### IEEE P802.11Wireless LANs

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| Proposed Draft WUR PHY Specification |
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Abstract

This document fills in the PHY portion of the draft outline recommended in document 802.11-17/1585r2.

It is based on the Task Group decisions recorded in document 802.11-17/575r8.

Text between square brackets “[]” is text used to make a comment or ask a question. It is not intended to be include in the final draft.

* Wake-Up Radio (WUR) PHY specification
* Introduction

Clause 32 (Wake-up Radio (WUR) PHY specification) specifies the PHY entity for orthogonal frequency division multiplexing (OFDM) and Multicarrier On-Off Keying (MC-OOK) system. In addition to the requirements in Clause 32 (Wake-up Radio (WUR) PHY specification), a STA that supports WUR PHY specification shall be capable of transmitting and receiving PPDUs that are compliant with the mandatory requirements of the following PHY specifications:

— Clause17 (Orthogonal frequency division multiplexing (OFDM) PHY specification).

A STA that supports WUR PHY specification may be a WUR transmitter STA. A WUR transmitter STA shall be capable of transmitting the wake-up PPDU.

A STA that supports WUR PHY specification may be a WUR receiver STA. A WUR receiver STA shall be capable of receiving the wake-up PPDU.

The WUR PHY is based on the PHY defined in Clause17 (Orthogonal frequency division multiplexing (OFDM) PHY specification).

The Wake-up Radio PHY provides support for data rates of 62.5kb/s and 250kb/s, where the bit symbol structures are respectively {[ON OFF ON OFF], [OFF ON OFF ON]} and {[ON OFF], [OFF ON]}.

The Wake-up Radio PHY provides support for Manchester code, which shall be applied to all data rates for the WUR Data field.

The Wake-up Radio PHY provides support for TBD (channel bandwidth, data rate, code type, etc.).

A Wake-up Radio STA shall support the following features:

— TBD

A Wake-up Radio STA may support the following features:

— TBD

* WUR PHY service interface

**32.2.1 Introduction**

The WUR PHY provides an interface to the WUR MAC. The interface includes WUR\_TXVECTOR, WUR\_RXVECTOR and WUR\_PHY-CONFIG\_VECTOR.

Using the WUR\_TXVECTOR, the MAC supplies the PHY with per PPDU transmit parameters. Using the WUR\_RXVECTOR, the PHY informs the MAC of the received PPDU parameters. Using the WUR\_PHY-CONFIG\_VECTOR, the MAC configures the PHY for operation, independent of frame transmission or reception.

**32.2.2 WUR\_TXVECTOR and WUR\_RXVECTOR parameters**

The parameters in Table 32-1 (WUR\_TXVECTOR and WUR\_RXVECTOR parameters) are defined as part of the WUR\_TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the WUR\_RXVECTOR parameter list in the PHY-RXSTART.indication and PHY\_RXEND.indication primitives.

**Table 32-1 – WUR\_TXVECTOR and WUR\_RXVECTOR parameters**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Condition** | **Value** | **WUR\_TXVECTOR** | **WUR\_RXVECTOR** |
| FORMAT |  | Determines the format of the PPDU.Enumerated type:WUR indicate wake-up PPDU format | Y | Y |
| LLENGTH | FORMAT is WUR | Indicates the length of the PSDU in octets in the range of 1 to TBD. This value is used by the PHY to determine the number of octet transfers that occur between the MAC and the PHY. | Y | N |
| Otherwise | TBD |
| LDATARATE | FORMAT is WUR | Indicates the value representing 6 Mb/s in the 20 MHz channel. | Y | N |
| Otherwise | TBD |
| CHANNEL BANDWIDTH | FORMAT is WUR | TBD | Y | N |
| Otherwise | TBD | N | N |
| WUR\_MCS | FORMAT is WUR | Determines the transmission bandwidth of the wake-up PPDU.Enumerated type:MCS0 indicates WUR MCS0 for the data rate 62.5 kb/sMCS1 indicates WUR MCS1 for the data rate 250 kb/s | Y | Y |
| Otherwise | TBD | N | N |
| RSSI | FORMAT is WUR | TBD | N | Y |
| Otherwise | TBD | N | Y |

**32.2.3 WUR\_PHY-CONFIG\_VECTOR parameters**

The WUR\_PHY-CONFIG\_VECTOR carried in a PHY-CONFIG.request primitive for a WUR PHY contains an OPERATING\_CHANNEL parameter, which identifies the operating channel. The PHY shall set dot11CurrentFrequency to the value of this parameter.

* WUR PHY
* Introduction

This subclause provides the procedure by which PSDUs are converted to and from transmissions on the wireless medium.

During transmission, a PSDU is processed and appended to the PHY preamble including legacy preamble and WUR-Sync field to create the wake-up PPDU. At the legacy receivers the legacy preamble is accordingly processed to aid in protection of the WUR PSDU. At the wake-up receiver the WUR-Sync is accordingly processed to aid in the detection, demodulation, and delivery of the PSDU.

* WUR PPDU format

A single PPDU format is defined for this PHY: the WUR-PPDU format. Figure 32- 1 shows the WUR-PPDU format.



Figure 32- 1 -- WUR-PPDU format

The fields of the WUR-PPDU format are summarized in Table 32- 1.

Table 32- 1 -- Fields of the WUR-PPDU

|  |  |
| --- | --- |
| **Field** | **Description** |
| L-STF | Non-HT Short Training field |
| L-LTF | Non-HT Long Training field |
| L-SIG | Non-HT SIGNAL field |
| WUR-Mark | Any BPSK modulated OFDM symbol |
| WUR-Sync | Wake-Up Radio Synchronization field |
| WUR-Data | Wake-Up Radio Data field carrying the PSDU |

[NOTE: Should we replace “Non-HT” with “Legacy”?]

The WUR-Sync can either be 64 µs or 128 µs long and is determined by the rate of the data field WUR-Data.

* Transmitter block diagram

The generation of each field in a WUR-PPDU uses the following blocks:

1. Repetition code
2. Manchester code
3. Symbol multiplier
4. Waveform symbol generation
5. Constellation mapper
6. Inverse discrete Fourier transform (IDFT)
7. Guard interval (GI) insertion
8. Masking
9. Truncation
10. Windowing

Figure 32- 2 to Figure 32- 4 show example transmitter block diagrams. The actual structure of the transmitter is implementation dependent. The transmitter block diagrams for L-STF, L-LTF, and L-SIG are described in Section 21.3.3.

[QUESTION: Here we reference the VHT (e.g. 11ac) clause versus the original 11a Clause 17. Which is our reference Clause 17, 19 or Clause 21?]



Figure 32- 2 – Digital waveform generation for the WUR-Sync and WUR-Data

[The Task Group needs to decide if we use CSD or something else]

The digital waveform generator (DWG) is shown in Figure 32- 2. [The bit generator is TBD]. The constellation mapper maps the generated bits to the 12 subcarriers -6 to -1 and 1 to 6. The mask selects a 2 µs part out of the 4 µs long symbol and is only used when *TSym* = 2 µs.



Figure 32- 3 -- The WUR signal generator for the Sync field

The WUR signal generator for the Sync field is shown in Figure 32- 3. The sync sequence is then used to switch between the digital waveform generator (DWG) and the zero generator (ZG). The ZG generates zeros over a time of *TSYM*. Note that for the Sync field, *TSym* = *TSync* in the DWG.



Figure 32- 4 -- The WUR signal generator for the Data field

[The Task Group needs to define the Window in the figure above]

The WUR signal generator for the Data field is shown in Figure 32-4. The information bits are repeated twice with a repetition code for MCS0. For both MCS0 and MCS1, the bits are Manchester coded. Each coded bit is then used to switch between the digital waveform generator (DWG) and the zero generator (ZG). The ZG generates zeros over a time of *TSym*. [Do we need to draw the zero generator?]

* Overview of the PPDU encoding process

**32.3.4.1 General**

This subclause provides an overview of the WUR-PPDU encoding process.

See section 21.3.4.2.

[QUESTION: Here we reference the VHT (e.g. 11ac) clause versus the original 11a Clause 17. Which is our reference Clause 17, 19 or Clause 21?] [Possibly tie the reference clause to the frequency band of operation]

**32.3.4.2 Construction of the L-STF**

See section 21.3.4.2.

[QUESTION: Here we reference the VHT (e.g. 11ac) clause versus the original 11a Clause 17. Which is our reference Clause 17, 19 or Clause 21?]

**32.3.4.3 Construction of the L-LTF**

See section 21.3.4.2.

**32.3.4.4 Construction of the L-SIG**

See section 21.3.4.2.

**32.3.4.5 Construction of the WUR-OFDM symbol**

<Texts to be filled> [I wait with this section until the figures in section 32.3.3 are done]

**32.3.4.6 Construction of the WUR-Sync**

<Texts to be filled> [I wait with this section until the figures in section 32.3.3 are done]

**32.3.4.6 Construction of the WUR-Data**

<Texts to be filled> [I wait with this section until the figures in section 32.3.3 are done]

* WUR modulation and coding schemes (WUR-MCSs)

The WUR MCS is a value that determines the modulation and coding used in the WUR Data field of the WUR PPDU. It is comprised of only two values: MCS0 and MCS1 for data rates of 62.5 kb/s and 250 kb/s, respectively, and differentiated by the pre-defined sequence in the WUR-Sync field. Rate-dependent parameters for both WUR MCS0 and MCS1 are shown in Table 32-xx (WUR MCSs). Repetition code is applied to WUR MCS0. Manchester code is applied to both WUR MCS0 and MCS1. Multicarrier On Off Keying (MC-OOK) is used for modulation of both WUR MCS0 and MCS1.

* Timing related parameters

Timing-related constants defines the timing-related parameters for WUR PPDU formats.

|  |
| --- |
| * Timing-related constants
 |
| 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 | Guard interval duration for the WUR PPDU |
| *TGI,*L-LTF | 1.6 µs | Guard interval duration for the L-LTF field |
| *TSYM0,ON* | 4 µs | ON duration of WUR MCS0 OOK symbol in WUR Data field |
| *TSYM0,OFF* | 4 µs | OFF duration of WUR MCS0 OOK symbol in WUR Data field |
| *TSYM0* | 4 µs = *TSYM0,ON* = *TSYM0,OFF*  | Duration of WUR MCS0 OOK symbol in WUR Data field |
| *TSYM1,ON* | 2 µs | ON duration of WUR MCS1 OOK symbol in WUR Data field |
| *TSYM1,OFF* | 2 µs | OFF duration of WUR MCS1 OOK symbol in WUR Data field |
| *TSYM1* | 2 µs = *TSYM1,ON* = *TSYM1,OFF*  | Duration of WUR MCS1 OOK symbol in WUR Data field |
| *TSYM* | *TSYM0* or *TSYM1* depending on WUR MCS | Duration of OOK symbol in WUR Data field |
| *TSync* | TBD | Duration of OOK symbol in WUR-Sync field |
| *T*L-STF | 8 µs = 10 × *TDFT,*WUR /4 | Non-HT Short Training field duration |
| *T*L-LTF | 8 µs = 2 × *TDFT,*WUR + *TGI,*L-LTF | Non-HT Long Training field duration |
| *T*L-SIG | 4 µs | Non-HT SIGNAL field duration |
| *T*WUR-Mark | 4 µs | WUR-Mark field duration |
| *T*WUR-Sync0 | 128 µs | WUR-Sync field duration for WUR MCS0 |
| *T*WUR-Sync1 | 64 µs | WUR-Sync field duration for WUR MCS1 |

 Frequently used parameters defines parameters used frequently in Clause 32.

|  |
| --- |
| * Frequently used parameters
 |
| Symbol | Explanation |
| *NSPDB* | Number of OOK symbols per data bit.For WUR MCS0, *NSPDB* =4. For WUR MCS1, *NSPDB* =2. |
| *NSPCB* | Number of OOK symbols per encoded bit. *NSPCB* =1. |
| *NCBPDB* | Number of coded bits per data bit.For WUR MCS0, *NCBPDB* =4.For WUR MCS1, *NCBPDB* =2. |
| *NTX* | Number of transmit chains |
| *NWUR-Sync* | Number of OOK symbols in the WUR-Sync field  |

* Mathematical description of signals

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal on transmit chain$ i\_{TX}$, $r\_{RF}^{(i\_{TX})}(t)$, is related to the complex baseband signal by the relation shown in Equation (32-xx).

$r\_{RF}^{(i\_{TX})}(t)=Re\{r\_{WUR-PPDU}^{(i\_{TX})}\left(t\right)exp⁡(j2πf\_{c}t)\}$ (32-xx)

Where

Re{.} Represents the real part of a complex variable
$f\_{c}$is the center frequency

 $r\_{WUR-PPDU}^{(i\_{TX})}\left(t\right)$ is the baseband WUR signal on transmit chain $i\_{TX}$.

The transmitted RF signal is derived by up-converting the complex baseband signal, which consists of
several fields. The timing boundaries for the various fields are shown in Figure 32-1 where *NWUR-Sync* is the
number of WUR-Sync symbols and is defined in Table 32-xx.



Fig. 32-1- Timing boundaries for the WUR-PPDU Fields

The time offset, $t\_{Field}$, determines the starting time of the corresponding field relative to the start of L-STF
(*t* = 0).

The baseband signal is constructed by the concatenation of several fields as shown in the Fig. 32-1. It can be mathematically described as

$$r\_{WUR-PPDU}^{(i\_{TX})}\left(t\right)=r\_{L-STF}^{(i\_{TX})}\left(t\right)+r\_{L-LTF}^{(i\_{TX})}\left(t-t\_{L-LTF}\right)+r\_{L-SIG}^{(i\_{TX})}\left(t-t\_{L-SIG}\right)+r\_{WUR-Mark}^{(i\_{TX})}\left(t-t\_{WUR-Mark}\right) +r\_{WUR-Sync}^{(i\_{TX})}\left(t-t\_{WUR-Sync}\right)+r\_{Data}^{(i\_{TX})}\left(t-t\_{Data}\right)$$

The timing offset values for various fields are given below:

$$t\_{L-LTF}=T\_{L-STF}$$

$$t\_{L-SIG}=t\_{L-LTF}+T\_{L-LTF}$$

$$t\_{WUR-Mark}=t\_{L-SIG}+T\_{L-SIG}$$

$$t\_{WUR-Sync}=t\_{WUR-Mark}+T\_{WUR-Mark}$$

$$t\_{Data}= t\_{WUR-Sync}+T\_{WUR-Sync}$$

Where $T\_{Field}$ is the duration of the field. $T\_{WUR-Sync}$ is the duration of WUR-Sync field; $T\_{WUR-Sync}=T\_{WUR-Sync0}$, if MCS0 is transmitted and $T\_{WUR-Sync}=T\_{WUR-Sync1}$, if MCS1 is transmitted. The duration of different fields of the WUR-PPDU are provided in Tab. 32-2.

For each of the L-STF, L-LTF, L-SIG, WUR-Mark fields and subfields of the WUR-Sync and WUR-Data, the baseband signal is obtained by taking the Inverse Discrete Fourier Transform (IDFT) as described below

$$r\_{Subfield}^{(i\_{TX})}\left(t\right)=\frac{1}{√N\_{Field}^{Tone} } w\_{T\_{Field}}\left(t\right)\sum\_{k=-N\_{SR,Field}}^{N\_{SR,Field}}X\_{Field}\left(k\right)exp⁡(j2πkΔf\_{Field}(t-T\_{GI,Field}-T\_{CS,Field}^{(i\_{TX})}))$$

Where

$w\_{T\_{Field}}\left(t\right)$ is a windowing function;

$Δf\_{Field}$ is the subcarrier frequency spacing;

$T\_{GI,Field}$ is the guard interval duration for each OFDM symbol in the field.

$T\_{CS,Field}^{\left(i\_{TX}\right)}$ is the cyclic shift applied to the signal from transmit chain $i\_{TX}$, for a particular field.

$N\_{SR,Field}$ is the maximum subcarrier index for a particular field.

$\{X\_{Field}\left(k\right), -N\_{SR,Field}\leq k\leq N\_{SR,Field}\}$ are the subcarrier coefficients for the field.

The parameter values for different fields and subfields are given in Tab. 32-3.

**Table 32-3- Parameter values for different fields and subfields**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | L-STF | L-LTF | L-SIG | WUR-Mark | WUR-Sync | WUR-Data |
| $$N\_{Field}^{Tone}$$ | 12 | 52 | 52 | TBD | TBD | TBD |
| $$w\_{T\_{Field}}\left(t\right)$$ | Ref. 17.3.2.5 | Ref. 17.3.2.5 | Ref. 17.3.2.5 | TBD | TBD | TBD |
| $$Δf\_{Field}$$ | 312.5 KHz | 312.5 KHz | 312.5 KHz | TBD | 312.5 KHz | TBD |
| $$T\_{GI,Field}$$ | 0.8 µs | 1.6 µs | 0.8 µs | TBD | TBD | TBD |
| $$N\_{SR,Field}$$ | 26 | 26 | 26 | TBD | TBD | TBD |
| $$X\_{Field}\left(k\right)$$ | Ref. 19.3.9.3 | Ref. 19.3.9.3 | Ref. 19.3.9.3 | TBD | TBD | TBD |
| $$T\_{CS,Field}^{\left(i\_{TX}\right)}$$ | TBD | TBD | TBD | TBD | TBD | TBD |

* WUR PHY Preamble
* Introduction

Since WUR has several use cases in outdoor and indoor scenarios, it is beneficial to support multiple data rates for the data field of WUR PPDU. The WUR supports two data rates for the WUR: (i) Low data rate of 62.5 kb/s. This provides sufficient receiver sensitivity to reach the cell edge stations. This data rate meets the range of the main radio (ii) High data rate of 250 kb/s. This provides sufficient receiver sensitivity for several devices in the network and enhanced spectral efficiency for the devices close to the access point.

The rate of the data portion of the WUR PPDU will be indicated using WUR-Sync. There will not be an explicit field in the WUR packet to indicate the data rate. To indicate a low data rate for data portion of WUR PPDU, a repeated sequence ([T T]) is transmitted. Here T is a 64 µs long sequence. To indicate a high data rate, a bit complement of the sequence T is transmitted.

* Non-WUR portion of WUR PHY preamble

The Non-WUR portion of the WUR PHY preamble consists of four fields: L-STF, L-LTF, L-SIG and WUR-Mark. All of these fields are 20 MHz.

The L-STF is constructed according to section 21.3.4.2.

The L-LTF is constructed according to section 21.3.4.3.

The L-SIG is constructed according to section 21.3.4.4 and 21.3.8.2.4. The value of TXTIME used in section 21.3.8.2.4 is set as TBD.

The WUR-Mark is a single 20-MHz OFDM symbol with BPSK modulation. The values of the BSPK subcarriers is TBD.

* WUR-Sync field

**32.3.8.3.1 Introduction**

The structure of the WUR-Sync Field depends on the MCS of the data field. For MCS0 the duration of the WUR-Sync Field is 128 µs. For MCS1 the duration of the WUR-Sync Field is 64 µs. The WUR-Sync Field is used by the receiver for packet detection, symbol timing recovery and determination of the MCS.

**32.3.8.3.2 Cyclic Shift for WUR-Sync Field**

TBD

**32.3.8.3.3 WUR-Sync Field for MCS0**

For MCS0 the WUR-Sync Field is constructed as a multicarrier on-off keying (MC-OOK) signal. The OOK signal is constructed by concatenating two copies of the sequence TBD-bit sequence $T$, where each bit in the sequence is duration TBD µs. A “one” in the OOK sequence indicates a signal amplitude of unity and a “zero” in the OOK sequence indicates a signal amplitude of zero. The bit sequence $T$ is given by,

$$\begin{array}{c}T=\{TBD, TBD, …, TBD\}\#\left(1\right)\end{array}$$

The OFDM portion of the WUR-Sync signal is constructed by concatenating 32 replicas of the same 4-µs OFDM symbol. This OFDM symbol consists of TBD subcarriers, which are modulated by the elements of the sequence $S$, given by,

$$\begin{array}{c}S\_{-6,6}= \left\{TBD, TBD, …, TBD\right\}\#(2)\end{array}$$

The OOK symbol modulates the multicarrier OFDM symbol.

[NOTE: Once we agree on the duration of the WUR-Sync bit duration, we can add an equation for the WUR-Sync field consisting of the OOK symbols times the OFDM symbol]

**32.3.8.3.4 WUR-Sync Field for MCS1**

For MCS1 the WUR-Sync Field is constructed as a multicarrier on-off keying (MC-OOK) signal. The OOK signal is constructed as the bit-wise complement of the sequence TBD-bit sequence $T$, where each bit in the sequence is duration TBD µs, where $T$ is given in Equation 1. This bit-wise complement sequence is given by,

$$\begin{array}{c}\overbar{T}=\{TBD, TBD, …, TBD\}\#\left(3\right)\end{array}$$

A “one” in the OOK sequence indicates a signal amplitude of unity and a “zero” in the OOK sequence indicates a signal amplitude of zero.

The OOK symbol modulates the multicarrier OFDM symbol.

[NOTE: Once we agree on the duration of the WUR-Sync bit duration, we can add an equation for the WUR-Sync field consisting of the OOK symbols times the OFDM symbol.]

* WUR Data field

The WUR Data field shall be encoded by repetition code for WUR-MCS0 as shown in Table 32.a (Repetition coded bits), and Manchester code for both WUR-MCS0 and WUR-MCS1 as shown in Table 32.b (Manchester coded bits). Encoding processes are illustrated in Figure 32.a (Encoding process for WUR-MCS0) and Figure 32.b (Encoding process for WUR-MCS1) for WUR-MCS0 and WUR-MCS1, respectively. Encoded bits corresponding to each input bit are shown in Table 32.c (Encoded bits for WUR-MCS0) and Table 32.d (Encoded bits for WUR-MCS1) for WUR-MCS0 and WUR-MCS1, respectively.

Table 32.a Repetition coded bits

|  |  |
| --- | --- |
| Input bit | Repetition coded bits |
| 0 | 0 0 |
| 1 | 1 1 |

Table 32.b Manchester coded bits

|  |  |
| --- | --- |
| Input bit | Manchester coded bits |
| 0 | 1 0 |
| 1 | 0 1 |



Figure 32.a Encoding process for WUR-MCS0



Figure 32.b Encoding process for WUR-MCS1

Table 32.c Encoded bits for WUR-MCS0

|  |  |
| --- | --- |
| Input bit | Encoded bits |
| 0 | 1 0 1 0 |
| 1 | 0 1 0 1 |

Table 32.d Encoded bits for WUR-MCS1

|  |  |
| --- | --- |
| Input bit | Encoded bits |
| 0 | 1 0 |
| 1 | 0 1 |

The encoded binary data shall be modulated by MC-OOK, i.e., encoded bits 0 and 1 shall be converted into OFF and ON symbols, respectively. The duration of the MC-OOK modulated symbol corresponding to each encoded bit is dependent on WUR-MCS. It is 4 µs for WUR-MCS0 while it is 2 µs for WUR-MCS1. The MC-OOK modulated symbol corresponding to each input bit for WUR-MCS0 is shown in Table 32.e (MC-OOK modulated symbol for WUR-MCS0). *SIM0,OFF* and *SIM0,ON* denote OFF and ON symbols with 4 µs duration for WUR-MCS0, respectively. The MC-OOK modulated symbol corresponding to each input bit for WUR MCS1 is shown in Table 32.f (MC-OOK modulated symbol for WUR MCS1). *SIM1,OFF* and *SIM1,ON* denote OFF and ON symbols with 2 µs duration for WUR-MCS1, respectively.

Table 32.e MC-OOK modulated symbol for WUR-MCS0

|  |  |
| --- | --- |
| Input bit | MC-OOK modulated symbol |
| 0 | *SIM0,ON + SIM0,OFF + SIM0,ON + SIM0,OFF* |
| 1 | *SIM0,OFF + SIM0,ON + SIM0,OFF + SIM0,ON* |

Table 32.f MC-OOK modulated symbol for WUR-MCS1

|  |  |
| --- | --- |
| Input bit | MC-OOK modulated symbol |
| 0 | *SIM1,ON + SIM1,OFF* |
| 1 | *SIM1,OFF + SIM1,ON* |

For *SIM0,ON* and *SIM1,ON* generation, a 20MHz OFDM transmission with the subcarrier spacing of 312.5 kHz is used by populating contiguous 13 subcarriers. The center subcarrier of contiguous 13 subcarriers is null. The other coefficients are TBD. Indices for contiguous 13 subcarriers are TBD.

* WUR transmit specification
	+ - 1. Transmit spectrum mask

NOTE 1—In the presence of additional regulatory restrictions, the device has to meet both the regulatory requirements and the mask defined in this subclause.

NOTE 2—Transmit spectral mask figures in this subclause are not drawn to scale

NOTE 3—For rules regarding TX center frequency leakage levels, see 22.3.18.4.2. The spectral mask requirements in this subclause do not apply to the RF LO.

[The assumption is that it suffices to meet the 20 MHz spectrum mask. Do we want to just have a copy of the 20 MHz TX spectrum mask, or should I make a figure illustrating e.g. a 4 MHz channel fitted in the 20 MHz mask? It was briefly discussed (Shahrnaz) that we may want to add a mask for 4 MHz. We don’t really have any decisions here, so maybe it is good to discuss what Motions would make sense to run in the next F2F meeting.]

* + - 1. Spectral flatness

[ I don’t believe we have any results related to this. I also expect this is quite different than OFDM in that for OFDM too poor flatness could impact e.g. the channel estimation. For OOK, it seems it rather the signal in the time domain that is important based on the simulation results we have seen.]

* + - 1. 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.]

[No reason to change from PCR as this is only about the TX part.]

* + - 1. Modulation accuracy

**[Transmitter constellation error?** Is it possible to have an eye diagram similar to what is done when you have frequency modulation? You define a “perfect” receiver, and then the eye-diagram that you get should have a certain eye-opening (height, and possibly also width). Since the symbol duration is different for the two modes, it probably should be defined for both and we cannot just have a single test.]

Transmitter modulation accuracy ~~(EVM)~~ test, see above.

Can have two different eye-diagrams corresponding to the two different rates]

* + - 1. Time of Departure accuracy

[Identical to PCR. Does only seem to relate to the L-preamble anyway.]

* WUR receiver specification

For tests in this subclause, the input levels are measured at the antenna connectors and are referenced as the average power per receive antenna.

[Single antenna receives only]

**32.3.11.1 Receiver minimum input sensitivity**

[The sensitivity much take allowed TX power relative to the PCR into account. -82dBm – 7dB = -89dBm? I don’t know if we can or should specify in another way, but clearly this is not good enough to have the same range as the PCR if a typically PCR has, say -94 dBm]

The packet error ratio (PER) shall be less than 10% for a PSDU length of 8 octets (TBD) with the rate-dependent input levels listed in Table XX

Table XX - Receiver minimum input level sensitivity

|  |  |
| --- | --- |
| Modulation | Minimum sensitivity(dBm) |
| WUR-MCS0 | TBD |
| WUR-MCS1 |  TBD |

**32.3.11.2 Adjacent channel rejection**

[Only needs to be tested with 20 MHz ACI, 16 + 7 dB = 23 dB. The +7 comes from that the WUR signal may be 7 dB lower that PCR signal and it should still work with same interference level]

Adjacent channel rejection for shall be measured by setting the desired signal’s strength 3 dB above the rate dependent sensitivity specified in Table XX and raising the power of the interfering signal of 20 MHz bandwidth until 10% PER is caused for a PSDU length of 8 octets (TBD). The power difference between the interfering and desired channel is the corresponding adjacent channel rejection. The center frequency of the adjacent channel shall be placed 20 MHz away from the center frequency of the desired signal.

The interfering signal in the adjacent channel shall be a conformant OFDM signal, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. For a conforming OFDM PHY, the corresponding rejection shall be no less than specified in Table YY

Table YY - Minimum required adjacent and nonadjacent channel rejection levels

|  |  |
| --- | --- |
| Modulation | Adjacent channel rejection (dB) |
| WUR-MCS0 | TBD [16 in PCR] |
| WUR-MCS1 | TBD |

**32.3.11.3 Nonadjacent channel rejection**

[Only needs to be tested with 20 MHz ACI, 32 + 7 dB= 39 dB. Should we just skip this?]

**32.3.11.4 Receiver maximum input level**

[The receiver shall provide a maximum PER of 10% at a PSDU length of 8 octets (TBD), for a maximum input level of –30 dBm, measured at each antenna for any baseband modulation.]

[-30dBm. Could be situation where this will be less than for the PCR due to the smaller bandwidth, but this should not be a problem for a WURx I believe. Would be easier to just take the same number.]

**32.3.11.5 CCA sensitivity**

[Not applicable. WURx is not used for CCA]

* WUR transmit procedure

<Texts to be filled>

* WUR receive procedure

<Texts to be filled>

* WUR PLME

**32.4.1 Table of PHY MIB Attributes(suspending)**

**32.4.2 TXTIME and PSDU Length calculation**

The number of equivalent symbols with the symbol duration equal to 4 μs legacy OFDM symbol duration is computed from the length of MCS0 PSDU(LENGTH) indicated in L-SIG field for MCS0 as follows:

$N\_{L-SYM}=8×LENGTH-\frac{T\_{WUR-SYNC0}}{T\_{L-SYM}}-1$ (32-xxx1)

where

$N\_{SPDB}$ is defined in Table 32-2(Frequently used parameters)

 $T\_{L-SYM}=4μs$

The number of equivalent symbols with the symbol duration equal to 4$ μs$ legacy OFDM symbol duration is computed from the length of PSDU(LENGTH) indicated in L-SIG field for MCS1 as follows:

$N\_{L-SYM}=8×LENGTH×N\_{SPDB}-\frac{T\_{WUR-SYNC1}}{T\_{L-SYM}}-1$ (32-xxx2)

The value of the TXTIME parameter shall be calculated for an WUR PPDU with MCS0 using Equation(32-xxx3).

$$TXTIME=T\_{L-STF}+T\_{L-LTF}+T\_{L-SIG}+T\_{WUR-MARK}+T\_{WUR-SYNC0}+T\_{L-SYM}×N\_{L-SYM}$$

(32-xxx3)

$T\_{L-STF}$ is defined in Table 32-1(Timing-related constants)

$T\_{L-LTF}$ is defined in Table 32-1(Timing-related constants)

 $T\_{L-SIG}$ is defined in Table 32-1(Timing-related constants)

 $T\_{WUR-MARK}$ is defined in Table 32-1(Timing-related constants)

 $T\_{WUR-SYNC}$ is defined in Table 32-1(Timing-related constants)

 $T\_{WUR-SYM}$ is defined in Table 32-1(Timing-related constants)

The value of the TXTIME parameter shall be calculated for an WUR PPDU with MCS1 using Equation(32-xxx4).

$$TXTIME=T\_{L-STF}+T\_{L-LTF}+T\_{L-SIG}+T\_{WUR-MARK}+T\_{WUR-SYNC1}+T\_{L-SYM}×N\_{L-SYM}$$

(32-xxx4)

where

 $T\_{WUR-SYNC}$ is defined in Table 32-1(Timing-related constants)

 $T\_{WUR-SYM}$ is defined in Table 32-1(Timing-related constants)

**32.4.3 Table of time and length characteristics**

|  |  |
| --- | --- |
| **Characteristics** | **Value** |
| aCCAMidTime | 25 µs [do we need this part?] |
| aPPDUMaxTime | 5.484 ms |
| aPSDUMaxLength | 166 octets (see NOTE 1) |
| aRxPHYStartDelay | 88 µs (see NOTE 2) |
| NOTE 1-This is the maximum length in octets for a WUR PPDU with MCS1, single stream, and limited by 1332 possible data symbols in aPPDUMaxTime. This is the maximum PSDU length a WUR PHY could support assuming no restrictions in MAC.NOTE 2-This value arises from the time to the end of WUR-SF with MCS1. |

* Parameters for WUR-MCSs

The rate-dependent parameters for 62.5 kb/s and 250 kb/s are given in Table 32-5-xxx1. Manchester code shall be used for all of the data rates for the Data field of the WUR PPDU.

**Table 32-5-xxx1—Wake-up PPDU-MCS**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| MCSIndex | Modulation | SymbolStructure | Symbol Duration | *NSPDB* | *NSPCB* | *NCBPDB* | Data rate (kb/s) |
| 0 | OOK | Information 0 | 4 µs ON+4 µs OFF+4 µs ON+4 µs OFF | 16 µs | 4 | 1 | 4 | 62.5 |
| Information 1 | 4 µs OFF+4 µs ON+4 µs OFF+4 µs ON |
| 1 | OOK | Information 0 | 2 µs ON+2 µs OFF | 4µs | 2 | 1 | 2 | 250 |
| Information 1 | 2 µs OFF+2 µs ON |