Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Rewrite of IEEE 802.16ab-01/01 Sec. 8.3.5.3.5, “Mode B - OFDMA”**
Date Submitted	**2001-10-19**
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Re:	This document is in response to the Working Group Review, IEEE 802.16-01/49. I shall submit a comment referencing this document
Abstract	Editorial rewrite of Sec. 8.3.5.3.5 of IEEE 802.16ab-01/01r2, Sept. 2001
Purpose	To be considered for the next revision of IEEE 802.16ab-01/01. .
Notice	
Release	
Patent Policy and Procedures	

8.3.5.3.4 Mode B - OFDMA

8.3.5.3.4.1 Carrier Assignments

$F_s = BW \cdot 8/7$. The mandatory FFT size is 2048.

8.3.5.3.4.1.1 Downlink

The 2048 or 4096 carriers in the OFDMA downlink symbol are partitioned into an unused DC carrier, guard tones, and used carriers.

The N_{used} used carriers are further partitioned into constant-location pilots, variable location pilots, and data subchannels,

The constant-location pilots are always located on the same carriers.

The variable-location pilots shift their location every symbol repeating every 4 symbols, according to the formula:

$$k = 3L + 12P_v$$

where:

$k \in \{0, \ldots, N_{used} - 1\}$ indices of used carriers

$L \in 0 \ldots 3$ denotes the symbol number with a cyclic period of 4

$P_v \geq 0$ is an integer number

The symbols are transmitted with the following order L=0,2,1,3. The mechanism is illustrated in Figure 229:

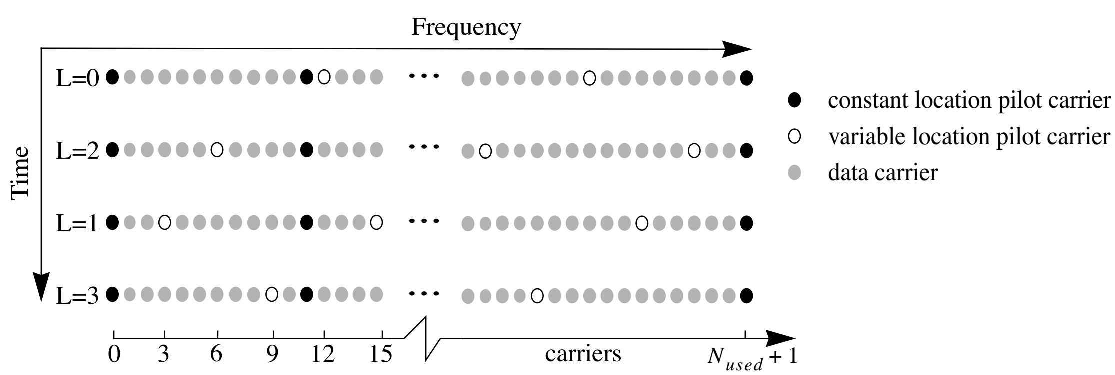

Figure 229 Pilot and data carrier location in DL OFDMA symbol

After so mapping the pilots, the remainder of the used carriers are the data subchannels. Note that since the variable locatiion pilots change location in each symbol, repeating every fourth symbol, the locations of the carriers in the data subchannels must change also.

To allocate the data subchannels, the remaining carriers are partitioned into groups of contiguous carriers. Each subchannnel consists of one carrier from each of these groups. The number of groups, N_{groups} , is equal to the number of carriers per subchannel, which is 53. The number of the carriers in a group is equal to the number of subchannels, $N_{subchannels}$. Thus, the number of data carriers is thus equal to $N_{groups} \cdot N_{subchannels}$.

The exact partitioning into subchannels is according to the formula:

$$carrier(n, s) = N_{subchannels} \cdot n + \{p_s[n_{mod(N_{subchannels})}] + ceil[(n+1)/N_{subchannels}] \cdot ID_{cell}\}_{mod(N_{subchannels})} \quad (23)$$

where

$carrier(n, s)$ = index number of carrier n of subchannel s.
s= index number of a subchannel, from the set [0..$N_{(subchannel)s}$ -1].
n = index number of a carrier within a subchannel from the set [0.. N_{groups} -1]
$N_{(subchannel)s}$ = number of subchannels.
$p_s[j]$ = the series obtained by rotating $\{PermutationBase_0\}$ cyclically to the left s times.
ceil[ ] = function which rounds its argument up to the next integer.
ID_{cell} = a positive integer assigned by the MAC to identify this particular base-station cell.
$X_{mod(k)}$ = the remainder of the quotient X/k (which is at most k-1).

Table 218 Downlink Symbol Parameters

N_{FFT}	Parameter	Value	
2048 (2K)	N_{used}	1703	
	Guard Carriers: Left, Right	173	173
	Subchannels, data carriers/subchannel	32	48
	Index numbers of the 32 constant-location pilots	{0,39, 261, 330, 342, 351, 522, 636, 645, 651, 708, 726, 756, 792, 849, 855, 918, 1017, 1143, 1155, 1158, 1185, 1206, 1260, 1407, 1419,1428, 1461, 1530,1545, 1572, 1701}	
	$\{PermutationBase_0\}$	{3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30}	
4096 (4K)	N_{used}	3406	
	Guard Carriers: Left, Right	345	345
	Subchannels, data carriers/subchannel	64	48
	Index numbers of constant-location pilots	{0, 39, 261, 330, 342, 351, 522, 636, 645, 651, 708, 726, 756, 792, 849, 855, 918, 1017, 1143, 1155, 1158, 1185, 1206, 1260, 1407, 1419, 1428, 1461, 1530, 1545, 1572, 1701, 1791, 1860, 1884, 1911, 1950, 2025, 2037, 2058, 2103, 2112, 2154, 2169, 2283, 2298, 2376, 2400, 2586, 2634, 2697, 2757, 2823, 2892, 2958, 3039, 3075, 3096, 3120, 3153, 3219, 3270, 3321, 3381, 3404}	
	$\{PermutationBase_0\}$	TBD	

8.3.5.3.4.1.2 Uplink

The 2048 or 4096 carriers in the OFDMA uplink symbol are partitioned into an unused DC carrier, guard tones, and used carriers.

The N_{used} used carriers are further partitioned into subchannels, Within each subchannel, there are constant-location and variable-location pilots.

To allocate the subchannels, the remaining carriers are partitioned into groups of contiguous carriers. Each subchannel consists of one carrier from each of these groups. The number of groups, N_{groups} , is equal to the number of carriers per subchannel, which is 53. The number of the carriers in a group is equal to the number of subchannels, $N_{subchannels}$. The partitioning is done according to the formula given in clause 8.3.5.3.4.1.1, with parameters as given in Table 219.

A subchannel is made up of 48 data carriers, 1 constant-location pilot and 4 variable-location pilot carriers. The partitioning of each UL subchannel is shown in Figure 230.

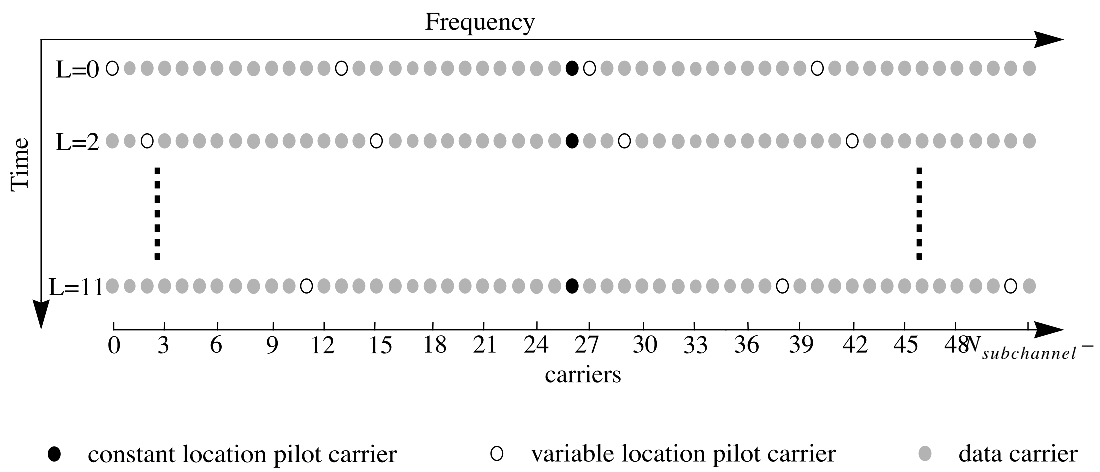

Figure 230 Pilot and data carrier Allocation of UL Sub-channel

The constant-location pilot is always at index 26.

The variable-location pilots change with each symbol, repeating every 13 symbols, indexed by index L=0 to L=12. The first symbol (L=0) is produced after the all-pilot symbols (preamble), which consist of permuted carriers modulated according to 8.3.5.3.2.2.2. For L=0 the variable location pilots are positioned at indices: 0,13, 27,40 for other L these location vary by addition of L to those position, for example for L=5 variable pilots location are: 5,18, 32, 45.

L is not incremented with each symbol, but follows the sequence: 0,2,4,6,8,10,12,1,3,5,7,9,11.

The remaining 48 carriers are data carriers. Thus, due to the motion of the variable-location pilots, the locations of these data carriers also change in accordance with L for each symbol.

The last method for defining the Sub-Channels involves programming by MAC message the carrier numbers for each Sub-Channel.:

Table 219 Uplink Symbol Parameters

N_{FFT}	Parameter	Value	
2048 (2K)	N_{used}	1696	
	Guard Carriers: Left, Right	176	175
	Subchannels, data carriers/subchannel	32	48
	$\{PermutationBase_0\}$	{3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30}	
4096 (4K)	N_{used}	3392	
	Guard Carriers: Left, Right	352	353
	Subchannels, data carriers/subchannel	64	48
	$\{PermutationBase_0\}$	{TBD}	

8.3.5.3.4.1.3 Permutation Example

This clause is informative only.

For clarity, an example for using the permutation procedure with the UL 2048 mode is given. The relevant parameters characterizing the UL 2048 mode are as follow:

- Number of Sub-Channels: $N_{subchannels} = 32$
- Number of carriers in each subchannel: $N_{groups} = 53$
- Number of data carriers in each subchannel = 48.
- $\{PermutationBase_0\}$ = {3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30}

Using the formula in clause 8.3.5.3.4.1.1,

1 The basic series of 32 numbers is {3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30}

2 In order to get 32 different permutation the series is rotated to the left (from no rotation at all up to 31 rotations). Choosing *s*=1 for this example, ($permutationbase_{s=1}$) is: {18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30, 3}

3 We repeat the permutated series 2 times and take the first 53 numbers only: {18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30, 3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30, 3}.

4 The concatenation depends on the ID_{cell} (which characterizes the working cell and can range from 0 to 15). For example when using permutation s=1 with $ID_{cell} = 2$, the last term in the equation becomes

$$\{p_s[k_{mod(32)}] + 2 \cdot ceil[(k+1)/32]\}_{mod(32)} \qquad \text{with } k = 0, 1, \ldots, 52$$

= {20, 4, 10, 18, 12, 13, 17, 28, 24, 8, 11, 29, 22, 27, 3, 31, 9, 23, 7, 30, 1, 25, 19, 6, 26, 2, 15, 14, 21, 16, 0, 7, 22, 6, 12, 20, 14, 15, 19, 30, 26, 10, 13, 31, 24, 29, 5, 1, 11, 25, 9, 0, 3}

5 Finally adding in the first term, the set of carriers is found: *carrier(n,1)* = {20, 36, 74, 114, 140, 173, 209, 252, 280, 296, 331, 381, 406, 443, 451, 511, 521, 567, 583, 638, 641, 697, 723, 742, 794, 802, 847, 878, 917, 944, 960, 999, 1046, 1062, 1100, 1140, 1166, 1199, 1235, 1278, 1306, 1322, 1357, 1407, 1432, 1469, 1477, 1505, 1547, 1593, 1609, 1632, 1667}.

8.3.5.3.4.2 Modulation and Coding

8.3.5.3.4.2.1 Uplink Scrambling (Randomization) Initialization

The scrambler (see clause 8.3.5.3.2.1.1) is initialized with the following vector

Figure 231 OFDMA Randomizer Initialization Vector

8.3.5.3.4.2.2 FEC

8.3.5.3.4.2.2.1 Concatenated Reed Solomon and Convolutional Coding

The encoding is performed by first passing the data in blocks through an RS encoder and then a tail biting convolutional encoder. Six schemes are defined, as shown in Table 220. All are mandatory except those involving 64QAM modulation, which are optional..

Table 220 Modulation/Coding Schemes Using Reed-Solomon FEC

Modulation	Uncoded Block Size (Bytes)	Overall Coding Rate	Coded Block Size (Bytes)	RS Code	CC Code Rate
QPSK	18	1/2	36	(24,18,3)	2/3
QPSK	26	~3/4	36	(30,26,2)	5/6
16 QAM	36	1/2	72	(48,36,6)	2/3
16 QAM	54	3/4	72	(60,54,3)	5/6
64 QAM	72	2/3	108	(81,72,4)	3/4
64 QAM	82	~3/4	108	(90,82,4)	5/6

8.3.5.3.4.2.2.2 Turbo Product Codes (Optional)

Table 221 gives the block sizes, code rates, channel efficiency, and code parameters the optional modulation-schemes.

Table 221 Modulation/Coding Schemes Using Turbo Product Codes

Modulation	Data Block Size (Bytes)	Coded Block Size (Bytes)	Overall Coding Rate	Efficiency bit/s/Hz	Constituent Codes	Code Parameters
QPSK	16	36	~1/2	0.9	(32,26)(16,11)	I_x=11,I_y=17,B=6
QPSK	25	36	~2/3	1.4	(8,7)(64,57)	I_x=2,I_y=17
16 QAM	40	72	~3/5	2.2	(32,26)(32,26)	,I_x=8,I_y=8
16 QAM	56	72	~4/5	3.1	(16,15)(64,57)	I_x=4,I_y=16
64 QAM	68	108	~5/8	3.8	(32,26)(32,26)	I_x=0,I_y=5,B=0
64 QAM	88	108	~4/5	4.9	(32,31)(16,15)	I_x=0,I_y=10

8.3.5.3.4.2.3 Interleaving

Table 222 shows the bit interleaver sizes as a function of modulation and coding.

Table 222 Bit Interleaved Block Sizes

Modulation	Coded Bits per Bit Interleaved Block
QPSK	288
16 QAM	576
64 QAM	864

8.3.5.3.4.3 Control Mechanisms

8.3.5.3.4.3.1 Ranging

The MAC shall reserve several Sub-Channels as a Ranging Channel. Users are allowed to collide on this Ranging Channel. To effect a ranging transmission, each user randomly chooses one code from a bank of specified binary codes. These codes are then BPSK modulated onto the carriers in the Ranging Channel, one bit per carrier

The binary codes are the pseudonoise (PN) codes produced by the PRBS described in Figure 232, which implements the polynomial generator $1 + X^1 + X^4 + X^7 + X^{15}$.

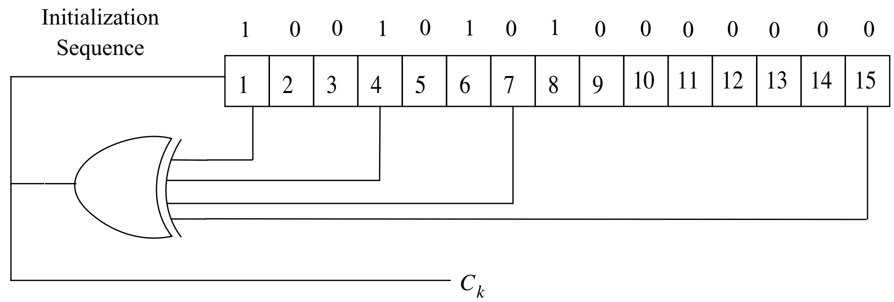

Figure 232 PRBS for Ranging Code Generation

Clocking the PRBS (where each clock produces one bit) subsequently produces the Ranging codes. The length of the ranging codes are multiples of 53 bits long. The default for the 2k mode is 2 Sub-Channels allocated as the Ranging Channel; in this casethe ranging code length is 106.

The first 16 codes produced are for First Ranging; it shall be used by a new user entering the system.

- The next 16 codes produced are used for maintenance Ranging for users that are already entered the system.
- The last 16 codes produced are for users, already connected to the system, issuing bandwidth requests.

These 48 codes are denoted as Ranging Codes and are numbered 0..47.

The number of active long ranging codes should be specified dynamically by the base station, and the default number should be set to two.

The Base Station can separate colliding codes and extract timing (ranging) information and power. In the process of user code detection, the Base Station gets the Channel Impulse Response (CIR) of the code, thus acquiring for the Base Station vast information about the user channel and condition. The time (ranging) and power measurements allow the system to compensate for the near/far user problems and the propagation delay caused by large cells.

8.3.5.3.4.3.1.1 Long Ranging transmission

The Long Ranging transmission shall be used by any SS that wants to synchronize to the system channel for the first time. A Long Ranging transmission shall be performed during the two first consecutive symbols of the UL frame. The same ranging code is transmitted during each symbol.

The preamble structure is defined by modulating one Ranging Code on the Ranging Channel. There shall not be any phase discontinuity on the Ranging Sub-Channel carriers during the period of the Long Ranging transmission.

8.3.5.3.4.3.1.2 Short Ranging transmission

The Short Ranging transmission shall be used only by a SS that has already synchronized to the system. The Short Ranging transmission shall be used for system maintenance ranging or for fast bandwidth allocation requests.

To perform a Short Ranging transmission, the SS shall modulate one Ranging Code on the Ranging Sub-Channel for a period of one OFDM symbol. This may occur on any OFDM symbol out of the six available ranging symbols. Bandwidth requests may incorporate a piggy-back mechanism provided by the MAC.

8.3.5.3.4.3.1.3 Ranging Pilot Modulation

The BPSK modulation, real and imaginary parts, is defined by the formula:

$$\Re\{Carrier_k\} = (1/2 - C_k)/6$$
$$\Im\{Carrier_k\} = 0 \qquad (24)$$

where Carrier_k is the k^{th} carrier of the Ranging Channel, and C_k depicts the k^{th} bit of the code generated according to clause 8.3.5.3.4.3.1.1

8.3.5.3.4.3.2 Power Control

8.3.5.3.4.4 Frame structure

8.3.5.3.4.4.1 Downlink

Each encoded frame of downlink information is transmitted on one subchannel over a period of three consecutive symbols. A downstream frame consists of N symbols, where the first symbol contains the carrier group, PHY control and uplink map. The remaining N-1 symbols containing data are orgainized as an integer number of groups of three symbols.

The transmission of the DL is performed on the subchannels of the OFDMA symbol, the amount of subchannels needed for the different transmissions (modulation and coding) and their mapping is defined in the PHY control. The mapping of the subchannels is performed in a two-dimensional grid, involving the subchannels in the frequency domain and OFDM symbols in the time domain.

8.3.5.3.4.4.2 Uplink

The basic allocation for a user UL transmission is made up of subchannels, a basic user allocation is made up of one Sub-Channel over duration of 4 OFDMA symbols. The first is a preamble and remaining are used for data transmission, adding more data symbols or subchannels increases the amount of data sent by the user, this allocation is presented in Figure 233:

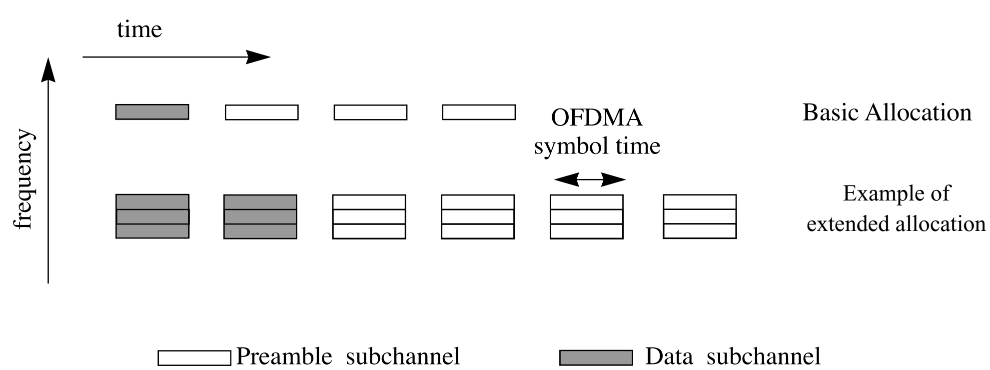

Figure 233 UL bandwidth Allocation

The framing structure used for the UL includes the transmission of a possible symbol for Jamming monitoring, an allocation for Ranging and an allocation for data transmission. The MAC sets the length of the UL framing, and the UL mapping.

The framing for these modes involve the allocation of ranging Sub-Channels within the OFDMA symbols, while the rest of the Sub-channels are used for users transmission, the UL mapping is illustrated in Figure 158. An optional Null symbol may be inserted to facilitate Jamming monitoring.

An example uplink burst showing two different subscribers with different PHY Burst structures and profiles is shown in Figure 234

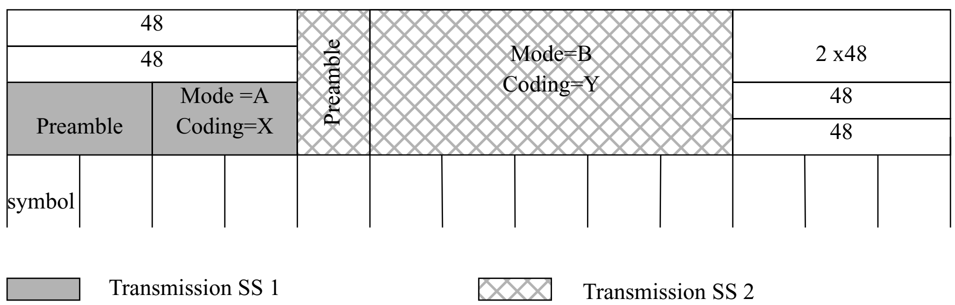

Figure 234 UL Burst definition Example #1

8.3.5.3.4.5 Alamouti STC preamble (optional)

Pilot tones are shared between the two antennas in time.

Again, synchronization, including phase noise estimation, is performed in the same way as with one Tx antenna. The estimation of the two channels is unchanged, but interpolation is more used (in the time domain).