11.2.4.2. MIMO Pilots

The MAC sublayer may insert multiple subsequent OFDM symbols into the PPDU in order to support channel estimation for multiple OFEs. The number of OFDM symbols *NPS* used for MIMO pilots the PPDU shall be indicated by the *MIMO PS Number* field in the PHY header.

The *MIMO Pilots* field contains *NPS* = 0, 2, 4 or 8 successive OFDM symbols for estimation of the distributed MIMO channel between multiple transmitting at each receiving OFE. MIMO pilots follow the header data fields as depicted in Figure 94. MIMO pilots are defined in the frequency and time domains in an orthogonal manner so that they can be transmitted from multiple OFEs simultaneously.

Figure 96

**Figure 96 Insertion of 0 to 7 MIMO pilot symbols after the header**

MIMO pilots shall be constructed as follows: In the frequency domain, each MIMO pilot consist of an OFDM symbol into which a regular comb of occupied subcarriers is mapped. All other subcarriers are unoccupied. Orthogonal assignment of the occupied subcarriers allows an orthogonal detection of MIMO pilots coming from multiple transmitting OFEs.

The sequence mapped onto occupied subcarriers in MIMO pilots is based on the same LFSR for constellation scrambling as used for the generation of the synchronization preamble, defined in 11.3.2.5. Masked subcarriers shall not be used.

On occupied and supported subcarriers, at first, a bit sequence of all ones is mapped using the 1-bit constellation. Next, the LFSR generator of the constellation scrambler is initialized with the value 0x16E6. The LFSR shall be advanced by two bits per subcarrier in the order specified in Figure 106. The output of the mapper shall then be rotated using the two LSBs of the LFSR, s1 and s2, as defined in Table 64, resulting in the constellation points Zi for subcarrier index i. The resulting constellation sequence is subsequently passed to the OFDM modulator described in 11.3.3.

Pilot symbols for the first transmitting OFE shall use the occupied subcarriers with indices

0, 1Δ, 2Δ, 3Δ, 4Δ, …, *N*-Δ, where

Δ is the comb spacing and a power of two

N is the total number of subcarriers as given in Table 53

The value of Δ is defined by the MAC sublayer for each transmission of a PPDU. The value of Δ shall respect the fundamental relation Δ ≤ N / NCP, NCP is the number of cyclic prefix samples*.*

The comb shift, *CS* isindicated in the *Comb Shift* field of the PHY header. When the comb shift is greater than zero, a cyclic shift of the comb shall be performed such that the occupied subcarriers are shifted by the value of the comb shift. The occupied subcarriers are given through the following series:

*CS*, Δ + *CS*, 2Δ + *CS*, 3Δ + *CS*, 4Δ + *CS*, …, N - Δ + *CS,* where

*CS* is the comb shift

Δ is the comb spacing

N is the total number of subcarriers

By varying the *CS*,up to Δ different OFEs can be identified in one OFDM Symbol, i.e. the wider the comb spacing, the more OFEs can be used. To increase the number of OFEs which can be identified by MIMO pilots, each MIMO pilot consists of *NPS*=2, 4 or 8 OFDM symbols. In the following, it is explained how the total number of MIMO pilots is increased.

The procedure starts with the original OFDM symbol defined in the frequency domain as explained above. Each OFDM symbol in a particular MIMO pilot is then obtained by multiplication of the OFDM symbol with either +1 or -1. The applicable sign is taken from the j-th row and the i-th column in the 2x2, 4x4 or 8x8 Hadamard matrix Hij.

H2x2 H4x4H8x8

For example, if 2 OFDM symbols are used, for the first OFE, the first OFDM symbol is multiplied by +1 and the second OFDM symbol by +1. For the second OFE, the first OFDM symbol is multiplied by +1 and the second OFDM symbol by -1.

The insertion of MIMO pilot symbols in each PPDU is controlled by the MAC. For each transmitted PPDU, the MAC determines the comb spacing *Δ*, the comb shift *CS* and number of OFDM symbols *NPS* to be inserted into the PPDU. The *CS* shall be the same for all pilot symbols in a PPDU and shall be indicated in the *MIMO Pilot Symbol Comb Spacing* field of the PHY header.

For a given transmitting OFE, each OFDM symbol in the corresponding MIMO pilot shall have a different comb shift and/or a different Hadamard sequence in the time domain. In this way, up to 𝑁𝑃𝑆⋅Δ transmitting OFEs may be identified at a receiver.

The relation between OFE index *i* and the variables *a* and *CS* shall be as follows:

*i* = (*a* - 1) ⋅ Δ + *CS,* where

*a* is an OFE group index counted between 1 and *NPS*

Δ is the comb spacing

*CS* is the comb shift counted between 0 and Δ-1.