Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**AAS enhancements for OFDMA PHY**
Date Submitted	**2004-04-29**
Source(s)	Dale Branlund, Lalit Kotecha, Mike Webb BeamReach Networks Adam Kerr, Paul Petrus ArrayComm Inc. Zion Hadad, Yigal Leiba Runcom Technologies Ltd. Jose Puthenkulam[3] Intel Corp. Panyuh Joo, Seungjoo Maeng, Jaeho Jeon, Soonyoung Yoon, Jeong-Heon Kim, Jaehyok Lee, Myungkwang Byun, Inseok Hwang, Jaehee Cho, Jiho Jang, Sanghoon Sung, Samsung Electronics Co. Ltd. Choongil Yeh, Hyoungsoo Lim, Yuro Lee, Jongee Oh, DongSeung Kwon, ETRI mailto: dbranlund@beamreachnetworks.com adam@arraycomm.com zionh@runcom.co.il lkotecha@beamreachnetworks.com jose.p.puthenkulam@intel.com petrus@arraycomm.com mwebb@beamreachnetworks.com yigall@runcom.co.il panyuh@samsung.com lim@etri.re.kr
Re:	IEEE P802.16-REVd/D4-2003
Abstract	This contribution introduces AAS enhancements for OFDMA PHY as an optional feature
Purpose	Adopt into P802.16d/D5 draft.
Notice	
Release	
Patent Policy and Procedures	

1 Introduction

Adaptive array systems (AAS) can extend cell coverage by improving the system link budget. Link budget gain is realized by an AAS through the coherent combining of signals received or transmitted from multiple antenna elements, as well as by the increase in diversity order offered by the antenna array. At the same time, AAS can increase base station capacity by enabling the use of higher order modulation through interference reduction and by enabling spectral reuse within the cell.

In order to enable effective AAS processing, several issues must be resolved, some of which require additional capabilities in the BS or SS. This document describes these new AAS capabilities, including support for new control signal structures, which are compatible with the OFDMA PHY.

Examples of AAS control signals include antenna array training and bandwidth request signals that are able to function in a co-channel RF environment. The current OFDMA standard is silent on the definition of these signals. To ensure compatibility across different base stations and SSs, the control signals must be defined. Accordingly, a compact set of AAS control signals, is proposed in this submission. The use of these controls is only required for systems using the optional AAS mode. Non-AAS systems are not required to use these signals, and therefore bear no inefficiency.

2 Problem Definition

Broadcast Control Messages and Range

Coherent beamforming with a base station antenna array can effectively increase the transmission range of the uni-cast channels, since there exists an optimum beamforming solution to serve the intended SS, but it cannot directly increase the range of broadcast messages on broadcast channels – most crucially, broadcast MAP bursts do not enjoy the extended range. An SS who cannot receive the broadcast DL-MAP is cut-off from receiving other downlink traffic intended for it even though enough link budget on a beamformed transmission exists. The same problem occurs on the uplink – any SS that cannot receive the broadcast UL-MAP will not be able to transmit, even though the base station can use coherent combining gain to close the link.

The present OFDMA standard attempts to resolve this problem in the AAS mode with the active AAS DL scan (Section 8.4.4.7), which broadcasts on a sequence of different transmit beams, references to private DL-MAP allocations transmitted on the relevant transmit beam.

We present two new AAS modes, the Diversity-Map Scan method, which is a superset of the current active AAS DL scan, and the Direct Signaling method. These methods will replace the current active AAS DL scan definition. Both methods are optional AAS modes.

Interference on Control Messages

AAS system that employ adaptive arrays for the purpose of increasing base station capacity do so by aggressive reuse of frequency – often by re-using frequencies within the cell several times. In such an RF environment, the control messages are buried by interference, not only from interference generated by adjacent cells, but by interference generated from multiple users within the same cell. Thus, it becomes imperative to protect control signaling that opens data flows between various SS and the serving base station from this interference. This implies that control signaling be structured to enable interference mitigation using either in time, frequency, spatial and/or coding dimensions.

Proposed Solution

The proposed solution introduces low overhead control symbols and signaling that can be overlaid onto the OFDMA PHY framing structure. This control signaling is specifically designed for the AAS mode and may be selectively removed in non-AAS modes. Specially, the control signaling is designed so that base stations that employ adaptive antenna arrays can use spatial or spatial/spectral filtering to isolate this critical signaling and maintain the link budget advantages described above.

3 AAS Control Signaling Overview Solution

The following paragraphs provide an overview of the physical layer control signaling supporting the optional AAS mode. The signaling mechanisms described herein have been rationalized and integrated with the OFDMA frame structure.

An outline of this section is as follows: First is a definition of an AAS-DLFP that carries broadcast information and is transmitted with beam-pattern diversity and carries a compressed DL-MAPs and an initial ranging allocation. This approach, or the Diversity-Map Scan method, is described in section 3.1 below. This method is effectively augmenting the functionality of the current Active DL AAS scan (8.4.4.7). Method 2 is the Direct-Signaling Method, and includes the definition of special symbols to support paging and access requests, and is described in section 3.2 below.

The Diversity-Map Scan Method has the benefits of:

- Increased link budget for broadcast information
- High spectral efficiency
- High base station capacity
- Uses existing MAC messaging for flexible BW allocations
- No significant additional processing requirements on the SS

Method #2, the Direct-Signaling Method, also defines an AAS-DLFP2 that carries broadcast information and is transmitted with beam-pattern and frequency diversity. AAS-DLFP2 carries the minimal set information needed to set up base station beamforming so that Map allocations and other broadcast information can be transferred with adequate link budget. Once the UL-Maps and DL-Map have transferred the data flow CIDs, burst parameters and map regions, PHY layer control signaling is used to page subscriber stations and to train the adaptive arrays in the co-channel environment. Method 2 applies only to the AMC sub-channel region and enables the following attributes (analysis for PUSC on going):

- Higher in-cell frequency reuse and higher base station capacity
- Reduced overhead & higher spectral efficiency
- Higher number of BW allocation/request opportunities per frame
- Supports lower-latency bandwidth allocations for multiple users
- Scalable, K logical BW allocation/access channels per 1 physical channel where K is proportional to the number of antennas M.

AAS Method 1 - Diversity-Map Scan

The purpose of the AAS-DLFP is to provide a robust transmission of the required base station parameters to enable SS initial ranging and access requests, as well as SS paging and access allocation. This is achieved through using the most robust form of modulation and coding (namely QPSK-1/2 rate, 2 repetitions). The AAS-DLFP is transmitted repeatedly throughout the DL subframe. The AAS-DLFP is also transmitted repeatedly throughout a single DL subframe using beamforming diversity (i.e. a different beamforming strategy is used between each AAS-DLFP transmission).

The AAS-DLFP supports the ability to transmit a MAP IE that carries a compressed DL-MAP. This allocation message can point to a broadcast DL-MAP that is beamformed or can be used to “page” a specific SS who cannot receive the normal DL-MAP. Once the initial allocations are provided to the user, private DL-MAPs and UL-MAPs can be sent on a beamformed transmission to the user at the highest modulation and lowest coding rate that can be supported by the link. The AAS-DLFP also has an uplink initial ranging allocation for AAS subscribers.

Proposed Text Changes

[Replace Section 8.4.4.7 "Optional Active DL AAS Scan" in IEEE802.16-REVd/D4 with the following section.]

8.4.4.7 Optional Diversity-Map Scan

8.4.4.7.1 AAS frame structure

The two highest numbered subchannels of the DL frame may be dedicated at the discretion of the BS for the AAS Diversity-Map Zone in PUSC, FUSC and optional FUSC permutation. In the AMC permutation, the 4^{th} and (N-4)th subchannels of the total N subchannels of the DL frame may be dedicated at the discretion of the BS for the AAS Diversity-Map Zone. For AMC permutation, each subchannel for the AAS diversity MAP consists of 3 bins by 2 symbol. When these subchannels are used for this purpose, they shall not be allocated in the normal DL-MAP message and shall be used only on the AAS portion of the DL sub-frame. These sub-channels will be used to transmit the AAS-DLFP() whose physical construction is shown in Figure 1.

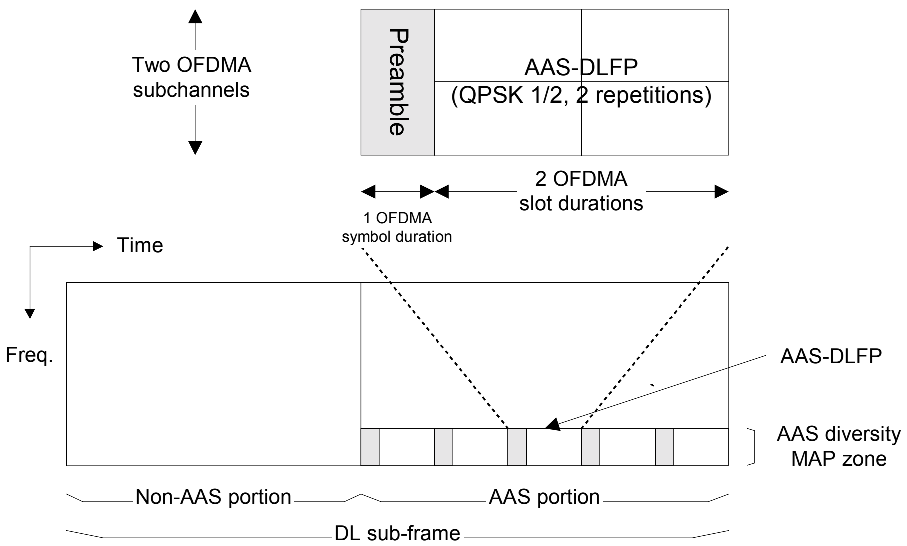

Figure 1—Example of allocation for AAS-DLFP

The AAS portion in the DL (or UL) may be transmitted either by the FUSC/PUSC permutation or by the optional AMC permutation. Figure 2 shows an example of a DL sub-frame for each of these two possible variations.

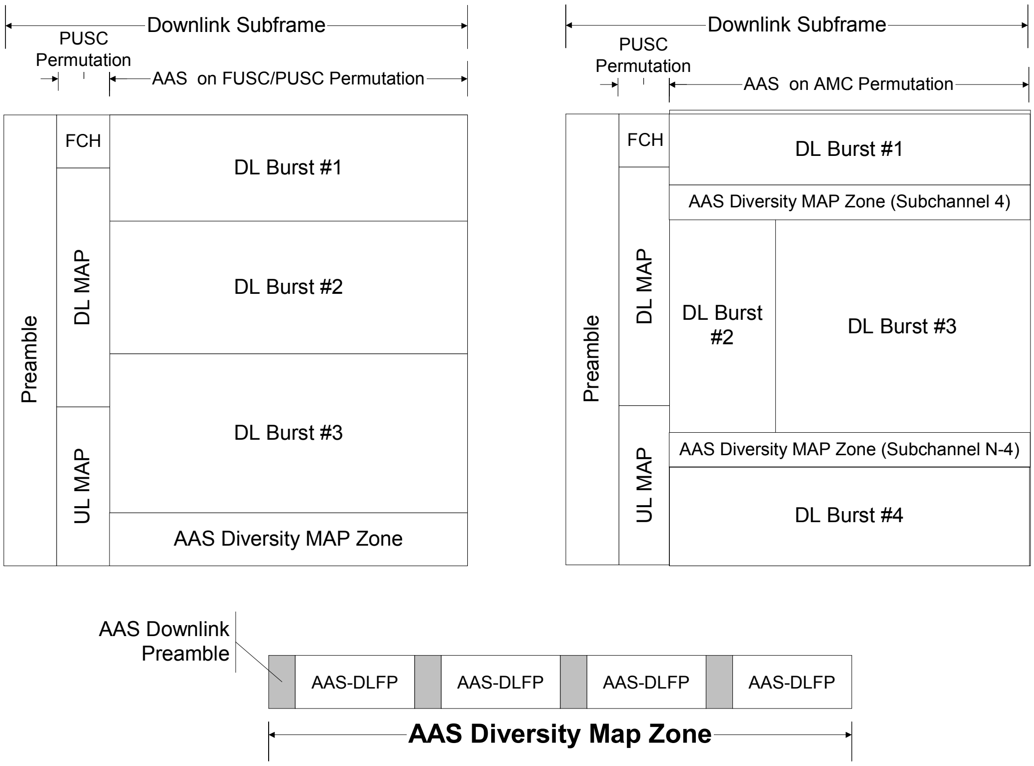

Figure 2: AAS Diversity Map Frame Structure

8.4.4.7.2 AAS-DLFP Format

The purpose of the AAS-DLFP is to provide a robust transmission of the required base station parameters to enable SS initial ranging, as well as SS paging and access allocation. This is achieved through using a highly robust form of modulation and coding (namely QPSK-1/2 rate with 2 repetitions). The start of an AAS-DLFP is marked by an AAS DL preamble. The AAS-DLFPs transmitted within the AAS Diversity Map Zone need not carry the same information. Different beams may be used within the AAS Diversity Map Zone, where each beam is transmitted in a different direction at a given time (all using the same AAS downlink preamble), however each AAS Downlink Preamble and associated AAS-DLFP must be transmitted on the same beam.

The AAS-DLFP supports the ability to transmit a MAP IE that carries a compressed DL-MAP. This allocation message can point to a broadcast DL-MAP that is beamformed or can be used to “page” a specific SS who cannot receive the normal DL-MAP. Once the initial allocations are provided to the user, private DL-MAPs and UL-MAPs can be sent on a beamformed transmission to the user at the lowest modulation and ~~lowest~~ highest coding rate that can be supported by the link (namely QPSK-1/2 rate with 2 repetitions). The AAS-DLFP also has an uplink initial ranging allocation for AAS subscribers.

The contents of the AAS-DLFP() payload is described by Table 1.

Table 1. AAS-DLFP Structure, Diversity-Map Scan

Syntax	Size	Notes
AAS-DLFP() {		
AAS beam index	4~~6~~ bits	This index is the index referred to by the AAS_Beam_Select message (see section 6.3.2.3.41).
Preamble select	1	0 – Frequency shifted Preamble 1 – Time shifted Preamble
~~Preamble presence~~	~~1 bit~~	~~0 = No preambles precede the AAS burst allocations in downlink & uplink.~~ ~~1 = A preamble precedes the AAS burst allocations in downlink & uplink.~~
Uplink_Preamble_Config	2 bits	00 – ~~1 symbol~~ 0 symbols 01 – ~~2 symbols~~ 1 symbols 10 – ~~3 symbols~~ 2 symbols 11 – ~~reserved 3~~ 3 symbols
Downlink_Preamble_Config	2 bits	00 – 0 symbols 01 – 1 symbols 10 – 2 symbols 11 – 2 symbols
Initial_Ranging_Allocation_IE() {		
OFDMA Symbol Offset	8 bits	
Subchannel offset	6 bits	
No of OFDMA Symbols	5 bits	
No of Subchannels	3 bits	
Ranging Method	2 bits	00 - Initial Ranging over two symbols 01 - Initial Ranging over four symbols 10 - BW Request/Periodic Ranging over one symbol 11 - BW Request/Periodic Ranging over three symbols
AAS_Comp_DL_IE()	50 bits	
HCS	8 bits	
Reserved	1	
Total	12 bytes	

Table 2. Structure of AAS_COMP_DL_IE ()

AAS_COMP_DL_IE() {		
CID	16 bits	
DIUC	4 bits	Set DIUC =15 to indicate the well known modulation of QPSK, encoded with the mandatory CC at rate ½.
OFDMA Symbol Offset	8 bits	
Subchannel offset	6 bits	
No of OFDMA Symbols	7 bits	
No of Subchannels	6 bits	
Boosting	3 bits	
Total	48 bits	
}		

8.4.4.7.1 AAS Downlink Preamble

The AAS-DLFP is preceded by an AAS downlink preamble. In addition, the "Preamble Presence" field of the AAS_DLFP indicates the presence of an AAS downlink preamble on any downlink allocation made by the DLFP. An AAS downlink preamble is formed by appropriately combining different preamble sequences defined in section 8.4.6.1.1. An AAS allocation could be in the FUSC/PUSC/AMC allocation and therefore, depending on the type of allocation, a preamble may span more than one original preamble sequence defined in section 8.4.6.1.1. In AMC allocation, the AAS downlink preamble occupies 9 subcarriers in each bin of the subchannels in AAS operation. The AAS down link preamble number, K, is derived from the AAS beam index carried by the AAS_DLFP(), and is limited to maximum 16 beams per segment (mainly in switching beams approach). When using the cyclic frequency shift preamble defined in 8.4.5.3.8, beams which use the same subchannels at the same time instance shall use a different AAS down link preamble number (K).

8.4.4.7.2 AAS Uplink Preamble

The "Preamble Presence" field of the AAS_DLFP indicates the presence of a preamble on any uplink bandwidth allocation made by the DLFP. The "Uplink_Preamble_Config" field indicates the size of the AAS uplink preamble. In the PUSC region, the AAS uplink preambles occupy 4 subcarriers and 1/2/3 symbols. The basic AAS preamble (4 subcarrier x 1 symbol for PUSC or 9 subcarrier x 1 symbol for AMC or 3 subcarrier x 1 symbol for optional PUSC) is derived from the preambles defined in section 8.4.6.1.1 similar to the downlink. In AMC allocation, the AAS uplink preamble occupies 9 subcarriers in each bin of the subchannels and 1, 2 or 3 symbols as specified in the AAS-DLFP.

8.4.5.3.8 DL-MAP Physical Modifier IE

The Physical Modifier Information Element indicates that the subsequent allocations shall utilize a preamble, which is either cyclically delayed in time or cyclically rotated in frequency.

In the case when the preamble is cyclically delayed in time by k samples, the preamble will contribute a component s'(t) to the transmitted waveform as defined below:

$$s'(t) = \mathrm{Re}\left\{ e^{j2\pi f_c t} \left[\sum_{\substack{k=-N_{used}/2 \\ k \neq 0}}^{k=N_{used}/2} c_k \times e^{j2\pi k / N_{FFT}} \right] \right\}$$

Eqn. 1

where c_k are the preamble tone values, and *t* is the time, elapsed since the beginning of the OFDMA symbol, with 0 < t < Ts. The PHYMOD_DL_IE can appear anywhere in the DL map, and it shall remain in effect until another PHYMOD_DL_IE is encountered, or until the end of the DL map.

In case when the preamble is cyclically shifted in frequency, the preamble subcarriers will be shifted such that

$$C_{New,K} = (C_{Original} + 5 \cdot K) \text{ modulo } N_{Used-Subcarriers} \qquad \text{(aaa)}$$

Where $C_{New,K}$ is the new subcarrier index and $C_{Original}$ is the original subcarrier index, and K is the frequency shift index indicated in the PHYMOD_DL_IE.

Table 3. Structure of PHYMOD_DL_IE ()

PHY_MOD_DL_IE() {		
Extended UIUC	4 bits	
Length	4 bits	
Preamble Modifier Type	1 bit	0 – Randomized preamble 1 – Cyclically shifted Preamble
if (Preamble Modifier Type == 0) {		
Preamble frequency shift index	4bits	Indicates the value of K in equation (aaa)
} else {		
Time index shift type	1 bit	0 – Rounded down shift 1 – Exact shift
If (Time index shift type ==0) {		
Preamble Time Shift Index	4 bits	For PUSC, 0 – 0 sample cyclic shift 1 – floor(Nfft/14) sample cyclic shift …. 13 – floor(Nfft/14*13) sample cyclic shift 14-15 – reserved For AMC permutation, 0 – 0 sample cyclic shift 1 – floor(Nfft/9) sample cyclic shift …. 8 – floor(Nfft/9*8) sample cyclic shift 9-15 – reserved
} else {		
Preamble Time Shift Index	4 bits	For PUSC, 0 – 0 sample cyclic shift 1 – (Nfft/14) sample cyclic shift …. 13 – (Nfft/14*13) sample cyclic shift 14-15 – reserved For AMC permutation, 0 – 0 sample cyclic shift 1 – (Nfft/9) sample cyclic shift …. 8 – (Nfft/9*8) sample cyclic shift 9-15 – reserved
}		
}		
Reserved	~~3~~ 2 bits	
}		

Preamble Modifier Type
This parameter defines whether the preamble will be cyclically shifted in time or in frequency.

Preamble frequency shift index
This parameter effects the cyclic shift of the preamble in frequency axis, as defined by equation (aaa)

Preamble Time Shift Index

This parameter defines how many samples of cyclic shift shall be introduced into the preamble symbols. The unit of cyclic shift depends on the subchannel permutation to ensure the frequency-domain orthogonality between the different preambles in the same subchannel.

8.4.5.4.9 UL-MAP Physical Modifier IE

The Physical Modifier Information Element indicates that the subsequent allocations shall utilize a preamble, which is either ~~randomized by frequency cyclic~~ cyclically shifted in frequency or cyclically delayed in time by *k* samples (see Equation (1)). The PHYMOD_UL_IE can appear anywhere in the UL map, and it shall remain in effect until another PHYMOD_UL_IE is encountered, or until the end of the UL map.

Table 4. Structure of PHYMOD_UL_IE ()

PHY_MOD_UL_IE() {		
Extended UIUC	4 bits	
Length	4 bits	
Preamble Modifier Type	1 bit	0 – Randomized frequency shift preamble 1 – Cyclically shifted Preamble
if (Preamble Modifier Type == 0) {		
Preamble ~~Randomizer Index~~ frequency shift index	4bits	Indicates the value of K in equation (aaa)
} else {		
Preamble Time Shift Index	4 bits	For PUSC, 0 – 0 sample cyclic shift 1 – floor(Nfft/4) sample cyclic shift …. 3 – floor(Nfft/4*3) sample cyclic shift 4-15 – reserved For optional PUSC, 0 – 0 sample cyclic shift 1 – floor(Nfft/3) sample cyclic shift 2 – floor(Nfft/3*2) sample cyclic shift 3-15 – reserved For AMC permutation, 0 – 0 sample cyclic shift 1 – floor(Nfft/9) sample cyclic shift …. 8 – floor(Nfft/9*8) sample cyclic shift 9-15 – reserved
}		
Reserved	3 bits	
}		

Preamble Modifier Type

This parameter defines whether the preamble will be randomized or cyclically shifted.

Preamble Frequency Shift Index

This parameter effects the cyclic shift of the preamble in frequency axis, as defined by equation (aaa)

Preamble Time Shift Index

The parameter defines how many samples of cyclic shift shall be introduced into the preamble symbols. The unit of cyclic shift depends on the subchannel permutation to ensure the frequency-domain orthogonality between the different preambles in the same subchannel.

[Remove the sentence in section 8.4.5.4, page 482 that states "~~A BS supporting the AAS option shall allocate subchannels 30 and 31, during the last 4 symbols of the uplink frame as initial ranging slot for AAS SS that have to initially alert the BS to their presence. This period shall be marked in the UL-MAP as Initial Ranging (UIUC=12), but shall be marked by a AAS initial ranging CID such that no non-AAS subscriber (or AAS subscriber that can decode the UL-MAP message) uses this interval for Initial Ranging.~~"]

[Modify section 6.3.2.3.41 as follows:]

6.3.2.3.41 AAS Beam Select message
The AAS Beam Select message may be used by a system supporting AAS. This message may be sent by the SS in an unsolicited manner, to inform the BS about the preferred beam ~~direction~~ for the AAS SS sending this message. The AAS Beam Select message shall be sent on the basic CID.

Table 5. AAS_Beam_Select message format

AAS_Beam_Select message format() {		
Management message type = 46	8 bits	
AAS beam ~~direction~~ index	4 bits	
Reserved	4 bits	
}		

AAS beam ~~direction~~ index
This index shall correspond to the direction the AAS beam is pointing at during the AAS_DLFP preferred by the SS (see 8.4.4.7)

[Modify section 6.3.7.6.3 as follows:]

6.3.7.6.3 AAS downlink synchronization
When the SS first attempts to synchronize to the downlink transmission, the BS is unaware of its presence, and therefore is not aiming the adaptive array at its direction. Nevertheless, the frame start preamble is a repetitive well-known pattern, and SS may utilize the inherent processing gain associated with it in order to synchronize timing and frequency parameters with the BS. The BS may further employ active scanning or diversity methods to speed up and enhance the process of downlink synchronization. These methods are PHY-specific, and described in the respective PHY section.

[Modify the table in section 11.8.3.7.2 and 11.8.3.7.3 as follows to support definition of the two AAS modes]

11.8.3.7.2 AAS additional options for OFDMA SS mandatory demodulator
This field indicates the different demodulator options supported by a WirelessMAN-OFDMA PHY SS (in addition to the mandatory) for downlink reception. This field is not used for other PHY specifications. A bit value of 0 indicates "not supported" while 1 indicates "supported."

Type	Length	Value	Scope
151	1	Bit #0: 64-QAM Bit #1: BTC Bit #2: CTC	SBC-REQ (see 6.3.2.3.23) SBC-RSP (see 6.3.2.3.24)

		Bit #3: STC Bit #4: AAS Diversity Map Scan Bit #5: AAS Direct Signaling Bit #6-7: *Reserved*	

11.8.3.7.3 AAS additional options for OFDMA SS mandatory modulator

This field indicates the different modulator options supported by a WirelessMAN-OFDMA PHY SS for uplink transmission. This field is not used for other PHY specifications. A bit value of 0 indicates “not supported”while 1 indicates “supported.”

Type	Length	Value	Scope
152	1	Bit #0: 64-QAM Bit #1: BTC Bit #2: CTC Bit #3: AAS Diversity Map Scan Bit #4: AAS Direct Signaling Bit #5-7: *Reserved*	SBC-REQ (see 6.3.2.3.23) SBC-RSP (see 6.3.2.3.24)