**IEEE P802.15**

**Wireless Personal Area Networks**

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| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) | |
| Title | **Text proposal for new PM-PHY MIMO Pilots** | |
| Date Submitted | 15 November, 2021 | |
| Source | Jonathan Schostak  Kai Lennert Bober  Volker Jungnickel]  Fraunhofer HHI | Voice: [ ] Fax: [ ] E-mail: [ ] |
| Re: |  | |
| Abstract | Draft text to replace the PM-PHY MIMO pilots with an improved version | |
| Purpose |  | |
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***Replace the content of 10.1.3 with the following text:***

The OFE index for each OFE is calculated using the following formula or table, where <Variant> specifies pilot variant and <Slot Position> specifies the slot number in which the symbol shall be transmitted. Values greater than 63 shall not be used. Thus, a maximum of 64 OFEs can be used with one device.

OFE index = <Slot Position>\*8 + <Variant>

***In Figure 73, rename “MIMO PS Num” to “MIMO Pilot Slots”***

***In Figure 73, change “Bit” range of “MIMO Pilot Slots” to B16-B19***

***Replace P111L18-20 with the following text:***

MIMO Pilot Slots specifies the number of slots for MIMO pilots in the PPDU.

***In Figure 73, change range of “reserved” field to B20-B23***

***Rename 10.2.6 to “MIMO Pilots”***

***Replace the content of subclause 10.2.6 with the following content and adapt subclause, figure and table numberings:***

The MIMO pilots allow measuring the phase and amplitude response of the MIMO channel between multiple transmitting OFEs and multiple receiving OFEs. MIMO pilots consist of predefined sequences. For MIMO pilots, repetitions, FEC, and line coding shall not apply.

A transmitter shall include zero to eight pilots in each pilot slot of the transmitted PPDU, as shown in Figure X. The number of pilot slots in a PPDU shall equal the number indicated by the *MIMO Pilot Slots* field of the PM PHY header.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Preamble | Header Channel estimation | PHY Header | Pilot Slot 0 | Pilot Slot 1 | ... | Pilot Slot 7 | Payload channel estimation | PSDU |

Figure X - PPDU including up to eight MIMO Pilots

Each OFE shall transmit exactly one pilot variant in a specific slot. The selection of slot and variant of the pilot depends on the OFE index. It shall be calculated by inverting the formula in 10.1.3:

Slot Position = ⌊<OFE index> / 8⌋

Variant = <OFE index> *modulo* 8

Table Y1 lists the relationship between variant, slot position and OFE indices. The assignment of the OFE indices to OFEs is implementation specific.

Table Y1 - Variant and Slot position for OFE indices zero to 63.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Variant | | | | | | | |
| Slot  Position |  | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| **0** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| **1** | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| **2** | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| **3** | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| **4** | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 |
| **5** | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 |
| **6** | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 |
| **7** | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 |

In addition, the actual pilot sequence shall vary depending on the OCR used to transmit the PPDU and indicated through MCS in the MCS ID field in the PHY Header.

*NOTE - This construction scheme allows using a lower OCR at the receiver (Variable Sampling Factor, VSF), while still being able to estimate the MIMO channel at the maximum resolution determined by the transmitter OCR. This is because all concurrently transmitted MIMO Pilots are guaranteed to be orthogonal in any OCR.*

Table Y2 lists the used sequences for each combination of OCR and variant. For the ith variant, respectively, the base sequence A1024;i from Annex B6 shall be the basis to construct the transmitted pilot. Based on the OCR, only every nth bit of the base sequence shall be transmitted, starting from the first bit of the base sequence, with n=24 - OCR. All other bits shall be left out for transmission.

Table Y2 – Sequences used as MIMO pilots for each combination of OCR and Variant

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | | OCR / MHz | | | | |
| 12,5 | 25 | 50 | 100 | 200 |
| Variant | 0 | Every 16th bit of A1024,0 | Every 8th bit of A1024,0 | Every 4th bit of A1024,0 | Every 2nd bit of A1024,0 | Every bit of A1024,0 |
| 1 | Every 16th bit of A1024,1 | Every 8th bit of A1024,1 | Every 4th bit of A1024,1 | Every 2nd bit of A1024,1 | Every bit of A1024,1 |
| 2 | Every 16th bit of A1024,2 | Every 8th bit of A1024,2 | Every 4th bit of A1024,2 | Every 2nd bit of A1024,2 | Every bit of A1024,2 |
| 3 | Every 16th bit of A1024,3 | Every 8th bit of A1024,3 | Every 4th bit of A1024,3 | Every 2nd bit of A1024,3 | Every bit of A1024,3 |
| 4 | Every 16th bit of A1024,4 | Every 8th bit of A1024,4 | Every 4th bit of A1024,4 | Every 2nd bit of A1024,4 | Every bit of A1024,4 |
| 5 | Every 16th bit of A1024,5 | Every 8th bit of A1024,5 | Every 4th bit of A1024,5 | Every 2nd bit of A1024,5 | Every bit of A1024,5 |
| 6 | Every 16th bit of A1024,6 | Every 8th bit of A1024,6 | Every 4th bit of A1024,6 | Every 2nd bit of A1024,6 | Every bit of A1024,6 |
| 7 | Every 16th bit of A1024,7 | Every 8th bit of A1024,7 | Every 4th bit of A1024,7 | Every 2nd bit of A1024,7 | Every bit of A1024,7 |

In slots where a specific OFE does not transmit a pilot, that OFE shall remain silent.

For example, Figure X2 depicts a single PPDU that is transmitted through 16 OFEs with two pilot slots, each having eight variants, being used to include MIMO pilots. A receiver is thus able to estimate the channel between the 16 transmitting OFEs and a single receiving OFE.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Preamble | Header Channel estimation | PHY Header | Pilot Slot 0 | Pilot Slot 1 | Payload channel estimation | PSDU |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Preamble | Header Channel estimation | PHY Header | Pilot Slot 0 | Pilot Slot 1 | Payload channel estimation | PSDU |

Figure X2 – A PPDU transmitted over 16 OFEs with different variants and slot positions per OFE index.

***Insert the following text as a new Annex B6 „VSF Sequences“:***

Sequences listed in hexadecimal, where the binary representation converts to PAM-2 representation as follows:

0b0 = -1

0b1 = +1

**A1024;0** = 6209128B710F43DC211296383A7DCB443EAC93CE1D2A26C5CFF9E1E87C62171BAE5055BC28AE1E4AA186004B5C13DCED4A9BD70CC04D4E27F041D7F6441778C14DAA8D59E2F7FB212356EB540F73779165D637779DBDB167521DF6B809E1A98A8BA5C4FA16A528269A149490BD5FFCE078BCCBB2BAFBA530A0C08463690EFFFF16

**A1024;1** = 6D0EE739128BF00FC3ECDAD569C8437231BB41636C399C1DDFFACD099B187865EE1BD767D34CAF5160825DBE0683A1142722B05354FCBB82B4E876B6AFF1C6EF7E3EB1950A9E66C7021EDB6E14AB8A74F399E5D9CF4F1E454C6028D28C4071D62DB50865B8F2116D55291DDC9190386802208584CA8A3C33A6C7A3377AA4FFFF16

**A1024;2** = 7AE47C0E6739038BF00FAD53A55511B72C8DCF44BF9C7C067422C97AA3C91A678125966451E755F341D18882DB7E6EFC4FEBC9A2B7932A43D47D23178F892971C1501701276A9ADE1EB86A5EA5D104941A3462E60D99588FF63AB39FC652E53F70E93A35F065BF32691242A99CDC11EFC6E8FB201484CC4AAA8CB038DCC8FFFF16

**A1024;3** = DECC7AC07E2E650D03BB0FF452B35F6EEE5CD376328FBF87841D73F236AAA1C6E0777B1A91905618AA13B9F18F5221759137B20BCC624A5CD798D182D93C88692EBE3B7B10DA257E62D5E4A89585A5DE04A4182B98C20A6DA0A40BC54E4F3C69E7107709C021F5B545196EC640999CD7EC2B3CECFB201160CBB1AD434DC7FFFF16

**A1024;4** = 58E7CFCC7EC07A8E742DF8E4E194AA0CB53115232C0926B04298827D9C1226154CC609E87DDA936FA9F85393BF91664DCA8A6B57A16B223DA423D047281DCE7C9B16D7A1392414DAC8E18F550F77913AB5FE05BBF48B8FA2E7724FFBE085A6703C56F1D09A89C2C11D8A42596AC644A67737110B3C6CF960131FD96E53BCFFFF16

**A1024;5** = 433450EF5FC4EEC87A86835217A4992BC5F3CACEF2D4AC36D68FDDD8FDBD1CA5469D247996A86AA5E427D1F8545BCF2E99B225C2749FD61CC5CABBDC38702F5D490373294056B1ACE46D3061E82A174009BAB5416D33FB4B6F158885A0BB08323E47A31E81D00D4122761ACA5A596271B3EE0737890333AC7E179CE0AE99FFFF16

**A1024;6** = AE99C33C50E7DFCC6EC085717C9A6F9B66D4BA0C353172EB5401D14FA218FD82E4A53EAAA3B1115715651C27D630AC6430D96672A2020B6829EB423DC3EBBFB028AAB13CF4D6C056499B1C65CF9668159740898D4D41EAF3037C10EAF74DD88C880DB98FDB168618757EA5BE1AC2DA669DB14BE6073F0EC3345B79E86317FFFF16

**A1024;7** = 6316AE1FC3B95025DFCF913B7AF684A6906399AA45F435CD8A1053052E09A2A105061C9D396AA48CEE97EDA71BA42EC853D9CF5B61F05D7CF4132E51BA02C4EBB8CCD050B642F4D338E9B158E35CCFAD6891973A714E4A44128EFC03EF6B0F34D8758F4A41CDDC577EE072FEA5BF1AB8252565B74BA1003E093833E28652FFFF16