### **IEEE P802.11Wireless LANs**

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| Spec Text on MC-OOK Symbol Randomization |
| Date: 2018-09-11 |
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**Abstract**

This document contains text on “MC-OOK Symbol Randomization” to be adopted into Draft 1.0.

**Discussion**

At the May IEEE meeting [1] it was shown that repeated occurrence of the MC-OOK On symbol causes spectral lines in the power spectral density, which prevents meeting FCC requirements.

At the July IEEE meeting several presentations were made suggesting solutions to this problem [2-4].

Here we propose Spec Text for a harmonized solution.

1. Steve Shellhammer, Bin Tian and Richard van Nee, “WUR Power Spectral Density,” IEEE 802.11/18-824r1, May 2018
2. Vinod Kristem, Shahrnaz Azizi, and Thomas Kenney, “WUR PSD Studies,” IEEE 802.11-1165r1, July 2018
3. Steve Shellhammer and Bin Tian, “Comparison of Symbol Randomization Techniques,” IEEE 802.11-1200r0, July 2018
4. Miguel Lopez, Dennis Sundman, and Leif Wilhelmsson, “Spectral line suppression for MC-OOK,” IEEE 802.11-1179r1, July 2018

**Straw Poll**

Do you support the Spec Text in this document 802.11-18/1567r0?

***Instructions to 802.11ba Editor***

***Replace Figure 32-6 with the following figure***



***Replace Figure 32-7 with the following figure***



***Editor Instructions: In Clause 32.2.3.1 add the text shown in Red.***

For a single 20-MHz WUR channel, the 2 µs MC-OOK On symbol can be constructed by the On-Waveform Generator (On-WG) using a 64-point IDFT, sampling at 20-MHz as follows:

* Thirteen subcarriers are used, (-6, -5, … -1, 0, 1, 2, … 6).
* The following subcarriers are null: (-5, -3, -1, 0, 1, 3, 5).
* The other subcarriers are selected from any of the following constellations: BPSK, QPSK, 16-QAM, 64-QAM, and 256-QAM.
* The first 32 values of the 64-point IDFT output are selected.
* Those 32 values are processed by the Symbol Randomizer
* The last 8 samples of those 32 samples are prepended to the 32 samples generating 40 samples, representing the MC-OOK 2 µs On symbol. This step corresponds to the GI Insertion in Figure 32-6.

***Editor Instructions: In Clause 32.2.3.2 add the text shown in Red.***

For a single 20-MHz WUR channel the 4 µs MC-OOK On symbol can be constructed by the On-Waveform Generator (On-WG) using a 64-point IDFT, sampling at 20-MHz as follows:

* Thirteen subcarriers are used, (-6, -5, … -1, 0, 1, 2, … 6).
* The DC subcarrier is null.
* The other subcarriers are selected from 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
* The last 16 values of the 64-point IDFT output are prepended to the 64 samples generating 80 samples, representing the 4 µs MC-OOK On symbol. This step corresponds to the GI Insertion in Figure 32-7.

***Editor Instructions: Add a new subclause Clause 32.2.3.4 add the text shown in Red.***

The symbol randomizer is used to remove any spectral lines in the power spectral density.

The Symbol Randomizer, shown in Figure 32-XX, uses a linear feedback shift register with a generator polynomial $G\left(z\right)=z^{-7}+z^{-4}+1$ to generate a sequence of pseudo random bits. At the beginning of each PPDU the LFSR is loaded with all ones.

One of the bits on the LFSR is converted to an integer *m*, with a value of either plus or minus one. A logical zero bit is converted to a +1 and a logical one bit is converted -1. The input waveform is then multiplied by either plus or minus one, based on the logical bit.

Three of the bits from the LFSR are converted to an integer value of between zero and seven, indicated by *n* in the figure. In the figure, b0 is the least significant bit (LSB) of the integer *n*, while b2 is the most significant bit of the integer *n*. This integer is used to lookup a cyclic shift value, from a table of cyclic shift values. A cyclic shift, corresponding to that value is then applied to the waveform.

Then the per-antenna cyclic shift is applied to the waveform.

The symbol randomizer is used for both the Sync Field and the Data Field. The LFSR is updated every $T\_{Sync}$ during the Sync Field and updated ever $T\_{Sym}$ during the Data Field.



Figure 32-XXX: Symbol Randomizer

***Editor Instructions: Replace Equation 32-2 with the following equation and add the text shown in Red.***

$$r\_{Sym}^{\left(i\_{TX}\right)}\left(t\right)=\frac{\sqrt{2}}{\sqrt{N\_{Sym}^{Tone}N\_{TX}}}w\_{T\_{Sym}}\left(t\right)m\sum\_{k=-6}^{6}X\_{Sym}\left(k\right)exp⁡\left(j2πk∆\_{F,WUR}\left(t-T\_{GI,Sym}-T\_{CS,Sym}^{i\_{TX}}-T\_{CSR,Sym}^{n}\right)\right)$$

The integer *m* is the binary pseudo-random phase rotation described in Clause 32.2.3.

The cyclic shift values $T\_{CSR,Sym}^{n}$ is the pseudo-random cyclic shift with cyclic shift index $n$ described in 32.2.3. Its values are specified in Tables X and Y.

Table X provides, for each value of the index *n*, the cyclic shift values, $T\_{CSR,Sym}^{n}$, for the Sync Field and the HDR Data Field.

Table Y provides, for each value of the index *n*, the cyclic shift values, $T\_{CSR,Sym}^{n}$, for the LDR Data Field.

|  |  |
| --- | --- |
| n | $T\_{CSR,Sym}^{n}$ (ns) |
| 0 | 0 |
| 1 | -200 |
| 2 | -400 |
| 3 | -600 |
| 4 | -800 |
| 5 | -1000 |
| 6 | -1200 |
| 7 | -1400 |

Table X: Values of $T\_{CSR,Sym}^{n}$ for the Sync Field and HDR Data Field

|  |  |
| --- | --- |
| n | $T\_{CSR,Sym}^{n}$ (ns) |
| 0 | 0 |
| 1 | -400 |
| 2 | -800 |
| 3 | -1200 |
| 4 | -1600 |
| 5 | -2000 |
| 6 | -2400 |
| 7 | -2800 |

Table Y: values of $T\_{CSR,Sym}^{n}$ for the LDR Data Field

Table XYZ1 provides the values for the LFSR, the three bits (b2, b1, b0), the index value *n*, and the time delay value for $T\_{CSR,Sym}^{n}$.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Time Step | LFSR X7…X1 | b2 b1 b0 | Index n | $T\_{CSR,Sym}^{n}$ (ns) |
| 1 | 1 1 1 1 1 1 1 | 1 1 1 | 7 | -1400 |
| 2 | 1 1 1 1 1 1 0 | 1 1 0 | 6 | -1200 |
| 3 | 1 1 1 1 1 0 0 | 1 0 0 | 4 | -800 |
| 4 | 1 1 1 1 0 0 0 | 0 0 0 | 0 | 0 |
| 5 | 1 1 1 0 0 0 0 | 0 0 0 | 0 | 0 |
| 6 | 1 1 0 0 0 0 1 | 0 0 1 | 1 | -200 |
| 7 | 1 0 0 0 0 1 1 | 0 1 1 | 3 | -600 |

*Table XYZ1: The values of the LFSR, bits b2, b1, b0, value of n, and* $T\_{CSR,Sym}^{n}$ *for the Sync Field*

***Editor Instructions: Replace Figure 32-4 with the following figure,***



***Editor Instructions: Replace Figure 32-5 with the following figure,***



***Editor Instructions: Replace Figure 32-8 with the following figure,***



***Editor Instructions: Make the edits in Clause 32.2.3.6 as shown in Red.***

* Construction of the WUR-Sync for a single 20 MHz channel

Construct the WUR-Sync filed for a single 20MHz channel defined in 32.2.8.3 (WUR SYNC field) as follows:

* Set the WUR\_DATARATE from the WUR\_TXVECTOR.
* Sync-bit sequence generation: Generate the Sync-bit sequence according to the WUR\_DATARATE as described in 32.2.8.3 (WUR SYNC field).
* Waveform generation: Generate the MC-OOK waveform by using either On-WG or Off-WG according to the Sync-bit. Sync-bit duration *TSync* is 2 µs.
* ~~CSD: Apply the CSD for each transmit chain.~~
* Windowing: Apply windowing.
* 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.

***Editor Instructions: Make the edits in Clause 32.2.3.7 as shown in Red.***

* Construction of the WUR-Data for a single 20 MHz channel

Construct the WUR-Data waveform as follows:

* Manchester based encoder: Pulse combination is determined according to the input bits as described in 32.2.9 (WUR-Data field).
* The output of Manchester based encoder determines which samples to take either from On-WGor from Off-WG, depending on the WUR\_DATARATE. The samples in Off-WG have zero energy. Each symbol duration, *TSym* is 2 µs for high data rate (*TSYM-HDR*) and 4 µs for low data rate (*TSYM-LDR*).
* ~~Apply the CSD for each RF chain.~~
* Apply the windowing.
* Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal based on the center frequency of the desired channel.

***Editor Instructions: Make the edits in Clause 32.2.3.8 as shown in Red.***

* Construction of the WUR-Sync and WUR-Data for the FDMA transmission

Construct the WUR-Sync and WUR-Data waveform for the FDMA transmission as follows:

* Determine the WUR\_DATARATE from the WUR\_TXVECTOR for each 20MHz sub-channel.
* Sync-bit sequence generation and Manchester based encoder for each 20MHz sub-channel: Generate the Sync-bit sequence according to the WUR\_DATARATE as described in 32.2.8.3 (WUR SYNC field)and Manchester encoded bits which follow the Sync-bit sequence according to the input bits as described in 32.2.9 (WUR-Data field) for each 20MHz sub-channel.
* Waveform generation for the WUR-Sync field: Generate the MC-OOK waveform for the WUR-Sync field by using either HDR On-WG or Off-WG according to the Sync-bit for each 20MHz subchannel. Each Sync-bit duration, *TSync* is 2 µs.
* Waveform generation for the WUR-Data field: The output of the *k*th Manchester based encoder determines which samples to take either from the *k*th HDR On-WGor LDR On-WG of corresponding 20 MHz sub-channel or from Off-WG, depending on the WUR\_BANDWIDTH and the WUR\_DATARATE, where *k* (0, 1, …, *K*-1) is the index of the 20 MHz sub-channel. The samples in Off-WG have zero energy. Each symbol duration, *TSym* is 2 μs for high data rate (T*SYM-HDR*) and 4 μs for low data rate (T*SYM-LDR*).
* Append the padding on non-punctured 20MHz sub-channel: If the duration of WUR transmission on any non-punctured 20MHz sub-channel is shorter than L\_LENGTH described in 32.3.1 (TXTIME and PSDU length calculation), the padding is used to align the length indicated by the LENGTH field in the L-SIG, and the padding is not applied to the punctured 20MHz sub-channel.
* ~~CSD: Apply the CSD for each RF chain per each 20 MHz respectively according to the WUR\_DATARATE of each 20 MHz sub-channel.~~
* The ~~CSD~~ output~~s~~ ~~for the same RF chain~~ per each 20 MHz sub-channel are added across the 20 MHz sub-channels, sample by sample.
* Windowing: Apply windowing.
* 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.