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FILING RECEIPT

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Date Mailed: 04/08/2015

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**** SMALL ENTITY ****

Title

CFO PRE-COMPENSATION AND ITS MAC-PHY INTERFACE FOR UPLINK MULTI-USER TRANSMISSION

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

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Attorney Docket No.: A303AA-012400PV
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Provisional Patent Application

CFO PRE-COMPENSATION AND ITS MAC-PHY INTERFACE FOR UPLINK MULTI-USER TRANSMISSION

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INVENTION DISCLOSURE FORM

TITLE OF THE INVENTION:

CFO PRE-COMPENSATION AND ITS MAC-PHY INTERFACE FOR UPLINK MULTI-USER TRANSMISSION

MOTIVATION OF THE INVENTION:

<Background of 802.11n (HT)>

Two formats are defined for the PPDU: HT-mixed format and HT-greenfield format. These two formats are called HT formats. Figure 20-1 (PPDU format) shows the non-HT format47 and the HT formats. There is also an MCS 32 format (specified in 20.3.11.11.5 (Transmission in MCS 32 format)) used for MCS 32 that provides the lowest rate in a 40 MHz channel. In addition to the HT formats, there is a non-HT duplicate format (specified in 20.3.11.12 (Non-HT duplicate transmission)) that duplicates the 20 MHz non-HT packet in two 20 MHz halves of a 40 MHz channel.

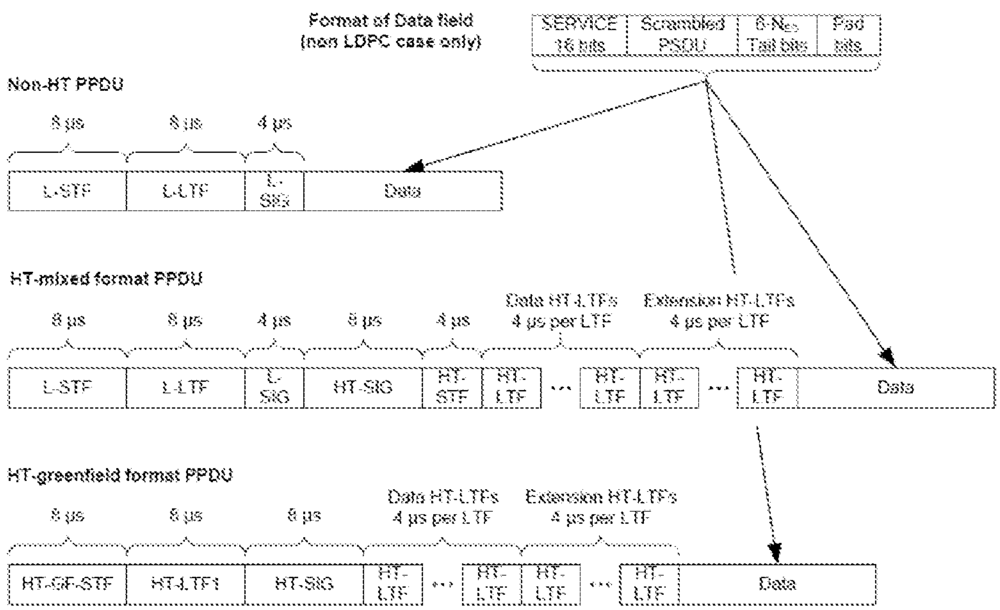


Figure 20-1—PPDU format

The FORMAT parameter determines the overall structure of the PPDU as follows:

— Non-HT format (NON_HT): Packets of this format are structured according to the Clause 18 (Orthogonal frequency division multiplexing (OFDM) PHY specification) (OFDM) or Clause 19 (Extended Rate PHY (ERP) specification) (ERP) specification. Support for non-HT format is mandatory.

— HT-mixed format (HT_MF): Packets of this format contain a preamble compatible with Clause 18 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 19 (Extended

Rate PHY (ERP) specification) receivers. The non-HT-STF (L-STF), the non-HT-LTF (L-LTF), and the non-HT SIGNAL field (L-SIG) are defined so they can be decoded by non-HT Clause 18 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and Clause 19 (Extended Rate PHY (ERP) specification) STAs. The rest of the packet cannot be decoded by Clause 18 (Orthogonal frequency division multiplexing (OFDM) PHY specification) or Clause 19 (Extended Rate PHY (ERP) specification) STAs. Support for HT-mixed format is mandatory.

— HT-greenfield format (HT_GF): HT packets of this format do not contain a non-HT compatible part.

Support for HT-greenfield format is optional. An HT STA that does not support the reception of an HT-greenfield format packet shall be able to detect that an HT-greenfield format packet is an HT transmission (as opposed to a non-HT transmission). In this case, the receiver shall decode the HT-SIG and determine whether the HT-SIG cyclic redundancy check (CRC) passes.

<Background of 802.11ac (VHT)>

Clause 22 specifies the PHY entity for a very high throughput (VHT) orthogonal frequency division multiplexing
(OFDM) system. In addition to the requirements in Clause 22, a VHT STA shall be capable of transmitting and receiving PPDUs that are compliant with the mandatory PHY specifications defined in Clause 20. The VHT PHY is based on the HT PHY defined in Clause 20, which in turn is based on the OFDM PHY defined in Clause 18. The VHT PHY extends the maximum number of space-time streams supported to eight and provides support for downlink multi-user (MU) transmissions. A downlink MU transmission supports up to four users with up to four space-time streams per user with the total number of space-time streams not exceeding eight.

NOTE—A VHT SU PPDU includes individually addressed and group addressed transmissions. The VHT PHY provides support for 20 MHz, 40 MHz, 80 MHz and 160 MHz contiguous channel widths and support for 80+80 MHz non-contiguous channel width. The VHT PHY data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), 64-QAM and 256-QAM. Forward error correction (FEC) coding (convolutional or LDPC coding) is used with coding rates of 1/2, 2/3, 3/4 and 5/6.

A VHT STA shall support the following features:

— Non-HT and non-HT duplicate formats (transmit and receive) for all channel widths supported by the VHT STA

— HT-mixed format (transmit and receive)

— VHT format (transmit and receive)

— 20 MHz, 40 MHz and 80 MHz channel widths

— Single spatial stream VHT-MCSs 0 to 7 (transmit and receive) in all supported channel widths

— Binary convolutional coding

A VHT STA may support the following features:

— HT-greenfield format (transmit and receive)

— 2 or more spatial streams (transmit and receive)

— 400 ns short guard interval (transmit and receive)

— Beamforming sounding (by sending a VHT NDP)

— Responding to transmit beamforming sounding (by providing compressed beamforming feedback)

— STBC (transmit and receive)

— LDPC (transmit and receive)

— VHT MU PPDUs (transmit and receive)

— Support for 160 MHz channel width

— Support for 80+80 MHz channel width

— VHT-MCSs 8 and 9 (transmit and receive)

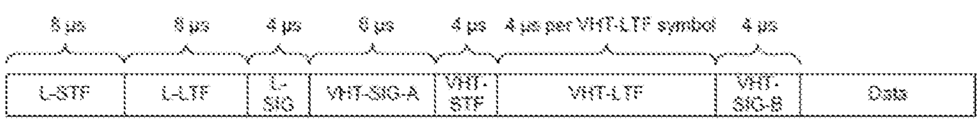


Figure 22-4—VHT PPDU format

The fields of the VHT PPDU format are summarized in Table 22-4 (Fields of the VHT PPDU).

Table 22-4—Fields of the VHT PPDU

Field	Description
L-STF	Non-HT Short Training field
L-LTF	Non-HT Long Training field
L-SIG	Non-HT SIGNAL field
VHT-SIG-A	VHT Signal A field
VHT-STF	VHT Short Training field
VHT-LTF	VHT Long Training field
VHT-SIG-B	VHT Signal B field
Data	The Data field carries the PSDU(s)

20.3.9.3.3 L-STF definition

The L-STF is identical to the Clause 18 (Orthogonal frequency division multiplexing (OFDM) PHY specification) short training symbol. The non-HT short training OFDM symbol in the 20 MHz channel width is shown in Equation (20-8).

$$\begin{aligned} S_{-26,26} = \sqrt{1/2} \\ &\{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, \\ &0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\} \end{aligned} \quad (20\text{-}8)$$

The normalization factor $\sqrt{1/2}$ is the QPSK normalization.

The non-HT short training OFDM symbol in a 40 MHz channel width is given by Equation (20-9), after rotating the tones in the upper subchannel (subcarriers 6–58) by +90° (see Equation (20-10)).

$$\begin{aligned} S_{-58,58} = \sqrt{1/2} \\ &\{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, \\ &0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, \\ &0, 0, 0, 0, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\} \end{aligned} \quad (20\text{-}9)$$

In HT-mixed format, the L-STF on transmit chain i_{TX} shall be as shown in Equation (20-10).

$$r_{L-STF}^{(i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{L-STF}^{Tone}}} w_{T_{L-STF}}(t) \sum_{k=-N_{SR}}^{N_{SR}} \Upsilon_k S_k \exp(j2\pi k \Delta_F (t - T_{CS}^{i_{TX}})) \quad (20\text{-}10)$$

where

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} and takes values from Table 20-9 (Cyclic shift for non-HT portion of packet)

Υ_k is defined in Equation (20-5) and Equation (20-6)

The L-STF has a period of 0.8 µs. The entire STF includes ten such periods, with a total duration of T_{L-STF} = 8 µs.

The L-STF field for a 20 MHz or 40 MHz transmission is defined by Equation (20-8) and Equation (20-9), respectively, in 20.3.9.3.3 (L-STF definition). For 80 MHz, the L-STF field is defined by Equation (22-18). Note that these equations do not include the phase rotation per 20 MHz subchannel.

$$S_{-122,122} = \{S_{-58,58}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, S_{-58,58}\} \quad (22\text{-}18)$$

where

$S_{-58,58}$ is defined in Equation (20-9)

For 160 MHz, the L-STF is defined by Equation (22-19).

$$S_{-250,250} = \{S_{-122,122}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, S_{-122,122}\} \quad (22\text{-}19)$$

where

$S_{-122,122}$ is defined in Equation (22-18)

22.3.8.3.3 VHT-SIG-A definition

The VHT-SIG-A field carries information required to interpret VHT PPDUs. The structure of the VHT-SIG-A field for the first part (VHT-SIG-A1) is shown in Figure 22-18 (VHT-SIG-A1 structure) and for the second part (VHT-SIG-A2) is shown in Figure 22-19 (VHT-SIG-A2 structure).

NOTE—Integer fields are represented in unsigned binary format with the least significant bit in the lowest numbered bit position.

INVENTION DISCLOSURE FORM

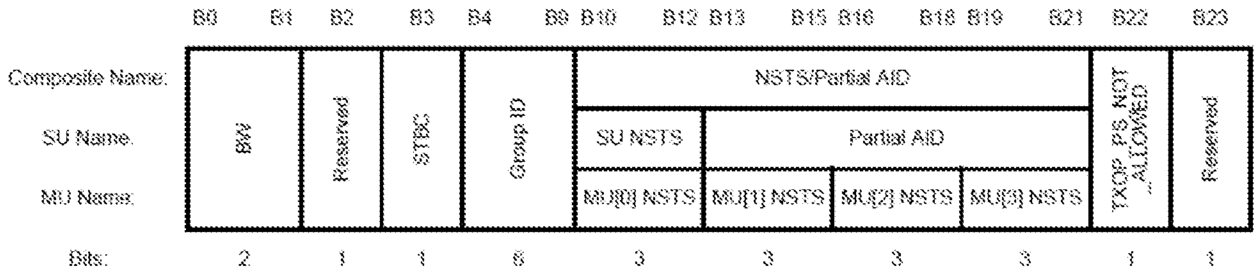


Figure 22-18—VHT-SIG-A1 structure

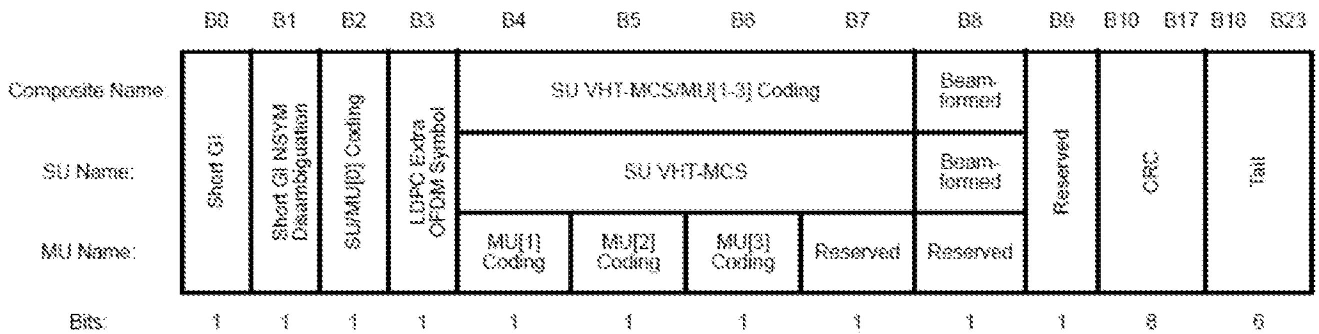


Figure 22-19—VHT-SIG-A2 structure

The VHT-SIG-A field contains the fields listed in Table 22-12 (Fields in the VHT-SIG-A field). The mapping of the fields is also described in Table 22-12 (Fields in the VHT-SIG-A field). Note that the mapping of the STBC field, the NSTS/Partial AID field, the SU/MU[0] Coding field, the SU VHT-MCS/MU[1-3] Coding field, and the Beamformed field is different for VHT SU and MU PPDUs.

The VHT-SIG-A field is composed of two parts, VHT-SIG-A1 and VHT-SIG-A2, each containing 24 data bits, as shown in Table 22-12 (Fields in the VHT-SIG-A field). VHT-SIG-A1 is transmitted before VHT-SIG-A2. The VHT-SIG-A symbols shall be BCC encoded at rate, R = 1/2, be interleaved, be mapped to a BPSK constellation, and have pilots inserted following the steps described in 18.3.5.6 (Convolutional encoder), 18.3.5.7 (Data interleaving), 18.3.5.8 (Subcarrier modulation mapping), and 18.3.5.9 (Pilot subcarriers), respectively. The first and second half of the stream of 96 complex numbers generated by these steps (before pilot insertion) is divided into two groups of 48 complex numbers $d_{k,n}$, $k = 0 \ldots 47$, where $n = 0, 1$, respectively. The first 48 complex numbers form the first symbol of VHT-SIG-A and the second 48 complex numbers form the second symbol of VHT-SIG-A after rotating by 90° counter-clockwise relative to the first symbol. The first symbol of VHT-SIG-A, which does not have the 90° rotation, is used to differentiate VHT PPDUs from HT PPDUs, while the second symbol of VHT-SIG-A, which has the 90° rotation, is used to differentiate VHT PPDUs from non-HT PPDUs. The time domain waveform for the VHT-SIG-A field in a VHT PPDU shall be as specified in Equation (22-28).

22.3.19 PHY transmit procedure

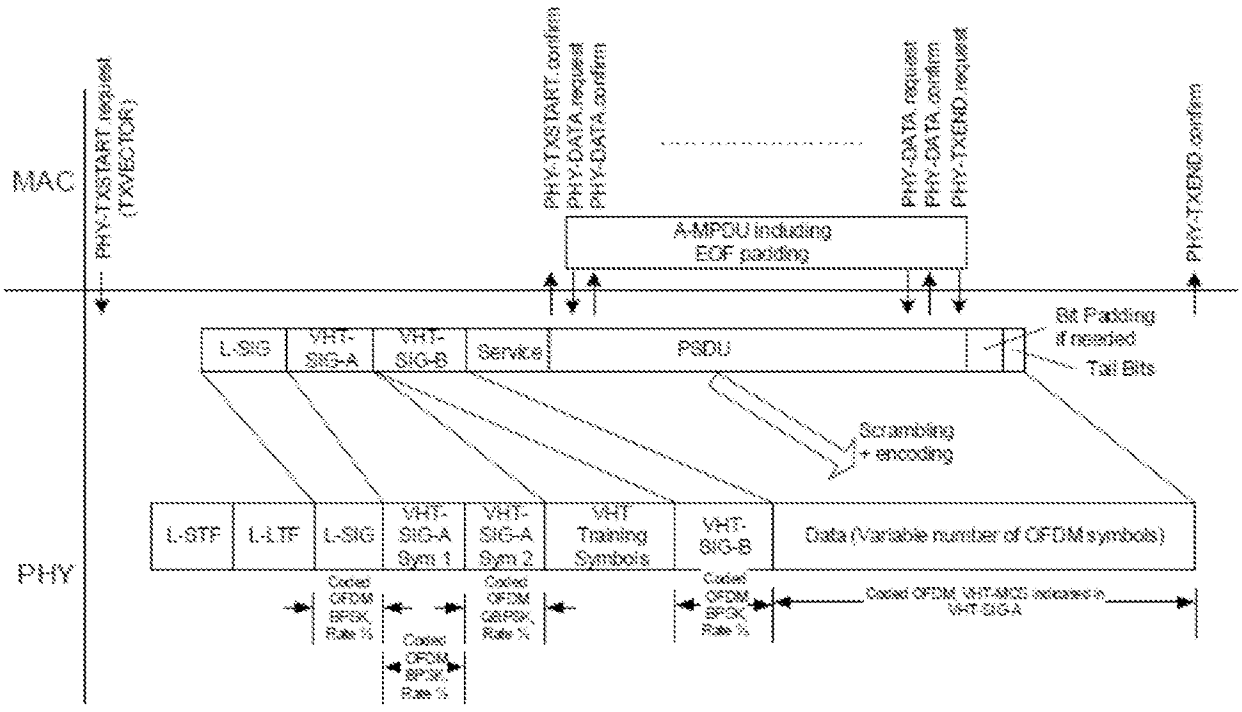
There are two paths for the transmit PHY procedure:

— The first path, for which typical transmit procedures are shown in Figure 22-34 (PHY transmit procedure for an SU transmission), is selected if the FORMAT parameter of the PHY-TXSTART.request(TXVECTOR) primitive is VHT. These transmit procedures do not describe the operation of optional features, such as LDPC, STBC or MU.

— The second path is to follow the transmit procedure in Clause 18 (Orthogonal frequency division multiplexing (OFDM) PHY specification) if the FORMAT parameter of the PHY-TXSTART.request(TXVECTOR) primitive is NON_HT and the NON_HT_MODULATION parameter is set to NON_HT_DUP_OFDM except that the signal referred to in Clause 18 (Orthogonal frequency division multiplexing (OFDM) PHY specification) is instead generated simultaneously on each of the 20 MHz channels that are indicated by the CH_BANDWIDTH parameter as defined in 22.3.8 (VHT preamble) and 22.3.10.12 (Non-HT duplicate transmission).

NOTE 1—For a VHT MU PPDU the A-MPDU is per user in the MAC sublayer and the VHT Training Symbols, VHT-SIG-B, and Data are per user in the PHY in Figure 22-34 (PHY transmit procedure for an SU transmission), with the number VHT Training Symbols depending on the total number of space-time streams across all users.

NOTE 2—The transmit procedure for NON_HT format where NON_HT_MODULATION is OFDM is specified in 22.2.4.2 (Support for NON_HT format when NON_HT_MODULATION is OFDM). The transmit procedure for HT_MF and HT_GF formats is specified in 22.2.4.3 (Support for HT formats).



NOTE—This procedure does not describe the operation of optional features, such as MU-MIMO, LDPC or STBC.

Figure 22-34—PHY transmit procedure for an SU transmission

In both paths, in order to transmit data, the MAC generates a PHY-TXSTART.request primitive, which causes the PHY entity to enter the transmit state. Further, the PHY is set to operate at the appropriate frequency through station management via the PLME, as specified in 22.4 (VHT PLME). Other transmit parameters, such as VHT-MCS Coding types and transmit power, are set via the PHY-SAP using the PHY-TXSTART.request(TXVECTOR) primitive, as described in 22.2.2 (TXVECTOR and RXVECTOR parameters). The remainder of the clause applies to the first path.

The PHY indicates the state of the primary channel and other channels (if any) via the PHY-CCA.indication primitive (see 22.3.18.5 (CCA sensitivity) and 7.3.5.12 (PHY-CCA.indication)). Transmission of the PPDU shall be initiated by the PHY after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request primitive are specified in Table 22-1 (TXVECTOR and RXVECTOR parameters).

Transmission of the PHY preamble may start if TIME_OF_DEPARTURE_REQUESTED is false, and shall start immediately if TIME_OF_DEPARTURE_REQUESTED is true, based on the parameters passed in the PHY-TXSTART.request primitive.

If all of the following conditions are met:

- if dot11TODImplemented and dot11TODActivated are true or if dot11TimingMsmtActivated is true,
- the TXVECTOR parameter TIME_OF_DEPARTURE_REQUESTED is true,

then the PHY shall issue a PHY-TXSTART.confirm(TXSTATUS) primitive to the MAC, forwarding the TIME_OF_DEPARTURE corresponding to the time when the first frame energy is sent by the transmitting port and TIME_OF_DEPARTURE_ClockRate parameter within the TXSTATUS vector. If dot11TimingMsmtActivated is true, then the PHY shall forward the value of TX_START_OF_FRAME_OFFSET in TXSTATUS vector.

After the PHY preamble transmission is started, the PHY entity immediately initiates data scrambling and data encoding. The encoding method for the Data field is based on the FEC_CODING, CH_BANDWIDTH, NUM_STS, STBC, MCS, and NUM_USERS parameter of the TXVECTOR, as described in 22.3.2 (VHT PPDU format).

The SERVICE field and PSDU are encoded as described in 22.3.3 (Transmitter block diagram). The data shall be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC, and PHY-DATA.confirm primitives issued by the PHY. Zero to seven PHY padding bits are appended to the PSDU to make the number of bits in the coded PSDU an integral multiple of the number of coded bits per OFDM symbol.

Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. PSDU transmission is terminated by receiving a PHY-TXEND.request primitive. Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY. In an SU transmission, normal termination occurs after the transmission of the final bit of the last PSDU octet, according to the number of OFDM symbols indicated by N_{SYM} (see 22.4.3 (TXTIME and PSDU_LENGTH calculation)).

In the PHY, the GI or short GI is inserted in every data OFDM symbol as a countermeasure against delay spread.

When the PPDU transmission is completed the PHY entity enters the receive state.

A typical state machine implementation of the transmit PHY for an SU transmission is provided in Figure 22-35 (PHY transmit state machine for an SU transmission). Request (.request) and confirmation (.confirm) primitives are issued once per state as shown. This state machine does not describe the operation of optional features, such as multi-user, LDPC or STBC.

22.3.21 PHY receive procedure

A typical PHY receive procedure is shown in Figure 22-36 for VHT format. A typical state machine implementation of the receive PHY is given in Figure 22-37. This receive procedure and state machine do not describe the operation of optional features, such as LDPC or STBC. If the detected format indicates a NON_HT PPDU, refer to the receive procedure and state machine in Clause 18. If the detected format indicates an HT PPDU format, refer to the receive procedure and state machine in Clause 20. Further, through station management (via the PLME) the PHY is set to the appropriate frequency, as specified in 22.4 (VHT PLME). The PHY has also been configured with group information (i.e., group membership and position in group) so that it can receive data intended for the STA. Other receive parameters, such as RSSI and indicated DATARATE, may be accessed via the PHY-SAP.

Upon receiving the transmitted PHY preamble overlapping the primary 20 MHz channel, the PHY measures a receive signal strength. This activity is indicated by the PHY to the MAC via a PHY-CCA.indication primitive. A PHY-CCA.indication(BUSY, channel-list) primitive is also issued as an initial indication of reception of a signal as specified in 22.3.19.5 (CCA sensitivity). The channel-list parameter of the PHY-CCA.indication primitive is absent when the operating channel width is 20 MHz. The channel-list parameter is present and includes the element primary when the operating channel width is 40 MHz, 80 MHz, 160 MHz or 80+80 MHz.

The PHY shall not issue a PHY-RXSTART.indication primitive in response to a PPDU that does not overlap the primary 20 MHz channel.

The PHY includes the most recently measured RSSI value in the PHY-RXSTART.indication(RXVECTOR) primitive issued to the MAC.

After the PHY-CCA.indication(BUSY, channel-list) is issued, the PHY entity shall begin receiving the training symbols and searching for L-SIG in order to set the maximum duration of the data stream. If the check of the L-SIG parity bit is not valid, a PHY-RXSTART.indication primitive is not issued, and instead the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive. If a valid L-SIG parity bit is indicated, the VHT PHY shall maintain PHY-CCA.indication(BUSY, channel-list) for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (22-105), for all supported modes, unsupported modes, Reserved VHT-SIG-A Indication, invalid VHT-SIG-A CRC and invalid L-SIG Length field value. The L-SIG Length field value of a VHT PPDU is invalid if it is not divisible by 3. Reserved VHT-SIG-A Indication is defined as a VHT-SIG-A with Reserved bits equal to 0 or MU[u] NSTS fields (u = 0, 1, 2, 3) set to 5-7 or Short GI field set to 0 and Short GI NSYM Disambiguation field set to 1, or a combination of VHT-MCS and N_{STS} not included in 22.5 (Parameters for VHT-MCSs) or any other VHT-SIG-A field bit combinations that do not correspond to modes of PHY operation defined in Clause 22. If the VHT-SIG-A indicates an unsupported mode, the PHY shall issue PHY-RXEND.indication(UnsupportedRate). If the VHT-SIG-A indicates an invalid CRC or Reserved VHT-SIG-A Indication or if the L-SIG Length field is invalid, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation).

After receiving a valid L-SIG and VHT-SIG-A indicating a supported mode, the PHY entity shall begin receiving the VHT training symbols and VHT-SIG-B. If the received group ID in VHT-SIG-A has a value indicating a VHT SU PPDU (see 9.17a (Group ID and partial AID in VHT PPDUs)), the PHY entity may choose not to decode VHT-SIG-B. If VHT-SIG-B is not decoded, subsequent to an indication of a valid VHT-SIG-A CRC, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. The RXVECTOR associated with this primitive includes the parameters specified in Table 22-1 (TXVECTOR and RXVECTOR parameters).

If the Group ID field in VHT-SIG-A has a value indicating a VHT MU PPDU (see 9.17a (Group ID and partial AID in VHT PPDUs)), the PHY, in a STA that is MU beamformee capable, shall decode VHT-SIG-B. If the VHT-SIG-B indicates an unsupported mode, the PHY shall issue the error condition PHY-RXEND.indication(UnsupportedRate) primitive.

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If VHT-SIG-B was decoded the PHY may check the VHT-SIG-B CRC in the SERVICE field. If the VHT-SIG-B CRC in the SERVICE field is not checked a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. The RXVECTOR associated with this primitive includes the parameters specified in Table 22-1 (TXVECTOR and RXVECTOR parameters).

The PHY optionally filters out the PPDU based on the GroupID, MU[0-3] NSTS and Partial AID fields of VHT-SIG-A and the contents of the PHYCONFIG_VECTOR as follows:

— The PHY shall not filter out the PPDU if one of the following is true:
  - ($g = 0$) and (l_{00} is true) and (*partialaid* is included in PARTIAL_AID_LIST_GID00)
  - ($g = 63$) and (l_{63} is true) and (*partialaid* is included in PARTIAL_AID_LIST_GID63)
  - ($1 \le g \le 62$) and (MembershipStatusInGroupID[g] = 1) and (n_{STS}[UserPositionInGroupID[g]] > 0)

— where
  - l_{NN} is the one of the LISTEN_TO_GID*NN* parameters of the PHYCONFIG_VECTOR
  - MembershipStatusInGroupID[g] is the Membership Status Array field of the GROUP_ID_MANAGEMENT parameter of the PHYCONFIG_VECTOR for group g
  - g is the value of the GroupID field of VHT-SIG-A
  - $n_{STS}[u]$ is the value of the MU[u] NSTS field of VHT-SIG-A
  - UserPositionInGroupID[g] is the User Position Array field of the GROUP_ID_MANAGEMENT parameter of the PHYCONFIG_VECTOR for group g
  - *partialaid* is the value of the Partial AID field of VHT-SIG-A

— Otherwise the PHY may filter out the PPDU.

If the PPDU is filtered out, the PHY shall issue a PHY-RXEND.indication(Filtered) primitive.

Following training and signal fields, the Data field shall be received. The number of symbols in the Data field is determined by Equation (22-104).

$$N_{SYM} = \begin{cases} N'_{SYM} - 1, \text{ if Short GI} = 1 \text{ and Short GI NSYM Disambiguation} = 1 \\ N'_{SYM}, \text{ otherwise} \end{cases} \tag{22-104}$$

where

$$N'_{SYM} = \left\lfloor \frac{\text{RXTIME} - \begin{pmatrix} T_{\text{L-STF}} + T_{\text{L-LTF}} + T_{\text{L-SIG}} + T_{\text{VHT-SIG-A}} + \\ T_{\text{VHT-STF}} + N_{LTF} T_{\text{VHT-LTF}} + T_{\text{VHT-SIG-B}} \end{pmatrix}}{T_{SYM}} \right\rfloor$$

$$\text{RXTIME}(\mu s) = \left\lceil \frac{\text{LENGTH} + 3}{3} \right\rceil \cdot 4 + 20 \tag{22-105}$$

NOTE—LENGTH in Equation (22-105) is the LENGTH field in L-SIG.

The value of the PSDU_LENGTH parameter returned in the RXVECTOR using BCC encoding is calculated using Equation (22-106).

$$\text{PSDU\_LENGTH} = \left\lfloor \frac{N_{SYM} N_{DBPS} - N_{service} - N_{tail} \cdot N_{ES}}{8} \right\rfloor \tag{22-106}$$

where

N_{SYM} is given by Equation (22-104)

$\lfloor x \rfloor$ denotes the largest integer smaller than or equal to x

For a VHT SU PPDU, the SU/MU[0] Coding field of VHT-SIG-A2 indicates the type of coding. The PHY entity shall use an LDPC decoder to decode the C-PSDU if this bit is 1, otherwise BCC decoding shall be used. For an MU transmission, the SU/MU[0] Coding, MU[1] Coding, MU[2] Coding and MU[3] Coding fields of VHT-SIG-A2 indicate the type of coding for user u with USER_POSITION[u] = 0, 1, 2 and 3, respectively. The PHY entity shall use an LDPC decoder to decode the C-PSDU for the respective user if its bit for its C-PSDU is 1. BCC decoding shall be used otherwise. When an LDPC decoder is to be used, N_{SYM} is obtained from Equation (22-107).

$$N_{SYM} = \begin{cases} N_{SYM}, \text{ if LDPC Extra OFDM Symbol} = 0 \\ N_{SYM} - 1, \text{ if LDPC Extra OFDM Symbol} = 1 \text{ and STBC} = 0 \\ N_{SYM} - 2, \text{ if LDPC Extra OFDM Symbol} = 1 \text{ and STBC} = 1 \end{cases} \quad (22\text{-}107)$$

where

LDPC Extra OFDM Symbol and STBC are fields in VHT-SIG-A (see Table 22-12 (Fields in the VHT-SIG-A field))

The value of the PSDU_LENGTH parameter returned in the RXVECTOR using LDPC encoding is calculated using Equation (22-108).

$$\text{PSDU\_LENGTH} = \left\lfloor \frac{N_{SYM} N_{DBPS} - N_{service}}{8} \right\rfloor \quad (22\text{-}108)$$

where

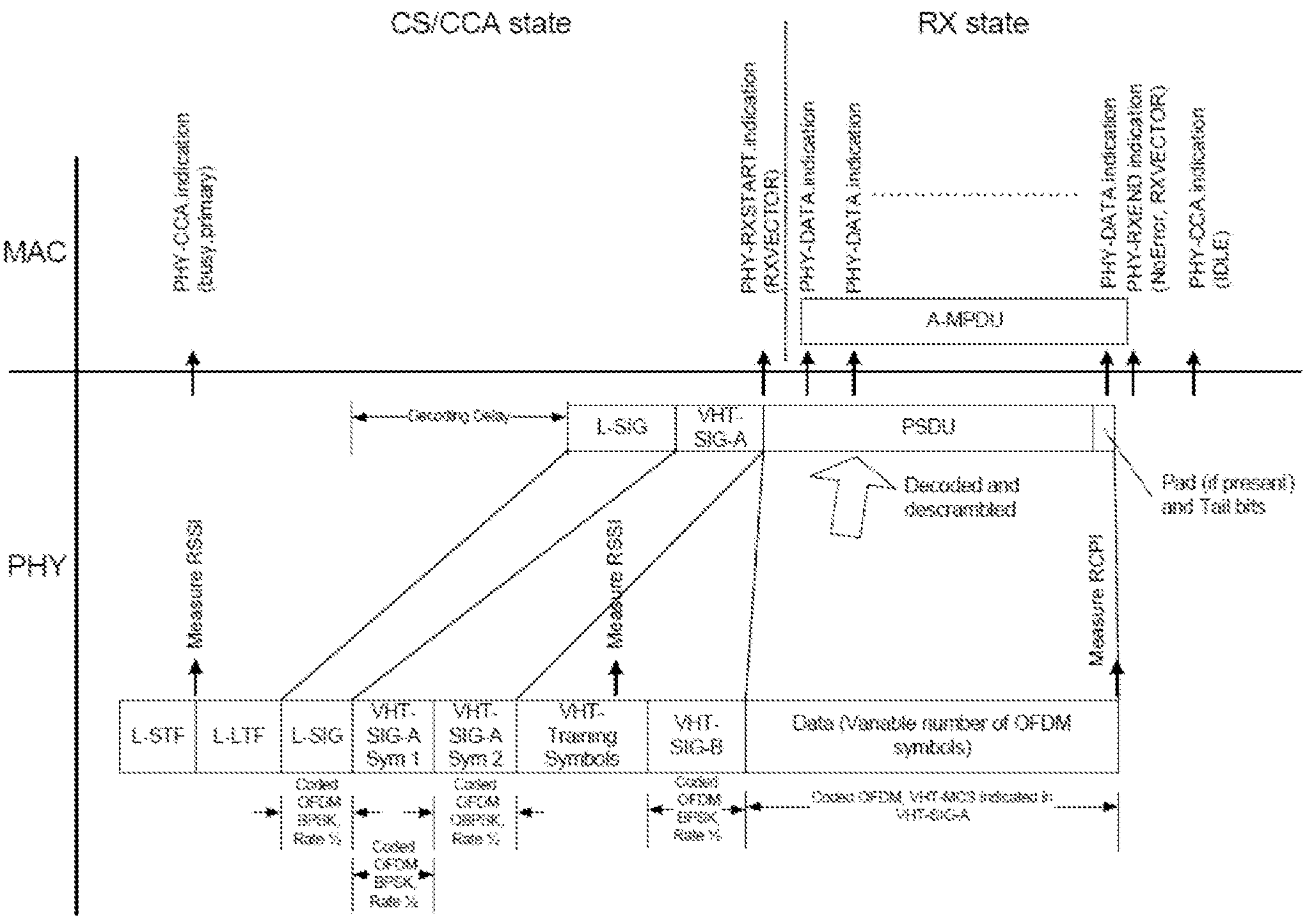
N_{SYM} is given by Equation (22-107)

The value of the PSDU_LENGTH parameter returned in the RXVECTOR for an NDP is 0.

If VHT-SIG-B is decoded and the VHT-SIG-B CRC in the SERVICE field is checked and not valid, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive. If the VHT-SIG-B field is decoded and the VHT-SIG-B CRC field is checked and valid, a PHY-RXSTART.indication(RXVECTOR) primitive shall be issued. The RXVECTOR associated with this primitive includes the parameters specified in Table 22-1 (TXVECTOR and RXVECTOR parameters).

If signal loss occurs during reception prior to completion of the PSDU reception, the error condition PHY-RXEND.indication(CarrierLost) shall be reported to the MAC. After waiting for the end of the PSDU as determined by Equation (22-105), the PHY shall set the PHY-CCA.indication(IDLE) primitive and return to the RX IDLE state.

The received PSDU bits are assembled into octets, decoded, and presented to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. Any final bits that cannot be assembled into a complete octet are considered pad bits and discarded. After the reception of the final bit of the last PSDU octet, and possible padding and tail bits, the receiver shall be returned to the RX IDLE state, as shown in Figure 22-37. A PHY-



NOTE—This procedure does not describe the operation of optional features, such as LDPC or STBC. This procedure describes the case where VHT-SIG-A indicates a mode not requiring decoding of VHT-SIG-B.

Figure 22-36—PHY receive procedure for an SU transmission

INVENTION DISCLOSURE FORM

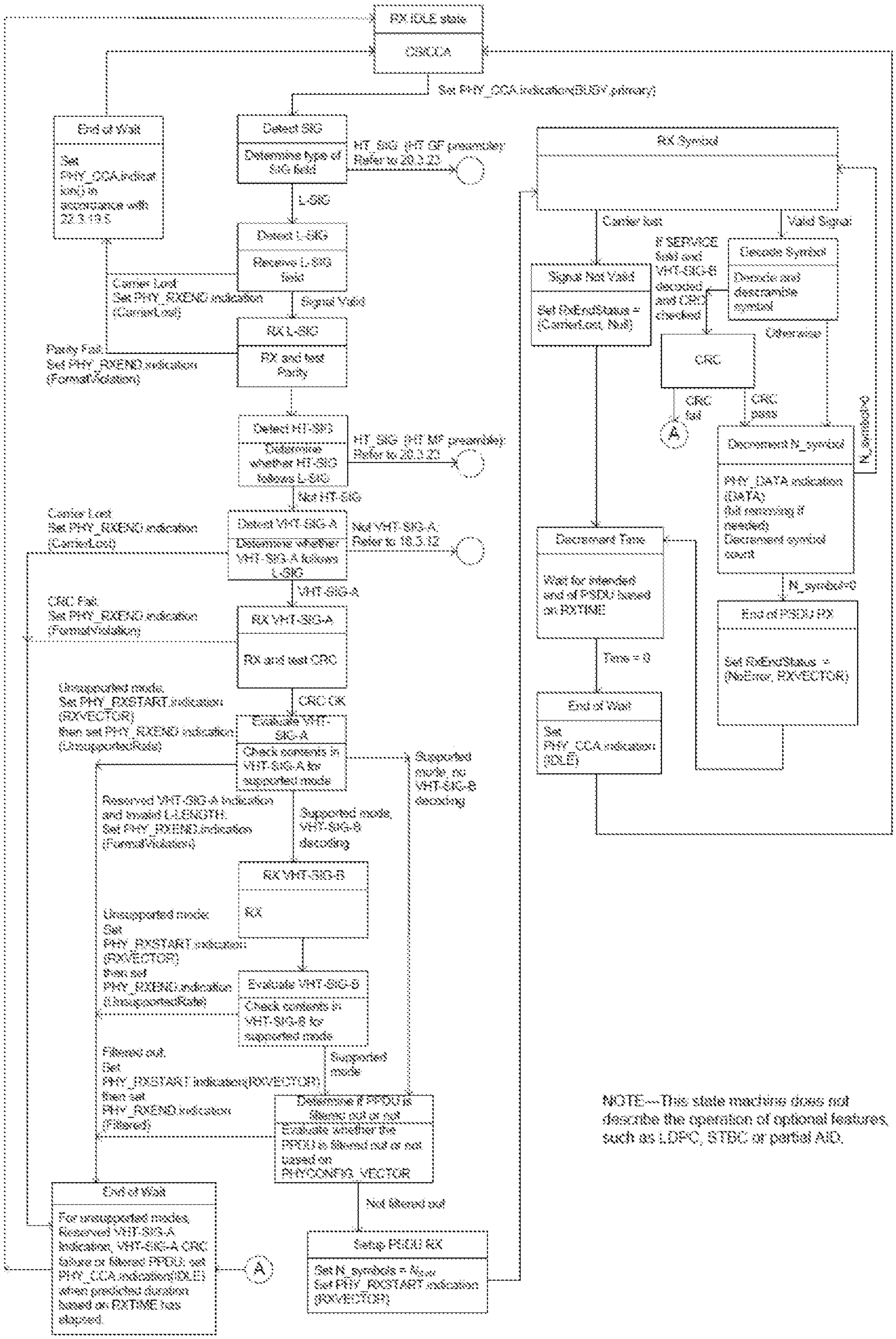


Figure 22-37—PHY receive state machine

Wireless LAN (WLAN) devices are currently being deployed in diverse environments. These environments are characterized by the existence of many access points and non-AP stations in geographically limited areas. Increased interference from neighboring devices gives rise to performance degradation. Additionally WLAN devices are increasingly required to support a variety of applications such as video, cloud access, and offloading. In particular video traffic is expected to be the dominant type of traffic in many high efficiency WLAN deployments. With the real-time requirements of some of these applications, WLAN users demand improved performance in delivering their applications, including improved power consumption for battery-operated devices.

Unlike previous amendments where the focus was on improving aggregate throughput, this amendment focuses on improving metrics that reflect user experience, such as average per station throughput, the 5th percentile of per station throughput of a group of stations, and area throughput. Improvements will be made to support environments such as wireless corporate office, outdoor hotspot, dense residential apartments, and stadiums.

- The focus of this amendment is on WLAN indoor and outdoor operation in the 2.4 GHz and the 5 GHz frequency bands. Additional bands between 1 GHz and 6 GHz may be added as they become available.

- The increase in average throughput per station is not limited to four times improvement. Improvement values in the range of 5-10 times are targeted, depending on technology and scenario.

- Outdoor operation is limited to stationary and pedestrian speeds.

- Average throughput per station is directly proportional to both aggregate basic service set (BSS) throughput and area throughput. The 5th percentile measure of the per station throughput may be used to determine that the desired distribution of throughput among a number of stations in an area is satisfied. These metrics, along with the satisfaction of the packet delay and the packet error ratio (PER) requirements of applications, will directly correspond to user experience in identified scenarios.

- Since the values of the metrics of interest will depend on the scenario, the focus will be on the relative improvement of these metrics compared to previous IEEE 802.11 amendments (IEEE 802.11n in 2.4 GHz and IEEE 802.11ac in 5 GHz).

- The amendment will be evaluated with a set of typical deployment scenarios representative of the main expected usage models that are likely to suffer bottlenecks in the coming years: residential, enterprise, indoor and outdoor hotspots. HEW SG has initiated the creation of a high-level simulation scenario working document (ref: 11-13/1001r5) to model these scenarios. The simulation scenarios may include system characteristics extracted from measured IEEE 802.11 operations in the field.

- These scenarios highlight three categories of objectives to improve WLAN efficiency:

o Make more efficient use of spectrum resources in scenarios with a high density of STAs per BSS.

o Significantly increase spectral frequency reuse and manage interference between neighboring overlapping BSS (OBSS) in scenarios with a high density of both STAs and BSSs.

o Increase robustness in outdoor propagation environments and uplink transmissions.

- This project may include the capability to handle multiple simultaneous communications in both the spatial and frequency domains, in both the uplink (UL) and downlink (DL) direction.

- Power efficiency is intended to measure consumption of devices which can reasonably be assumed to be powered by batteries and will take into account average power consumption for a given scenario

OFDMA (Orthogonal frequency-division multiple access)
OFDMA is a multi-user version of the popular orthogonal frequency-division multiplexing OFDM digital modulation scheme. Multiple access is achieved in OFDMA by assigning subsets of subcarriers to individual users as multi-user diversity. Different users perceive different channel qualities, a deep faded channel for one user may still be favorable to others.

MU-MIMO(Multi-User Multiple Input Multiple Output)

MU-MIMO is a transmission method for point-to-multipoint and multipoint-to-point scenario, e.g., downlink (an AP to multiple STAs) and uplink (Multiple STAs to an AP). By using the proper beamforming matrices (or vectors), multiple space-time streams from an AP can be transmitted to the associated STAs without interference. To this end, channel sounding process which acquires channel information from an AP to a STA is needed in a DL cases. In an UL case, however, channel sounding is not required because an AP with multiple receive antennas can decode and separate the data streams from each STA.

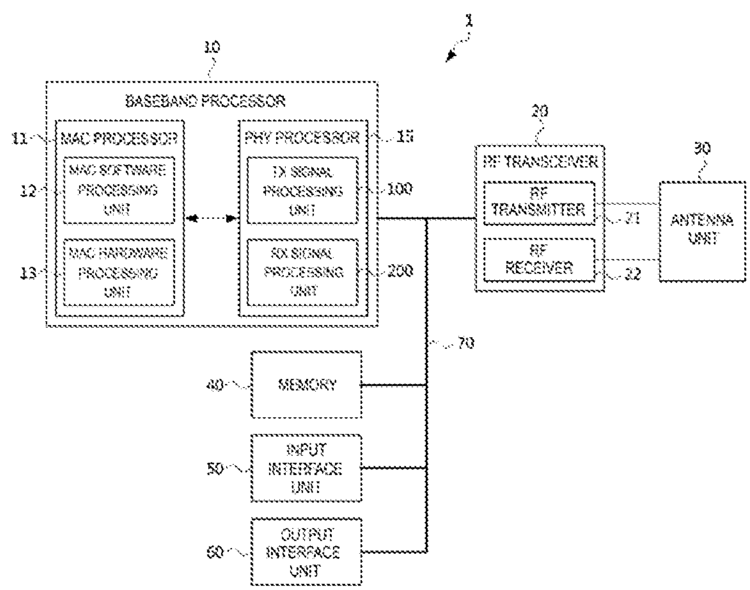
For the next generation of WLAN, 802.11ax (so called HEW, High Efficiency WLAN) requires robustness in outdoor channels, higher indoor efficiency. Technically, UL MU-MIMO and UL/DL OFDMA can be included as key technologies to achieve high efficiency in IEEE 802.11ax. In DL MU transmissions, one source, i.e., an AP, transmits the same packet to all STAs and then single CFO (carrier frequency offset) and timing offset are needed to be resolved at each STA. However, in UL MU transmissions, multiple sources, i.e., STAs, transmit their own packet to one destination, the AP, and each packet has different CFO, timing offset, and power level. Then, these mismatches cause the performance degradation. To avoid or minimize the degradation, CFO and SFO pre-compensation at transmitter, transmission timing adjustment and transmit power control are needed. In this intention, we propose the way to resolve the CFO and SFO precompensation issue in IEEE 802.11ax.

DETAILED DESCRIPTION:

In the following detailed description, only certain embodiments of the present invention have been shown and described, simply by way of illustration. As those skilled in the art would realize, the described embodiments may be modified in various different ways, all without departing from the spirit or scope of the present invention. Accordingly, the drawings and description are to be regarded as illustrative in nature and not restrictive. Like reference numerals designate like elements throughout the specification.

In a wireless local area network (WLAN), a basic service set (BSS) includes a plurality of WLAN devices. The WLAN device may include a medium access control (MAC) layer and a physical (PHY) layer according to IEEE (Institute of Electrical and Electronics Engineers) 802.11 standard. In the plurality of WLAN devices, at least one WLAN device may be an access point and the other WLAN devices may be non-AP stations (non-AP STAs). Alternatively, all the plurality of WLAN devices may be non-AP STAs in Ad-hoc networking. In general, the AP STA and the non-AP STA may be collectively called the STA. However, for easy description, only the non-AP STA may be called the STA.

The below drawing is a schematic block diagram exemplifying a WLAN device.



Referring the above drawing, the WLAN device 1 includes a baseband processor 10, a radio frequency (RF) transceiver 20, an antenna unit 30, a memory 40, an input interface unit 50, an output interface unit

60, and a bus 70.

The baseband processor 10 performs baseband signal processing, and includes a MAC processor 11 and a PHY processor 15.

In one embodiment, the MAC processor 11 may include a MAC software processing unit 12 and a MAC hardware processing unit 13. The memory 40 may store software (hereinafter referred to as "MAC software") including at least some functions of the MAC layer. The MAC software processing unit 12 executes the MAC software to implement the some functions of the MAC layer, and the MAC hardware processing unit 13 may implement remaining functions of the MAC layer as hardware (hereinafter referred to "MAC hardware"). However, the MAC processor 11 is not limited to this.

The PHY processor 15 includes a transmitting signal processing unit 100 and a receiving signal processing unit 200.

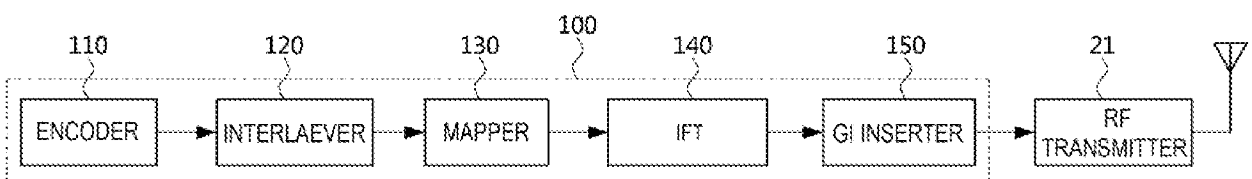
The baseband processor 10, the memory 40, the input interface unit 50, and the output interface unit 60 may communicate with each other via the bus 70.

The RF transceiver 20 includes an RF transmitter 21 and an RF receiver 22.

The memory may further store an operating system and applications. The input interface unit 50 receives information from a user, and the output interface unit 60 outputs information to the user.

The antenna unit 30 includes one or more antennas. When multiple-input multiple-output (MIMO) or multi-user MIMO (MU-MIMO) is used, the antenna unit 30 may include a plurality of antennas.

The below drawing is a schematic block diagram exemplifying a transmitting signal processor in a WLAN.



Referring the drawing, a transmitting signal processing unit 100 includes an encoder 110, an interlaever 120, a mapper 130, an inverse Fourier transformer (IFT) 140, and a guard interval (GI) inserter 150.

The encoder 110 encodes input data. For example, the encoder 100 may be a forward error correction (FEC) encoder. The FEC encoder may include a binary convolutional code (BCC) encoder followed by a puncturing device, or may include a low-density parity-check (LDPC) encoder.

The transmitting signal processing unit 100 may further include a scrambler for scrambling the input data before the encoding to reduce the probability of long sequences of 0s or 1s. If BCC encoding is used in the encoder, the transmitting signal processing unit 100 may further include an encoder parser for demultiplexing the scrambled bits among a plurality of BCC encoders. If LDPC encoding is used in the encoder, the transmitting signal processing unit 100 may not use the encoder parser.

The interleaver 120 interleaves the bits of each stream output from the encoder to change order of bits. Interleaving may be applied only when BCC encoding is used. The mapper 130 maps the sequence of bits output from the interleaver to constellation points. If the LDPC encoding is used in the encoder, the mapper 130 may further perform LDPC tone mapping besides the constellation mapping.

When the MIMO or the MU-MIMO is used, the transmitting signal processing unit 100 may use a plurality of interleavers 120 and a plurality of mappers corresponding to the number of N_{SS} of spatial streams. In this case, the transmitting signal processing unit 100 may further include a stream parser for dividing outputs of the BCC encoders or the LDPC encoder into blocks that are sent to different interleavers 120 or mappers 130. The transmitting signal processing unit 100 may further include a space-time block code (STBC) encoder for spreading the constellation points from the N_{SS} spatial streams into N_{STS} space-time streams and a spatial mapper for mapping the space-time streams to transmit chains. The spatial mapper may use direct mapping, spatial expansion, or beamforming.

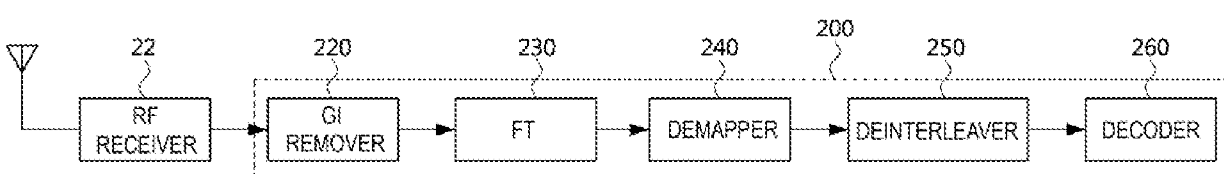
The IFT 140 converts a block of the constellation points output from the mapper 130 or the spatial mapper to a time domain block (i.e., a symbol) by using an inverse discrete Fourier transform (IDFT) or an inverse fast Fourier transform (IFFT). If the STBC encoder and the spatial mapper are used, the inverse Fourier transformer 140 may be provided for each transmit chain.

When the MIMO or the MU-MIMO is used, the transmitting signal processing unit 100 may insert cyclic shift diversities (CSDs) to prevent unintentional beamforming. The CSD insertion may occur before or after the inverse Fourier transform. The CSD may be specified per transmit chain or may be specified per space-time stream. Alternatively, the CSD may be applied as a part of the spatial mapper.

When the MU-MIMO is used, some blocks before the spatial mapper may be provided for each user.

The GI inserter 150 prepends a GI to the symbol. The transmitting signal processing unit 100 may optionally perform windowing to smooth edges of each symbol after inserting the GI. The RF transmitter 21 converts the symbols into an RF signal and transmits the RF signal via the antenna unit 30. When the MIMO or the MU-MIMO is used, the GI inserter 150 and the RF transmitter 21 may be provided for each transmit chain.

The below drawing is a schematic block diagram exemplifying a receiving signal processing unit in the WLAN.



Referring to the drawing, a receiving signal processing unit 200 includes a GI remover 220, a Fourier transformer (FT) 230, a demapper 240, a deinterleaver 250, and a decoder 260.

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An RF receiver 22 receives an RF signal via the antenna unit 30 and converts the RF signal into the symbols. The GI remover 220 removes the GI from the symbol. When the MIMO or the MU-MIMO is used, the RF receiver 22 and the GI remover 220 may be provided for each receive chain.

The FT 230 converts the symbol (i.e., the time domain block) into a block of the constellation points by using a discrete Fourier transform (DFT) or a fast Fourier transform (FFT). The Fourier transformer 230 may be provided for each receive chain.

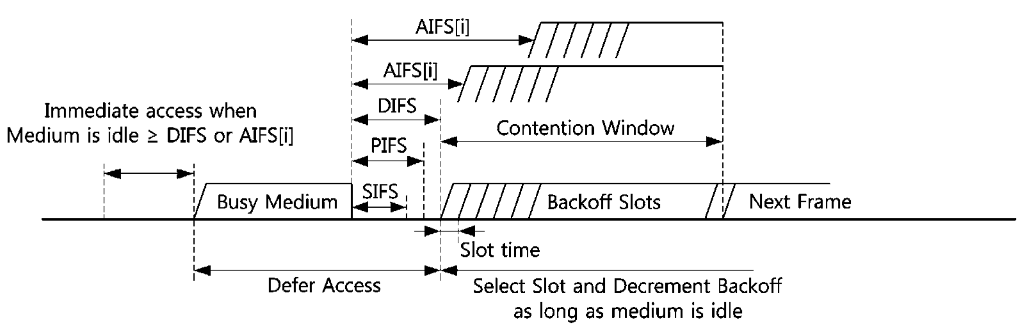
When the MIMO or the MU-MIMO is used, the receiving signal processing unit 200 may a spatial demapper for converting the Fourier transformed receiver chains to constellation points of the space-time streams, and an STBC decoder for despreading the constellation points from the space-time streams into the spatial streams.

The demapper 240 demaps the constellation points output from the Fourier transformer 230 or the STBC decoder to the bit streams. If the LDPC encoding is used, the demapper 240 may further perform LDPC tone demapping before the constellation demapping. The deinterleaver 250 deinterleaves the bits of each stream output from the demapper 240. Deinterleaving may be applied only when BCC encoding is used.

When the MIMO or the MU-MIMO is used, the receiving signal processing unit 200 may use a plurality of demappers 240 and a plurality of deinterleavers 250 corresponding to the number of spatial streams. In this case, the receiving signal processing unit 200 may further include a stream deparser for combining the streams output from the deinterleavers 250.

The decoder 260 decodes the streams output from the deinterleaver 250 or the stream deparser. For example, the decoder 100 may be an FEC decoder. The FEC decoder may include a BCC decoder or an LDPC decoder. The receiving signal processing unit 200 may further include a descrambler for descrambling the decoded data. If BCC decoding is used in the decoder, the receiving signal processing unit 200 may further include an encoder deparser for multiplexing the data decoded by a plurality of BCC decoders. If LDPC decoding is used in the decoder, the receiving signal processing unit 100 may not use the encoder deparser.

The below drawing exemplifies interframe space (IFS) relationships.

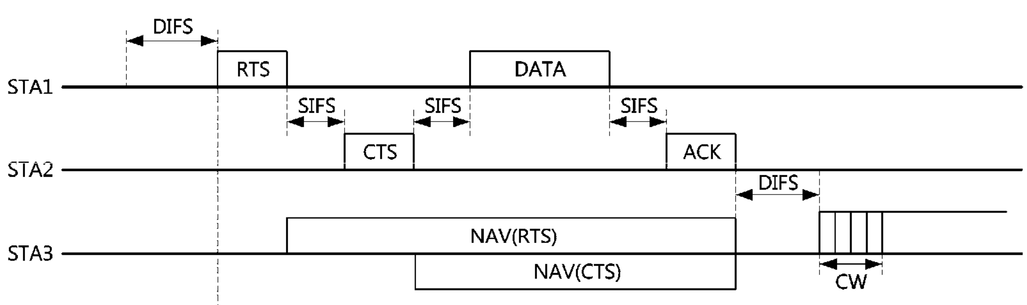


A data frame, a control frame, or a management frame may be exchanged between WLAN devices.

The data frame is used for transmission of data forwarded to a higher layer. The WLAN device transmits the data frame after performing backoff if a distributed coordination function IFS (DIFS) has elapsed from a time when the medium has been idle. The management frame is used for exchanging management information which is not forwarded to the higher layer. Subtype frames of the management frame include a beacon frame, an association request/response frame, a probe request/response frame, and an authentication request/response frame. The control frame is used for controlling access to the medium. Subtype frames of the control frame include a request to send (RTS) frame, a clear to send (CTS) frame, and an acknowledgement (ACK) frame. In the case that the control frame is not a response frame of the other frame, the WLAN device transmits the control frame after performing backoff if the DIFS has elapsed. In the case that the control frame is the response frame of the other frame, the WLAN device transmits the control frame without performing backoff if a short IFS (SIFS) has elapsed. The type and subtype of frame may be identified by a type field and a subtype field in a frame control field.

On the other hand, a Quality of Service (QoS) STA may transmit the frame after performing backoff if an arbitration IFS (AIFS) for access category (AC), i.e., AIFS[AC] has elapsed. In this case, the data frame, the management frame, or the control frame which is not the response frame may use the AIFC[AC].

The below drawing is a schematic diagram explaining a CSMA (carrier sense multiple access)/CA (collision avoidance) based frame transmission procedure for avoiding collision between frames in a channel.



Referring the drawing, STA1 is a transmit WLAN device for transmitting data, STA2 is a receive WLAN device for receiving the data, and STA3 is a WLAN device which may be located at an area where a frame transmitted from the STA1 and/or a frame transmitted from the STA2 can be received by the WLAN device.

The STA1 may determine whether the channel is busy by carrier sensing. The STA1 may determine the channel occupation based on an energy level on the channel or correlation of signals in the channel, or may determine the channel occupation by using a network allocation vector (NAV) timer.

When determining that the channel is not used by other devices during DIFS (that is, the channel is idle), the STA1 may transmit an RTS frame to the STA2 after performing backoff. Upon receiving the RTS frame, the STA2 may transmit a CTS frame as a response of the CTS frame after SIFS.

When the STA3 receives the RTS frame, it may set the NAV timer for a transmission duration of subsequently transmitted frames (for example, a duration of SIFS + CTS frame duration + SIFS + data frame duration + SIFS + ACK frame duration) by using duration information included in the RTS frame. When the STA3 receives the CTS frame, it may set the NAV timer for a transmission duration of subsequently transmitted frames (for example, a duration of SIFS + data frame duration + SIFS + ACK frame duration) by using duration information included in the RTS frame. Upon receiving a new frame before the NAV timer expires, the STA3 may update the NAV timer by using duration information included in the new frame. The STA3 does not attempt to access the channel until the NAV timer expires.

When the STA1 receives the CTS frame from the STA2, it may transmit a data frame to the STA2 after SIFS elapses from a time when the CTS frame has been completely received. Upon successfully receiving the data frame, the STA2 may transmit an ACK frame as a response of the data frame after SIFS elapses.

When the NAV timer expires, the STA3 may determine whether the channel is busy by the carrier sensing. Upon determining that the channel is not used by the other devices during DIFS after the NAV timer has expired, the STA3 may attempt the channel access after a contention window according to random backoff elapses.

To begin the UL transmission, any kind of a trigger frame from an AP should initiate the UL transmission of STAs. This trigger frame is sent by the AP and TXOP for UL transmission will start. With this trigger frame, each UL STA can estimate the carrier frequency offset with L-STF and L-LTF, and further track the frequency offset with pilots in each DATA OFDM symbols as shown in Fig. 1. This CFO estimate is calculated in PHY layer and this value can be used as a pre-compensation CFO without any aid of MAC layer when the next transmitted packet is sent to an AP, i.e. an UL MU packet. However, we cannot guarantee that the UL frame from a STA is always transmitted right after the UL trigger frame. In some cases, the STAs can transmit multiple UL frames without any feedback frame from the AP. In another case, the packet from neighboring BSS can interrupt a normal frame exchange. In PHY layer, there is no information about the source of the packet because the source address is in the MAC header. PHY layer just decodes the payload and delivers it to MAC layer with additional information, including RCPI and control information in L-SIG and VHT-SIG, via a TXVECTOR. Therefore, we can decide which packet requires CFO and SFO precompensation and the value of CFO with an aid MAC layer if the decoded packet is delivered to MAC layer with the estimated CFO value corresponding to the packet. To this end, the estimated CFO value should be included in RXVECTOR delivered by PHY layer to MAC layer. Then, MAC layer can know which packet comes from an AP based on source address in a MAC header and CFO value in RXVECTOR associated with AP’s packet. Next, MAC layer delivers the CFO value to PHY layer for CFO and SFO precompensation. By pre-compensateing the CFO and SFO at each UL STAs, CFOs and SFOs of multiple UL packets can have the same CFO and SFO values, respectively, as in Fig. 2. When non-zero CFO value is delivered from MAC, PHY performs pre-compensation of CFO and SFO (sampling frequency offset) with the value in time and frequency domains, respectively, as shown in Fig. 3. In IEEE 802.11, carrier frequency and sampling frequency are generated with the same oscillator. Based on this fact, SFO can be obtained with the CFO value if carrier frequency (channel frequency) is known. If a CFO value is defined as an incremental phase between two consecutive samples in time domain, its relative value in ppm is given by

$$SFO = CFO*\Delta f *(f_o/f_c)*T_{OFDM}$$

where Δf is a subcarrier spacing, f_o is an operating frequency CFO estimation, i.e., an inverse of sample duration, f_c is a carrier frequency and T_{OFDM} is an OFDM symbol duration. This detail equation can be different depending on the implementation.

Then CFO in TXVECTOR can be used both SFO precompensation block and CFO precompensation block. These two precompensation can be applied in time domain (after IDFT) and frequency domain (before IDFT). Because CFO is an incremental phase in time domain, it can be applied in time domain as in Fig. 3. SFO is an incremental phase in frequency domain if the accumulated offset does exceed the sample boundary, i.e., SFO is in fractional sample level. Therefore, SFO pre-compensation is done in frequency domain. In a case where accumulated time offset exceed the one sample, we add or delete the one sample in the GI insertion block after an IDFT block.

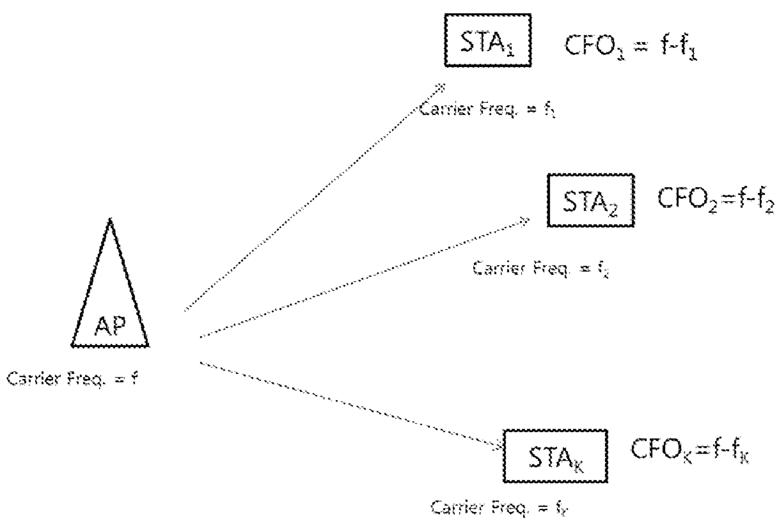


Fig. 1. CFO estimation at UL STAs with an UL trigger frame.

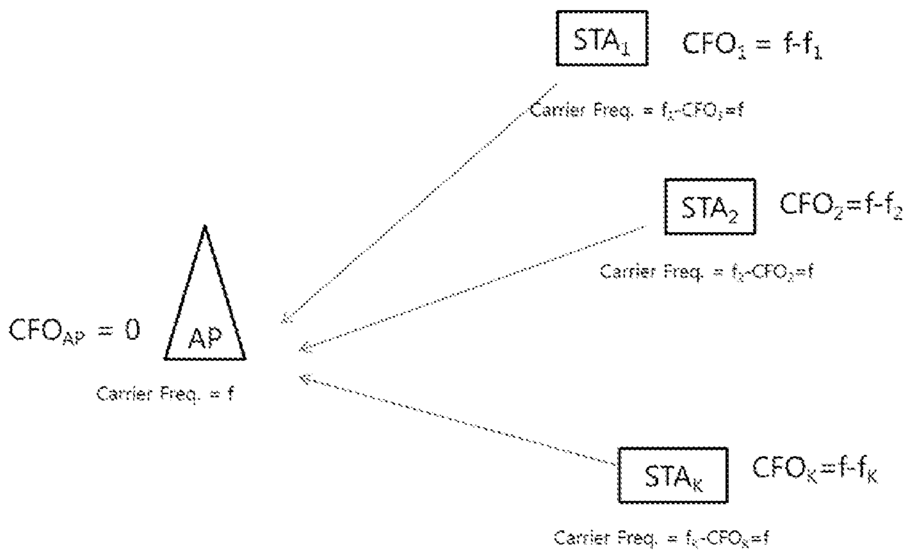


Fig. 2. UL MU transmission with CFO precompensation. (SFO precompensation is not included in this figure.)

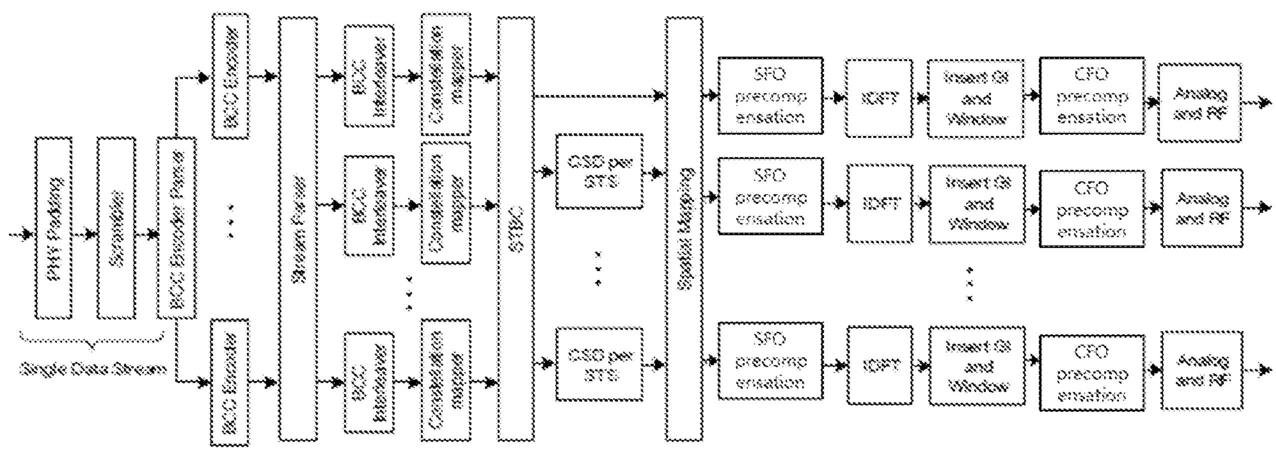


Fig. 3. An example of TX block diagram with CFO and SFO pre-compensation for IEEE 802.11ax.

As mentioned previously, CFO value should be defined in TXVECTOR and RXVECTOR in addition to them in IEEE 802.11ac. Moreover, SFO value for precompensation is calculated with the carrier frequency information (channel information), sample duration and other OFDM parameters (OFDM symbol duration and subcarrier spacing) and then SFO value used for SFO pre-compensation in a TX block diagram in Fig. 3. Therefore, only CFO is needed in TXVECTOR and RXVECTOR in addition to current TXVECTOR and RXVECTOR in IEEE 802.11ac.

Table. 1. TXVECTOR and RXVECTOR for IEEE 802.11ax

Parameter	Condition	Value	TXVECTOR	RXVECTOR
CFO_value	FORMAT is HE	This in RXVECTOR indicates the value of CFO estimated in the receiver. This in TXVECTOR indicate the value of CFO pre-compensated in a transmitter.	Y	Y
	Otherwise	Not present	N	N

In addition to PHY MIB values in IEEE 802.11ac, this CFO value can be defined as HE PHY MIB value as follows:

dot11PHYHETable		
Managed Object	Default value/range	Operational semantics
dot11CFOSFOprecompensationActivated	False/Boolean	Dynamic
dot11CFOvalue	Implementation dependent	Dynamic

Based on the these MIB entities, PHY can applied the CFO and SFO precompensation. Only when dot11CFOSFOprecompensationActived is true, the precompensation blocks are operating with the value of dot11CFOvalue.

In receiver operation, PHY layer calculates the CFO value to decode the received packet. This CFO value is delivered to MAC with other information of TXVOCTOR and received data. RX MAC can know what kind of packet is associated with this CFO value. If the CFO is from AP which triggers UL MU transmission, the value is used for precompensation in UL MU transmission. Otherwise, the CFO value is ignored.

The transmit operation can be described as follows. To inform the proper CFO value to PHY layer, MAC uses TXVECTOR with the UL MU data frame. The CFO value is nonzero (it means dot11CFOSFOprecompensationActivated is ture), the CFO value in RXVECTOR (it is equal to dot11CFOvalue) is used for CFO precompensation. In detail, the transmit samples are rotated with an incremental phase of "-CFO", i.e., -CFO*t (t is sample time index). In addition to CFO precompensation, SFO is also precompensated in a SFO precompendation block and a GI inversion block. In detail, SFO value is calculated with CFO and operation frequency of CFO estimation block, carrier frequency (channel frequency), and OFDM parameter. An example of the conversion formula is as follows:

SFO = CFO*(operation frequency of CFO block)/(carrier frequency)*(subcarrier spacing)*(OFDM symbol duration)

Then, timing offset at a given sample index (time index) t, is SFO*t. Then "–SFO*t" is the precompensation value. If this quantity is in the range of [0.5, 0.5], i.e., timing offset does not exceed the half of sample duration, the frequency domain compensation is enough. The frequency domain precompensation is phase rotation of "-SFO*t*k" where k denotes a subcarrier index, i.e., the ration of incremental phase in frequency domain with a subcarrier index. If the value of "-SFO*t" is exceed the half of sample duration, add or drop of one sample of IDFT output in the GI addition process and the phase of SFO precompensation is corrected by subtracting or add 0.5, i.e., -SFO*t+0.5 or –SFO*t+0.5.

ABSTRACT:

In this invention, CFO and SFO pre-compensation method is proposed for UL MU transmission. To implement this function in IEEE 802.11ax, the MAC-PHY interface signal in TXVECTOR and RXVECTOR is defined. PHY MIB is also defined. Furthermore, we explain the procedure of transmission and reception, i.e., how to use CFO value in TXVECTOR and RXVECTOR. By defining such parameters in the standard and implementing them, all UL MU packet can be synchronized in terms of CFO and SFO.