IEEE P802.11  
Wireless LANs

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| Proposed TGme Comment Resolution CID 2346 | | | | |
| Date: 2023-03-14 | | | | |
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Abstract

This document provides proposed comment resolutions for CID 2346 submitted in response to the 802.11 TGme D1.0 WG letter ballot.

r1: This document was reviewed at the TGme August 2022 Ad Hoc meeting in San Diego and is updated based on discussion at the Ad Hoc. Also, there was some additional editorial clean up.

r2: This comment was not resolved prior to the 802.11 Letter Ballot for 802.11REVme D2.0. There were multiple related comments generated during the Letter Ballot on D2.0. The solution previously proposed is updated to use D2.0 as a baseline and is being proposed as a resolution to these related comments. CID:

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| **CID** | **Commenter** | **Clause** | **Page/Line** | **Comment** | **Proposed Change** | **Resolution** |
| 3068 | Sean Coffey | 30.1 | 4579/54 | "The WUR PHY uses the multi-carrier on-off keying (MC-OOK) modulation for WUR-Sync and WUR-Data fields. MC-OOK is on-off keying, modulated with a multicarrier signal". This is descriptive, not normative. Is there any normative statement that says that the WUR PHY shall use a multicarrier signal? The following sentence says that the multicarrier signal "should" be generated by using 13 contiguous carriers. But "should" implies that it is permissible to generate the signal some other way, i.e., that a compliant WUR PHY might not use 13 contiguous carriers, and indeed (it seems) might not use multicarrier keying at all. If so, the first sentence here is misleading. (Note that the proposed change mirrors the last sentence in the paragraph: "The subcarrier coefficients may take values from the BPSK, QPSK, 16-QAM, 64-QAM, or 256-QAM constellation symbols.") | Change "The WUR PHY uses" to "The WUR PHY may use". | **Accepted** |
| 3071 | Sean Coffey | 30.3.8 | 4596/46 | "This general representation holds for WUR-Sync and WUR-Data fields, and the field specific parameters are provided in Table 30-5". Again, this is descriptive, i.e., it describes something as being true, but not normative, i.e., saying that it has to be true. There do not seem to be normative statements anywhere in the clause that say this has to be true. The previous sentence says that the baseband signal "should" be obtained by taking the IDFT of a set of subcarrier coefficients. This implies that it is permissible for a compliant device to obtain the baseband signal some other way. This is very confusing, bordering on misleading. | Change " This general representation holds for WUR-Sync and WUR-Data fields, and the field specific parameters are provided in Table 30-5 (Field specific parameter values for the MC-OOK symbols in WUR-Sync and WUR-Data fields(11ba))" to "When the baseband signal is generated in this way, the field specific parameters are as shown in Table 30-5 (Field specific parameters for the MC-OOK symbols in WUR-Sync and WUR-Data fields when the baseband signal is generated by taking the IDFT of 13 contiguous subcarriers)". Also, change the title of Table 30-5 (4597.37) to "Field specific parameters for the MC-OOK symbols in WUR-Sync and WUR-Data fields when the baseband signal is generated by taking the IDFT of 13 contiguous subcarriers". | **Accepted** |
| 3072 | Sean Coffey | 30.3.8 | 4598/1 | The discussion in this section up to here is very unclear on what a WUR signal is. Elements of the signal are called MC-OOK, without any requirement that they are generated by a multi-carrier signal. A mathematical description of a multi-carrier signal is provided, without any requirement that the WUR signal is constructed in this way (there's a "should", but this implies "may do something else"). This is an important issue, because subclause 30.3.13.1 (Receiver minimum input sensitivity) imposes normative requirements on the receiver: it has to be able to receive (any) WUR PPDU with specified reliability at the given levels. For that requirement to have any meaning, there has to be adequate notice of the range of different transmitted signals that the receiver might encounter. This should (at the very least) be spelled out in a note. | Add a second note: "NOTE 2--The transmitter's baseband signal is not required to correspond to the IDFT of subcarrier coefficients derived from the stated constellations, and is not required to match the description in Equation (30-3). The only normative requirements that apply to the WUR-Sync and WUR-Data fields are provided in subclauses 30.3.12.1 (Transmit spectrum mask), 30.3.12.2 (Spectral flatness), 30.3.12.3 (Transmit center frequency and symbol clock frequency tolerance) and 30.3.12.4 (Transmit On and Off Symbols power ratio). For the avoidance of doubt, elements of WUR PPDUs that are labeled "MC-OOK" in this clause are not required to be "multi-carrier". | **Accepted** |
| 3095 | Joseph Levy | 3.2 | 218/43 | The definition of MC-OOK symbol is confusing and is not sufficient: The definition is self-referential and MC-OOK symbols are not normatively defined. The 802.11 specification normatively defines the OOK modulation that may be generated using an MC-OOK implementation. But calling these symbols these symbols "MC-OOK symbols" is confusing and incorrect. | Delete the definition | **Revised**  Make the changes shown in 22/1035r1  Note to editor this is the same resolution as provided for CID 3438 |
| 3096 | Joseph Levy | 30 | 4552/00 | |  |  | | --- | --- | | The term MC-OOK is used inconsistently in specification. MC-OOK is used to describe an implementation that can generate the OOK symbols used by WUR using a multi-carrier transmitter. In addition these WUR OOK symbols are referred to as MC-OOK symbols in several locations.in the specification. using the same term to refer to and implementation technique and the modulation symbols is confusing and incorrect. | Use term MC-OOK when referring to the multi-carrier implementation technique for generating the OOK symbols used in WUR. Do not refer to these OOK symbols or modulations using the term MC-OOK as this confuses the implementation technique with the normatively defined symbols and modulations used in WUR. Make the changes provided in 11-22/1035. | | Use term MC-OOK when referring to the multi-carrier implementation technique for generating the OOK symbols used in WUR. Do not refer to these OOK symbols or modulations using the term MC-OOK as this confuses the implementation technique with the normatively defined symbols and modulations used in WUR. Make the changes provided in 11-22/1035. | **Accept**  **Note to Editor:** Make the changes shown in 22/1035r2 |
| 3278 | Mark Rison | 30.3.4 | 4588/56 | "With the 4 us duration MC-OOK On and Off Symbols, the PPDU should meet the Correlation test defined  in 30.3.12.5 (Correlation test on MC-OOK symbols)." -- this should be a "shall" else there may be interop issues | Change "should" to "shall" at the referenced location and at line 4 | **Revised**  Make the changes shown in 22/1035r2 |
| 3283 | Mark Rison | 30 |  | MC-OOK is just an example way of generating waveforms, but the actual requirements on the OOK used for WUR are not specified | Add a subclause defining the "shall"s for WUR PPDUs, and then give MC-OOK as the "should" way to generate them | **Revised**  Make the changes shown in 22/1035r3 |
| 3458 | Mark Rison | 30 | 4579/1 | MC-OOK is a strange definition. Is MC-OOK symbol different than regular OOK symbols, particularly the definition of MC-OOK OFF symbol sounds rather strange. | Make the changes shown in 22/1035r1 | **Revised**  Make the changes shown in 22/1035r3 tagged with #3458 |

**Proposed red lined text, to resolve the comment (page.line numbers based on 802.11REVme D2.0:**

(218.43)

**multicarrier on-off keying (MC-OOK) symbol:** (#2242,3458) A wake up receiver (WUR) OOK symbol generated using multiple carriers, either an WUR OOK On Symbol where the multicarrier signal is present or an WUR OOK Off Symbol where no signal is present.(11ba)

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(4555.57)

A WUR AP sending a WUR Beacon frame shall set the Type Dependent Control field of the WUR Beacon frame to the TSF timer [5:16] of the WUR AP’s TSF timer at the time that the start of the first WUR On-Off Keying (OOK) symbol containing the first bit of the Type Dependent Control field is transmitted by the PHY plus the WUR AP’s delays through its local PHY from the MAC-PHY interface to its interface with the WM.

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(4579.7)

Clause 30 (Wake-Up Radio (WUR) PHY specification(11ba)) specifies the PHY entity for orthogonal frequency division multiplexing (OFDM) and WUR On-Off Keying (OOK) systems. In addition to the requirements in Clause 30 (Wake-Up Radio (WUR) PHY specification(11ba)), a WUR STA that supports WUR PHY specification shall support(#546) transmitting and receiving PPDUs that are compliant with the mandatory requirements of the following PHY specifications:

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(4579.53)

The WUR PHY uses WUR OOK modulation for (#1128)WUR-Sync and WUR-Data fields. These WUR OOK fields may be generated by multicarrier on-off-keying (MC-OOK), a technique to generate an WUR OOK modulation with a multicarrier signal. The multicarrier signal should be generated using contiguous 13 subcarriers, centered within a 20 MHz channel, with a subcarrier spacing of 312.5 kHz and the center subcarrier (#1131)being null. The subcarrier coefficients may take values from the BPSK, QPSK, 16-QAM, 64-QAM, or 256-QAM constellation symbols.

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(4587.47)

For a single 20 MHz WUR channel, the 2 µs duration WUR OOK On Symbol may be generated by MC-OOK by the On-WG using (#1137)the center 13 subcarriers of a 64-point IDFT, sampling at 20 MHz as follows:

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(4587.60)

* The last 8 samples of those 32 samples are prepended to the 32 samples generating 40 samples, representing the 2 µs duration WUR OOK On Symbol. This step corresponds to the GI Insertion in Figure 30-6 (An example of an On-WG for the WUR-Sync and WUR-Data fields with WUR HDR(11ba)).

For a single 20 MHz WUR channel, the 2 µs duration WUR OOK Off Symbol may be generated by MC-OOK by the Off-Waveform Generator (Off-WG) as zero for 2 µs.

With the 2 µs duration WUR OOK On and Off Symbols, the PPDU should meet the Correlation test defined in 30.3.12.5 (Correlation test on MC-OOK symbols).

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(4588.36)

For a single 20 MHz WUR channel the 4 µs duration WUR OOK On Symbol may be generated by MC-OOK by the On-WG using (#1139)the center 13 subcarriers of a 64-point IDFT, sampling at 20 MHz as follows:

* The 12 subcarriers with subcarrier indices *k* = (–6, –5, … –1, 1, 2, … 6) are used with nonzero input. Other subcarriers are null.
* The coefficients of the nonzero subcarriers are selected from the symbols of any of the following constellations: BPSK, QPSK, 16-QAM, 64-QAM, and 256-QAM.
* The 64 values from the 64-point IDFT are processed by the Symbol Randomizer as described in 30.3.4.4 (Symbol Randomizer and Per-transmit chain Cyclic Shift).
* The last 16 values of the 64-point IDFT output are prepended to the 64 samples generating 80 samples, representing the 4 µs duration WUR OOK On Symbol. This step corresponds to the GI Insertion in Figure 30-7 (An example of an On-WG for the WUR-Data fields with WUR LDR(11ba)).

For a single 20 MHz WUR channel the 4 µs duration WUR OOK Off Symbol may be generated by MC-OOK by the Off-Waveform Generator (Off-WG) as zero for 4 µs.

With the 4 µs duration WUR OOK On and Off Symbols, the PPDU should meet the Correlation test defined in 30.3.12.5 (Correlation test on MC-OOK symbols).

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(4589.31)

The WUR OOK On Symbol for the 20 MHz WUR waveform should be generated according to 30.3.4.1 (WUR Basic PPDU waveform generation for WUR-Sync field and WUR-Data field with WUR HDR) or 30.3.4.2 (WUR Basic PPDU waveform generation for WUR-Data field with WUR LDR) depending on WUR\_DATARATE. The 40 MHz or 80 MHz WUR FDMA PPDU should be generated by multiplexing multiple 20 MHz WUR waveforms in the corresponding channel as shown in Figure 30-8 (An example of a WUR-Data field signal generator for the FDMA transmission(11ba)).

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(4592.63)

* Waveform generation: Generate the WUR OOK waveform by using either On-WG or Off-WG according to the WUR-Sync. The samples in Off-WG have zero energy. WUR-Sync bit duration *TSync* is 2 µs. Symbol randomization and per-transmit-chain CSD is applied within the waveform generation step.

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(4593.33)

* Waveform generation for the WUR-Sync field: Generate the WUR OOK waveform for the WUR-Sync field by using either On-WG or Off-WG according to the WUR-Sync bit for each 20 MHz subchannel. The samples in Off-WG have zero energy. Each WUR-Sync bit duration, *TSync* is 2 µs.

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(4593.60)

The WUR data rate represents the data rate used in the WUR-Data field of the WUR PPDU. There are two data rates: 62.5 kb/s and 250 kb/s, respectively, which are denoted as WUR LDR and WUR HDR. WUR LDR and WUR HDR are distinguished by the predefined sequence in the WUR-Sync field. Rate-dependent parameters are shown in Table 30-14 (WUR PPDU data rates(11ba)).WUR encoding is applied to both WUR data rates. MC-OOK may be used for modulation of both WUR data rates.

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(4594.10)

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| * Timing-related constants(11ba) | | |
| Parameter | Value | Description |
|  | 312.5 kHz | Subcarrier frequency spacing for WUR PPDU |
| *TDFT,WUR* | 3.2 µs | IDFT/DFT period for the WUR PPDU |
| *TGI,WUR* | 0.8 µs for 4 µs duration WUR OOK symbols; 0.4 µs for 2 µs duration WUR OOK symbols | Guard interval duration for the WUR PPDU |
| *TGI,2* | 1.6 µs | Guard interval duration for the L-LTF field |
| *TSym-LDR* | 4 µs | Duration of WUR LDR WUR OOK symbol in WUR-Data field |
| *TSym-HDR* | 2 µs | Duration of WUR HDR WUR OOK symbol in WUR-Data field |
| *TSym* | *TSym-LDR* or *TSym-HDR* depending on WUR data rate | Duration of WUR OOK symbol in WUR-Data field |
| *TSync* | 2 µs | Duration of WUR OOK symbol in WUR-Sync field |
| *TL-STF* | 8 µs = 10 × *TDFT,WUR* /4 | Non-HT Short Training field duration |
| *TL-LTF* | 8 µs = 2 × *TDFT,WUR + TGI,L-LTF* | Non-HT Long Training field duration |
| *TL-SIG* | 4 µs | Non-HT SIGNAL field duration |
| *TBPSK-Mark1* | 4 µs | BPSK-Mark1 field duration |
| *TBPSK-Mark2* | 4 µs | BPSK-Mark2 field duration |
| *TWUR-Sync-LDR* | 128 µs | WUR-Sync field duration for WUR LDR |
| *TWUR-Sync-HDR* | 64 µs | WUR-Sync field duration for WUR HDR |
| *TWUR-Sync* | *TWUR-Sync-LDR* or *TWUR-Sync-HDR* depending on WUR data rate | WUR-Sync field duration for WUR PPDU |

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| --- | --- |
| * Frequently used parameters(11ba) | |
| Symbol | Explanation |
| *NSPDB* | Number of WUR OOK symbols per information data bit.  For WUR LDR, *NSPDB* =4.  For WUR HDR, *NSPDB* =2. |
| *NTX* | Number of transmit chains |
| *NWUR-Sync* | Number of WUR OOK symbols in the WUR-Sync field.  For WUR LDR, *NWUR-Sync*=64.  For WUR HDR, *NWUR-Sync*=32. |

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(4595.34)

The transmitted RF signal is obtained by up-converting the complex baseband signal, which consists of several fields. The timing boundaries for the various fields are shown in Figure 30-10 (Timing boundaries for the WUR Basic PPDU fields(11ba)) where *NWUR-Sync* is the number of WUR OOK symbols in the WUR-Sync field and is defined in Table 30-4 (Frequently used parameters(11ba)).

*Note to editor – Figure 30-10 should be updated to replace MC-OOK with WUR OOK – attached below.*

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(4596.28)

where *TField* is the duration of the field, *TWUR-Sync* is the duration of WUR-Sync field, as defined in Table 30-3 (Timing-related constants(11ba)). *TWUR-Data* is the duration of WUR-Data field, with *TWUR-Data*=*Nsym* X *Tsym,* where *Nsym* is the number of WUR OOK symbols in the WUR-Data field, as given in Equation (30-14).

The duration of different fields of the WUR Basic PPDU are provided in Table 30-3 (Timing-related constants(11ba)).

For the L-STF, L-LTF, L-SIG, BPSK-Mark1, and BPSK-Mark2 fields, the baseband signal is constructed as described in 30.3.9.2 (Non-WUR portion of WUR PHY preamble).

The WUR-Sync and WUR-Data fields comprises of WUR OOK symbols as described in 30.3.9.3 (WUR-Sync field) and 30.3.10 (WUR-Data field), respectively. For the WUR OOK On Symbols in the WUR-Sync field (WUR-Sync On Symbols) and the WUR OOK On Symbols in the WUR-Data field (SymLDROn and SymHDROn), the baseband signal may be obtained by MC-OOK taking the Inverse Discrete Fourier Transform (IDFT) of a set of subcarrier coefficients, which is described by Equation (30-3). This general representation holds for WUR-Sync and WUR-Data fields, and the field specific parameters are provided in Table 30-5 (Field specific parameter values for the MC-OOK symbols in WUR-Sync and WUR-Data fields(11ba)).

where

 is the scaling factor to compensate for 50% duty cycle from WUR OOK.

 is the number of transmit chains as defined in Table 30-4 (Frequently used parameters(11ba)).

 is a windowing function of duration T used to control spectral leakage. Refer to 17.3.2.5 (Mathematical conventions in the signal descriptions) for a discussion of windowing functions.

*m* and *n* are described in 30.3.4.4 (Symbol Randomizer and Per-transmit chain Cyclic Shift). These parameter values may vary across WUR OOK symbols within the field.

 is the subcarrier frequency spacing and is given in Table 30-3 (Timing-related constants(11ba)).

 is the length of cyclic prefix.

 is the cyclic shift applied to the signal from transmit chain , and equals either  or , as given in Table 30-5 (Field specific parameter values for the MC-OOK symbols in WUR-Sync and WUR-Data fields(11ba)).  and  are implementation dependent, and example values are given in Table AC-3 (Recommended CSD values for the WUR-Sync field and WUR-Data field with WUR HDR(11ba)) and Table AC-4 (Recommended CSD values for the WUR-Data field with WUR LDR(11ba)).

 is the pseudorandom cyclic shift with cyclic shift index *n* described in 30.3.4.4 (Symbol Randomizer and Per-transmit chain Cyclic Shift). Its values are specified in Table 30-6 (Values of pseudorandom cyclic shift with cyclic shift index n for the WUR-Sync field and WUR-Data field with WUR HDR(11ba)) and Table 30-7 (Values of pseudorandom cyclic shift with cyclic shift index n for the WUR-Data field with WUR LDR(11ba)).

are the field specific subcarrier coefficients, and equals either  or , as given in Table 30-5 (Field specific parameter values for the MC-OOK symbols in WUR-Sync and WUR-Data fields(11ba)).  and  are implementation dependent sequences, and example values for these sequences are given in Table AC-1 (Example Values for the Sequence SHDR used for the Construction of the 2 µs duration MC-OOK On Symbol(11ba)) and Table AC-2 (Example Values for the Sequence SLDR used for the Construction of the 4 µs duration MC-OOK On Symbol(11ba))

 is a tone scaling factor.

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(4597.63)

For the WUR OOK Off Symbols in the WUR-Sync and WUR-Data fields, .

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(4904.60)

Table 30-8 (The states of the LFSR, the values of the bits b2, b1, b0, the value of n, and the pseudorandom cyclic shift with cyclic shift index n for the first seven WUR OOK symbols in the WUR-Sync field(11ba)) provides the values of the LFSR, the three bits (b2, b1, b0), the index value *n*, and the time delay value of  for the first seven states of the LFSR.

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| * The states of the LFSR, the values of the bits b2, b1, b0, the value of n, and the pseudorandom cyclic shift with cyclic shift index nfor the first seven WUR OOK symbols in the WUR-Sync field(11ba) |

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(4602.36)

* Cyclic Shift for WUR-Sync field

Recommended cycle shift diversity (CSD) values for the WUR-Sync field, which is constructed from 2 µs duration WUR OOK symbols, are provided in Annex AC.

* WUR-Sync field for WUR LDR

For WUR LDR, the WUR-Sync field shall be constructed as an WUR OOK signal. The WUR-Sync sequence is constructed by concatenating two copies of the 32-bit sequence *W*, where each bit in the sequence is mapped to an WUR OOK symbol of duration 2 µs, and *W* is defined in Equation (30-9).

This WUR-Sync sequence is used to construct the WUR-Sync field waveform as shown in Figure 30-4.

* WUR-Sync field for WUR HDR

For WUR HDR, the WUR-Sync field shall be constructed as an WUR OOK signal. The WUR-Sync sequence is constructed as the bitwise complement of the 32-bit sequence *W*, where each bit in the sequence is mapped to an MC-OOK symbol of duration 2 µs, and *W* is defined in Equation (30-9). This bitwise complement sequence is defined in Equation (30-10).

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(4603.9)

* WUR-Data field
* Cyclic Shift for WUR-Data field

Recommended cycle shift diversity (CSD) values for the WUR-Data field with WUR LDR, which is constructed from 4 µs duration WUR OOK symbols, are provided in Annex AC.

Recommended cycle shift diversity (CSD) values for the WUR-Data field with WUR HDR, which is constructed from 2 µs duration WUR OOK symbols, are provided in Annex AC.

* WUR-Data field for WUR LDR and WUR HDR

The WUR-Data field shall be encoded by WUR encoding. Encoded bits corresponding to each input bit are shown in Table 30-9 (WUR encoded bits for WUR LDR(11ba)) and Table 30-10 (WUR encoded bits for WUR HDR(11ba)) for WUR LDR and WUR HDR, respectively.

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| * WUR encoded bits for WUR LDR(11ba) | |
| Input bit | Encoded bits |
| 0 | 1010 |
| 1 | 0101 |

|  |  |
| --- | --- |
| * WUR encoded bits for WUR HDR(11ba) | |
| Input bit | Encoded bits |
| 0 | 10 |
| 1 | 01 |

The encoded binary data shall be modulated using WUR OOK, i.e., encoded bits 0 and 1 shall be represented by Off and On Symbols, respectively. The duration of the WUR OOK symbol corresponding to each encoded bit is dependent on WUR data rate: 4 µs for WUR LDR and 2 µs for WUR HDR.

For WUR LDR, 4 µs duration WUR OOK Off and On Symbols are denoted as SymLDROff and SymLDROn, respectively. For WUR HDR, 2 µs duration WUR OOK Off and On Symbols are denoted as SymHDROff and SymHDROn, respectively.

SymLDROn and SymHDROn should be generated using contiguous 13 subcarriers, centered within a 20 MHz channel, with a subcarrier spacing of 312.5 kHz and the center subcarrier being null. The subcarrier coefficients may take values from the BPSK, QPSK, 16-QAM, 64-QAM, or 256-QAM constellation symbols.

When a single 20 MHz WUR channel is used for transmission of a WUR Basic PPDU, SymHDROn and SymLDROn are described in 30.3.8 (Mathematical description of signals). The generation of SymHDROn and SymLDROn is described in 30.3.4.1 (WUR Basic PPDU waveform generation for WUR-Sync field and WUR-Data field with WUR HDR) and 30.3.4.2 (WUR Basic PPDU waveform generation for WUR-Data field with WUR LDR), respectively.

For a FDMA transmission, the WUR OOK waveform generation is described in 30.3.4.3 (WUR FDMA PPDU WUR-Data field waveform generation).

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(4604.12)

* WUR Padding field for a WUR FDMA PPDU

For a WUR FDMA PPDU, if padding is needed on any 20 MHz subchannels, the padding waveform shall be generated by repeating the WUR OOK waveform of WUR HDR information bit 1 as described in Table 30-14 (WUR PPDU data rates(11ba)). The symbol randomizer as described in 30.3.4.4 (Symbol Randomizer and Per-transmit chain Cyclic Shift) should be used in the padding field continued from the WUR-Data field. The state of the LSFR is updated every  during the padding field.

For a nonpunctured WUR FDMA 20 MHz subchannel, , the number of padding WUR HDR bits is calculated as:

* 

where

 and  denote  and  for 20 MHz subchannel , respectively.  and  are defined in Table 30-3 (Timing-related constants(11ba)).

 is the number of WUR OOK symbols in the WUR-Data field for 20 MHz subchannel. It is a function of the length of WUR MAC frame in the WUR-Data field (WUR\_MPDU\_LENGTH) for 20 MHz subchannel  and  as defined in Equation (30-14).

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(4608.5)

* Correlation test on WUR OOK symbols

An autocorrelation metric indicative of that used for L-STF detection in non-WUR receivers is defined. The correlation metric is given in Equation (30-12),

where *M* = 16, which is the number of samples in an 800 ns time period, sampled at 20 MHz, and *N*=6, which is the number of 800 ns time periods over which the correlation metric is calculated.

This metric is calculated over the WUR-Sync and WUR-Data fields, at a sampling rate of 20 MHz using the WUR OOK symbols. Hence, the value of *n* spans from the beginning of the WUR-Sync field to the end of the WUR-Data field. The PPDU should be tested for both the WUR LDR and WUR HDR with a 6-byte data field of random data. The maximum value of the correlation metric should be less than 0.4.

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(4610.6)

*Note to editor – Figure 30-14, 30-15, 30-17, 30-18 should be updated to replace “WUR coded MC-OOK” with “WUR OOK”, “MC-OOK Symbols” with “WUR OOK Symbols” – attached below.*

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(4614.61)

The PHY entity shall begin receiving the WUR OOK symbols in the WUR-Data field. If signal loss occurs during reception, prior to completion of the PPDU reception, the error condition PHY-RXEND.indication (CarrierLost) shall be reported to the MAC. The received PPDU bits are decoded, assembled into octets and presented to the MAC using a series of PHY-DATA.indication (DATA) primitive exchanges. Any remaining bits, which could not be assembled into a complete octet are discarded. RCPI measurement is made during the reception of the data field as described in 19.3.19.7 (Received channel power indicator (RCPI) measurement). Since the WUR PHY is not aware of the end of the WUR PPDU, the PHY shall keep decoding until receive signal strength drops significantly. Alternatively, the WUR MAC may also indicate the end of WUR PPDU to PHY by means of PHY-CCARESET.request primitive. On termination, the WUR PHY enters the RX IDLE state. If the WUR PHY terminates due to reduction of the receive signal strength, a PHY-RXEND.indication (NoError) primitive shall be issued. If it terminates due to PHY-CCARESET.request, a PHY-RXEND.indication (MAC Request) primitive shall be issued.

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(4615.24)

where

*TL-STF*, *TL-LTF*, *TL-SIG*, *TBSPK-Mark1*, *TBSPK-Mark2, TWUR-Sync*, and *TSym*are defined in Table 30-3 (Timing-related constants(11ba)), and *NSym* is the number of WUR OOK symbols in the WUR-Data field.

The number of WUR OOK symbols is a function of the length of WUR MAC frame in the WUR-Data field (WUR\_MPDU\_LENGTH) and *NSPDB* and is calculated as follows:

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(4616.38)

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| --- | --- | --- | --- | --- | --- | --- |
| * WUR PPDU data rates(11ba) | | | | | | |
| Data rate | Modulation | Symbol structure | | Equivalent information bit duration | NSPDB | Data rate (kb/s) |
| WUR LDR | WUR OOK | Information 0 | [SymLDROn, SymLDROff, SymLDROn, SymLDROff] | 16 µs | 4 | 62.5 |
| Information 1 | [SymLDROff, SymLDROn, SymLDROff, SymLDROn] |
| WUR HDR | WUR OOK | Information 0 | [SymHDROn, SymHDROff] | 4 µs | 2 | 250 |
| Information 1 | [SymHDROff, SymHDROn] |

**11-22/1035r1 – previous proposed resolution:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **CID** | **P.L** | **C** | **Comment** | **Proposed Change** | **Resolution** |
| 2346 | 256.53 | 3.4 | MC-OOK is a strange definition. Is MC-OOK symbol different than regular OOK symbols, particularly the definition of MC-OOK OFF symbol sounds rather strange. | please clarify how MC-OOK is different than regular OOK, and is the spec mandating this OOK symbol must be generated by Multiple Carrier? If not, consider removing this definition. |  |

**Comment resolution history:**

This comment led to significant discussion in the TGme Ad Hoc April 26-28 2022 (from the minutes 11-22/0679r0:

* + 1. CID 2346 GEN

6.4.15.1 Straw Poll:

1. Reject - MC-OOK was added by 11ba and indicates the symbols used by 11ba. The definition is for a multicarrier on-off keying (MC-OOK) symbol. There is no use of just "OOK", only this definition and usage. Y/4, N/2, No answer/6
2. Revised: Delete the definition at p277.49.

Y/2, N/5, No answer/5

3. Reject - Insufficient details. Y/4, N/2, No answer/6

* + - 1. Straw Poll Option 1 was chosen.
      2. This will be run as a separate motion.
      3. 6.4.15.4 Proposed Resolution: REJECTED (GEN: 2022-04-27 21:11:08Z) MC-OOK was added by 11ba and indicates the symbols used by 11ba. The definition is for a multicarrier on-off keying (MC-OOK) symbol. There is no use of just "OOK", only this definition and usage.
      4. Mark Ready for Motion

At the May 802.Wireless Interim Meeting the CID 2346 led to significant discussion and the motion failed and this comment was assigned to Joseph Levy for a proposed resolution (from the minutes 11-22/0782r2):

* 1. **Motion #61 – MC-OOK (GEN) (2022-05-16)**
     + 1. Approve the comment resolution for CID 2346 on the “Gen Motion MC-OOK” tab in <https://mentor.ieee.org/802.11/dcn/22/11-22-0067-09-000m-gen-adhoc-revme-wg-lb258-comments.xlsx>,
       2. Moved: Jon ROSDAHL
       3. 2nd: Emily QI
       4. Results: 4y/6n/5a - Motion Fails –
       5. Assign CID 61 to Joseph Levey – Marked Submission Required.

*Note: there is a typo in the minutes the CID number is 2346 on line 5.4.6.5.*

**Discussion**

This contribution attempts to provide a resolution to CID 2346 as well as discussion to justify the proposed resolution.

Starting with a discussion of the status of the term MC-OOK in the 802.11REVme and how this relates to the comment on the definition of MC-OOK:

Clause 30.1 contains 7 “shall’s” in the requirements to the transmitting or receiving of PPDUs, WUR encoding, support of specific frame types and restrict on WUR AP transmission of WUR PPDU based on operating class, with DFS\_50\_100\_Behavior. None of these “shall’s” in this clause are related to MC-OOK.

The first sentence of Clause 30.1 contains a descriptive statement:

Clause 30 (Wake-Up Radio (WUR) PHY specification(11ba)) specifies the PHY entity for orthogonal frequency division multiplexing (OFDM) and Multicarrier On-Off Keying (MC-OOK) systems.

This sentence is not a requirement.

There are other mentions of MC-OOK in clause 30.1, but none are normative “shall” requirements:

The WUR PHY uses the multicarrier on-off keying (MC-OOK) modulation for (#1128)WUR-Sync and WUR-Data fields. MC-OOK is defined as an on-off keying, modulated with a multicarrier signal. The multicarrier signal should be generated using contiguous 13 subcarriers, cantered within a 20 MHz channel, with a subcarrier spacing of 312.5 kHz and the centre subcarrier (#1131)being null. The subcarrier coefficients may take values from the BPSK, QPSK, 16-QAM, 64-QAM, or 256-QAM constellation symbols.

The choice of verbs “uses” and “should” instead of the typical normative requirement may or shall was much debated in TGba, and consensus was that “uses” and “should” would be used.

The description of the WUR-Sync field 30.3.9.3 WUR-Sync field:

* 30.3.9.3 WUR-Sync field for WUR LDR

For WUR LDR, the WUR-Sync field shall be constructed as an MC-OOK signal. The WUR-Sync sequence is constructed by concatenating two copies of the 32-bit sequence *W*, where each bit in the sequence is mapped to an MC-OOK symbol of duration 2 µs, and *W* is defined in Equation (30-9).

* WUR-Sync field for WUR HDR

For WUR HDR, the WUR-Sync field shall be constructed as an MC-OOK signal. The WUR-Sync sequence is constructed as the bitwise complement of the 32-bit sequence *W*, where each bit in the sequence is mapped to an MC-OOK symbol of duration 2 µs, and *W* is defined in Equation (30-9). This bitwise complement sequence is defined in Equation (30-10).

These two requirements state that these fields shall be constructed as an “MC-OOK signal”. But what an MC-OOK signal is not defined by normative statements. Examples of how an MC-OOK can be generated are given in Annex AC, which is informative. These examples are only examples and there is no normative text as to how to generate an MC-OOK signal. Therefore, the “shall” requirements in 30.3.9.3 and 30.3.9.4 as they are currently stated are incomplete and poorly specified as there are no requirements in the specification as to what an MC-OOK signal is. The OOK signal requirements that do apply to the WUR LDR and WUR HDR are defined in the specification. The specification clearly specifies the OOK signal with the OOK parameters given in clause 30.3.12. While the requirements in clause 30.3.12 for the “signal” may be met by the signal generation technique of MC-OOK as described in Annex AC, the MC-OOK signal generation technique is not the only way to generate a signal that meets the specified OOK properties.

Therefore, to clear up these issues in the specification it is suggested that the term MC-OOK should only be used to describe a possible method to generate WUR OOK signals that meet the requirements in 30.3.12. It is further suggested that where the requirement refers to a signal or waveform meeting the WUR OOK requirements it be referred to as “WUR OOK” and not as “MC-OOK”.

* WUR-Sync field for WUR LDR

The WUR-Sync field shall consist of two concatenated copies of the 32-bit sequence *W*, where each bit in the sequence is modulated as an OOK symbol of duration 2 µs, and *W* is defined in Equation (30-9).

Similar requirements are made regarding the WUR-Data field in 30.3.10:

* WUR-Data field for WUR LDR and WUR HDR

The WUR-Data field shall be encoded by WUR encoding. Encoded bits corresponding to each input bit are shown in Table 30-9 (WUR encoded bits for WUR LDR(11ba)) and Table 30-10 (WUR encoded bits for WUR HDR(11ba)) for WUR LDR and WUR HDR, respectively.

….

The encoded binary data shall be modulated using MC-OOK, i.e., encoded bits 0 and 1 shall be represented by Off and On Symbols, respectively. The duration of the MC-OOK symbol corresponding to each encoded bit is dependent on WUR data rate: 4 µs for WUR LDR and 2 µs for WUR HDR.

However the specification normative text is silent on what being modulated using MC-OOK is.

Clause 30.3.12 “WUR transmit specification” provide requirements for the transmit spectrum mask in clause 30.2.12.1, spectral flatness in discussed in clause 30.2.12.2 – but there are no shall requirements, transmit center frequency and symbol clock frequency tolerance requirements are in clause 30.3.12.3 (see below), transmit On and Off symbols power ratio requirements are in clause 30.3.12.4 (see below), clause 30.3.12.5 “Correlation test on MC-OOK symbols” continues the only mention of MC-OOK in clause 30.3.12 - but this clause has no “shall” requirements, only a “should”, so the normative purpose of this test is not defined.

The normative requirements for transmit center frequency, symbol clock frequency tolerance and On/Off symbols power ration are typical OOK modulation requirements and make no mention of MC-OOK:

* Transmit center frequency and symbol clock frequency tolerance

The symbol clock frequency and transmit center frequency tolerance shall be ±20 ppm maximum. The transmit center frequency and the symbol clock frequency for all transmit antennas and frequency segments shall be derived from the same reference oscillator.

* Transmit On and Off Symbols power ratio

For each input bit of the WUR-Data field transmitted at WUR HDR, the ratio between the averaged power of the On Symbol and the averaged power of the Off Symbol of the transmit signal in the WUR-Data field shall be at least 20 dB.

For each input bit of the WUR-Data field transmitted at WUR LDR, the ratio between the averaged power over On Symbols and the averaged power over Off Symbols of the transmit signal in the WUR-Data field shall be at least 20 dB.

For the WUR-Sync field transmission, the ratio between the averaged power over all On Symbols and the averaged power over all Off Symbols in the WUR-Sync field shall be at least 20 dB.

For FDMA transmission, the above requirement on the transmit On and Off Symbols power ratio applies to each 20 MHz channel.

There is no mention of MC-OOK in clause 30.3.13, and 30.3.14

Clause 30.3.15 WUR receive procedure MC-OOK is mentioned once in the last paragraph of the clause, in the requirement below:

“The PHY entity shall begin receiving the MC-OOK symbols in the WUR-Data field. If signal loss occurs during reception, prior to completion of the PPDU reception, the error condition PHY-RXEND.indication (CarrierLost) shall be reported to the MAC. …”

Clause 30.4 WUR PLME uses MC-OOK to define a type of symbol “MC-OOK symbols.

Clause 30.5 WUR Data Rates uses MC-OOK as a modulation type.

**Proposed red lined text, to resolve the comment (page.line numbers based on 802.11REVme D1.3):**

(228.28)

**multicarrier on-off keying (MC-OOK) symbol:** (#2242) A wake up receiver (WUR) OOK symbol generated using multiple carriers, either an WUR OOK On Symbol where the multicarrier signal is present or an WUR OOK Off Symbol where no signal is present.(11ba)

….

(4861.57)

A WUR AP sending a WUR Beacon frame shall set the Type Dependent Control field of the WUR Beacon frame to the TSF timer [5:16] of the WUR AP’s TSF timer at the time that the start of the first WUR On-Off Keying (OOK) symbol containing the first bit of the Type Dependent Control field is transmitted by the PHY plus the WUR AP’s delays through its local PHY from the MAC-PHY interface to its interface with the WM.

….

(4885.7)

Clause 30 (Wake-Up Radio (WUR) PHY specification(11ba)) specifies the PHY entity for orthogonal frequency division multiplexing (OFDM) and On-Off Keying (OOK) systems. In addition to the requirements in Clause 30 (Wake-Up Radio (WUR) PHY specification(11ba)), a WUR STA that supports WUR PHY specification shall support(#546) transmitting and receiving PPDUs that are compliant with the mandatory requirements of the following PHY specifications:

….

(4885.53)

The WUR PHY uses OOK modulation for (#1128)WUR-Sync and WUR-Data fields. These OOK fields may be generated by multicarrier on-off-keying (MC-OOK), a technique to generate an OOK modulation with a multicarrier signal. The multicarrier signal should be generated using contiguous 13 subcarriers, centered within a 20 MHz channel, with a subcarrier spacing of 312.5 kHz and the center subcarrier (#1131)being null. The subcarrier coefficients may take values from the BPSK, QPSK, 16-QAM, 64-QAM, or 256-QAM constellation symbols.

….

(4893.47)

For a single 20 MHz WUR channel, the 2 µs duration WUR OOK On Symbol may be generated by MC-OOK by the On-WG using (#1137)the center 13 subcarriers of a 64-point IDFT, sampling at 20 MHz as follows:

….

(4893.60)

* The last 8 samples of those 32 samples are prepended to the 32 samples generating 40 samples, representing the 2 µs duration WUR OOK On Symbol. This step corresponds to the GI Insertion in Figure 30-6 (An example of an On-WG for the WUR-Sync and WUR-Data fields with WUR HDR(11ba)).

For a single 20 MHz WUR channel, the 2 µs duration WUR OOK Off Symbol may be generated by MC-OOK by the Off-Waveform Generator (Off-WG) as zero for 2 µs.

With the 2 µs duration WUR OOK On and Off Symbols, the PPDU should meet the Correlation test defined in 30.3.12.5 (Correlation test on MC-OOK symbols).

….

(4894.36)

For a single 20 MHz WUR channel the 4 µs duration WUR OOK On Symbol may be generated by MC-OOK by the On-WG using (#1139)the center 13 subcarriers of a 64-point IDFT, sampling at 20 MHz as follows:

* The 12 subcarriers with subcarrier indices *k* = (–6, –5, … –1, 1, 2, … 6) are used with nonzero input. Other subcarriers are null.
* The coefficients of the nonzero subcarriers are selected from the symbols of any of the following constellations: BPSK, QPSK, 16-QAM, 64-QAM, and 256-QAM.
* The 64 values from the 64-point IDFT are processed by the Symbol Randomizer as described in 30.3.4.4 (Symbol Randomizer and Per-transmit chain Cyclic Shift).
* The last 16 values of the 64-point IDFT output are prepended to the 64 samples generating 80 samples, representing the 4 µs duration WUR OOK On Symbol. This step corresponds to the GI Insertion in Figure 30-7 (An example of an On-WG for the WUR-Data fields with WUR LDR(11ba)).

For a single 20 MHz WUR channel the 4 µs duration WUR OOK Off Symbol may be generated by MC-OOK by the Off-Waveform Generator (Off-WG) as zero for 4 µs.

With the 4 µs duration WUR OOK On and Off Symbols, the PPDU should meet the Correlation test defined in 30.3.12.5 (Correlation test on MC-OOK symbols).

….

(4895.31)

The WUR OOK On Symbol for the 20 MHz WUR waveform should be generated according to 30.3.4.1 (WUR Basic PPDU waveform generation for WUR-Sync field and WUR-Data field with WUR HDR) or 30.3.4.2 (WUR Basic PPDU waveform generation for WUR-Data field with WUR LDR) depending on WUR\_DATARATE. The 40 MHz or 80 MHz WUR FDMA PPDU should be generated by multiplexing multiple 20 MHz WUR waveforms in the corresponding channel as shown in Figure 30-8 (An example of a WUR-Data field signal generator for the FDMA transmission(11ba)).

….

(4898.63)

* Waveform generation: Generate the WUR OOK waveform by using either On-WG or Off-WG according to the WUR-Sync. The samples in Off-WG have zero energy. WUR-Sync bit duration *TSync* is 2 µs. Symbol randomization and per-transmit-chain CSD is applied within the waveform generation step.

….

(4899.33)

* Waveform generation for the WUR-Sync field: Generate the WUR OOK waveform for the WUR-Sync field by using either On-WG or Off-WG according to the WUR-Sync bit for each 20 MHz subchannel. The samples in Off-WG have zero energy. Each WUR-Sync bit duration, *TSync* is 2 µs.

….

(4899.60)

The WUR data rate represents the data rate used in the WUR-Data field of the WUR PPDU. There are two data rates: 62.5 kb/s and 250 kb/s, respectively, which are denoted as WUR LDR and WUR HDR. WUR LDR and WUR HDR are distinguished by the predefined sequence in the WUR-Sync field. Rate-dependent parameters are shown in Table 30-14 (WUR PPDU data rates(11ba)).WUR encoding is applied to both WUR data rates. MC-OOK may be used for modulation of both WUR data rates.

….

(4900.10)

|  |  |  |
| --- | --- | --- |
| * Timing-related constants(11ba) | | |
| Parameter | Value | Description |
|  | 312.5 kHz | Subcarrier frequency spacing for WUR PPDU |
| *TDFT,WUR* | 3.2 µs | IDFT/DFT period for the WUR PPDU |
| *TGI,WUR* | 0.8 µs for 4 µs duration WUR OOK symbols; 0.4 µs for 2 µs duration WUR OOK symbols | Guard interval duration for the WUR PPDU |
| *TGI,2* | 1.6 µs | Guard interval duration for the L-LTF field |
| *TSym-LDR* | 4 µs | Duration of WUR LDR WUR OOK symbol in WUR-Data field |
| *TSym-HDR* | 2 µs | Duration of WUR HDR WUR OOK symbol in WUR-Data field |
| *TSym* | *TSym-LDR* or *TSym-HDR* depending on WUR data rate | Duration of WUR OOK symbol in WUR-Data field |
| *TSync* | 2 µs | Duration of WUR OOK symbol in WUR-Sync field |
| *TL-STF* | 8 µs = 10 × *TDFT,WUR* /4 | Non-HT Short Training field duration |
| *TL-LTF* | 8 µs = 2 × *TDFT,WUR + TGI,L-LTF* | Non-HT Long Training field duration |
| *TL-SIG* | 4 µs | Non-HT SIGNAL field duration |
| *TBPSK-Mark1* | 4 µs | BPSK-Mark1 field duration |
| *TBPSK-Mark2* | 4 µs | BPSK-Mark2 field duration |
| *TWUR-Sync-LDR* | 128 µs | WUR-Sync field duration for WUR LDR |
| *TWUR-Sync-HDR* | 64 µs | WUR-Sync field duration for WUR HDR |
| *TWUR-Sync* | *TWUR-Sync-LDR* or *TWUR-Sync-HDR* depending on WUR data rate | WUR-Sync field duration for WUR PPDU |

|  |  |
| --- | --- |
| * Frequently used parameters(11ba) | |
| Symbol | Explanation |
| *NSPDB* | Number of WUR OOK symbols per information data bit.  For WUR LDR, *NSPDB* =4.  For WUR HDR, *NSPDB* =2. |
| *NTX* | Number of transmit chains |
| *NWUR-Sync* | Number of WUR OOK symbols in the WUR-Sync field.  For WUR LDR, *NWUR-Sync*=64.  For WUR HDR, *NWUR-Sync*=32. |

 ….

(4901.34)

The transmitted RF signal is obtained by up-converting the complex baseband signal, which consists of several fields. The timing boundaries for the various fields are shown in Figure 30-10 (Timing boundaries for the WUR Basic PPDU fields(11ba)) where *NWUR-Sync* is the number of WUR OOK symbols in the WUR-Sync field and is defined in Table 30-4 (Frequently used parameters(11ba)).

*Note to editor – Figure 30-10 should be updated to replace MC-OOK with WUR OOK – attached below.*

|  |
| --- |
|  |

….

(4902.28)

where *TField* is the duration of the field, *TWUR-Sync* is the duration of WUR-Sync field, as defined in Table 30-3 (Timing-related constants(11ba)). *TWUR-Data* is the duration of WUR-Data field, with *TWUR-Data*=*Nsym* X *Tsym,* where *Nsym* is the number of WUR OOK symbols in the WUR-Data field, as given in Equation (30-14).

The duration of different fields of the WUR Basic PPDU are provided in Table 30-3 (Timing-related constants(11ba)).

For the L-STF, L-LTF, L-SIG, BPSK-Mark1, and BPSK-Mark2 fields, the baseband signal is constructed as described in 30.3.9.2 (Non-WUR portion of WUR PHY preamble).

The WUR-Sync and WUR-Data fields comprises of WUR OOK symbols as described in 30.3.9.3 (WUR-Sync field) and 30.3.10 (WUR-Data field), respectively. For the WUR OOK On Symbols in the WUR-Sync field (WUR-Sync On Symbols) and the WUR OOK On Symbols in the WUR-Data field (SymLDROn and SymHDROn), the baseband signal may be obtained by MC-OOK taking the Inverse Discrete Fourier Transform (IDFT) of a set of subcarrier coefficients, which is described by Equation (30-3). This general representation holds for WUR-Sync and WUR-Data fields, and the field specific parameters are provided in Table 30-5 (Field specific parameter values for the MC-OOK symbols in WUR-Sync and WUR-Data fields(11ba)).



where

 is the scaling factor to compensate for 50% duty cycle from WUR OOK.

 is the number of transmit chains as defined in Table 30-4 (Frequently used parameters(11ba)).

 is a windowing function of duration T used to control spectral leakage. Refer to 17.3.2.5 (Mathematical conventions in the signal descriptions) for a discussion of windowing functions.

*m* and *n* are described in 30.3.4.4 (Symbol Randomizer and Per-transmit chain Cyclic Shift). These parameter values may vary across WUR OOK symbols within the field.

 is the subcarrier frequency spacing and is given in Table 30-3 (Timing-related constants(11ba)).

 is the length of cyclic prefix.

 is the cyclic shift applied to the signal from transmit chain , and equals either  or , as given in Table 30-5 (Field specific parameter values for the MC-OOK symbols in WUR-Sync and WUR-Data fields(11ba)).  and  are implementation dependent, and example values are given in Table AC-3 (Recommended CSD values for the WUR-Sync field and WUR-Data field with WUR HDR(11ba)) and Table AC-4 (Recommended CSD values for the WUR-Data field with WUR LDR(11ba)).

 is the pseudorandom cyclic shift with cyclic shift index *n* described in 30.3.4.4 (Symbol Randomizer and Per-transmit chain Cyclic Shift). Its values are specified in Table 30-6 (Values of pseudorandom cyclic shift with cyclic shift index n for the WUR-Sync field and WUR-Data field with WUR HDR(11ba)) and Table 30-7 (Values of pseudorandom cyclic shift with cyclic shift index n for the WUR-Data field with WUR LDR(11ba)).

are the field specific subcarrier coefficients, and equals either  or , as given in Table 30-5 (Field specific parameter values for the MC-OOK symbols in WUR-Sync and WUR-Data fields(11ba)).  and  are implementation dependent sequences, and example values for these sequences are given in Table AC-1 (Example Values for the Sequence SHDR used for the Construction of the 2 µs duration MC-OOK On Symbol(11ba)) and Table AC-2 (Example Values for the Sequence SLDR used for the Construction of the 4 µs duration MC-OOK On Symbol(11ba))

 is a tone scaling factor.

….

(4903.63)

For the WUR OOK Off Symbols in the WUR-Sync and WUR-Data fields, .

….

(4904.60)

Table 30-8 (The states of the LFSR, the values of the bits b2, b1, b0, the value of n, and the pseudorandom cyclic shift with cyclic shift index n for the first seven WUR OOK symbols in the WUR-Sync field(11ba)) provides the values of the LFSR, the three bits (b2, b1, b0), the index value *n*, and the time delay value of  for the first seven states of the LFSR.

|  |
| --- |
| * The states of the LFSR, the values of the bits b2, b1, b0, the value of n, and the pseudorandom cyclic shift with cyclic shift index nfor the first seven WUR OOK symbols in the WUR-Sync field(11ba) |

….

(4908.42)

* Cyclic Shift for WUR-Sync field

Recommended cycle shift diversity (CSD) values for the WUR-Sync field, which is constructed from 2 µs duration WUR OOK symbols, are provided in Annex AC.

* WUR-Sync field for WUR LDR

For WUR LDR, the WUR-Sync field shall be constructed as an WUR OOK signal. The WUR-Sync sequence is constructed by concatenating two copies of the 32-bit sequence *W*, where each bit in the sequence is mapped to an WUR OOK symbol of duration 2 µs, and *W* is defined in Equation (30-9).



This WUR-Sync sequence is used to construct the WUR-Sync field waveform as shown in Figure 30-4.

* WUR-Sync field for WUR HDR

For WUR HDR, the WUR-Sync field shall be constructed as an WUR OOK signal. The WUR-Sync sequence is constructed as the bitwise complement of the 32-bit sequence *W*, where each bit in the sequence is mapped to an MC-OOK symbol of duration 2 µs, and *W* is defined in Equation (30-9). This bitwise complement sequence is defined in Equation (30-10).

….

(4909.9)

* WUR-Data field
* Cyclic Shift for WUR-Data field

Recommended cycle shift diversity (CSD) values for the WUR-Data field with WUR LDR, which is constructed from 4 µs duration WUR OOK symbols, are provided in Annex AC.

Recommended cycle shift diversity (CSD) values for the WUR-Data field with WUR HDR, which is constructed from 2 µs duration WUR OOK symbols, are provided in Annex AC.

* WUR-Data field for WUR LDR and WUR HDR

The WUR-Data field shall be encoded by WUR encoding. Encoded bits corresponding to each input bit are shown in Table 30-9 (WUR encoded bits for WUR LDR(11ba)) and Table 30-10 (WUR encoded bits for WUR HDR(11ba)) for WUR LDR and WUR HDR, respectively.

|  |  |
| --- | --- |
| * WUR encoded bits for WUR LDR(11ba) | |
| Input bit | Encoded bits |
| 0 | 1010 |
| 1 | 0101 |

|  |  |
| --- | --- |
| * WUR encoded bits for WUR HDR(11ba) | |
| Input bit | Encoded bits |
| 0 | 10 |
| 1 | 01 |

The encoded binary data shall be modulated using WUR OOK, i.e., encoded bits 0 and 1 shall be represented by Off and On Symbols, respectively. The duration of the WUR OOK symbol corresponding to each encoded bit is dependent on WUR data rate: 4 µs for WUR LDR and 2 µs for WUR HDR.

For WUR LDR, 4 µs duration WUR OOK Off and On Symbols are denoted as SymLDROff and SymLDROn, respectively. For WUR HDR, 2 µs duration WUR OOK Off and On Symbols are denoted as SymHDROff and SymHDROn, respectively.

SymLDROn and SymHDROn should be generated using contiguous 13 subcarriers, centered within a 20 MHz channel, with a subcarrier spacing of 312.5 kHz and the center subcarrier being null. The subcarrier coefficients may take values from the BPSK, QPSK, 16-QAM, 64-QAM, or 256-QAM constellation symbols.

When a single 20 MHz WUR channel is used for transmission of a WUR Basic PPDU, SymHDROn and SymLDROn are described in 30.3.8 (Mathematical description of signals). The generation of SymHDROn and SymLDROn is described in 30.3.4.1 (WUR Basic PPDU waveform generation for WUR-Sync field and WUR-Data field with WUR HDR) and 30.3.4.2 (WUR Basic PPDU waveform generation for WUR-Data field with WUR LDR), respectively.

For a FDMA transmission, the WUR OOK waveform generation is described in 30.3.4.3 (WUR FDMA PPDU WUR-Data field waveform generation).

….

(4910.12)

* WUR Padding field for a WUR FDMA PPDU

For a WUR FDMA PPDU, if padding is needed on any 20 MHz subchannels, the padding waveform shall be generated by repeating the WUR OOK waveform of WUR HDR information bit 1 as described in Table 30-14 (WUR PPDU data rates(11ba)). The symbol randomizer as described in 30.3.4.4 (Symbol Randomizer and Per-transmit chain Cyclic Shift) should be used in the padding field continued from the WUR-Data field. The state of the LSFR is updated every  during the padding field.

For a nonpunctured WUR FDMA 20 MHz subchannel, , the number of padding WUR HDR bits is calculated as:

* 

where

 and  denote  and  for 20 MHz subchannel , respectively.  and  are defined in Table 30-3 (Timing-related constants(11ba)).

 is the number of WUR OOK symbols in the WUR-Data field for 20 MHz subchannel. It is a function of the length of WUR MAC frame in the WUR-Data field (WUR\_MPDU\_LENGTH) for 20 MHz subchannel  and  as defined in Equation (30-14).

….

(4914.5)

* Correlation test on WUR OOK symbols

An autocorrelation metric indicative of that used for L-STF detection in non-WUR receivers is defined. The correlation metric is given in Equation (30-12),



where *M* = 16, which is the number of samples in an 800 ns time period, sampled at 20 MHz, and *N*=6, which is the number of 800 ns time periods over which the correlation metric is calculated.

This metric is calculated over the WUR-Sync and WUR-Data fields, at a sampling rate of 20 MHz using the WUR OOK symbols. Hence, the value of *n* spans from the beginning of the WUR-Sync field to the end of the WUR-Data field. The PPDU should be tested for both the WUR LDR and WUR HDR with a 6-byte data field of random data. The maximum value of the correlation metric should be less than 0.4.

….

(4916.6)

*Note to editor – Figure 30-14, 30-15, 30-17, 30-18 should be updated to replace “WUR coded MC-OOK” with “WUR OOK”, “MC-OOK Symbols” with “WUR OOK Symbols” – attached below.*

….

(4920.61)

The PHY entity shall begin receiving the WUR OOK symbols in the WUR-Data field. If signal loss occurs during reception, prior to completion of the PPDU reception, the error condition PHY-RXEND.indication (CarrierLost) shall be reported to the MAC. The received PPDU bits are decoded, assembled into octets and presented to the MAC using a series of PHY-DATA.indication (DATA) primitive exchanges. Any remaining bits, which could not be assembled into a complete octet are discarded. RCPI measurement is made during the reception of the data field as described in 19.3.19.7 (Received channel power indicator (RCPI) measurement). Since the WUR PHY is not aware of the end of the WUR PPDU, the PHY shall keep decoding until receive signal strength drops significantly. Alternatively, the WUR MAC may also indicate the end of WUR PPDU to PHY by means of PHY-CCARESET.request primitive. On termination, the WUR PHY enters the RX IDLE state. If the WUR PHY terminates due to reduction of the receive signal strength, a PHY-RXEND.indication (NoError) primitive shall be issued. If it terminates due to PHY-CCARESET.request, a PHY-RXEND.indication (MAC Request) primitive shall be issued.

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(4921.24)

where

*TL-STF*, *TL-LTF*, *TL-SIG*, *TBSPK-Mark1*, *TBSPK-Mark2, TWUR-Sync*, and *TSym*are defined in Table 30-3 (Timing-related constants(11ba)), and *NSym* is the number of WUR OOK symbols in the WUR-Data field.

The number of WUR OOK symbols is a function of the length of WUR MAC frame in the WUR-Data field (WUR\_MPDU\_LENGTH) and *NSPDB* and is calculated as follows:

….

(4922.38)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| * WUR PPDU data rates(11ba) | | | | | | |
| Data rate | Modulation | Symbol structure | | Equivalent information bit duration | NSPDB | Data rate (kb/s) |
| WUR LDR | WUR OOK | Information 0 | [SymLDROn, SymLDROff, SymLDROn, SymLDROff] | 16 µs | 4 | 62.5 |
| Information 1 | [SymLDROff, SymLDROn, SymLDROff, SymLDROn] |
| WUR HDR | WUR OOK | Information 0 | [SymHDROn, SymHDROff] | 4 µs | 2 | 250 |
| Information 1 | [SymHDROff, SymHDROn] |

**Updated Visio files:**









**References:**