IEEE P802.11  
Wireless LANs

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| PDT PHY Enhanced Long Range (ELR) | | | | |
| Date: 2024-11-19 | | | | |
| Author(s): | | | | |
| Name | Affiliation | Address | Phone | email |
| Lin Yang | Qualcomm |  |  | linyang@qti.qualcomm.com |
| Wook Bong Lee | Apple |  |  |  |
| Rethna Pulikkoonattu | Broadcom Inc |  |  |  |
| Rui Yang | InterDigital |  |  |  |
| Jiyang Bai |  |  |  |  |
| Xuwen Zhao |  |  |  |  |
| Shengquan Hu | MediaTek |  |  |  |
| Jianhan Liu | MediaTek |  |  |  |
| Juan Fang | Intel |  |  |  |
| Leonardo Lanante | Ofinno |  |  |  |
| Mahmoud Kamel | InterDigital |  |  |  |
| Bo Sun | Sanechips |  |  |  |
| Thomas Handte | Sony |  |  |  |
| Genadiy Tsodik | Huawei |  |  |  |
| Bo Cao | ZTE |  |  |  |
| Daniel Verenzuela | Sony |  |  |  |
| Rocco Di Taranto | Ericsson |  |  |  |
| Ying Wang | InterDigital |  |  |  |
| Bo Gong | Huawei |  |  |  |
| Junghoon Suh | Huawei |  |  |  |
| Dongguk Lim | LG Electronics |  |  |  |
| Yunbo Li | Huawei |  |  |  |
| Chenchen Liu | Huawei |  |  |  |
| Ming Gan | Huawei |  |  |  |
| Yapu Li | Oppo |  |  |  |
| Toshizoh NOGAMI | Sharp |  |  |  |
| Pelin Salem |  |  |  |  |
| Lei Zhou | H3C |  |  |  |
| Jeongki Kim |  |  |  |  |
| Sigurd Schelstraete | MaxLinear |  |  |  |
| Tzu-Hsuan (Henry) Chou | Qualcomm |  |  |  |
| Youhan Kim | Qualcomm |  |  |  |
| Xiandong Dong | Xiaomi |  |  |  |
| Alfred Asterjadhi | Qualcomm |  |  |  |
| Nima Namvar | Xiaomi |  |  |  |
| Ross Jian Yu | Huawei |  |  |  |
| Insun Jang | LG Electronics |  |  |  |
| Ke Zhong | Ruijie |  |  |  |
| Aditi Singh | Charter |  |  |  |
| Xiaofei Wang | InterDigital |  |  |  |
| Qinghua Li | Intel |  |  |  |
| Rong Zhang | Apple |  |  |  |
| Hari Ram Balakrishnan | NXP |  |  |  |
| Aniruddh Rao Kabbinale | Samsung |  |  |  |
| Rui Cao | NXP |  |  |  |
| Yan Zhang | Apple |  |  |  |
| Alice Chen | Qualcomm |  |  |  |

Abstract

This document contains Proposed Draft Text (PDT) for the Enhanced Long Range (ELR) feature of the proposed TGbn (UHR, Ultra High Reliability) amendment to the 802.11 standard.

# Revision information

The following is a summary of the important changes that occurred within each revision of this document:

|  |  |
| --- | --- |
| **Revision** | **Major changes** |
| 0 | Initial revision |
| 1 | Added contents based on relevant motions in 11-24/0171r21. Mainly ELR PHY. |
|  |  |
|  |  |
|  |  |
|  |  |

# Introduction

Interpretation of a Motion to Adopt

A motion to approve this submission means that the editing instructions and any changed or added material are actioned in the TGbn Draft. The abstract, revision information, introduction, explanation of the proposed changes, and references sections are not part of the adopted material.

***Editing instructions formatted like this are intended to be copied into the TGbn Draft (i.e. they are instructions to the 802.11 editor on how to merge the text with the baseline documents).***

## Explanation of the proposed changes:

The proposed changes to the 802.11 TGbn draft within this document are based on the following motions adopted by the TGbn task group.

### Relevant passing motions:

[Motion #24, [1]]

* Define Enhanced Long Range (ELR) PPDU and potentially other Range Extension mechanism.

[Motion #32, [1]]

* ELR PPDU starts with a legacy preamble in the PPDU for the ELR transmission
  + The legacy preamble contains the L-STF, L-LTF, L-SIG, RL-SIG, and U-SIG.

[Motion #33, [1]]

* In the U-SIG field of a UHR ELR PPDU, the PHY Version Identifier is set to 1. And the PPDU Type And Compression Mode is used to indicate ELR PPDU.

[Motion #36, [1]]

* ELR-SIG is located right after ELR-LTF in ELR PPDU
  + Note that ELR-LTF is the short name of UHR-LTF for ELR PPDU.

[Motion #74, [1]]

* Define an enhanced long range (ELR) PPDU in IEEE 802.11bn with the following targets
  + Downlink and Uplink in 2.4 GHz (within BSS range with 11b beacon)
  + Uplink only in 5 GHz and 6 GHz bands
  + Minimum data rate is greater than or equal to 1.5 Mbps.

[Motion #75, [1]]

* In ELR PPDU, STA boosts L-STF and L-LTF by 3 dB
  + For UL, non-AP STA corrects CFO before transmission
  + Note: Non-AP STA pre-correction CFO requirement for residual CFO is TBD.

[Motion #76, [1]]

* ELR PPDU only supports the following two modulation and coding schemes:
  + BPSK with coding rate R=1/2
  + QPSK with coding rate R=1/2.

[Motion #77, [1]]

* ELR transmission shall apply the phase rotations as below for both BPSK and QPSK modulations
  + The rotation of -1 will be applied on data subcarriers of lower half of RU3 and upper half of RU4 for 52-tone regular RU (RRU52) on 20MHz.

A diagram of a graph

Description automatically generated

[Motion #78, [1]]

* ELR packet detection is done at L-STF, which has same length as legacy with 3dB power boosting
  + L-LTF also has same length as legacy with same power boosting as L-STF.

[Motion #79, [1]]

* U-SIG carries STA-ID in ELR PPDU.

[Motion #80, [1]]

* Define two ELR-Mark symbols for ELR mode classification
  + ELR-Mark symbols carry a known sequence to receiver
  + ELR-Mark symbols carry BSS color info in ELR-Mark sequence
  + No power boosting on ELR-Mark symbols
  + Two ELR-Mark symbols are both QBPSK modulated on data subcarriers
  + ELR-Mark symbols use the following tone plan
    - 4 regular pilots as EHT-SIG + 48 data tones.

[Motion #81, [1]]

* 11bn defines the following PPDU frame format for ELR
  + PE TBD.



[Motion #82, [1]]

* ELR PPDU has 3dB boosting applied on both ELR-STF and ELR-LTF
  + ELR PPDU has ELR-STF duration and sequence same as that of UHR DL SU/MU PPDU
    - 4us using EHT-STF sequence for 20MHz
  + ELR PPDU defines a fixed/single mode of LTF+GI
    - 11bn supports 2x LTF+1.6us GI only for ELR PPDU
    - 11bn uses two UHR-LTF symbols for ELR PPDU
* Note that ELR-STF/ELR-LTF are the short names of UHR-STF/UHR-LTF for ELR PPDU

[Motion #83, [1]]

* ELR PPDU defines two symbols for ELR-SIG, specifically
  + ELR PPDU defines separately encoded two symbols for ELR-SIG
    - Each symbol has separate CRC and tail bits (6 bits)
  + ELR-SIG has same tone plan and duplication scheme as ELR-data and BCC encoded with MCS0.

[Motion #91, [1]]

* The U-SIG field in ELR PPDU consists of 2 OFDM symbols and includes the same version independent fields defined in the U-SIG field of EHT PPDU
* The details for the version dependent fields are TBD.

[Motion #92, [1]]

* The BW of ELR PPDU is 20MHz and one Spatial stream is used for ELR transmission.

[Motion #93, [1]]

* In the ELR transmission, a repeating of 52-tone RRU is used in 20MHz.
  + The same data is repeated in four 52-tone RRUs in 20 MHz.
  + The subcarrier allocation of 52-tone RRU equals the 52-tone RU defined in 11be.

[Motion #94, [1]]

* ELR LDPC rate matching will reuse the existing 802.11ac LDPC rate matching with 1-bit LDPC extra OFDM symbol indication.

[Motion #95, [1]]

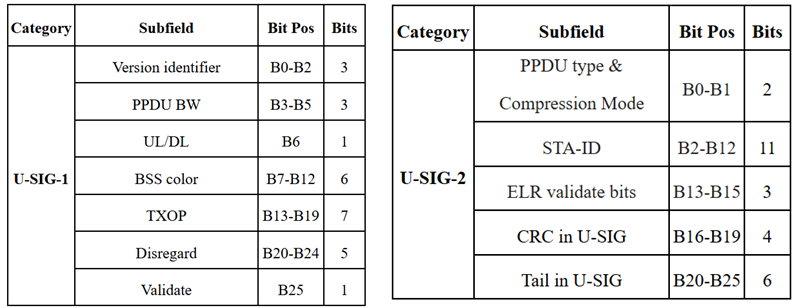
* ELR-SIG will use the following two OFDM symbols design.

A black background with a black square

Description automatically generated with medium confidence

[Motion #96, [1]]

* The contents of the U-SIG field in ELR PPDU is defined as follows.



* + ELR PPDU indication: PPDU type & compression mode set to ‘11’.
  + STA-ID (11 bit): B2-B12 bit in USIG-2.
  + ELR validate bits (B13-B15 of USIG-2): Set to all ‘1’ for ELR PPDU.
  + Note: B11-B15 – in EHT MU PPDU indicates “Number of EHT-Sig symbols”, and in UHR MU PPDU indicates “Number of UHR-Sig symbols”

[Motion #104, [1]]

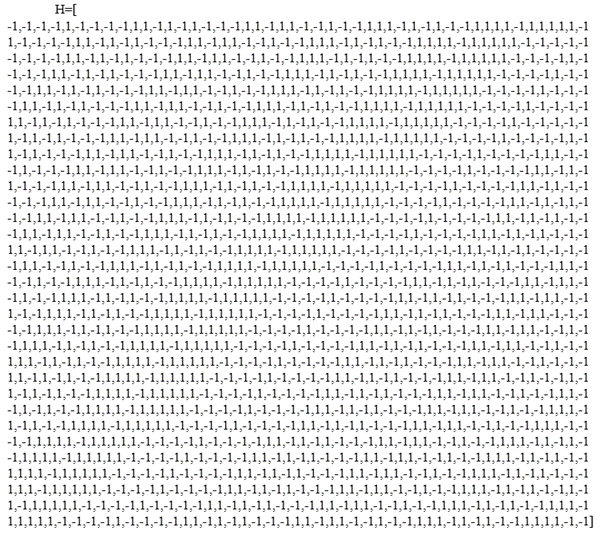
* ELR Mark symbols will be composed of two 1x OFDM symbols. Each symbol will have a duration of 4μS (3.2μS + GI=0.8μS).

[Motion #105, [1]]

* ELR Mark symbols will have the following tone mapping:
  + The 48 data tones are Q-BPSK mapped
  + The pilots follow BPSK mapping (polarity -1 applied to [1,1,1,-1])

[Motion #94, [1]]

* Adopt the ELR Mark sequence design as described by the matrix H in 24/1571r2. The detailed design is as described in the slides 8-9 of 24/1571r2.
  + 𝐻́  = [𝐻 𝐻𝕁; 𝐻 -𝐻𝕁], where 𝕁 is the exchange matrix of size 48x48.



[Motion #110, [1]]

* Pilot values and mapping rules of ELR-SIG and Data symbols in ELR PPDU are the same as that of four RRU52 in DL OFDMA.

# Text to be adopted begins here:

***TGbn editor: Please add the following new subclauses for Enhanced Long Range PPDU to the 802.11bn draft D0.1:***

# 38.3.6 UHR PPDU formats

TBD UHR PPDU formats are defined: UHR … PPDU, …, and UHR ELR PPDU.

The format of the UHR ELR PPDU is defined in Figure 38-xx (UHR ELR PPDU format). This format is used for SU transmission.



Figure 38-xx — UHR ELR PPDU format

The fields of the UHR ELR PPDU format are summarized in Table 38-yy (UHR ELR PPDU fields).

Table 38-yy — UHR ELR PPDU fields

|  |  |
| --- | --- |
| Field | Description |
| L-STF | Non-HT Short Training field |
| L-LTF | Non-HT Long Training field |
| L-SIG | Non-HT SIGNAL field |
| RL-SIG | Repeated Non-HT SIGNAL field |
| U-SIG | Universal SIGNAL field |
| ELR-MARK | ELR MARK field |
| UHR-STF | UHR Short Training field |
| UHR-LTF | UHR Long Training field |
| ELR-SIG | ELR SIGNAL field |
| Data | The Data field carrying the PSDU(s) |
| PE | Packet Extension field |

The L-STF, L-LTF, L-SIG, RL-SIG, U-SIG, UHR-STF, UHR-LTF, and PE fields are present in all UHR PPDU formats. The ELR-MARK and ELR-SIG fields are present only in the UHR ELR PPDU format.

# 38.3.7 Enhanced Long Range PPDU

A UHR Enhanced Long Range (ELR) PPDU can be used to overcome the link budget imbalance between downlink and uplink or can be used to achieve higher data rate when compared to a DSSS PPDU defined in Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications).

A UHR ELR PPDU is applicable for 2.4 GHz, 5 GHz, and 6 GHz bands in uplink, and only for 2.4 GHz in downlink. A UHR ELR PPDU is defined only for 20 MHz PPDU bandwidth, a single spatial stream and UHR-MCSs 0 and 1 with four times frequency domain duplication over 52-tone regular RUs (RRU52s or 52-tone RRUs) in primary 20 MHz channel. UHR ELR PPDU supports using BCC and LDPC coding with codeword block length up to 1944 bits. A UHR ELR PPDU sets the PPDU Type And Compression Mode subfield in the U-SIG field (Table 38-xxx (U-SIG field of a UHR ELR PPDU)) to 3, and includes the ELR-MARK field right after the U-SIG field.

# 38.3.8 Transmitter block diagram

The generation of each field in a UHR PPDU uses many of the following blocks:

1. Pre-FEC PHY padding
2. Scrambler
3. FEC (BCC or LDPC) encoders
4. Post-FEC PHY padding
5. Stream parser
6. Segment parser (for RU or MRU size larger than 996 tones)
7. BCC interleaver
8. Constellation mapper
9. DCM tone mapper
10. Pilot insertion
11. Replication over multiple 20 MHz (for bandwidth greater than 20 MHz)
12. LDPC tone mapper
13. Segment deparser
14. Frequency domain duplication over 52-tone regular RUs (RRU52s) if a UHR ELR PPDU is transmitted.
15. CSD per spatial stream insertion
16. Spatial mapper
17. Frequency mapping
18. IDFT
19. CSD per chain insertion
20. GI insertion
21. Windowing

Figure 38-xx (Transmitter block diagram for the UHR ELR-SIG field of a UHR ELR PPDU) shows the transmit process for the UHR ELR-SIG field of a UHR ELR PPDU.

A diagram of a system

Description automatically generated

**Figure 38-xx Transmitter block diagram for the UHR ELR-SIG field of a UHR ELR PPDU**

Figure 38-xx (Transmitter block diagram for the Data field of a UHR ELR PPDU transmission with BCC encoding) shows the transmit blocks used to generate the Data field of a UHR ELR PPDU with BCC encoding.

A diagram of a computer system

Description automatically generated

**Figure 38-xx Transmitter block diagram for the Data field of a UHR ELR PPDU transmission with BCC encoding**

Figure 38-xx (Transmitter block diagram for the Data field of a UHR ELR PPDU transmission with LDPC encoding) shows the transmit blocks used to generate the Data field of a UHR ELR PPDU with LDPC encoding.

A diagram of a computer system

Description automatically generated

**Figure 38-xx Transmitter block diagram for the Data field of a UHR ELR PPDU transmission with LDPC encoding**

# 38.3.9 Overview of the PPDU encoding process

## 38.3.9.1 General

This subclause provides an overview of the UHR PPDU encoding process. A UHR ELR PPDU shall comply with transmit requirements as described in 38.3.19 (Transmit requirements for a UHR ELR PPDU). A UHR TB PPDU shall comply with the transmit requirements as described in 38.3.18 (Transmit requirements for PPDUs sent in response to a triggering frame).

## 38.3.9.2 Construction of L-STF

Construct the L-STF field as defined in 38.3.14.3 (L-STF) with the following highlights:

1. Determine the channel bandwidth from the TXVECTOR parameter CH\_BANDWIDTH.
2. Sequence generation: Generate the L-STF sequence over the channel bandwidth as described in 38.3.14.3 (L-STF). Apply a 3 dB power boost if transmitting a UHR ELR PPDU as described in 38.3.14.3 (L-STF).
3. Phase rotation: Apply appropriate phase rotation for each occupied 20 MHz subchannel as described in 38.3.13 (Mathematical description of signals) and 38.3.13.4 (Transmitted signal).
4. IDFT: Compute the inverse discrete Fourier transform.
5. CSD per chain: Apply CSD per chain for each transmit chain as described in 38.3.14.2.1 (Cyclic shift for pre-UHR modulated fields).
6. Insert GI and apply windowing: Prepend a GI () and apply windowing as described in 38.3.13 (Mathematical description of signals).
7. Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 38.3.13 (Mathematical description of signals) and 38.3.14 (UHR preamble) for details.

## 38.3.9.3 Construction of L-LTF

Construct the L-LTF field as defined in 38.3.14.4 (L-LTF) with the following highlights:

1. Determine the channel bandwidth from the TXVECTOR parameter CH\_BANDWIDTH.
2. Sequence generation: Generate the L-LTF sequence over the channel bandwidth as described in 38.3.14.4 (L-LTF). Apply a 3 dB power boost if transmitting a UHR ELR PPDU as described in 38.3.14.4 (L-LTF).
3. Phase rotation: Apply appropriate phase rotation for each occupied 20 MHz subchannel as described in 38.3.13 (Mathematical description of signals) and 38.3.13.4 (Transmitted signal).
4. IDFT: Compute the inverse discrete Fourier transform.
5. CSD per chain: Apply CSD per chain for each transmit chain as described in 38.3.14.2.1 (Cyclic shift for pre-UHR modulated fields).
6. Insert GI and apply windowing: Prepend a GI () and apply windowing as described in 38.3.13 (Mathematical description of signals).
7. Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the carrier frequency of the desired channel and transmit. Refer to 38.3.13 (Mathematical description of signals) and 38.3.14 (UHR preamble) for details.

## 38.3.9.7 Construction of ELR-MARK

The ELR-MARK field consists of two OFDM symbols. Construct the ELR-MARK field as defined in 38.3.14.8 (ELR-MARK field) with the following highlights:

1. Determine the BSS color from the TXVECTOR parameter BSS\_COLOR.
2. Sequence generation: Generate the ELR-MARK sequence corresponding to the chosen BSS color as described in 38.3.14.8 (ELR-MARK field). Assign the first 48 elements of the sequence to the first OFDM symbol of the ELR-MARK field, and the remaining 48 elements of the sequence to the second OFDM symbol of the ELR-MARK field.

Steps below apply for each OFDM symbol of the ELR-MARK field:

1. Constellation mapper: QBPSK modulate the 48 elements and map them onto the 48 data tones of the OFDM symbol as described in 38.3.14.8 (ELR-MARK field).
2. Pilot insertion: Insert pilots as described in 38.3.14.8 (ELR-MARK field).
3. IDFT: Compute the inverse discrete Fourier transform.
4. CSD per chain: Apply CSD per chain for each transmit chain as described in 38.3.14.2.1 (Cyclic shift for pre-UHR modulated fields).
5. Insert GI and apply windowing: Prepend a GI () and apply windowing as described in 38.3.13 (Mathematical description of signals).
6. Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the carrier frequency of the desired channel and transmit. Refer to 38.3.13 (Mathematical description of signals) and 38.3.14 (UHR preamble) for details.

## 38.3.9.9 Construction of UHR-STF

Construct the UHR-STF field as defined in 38.3.14.10 (UHR-STF) with the following highlights:

1. Sequence generation: Generate the UHR-STF in the frequency domain over the bandwidth indicated by the TXVECTOR parameter CH\_BANDWIDTH as described in 38.3.14.10 (UHR-STF). Apply a 3 dB power boost if transmitting a UHR ELR PPDU as described in 38.3.14.10.4 (UHR-STF for ELR PPDU).
2. CSD: Apply CSD for each spatial stream as described in 38.3.14.2.2 (Cyclic shift for UHR modulated fields).
3. Spatial mapping: Apply the *Q* matrix as described in 38.3.14.10 (UHR-STF).
4. IDFT: Compute the inverse discrete Fourier transform.
5. Insert GI and apply windowing: Prepend a GI of 0.8 μs for UHR MU PPDU and UHR ELR PPDU, and 1.6us for UHR TB PPDU, respectively. Apply windowing as described in 38.3.13 (Mathematical description of signals).
6. Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 38.3.13 (Mathematical description of signals) and 38.3.14 (UHR preamble) for details.

## 38.3.9.10 Construction of UHR-LTF

Construct the UHR-LTF field as defined in 38.3.14.11 (UHR-LTF) with the following highlights:

1. Sequence generation: Generate the UHR-LTF sequence in frequency domain over the bandwidth indicated by CH\_BANDWIDTH as described in 38.3.14.11 (UHR-LTF). For a UHR ELR PPDU, 2x UHR-LTF is used. Apply a 3 dB power boost if transmitting a UHR ELR PPDU as described in 38.3.14.11 (UHR-LTF).
2. matrix mapping: Apply the matrix to the data tones of the UHR-LTF sequence and apply the matrix to pilot subcarriers of the UHR-LTF sequence except for a UL MU-MIMO transmission using 1×UHR-LTF as described in 38.3.14.11 (UHR-LTF).
3. CSD: Apply CSD for each spatial stream as described in 38.3.14.2.2 (Cyclic shift for UHR modulated fields).
4. Spatial mapping: Apply the *Q* matrix as described in 38.3.14.11 (UHR-LTF).
5. IDFT: Compute the inverse discrete Fourier transform.
6. Insert GI and apply windowing: Prepend a GI indicated by the TXVECTOR parameter GI\_TYPE and apply windowing as described in 38.3.13 (Mathematical description of signals).
7. Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 38.3.13 (Mathematical description of signals) and 38.3.14 (UHR preamble) for details.

## 38.3.9.11 Construction of ELR-SIG

The ELR-SIG field consists of two subfields, ELR-SIG-1 and ELR-SIG-2, as defined in 38.3.14.12 (ELR-SIG). Construct the ELR-SIG field as defined in 38.3.14.12 (ELR-SIG) with the following highlights:

1. Obtain the ELR-SIG field values from the TXVECTOR.

Steps below apply to each subfield of the ELR-SIG field:

1. Append the calculated 4 CRC bits and then append the 6 tail bits as described in 38.3.14.12 (ELR-SIG). This results in 24 uncoded bits.
2. BCC encoder: Encode the data by a convolutional encoder at the rate of as described in 17.3.5.6 (Convolutional encoder).
3. BCC interleaver: Interleave as described in 27.3.12.8 (BCC interleavers) for 52-tone RRU.
4. Constellation mapper: BPSK modulate the 48 interleaved bits and map them onto the 52-tone RRU 1 of a UHR ELR PPDU as described in 38.3.14.12 (ELR-SIG).
5. Pilot insertion: Insert pilots as described in 38.3.15.7 (Pilot subcarriers) for UHR ELR PPDU.
6. Frequency domain duplication: For a UHR ELR PPDU, steps d)-f) are done for the 52-tone RRU 1, and then the 52-tone RRU 1 is duplicated to the 52-tone RRU 2, 52-tone RRU 3 and 52-tone RRU 4 as described in 38.3.14.12 (ELR-SIG). Apply PAPR reduction mask on data tones, as described in 38.3.14.12 (ELR-SIG).
7. CSD: Apply CSD for each spatial stream as described in 38.3.14.2.2 (Cyclic shift for UHR modulated fields).
8. Spatial mapping: Apply the *Q* matrix as described in 38.3.15.8 (OFDM modulation).
9. IDFT: Compute the inverse discrete Fourier transform.
10. Insert GI and apply windowing: Prepend a GI of 1.6 μs and apply windowing as described in 38.3.13 (Mathematical description of signals).
11. Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 38.3.13 (Mathematical description of signals) and 38.3.14 (UHR preamble) for details.

## 38.3.9.12 Construction of Data field in a UHR PPDU

### 38.3.9.12.2 ELR PPDU

Construct the UHR ELR-Data field as defined in 38.3.15 (Data field) with the following highlights:

1. Construct the SERVICE field as described in 38.x (SERVICE field) and append the PSDU to the SERVICE field.
2. Pre-FEC padding: Append the pre-FEC padding bits as described in 38.3.15 (Data field). If the user is using BCC, then add tail bits.
3. Scrambler: Scramble the pre-FEC padded data as described in 38.x (UHR PHY DATA scrambler and descrambler).
4. Encoder: If the user is using BCC, then BCC encode as described in 38.3.15.1.2 (BCC coding). If the user is using LDPC, then LDPC encode as described in 38.x (LDPC coding).
5. BCC interleaver: If the user is using BCC, interleave as described in 27.3.12.8 (BCC interleavers) for 52-tone RRU. This block is bypassed if the user is using LDPC.
6. Constellation mapper: Map to BPSK or QPSK constellation points as described in 38.x (Constellation mapping). These constellation points are then mapped onto the 52-tone RRU 1 of a UHR ELR PPDU as described in 38.x (Data field).
7. LDPC tone mapper: If the user is using LDPC, the LDPC tone mapping is performed on all LDPC encoded streams on the 52-tone RRU 1 of the UHR ELR PPDU with corresponding to 52-tone RRU with no DCM as described in 38.x (LDPC tone mapper). This block is bypassed if the user is using BCC.
8. Frequency domain duplication: For a UHR ELR PPDU, steps e) to g) are done for the 52-tone RRU 1, and then the 52-tone RRU 1 is duplicated to the 52-tone RRU 2, 52-tone RU 3 and 52-tone RRU 4 as described in 38.3.15.6 (Frequency domain doplication). Apply PAPR reduction mask on data tones, as described in 38.3.15.6 (Frequency domain doplication).
9. Pilot insertion: Insert pilots as described in 38.3.15.7 (Pilot subcarriers) for UHR ELR PPDU.
10. CSD: Apply CSD for each spatial stream as described in 38.3.14.2.2 (Cyclic shift for UHR modulated fields).
11. Spatial mapping: Apply the *Q* matrix as described in 38.3.15.8 (OFDM modulation).
12. IDFT: Compute the inverse discrete Fourier transform.
13. Insert GI and apply windowing: Prepend a GI of 1.6 μs and apply windowing as described in 38.3.13 (Mathematical description of signals).
14. Analog and RF: Upconvert the resulting complex baseband waveform with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 38.3.13 (Mathematical description of signals) for details.

# 38.3.10 UHR modulation and coding schemes (UHR-MCSs) and Unequal modulation (UEQM)

The ELR modulation and coding scheme is carried in the MCS field of the ELR-SIG field in the UHR ELR PPDU and supports UHR-MCS 0 and UHR-MCS 1 with transmission parameters as defined in Table 38-xx (UHR-MCSs for 52-tone RU, NSS,u = 1).

# 38.3.12 Timing related parameters

Table 38-xx (Timing related constants) defines the timing-related parameters for EHT PPDU format.

**Table 38-18—Timing-related constants**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Value** | **Description** |
| *F* Pre-UHR | 312.5 kHz | Subcarrier frequency spacing for the pre-UHR modulated fields |
| *F* UHR | 78.125 kHz | Subcarrier frequency spacing for the UHR modulated fields |
| *TDFT* Pre-UHR | 3.2 µs | IDFT/DFT period for the pre-UHR modulated fields |
| *TDFT* UHR | 12.8 µs | IDFT/DFT period for the UHR modulated fields |
| *TGI* ELR-MARK | 0.8 µs | Guard interval duration for the ELR-MARK field |
| *TGI* ELR-LTF | 1.6 µs | Guard interval duration for the ELR-LTF field |
| *TGI* ELR-SIG | 1.6 µs | Guard interval duration for the ELR-SIG field |
| *TGI* ELR-Data | 1.6 µs | Guard interval duration for the ELR-Data field |
| *T*ELR-LTF | 6.4 µs | Duration of each ELR-LTF OFDM symbol without GI |
| *TSYM,* ELR-MARK | 4 µs = *TDFT* Pre-UHR *+ TGI* ELR-MARK | OFDM symbol duration for ELR-MARK field |
| *TSYM* ELR-LTF | 8 µs = *T*ELR-LTF *+* *TGI*, ELR-LTF | OFDM symbol duration for ELR-LTF field including GI |
| *TSYM* ELR-SIG | 14.4 µs = *TDFT*,UHR *+* *TGI*, ELR-SIG *=*  1.125  *TDFT* UHR | OFDM symbol duration for ELR-SIG field including GI |
| *TSYM* ELR-Data | 14.4 µs = *TDFT*,UHR *+* *TGI*, ELR-Data *=*  1.125  *TDFT* UHR | OFDM symbol duration for ELR-Data field including GI |
| *T*ELR-MARK | 8 µs = *TSYM,* ELR-MARK2 | ELR-MARK field duration |
| *T*ELR-STF | 4 µs = 5   µs | ELR-STF field duration |
| *T*ELR-LTF | 16 µs = *TSYM* ELR-LTF 2 | ELR-LTF field duration |
| *T*ELR-SIG | 28.8µs*TSYM* ELR-SIG2 | ELR-SIG field duration |

Table 38-yy (Subcarrier allocation related constants for the UHR ELR PPDU) defines tone allocation related parameters for an ELR PPDU.

**Table 38-yy—Subcarrier allocation related constants for the UHR ELR PPDU**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **ELR PPDU** | **Description** |
| *NSD,total* | 192 | Total number of data subcarriers |
| *NSP* | 16 | Number of pilot subcarriers |
| *NST* | 208 | Total number of subcarriers |
| *NSR* | 121 | Highest data subcarrier index |
| *NDC* | 7 | Number of null subcarriers at DC |
| *NGuard,Left* | 6 | Number of low frequency guard subcarriers |
| *NGuard,Right* | 5 | Number of high frequency guard subcarriers |

# 38.3.13 Mathematical description of signals

## 38.3.13.4 Transmitted signal

In a UHR MU PPDU and UHR ELR PPDU, for each field excluding the PE field, , is defined as the summation of one or more subfields. Each subfield, , is defined to be an inverse Fourier transform in Equation (38-9).

(38-9)

In a UHR TB PPDU, transmitted by user *u* in the *r*-th occupied RU or MRU, each subfield, , is defined in Equation (38-10).

(38-10)

In a UHR MU PPDU and UHR ELR PPDU, the total power of the time domain UHR modulated field signals summed over all transmit chains should not exceed the total power of the time domain pre-UHR modulated field signals summed over all transmit chains.

ηField is the power scaling factor of a given field within an OFDM symbol. For UHR ELR PPDU, ηField is for all the subcarriers of the L-STF, L-LTF, UHR-STF, and UHR-LTF fields, and ηField = 1 in all other fields.

…

# 38.3.14 UHR preamble

## 38.3.14.1 Introduction

The UHR preamble consists of pre-UHR modulated fields and UHR modulated fields. The pre-UHR modulated fields for the three UHR PPDU formats are the following:

— L-STF, L-LTF, L-SIG, RL-SIG, and U-SIG fields of a UHR TB PPDU

— L-STF, L-LTF, L-SIG, RL-SIG, U-SIG, and UHR-SIG fields of a UHR MU PPDU

— L-STF, L-LTF, L-SIG, RL-SIG, U-SIG, and ELR-MARK fields of a UHR ELR PPDU

The UHR modulated fields in the preamble for the UHR TB PPDU and UHR MU PPDU formats are the UHR-STF and UHR-LTF fields.

The UHR modulated fields in the preamble for the UHR ELR PPDU format are the UHR-STF, UHR-LTF and ELR-SIG fields.

For a UHR STA with operating bandwidth larger than 80 MHz, the pre-UHR modulated field design ensures that a UHR STA is required to process only one 80 MHz frequency subblock of the pre-UHR modulated fields to get all the assignment information for itself. For a UHR PPDU with bandwidth larger than 80 MHz, a UHR STA can get all required information from processing the primary 80 MHz or the 80 MHz in which the STA is operating and does not need to process other 80 MHz frequency subblocks.

The pre-UHR modulated fields (see Figure 38-xx (Timing boundaries for UHR PPDU fields)) are not transmitted in 20 MHz subchannels in which the preamble is punctured.

## 38.3.14.2 Cyclic shift

### 38.3.14.2.1 Cyclic shift for pre-UHR modulated fields

The cyclic shift value for the L-STF, L-LTF, L-SIG, RL-SIG, U-SIG, UHR-SIG, and ELR-MARK fields of the PPDU for transmit chain *iTX* out of a total of *NTX* are defined in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU). In UL MU transmission, the cyclic shift value is based on the local transmit chain indices at each STA.

### 38.3.14.2.2 Cyclic shift for UHR modulated fields

Throughout the UHR modulated fields of the preamble, cyclic shifts are applied to prevent unintended beamforming when correlated signals are transmitted in multiple spatial streams. The same cyclic shifts are also applied to these streams during the transmission of the Data field of the UHR PPDU. For the *r*-th RU, the cyclic shift value *TCS*,UHR(*n*) for the UHR modulated fields for spatial stream *n* out of *NSS,r,total* total spatial stream is shown in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU).

## 38.3.14.3 L-STF

The time domain representation of the L-STF field, transmitted on transmit chain *iTX*shall be as specified in Equation (38-15). The equation applies to all signals up to 320 MHz bandwidth PPDU with or without preamble puncturing.

(38-15)

where

ηL-STF is defined in Equation (38-9) and is for a UHR ELR PPDU.

## 38.3.14.4 L-LTF

The time domain representation of the L-LTF field, transmitted on transmit chain *iTX*, shall be as specified in Equation (38-16). The equation applied to all signals up to 320 MHz bandwidth PPDU with or without preamble puncturing.

(38-16)

where

ηL-LTF is defined in Equation (38-9) and is for a UHR ELR PPDU.

## 38.3.14.5 L-SIG

The time domain waveform of the RL-SIG field, transmitted on transmit chain *i*TX, shall be as given by Equation (38-18).

(38-18)

where

ηL-SIG is defined in Equation (38-9) and is 1 for a UHR ELR PPDU.

## 38.3.14.6 RL-SIG

The RL-SIG field is a repeat of the L-SIG field and is used to differentiate a UHR PPDU from a non-HT PPDU, HT PPDU, and VHT PPDU.

The time domain waveform of the L-SIG field, transmitted on transmit chain *i*TX, shall be as given by Equation (38-19).

(38-19)

where

ηRL-SIG is defined in Equation (38-9) and is 1 for a UHR ELR PPDU.

## 38.3.14.7 U-SIG

### 38.3.14.7.1 General

The U-SIG field carries information necessary to interpret UHR PPDUs. The integer fields of the U-SIG

field are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit

position.

### 38.3.14.7.2 Content

The U-SIG field for a UHR ELR PPDU contains the fields listed in Table 38-xxx (U-SIG field of a UHR ELR PPDU).

**Table 38-xxx U-SIG field of a UHR ELR PPDU**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Two parts of U-SIG** | **Bit** | **Field** | **Number of bits** | **Description** |
| U-SIG-1 | B0-B2 | PHY Version Identifier | 3 | Differentiate between different PHY clauses.  Set to 1 for UHR.  Values 2-7 are Validate.  NOTE-Set to 0 for EHT (see 36.3.12.7.2). |
| B3-B5 | Bandwidth | 3 | Set to 0.  Values 1-7 are Validate. |
| B6 | UL/DL | 1 | Indicates whether the PPDU is sent in UL or DL. Set to the TXVECTOR parameter UPLINK\_FLAG.  A value of 1 indicates the PPDU is addressed to an AP.  A value of 0 indicates the PPDU is addressed to a non-AP STA.  NOTE- In 5 GHz band or 6 GHz band, the value is always set to 1. |
| B7-B12 | BSS Color | 6 | An identifier of the BSS.  Set to the TXVECTOR parameter BSS\_COLOR. |
| B13-B19 | TXOP | 7 | If the TXVECTOR parameter TXOP\_DURATION is UNSPECIFIED, set to 127 to indicate the absence of duration information.  If the TXVECTOR parameter TXOP\_DURATION is an integer value, set to a value less than 127 to indicate duration information for NAV setting and protection of the TXOP as follows:  If the TXVECTOR parameter TXOP\_DURATION is less than 512, set to 2x**⎣**TXOP\_DURATION/8**⎦**.  Otherwise, set to 2x**⎣**(TXOP\_DURATION-512)/128**⎦+**1. |
| B20-B24 | Disregard | 5 | Set to all 1s and treat as Disregard |
| B25 | Validate | 1 | Set to 1 and treat as Validate. |

**Table 38-xxx U-SIG field of a UHR ELR PPDU (continued)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Two parts of U-SIG** | **Bit** | **Field** | **Number of bits** | **Description** |
| U-SIG-2 | B0-B1 | PPDU Type And Compression Mode | 2 | Set to 3 for an ELR PPDU.  Other values indicate other PPDU types, refer to Table 38-A (U-SIG field of a UHR MU PPDU) and Table 38-C (U-SIG field of a UHR TB PPDU).  For further clarification on the values of this field, refer to Table 38-yyy (Combination of UL/DL and PPDU Type And Compression Mode field). |
| B2-B12 | STA-ID | 11 | Set to a value of the TXVECTOR parameter STA-ID (see 35.11.1.1 (STA\_ID)). |
| B13-B15 | ELR Validate | 3 | Set to a value of 7.  Values 0-6 are Validate. |
| B16-B19 | CRC | 4 | CRC for bits 0-41 of the U-SIG field. Bits 0-41 of the U-SIG field correspond to bits 0-25 of the U-SIG-1 field followed by bits 0-15 of the U-SIG-2 field. The CRC computation uses the same polynomial as that in 27.3.11.7.3 (CRC computation). |
| B20-B25 | Tail | 6 | Used to terminate the trellis of the convolutional decoder. Set to 0. |

**Table 38-yyy Combination of UL/DL and PPDU Type And Compression Mode field**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **U-SIG fields** | | **Description** | | | | | |
| **UL/DL** | **PPDU Type And Compression Mode** | **UHR PPDU format** | **UHR-SIG present?** | **RU Allocation subfields present?** | **ELR-MARK and ELR-SIG present?** | **Total number of User fields in MU PPDU or transmitters in TB PPDU or ELR PPDU** | **Note** |
| 0 (DL) | 0 | UHR MU | Yes | Yes | No | ≥ 1 | DL OFDMA (including non-MU-MIMO and MU-MIMO) |
|  | 1 | UHR MU | Yes | No | No | 1 | UHR SU transmission that is not addressed to an AP. |
|  | 2 | UHR MU | Yes | No | No | > 1 | DL non-OFDMA MU-MIMO |
|  | 3 | UHR ELR | No | No | Yes | 1 | UHR ELR transmission that is not addressed to an AP. |

**Table 38-yyy Combination of UL/DL and PPDU Type And Compression Mode field (continued)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **U-SIG fields** | | **Description** | | | | | |
| **UL/DL** | **PPDU Type And Compression Mode** | **UHR PPDU format** | **UHR-SIG present?** | **RU Allocation subfields present?** | **ELR-MARK and ELR-SIG present?** | **Total number of User fields in MU PPDU or transmitters in TB PPDU or ELR PPDU** | **Note** |
| 1 (UL) | 0 | UHR TB | No | No | No | ≥ 1 | UL OFDMA or UL non-OFDMA (including non-MU-MIMO and MU-MIMO) |
|  | 1 | UHR MU | Yes | No | No | 1 | UHR SU transmission that is addressed to an AP. |
|  | 2 | – | – | – | – | – | Validate. |
|  | 3 | UHR ELR | No | No | Yes | 1 | UHR ELR transmission that is addressed to an AP. |

### 38.3.14.7.3 Encoding and modulation

…

For the U-SIG field in a UHR ELR PPDU, the BPSK constellation point assigned to the *k*-th data subcarrier of the *n*-th symbol is denoted as . The time domain waveform for the U-SIG field of a UHR ELR PPDU, transmitted on transmit chain *iTX*, shall be as specified in Equation (38-20).

(38-20)

where

η UHR-ELR, U-SIG is 1.

is defined as in 21.3.7.5 (Definition of tone rotation).

and are defined in 17.3.5.10 (OFDM modulation).

Other variables in Equation (38-20) are defined in 38.3.12 (Timing-related parameters) and 38.3.13 (Mathematical description of signals).

## 38.3.14.8 ELR-MARK

The ELR-MARK field in the ELR preamble provides additional signaling to distinguish a UHR ELR PPDU from other PPDUs. It helps to improve the detection by utilizing predefined tone patterns for cross-correlation, enhancing performance in low-SNR environments, and enabling coherent combining across multiple receiving antennas.

Additionally, the ELR-MARK field includes a unique identifier BSS\_COLOR, indicating the station’s BSS color. The value of BSS\_COLOR ranges from 0 to 63 (see 35.11.1.4 BSS\_COLOR). A 64 × 96 matrix Ḧ, called ELR-MARK matrix, specifies 64 orthogonal sequences. Each row corresponds to a BSS Color, while each column corresponds to the data conveyed over each subcarrier of the two ELR-MARK symbols. These orthogonal sequences allow STAs to determine if the UHR ELR PPDU is from OBSS.

### 38.3.14.8.1 ELR-MARK Matrix

The 64x96 matrix Ḧ, is derived from a compact orthogonal matrix Ḣ of size 32x48, based on the mapping described by Equation (38-21),

(38-21)

where the matrix 𝕁 is the exchange matrix of order 48 given by Equation (38-22),

(38-22)

and the matrix Ḣ is specified as,

(38-xx)

Ḣ = [

-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1

1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,-1

-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1

-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1

-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1

-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1

1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,-1

1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,-1

1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,-1

-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1

1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,-1

-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1

-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1

-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1

1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,-1

-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1

-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1

-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1

1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,-1

-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1

-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1

1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,-1

1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,-1

1,-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,-1

-1,1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1

1,-1,1,-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,-1

-1,-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1

-1,1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1

1,1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,-1

1,1,1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,-1

1,-1,1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,-1

1,1,1,1,1,-1,-1,-1,-1,1,-1,-1,-1,-1,1,1,-1,1,-1,1,-1,-1,-1,1,1,-1,1,1,-1,-1,1,-1,-1,1,1,1,-1,1,-1,1,-1,-1,1,1,1,1,-1,-1

].

The 32 x 48 matrix Ḣ is also depicted in Figure 38.xxx for visual clarity.

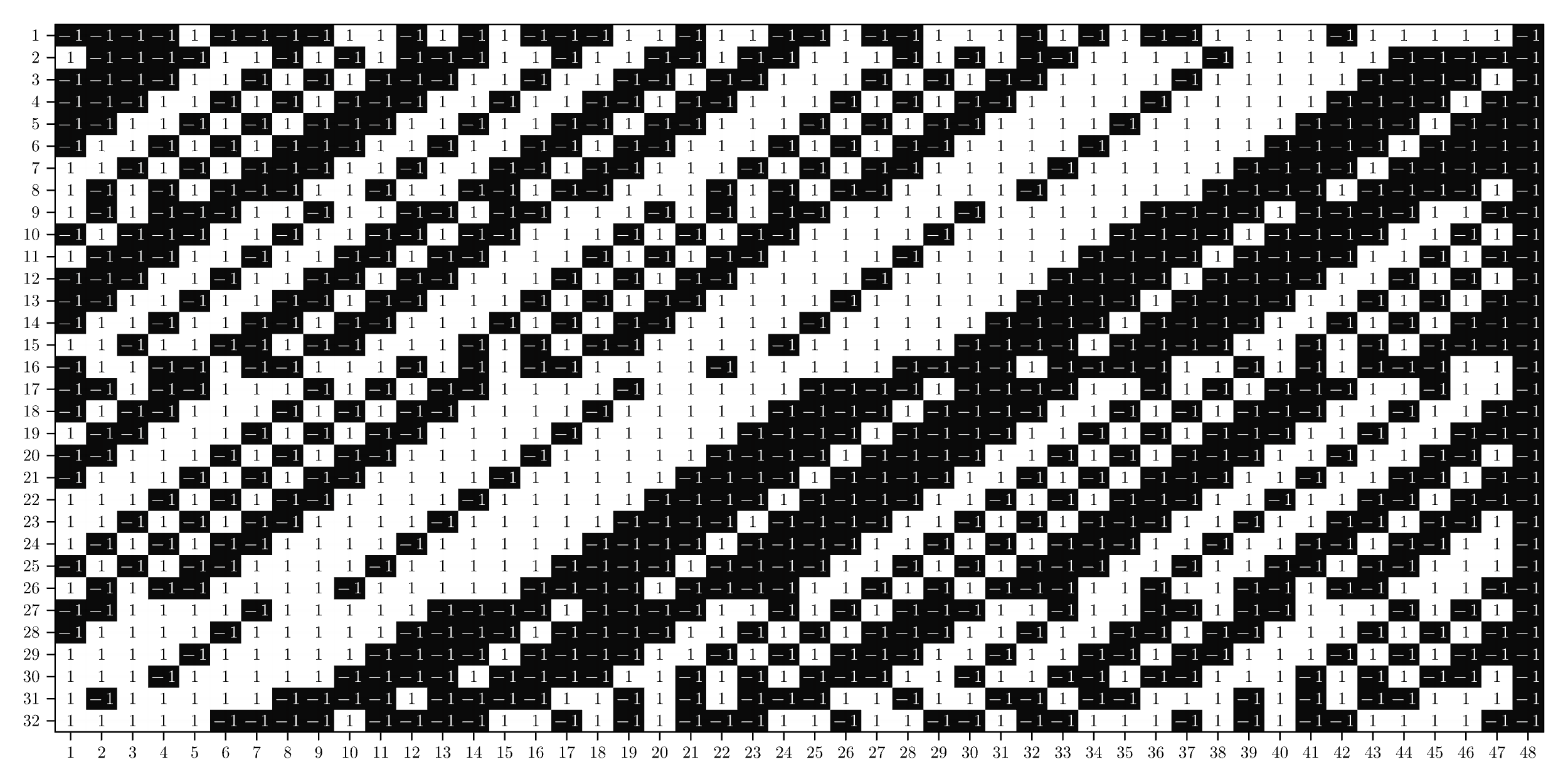


Figure 38-xxx - The 32 x 48 ELR mark sequence matrix Ḣ

A graphical representation of the complete 64x96 matrix Ḧ is shown in Figure 38-xxy.

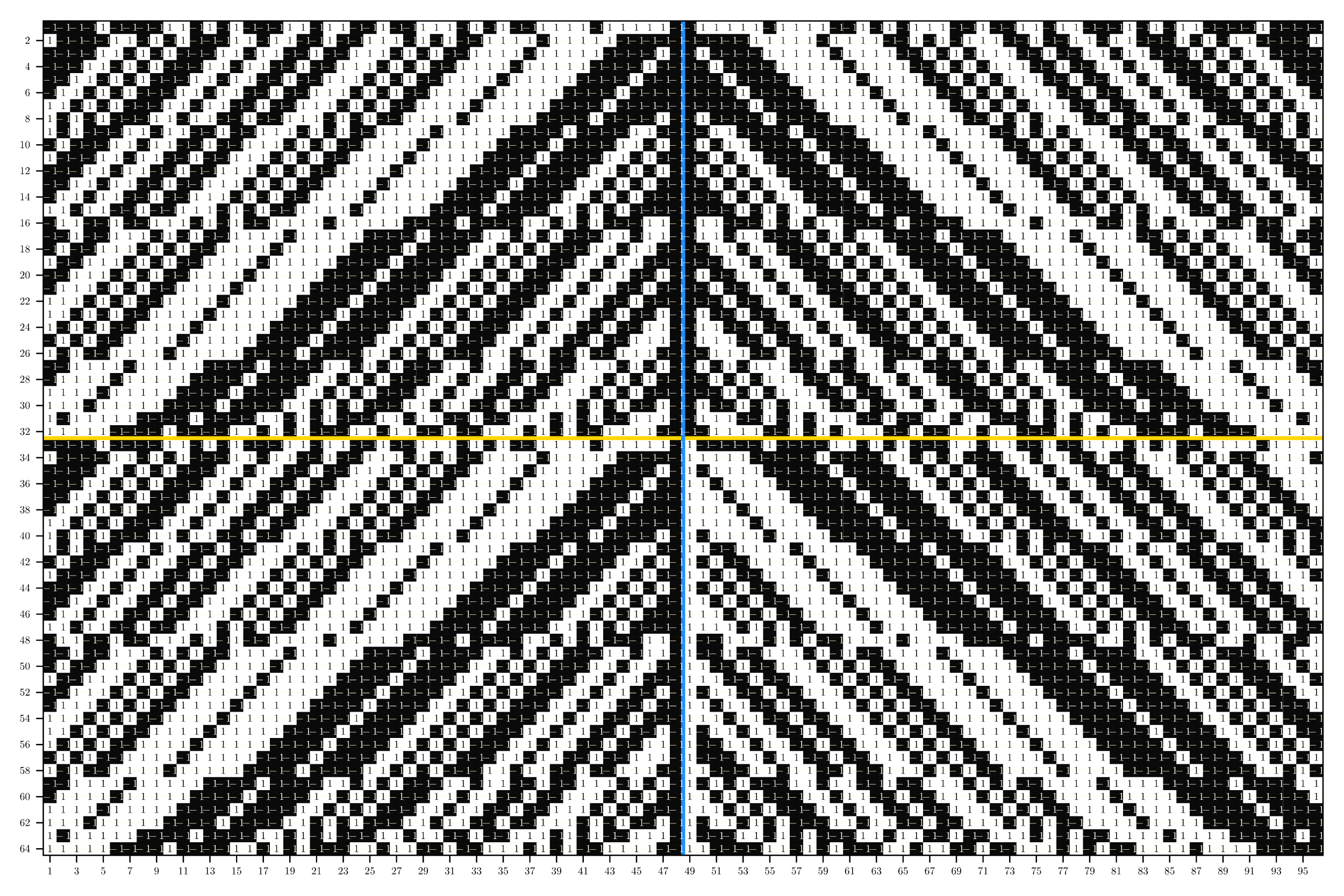


Figure 38-xxy Graphical view of the complete 64x96 matrix Ḧ corresponding to the ELR-Mark symbols

### 38.3.14.8.2 Encoding and Modulation

A row of the ELR-MARK matrix is chosen as the ELR-MARK sequence and is transmitted in the ELR-MARK field using QBPSK modulation to enhance detection performance and reduce the likelihood of missed or false detections. The ELR-MARK field comprises two OFDM symbols, referred to as ELR-MARK-1 and ELR-MARK-2. In the frequency domain, each OFDM symbol contains 52 tones: 48 data tones modulated using QBPSK and 4 pilot tones modulated using BPSK. The ELR-MARK symbols are generated as follows.

1. For a given BSS color 𝑏 ∈ [0,63], the sequence 𝕄 = [Ḧ]*b*+1,1:96 (the *b*+1 th row of the matrix Ḧ) is used for the ELR-MARK symbols. The sequence 𝕄 containing 96 (± 1) values are individually translated to ± , using QBPSK mapping, i.e., 1 → *j*, -1 → -*j*. This sequence 𝕄 is split into two segments, each of length 48 elements.
2. The first 48 elements of 𝕄, namely 𝕄1 = 𝕄[1:48], are allocated to the 48 data subcarriers of an OFDM symbol. Pilots with values [-1, -1, -1, 1] are mapped to [-21, -7, 7, 21] subcarriers. This forms the frequency domain representation of the ELR-MARK-1 symbol. An IFFT is then applied to generate the time domain version of the ELR-MARK-1 symbol.
3. The last 48 elements of 𝕄, namely 𝕄2 = 𝕄[49:96], are assigned to the 48 data subcarriers of an OFDM symbol. Pilots with values [-1, -1, -1, 1] are mapped to [-21, -7, 7, 21] subcarriers. This constitutes the frequency domain representation of the ELR-MARK-2 symbol. An IFFT is subsequently applied to obtain the time domain version of the ELR-MARK-2 symbol.
4. The mathematical representation of the time domain waveform for the ELR-MARK field, transmitted on transmit chain *iTX*, shall be as specified in Equation (38-24).

(38-24)

(38-25)

where is the element of matrix Ḧ at row and column .

## 38.3.14.10 UHR-STF

### 38.3.14.10.4 UHR-STF for ELR PPDU

The main purpose of the UHR-STF field is to improve automatic gain control estimation in a MIMO transmission. The UHR-STF field is positioned immediately after the ELR-MARK field for UHR ELR PPDU. The duration of the UHR-STF field for UHR ELR PPDU is *T*UHR-STF-NT (periodicity of 0.8 µs with 5 periods as given in [Table 38-18 (Timing-related constants)](#_bookmark63)). A 3dB power boost shall be applied on UHR-STF field in UHR ELR PPDU.

For UHR ELR PPDU, UHR-STF uses same frequency domain sequence as for UHR MU PPDU with a 20 MHz transmission, that is given by [Equation (38-](#_bookmark144)xx).

(38-xx)

where *UHRSa*:*b*:*c* means coefficients of the UHR-STF on every *b* subcarrier indices from *a* to *c* subcarrier indices and coefficients on other subcarrier indices are set to zero and *HES*-112:16:112 is defined in Equation (27-23).

The coefficients in [Equation (38-xx)](#_bookmark144) are set to zero if those values are corresponding to subcarrier indices that are not modulated in the Data field, such as subcarriers falling within RUs that have no users assigned to them in OFDMA or subcarriers that are punctured.

It is recommended that the spatial mapping matrix applied to UHR-STF and beyond is chosen such that it preserves the smoothness of the physical channel, achieved by limiting the variation of each element's real and imaginary values in the spatial mapping matrix across successive tones within assigned RU(s).

In a UHR ELR PPDU, the time domain representation of the UHR-STF waveform transmitted on the transmit chain *iTX* shall be as described in [Equation (38-x11)](#_bookmark168) in 38.3.14.10.1 (UHR-STF for RRUs).

where

## 38.3.14.11 UHR-LTF

### 38.3.14.11.2 UHR-LTF for ELR PPDU

The UHR-LTF field provides a means for the receiver to estimate the MIMO channel between the set of constellation mapper outputs and the receive chains. In a UHR ELR PPDU, the transmitter provides training for one spatial stream used for the transmission of the PSDU in the four 52-tone RUs. For each subcarrier in the four 52-tone RUs, the MIMO channel that can be estimated is an *NRX × 1* matrix. A UHR ELR transmission contains two 2**×** UHR-LTF symbols, where all tones of each 2x UHR-LTF symbol are multiplied by entries belonging to a matrix *P*UHR-LTF, to enable channel estimation at the receiver. *P*UHR-LTF is defined such that each modulated spatial stream in an RU or MRU is active on all subcarriers in that RU or MRU for which the UHR-LTF sequence takes a nonzero value. A 3dB power boost shall be applied on UHR-LTF field in UHR ELR PPDU.

A UHR ELR PPDU supports 2**×** UHR-LTF and GI\_TYPE = 1.6 µs GI only, with *T*UHR-LTF = *T*UHR-LTF-2X defined in [Table 38-18 (Timing-related constants)](#_bookmark63).

In a 20 MHz transmission, the 2**×** UHR-LTF sequence transmitted on subcarriers [–122: 122] is given by Equation (27-42) with *HELTF*–122,122 replaced by *UHRLTF*–122,122.

A UHR ELR transmission uses the same 2**×** UHR-LTF sequence in 20MHz, but only populates subcarriers corresponding to four 52-tone RUs in 20MHz. For non-populated subcarriers the values of 2**×** UHR-LTF sequence are replaced by zero.

The generation of the time domain symbols of a 2**×** UHR-LTF is equivalent to modulating every second subcarriers in an OFDM symbol of 12.8 µs excluding GI, and then transmitting only the first half of the OFDM symbol in the time domain as shown in [Figure 38-49 (Generation of 2× UHR-LTF symbols)](#_bookmark169).

CSD per SS

IDFT

IDFT

Truncate ½ of Time Symbol

CSD per SS

Truncate ½ of Time Symbol

Insert GI and Window

Truncate ½ of Time Symbol

IDFT

Analog and RF

Analog and RF

Analog and RF

**...**

**...**

**...**

**...**

**...**

**...**

Modulate Every 2nd Tone

AEHT-LTF

Spatial Mapping

Insert GI and Window

Insert GI and Window

Figure 38-49—Generation of 2× UHR-LTF symbols

In a UHR ELR PPDU, the time domain representation of the UHR-LTF waveform transmitted on the transmit chain *iTX* shall be as described in [Equation (38-yy)](#_bookmark168)

(38-yy)

where

## 38.3.14.12 ELR-SIG

### 38.3.14.12.1 General

The ELR-SIG field carries information necessary to interpret UHR ELR PPDU. The integer fields of the ELR-SIG field are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.

### 38.3.14.12.2 Content

The ELR-SIG field for a UHR ELR PPDU contains the fields listed in Table xxx (ELR-SIG field for a UHR ELR PPDU).

Table xxx---ELR-SIG field of a UHR ELR PPDU

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Two parts of ELR-SIG** | **Bit** | **Field** | **Number of bits** | **Description** |
| ELR-SIG-1 | B0 | ELR version Identifier | 1 | Differentiate between different ELR versions.  Set to 0 for UHR ELR PPDU  Value 1 is Validate |
| B1 | UL/DL | 1 | Indicates whether the UHR ELR PPDU is sent in UL or DL. Set to the TXVECTOR parameter UPLINK\_FLAG.   * A value of 1 indicates the UHR ELR PPDU is addressed to an AP. * A value of 0 indicates the UHR ELR PPDU is addressed to a non-AP STA. |
| B2 | MCS | 1 | Indicates the MCS used for modulating the ELR-Data field:   * Set to 0 for BPSK with coding rate of ½ * Set to 1 for QPSK with coding rate of ½ |
| B3 | Coding | 1 | Indicates whether BCC or LDPC is used:   * Set to 0 for BCC. * Set to 1 for LDPC with nominal codeword length of 648,1296 or 1944 |
| B4-B12 | Length | 9 | Indicates the number of ELR-Data symbols. Set to a value that is the number of ELR-Data symbols minus 1 |
| B13 | LDPC Extra OFDM Symbol | 1 | Indicates the presence of the LDPC extra symbol:   * Set to 1 if an LDPC extra symbol is present. * Set to 0 if an LDPC extra symbol is not present |
| B14-B17 | CRC | 4 | CRC for bits 0–13 of the ELR-SIG-1 field. The CRC computation uses the same polynomial as that in 27.3.11.7.3 (CRC computation). |
| B18-B23 | Tail | 6 | Used to terminate the trellis of the convolutional decoder. Set to 0. |
| ELR-SIG-2 | B0-B10 | STA-ID | 11 | Set to a value of the TXVECTOR parameter STA-ID (see 35.11.1.1 (STA\_ID)). |
| B11-B13 | Disregard | 3 | Set to all 1s |
| B14-B17 | CRC | 4 | CRC for bits 0–13 of the ELR-SIG-2 field. The CRC computation uses the same polynomial as that in 27.3.11.7.3 (CRC computation). |
| B18-B23 | Tail | 6 | Used to terminate the trellis of the convolutional decoder. Set to 0. |

### 38.3.14.12.3 Encoding and modulation

For a UHR ELR PPDU, the ELR-SIG field is composed of two parts, the ELR-SIG-1 and ELR-SIG-2 subfields, each containing 24 uncoded data bits as described in 38.3.14.12.2 (Content). The ELR-SIG-1 field is transmitted before the ELR-SIG-2 field. The data bits of the ELR-SIG OFDM symbols shall be BCC encoded separately for each of the OFDM symbols at rate R=1/2, interleaved, mapped to a BPSK constellation, and have pilots inserted following steps described in 38.3.9.11 (Construction of ELR-SIG).

ELR-SIG is transmitted using the same tone plan, same frequency domain duplication, and tone rotation as the Data field in UHR ELR PPDU, as shown in 38.3.15.6(Frequency domain duplication).

The time domain waveform for the ELR-SIG field of a UHR ELR PPDU, transmitted on transmit chain , , shall be as specified in Equation (38-xx).

where

is defined in Table 38-18 (Timing-related constants)

is defined in Table 38-yy (Subcarrier allocation related constants for the ELR PPDU)

is the data and pilot subcarrier index sets for the *r*-th 52-tone RU and is defined in Table 27-8 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU(11ax)) based on the PPDU BW, which is 20MHz.

is defined in 17.3.5.10 (OFDM modulation)

is the pilot mapping for subcarrier *k* for symbol *n* as defined in Equation (27-102).

represents the cyclic shift for transmit chain with a value given in 38.3.14.2.1 (Cyclic shift for pre-UHR modulated fields)

is the guard interval duration as defined in Table 38-xxx (Timing-related constants “”).

is the transmitted constellation in the *r*-th 52-tone RU at subcarrier *k* and ELR-SIG field OFDM symbol *n* and is defined by Equation (38-xxx)

(38-xxx)

where is defined in Table 27-40 (Pilot indices for 52-tone RU transmission(11ax)) based on the PPDU BW, which is 20MHz.

where

n=0, 1

is defined in Equation (38-xxx)

(38-xxx)

where

(38-xxx)

NOTE --- translates a subcarrier index () into the index of data symbols in a transmission over r-th 52-tone RU, (). The subcarrier index *k* for the data subcarrier is first offset by the minimum value of subcarrier index (for the lower edge subcarrier) in this RU and number of the unoccupied tones, and then subtracted by the number of pilot subcarriers falling in between the data subcarrier and the edge subcarrier.

# 38.3.15 Data field

## 38.3.15.1 Coding

### 38.3.15.1.1 general

The ELR-Data field shall be encoded using either BCC defined in 38.3.15.1.2 (BCC coding) or the LDPC code defined in 38.3.15.1.3 (LDPC coding). For a UHR ELR PPDU, the coding type is selected by the Coding field in ELR-SIG-1, as defined in 38.3.14.12.2 (ELR-SIG).

When conducting BCC FEC encoding for a UHR ELR PPDU, the number of encoders is always 1.

### 38.3.15.1.2 BCC coding

BCC encoding process is described in 27.3.12.5.1 (BCC coding and puncturing)

### 38.3.15.1.3 LDPC coding

When using LDPC, UHR ELR only supports codeword lengths up to 1944. For a UHR ELR PPDU using LDPC coding to encode the Data field, the LDPC code described in 19.3.11.7 (LDPC codes) shall be used, except that the LDPC PPDU encoding process is defined in 38.3.15.1.7.

### 38.3.15.1.4 UHR ELR PPDU padding process

A single step padding process, pre-FEC padding process including both pre-FEC MAC and pre-FEC PHY padding, is applied to a UHR ELR PPDU before conducting FEC coding.

### 38.3.15.1.7 Encoding process for a UHR ELR PPDU

In a UHR ELR PPDU transmission, the transmitter first computes the initial number of OFDM symbols, *,* using Equation (38-xxx)

(38-xxx)

where

is the number oftails bits per encoder as defined in Table 38-18 (Timing-related constants).

is the number ofbits in the SERVICE field as defined in Table 38-18 (Timing-related constants).

is the number ofdata bits per OFDM symbol as defined in Table 38-23 (Frequently used parameters).

When LDPC encoding is used, the parameter and for UHR ELR PPDU are computed using Equation (38-xxx) and Equation (38-xxx), respectively.

(38-xxx)

(38-xxx)

When LDPC encoding is used, continue LDPC encoding process as in 19.3.11.7.5 (LDPC PPDU encoding process) starting with parameters and . If the following condition in step d) of LDPC encoding process as described in 19.3.11.7.5 (LDPC PPDU encoding process) is met:

where , , , and are the LDPC encoding parameters as defined in 19.3.11.7.5 (LDPC PPDU encoding process), and *R* is the coding rate, then the LDPC Extra OFDM Symbol field of ELR-SIG-1 shall be set to 1, shall be increased according to Equation (38-xxx), and shall be recomputed as Equation (19-40).

 (38-xxx)

Then update the value using Equation (38-xxx)

(38-xxx)

If the condition mentioned above in step d) of the LDPC encoding process as described in 19.3.11.7.5 (LDPC PPDU encoding process) is not met when LDPC encoding is used, or the UHR ELR PPDU is BCC encoded,, then the LDPC Extra OFDM Symbol field of ELR-SIG-1 shall be set to 0, and shall be updated by equation (38-xxx)

(38-xxx)

The number of pre-FEC padding bit is computed as in Equation (38-xxx)

(38-xxx)

Among the pre-FEC padding bits, the MAC delivers a PSDU that fills the available octets in the Data field of the UHR ELR PPDU, toward the end of initial last OFDM symbol represented by encoded by LDPC, and toward the end of last OFDM symbol represented by encoded by BCC. The PHY then determines the number of padding bits to add and appends them to the PSDU. The number of pre-FEC padding bits added by PHY will always be 0 to 7. The procedure is defined in Equation (38-xxx) and Equation (38-xxx).

(38-xxx)

(38-xxx)

## 38.3.15.x Stream parser

## 38.3.15.2 Segment parser

The segment parser is bypassed for a UHR ELR PPDU.

## 38.3.15.3 BCC interleavers

The interleaver parameters for the UHR ELR PPDU Data field, and , shall be the same as those defined in Table 27-36 (BCC interleave parameters) for the 52-tone RU size and DCM not used.

Note: Since only one spatial stream is used in UHR ELR transmission, is not applicable.

## 38.3.15.x Constellation mapping

## 38.3.15.4 LDPC tone mapper

The LDPC tone mapping for the UHR ELR PPDU Data field shall be applied to a 52-tone regular RU, using the same LDPC tone mapping distance parameter as defined in Table 36-52 (LDPC tone mapping distance for each RU or MRU size within an 80 MHz frequency subblock) for the 52-tone RU size.

## 38.3.15.5 Segment deparser

The segment deparser is bypassed for a UHR ELR PPDU.

## 38.3.15.6 Frequency domain duplication

The ELR-SIG and payload portion of the UHR ELR PPDU are transmitted over 52-tone regular RU (RRU52) with four times duplication in frequency domain across four RRU52s (RRU52 4x DUP) in 20 MHz. The frequency domain duplication is described as follows:

* Encoding and BPSK or QPSK modulation are done for the 52-tone RRU 1 (the RU 1 for 52-tone RU in Table 27-8 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU(11ax)) in 20 MHz PPDU, and then the 52-tone RRU 1 is duplicated to the 52-tone RRU 2, 52-tone RRU 3 and 52-tone RRU 4 in 20 MHz PPDU.
* The phase rotation of -1 shall be applied on data subcarriers of the lower half of the 52-tone RRU 3 and the upper half of the 52-tone RRU 4 in 20MHz PPDU to reduce PAPR, as illustrated in Figure 38-xx (RRU52 4x DUP). See Equations (38-xx) to (38-xx) for further details. This phase rotation of -1 is not applied on pilot subcarriers.
* The above frequency domain duplication over four 52-tone RRUs occurs after LDPC tone mapping operation if LDPC encoding is used or after constellation mapping operation if BCC encoding is used.

A black background with white and blue text

Description automatically generated

**Figure 38-xx RRU52 4x DUP**

UHR ELR PPDU transmission uses UHR-MCS 0 or UHR-MCS 1, where the rate-dependent parameters for UHR-MCS 0 and UHR-MCS 1 for UHR ELR PPDU are defined in Table 38-xx (UHR ELR PPDU with UHR-MCS0 and UHR-MCS1). Guard interval duration for the data field of a UHR ELR PPDU is *TGI2*,Data (1.6 μs). The output of the LDPC tone mapper (when LDPC is used) or constellation mapper (when BCC is used) is further duplicated to map to four 52-tone regular RUs (RRU52s) according to [Equation (38-xx)](file:///C:\SHU-workfolder\2024-workfolder\doc-from-UHR-Collab\UHR%20Spec%20Draft\TGbe_Cl_36-DRU-Shengquan.docx#_bookmark231), Equation (38-xx), and [Equation (38-xx)](file:///C:\SHU-workfolder\2024-workfolder\doc-from-UHR-Collab\UHR%20Spec%20Draft\TGbe_Cl_36-DRU-Shengquan.docx#_bookmark232).

, 0-1 (38-xx)

(38-xx)

(38-xx)

where

*m* = 1 since *NSS*, *r*, *u*

= 1 for UHR ELR PPDU.

*n* = 0, 1, ¼, *NSYM* – 1

*r* = 0

*u* = 0, since UHR ELR PPDU supports only one user.

*NSD =* 48 since UHR ELR PPDU uses 52-tone RRUs

Here, *d*˜*k*, *m*, *n*, *r*, *u* maps to data subcarriers in RU1, *d*˜*k*, *m*, *n*, *r* + 1, *u* maps to data subcarriers in RU2, *d*˜*k*, *m*, *n*, *r+2*, *u* maps to data subcarriers in RU3, and *d*˜*k*, *m*, *n*, *r+3*, *u* maps to data subcarriers in RU4, where RU1, RU2, RU3, and RU4 correspond to 52-tone regular RUs (RRU52s) for a 20 MHz PPDU (see Table 27-8 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU(11ax))).

Table 38-xx UHR ELR PPDU with UHR-MCS0 and UHR-MCS1

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **UHR-MCS** | **Modulation** | **R** | ***NBPSCS*** | ***NSD*** | ***NCPBS*** | ***NDPBS*** | **Data rate (Mb/s)** |
| **1.6us GI** |
| 0 | BPSK | 1/2 | 1 | 48 | 48 | 24 | 1.67 |
| 1 | QPSK | 1/2 | 2 | 48 | 96 | 48 | 3.33 |

## 38.3.15.7 Pilot subcarrier

For UHR ELR PPDU, the ELR-SIG and data symbols are transmitted on four 52-tone regular RUs (RRU52s). The pilot mapping and pilot subcarriers are the same as that of four RRU52s in 20 MHz PPDU in DL OFDMA as defined in 27.3.12.13 (Pilot subcarriers).

## 38.3.15.8 OFDM modulation

The time domain waveform of the Data field of a UHR ELR PPDU for transmit chain, , shall be defined in Equation (38-xx).

) (38-xx)

Where

u = 0, since UHR ELR PPDU only supports UHR SU transmission

*m* = 1 since *NSS*, *r*, *u* = 1 for UHR ELR PPDU

# 38.3.19 Transmit requirements for a UHR ELR PPDU

## 38.3.19.1 Introduction

A non-AP STA and an AP STA may transmit a UHR ELR PPDU. A non-AP STA that supports UHR ELR PPDU transmission shall meet the pre-correction accuracy requirement described in 38.3.19.2 (Pre-correction accuracy requirements). There is no requirement for an AP STA.

## 38.3.19.2 Pre-correction accuracy requirements

A non-AP STA compensates for carrier frequency offset (CFO) error and symbol clock error with respect to PPDU(s) carrying frame(s) by a target AP STA that is addressed to the STA or broadcast frame when transmitting a UHR ELR PPDU.

The residual CFO error measurement on a UHR ELR PPDU shall be made after the U-SIG field. The symbol clock error shall be compensated by the same ppm amount as the CFO error.

# Text to be adopted ends here.

**References:**

1. [11-24-0171r21](https://mentor.ieee.org/802.11/dcn/24/11-24-0171-21-00bn-tgbn-motions-list-part-1.pptx): 11-24-0171-21-00bn-tgbn-motions-list-part-1, Alfred Asterjadhi (Qualcomm Inc.)