.1964i | -0.3580 + 0.1963i | -0.4082 - 0.0055i |
| **6** | -0.3926 + 0.1118i | 0.0940 + 0.3973i | -0.3610 - 0.1906i | -0.1204 - 0.3901i |
|  | **Sequence #** | **17** | **18** |  |  |
| **Sequence**  **Sample #** | **1** | -0.1234 - 0.3891i | -0.0403 - 0.4063i |  |  |
| **2** | -0.3884 + 0.1257i | -0.0692 + 0.4023i |  |  |
| **3** | 0.3979 - 0.0914i | 0.0233 + 0.4076i |  |  |
| **4** | -0.3194 - 0.2543i | -0.2744 - 0.3022i |  |  |
| **5** | -0.3812 + 0.1461i | 0.2992 - 0.2777i |  |  |
| **6** | 0.0883 + 0.3986i | -0.0814 - 0.4000i |  |  |

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#### NOCA

NOCA (Non-Orthogonal Coded Access) is a symbol level spreading scheme. The transmitter side strucuture is as in Figure 3 in section 2.2.1. Each modulated symbol is spread by a sequence and then mapped to the physical resource elements. The NOCA spreading sequence set is generated from QPSK sequences , where is the sequence root, and each value offor each root is chosen from the QPSK constellation points. By down-selecting some of sequence root based on computer search, the obtained NOCA sequence set has good correlation properties. This kind of operation is actually same with that in LTE UL DMRS design thus has little standard impact. The QPSK sequence has a constant amplitude.

Following the same computer search criteria, it is possible to generate any candidate number of sequences for any candidate spreading factors. In the Annex x.6, an example of NOCA sequences for spreading factor 4,6 and 12 is given. It is quite flexible to add more roots or remove some of the roots based on different requirements. It should be noted in practice, if the speading sequence is pre-configured, the way of configuration could be at first configuring each UE a cyclic shift under a same root, then configuring UE a cyclic shift of a different root, if the number of UEs are larger than the number of cyclic shifts. This ensures the low cross correlations among MA signatures and is benefitial for the detection performance.

For the same user, a same or different spreading sequence is applied to each modulated symbol. The latter is used to enable lower PAPR. The pattern of spreading sequences across modulated symbols is refered to as the spreading sequence pattern. Any two spreading sequence patterens use different sequences for each modulated symbol. The spreading sequence pattern is determined by the spreading sequence of the first modulated symbol, the spreading sequences used for the following modulated symbols follow a predefined rule. As an example, the rule could be firstly following an increasing order of cyclic shift at the same root, then going to the higher root.

Different UEs are allocated with different spreading sequence patterns by gNB. Alternatively the UEs can be configured to autonomously select one spreading sequence pattern, in which case it should be guatanteed that the sequence collision rate from different UEs shall be as low as possible~~.~~

The NOCA multi-branch transmission transmission structure is capturated in Figure 11(c) in section 2.4. Each branch is spread using different spreading sequences. The sequences for each branch are associated such that gNB will not configure a spreading sequence for each branch.

In the receiver side, joint MMSE plus IC receiver is used in the simulator. The structure is illustrated in Figure 3.1.7-1.



Figure 3.1.7-1: Receiver for NOCA.

The received signal is expressed by,



Where **A** is the equivalent channel considering spreading



**H** is the estimated frequency domain channel and **S** is the spreading sequence, and K is the number of UEs

The MMSE receiver is known as,



,

In the first iternation, **y** is equal to **y***residual*. In each iteration, the successfully detected signals are re-constrcuted and removed from the received signals, then MMSE receiver is used for the residual signals. The operation will be continued until the end of the iterations.

In case the received signal power is different for different UEs, the detection will be done for the stronger power UEs in the first step, i.e., the MMSE matrix is constructed from the equivalent channels of these UEs. After that, the signal from higher power UEs will be removed, and the other round of MMSE reciver with IC iteration is started for low power UEs.

#### Spreading based NCMA

Spreading based NCMA (Non-orthogonal Coded Multiple Access) scheme use low cross-correlation sequences as the MA signature [15][16][17]. Symbols is drawn from QPSK as well as higher order QAM constellations to adjust spectral efficiency. The transmitter processing procedure can be found in Figure 3.1.8-1.



Figure 3.1.8-1 Transmitter procedure for spreading based NCMA with NR legacy modulation

Spreading based NCMA scheme [15][16] utilize the same transmitter processing procedure as Rel-15 NR PUSCH including channel encoding, rate matching, bit-level scrambling and then modulator, as shown in Figure 1. Bit level scrambling function is defined in TS 38.211 Section 6.3.1.1 [12]. In addition, to mitigate inter-user interference, MA signature described in Section 2.2.1 -3) for spreading based NCMA is defined in a UE/layer-specific manner. Examples of symbol-level spreading sequences for spreading based NCMA are respresented as follows:

* *Examples of Grassmannian Sequence based spreading codebook*

Table X.4-1 Grassmannian Sequence based codebook for Spreading Factor: N = 2

|  |  |
| --- | --- |
| # of sequences (K) | Examples of spreading codebook |
| 2 | |  |  | | --- | --- | | 0.5+0.5i | 0.5+0.5i | | 0.5+0.5i | -0.5-0.5i | |
| 3 | |  |  |  | | --- | --- | --- | | -0.6263+0.7075i | -0.573-0.0791i | -0.5129+0.0638i | | -0.0133+0.3272i | 0.673+0.4609i | -0.455-0.7251i | |
| 4 | |  |  |  |  | | --- | --- | --- | --- | | -0.332+0.5287i | -0.4097+0.8563i | -0.1019-0.3184i | -0.7084-0.3089i | | 0.2967+0.7227i | -0.3059+0.0722i | 0.9012-0.2757i | 0.4757+0.42i | |
| 6 | |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.3216+0.1994i | -0.6835-0.3756i | -0.0804-0.5006i | -0.4603+0.3705i | -0.1868-0.9794i | -0.8377+0.1357i | | 0.8477-0.3719i | -0.5584+0.2827i | -0.084-0.8579i | -0.5978-0.5418i | -0.0455-0.0625i | 0.3387-0.4064i | |
| 8 | |  |  |  |  | | --- | --- | --- | --- | | -0.4355-0.8256i | -0.8275-0.133i | -0.2565-0.2043i | -0.1369-0.5129i | | -0.1733-0.3142i | 0.0924-0.5376i | -0.1633+0.9305i | -0.4608-0.7112i |   ...   |  |  |  |  | | --- | --- | --- | --- | | -0.316-0.094i | -0.9512+0.0838i | -0.3073-0.7312i | -0.1059+0.6197i | | 0.0767-0.941i | 0.2937+0.0432i | -0.5853+0.1684i | -0.1573-0.7615i | |
| 12 | |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.4674-0.5448i | -0.389-0.3685i | -0.9054-0.4138i | -0.2598-0.2783i | -0.258+0.1298i | -0.1395-0.7374i | | 0.6583-0.2265i | 0.0489+0.8429i | 0.0506+0.0802i | -0.1676-0.9094i | 0.1195-0.9499i | -0.6574-0.0676i |   …   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.9257+0.0341i | -0.709-0.2363i | -0.2001-0.2789i | -0.789-0.3244i | -0.2703+0.6757i | -0.1207-0.8743i | | -0.0837-0.3674i | -0.3586-0.5594i | -0.9337+0.1017i | 0.199+0.4823i | 0.069-0.6823i | -0.2052-0.423i | |

Table X.4-2 Grassmannian Sequence based codebook for Spreading Factor: N = 4

|  |  |
| --- | --- |
| # of sequences (K) | Examples of spreading codebook |
| 4 | |  |  |  |  | | --- | --- | --- | --- | | 0.3536+0.3536i | 0.3536+0.3536i | 0.3536+0.3536i | 0.3536+0.3536i | | 0.3536+0.3536i | -0.3536-0.3536i | 0.3536+0.3536i | -0.3536-0.3536i | | 0.3536+0.3536i | 0.3536+0.3536i | -0.3536-0.3536i | -0.3536-0.3536i | | 0.3536+0.3536i | -0.3536-0.3536i | -0.3536-0.3536i | 0.3536+0.3536i | |
| 6 | |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.5659+0.2301i | -0.2438+0.0689i | -0.0199-0.8583i | -0.0756+0.1161i | -0.4797+0.3517i | -0.1779+0.0383i | | -0.3658+0.0035i | -0.0102-0.3345i | -0.3024+0.0388i | 0.2302+0.3263i | -0.2896-0.5898i | 0.3838+0.5954i | | 0.1548+0.1412i | -0.0633-0.693i | -0.0159-0.2511i | -0.1419+0.7303i | 0.2695+0.2056i | 0.4001-0.4804i | | 0.1012-0.6625i | -0.5252+0.2524i | -0.3086+0.1071i | -0.406+0.3209i | -0.112+0.2949i | 0.073+0.2622i | |
| 8 | |  |  |  |  | | --- | --- | --- | --- | | -0.3769-0.1993i | -0.4946+0.0729i | -0.0349-0.1744i | -0.4983-0.2361i | | 0.0071-0.4246i | 0.0484+0.2172i | -0.4864+0.5118i | 0.3678-0.0002i | | -0.7438-0.2074i | 0.1526-0.5642i | -0.1478+0.1545i | 0.6445+0.1123i | | 0.0662-0.1932i | 0.1281-0.5852i | -0.3512+0.5484i | -0.1883+0.3118i |   …   |  |  |  |  | | --- | --- | --- | --- | | -0.0589-0.2775i | -0.3141-0.2162i | -0.3118-0.2513i | -0.6128+0.4861i | | 0.6654-0.2483i | 0.2752+0.0869i | -0.0147+0.3864i | -0.3671+0.3724i | | -0.4067+0.4932i | -0.2122-0.4038i | -0.3986+0.2848i | -0.1428-0.0632i | | 0.072+0.0362i | -0.5858+0.4691i | 0.5659-0.3604i | 0.282+0.104i | |
| 12 | |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.1211 + 0.1742i | -0.1864 + 0.1486i | -0.4450 - 0.2565i | -0.1650 + 0.3506i | -0.4503 + 0.2070i | -0.3310 - 0.2575i | | 0.5284 - 0.0028i | 0.5630 - 0.0523i | -0.5537 + 0.0264i | 0.2754 + 0.1722i | 0.0650 - 0.1528i | -0.5335 + 0.6004i | | 0.1518 - 0.5314i | 0.2665 - 0.4503i | 0.3965 + 0.2446i | -0.2259 + 0.3311i | -0.1173 + 0.3294i | -0.1120 - 0.2999i | | 0.3043 + 0.5270i | 0.2024 - 0.5556i | 0.3116 - 0.3387i | -0.3280 - 0.6900i | 0.6983 + 0.3420i | -0.1290 + 0.2449i |   …   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.2344 - 0.1865i | -0.4251 + 0.0869i | -0.2091 - 0.5656i | -0.8263 - 0.3684i | -0.5363 - 0.1981i | -0.6964 - 0.1831i | | 0.1663 - 0.2439i | 0.6626 - 0.4120i | -0.1403 - 0.1177i | 0.1024 + 0.0356i | 0.3090 - 0.5397i | 0.1029 + 0.2755i | | 0.7183 - 0.0739i | -0.0365 - 0.0355i | -0.0380 - 0.3106i | 0.2040 - 0.3275i | -0.1106 + 0.2210i | -0.0585 + 0.6228i | | -0.4388 - 0.3303i | -0.3826 + 0.2322i | -0.1052 - 0.7027i | 0.1073 + 0.0961i | 0.2328 - 0.4136i | -0.0382 - 0.0488i | |
| 24 | |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.4830 - 0.2050i | -0.6615 - 0.0671i | -0.6259 + 0.0369i | -0.3959 - 0.0233i | -0.1603 - 0.2521i | -0.6038 + 0.4112i | | -0.2624 - 0.1541i | 0.4989 + 0.1979i | 0.4263 + 0.1862i | 0.2071 + 0.0445i | -0.4414 - 0.4468i | -0.0881 - 0.4998i | | 0.1666 + 0.6409i | -0.1865 + 0.1094i | 0.2179 - 0.0776i | 0.1435 + 0.2335i | 0.4663 + 0.1111i | -0.4010 - 0.1035i | | 0.4013 - 0.1805i | 0.1638 + 0.4431i | -0.2700 - 0.5139i | -0.7073 + 0.4716i | -0.0505 + 0.5329i | 0.0192 - 0.1919i |   …   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.1635 - 0.1720i | -0.1179 + 0.0788i | -0.1956 + 0.0307i | -0.2600 + 0.2399i | -0.2038 - 0.6405i | -0.4881 - 0.5159i | | 0.7563 + 0.0361i | -0.4599 - 0.1309i | -0.1232 - 0.6046i | -0.3615 - 0.4122i | -0.2539 + 0.0586i | -0.1130 - 0.4476i | | -0.2782 - 0.2679i | -0.1685 + 0.6825i | 0.6386 - 0.1426i | -0.2622 - 0.5184i | -0.0735 - 0.5538i | 0.2439 + 0.0633i | | -0.4506 + 0.1348i | -0.3230 + 0.3907i | 0.3472 - 0.1775i | 0.1503 + 0.4628i | 0.1120 - 0.3945i | -0.1279 - 0.4501i |   …   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.3285 - 0.2600i | -0.0493 - 0.1783i | -0.0727 + 0.7759i | -0.1140 - 0.0059i | -0.4202 + 0.0846i | -0.1926 - 0.5845i | | -0.2321 + 0.4945i | -0.0936 - 0.1371i | -0.0051 - 0.0993i | 0.8473 - 0.2674i | -0.6712 + 0.0690i | 0.4597 + 0.1189i | | -0.3453 + 0.6286i | 0.0050 - 0.5683i | -0.0618 - 0.5636i | 0.1556 + 0.0334i | -0.2547 + 0.0501i | -0.5381 + 0.1646i | | -0.0900 - 0.0602i | -0.7617 - 0.1871i | 0.2389 - 0.0656i | 0.1766 - 0.3756i | 0.1964 - 0.5051i | 0.0392 - 0.2784i |   …   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.1330 + 0.5960i | -0.0860 + 0.0279i | -0.1848 - 0.7667i | -0.4759 - 0.0853i | -0.5030 - 0.1257i | -0.3274 + 0.1413i | | 0.6664 + 0.3456i | -0.2417 - 0.5119i | -0.0172 - 0.4039i | 0.1071 - 0.0115i | -0.0097 + 0.3024i | 0.1559 + 0.1646i | | -0.0779 - 0.2098i | -0.1963 + 0.4415i | -0.2174 - 0.1382i | 0.2280 - 0.1530i | -0.5637 + 0.0694i | -0.4217 - 0.7887i | | 0.0142 + 0.1150i | -0.0101 - 0.6617i | -0.3424 + 0.1762i | 0.7979 - 0.2064i | 0.5591 - 0.0670i | -0.0345 + 0.1433i | |

Table X.4-3 Grassmannian Sequence based codebook for Spreading Factor: N = 6

|  |  |
| --- | --- |
| # of sequences (K) | Examples of spreading codebook |
| 6 | |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.0067 + 0.1511i | -0.4237 - 0.3591i | -0.1953 - 0.0263i | -0.2925 - 0.4896i | -0.0118 + 0.0830i | -0.1683 + 0.5188i | | 0.1368 + 0.4258i | -0.0108 + 0.2746i | 0.7358 + 0.1501i | 0.1518 - 0.1068i | 0.0716 - 0.0748i | -0.1933 + 0.2792i | | -0.5648 - 0.1014i | -0.0970 + 0.4963i | -0.1376 - 0.2277i | 0.3041 - 0.1107i | -0.3406 - 0.1132i | 0.0733 + 0.3244i | | 0.1170 + 0.1862i | -0.4994 + 0.2468i | 0.0429 - 0.3209i | -0.0097 - 0.1937i | -0.1889 + 0.3199i | -0.1491 - 0.5819i | | 0.0510 + 0.5028i | -0.1730 - 0.1237i | -0.2822 - 0.3193i | 0.3790 + 0.4902i | 0.3024 + 0.0765i | 0.0360 + 0.1876i | | -0.2469 - 0.2882i | -0.0678 + 0.0059i | 0.1937 - 0.0511i | 0.2007 - 0.2713i | 0.6612 + 0.4253i | 0.2814 - 0.0048i | |
| 9 | |  |  |  |  |  | | --- | --- | --- | --- | --- | | -0.1750 - 0.4216i | -0.0946 + 0.1509i | -0.4759 - 0.1498i | -0.4398 - 0.4474i | -0.3105 + 0.3168i | | -0.3774 + 0.2254i | 0.3676 - 0.5634i | -0.0470 + 0.0828i | -0.1229 - 0.2901i | -0.0986 - 0.2838i | | 0.2603 - 0.2223i | 0.1551 - 0.1842i | -0.0355 - 0.6399i | 0.1221 + 0.4573i | -0.1649 + 0.3555i | | 0.3240 - 0.1133i | 0.3985 + 0.1683i | 0.1904 - 0.0575i | -0.2519 + 0.1605i | 0.3528 + 0.1098i | | 0.2924 + 0.2830i | 0.0595 - 0.1749i | -0.3949 - 0.1124i | -0.3052 + 0.1304i | 0.5112 - 0.2972i | | -0.0755 - 0.4383i | 0.3266 - 0.3604i | -0.3949 - 0.1124i | -0.1440 + 0.2510i | -0.0049 + 0.2705i |   …   |  |  |  |  | | --- | --- | --- | --- | | -0.1162 - 0.3727i | -0.0648 - 0.2974i | -0.0177 - 0.2267i | -0.2034 + 0.0548i | | -0.0352 - 0.3251i | 0.0709 - 0.0592i | -0.3009 + 0.3806i | -0.1825 - 0.4514i | | -0.4636 + 0.1430i | 0.0111 + 0.0995i | -0.4061 - 0.0636i | -0.1006 - 0.4420i | | 0.1034 - 0.2690i | 0.7401 - 0.0802i | -0.0695 + 0.1943i | -0.3844 + 0.4339i | | 0.2077 + 0.0577i | -0.1192 - 0.1341i | 0.2391 - 0.6253i | -0.1846 - 0.2280i | | 0.6084 - 0.0748i | -0.5224 + 0.1717i | 0.2217 + 0.0637i | -0.2966 + 0.0553i | |
| 12 | |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.1799 + 0.0182i | -0.3752 - 0.0780i | -0.0550 + 0.5153i | -0.6672 + 0.0053i | -0.4456 + 0.2529i | -0.1911 + 0.0966i | | 0.2918 + 0.4154i | 0.3932 - 0.2216i | 0.0912 + 0.2021i | -0.2390 - 0.5541i | 0.0746 + 0.1821i | -0.4875 + 0.0236i | | -0.3001 + 0.3627i | -0.0245 + 0.1734i | -0.0135 + 0.0519i | 0.0633 + 0.0018i | 0.0004 - 0.1361i | 0.0218 + 0.1235i | | 0.2107 - 0.0750i | -0.0247 + 0.1896i | 0.3250 + 0.4860i | 0.0870 - 0.2467i | -0.4553 + 0.1958i | 0.2442 - 0.4576i | | -0.4704 + 0.0977i | -0.2204 - 0.5670i | 0.1762 + 0.0893i | 0.2063 + 0.2215i | 0.2710 + 0.0832i | -0.4821 - 0.3798i | | -0.4475 + 0.0829i | 0.0399 - 0.4588i | -0.3544 - 0.4159i | 0.0116 - 0.1629i | 0.0416 + 0.5937i | 0.2329 - 0.0193i |   …   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.1602 - 0.2034i | -0.0230 - 0.0010i | -0.3547 + 0.4951i | -0.1954 - 0.0178i | -0.5962 - 0.0794i | -0.2205 + 0.3040i | | 0.0053 - 0.3703i | -0.2725 + 0.1803i | 0.1958 + 0.0695i | 0.1745 + 0.2030i | 0.4328 + 0.4512i | -0.2995 - 0.1768i | | 0.2836 + 0.2482i | 0.5987 - 0.4278i | 0.5229 + 0.2682i | 0.2627 - 0.0545i | 0.0088 - 0.2753i | -0.6204 + 0.2082i | | -0.2787 + 0.6350i | -0.2270 + 0.3232i | 0.3061 - 0.1277i | -0.0315 + 0.0366i | 0.1001 - 0.2319i | -0.2803 + 0.1567i | | -0.2379 + 0.0987i | -0.0976 + 0.0064i | 0.1490 - 0.2797i | -0.2829 - 0.6616i | -0.1003 + 0.1802i | -0.3775 - 0.1088i | | -0.0326 + 0.3247i | -0.4007 - 0.1584i | 0.1727 - 0.0154i | -0.2890 + 0.4628i | 0.2504 - 0.0492i | 0.0224 + 0.2275i | |
| 18 | |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.0536 + 0.2198i | -0.2693 - 0.4333i | -0.6187 - 0.3042i | -0.3505 + 0.2617i | -0.1589 + 0.2300i | -0.1636 + 0.6216i | | 0.1610 + 0.2080i | 0.0330 - 0.0319i | -0.2020 + 0.0123i | 0.0084 - 0.0715i | 0.4481 - 0.4723i | 0.0572 + 0.3221i | | -0.1757 - 0.3555i | -0.1606 + 0.0675i | -0.3890 - 0.1223i | -0.1811 - 0.1130i | 0.2193 + 0.0070i | 0.0979 - 0.0995i | | 0.1967 - 0.2453i | 0.3753 - 0.4278i | -0.1664 + 0.1142i | 0.4995 + 0.3997i | 0.1433 + 0.1017i | 0.1512 - 0.0650i | | -0.3967 - 0.6296i | -0.3954 - 0.2248i | -0.1870 + 0.4162i | -0.3456 - 0.0821i | 0.1803 + 0.5078i | -0.3314 + 0.4116i | | 0.2579 - 0.0575i | -0.0923 + 0.4099i | -0.2609 - 0.0201i | 0.1127 + 0.4580i | 0.2118 + 0.2895i | -0.2658 - 0.2887i |   …   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.0836 - 0.0713i | -0.1902 + 0.2305i | -0.1258 - 0.3152i | -0.0598 - 0.0660i | -0.0416 - 0.6963i | -0.2187 + 0.0966i | | 0.2830 + 0.0819i | 0.2434 + 0.5321i | 0.1513 + 0.2619i | -0.0409 - 0.3969i | -0.1199 + 0.4086i | -0.3253 - 0.6174i | | -0.2828 + 0.4158i | 0.5634 + 0.1299i | 0.3199 - 0.3650i | -0.0537 - 0.1960i | 0.0041 - 0.2080i | 0.0488 - 0.3033i | | -0.6601 + 0.2903i | -0.2645 + 0.2004i | 0.2574 + 0.1827i | -0.1445 + 0.3869i | 0.2050 - 0.2825i | -0.0355 - 0.1696i | | 0.1783 + 0.0362i | 0.0462 - 0.2951i | 0.0834 + 0.3910i | -0.4705 + 0.2520i | 0.3482 + 0.0103i | -0.2860 - 0.4483i | | 0.1443 + 0.2727i | -0.0046 - 0.1861i | -0.5331 - 0.1190i | 0.5797 - 0.0054i | 0.1597 - 0.1420i | -0.1695 + 0.1414i |   …   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.3305 - 0.1589i | -0.3229 - 0.1153i | -0.3847 - 0.2045i | -0.2858 + 0.0966i | -0.0293 - 0.3977i | -0.3220 - 0.2467i | | -0.0072 - 0.1362i | 0.0003 + 0.1612i | -0.0727 + 0.2529i | -0.4430 - 0.4194i | -0.4484 - 0.0575i | 0.4686 - 0.0367i | | 0.2791 - 0.6295i | -0.1596 + 0.0026i | 0.3451 + 0.3977i | -0.1290 + 0.3090i | 0.6156 + 0.1897i | -0.2436 - 0.0584i | | -0.0907 + 0.2319i | 0.1119 + 0.1202i | 0.5727 - 0.0428i | -0.3128 + 0.3001i | 0.0484 - 0.3115i | 0.5536 + 0.0751i | | 0.2236 - 0.0605i | 0.3439 + 0.1623i | 0.0183 + 0.3426i | 0.1422 - 0.1277i | -0.0379 - 0.2246i | -0.2479 + 0.1114i | | 0.1836 - 0.4726i | 0.7750 + 0.2425i | 0.0941 + 0.0857i | -0.2265 - 0.3859i | -0.2611 + 0.0467i | 0.0434 - 0.4048i | |
| 24 | |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.1205 - 0.0906i | -0.2429 + 0.0101i | -0.1958 + 0.0334i | -0.5558 - 0.3450i | -0.0762 - 0.2053i | -0.1104 + 0.1181i | | 0.2126 - 0.1759i | 0.0735 + 0.2287i | -0.0088 - 0.1481i | -0.0654 - 0.0106i | -0.2058 - 0.6040i | -0.3184 + 0.2838i | | 0.2841 + 0.1491i | -0.5703 + 0.1454i | -0.0281 - 0.6488i | -0.0644 - 0.1848i | -0.0863 + 0.1620i | 0.5370 + 0.1881i | | -0.6343 - 0.0281i | -0.1898 + 0.2781i | 0.5698 - 0.2672i | -0.0118 - 0.2547i | 0.1953 - 0.6045i | 0.1292 - 0.1513i | | 0.2070 + 0.2441i | -0.0429 + 0.1770i | 0.0323 + 0.2969i | -0.5527 + 0.3919i | 0.0008 - 0.2196i | -0.2188 - 0.4891i | | 0.2647 - 0.4717i | -0.2798 + 0.5585i | -0.1664 - 0.0624i | 0.0639 - 0.0334i | 0.2386 + 0.0484i | 0.1780 + 0.3312i |   …   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.1405 + 0.7400i | -0.3438 + 0.3117i | -0.2251 + 0.1306i | -0.1659 + 0.5745i | -0.0835 - 0.7271i | -0.3349 + 0.1225i | | 0.3308 - 0.1548i | -0.0342 - 0.1486i | 0.1171 - 0.0360i | 0.0376 + 0.3678i | 0.2232 + 0.2730i | 0.5830 + 0.4476i | | 0.1930 - 0.2437i | -0.0099 - 0.1051i | -0.4569 - 0.0981i | -0.3908 + 0.2070i | -0.0484 - 0.2027i | -0.3928 - 0.1026i | | 0.0669 + 0.3682i | 0.4912 + 0.0310i | 0.5227 + 0.2637i | -0.1248 - 0.0970i | -0.0507 + 0.3744i | 0.0820 - 0.1718i | | -0.1003 - 0.0071i | 0.5636 - 0.2794i | -0.2933 + 0.3081i | -0.5188 + 0.0279i | 0.0441 - 0.0585i | 0.2717 + 0.0624i | | 0.1977 - 0.1158i | 0.1010 - 0.3195i | 0.4177 - 0.0264i | 0.0819 - 0.0917i | -0.1485 - 0.3556i | 0.2313 + 0.0170i |   …   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.3658 + 0.3791i | -0.3840 - 0.1457i | -0.2731 - 0.0015i | -0.1237 - 0.4324i | -0.4458 - 0.3228i | -0.3369 - 0.2023i | | -0.2440 + 0.3924i | 0.3868 - 0.5010i | 0.1135 - 0.0866i | -0.0334 + 0.2990i | -0.3695 - 0.2152i | -0.0237 - 0.0792i | | 0.1990 + 0.2832i | 0.0352 - 0.3687i | 0.1787 + 0.1482i | 0.1434 + 0.1604i | 0.2443 + 0.1392i | 0.2139 + 0.2847i | | 0.4762 + 0.3122i | 0.0183 - 0.0049i | -0.0222 - 0.4405i | 0.7431 - 0.2009i | 0.1677 - 0.1024i | -0.1170 - 0.0208i | | -0.0914 + 0.2299i | -0.1498 - 0.2164i | 0.6446 + 0.0964i | 0.1748 - 0.1145i | 0.1808 + 0.2664i | -0.1995 - 0.6235i | | -0.0604 + 0.0091i | 0.3436 - 0.3252i | 0.1246 + 0.4651i | 0.0934 - 0.1258i | -0.3477 - 0.4148i | -0.2578 - 0.4502i |   …   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -0.2107 - 0.0633i | -0.2499 - 0.0492i | -0.1906 + 0.0636i | -0.0005 - 0.2597i | -0.4153 + 0.0351i | -0.1159 + 0.2327i | | 0.3673 + 0.2826i | 0.2659 - 0.2545i | 0.1698 + 0.4714i | 0.1146 + 0.3938i | 0.0363 + 0.3590i | -0.2075 - 0.1135i | | 0.2240 + 0.5811i | -0.1207 + 0.2402i | -0.1359 + 0.1650i | 0.6185 + 0.0954i | 0.0692 - 0.0723i | 0.6153 + 0.2655i | | 0.0808 + 0.1921i | -0.2030 - 0.1218i | 0.2503 + 0.4427i | -0.0807 - 0.2431i | 0.1282 + 0.0604i | -0.2904 + 0.2418i | | 0.4247 + 0.0662i | -0.4125 - 0.5222i | 0.0571 - 0.6091i | -0.1775 + 0.3962i | -0.1271 + 0.0215i | 0.1794 + 0.3055i | | -0.2556 - 0.2355i | 0.1366 + 0.4580i | 0.1723 - 0.0152i | -0.2674 - 0.2171i | 0.2468 - 0.7671i | -0.0960 + 0.3870i | |

NOTE: All of spreading codebooks are normalized by multiplying ,which is () normalized matrix for the power constraints, . Here, .

Above tables X 4-1, 4-2 and 4-3 can be quantized via coeffcients from 64QAM modulation as follows.

* *Examples of 64QAM-quantized Grassmannian Sequence based spreading codebook*

Table X.4-4 64QAM-quantized Grassmannian Sequence based codebook for Spreading Factor: N = 2

|  |  |
| --- | --- |
| # of sequence (K) | Examples of spreading codebook |
| 2 | |  |  | | --- | --- | | 5+5i | 5+5i | | 5+5i | -5-5i | |
| 3 | |  |  |  | | --- | --- | --- | | -5+7i | -5-1i | -5+1i | | -1+3i | 7+5i | -5-7i | |
| 4 | |  |  |  |  | | --- | --- | --- | --- | | -3+5i | -3+7i | -1-3i | -7-3i | | 3+7i | -3+1i | 7-3i | 5+3i | |
| 6 | |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -3+1i | -7-3i | -1-5i | -5+3i | -1-7i | -7+1i | | 7-3i | -5+3i | -1-7i | -5-5i | -1-1i | 3-3i | |
| 8 | |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | -3-7i | -7-1i | -3-1i | -1-5i | -3-1i | -7+1i | -3-7i | -1+5i | | -1-3i | 1-5i | -1+7i | -5-7i | 1-7i | 3+1i | -5+1i | -1-7i | |
| 12 | |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | -5-5i | -3-3i | -7-3i | -3-3i | -3+1i | -1-7i | -7+1i | -7-3i | -1-3i | -7-3i | -3+7i | -1-7i | | 7-3i | 1+7i | 1+1i | -1-7i | 1-7i | -7-1i | -1-3i | -3-5i | -7+1i | 1+5i | 1-7i | -1-3i | |

Table X.4-5 64QAM-quantized Grassmannian Sequence based codebook for Spreading Factor: N = 4

|  |  |
| --- | --- |
| # of sequence (K) | Examples of spreading codebook |
| 4 | |  |  |  |  | | --- | --- | --- | --- | | 5+5i | 5+5i | 5+5i | 5+5i | | 5+5i | -5-5i | 5+5i | -5-5i | | 5+5i | 5+5i | -5-5i | -5-5i | | 5+5i | -5-5i | -5-5i | 5+5i | |
| 6 | |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -7+3i | -3+1i | -1-7i | -1+1i | -7+5i | -3+1i | | -5+1i | -1-5i | -3+1i | 3+5i | -3-7i | 5+7i | | 3+1i | -1-7i | -1-3i | -1+7i | 3+3i | 5-7i | | 1-7i | -7+3i | -3+1i | -5+5i | -1+3i | 1+3i | |
| 8 | |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | -5-3i | -7+1i | -1-3i | -7-3i | -1-3i | -5-3i | -5-3i | -7+7i | | 1-5i | 1+3i | -7+7i | 5-1i | 7-3i | 3+1i | -1+5i | -5+5i | | -7-3i | 1-7i | -1+3i | 7+1i | -5+7i | -3-5i | -5+3i | -1-1i | | 1-3i | 1-7i | -5+7i | -3+5i | 1+1i | -7+7i | 7-5i | 3+1i | |
| 12 | |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | -1+3i | -3+1i | -5-3i | -3+5i | -5+3i | -5-3i | -3-3i | -5+1i | -3-7i | -7-5i | -7-3i | -7-3i | | 7-1i | 7-1i | -7+1i | 3+3i | 1-1i | -7+7i | 3-3i | 7-5i | -1-1i | 1+1i | 5-7i | 1+3i | | 1-7i | 3-5i | 5+3i | -3+5i | -1+5i | -1-3i | 7-1i | -1-1i | -1-5i | 3-5i | -1+3i | -1+7i | | 3+7i | 3-7i | 5-5i | -5-7i | 7+5i | -1+3i | -5-5i | -5+3i | -1-7i | 1+1i | 3-5i | -1-1i | |
| 24 | |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | -7-3i | -7-1i | -7+1i | -5-1i | -3-3i | -7+5i | -3-3i | -1+1i | -3+1i | -3+3i | -3-7i | -7-7i | | -3-1i | 7+3i | 5+3i | 3+1i | -5-5i | -1-7i | 7+1i | -5-1i | -1-7i | -5-5i | -3+1i | -1-5i | | 3+7i | -3+1i | 3-1i | 1+3i | 7+1i | -5-1i | -3-3i | -3+7i | 7-1i | -3-7i | -1-7i | 3+1i | | 5-3i | 3+5i | -3-7i | -7+7i | -1+7i | 1-3i | -5+1i | -5+5i | 5-3i | 1+5i | 1-5i | -1-5i |   …   |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | -5-3i | -1-3i | -1+7i | -1-1i | -5+1i | -3-7i | -1+7i | -1+1i | -3-7i | -7-1i | -7-1i | -5+1i | | -3+7i | -1-1i | -1-1i | 7-3i | -7+1i | 5+1i | 7+5i | -3-7i | -1-5i | 1-1i | -1+3i | 3+3i | | -5+7i | 1-7i | -1-7i | 3+1i | -3+1i | -7+3i | -1-3i | -3+5i | -3-1i | 3-1i | -7+1i | -5-7i | | -1-1i | -7-3i | 3-1i | 3-5i | 3-7i | 1-3i | 1+1i | -1-7i | -5+3i | 7-3i | 7-1i | -1+1i | |

Table X.4-6 64QAM-quantized Grassmannian Sequence based codebook for Spreading Factor: N = 6

|  |  |
| --- | --- |
| # of sequence (K) | Examples of spreading codebook |
| 6 | |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | -1+3i | -7-5i | -3-1i | -5-7i | -1+1i | -3+7i | | 3+7i | -1+5i | 7+3i | 3-1i | 1-1i | -3+5i | | -7-1i | -1+7i | -3-3i | 5-1i | -5-1i | 1+5i | | 1+3i | -7+3i | 1-5i | -1-3i | -3+5i | -3-7i | | 1+7i | -3-1i | -5-5i | 7+7i | 5+1i | 1+3i | | -3-5i | -1+1i | 3-1i | 3-5i | 7+7i | 5-1i | |
| 9 | |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | -3-7i | -1+3i | -7-3i | -7-7i | -5+5i | -1-5i | -1-5i | -1-3i | -3+1i | | -5+3i | 5-7i | -1+1i | -1-5i | -1-5i | -1-5i | 1-1i | -5+7i | -3-7i | | 5-3i | 3-3i | -1-7i | 1+7i | -3+5i | -7+3i | 1+1i | -7-1i | -1-7i | | 5-1i | 7+3i | 3-1i | -3+3i | 5+1i | 1-5i | 7-1i | -1+3i | -7+7i | | 5+5i | 1-3i | -7-1i | -5+3i | 7-5i | 3+1i | -1-3i | 3-7i | -3-3i | | -1-7i | 5-5i | 5-1i | -3+3i | -1+5i | 7-1i | -7+3i | 3+1i | -5+1i | |
| 12 | |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | -3+1i | -5-1i | -1+7i | -7+1i | -7+5i | -3+1i | -3-3i | -1-1i | -5+7i | -3-1i | -7-1i | -3+5i | | 5+7i | 7-3i | 1+3i | -3-7i | 1+3i | -7+1i | 1-5i | -5+3i | 3+1i | 3+3i | 7+7i | -5-3i | | -5+5i | -1+3i | -1+1i | 1+1i | 1-3i | 1+1i | 5+3i | 7-7i | 7+5i | 5-1i | 1-5i | -7+3i | | 3-1i | -1+3i | 5+7i | 1-3i | -7+3i | 3-7i | -5+7i | -3+5i | 5-3i | -1+1i | 1-3i | -5+3i | | -7+1i | -3-7i | 3+1i | 3+3i | 5+1i | -7-7i | -3+1i | -1+1i | 3-5i | -5-7i | -1+3i | -5-1i | | -7+1i | 1-7i | -5-7i | 1-3i | 1+7i | 3-1i | -1+5i | -7-3i | 3-1i | -5+7i | 3-1i | 1+3i | |
| 18 | |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | -1+3i | -5-7i | -7-5i | -5+5i | -3+3i | -3+7i | -1-1i | -3+3i | -1-5i | | 3+3i | 1-1i | -3+1i | 1-1i | 7-7i | 1+5i | 5+1i | 3+7i | 3+5i | | -3-5i | -3+1i | -7-1i | -3-1i | 3+1i | 1-1i | -5+7i | 7+3i | 5-5i | | 3-3i | 5-7i | -3+1i | 7+7i | 3+1i | 3-1i | -7+5i | -5+3i | 5+3i | | -7-7i | -7-3i | -3+7i | -5-1i | 3+7i | -5+7i | 3+1i | 1-5i | 1+7i | | 5-1i | -1+7i | -5-1i | 1+7i | 3+5i | -5-5i | 3+5i | -1-3i | -7-1i |   …   |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | -1-1i | -1-7i | -3+1i | -5-3i | -5-1i | -7-3i | -5+1i | -1-7i | -5-3i | | -1-7i | -1+7i | -5-7i | -1-3i | 1+3i | -1+5i | -7-7i | -7-1i | 7-1i | | -1-3i | 1-3i | 1-5i | 5-7i | -3+1i | 5+7i | -3+5i | 7+3i | -3-1i | | -3+7i | 3-5i | -1-3i | -1+3i | 1+1i | 7-1i | -5+5i | 1-5i | 7+1i | | -7+5i | 5+1i | -5-7i | 3-1i | 5+3i | 1+5i | 3-3i | -1-3i | -3+1i | | 7-1i | 3-3i | -3+3i | 3-7i | 7+3i | 1+1i | -3-7i | -5+1i | 1-7i | |
| 24 | |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | -1-1i | -3+1i | -3+1i | -7-5i | -1-3i | -1+1i | -3+7i | -5+5i | -3+3i | -3+7i | -1-7i | -5+1i | | 3-3i | 1+3i | -1-3i | -1-1i | -3-7i | -5+5i | 5-3i | -1-3i | 1-1i | 1+5i | 3+5i | 7+7i | | 5+3i | -7+3i | -1-7i | -1-3i | -1+3i | 7+3i | 3-3i | -1-1i | -7-1i | -7+3i | -1-3i | -7-1i | | -7-1i | -3+5i | 7-5i | -1-5i | 3-7i | 3-3i | 1+5i | 7+1i | 7+5i | -1-1i | -1+5i | 1-3i | | 3+3i | -1+3i | 1+5i | -7+7i | 1-3i | -3-7i | -1-1i | 7-5i | -5+5i | -7+1i | 1-1i | 5+1i | | 5-7i | -5+7i | -3-1i | 1-1i | 3+1i | 3+5i | 3-1i | 1-5i | 7-1i | 1-1i | -3-5i | 3+1i |   …   |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | -5+7i | -7-3i | -5-1i | -1-7i | -7-5i | -5-3i | -3-1i | -3-1i | -3+1i | -1-5i | -7+1i | -1+3i | | -3+7i | 7-7i | 1-1i | -1+5i | -5-3i | -1-1i | 5+5i | 5-5i | 3+7i | 1+7i | 1+5i | -3-1i | | 3+5i | 1-5i | 3+3i | 3+3i | 3+3i | 3+5i | 3+7i | -1+3i | -3+3i | 7+1i | 1-1i | 7+5i | | 7+5i | 1-1i | -1-7i | 7-3i | 3-1i | -1-1i | 1+3i | -3-1i | 3+7i | -1-3i | 3+1i | -5+3i | | -1+3i | -3-3i | 7+1i | 3-1i | 3+5i | -3-7i | 7+1i | -7-7i | 1-7i | -3+7i | -3+1i | 3+5i | | -1+1i | 5-5i | 1+7i | 1-1i | -5-7i | -5-7i | -5-3i | 3+7i | 3-1i | -5-3i | '3-7i' | -1+7i | |

NOTE: All of spreading codebooks are normalized by multiplying ,which is () normalized matrix for the power constraints, . Here, .

NOTE: Tables 4-1, 4-2 and 4-3 can be quantized by other coefficients, e.g., QPSK, 9QAM, 16QAM.

#### MUI optimized sequence generation method.

MUI optimized sequence generation method starts with a set of orthogonal sequences as its base. Later, while taking into account the total number of required sequences, it is possible to create a spreading code sequence set with minimum average MUI. This is done by identifying all possible hyperplanes defined by the base set of orthogonal vectors and generating additional set of equaly spaced vectors with maximum distance.

The following equation shows the relationship between the number of orthogonal vector (N), the number of non-orthogonal vectors per hyperplane (L) and the sequence pool size (M):

.

Using this spreading code it is possible to multiplex several users on the same resource blocks.

An already generated sequence pool can be expended by enhancing the sequence pool. For example, assume the gNB generated a resource pool with orthogonal base 4 with 2 non orthogonal vectors per hyperplane. Using the calculations it is possible to generate a resource pool with orthogonal base 4 and 5 non orthogonal vectors per hyperplane. The new resource pool will still have the previously generated sequences thus concerving the need to redistribute codes to the UE’s. The sequences may be viewed in table 3.1.9-1 and table 3.1.9-2

The algorithm for generating MUI sequence along with more details can be found in *Annex X.8*.

Table 3.1.9-1 - N=4, L=2 proposed sequence pool

|  |  |  |  |
| --- | --- | --- | --- |
| a1 | a2 | a3 | a4 |
| 1 | 1 | 1 | 1 |
| 1 | 0+1i | -1 | -0-1i |
| 1 | -1 | 1 | -1 |
| 1 | -0-1i | -1 | 0+1i |
| 0.866+0.5i | 0.366 | 0.866-0.5i | 1.366 |
| 0.5+0.866i | -0.366 | 0.5-0.866i | 1.366 |
| 0.866+0.5i | 0.866-0.5i | 0.866+0.5i | 0.866-0.5i |
| 0.5+0.866i | 0.5-0.866i | 0.5+0.866i | 0.5-0.866i |
| 0.866+0.5i | 1.366 | 0.866-0.5i | 0.366 |
| 0.5+0.866i | 1.366 | 0.5-0.866i | -0.366 |
| 0.866+0.5i | -0+0.366i | -0.866+0.5i | -0-1.366i |
| 0.5+0.866i | -0-0.366i | -0.5+0.866i | -0-1.366i |
| 0.866+0.5i | 0.5+0.866i | -0.866-0.5i | -0.5-0.866i |
| 0.5+0.866i | 0.866+0.5i | -0.5-0.866i | -0.866-0.5i |
| 0.866+0.5i | -0.366 | 0.866-0.5i | -1.366 |
| 0.5+0.866i | 0.366 | 0.5-0.866i | -1.366 |

Table 3.1.9-2 – N=4, L=5 proposed sequence pool

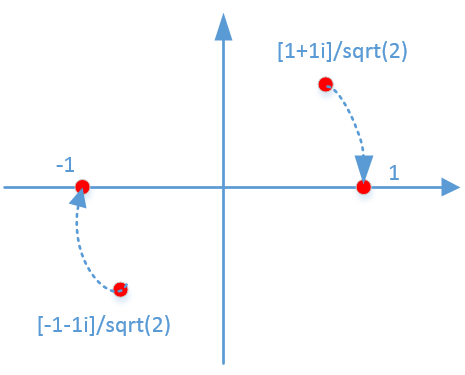
|  |  |  |  |
| --- | --- | --- | --- |
| a1 | a2 | a3 | a4 |
| 1 | 1 | 1 | 1 |
| 1 | 0+1i | -1 | -0-1i |
| 1 | -1 | 1 | -1 |
| 1 | -0-1i | -1 | 0+1i |
| 0.9659+0.2588i | 0.7071 | 0.9659-0.2588i | 1.2247 |
| 0.866+0.5i | 0.366 | 0.866-0.5i | 1.366 |
| 0.7071+0.7071i | 0 | 0.7071-0.7071i | 1.4142 |
| 0.5+0.866i | -0.366 | 0.5-0.866i | 1.366 |
| 0.2588+0.9659i | -0.7071 | 0.2588-0.9659i | 1.2247 |
| 0.9659+0.2588i | 0.9659-0.2588i | 0.9659+0.2588i | 0.9659-0.2588i |
| 0.866+0.5i | 0.866-0.5i | 0.866+0.5i | 0.866-0.5i |
| 0.7071+0.7071i | 0.7071-0.7071i | 0.7071+0.7071i | 0.7071-0.7071i |
| 0.5+0.866i | 0.5-0.866i | 0.5+0.866i | 0.5-0.866i |
| 0.2588+0.9659i | 0.2588-0.9659i | 0.2588+0.9659i | 0.2588-0.9659i |
| 0.9659+0.2588i | 1.2247 | 0.9659-0.2588i | 0.7071 |
| 0.866+0.5i | 1.366 | 0.866-0.5i | 0.366 |
| 0.7071+0.7071i | 1.4142 | 0.7071-0.7071i | 0 |
| 0.5+0.866i | 1.366 | 0.5-0.866i | -0.366 |
| 0.2588+0.9659i | 1.2247 | 0.2588-0.9659i | -0.7071 |
| 0.9659+0.2588i | 0+0.7071i | -0.9659+0.2588i | -0-1.2247i |
| 0.866+0.5i | -0+0.366i | -0.866+0.5i | -0-1.366i |
| 0.7071+0.7071i | 0 | -0.7071+0.7071i | -0-1.4142i |
| 0.5+0.866i | -0-0.366i | -0.5+0.866i | -0-1.366i |
| 0.2588+0.9659i | -0-0.7071i | -0.2588+0.9659i | -0-1.2247i |
| 0.9659+0.2588i | 0.2588+0.9659i | -0.9659-0.2588i | -0.2588-0.9659i |
| 0.866+0.5i | 0.5+0.866i | -0.866-0.5i | -0.5-0.866i |
| 0.7071+0.7071i | 0.7071+0.7071i | -0.7071-0.7071i | -0.7071-0.7071i |
| 0.5+0.866i | 0.866+0.5i | -0.5-0.866i | -0.866-0.5i |
| 0.2588+0.9659i | 0.9659+0.2588i | -0.2588-0.9659i | -0.9659-0.2588i |
| 0.9659+0.2588i | -0.7071 | 0.9659-0.2588i | -1.2247 |
| 0.866+0.5i | -0.366 | 0.866-0.5i | -1.366 |
| 0.7071+0.7071i | 0 | 0.7071-0.7071i | -1.4142 |
| 0.5+0.866i | 0.366 | 0.5-0.866i | -1.366 |
| 0.2588+0.9659i | 0.7071 | 0.2588-0.9659i | -1.2247 |

#### Symbol level processing with BPSK modulation and sub-RB RE mapping

**Modulation**

BPSK modulation can be adopted as a general modulation for any NOMA scheme for CP-OFDM waveform. In the transmitter side, the encoded bits are modulated with BPSK modulation as described in [TS 38.211]. On the other hand, phase rotation is adopted in receiver side such that a BPSK modulated symbol becomes a real number, where the imaginary component of the BPSK modulated symbol equals to zero. An example is shown in Figure 3.1.10-1 below. It exploits the additional degrees of freedom from the real and imaginary part of the received signal to enhance suppression of interference among usersBesides, simple receiver processing can be adopted, e.g. legacy MMSE-IRC processing.

BPSK modulation with low to middle code rate for CP-OFDM waveform can be beneficial. In [2], it can be seen that BPSK for MU-MIMO can outperform QPSK with low code rate or middle code rate.



**Figure 3.1.10-1: Constellation points of BPSK modulation for transmitter side and receier side**

**Sub-RB level RE mapping**

Different from RB-level mapping, a method of distributed RE mapping across RBs can be considered. For example, the frequency resources are divided into two parts, where each part occupies half of the REs of the total frequency resources and spans on the whole bandwidth. Occupying partial REs in allocated bandwidth can be regarded as comb-like structure. In such case, different multiplexed UEs can occupy different part of RE allocation, which would reduce the collision probability. There may be an issue that the code rate may be higher due to fewer REs for UL transmission. Therefore, it is import to achieve trade-off between collision probability and code rate.

With distributed RE mapping, the NOMA signal is spanning onto the whole bandwidth. Thus, frequency diversity can be achieved. Besides, comparing to the case the half bandwidth localized RE mapping, frequency diversity of distributed RE mapping is better. On the other hand, distributed RE mapping can be combined with comb-based DMRS structure.

#### IGMA

The proposed NOMA scheme, IGMA [19], can be depicted by Fig. 3.1.11-1. Basically the proposed IGMA can synergize *bit-level randomizer* and *randomized sparsity* by symbol-level interleaving with zero padding.



Fig. 3.1.11-1 – The schematic of IGMA transmitter

***Bit-level operation***:

The bit-level randomizer could be either of following:

*Option 1*: NR common bit level interleaving in rate matching + Rel-15 NR UE specific scrambling;

*Option 2*: UE specific bit level interleaving in rate matching.

Option 1 follows corresponding descriptions in Rel-15 NR specifications. While for the UE specific bit level interleaving in rate matching in option 2, the generation method could refer to Section 2.1.2 and Annex X-11 of [1]. Option 2 is preferably being studied for some cases, e.g. large-TBS cases in URLLC scenarios.

***Symbol-level operation***:

In the proposed IGMA design, the symbol level operation is the grid mapping process. More specifically, it consists of zero padding and symbol level interleaving process, the detailed generation method could refer to 2.2.4 and Annex X-11 of [1].

***Multi-Branch operation:***



Fig. 3.1.11-2. – The schematic of multi-branch transmission using IGMA

The multi-branch transmision from a UE using IGMA can be depicted as Fig. 3.1.11-2, which can be optionally considered on a need basis.

MA signatures supporting multi-branch transmission from a single UE can be branch specific symbol level grid mapping patterns (i.e. consists of zero padding and symbol level interleaving). Orthogonal zero padding patterns are preferred (e.g., [1,0,1,0] and [0,1,0,1]). In case of non-orthogonal zero padding patterns are used, the branch specific power/phase adjustments GN could be applied.

***Waveform***

IGMA could support both CP-OFDM and DFT-s-OFDM. When DFT-s-OFDM is applied, the DFT operation can be performed after grid mapping process and before RE mapping.

***DMRS extension for evaluation***

Extension with *CS(Cyclic Shift) + Comb + TD-OCC* based on NR Type-1 DMRS configuration for both CP-OFDM and DFT-s-OFDM, as detailed in [19]*.*

### Bit level processing based

#### LCRS

LCRS (Low Code Rate Spreading) transmission scheme is the same as the current NR UL transmission. As shown in Figure 3.2.1-1, it utilizes same coding procedure as Rel-15 NR PUSCH including channel encoding, rate matching, bit-level scrambling, and modulation. Both OFDMA and SC-FDMA are supported with and without DFT precoding. The bit-level scrambling part performs as the user separation by randomizing the signals from other users and then making multi-user interference as random as possible. Here the MA signatures are UE-specific scrambling codes and the scrambling function defined in Section 6.3.1.1 of 38.211 can be used for the generation of the scrambling codes.



Figure 3.2.1-1. Transmitter procedure for LRCS

#### IDMA (Interleave Division Multiple Access) – source 1 [21]

A user specific interleaver is used as the MA signature. The user specific interleaver can be placed before or after the modulator. Figure 3.2.2-1 shows the IDMA transmitter structure, where the user specific interleaver is placed before the modulator. The user specific interleaver is realized by using a user-independent interleaver preceded by a cylic shift block. Different users are allocated different cyclic shifts by the gNB.

The repetition factor is a degree of freedom in the design to control the overloading factor and the number of users to multiplex. Example reperion factor can be 2, but other values are also possible.

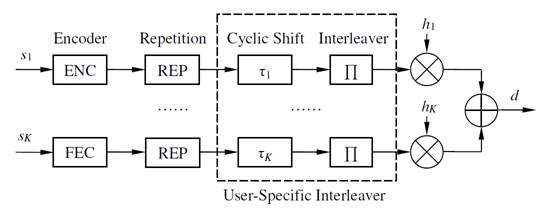


Figure 3.2.2-1: IDMA Transmitter Structure before modulator.

The ESE (Elementary Signal Estimator receiver is used to receive the IDMA multiplexed UEs. The block diagram of the ESE receiver is shown in Figure 3.2.2-2.



Figure 3.2.2-2: IDMA Receiver structure based on ESE receiver.

The steps of the receive processing are (where It is the number of ESE iteration and K is the numbers of users/layer multiplexed together – j denotes the RE index and k denotes the UE/layer index):

**Step 1: Initialization**

,  (3.2.2-1)

,  (3.2.2-2)

,  (3.2.2-3)

,  (3.2.2-4)

**Step 2: Iteration (Loop over** *It***)**

**Step 2.1: Update the statistics of receiver sum signal**

 (3.2.2-5)

 (3.2.2-6)

 (3.2.2-7)

 (3.2.2-8)

 (3.2.2-9)

**Step 2.2: First loop over** *K*

 (3.2.2-10a)

 (3.2.2-10b)



 (3.2.2-11a)



 (3.2.2-11b)

 (3.2.2-12a)

 (3.2.2-12b)

**End of first loop over** *K*

**Step 2.3: Second loop over** *K*

Step 2.3.1: De-interleaving

 (3.2.2-13a)

 (3.2.2-13b)

Step 2.3.2: De-repetition

 (3.2.2-14a)

 (3.2.2-14b)

with  and .

Step 2.3.4: De-Modulation

 (3.2.2-15)

with  for QPSK

Step 2.3.5: De-Coding

 (3.2.2-16)

Step 2.3.5: Extrinsic information

 (3.2.2-17a)

 (3.2.2-17b)

Step 2.3.6: Update the statistics of user signal

 (3.2.2-18a)

 (3.2.2-18b)

 (3.2.2-19a)

 (3.2.2­-19b)

**End of second loop over** *K*

**End of iteration over** *It*

#### IDMA (Interleave Division Multiple Access) – source 2 [22]

Figure 3.2.3-1 shows the basic structure of an IDMA-based NOMA transmission [23]. At the transmitter, UE payload is coded and then randomized prior to transmission in the shared channel. The randomization operation is user-specific, that is implemented by an interleaving function. The operation of the transmitter can be summarized in the following steps:

* The bit sequence input for a given code block to channel coding is denoted by , where  is the number of bits to encode. After encoding the bits are denoted by , where *N* is the number of bits in the coded block.
* The rate matching for LDPC code is defined per coded block and consists of bit selection and bit interleaving. The output bit sequence after rate matching is denoted as . The parameter *E* that reflects the effective spreading achieved through coding and rate matching is determined based on the expected overloading capability. The rate-matched sequence is then scrambled to produce the sequence [24].
* The scrambled block of bits , is interleaved in a UE-specific manner resulting in a block of interleaved bits . The employed interleaver function is based on random interleaving, however other implementations may be considered as well. As shown in Figure 3.2.3-2, the random interleaver changes the order of the elements of the input bit stream based on a permuted version of the input index. The permutation pattern is UE specific and it is considered as the index for MA signature for IDMA operation.
* The interleaved payload is then delivered to the modulator and the waveform generation functions [12].

Figure 3.2.3-1 IDMA transmitter Processing

In a multi-layer NOMA transmission, the same described process as shown in Figure 3.2.3-1 is re-instantiated according to the number of layers. Figure 3.2.3-3 shows an *L* layer IDMA transmitter where each layer is configured with a different IDMA signature, i.e., interleaving pattern.



Figure 3.2.3-2 Random interleaver



Figure 3.2.3-3 A L-layer IDMA-based NOMA transmitter

#### Coding based NCMA

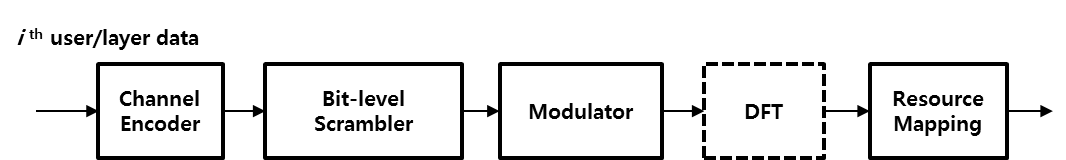


Figure 3.2.4-1 Transmitter procedure for coding based NCMA with NR legacy modulation

Coding based NCMA (Non-orthogonal Coded Multiple Access) scheme [15][16] utilize the same transmitter processing procedure as Rel-15 NR PUSCH including channel encoding, rate matching, bit-level scrambling and then modulator, as shown in Figure 3.2.4-1. Bit level scrambling function defined in TS 38.211 Section 6.3.1.1 [12] can be the MA signature as it is defined in a UE/layer-specific manner. To mitigate inter-user interference, MA signature of coding based NCMA is described in Section 2.1.1.

#### “STABLE” (Simultaneous Transmission Access Boosting Low laTency)

Figure 3.2.5-1 shows our proposed structure of TX (or UE) side processing at UE side (UE*k*) for UL NOMA.

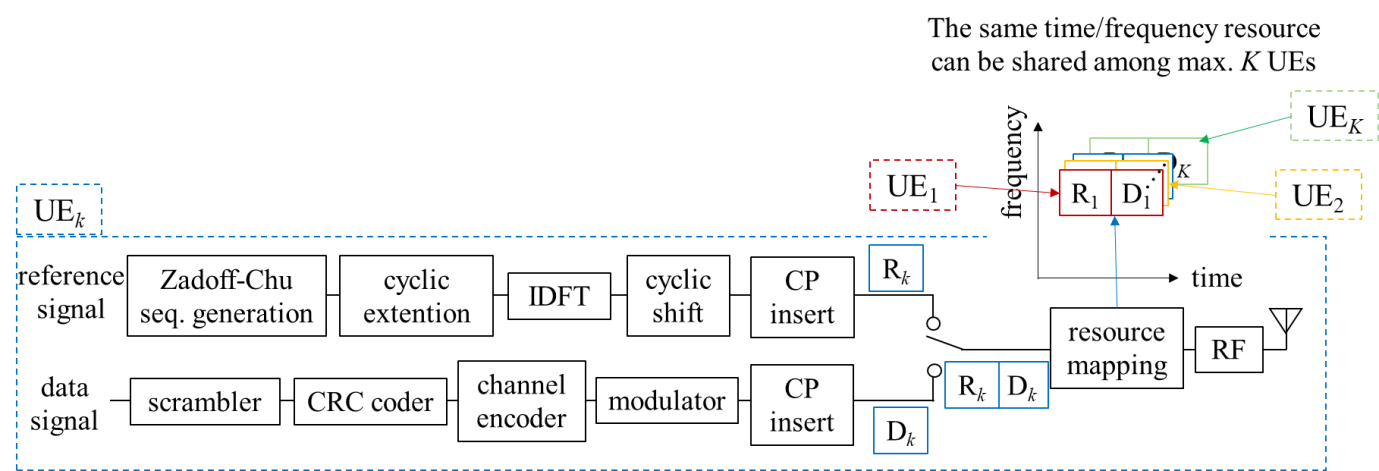


Figure 3.2.5-1 Proposed UL NOMA Transmitter Side Processing

Upper layer in Figure 3.2.5-1 shows the processing of reference signal (RS*k*) for UE*k* (*k*=1,2…,*K*), where *K* is the size of RS pools. RS for each UE is given by network side so that the RS collision doesn’t occur among UEs using the same time/frequency RB. RS***k*** is based on Zadoff-Chu sequence with user-specific cyclic shifts in frequency domain. Since each RS*k* with different cyclic shift is orthogonal each other, RS is used for UE identification as well as the channel estimation for UE***k***. At receiver side (gNB), channel impulse response (CIR) is obtained by multiplying complex conjugate of the Zadoff-Chu sequence.

Lower layer in Figure 3.2.5-1 shows the processing of the data signal *Dk* for UE*k*. Data scrambling, CRC coding, channel encoding, modulating and CP insert are conducted in the same way as LTE.

Reference signal (RS*k*) and data signal D*k* are mapped onto the same slot. Therefore reference signals RS*k* (*k*=1,2…,*K*) are orthogonal among each UE*k* as long as K is smaller than or equal to the available size of RS. Data signals D*k* (*k*=1,2…,*K*) are superimposed on the same time/frequency resource (i.e. non-orthogonal).

Data separation at receiver side (BS) is based on the received power difference of each UE and channel difference estimated by the RS. Therefore, accurate transmission power control for each UE is required to enhance the reliability of data separation in this scheme. Since this scheme has no spreading for data, low latency transmission is achieved. We named this NOMA scheme (UL NOMA with low latency) as “STABLE” (Simultaneous Transmission Access Boosting Low laTency).

(For reference)

With the scheme described in Section 2, link level simulation is conducted for the case shown in Table 3.2.5-1. Figure 3.2.5-2 shows the simulation results for TDL-C environment.

Table 3.2.5-1 LLS assumptions

|  |  |
| --- | --- |
| Item | Spec., or Value |
| Scenario | mMTC |
| Carrier Frequency | 700 MHz |
| Rx Number | 2 |
| SNR distribution | Unequal |
| Waveform | DFT-s-OFDM |
| MA signature allocation | Fixed |
| Channel Mode | TDL-C 300ns, 3km/h |
| Channel Estimation | Realistic |
| TBS | 10 |
| Timing offset/Frequency offset | No |
| Overloading factor | 100 to 500% |
| Receiver | MMSE-SIC |



Figure 3.2.5-2 Simulation Results for TDL-C 300ns, 3km/h environment for overloading factor up to 500 % (SNR is the mean of true value of received signal power of each UE to Noise Ratio)

### Miscellaneous schemes

#### ACMA

Text to be added to Section 2.6 -1) of R1-1809974.

🡨**-------------------------------------------Begin Text Update-----------------------------------------------**🡪

Random time staggering is a general technique that can apply to many proposed schemes. In combination with other MA signatures such as bit level or symbol level processing, or scrambling, randomly staggered timing is used to improve overloading capability by distributing multi-user interference randomly. Time staggering can be used when time slots are aggregated in N time slots for NOMA application. The start time of each transmission is randomly distributed over the OFDM symbols of the first N-1 time slots, or 14(N-1) OFDM symbols in a total time period of N time slots as shown in Figure 2.6.1. This figure also shows that at the end of slot N all NOMA transmissions will have completed allowing other uses of the resources.

1

2

…

N-1

N

Slots for

Other use

Slots for

Other use

Aggregated resource

Transmission Start any time in this interval

Figure 2.6.1. Time Staggered Transmission time in N aggregated time slots.

A block diagram for the transmitter for a single-branch ACMA [63] illustrating the use of time-staggered transmission in conjunction with bit or symbol-level scrambling is shown in Figure 2.6.2.



Figure 2.6.2. Block Diagram of ACMA transmit (single branch)

🡨**-------------------------------------------End Text Update-----------------------------------------------**🡪

*Detailed description of ACMA are as below.*

A block diagram of the ACMA [20] transmit side (for single branch) is shown in Figure 3.3.1-1.



Figure 3.3.1-1. ACMA transmit block diagram (single branch)

After mapping to constellation points (QPSK), the symbols are scrambled by the random sequence ci,k,nwhich is the *i*th symbol of the *k*th UE of the *n*th transmission, and dk,n is the delay value for the *k*th UE for the *n*th transmission. Note the 3 indices for the scrambling pattern and 2 indices for the delay value (delay is applied to each transmission while scrambling is applied to each symbol). This notation allows the MA signature for each UE (index *k*) and/or each transmission (index *n*) to be either randomly selected or pre-assigned.

ACMA uses a combination of randomly staggered timing and symbol-based scrambling, based on pseudo-random sequences such as Gold sequences with different seeds as MA signature (section 2.2.3.) The receiver is based on standard ESE receiver. No additional MMSE detection is needed.

For higher TBS sizes multi-branch transmission is adopted (section 2.4.). In particular, multi-branch transmission before FEC (scheme a) is adopted for two reasons:

1. It allows the receiver to treat each branch as if it is an additional user.

2. It allows the receiver to stop iterating on already converged branches.

For TBS sizes of 10 and 20 bytes, a single branch is used, whereas for TBS sizes of 40, 60, and 75 bytes, 3 branches are used with a uniform power difference, p, of 3.5 dB between branches

Consider the case of M branches. The power of the ith branch, in dB, is given by



for even M; and for odd M.

ACMA uses randomly staggered timing to improve overloading capability by randomly distributing multi-user interference, wherein the start time of each transmission is randomly distributed over the symbols of a slot. Figure 3.3.1-2 illustrates the range of start and end of transmissions.



Figure 3.3.1-2. Illustration showing distribution of start and end timing of transmissions

The transmission can be symbol synchronous or symbol asynchronous without any significant performance difference. To support K simultaneous UEs per slot over a time period corresponding to N consecutive slots, K x N UEs access the channel. ACMA uniformly randomizes the starting transmission point of K x N UEs to any OFDM symbol (for symbol synchronous transmission) within the first N-1 slots. By the end of Nth slot, all K x N UEs are done transmitting and the channel can be used for another purpose, to support other services or TDD operation. In our simulations, we use N=5.

For high overloading capability it is necessary to both increase the number of DMRS symbols and to obtain a larger number of DMRS sequences. As an example, three DMRS symbols can be Sa, Sb, and Sc. Take the case of 6 RB or 72 subcarriers. Each of these symbols will be a size 71 ZC sequence, cyclically extended to 72. There are 70 different ZC sequences available of length 71. In addition, each cyclic shift of each of these sequences is available. Thus, there are 70x72 sequences. In the case where, for example, 3 DMRS symbols are used, each UE is assigned 3 of the available 70x72 sequences. A 1 to 1 mapping between the ZC sequence assignment and the pseudo-random symbol scrambling code is used.

#### RAMA (Rate adaptative multiple access) for multi-branch structure

*Multi-branch structures are described in Section 2.2.4. The details for realizing adaptative coding rate for multi-branch structure in Figure 11(a) of Section 2.4 (i.e., option 1 in Section 3.3.2.1)and Figure 11(d) of Section 2.4(d) (i.e., option 2 in Section 3.3.2.1) are provided below.*

3.3.2.1 Adaptative coding rate for multi-branch structure

1. Required parameters for multi-brach structure

The related parameters for multi-branch structure in Figure 11(a) and (d) of Section 2.4 are configured or pre-configured by higher-layer signalling or dynamic signalling, as follows

* Option 1: Figure 11(a) in Section 2.4

|  |  |
| --- | --- |
| Parameter | Notation of parameters |
| Number of branches | *L* |
| Coding rate of *l*-th branch |  |
| NR legacy Modulation of *l*-th branch; superscript “(1)” represents Option 1 |  |
| Power coefficient of *l*-th branch | , satisfying |
| Rotation angle of *l*-th branch |  |
| TBS of *l*-th branch |  |
| Total TBS of a user |  |

* Option 2: Figure 11(d) in Section 2.4

|  |  |
| --- | --- |
| Parameter | Notation of parameter |
| Number of branches | *L* |
| Coding rate of *l*-th branch |  |
| NR legacy modulation; superscript “(2)” represents Option 2 |  |
| Multiplexing function, which maps *L* streams of coded bits into one stream of coded bits |  |
| TBS of *l*-th branch |  |
| Total TBS of a user |  |

1. Source bit partition

For each user, the source data bits are partitioned into *L* streams of data bits, i.e., , where .

1. Channel coding and bit level processing

For the *l*-th branch, CRC can be attached to to generate . Then is encoded to generate coded bits . Bit-level processing, such as branch-specific bit-level interleaving and/or scrambling defined in *Section 2.1* are not precluded.

1. Bit-to-symbol mapping

* Option 1: Branch-wise modulation followed by superposition of multiple branches as show in Figure 11(a) of *Section 2.4*.

For the *l*-th branch, is mapped to the modulated symbols according to NR legacy modulation . The symbol-level processing, such as symbol-level spreading, is not precluded. The generated symbols in the *l*-th branch are defined as . The output of symbols after superposition is defined as

Symbol-level processing based on after modulation, as mentioned in *Section 2.2.1 and 2.2.2* is not precluded.

* Option 2: Multi-branch transmission before FEC and combined before modulation as show in Figure 11(d) of *Section 2.4*.

maps the coded bits of *L* branches into a single stream of coded bits . Then is modulated according to . Symbol-level processing based on after modulation, as mentioned in *Section 2.2.1 and 2.2.2* is not precluded.

3.3.2.2 Parameter selection and typical implementation examples

Assume that *l*1-th branch shall have better protection than *l*2-th branch if *l*1< *l*2. Some exemplary criteria of Options 1 and 2 are respectively listed as follows:

* Option 1

At least following cases can be considered for the (pre-)configuration or selection of , , and ,

* Case 1: ,,.
* Case 2: ,,.
* Case 3: ,,.
* Case 4: ,,.
* Case 5: ,,.
* Case 6: ,,.
* Case 7: ,,.

Besides, is a fixed value, which is calculated to optimize the capacity constrained by the composite constellation according to . Some examples for the parameters in Option 1 are provided in Table 3.3.2-1.

**Table 3.3.2-1 Examples of parameters in Option 1**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Index | *L* |  |  |  |  |  |  |  |
| 0 | 2 | 1 |  |  |  |  | 0 |  |
| 1 | 2 | 0.83 |  |  |  |  | 0 |  |
| 2 | 2 | 1 | BPSK | BPSK | 0.707 | 0.707 | 0 |  |
| 3 | 2 | 1 | QPSK | BPSK | 0.9 | 0.45 | 0 |  |
| 4 | 2 | 1 | QPSK | QPSK | 0.9 | 0.45 | 0 | 0 |
| 5 | 2 | 1 | QPSK | QPSK | 0.707 | 0.707 | 0 |  |

* Option 2

Some examples of parameters in Option 2 are provided in Table 3.3.2-2, where denotes the *j*-th bit of *i*-th branch.

**Table 3.3.2-2 Examples of coding rate ratio, modulation and MUX in Figure 11(d) of Section 2.4 (i.e., Option 2)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Index | *L* |  |  | Outputs of MUX |
| 0 | 2 | 0.7 | QPSK |  |
| 1 | 2 |  | QPSK |  |
| 2 | 2 | 0.8 | 16QAM |  |
| 3 | 2 | 1 | 16QAM |  |

Given total TBS and PRB size, according to the (relationships among) parameters in Table **3.3.2-1 and 3.3.2-2**, all parameters listed in Section 3.3.2.1 -1) can be derived.

#### Sparse resource mapping

Text to be added to Section 2.3 of R1-1809974.

🡨**-------------------------------------------Begin Text Update-----------------------------------------------**🡪

2.3 UE-specific sparse RE mapping

Sparse RE mapping is proposed in some NOMA schemes including SCMA [39], PDMA [43], and IGMA [47], where zeros are trasnmitted in some REs within the assigned PRBs.

It is noticed that in some cases, the sparse RE mapping can also be realized by applying sparse spreading sequences as shown in Section 2.2.1 [40][41][43][46][50].

For a NOMA system with regular-sparse resource mapping, where users share resources in a non-orthogonal fashion, design parameters are the sparsity of the signatures (number of non-zero elements as fraction of ) and the overloading factor . An example is depicted in Figure x, where the explicit sparse resource mapping is represented as a binary matrix . As an example shown in Figure x, the construction has the property that the number of ones in each row, as well as the number of ones in each column, is fixed. The overlap between the columns of is at most 1 (i.e. the UE-specific signatures overlap at most one position).

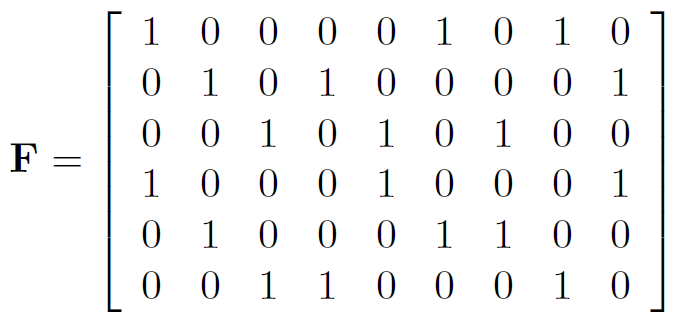


Figure x. Example of UE-specific sparse resource mapping. The rows correspond to the resources, and the columns represent the UE-specific signatures. In the example, users in total are mapped to resources, where users access the same resource, and each user accesses resources. The corresponding overloading factor is .

🡨**-------------------------------------------End Text Update-----------------------------------------------**🡪

In practice, it is important to have a flexible design of the matrix , with appropriate dimension scaling, which allows to trade-off different service requirements.

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# **Change history**

|  |  |  |
| --- | --- | --- |
| Version and date | Company | Comment |
| v00 | ZTE | Initial version, as a template |
| v01 | All | Merged version with companies’ input on scheme description |
| v02, 2018/8/30 | ZTE, Fraunhofer, vivo | Updates based on email discussion |
| v03, 2018/8/31 | ZTE, Samsung | Updates based on email discussion |
| V04, 2018/8/31 | HUGHES, Nokia, InterDigital, ZTE, Qualcomm | Updates based on email discussion |
| V05, 2018/9/3 | Samsung | Updates based on email discussion |
| V06, 2018/9/3 | Fraunhofer | Updates based on email discussion |