Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Enable the common SYNC symbol to convey preamble location information**
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Re:	IEEE P802.16e/D5 Sponsor Ballot
Abstract	Enable the common SYNC symbol to convey preamble location information
Purpose	Adoption of proposed changes into P802.16e
Notice	
Release	
Patent Policy and Procedures	

Enable the common SYNC symbol to convey preamble location information

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1 Introduction

In IEEE 802/16e/D5 section 8.4.6.1.1.1, an optional common SYNC symbol (common to all cells) was defined to help the SS to perform initial cell search and system acquisition. In particular, it was stated that "in every fourth downlink transmission frame, the last OFDM symbol is the common SYNC symbol". In an FDD system where downlink subframes immediately follow each other, the detection of the common SYNC symbol is sufficient to locate the cell-specific preamble of the next DL frame as the next symbol. However, in a TDD system, the distance between the common SYNC symbol and the cell-specific preamble not known to an SS at initial acquisition (since the SS cannot decode the DL subframe length being used until *after* initial acquisition). This contribution provides a simple method for improving the ability of a SS to locate the cell-specific preamble based on the detected common SYNC symbol during initial synchronization. In the proposed method, the BS transmits a cyclically shifted version of the common SYNC sequence, where the amount of cyclic shift corresponds to a separation value (in number of OFDM symbols) between the common SYNC symbol and the preamble. A simple receive algorithm can be used to detect the shift.

2 Detail of the Solution

Basically, the only change being proposed to the common SYNC symbol is that the existing binary sequence can be cyclically shifted before it is mapped onto the OFDMA subcarriers. Denote the BPSK common SYNC sequence as $\boldsymbol{s}$, whose length L is equal to the number of occupied subcarriers (i.e., L=53 for 128-FFT, L=213 for 512-FFT, and L=426 for 1024-FFT), and denote the cyclically shifted version of $\boldsymbol{s}$ as $C(\boldsymbol{s},d)$ where d is the shift (a positive integer for right shift and negative for left shift). The sequence $C(\boldsymbol{s},d)$ will be loaded on the same set of subcarriers where d is determined by the BS according to the separation between the common SYNC and preamble in the same DL subframe. The mapping between d and the separation value will be known to both the SS and BS, so that the SS will be able to determine preamble location after detecting d.

Note that the maximum number of unique cyclic shifts is the sequence length L, but the separation could be larger than L OFDMA symbols for the longest frame lengths. Therefore, each shift value d will actually correspond to a small *range* of separation values rather than an *exact* separation value. Moreover, the detected value d may be off by a small integer if the initial frequency offset of the SS is very large, so we should not use all of the possible the shift values, but instead choose d that are sufficiently spaced apart to handle the maximum expected frequency offset.

The receive processing is described next. Only initial synchronization is discussed here since after the shift is detected, the exact common SYNC symbol is known. The tracking and cell search can be processed as usual.

First, the SS will exploit the repetition structure of the common SYNC symbol to coarsely locate the SYNC using methods well known in the field. Any frequency offset that is within +/-1 subcarrier spacing can also be corrected, after which the frequency offset can only be 2*q* times of subcarrier spacing where q is an integer including zero. That integer part *q* is dependent on the accuracy of the MS oscillator (e.g., +/-10ppm @ 2.6GHz gives about +/-2.6 subcarrier offset for a subcarrier spacing of 10KHz). Then, starting from the coarse timing synchronization point, a block of *N* received time-domain data is transformed to the frequency domain through an N-point FFT. Denoting the frequency data at those occupied every other subcarriers as *Y*(*m*) where *m* (from 1 to *L*) corresponds to the subcarrier index 2*m* (For notation simplicity the subcarriers are assumed to be indexed in a way such as the *m*-th entry of the SYNC sequence is transmitted on subcarrier 2*m*), we have

$$Y(m) = c_d(m)H(2m) + noise, m = 1,\cdots,L \quad . \qquad (1)$$

where $c_{s,d}(m)$ is the *m*-th entry of the shifted sequence $C(\boldsymbol{s},d)$. With unknown frequency offset of 2*q* subcarrier spacing, the data *Y*(*m*) could actually correspond to $c_d(m-q)H(2m-2q)$.

The task is to detect the shift *d* from *Y*(*m*), which will be described here. Based on *Y*(*m*), a length-(*L*-1) vector of "differential-based" values is first computed based on the pairs of occupied subcarriers:

$$Z(m) = Y(m) * conj(Y(m+1)), m = 1,\cdots,L-1 \quad . \qquad (2)$$

where "conj()" denotes conjugation. Assuming the channel between two adjacent occupied subcarriers does not change drastically, which is often met as long as the spacing of occupied subcarriers (i.e., two subcarrier apart or about 20KHz in this case) is not too large, *Z*(*m*) can be further written as (ignoring noise)

$$Z(m) = H(2m) * conj(H(2m+2))[c(m)c(m+1)] \approx |H(2m)|^2 \, [c(m)c(m+1)] \quad . \qquad (3)$$

Denoting the differential vector of $\boldsymbol{s}$ as $\boldsymbol{s}_{\text{diff}}$

$$s_{diff} = [s_{diff}(1),\ldots,s_{diff}(L)] = [s_1s_2, s_2s_3, \ldots, s_{L-1}s_L, s_Ls_1]. \qquad (4)$$

we have $[c(m)c(m+1)]$ in (3) equal to the first L-1 entries of C($\boldsymbol{s}_{\text{diff}}$,d). Thus, we compute for each possible shift *k*

$$P(k) = \sum_{m=1}^{L-1} Z(m)C_{s\_diff,k}(m) \approx \sum_{m=1}^{L-1} |H(2m)|^2 c_{s\_diff,d}(m)c_{s\_diff,k}(m). \qquad (5)$$

When the correct shift value is tested, *P*(*k*=*d*) approximates the summation of channel powers at the occupied subcarriers. Otherwise, since $C(s_{diff},d)C(s_{diff},k \neq d)$ is not an all-one sequence, $P(k \neq d)$ will be small. Note that the prominence of the peak relative to the sidelobes depends on the cyclic auto-correlation of $\boldsymbol{s}_{\text{diff}}$. Note also that when there is a frequency offset of *2q* subcarriers the peak will show up at *d-q.*

3 Specific Text Changes

[*add the following at the end of section 8.4.6.1.1.1*]

The common SYNC sequence is cyclically shifted by *d* according to the table XXX before mapping onto the OFDMA subcarriers

Table XXX. Mapping between cyclic shift and the SYNC-preamble separation

Separation from common SYNC to preamble	Cyclic shift d
k ≤ 10	0
10 < k ≤ 15	4
15 < k ≤ 20	8
20 < k ≤ 25	12
25 < k ≤ 30	16
30 < k ≤ 35	20
35 < k	24

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4 Simulation Results

The 1024-, 512, 128-point FFT OFDM systems are simulated. In each case, the subcarrier spacing is the same at about 11.2 kHz. The simulated channel has 100 multipaths with an exponential power profile to give an RMS delay spread of 0.6 us. The three sequences currently defined in IEEE 802/16e/D5 section 8.4.6.1.1.1 are used for the three FFT sizes. Also, a low SNR of 0 dB per occupied subcarrier is simulated. Example results will be given for the case where the cyclic shift value is set to d=20.

In Figure 1 (1024-FFT case), the left plot shows the correlation $C(s_{diff},d)C(s_{diff},k)$ (i.e., cyclic autocorrelation of $\boldsymbol{s}_{\text{diff}}$ at all shifts) and the right plot shows the detection variable (normalized $P(k)$ for 50 runs). As we can see, even though the cyclic autocorrelation of $\boldsymbol{s}_{\text{diff}}$ has significant sidelobes, the detection of the shift is still robust, with no falsing even at 0dB SNR. Figure 2 and Figure 3 show the case for 512 and 128 FFT sizes.

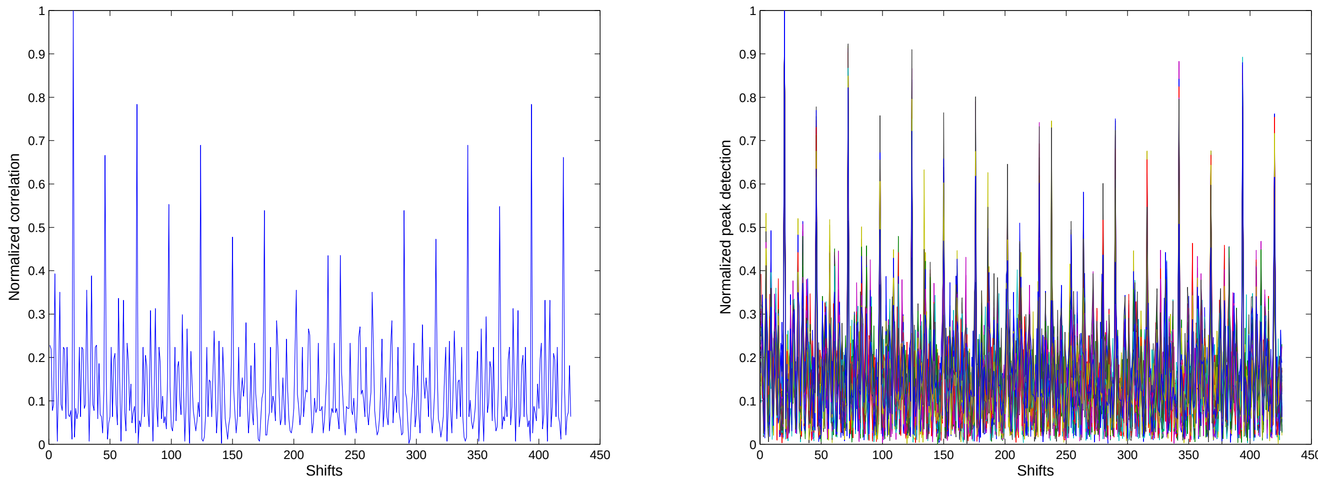

Figure 1. Left: Cyclic correlation between the differential of the shifted SYNC sequence (by d = 20) and the differential of the SYNC at all shifts; Right: Performance for detecting the peak that corresponds to the shift *d*=20 (SNR = 0 dB per occupied subcarrier, subcarrier spacing 11.2 kHz, 0.6 us rms delay spread, 1024 FFT)

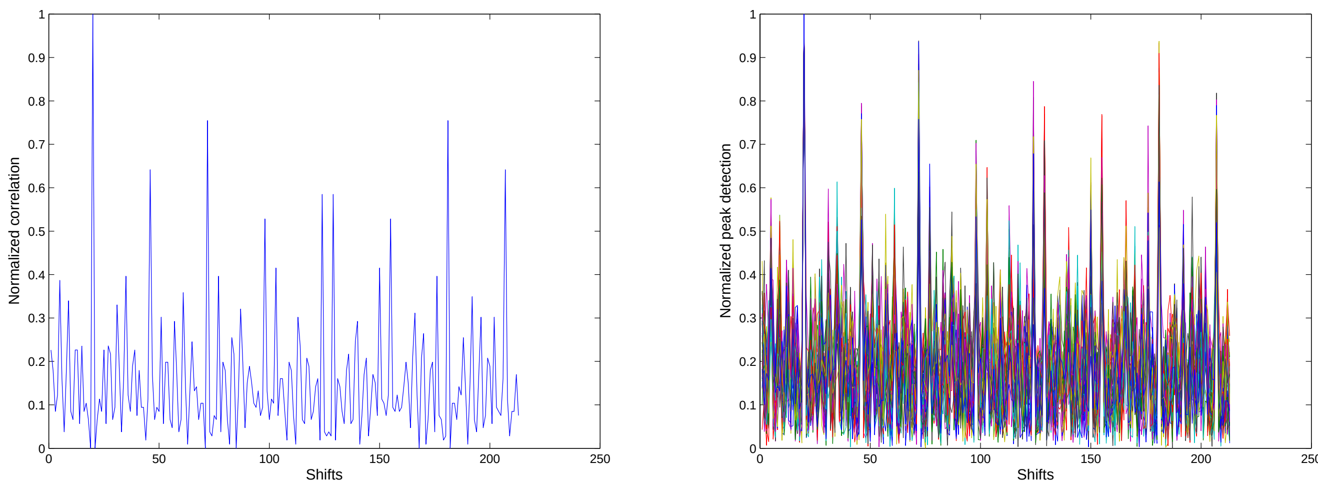

Figure 2. Left: Cyclic correlation between the differential of the shifted SYNC sequence (by d = 20) and the differential of the SYNC at all shifts; Right: Performance for detecting the peak that corresponds to the shift *d*=20 (SNR = 0 dB per occupied subcarrier, subcarrier spacing 11.2 kHz, 0.6 us rms delay spread, 512 FFT)

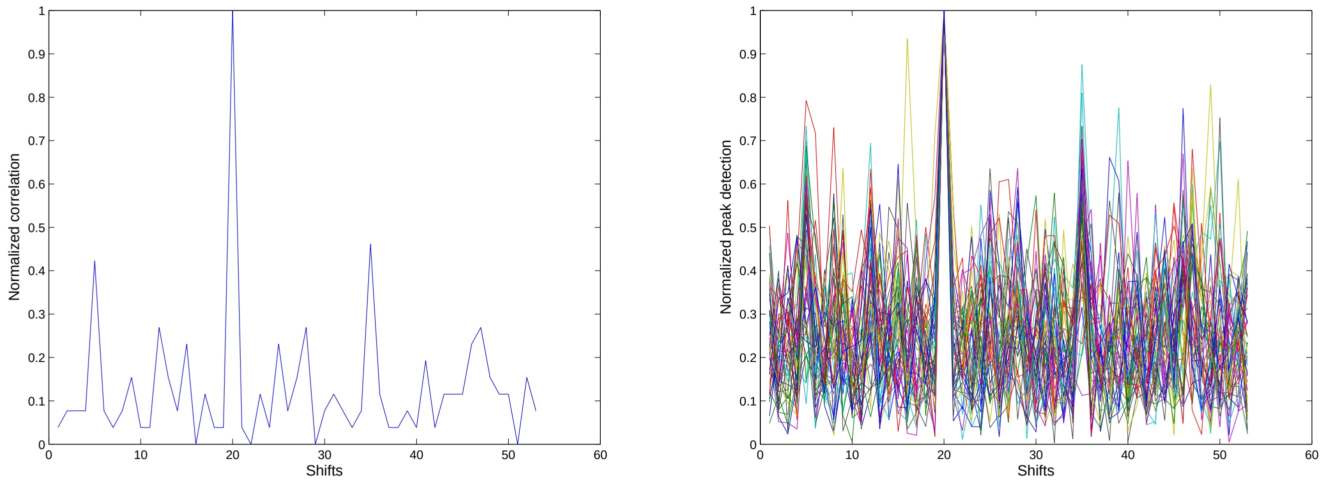

Figure 3. Left: Cyclic correlation between the differential of the shifted SYNC sequence (by d = 20) and the differential of the SYNC at all shifts; Right: Performance for detecting the peak that corresponds to the shift *d*=20 (SNR = 0 dB per occupied subcarrier, subcarrier spacing 11.2 kHz, 0.6us rms delay spread, 128 FFT)