Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**BPSK Modulation for IEEE 802.16 WirelessMAN^{TM} OFDM**
Date Submitted	**2003-12-29**
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Re:	Supporting document for Letter Ballot #13
Abstract	In P802.16 REVd/D2 [1], both Single-Carrier and OFDMA PHY modes use BPSK as a robust type of modulation recommended for data and/or control channels. In particular, comments 206 and 429 from Working Group Letter Ballot #13 are referring to application of BPSK in SCa-PHY. Currently OFDM-PHY only supports robust modes of operations such as AAS and STC only on data channels and not on the control channels. To achieve true link budget enhancement expected from these optional modes of operation, it is proposed to make BPSK modulation mandatory on the FCH portion of the channel and optional on the data portion. This contribution includes simulation results that show over 3 dB gain for BPSK modulation over its equivalent QPSK modulation mode. As best we could, all the requisite changes were made in the standard.
Purpose	Adoption
Notice	
Release	
Patent Policy and Procedures	

BPSK Modulation for IEEE 802.16 WirelessMAN OFDM

1 Introduction

The 802.16 combined specification 802.16REVd/D2 [1], defines the coding modes of operation in Table 187 where the most robust coding mode is QPSK rate 1/2. For reasons of robustness and link budget enhancement, including BPSK modulation is desirable. The intent of this contribution is to propose to make BPSK modulation mandatory on the FCH portion and optional on the data portion. Addition of BPSK provides range extension by allowing AAS and STC stations opportunity to see FCH part of transmission.

The rest of the document is organized as follows. In Section 2, the new coding modes are described and performance data is presented. Section 3 describes the requisite changes in the standard required to support BPSK modulation. Finally, Sections 4 and 5 include conclusion and references.

2 Description of Coding Modes

We propose adoption of two new coding modes:

- BPSK, rate 1/2 Unpunctured Convolutional Code (CC), no RS
- BPSK, rate 3/4 Punctured CC, no RS

These two coding modes are similar to the QPSK coding modes in the 802.16REVd/D2 standard, except that the RS code is turned off. The following set of simulations show the increase in performance of BPSK modulation over QPSK modulation for several channel scenarios at several SNRs. The following setup is used:

- 3.5 MHz BW
- Oversampling ratio 8/7
- Guard Interval (GI)=1/16

Figure 1 and Figure 2 show the performance of the new BPSK mode versus the QPSK rate 1/2 in AWGN.

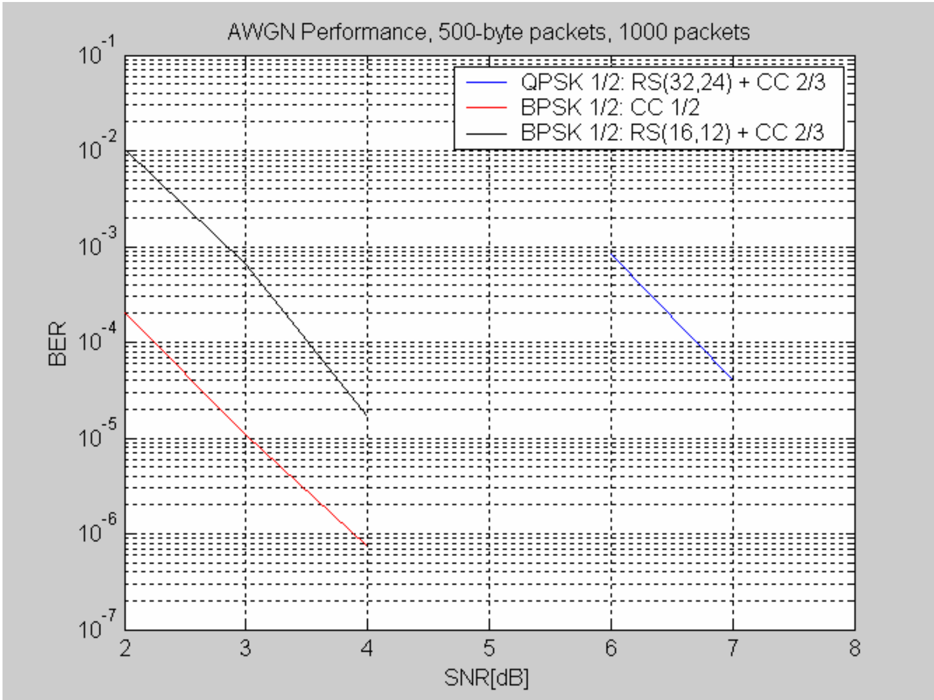


Figure 1. Performance of Suggested 802.16 OFDM BPSK and QPSK in AWGN: Bit Error Rate

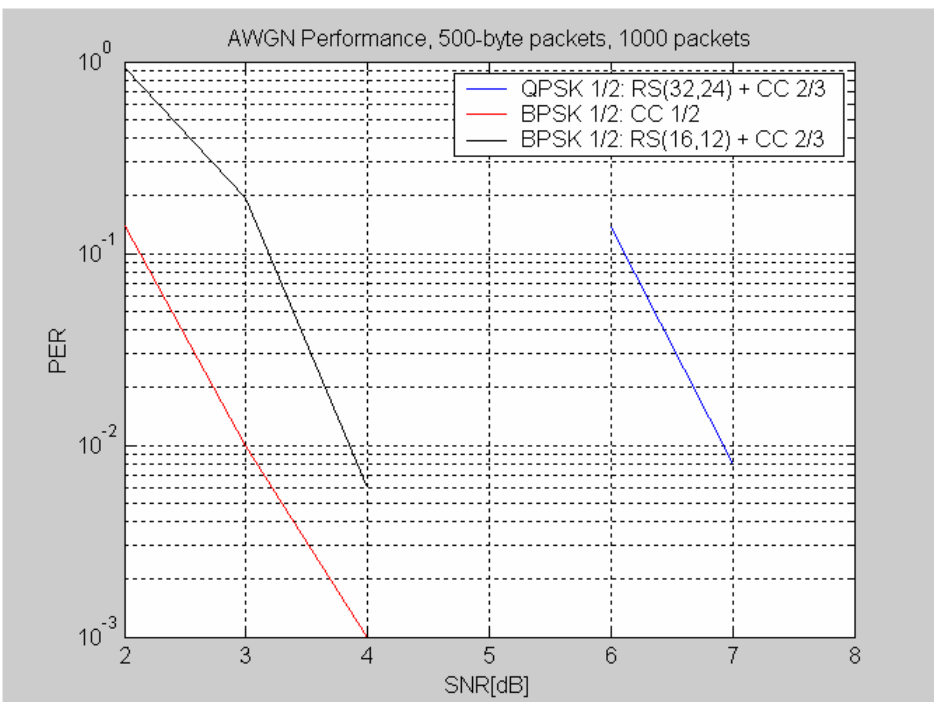


Figure 2. Performance of Suggested 802.16 OFDM BPSK and QPSK in AWGN: Packet Error rate

Figure 1 and Figure 2 show that BPSK modulation can increase performance by at least 3 dB. Simulation results show an additional enhancement when the RS encoder is turned off. In LOS conditions, this can lead up to two times the coverage. In other realistic channel scenarios, the coverage increase is less.

3 Inclusion of BPSK modulation into 802.16REVd

In order to include BPSK modulation in a consistent manner, there are many modifications that are required to be made in IEEE P802.16-REVd/D2-2003 [1]. By reading through the standard, we determined several instances of required changes.

Change 1:

In Section 4, page 13 add "*BPSK* *Binary Phase Shift Keying*" after line 14.

Change 2:

In Table 187 pre-pend the following 2 rows:

BPSK	12	24	1/2	(12,12,0)	1/2
BPSK	18	24	3/4	(18,18,0)	3/4

And add *"In the case of BPSK modulation, RS encoder should be bypassed.*"

Change 3:

In Section 8.3.3.3, make the following modification starting at line 45, page 409:

"Let N_{cpc} be the number of coded bits per subcarrier, i.e., 1, 2, 4 or 6 for BPSK, QPSK, 16-QAM or 64-QAM, respectively. Let s = ceil(N_{cpc}/2)."

Change 4:

In Table 194, pre-pend the following row:

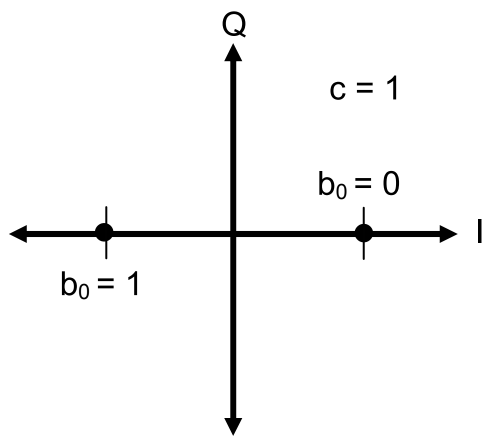
BPSK	192	96	48	24	12

Change 5:

In 8.3.3.4.1 make the following modification starting at line 42, page 410:
"After bit interleaving, the data bits are entered serially to the constellation mapper. BPSK, Gray-mapped QPSK and 16-QAM as shown in Figure 197 shall be supported, whereas the support of 64-QAM is optional. The constellations as shown in Figure 197 shall be normalized by multiplying the constellation point with the indicated factor c to achieve equal average power."

Change 6:

On page 411, Figure 197, add BPSK as follows to the set of constellation options:



Also change the caption on Figure 197 accordingly and as follows:

"BPSK, QPSK, 16-QAM and 64-QAM constellations"

Change 7:

Replace Table 195 with the following table to include BPSK modulation:

Rate ID	Modulation RS-CC Rate
0	BPSK 1/2
1	BPSK 3/4
2	QPSK 1/2
3	QPSK 3/4
4	16-QAM 1/2
5	16-QAM 3/4
6	64-QAM 2/3
7	64-QAM 3/4
8-15	Reserved

Alternatively, one can add the BPSK 1/2 and 3/4 as Rate IDs 6 and 7 instead to minimize changes in any existing implementation.

Change 8:

Section 8.3.4.1, page 417, starting line 51, make the following modifications:

"A downlink PHY PDU starts with a long preamble, which is used for PHY synchronization. The preamble is followed by a FCH burst. The FCH burst is one OFDM symbol long and is transmitted using BPSK~~QPSK~~ rate 1/2 with the mandatory coding scheme. The FCH contains DL_Frame_Prefix to specify the burst profile and length of the downlink burst #1. The Rate_ID encoding is defined in Table 195. A DL-MAP message shall immediately follow the DL_Frame_Prefix. An UL-MAP message shall immediately follow the DL-MAP message. Note that in the case of the remainder of the FCH being smaller than the size of the two messages

combined they will ‘spill’ over into downlink Burst #1. UCD and DCD messages may be transmitted following the DL-MAP and UL-MAP messages. Although the downlink burst #1 contains broadcast MAC control messages, it is not necessary to use the most robust well-know modulation/coding. A more efficient modulation/coding may be used if it is supported and applicable to all the SSs of a BS. With exception of the maps, no MAC PDUs shall be split over multiple consecutive bursts with different burst profiles.”

Change 9:

Section 8.3.4.2, page 421, line 19, make the following modifications:
“All transmissions in the control subframe are sent using BPSK ~~QPSK~~ 1/2 with the mandatory coding scheme. The data subframe is divided into minislots, which are, with possible exception of the last minislot in the frame, of size ceiling [(OFDM symbols per frame-Mesh-Ctrl-Length)/256]. A scheduled allocation consists of one or more minislots.”

Change 10:

Section 8.3.6.2, page 432, starting from line 61, replace
"Initial ranging transmissions shall consist of a long preamble and one OFDM symbol using the most robust mandatory burst profile"

with

"Initial ranging transmissions shall consist of a long preamble and a number of OFDM symbols using the most robust mandatory burst profile".

Change 11:

Section 8.3.6.4, page 436, line 39, make the following modifications:
“The current transmitted power is the power of the burst which carries the message. The maximum available power is reported for BPSK, QPSK QAM16 and QAM64 constellations. The current transmitted power and the maximum power parameters are reported in dBm. The parameters are quantized in 0.5dBm steps ranging from -64dBm (encoded 0x00) to 63.5dBm (encoded 0xFF). Values outside this range shall be assigned the closest extreme. SSs that do not support QAM64 shall report the value of 0x00 in the maximum QAM64 power field.”

Change 12:

Section 8.3.9.1.2, page 439, line 31, pre-pend the following two rows to Table 220:

BPSK- 1/2	-13
BPSK- 3/4	-15.5

Change 13:

Section 8.3.10.1, page 443, line 31, pre-pend the following two rows to Table 222:

BPSK	1/2	6.4
	3/4	8.2

Also insert *“SBPSK=[0xE4,0xB1]”* on line 59.

Also, replace lines 7-9 with:

“Short length test message payload (288 data bytes): (144, SBPSK),(72,SQPSK), (36,S16QAM), (6,S64QAM)

Mid length test message payload (864 data bytes): (512, SBPSK) ,(216,SQPSK), (108,S16QAM), (18,S64QAM)

Long length test message payload (1536 data bytes): <u>(768, SBPSK)</u> , (384,SQPSK), (192,S16QAM), (32,S64QAM)"

Change 14:

Section 11.1.1.2, page 592, Table 271, replace *"value/variable length"* entry of the table corresponding to the row *"FEC code type"* with the following:

0= BPSK (RS) 1/2
1= BPSK (RS) 3/4
2 = QPSK (RS+CC) 1/2
3= QPSK (RS+CC) 3/4
4= 16-QAM (RS+CC) 1/2
5= 16-QAM (RS+CC) 3/4
6= 64-QAM (RS+CC) 2/3
7= 64-QAM (RS+CC) 3/4
8= QPSK (BTC) 1/2
9= QPSK (BTC) 3/4 or 2/3
10= 16-QAM (BTC) 3/5
11= 16-QAM (BTC) 4/5
12 = 64-QAM (BTC) 2/3 or 5/8
13 = 64-QAM (BTC) 5/6 or 4/5
14 = QPSK (CTC) 1/2
15 = QPSK (CTC) 2/3
16 = QPSK (CTC) 3/4
17 = 16-QAM (CTC) 1/2
18 = 16-QAM (CTC) 3/4
19 = 64-QAM (CTC) 2/3
20 = 64-QAM (CTC) 3/4
21–255 Reserved

Note: Alternatively, one can add the BPSK 1/2 and 3/4 as FEC code types 19 and 20 instead to minimize changes in any existing implementation.

Change 15:

Section 11.1.2.2, page 592, Table 276, replace *"value/variable length"* entry of the table corresponding to the row *"FEC code type"* with the following:

0= BPSK (RS) 1/2
1= BPSK (RS) 3/4
2= QPSK (RS+CC) 1/2
3= QPSK (RS+CC) 3/4
4= 16-QAM (RS+CC) 1/2
5= 16-QAM (RS+CC) 3/4
6= 64-QAM (RS+CC) 2/3
7= 64-QAM (RS+CC) 3/4
8= QPSK (BTC) 1/2
9= QPSK (BTC) 3/4 or 2/3
10= 16-QAM (BTC) 3/5
11= 16-QAM (BTC) 4/5

12 = 64-QAM (BTC) 2/3 or 5/8
13 = 64-QAM (BTC) 5/6 or 4/5
14 = QPSK (CTC) 1/2
15 = QPSK (CTC) 2/3
16 = QPSK (CTC) 3/4
17 = 16-QAM (CTC) 1/2
18 = 16-QAM (CTC) 3/4
19 = 64-QAM (CTC) 2/3
20 = 64-QAM (CTC) 3/4
21–255 Reserved

Note: Alternatively, can add the BPSK 1/2 and 3/4 as FEC code types 19 and 20 instead to minimize changes in any existing implementation.

Change 16:

Section 11.4.2.2.12, page 623, line 40, replace the first sentence with
"The maximum available power for BPSK, QPSK, QAM16 and QAM64 constellations."

Also, replace the table in the section with the following:

Type	Length	Value	**Scope**
5.12.31	4	Byte 0: Transmit power backoff for BPSK Byte 1: Transmit power backoff for QPSK Byte 2: Transmit power backoff for QAM16 Byte 3: Transmit power backoff for QAM64. SSs that do not support QAM64 shall report the value 0x00.	Sca, OFDM, OFDMA: SBC-REQ

Note: Alternatively, can specify the BPSK transmit power backoff for BPSK in Byte 3 instead to minimize changes in any existing implementation.

Change 17:

Section 12.3.2, page 699, Table 303, replace the row corresponding to *"Tx relative constellation error"* with the following:

Tx relative constellation error: BPSK-1/2 BPSK-3/4 QPSK-1/2 QPSK-3/4 16QAM-1/2 16QAM-3/4 64QAM-2/3 (if 64-QAM supported) 64QAM-3/4 (if 64-QAM supported)	 ≤ -13.0 dB ≤ -15.5 dB ≤ -16.0 dB ≤ -18.5 dB ≤ -21.5 dB ≤ -25.0 dB ≤ -28.5 dB ≤ -31.0 dB

Change 18:

Section 12.3.2.1, page 700, Table 304, replace the row corresponding to *"BER performance threshold, BER=10^{-6}"* with the following:

BER performance threshold, BER=10^{-6}: BPSK-1/2 BPSK-3/4 QPSK-1/2 QPSK-3/4 16QAM-1/2 16QAM-3/4 64QAM-2/3 (if 64-QAM supported) 64QAM-3/4 (if 64-QAM supported) Threshold change if subchannelization used	 ≤ -94 dBm ≤ -92 dBm ≤ -91 dBm ≤ -89 dBm ≤ -83 dBm ≤ -82 dBm ≤ -77 dBm ≤ -75 dBm $10 \cdot \log(N_{subchannels}/16)$

Change 19:

Section 12.3.2.2, page 701, Table 305, replace the row corresponding to *"BER performance threshold, BER=10^{-6}"* with the following:

BER performance threshold, BER=10^{-6}: BPSK-1/2 BPSK-3/4 QPSK-1/2 QPSK-3/4 16QAM-1/2 16QAM-3/4 64QAM-2/3 (if 64-QAM supported) 64QAM-3/4 (if 64-QAM supported) Threshold change if subchannelization used	 ≤ -90 dBm ≤ -88 dBm ≤ -87 dBm ≤ -85 dBm ≤ -80 dBm ≤ -78 dBm ≤ -74 dBm ≤ -72 dBm $10 \cdot \log(N_{subchannels}/16)$

Change 20:

Section 12.3.2.3, page 702, Table 306, replace the row corresponding to *"BER performance threshold, BER=10^{-6}"* with the following:

BER performance threshold, BER=10^{-6}: BPSK-1/2 BPSK-3/4 QPSK-1/2 QPSK-3/4 16QAM-1/2 16QAM-3/4 64QAM-2/3 (if 64-QAM supported) 64QAM-3/4 (if 64-QAM supported) Threshold change if subchannelization used	 ≤ -87 dBm ≤ -85 dBm ≤ -84 dBm ≤ -82 dBm ≤ -77 dBm ≤ -75 dBm ≤ -71 dBm ≤ -69 dBm $10 \cdot \log(N_{subchannels}/16)$

Change 21:

Section 12.3.2.4, page 703, Table 307, replace the row corresponding to *"BER performance threshold, BER=10^{-6}"* with the following:

BER performance threshold, BER=10^{-6}: BPSK-1/2 BPSK-3/4 QPSK-1/2 QPSK-3/4 16QAM-1/2 16QAM-3/4 64QAM-2/3 (if 64-QAM supported) 64QAM-3/4 (if 64-QAM supported) Threshold change if subchannelization used	 ≤ -91 dBm ≤ -89 dBm ≤ -88 dBm ≤ -86 dBm ≤ -81 dBm ≤ -79 dBm ≤ -75 dBm ≤ -73 dBm $10 \cdot \log(N_{subchannels}/16)$

Change 22:

Section 12.3.2.5, page 703, Table 308, replace the row corresponding to *"BER performance threshold, BER=10^{-6}"* with the following:

BER performance threshold, BER=10^{-6}: BPSK-1/2 BPSK-3/4 QPSK-1/2 QPSK-3/4 16QAM-1/2 16QAM-3/4 64QAM-2/3 (if 64-QAM supported) 64QAM-3/4 (if 64-QAM supported) Threshold change if subchannelization used	 ≤ -88 dBm ≤ -87 dBm ≤ -85 dBm ≤ -83 dBm ≤ -78 dBm ≤ -76 dBm ≤ -72 dBm ≤ -70 dBm $10 \cdot \log(N_{subchannels}/16)$

Change 23:

Section 12.3.2.6, page 704, Table 309, replace the row corresponding to *"BER performance threshold, BER=10^{-6}"* with the following:

BER performance threshold, BER=10^{-6}: BPSK-1/2 BPSK-3/4 QPSK-1/2 QPSK-3/4 16QAM-1/2 16QAM-3/4 64QAM-2/3 (if 64-QAM supported) 64QAM-3/4 (if 64-QAM supported) Threshold change if subchannelization used	 ≤ -86 dBm ≤ -84 dBm ≤ -83 dBm ≤ -81 dBm ≤ -76 dBm ≤ -74 dBm ≤ -69 dBm ≤ -68 dBm $10 \cdot \log(N_{subchannels}/16)$

4 Conclusion

Addition of BPSK provides range extension of at least 3 dB allowing AAS and STC stations the opportunity to see FCH part of transmission.

5 References

[1] IEEE P802.16-REVd/D2-2003 Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems