Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**The effect of filling Unique Words to guard interval for OFDM system**
Date Submitted	**2002-09-18**
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Abstract	This document contains analysis and proposal for filling Unique Words to guard interval for the OFDM system.
Purpose	This proposal provide analysis for filling Unique Words to guard interval for the OFDM system.
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The effect of Filling Unique Words to Guard Interval for OFDM System

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Introduction

In this contribution, a novel method of filling Unique Words to the formerly guard interval position in OFDM systems is proposed.

Background

In this contribution, we propose filling Unique Words (UW) to the formerly guard interval position in OFDM systems. Key characteristic of a Unique Word are that it has good periodic correlation properties , and its symbols have a constant amplitude. Ideally, the sequence is CAZAC (Constant Amplitude Zero Auto-Correlation) sequence. Recur to our proposed OFDM symbol structure, Unique Words could be used for channel , timing and carrier offset estimation for OFDM system. In some cases, the filled Unique Words sequence to the guard interval will generate an interference on the OFDM data field, In this contribution, the method of removing this type of interference is proposed, and the associated transmitter and receiver are also proposed. Using the method of filling UW to guard interval position, the need for pilots could be beardless or large reduced, which means the transmission efficiency could be increased more using our proposed method .

The proposed OFDM symbol structure

Figure 1 shows our proposed OFDM symbol structure. In our proposal, one or more UW is filled in front of each OFDM symbol, after UW is copy prefix, the length of UW field and CP field equal to the guard interval. Figure 1.1 and figure1.2 shows one or two more UW is filled in front of OFDM symbol , the rest of guard interval is filled using CP, we could use the auto and periodic auto correlation of UW to do channel , timing and carrier offset estimation; Figure1.2 shows one UW is filled total of guard interval, in this case, the UW length is more than maximum of channel impulse response, this assumption could help us to do channel estimation.

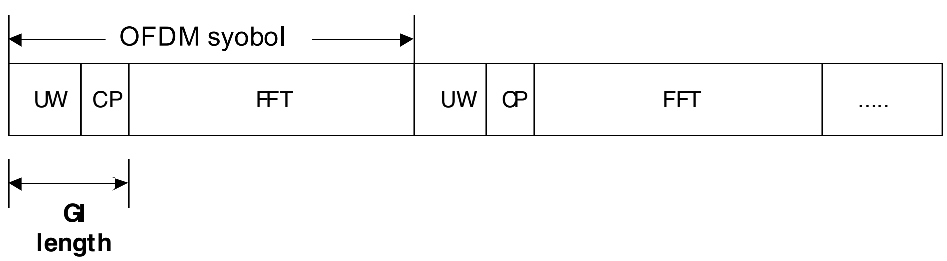

Figure 1.1 Proposed OFDM symbol structure –1

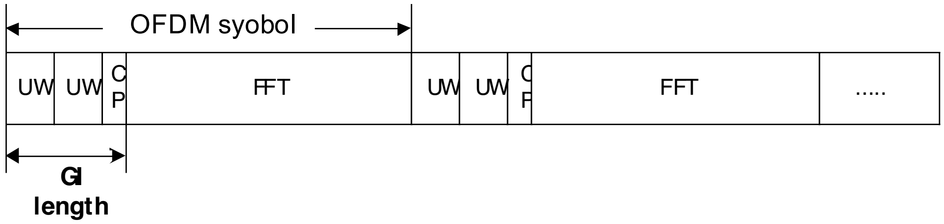

Figure 1.2 Proposed OFDM symbol structure –2

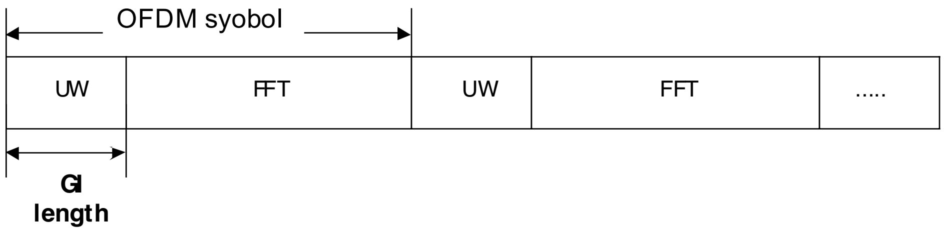

Figure 1.3 Proposed OFDM symbol structure –3

Assume that N is the subcarrier number of x(n), the length of UW $x_{TP}(n)$ field is $N_{p,}$ here $x_{TP}(n)$ field could contain one or more UW sequences. And the length of copy prefix field is N_g. Then the generated OFDM symbol signal is:

For Figure 1.1 and figure1.2, the generated OFDM symbol signal could be expressed as:

$$x_g(n) = \begin{cases} x_{TP}(n + N_p + N_g) & n = -N_p - N_g, -N_p - N_g + 1, \ldots, -N_g - \\ x(N+n) & n = -N_g, -N_g + 1, \ldots, -1 \\ x(n) & n = 0, 1, \ldots, N-1 \end{cases} \quad (1.1)$$

For Figure 1.3, the generated OFDM symbol signal could be expressed as:

$$x_g(n) = \begin{cases} x_{TP}(n + N_p) & n = -N_p, -N_p + 1, \ldots, -1 \\ x(n) & n = 0, 1, \ldots, N-1 \end{cases} \quad (1.2)$$

Definition of Unique Word

In section 8.3.1.3.2.2 of 80216a D5, for different UW length, the Unique Word is defined as Chu and Frank-Zadoff sequence, which does qualify as a CAZAC sequence. and the length of UW is power of 2. In our proposal, the definition of UW is the same as section 8.3.1.3.2.2 of 80216a D5.

Removing UW influence

The received signal $y_g(n)$ can be represented by

$$y_g(n) = x_g(n) \otimes h(n) + w(n) \qquad (2)$$

where h(n) is the impulse response of channel and w(n) is the additive white Guassian noise. The channel impulse response h(n) can be expressed as

$$h(n) = \sum_{i=0}^{K-1} h_l(t)\delta(\tau - \tau_i) \qquad (3)$$

where K the total number of propagation paths, $h_l(t)$the complex impulse response of the l-th path, and τ_l the l-th path delay time normalized by sampling time.

Assume that the length of guard interval τ is more than the maximum channel impulse response delay τ_K, that is $\tau ? \tau_K$. Assume perfect timing synchronization, then we could use the auto –correlation relationship of the UW and our proposed OFDM structure to do channel estimation and remove UW interference in the field of $[0, N_P + \tau - 1]$.

In the field $[0, N_P + \tau - 1]$, the received signal $\bar{Y}$ could be expressed as:

$$\bar{Y} = \bar{D} + \bar{I} + \{\bar{R}_1 + ,..., + \bar{R}_K\} + \bar{W} , \qquad (4)$$

where $\bar{I}$ is the ISI from the previous OFDM symbol, while $\tau ? \tau_K$, this ISI could be removed after remove copy prefix. $\bar{W}$ is the additive Guassian noise, $\bar{D}$ expresses the data signal and its delay part. $\bar{R}_1 ,\ldots,\bar{R}_K$ is the K copy of the UW due to the K paths influence.

Also assume we have estimated the channel parameters $\{\tilde{h}_l(t),\ l = 0,1,..., K\}$ and $\{\tilde{\tau}_l,\ l = 0,1,..., K\}$.

Then we could expressed $\bar{R}_1 ,\ldots,\bar{R}_K$ as:

$$\begin{cases} \bar{R}_1 = \{x_{TP}(0), x_{TP}(1),..., x_{TP}(N_P - 1), \overbrace{0,0,...,0}^{\tau}\} * \tilde{h}_1(t) \\ \cdots \\ \bar{R}_l = \{\overbrace{0,0,...0}^{\tau_l}, x_{TP}(0), x_{TP}(1),..., x_{TP}(N_P - 1), \overbrace{0,0,...0,}^{\tau-\tau_l}\} * \tilde{h}_K(t) \\ \cdots \\ \bar{R}_K = \{\overbrace{0,0,...0}^{\tau}, x_{TP}(0), x_{TP}(1),..., x_{TP}(N_P - 1)\} * \tilde{h}_K(t) \end{cases} \qquad (5)$$

Define R_{pr} as the expression (6):

$$R_{pr} = \bar{Y} - \{\bar{R}_1 + \cdots + \bar{R}_K\} , \qquad (6)$$

then we could remove the UW interference using expression (5) (6) .

Transceiver based on our proposed OFDM symbol structure

The figure 3 shows our proposed transmitter based on our proposed OFDM symbol structure. After FFT and P/S conversion, the copy prefix and UW sequence could be mixed , and filled on the original guard interval field as expressed above.

The figure 4 shows our proposed receiver based on our proposed OFDM symbol structure. We could use the expression _5__6_ to do channel estimation and remove the interference of the UW in the field of $[0, N_P + \tau - 1]$. The timing and carrier offset estimation could be based on the auto or periodic auto correlation relationship of the UW and the proposed OFDM structure.

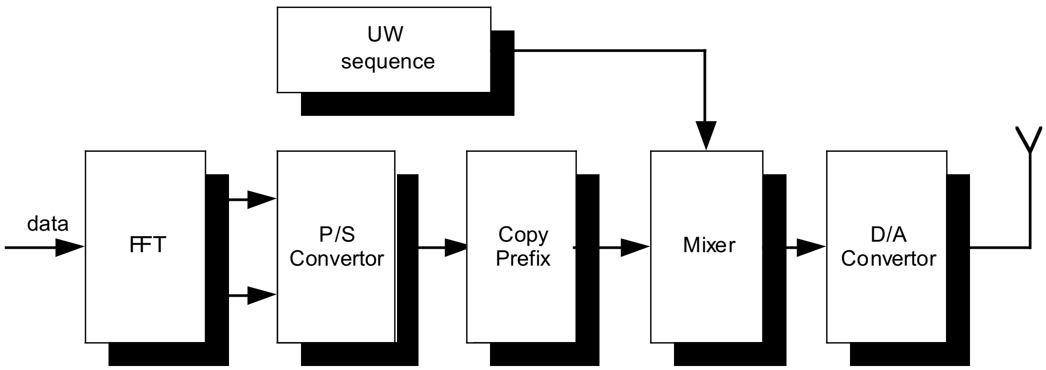

Figure 2 The transmitter based on our proposed OFDM symbol structure

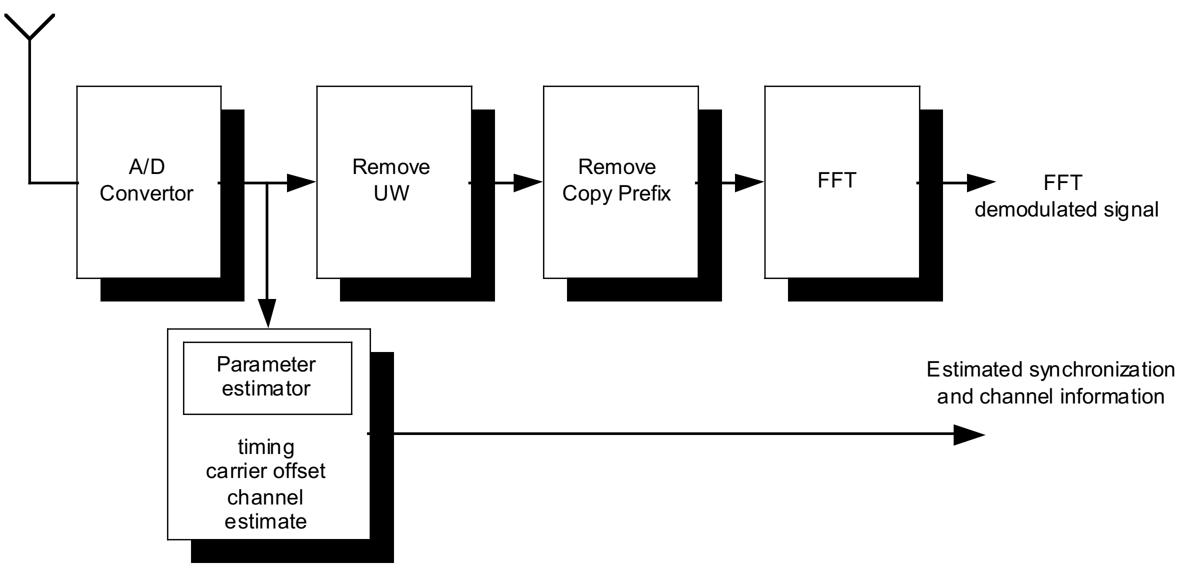

Figure 3 The receiver based on our proposed OFDM symbol structure

Simulation Results

In this section we shall consider the case of filling Unique Words to the guard interval under SUI channel model environments. As noted above, the filled Unique Words sequence to the guard interval will generate an interference on the OFDM data field , but because the sequence could be known in the receiver, so if we could estimated channel parameters, we could remove this type of interference , the associated algorithm expressions is (4)(5)(6). The simulations focus on the effect of removing the Unique Words 'interference under different UW length.
The conditions for the simulation are as following:

1. FFT size :256
2. Guard interval size:64
3. Bandwidth: 5MHz
4. Multipath channel: SUI 3, SUI4, SUI 5
5. Modulation : QPSK
6. Coding: CC with bit interleaver
7. Perfect synchronization is assumed
8. Perfect channel estimation is assumed
9. Inserted UW length (UW len)is: 16 , 32 , 64

From the simulation, we could see that while the UW length and the maximum channel impulse response delay normalized by sampling time is less than the guard interval size, for example, UW length is 16,32 in SUI 3 and SUI 4 model , then while after the remove copy prefix module, the inserted UW 's interference could be easily removed, so their BER performance under different Eb/N0 is the same as the associated ideal case(without inserted UW and only copy prefix).

While the UW length and the maximum channel impulse response delay normalized by sampling time is more than the guard interval size, the filling UW will be an interference on the data field , if only use remove copy prefix module, the interference could not be removed clearly. But because we could know the sequence in the receiver, so it is easily to remove this type of interference if we could get accurately channel information. For example, while UW length is 64 in SUI 3 ,4,5 , and UW length is 16,32,64 in SUI 5 model, they fit for this case, we could see while filling UW in the guard interval, that there will have 1-3dB Eb/No performance reduction compared with the associated ideal case. But the filled Unique Words could be used for channel , timing and carrier offset estimation for OFDM system. the need for pilots could be beardless or large reduced, which means the transmission efficiency could be increased more using our proposed method .

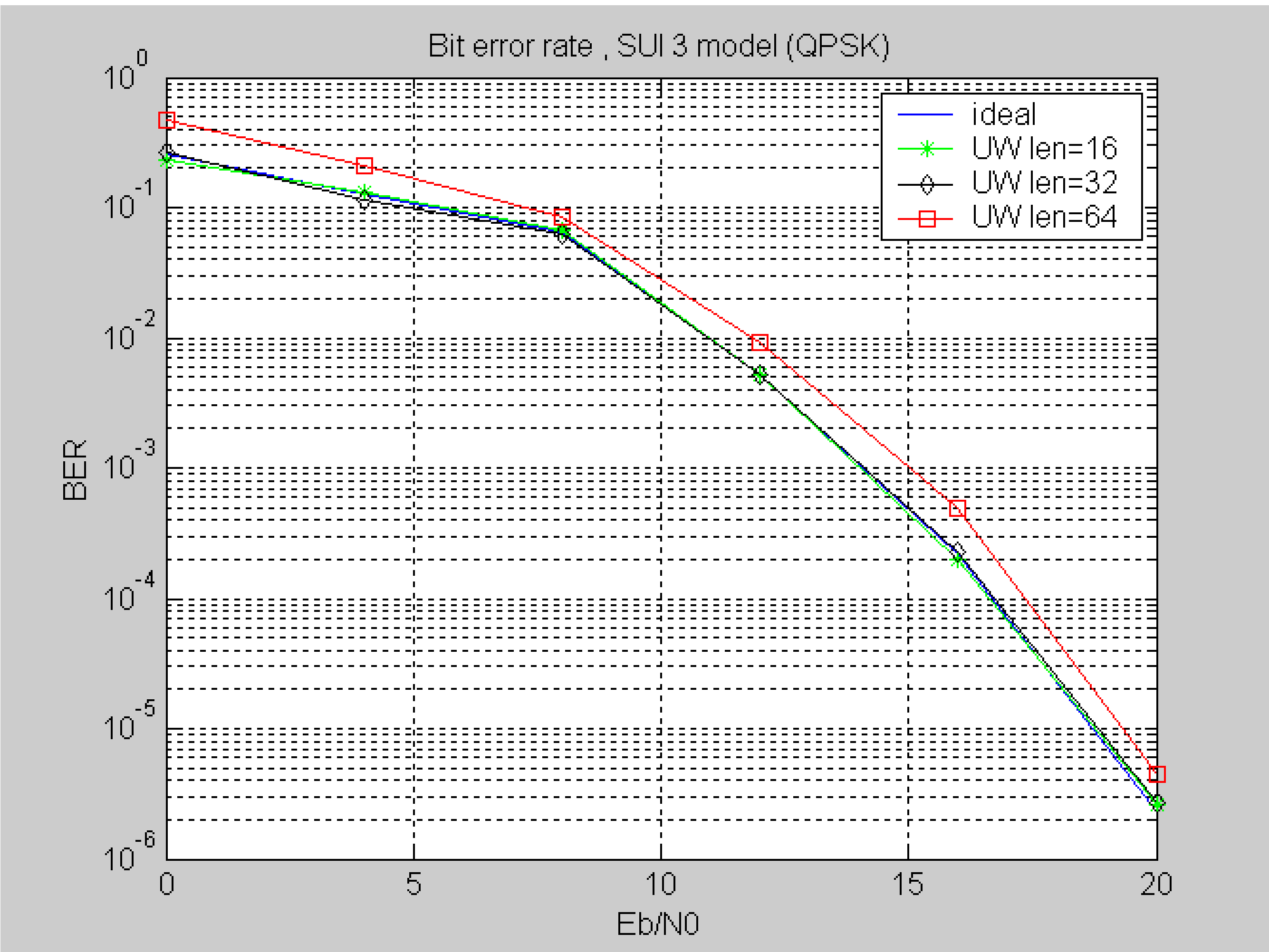

Figure 4. SUI 3 simulation results

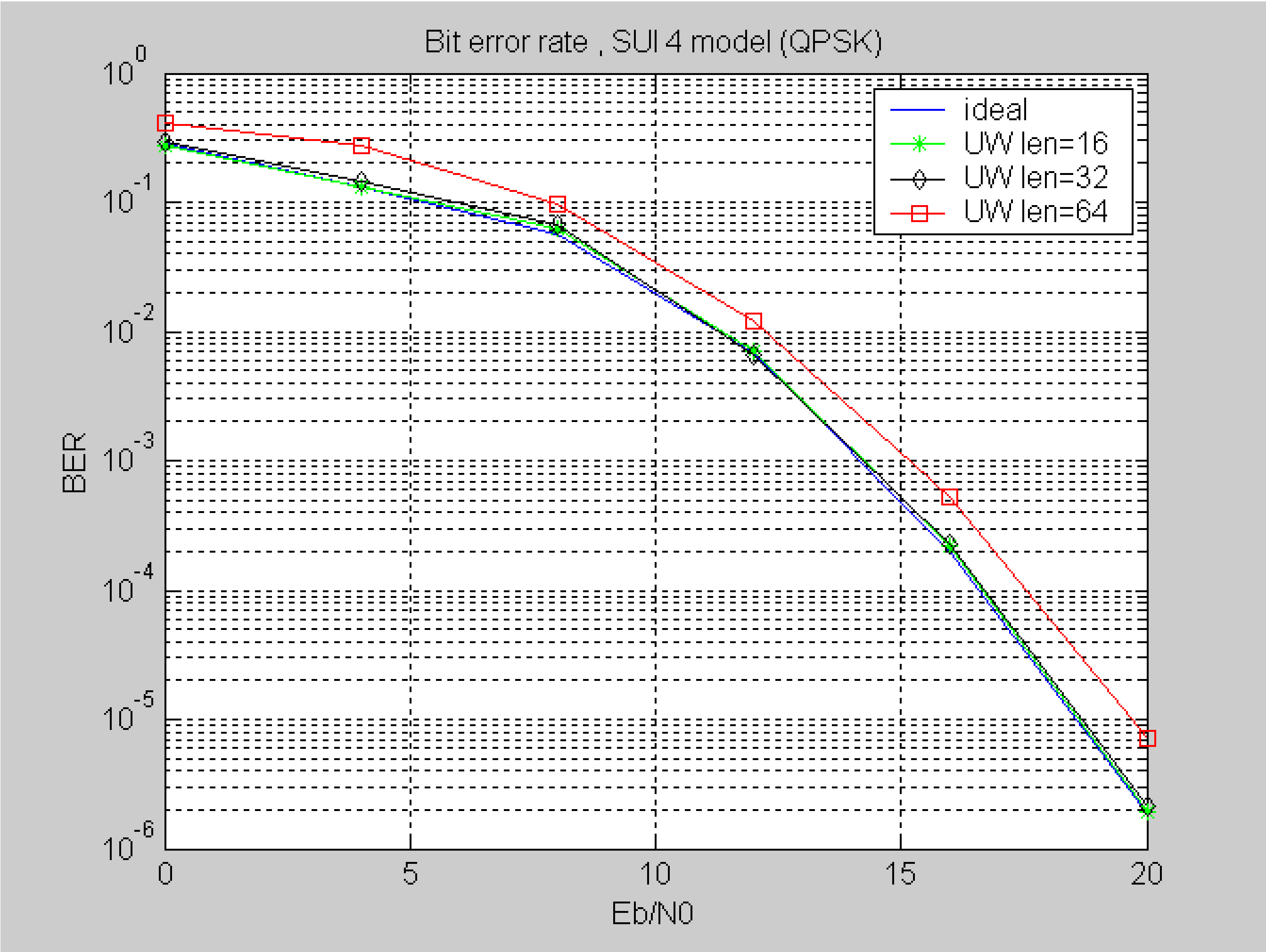

Figure 5 . SUI 4 simulation results

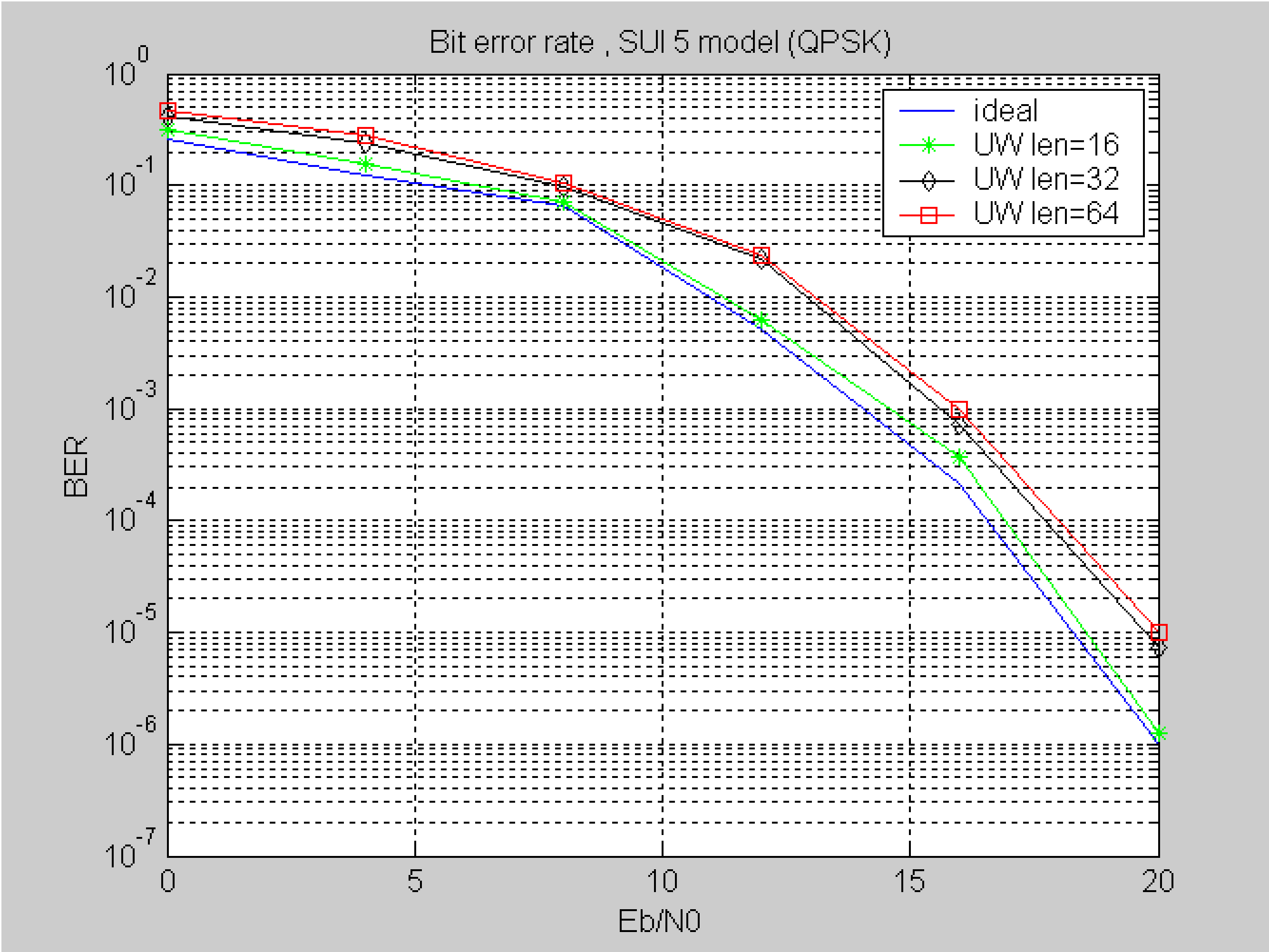

Figure 6 . SUI 5 simulation results

Conclusion

· Characteristics of filling Unique words for OFDM system

Filled one or more Unique Words sequence to the front of guard interval, the residual of guard interval use the guard interval to filled. In the transmit part, the filling procedure is after the copy prefix module; In the receive part, the removing UW sequence procedure should be before the removing CP. The filled UW sequence could be used for synchronization and channel parameter estimation.

· Advantage of filling Unique words for OFDM system

The filled Unique Words could benefit for channel , timing and carrier offset estimation for OFDM system, that is, the need for pilots could be beardless or large reduced, which means the transmission efficiency could be increased more using our proposed method .

· Comparison with conventional OFDM

The conventional OFDM systems use the copy prefix to fill the guard interval, the copy prefix could benefit for demodulation because we could use its cyclic convolution relationship even if there has some timing offset, which could benefit for reducing the ISI and ICI. But it is not easy to get the channel information , so it need inserting pilots to some of the subcarriers in the OFDM symbols. In our proposal, Unique Word sequence is filled to the guard interval, the filled Unique Words could be used synchronization and channel estimation. Although the filled UW have not the cyclic convolution relationship , but we could get more clearly timing information from the filled UW , which could also benefit for reducing ISI and ICI. The filled UW sequence will have some interference on the FFT field, but because we could know the sequence exactly in the receiver, so it is easily to largely remove the UW sequence effect if we could get the channel parameter information.

· ***The Proposal could be a standby OFDM system***

References

[1] Brian Eidson and Russell Mckown. " Proposed Revision to Section 8.3.5.12 " .802.163c-01_78.pdf