Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	Hierarchical Preamble Design for 128, 512 and 1024 point FFT sizes in the OFDMA PHY Layer
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Re:	Contribution to the IEEE P802.16e Preamble Ad-Hoc committee
Abstract	The purpose of this document is to propose a simplified synchronization and decoding method for the OFDMA PHY using hierarchical sequences in the preamble. The encoder and decoder are described in this document and sequences for 128, 512 and 1024 point FFT lengths are proposed. Correlation and cross-correlation figures are also provided.
Purpose	Adoption
Notice	
Release	
Patent Policy and Procedures	

Hierarchical Preamble Design for 128, 512 and 1024 point FFT sizes in the OFDMA PHY Layer

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1. Introduction

The current 802.16-2004 preamble for the OFDMA PHY has been designed primarily for fixed wireless deployment [1]. Given the current number of cell IDs and segments in the pending standard, the SS (Subscriber Station) must perform correlations with 96 different frequency-domain PN (pseudo-noise) sequences to determine the relevant information (cell ID and segment). Furthermore, if the SS synchronization is performed in time domain, due to the lack of timing and frequency offset information, this will require a correlator that operates on complex valued data. This configuration is not desirable for mobile applications where power consumption is of primary concern and the cell identification and selection can occur frequently.

In this contribution, we propose a three stage approach to BS synchronization similar to the technique used in the 3G cellular standards. The first stage consists of acquiring the timing to a preamble common to all the base-stations. Using this timing information, correlations are performed with base station specific secondary preamble, which indicates the BS group. The BS specific preambles within the particular BS group are then searched in the third stage to synchronize to the base station.

This contribution also offers a time-domain hierarchical preamble that greatly reduces the overall complexity of the MSS (Mobile Subscriber Station) synchronization algorithm. The time domain hierarchical preambles facilitate time domain synchronization to obtain both timing and BS group information by replacing complex multiplies with additions and reduces the number of sequences for the frequency-domain correlation process required to determine the cell ID and segment.

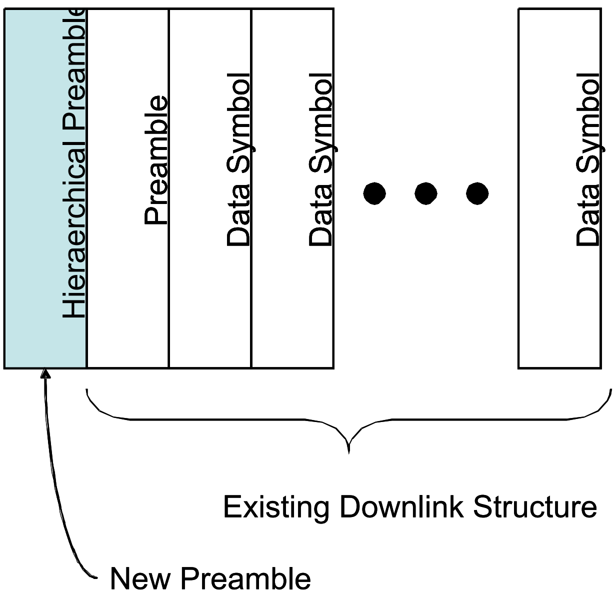


Figure 1. Modified Downlink Transmission Structure

The modified structure for the downlink transmission is shown in Figure 1. Notice that an additional preamble has been pre-pended to the existing downlink transmission structure to form the modified structure. This new structure is backwards compatible with the 802.16-2004 preamble and can be use to simplify the search process for the transmitted PN sequence using hierarchical sequences. Furthermore, the hierarchical sequences can be designed so that synchronization can occur in conjunction with the cell ID and segment decoding process. The following section describes the encoding and decoding process in detail.

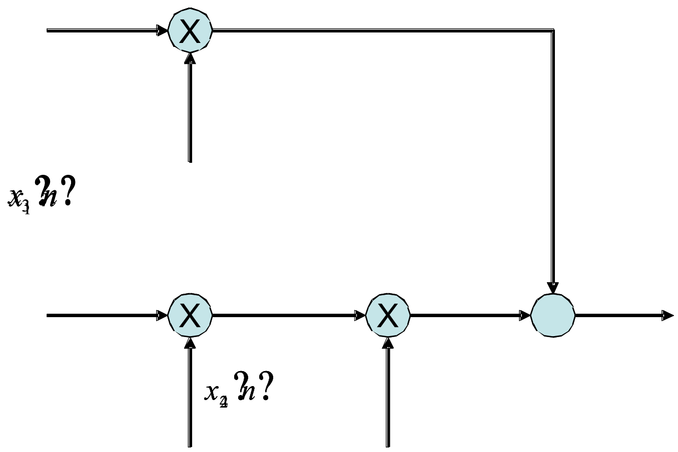


Figure 2. Hierarchical Encoder

2. Hierarchical Encoding and Decoding

The basic premise behind hierarchical sequences is to partition the encoding process at the transmitter into a hierarchy so that the complexity of the decoding process at the receiver is reduced. For this contribution, the hierarchical sequences consists of two binary sequences (i.e. all elements are of the set {-1,1}) $x_1[n]$ and $x_2[n]$ of length N_1 and N_2, respectively. Mathematically, a hierarchical sequence $s[n]$ of length $N = N_1 * N_2$ can be expressed as

$$s[n] = x_1[n \text{ div } n_2] * x_2[n \bmod n_2] \tag{1}$$

where n=0,…,N-1. Notice that the construction of the hierarchical sequence $s[n]$ is identical to spreading the data stream $x_1[n]$ by the spreading sequence $x_2[n]$.

Figure 2 shows a block diagram of the encoding process at the transmitter. The primary sequence, $x_P[n]$, is created by spreading the $x_1[n]$ sequence by $x_2[n]$. Similarly, the secondary sequence, $x_S[n]$, is created by spreading the $x_3[n]$ sequence by $x_4[n]$ and then multiplying the result by a Hadamard sequence $h[i]$ to make it orthogonal to the primary sequence. For the spreading sequence for the 128, 512 and 1024 point FFT sizes in the OFDMA PHY, see Table X. Notice that the Ad-Hoc committee must still determine the mapping of the cell ID and segment to the secondary spreading sequence $x_4[n]$.

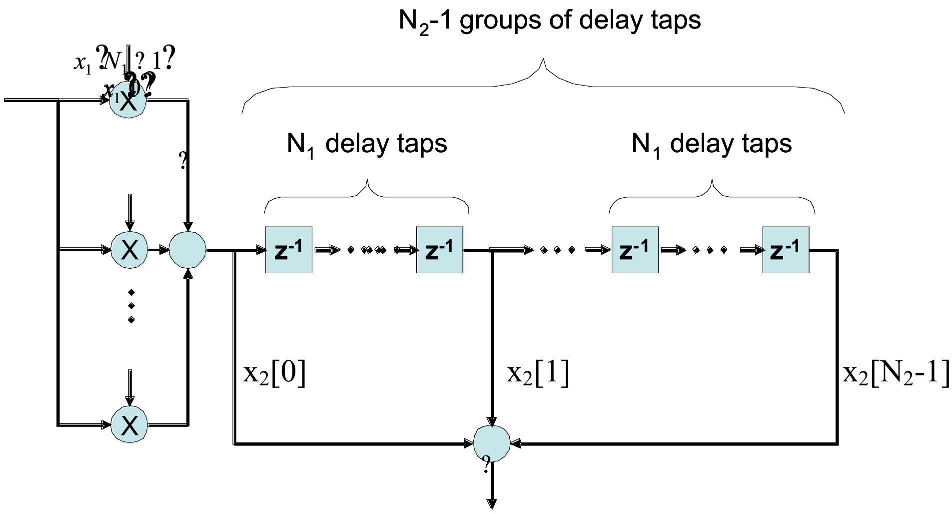


Figure 3. Hierarchical Decoder for Primary Sequence

Figure 3 shows a block diagram of the decoding process for the primary sequence at the receiver. The complex-valued received data, $y[n]$, is first correlated with the $x_1[n]$ sequence. Notice that the operation is just a sequence of additions and subtractions due to the binary nature of $x_1[n]$. After the summation, the result is passed through a sequence of delay taps that are summed at intervals of N_1 data values. The final summation result can then be used to synchronize the receiver. This receiver architecture involved only $2(N_1+N_2)$ real additions and is much simpler than the existing frequency-domain approach that is implied by the 802.16-2004 standard. Typical numbers for N_1, N_2 for different lengths are given in table below.

Table 1: The typical values of N_1, N_2 and the number of additions per shift of the primary synchronization preamble correlation.

Length	N_1	N_2	Total additions per shift
128	16	8	48
512	32	16	96
1024	32	32	128

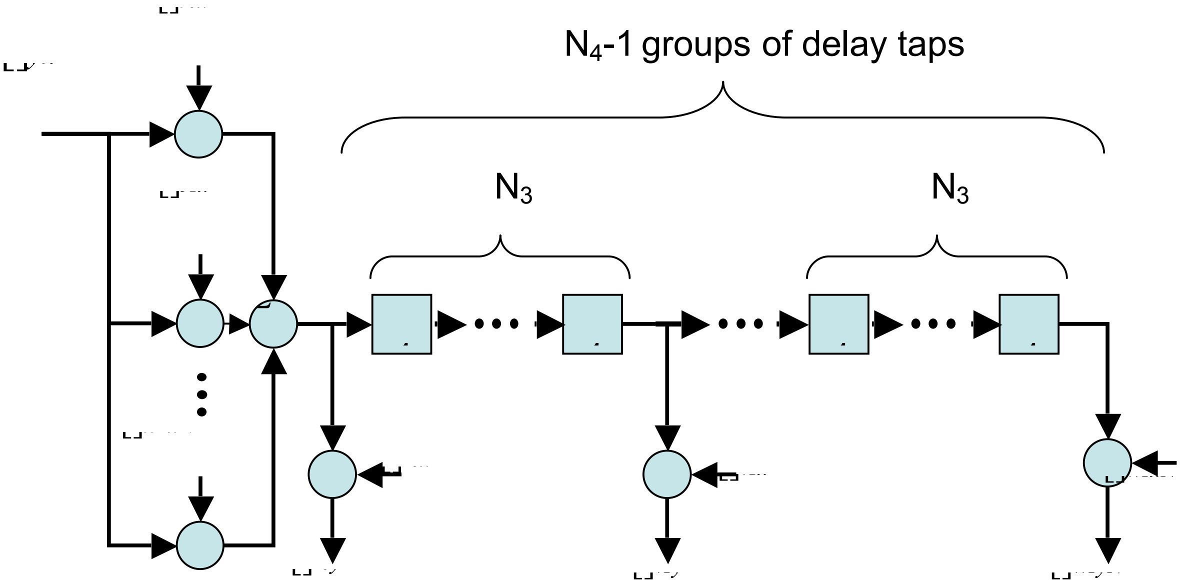


Figure 4. Hierarchical Decoder for the Secondary Sequence

To determine the cell ID and the segment, the secondary sequence must be decoded at the receiver. Figure 4 shows a block diagram of the decoding process. The complex-valued received data, $y[n]$, is first correlated with the $x_3[n]$ sequence. Notice that the operation is just a sequence of additions and subtractions due to the binary nature of $x_3[n]$. After the summation, the result at intervals of N_3 data values is then multiplied by a Hadamard transform matrix to determine the correlations due to all the secondary sequences. With a known mapping of the secondary sequences, the cell ID and the segment can be determined at the receiver. The receiver then needs to search only for the BS specific preambles within the BS group indicated by the secondary synchronization preamble.

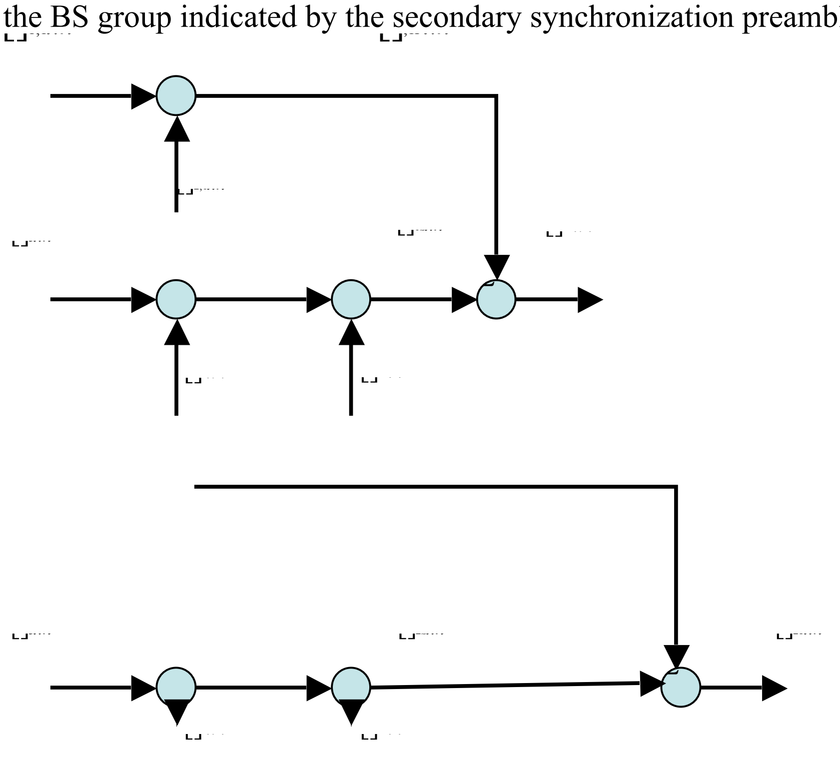


Figure 5. Hierarchical Encoder for MIMO

3. Extension to MIMO

The hierarchical encoding and decoding structure given in Figure 2, Figure 3 and Figure 4 can be extended to MIMO (Multiple-Input, Multiple-Output) systems. Figure 5 shows the extension of the hierarchical sequences to a MIMO with two transmit paths. The second Hadamard sequence, $h_2[n]$, is chosen with good correlation properties with respect to the first Hadamark sequence, $h_1[n]$. This structure can be extended to additional transmit paths by determined additional Hadamard sequences.

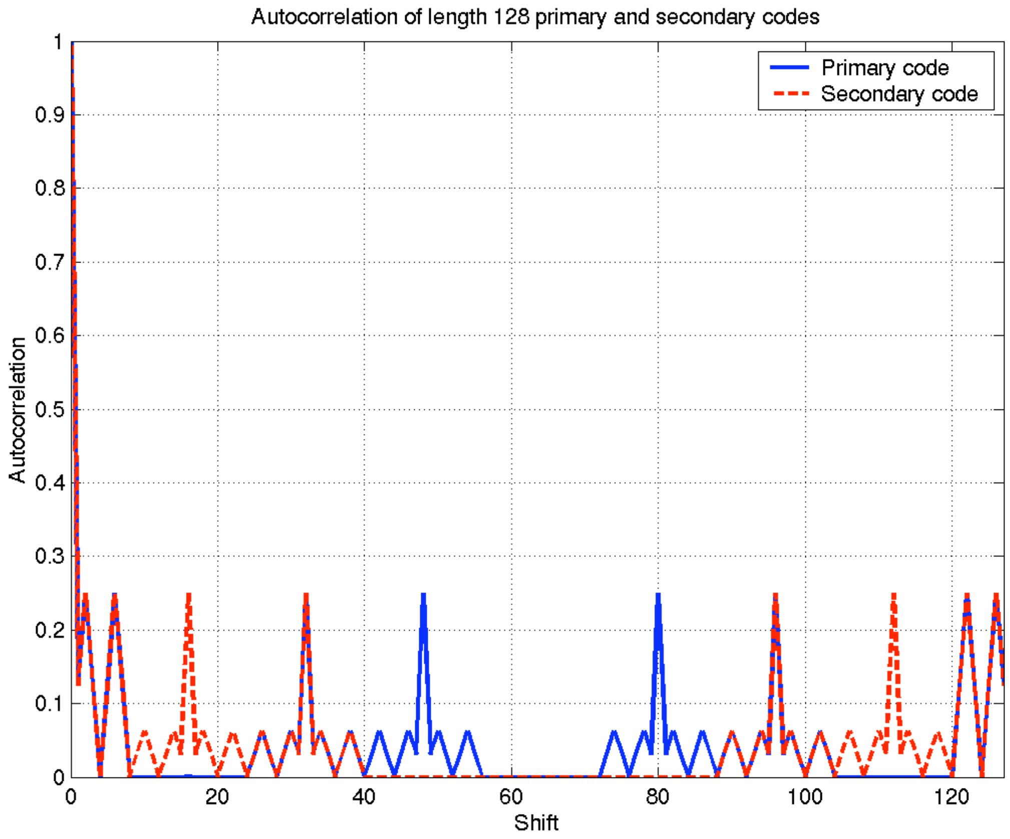
4. Different codes and their properties

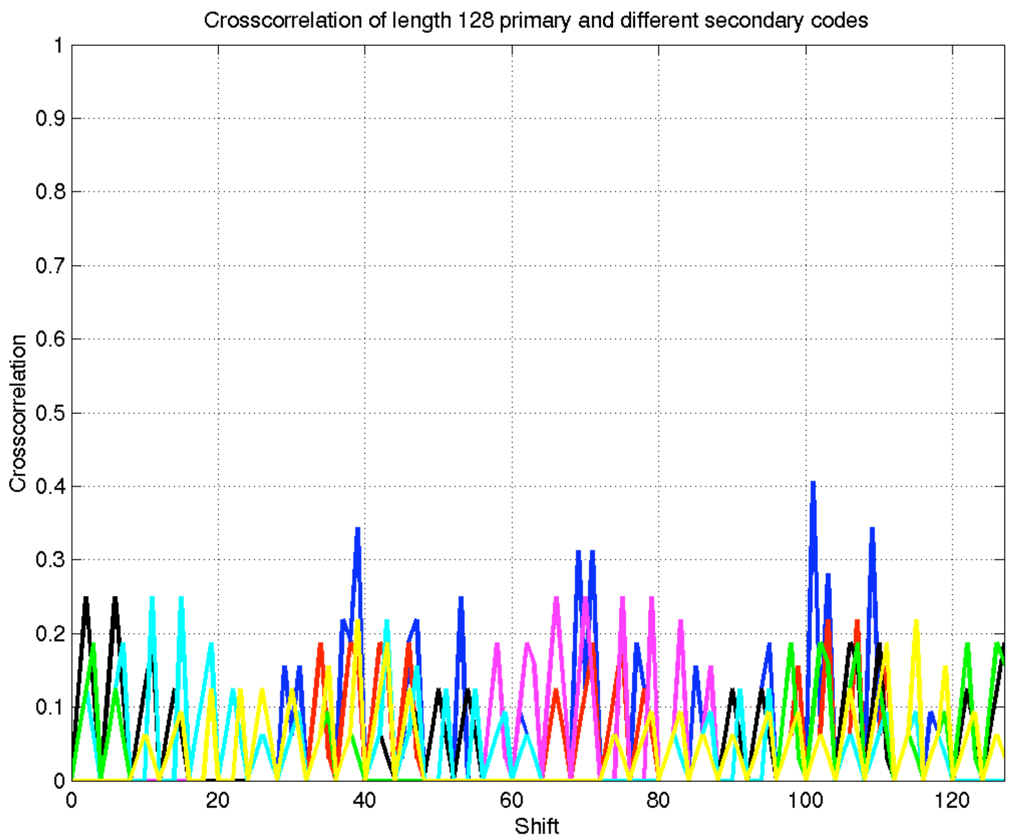
In this section we give the base sequences to generate the primary and secondary sequences for different lengths, 128, 512 and 1024. We also show some of the auto and cross correlation properties for these sequences.

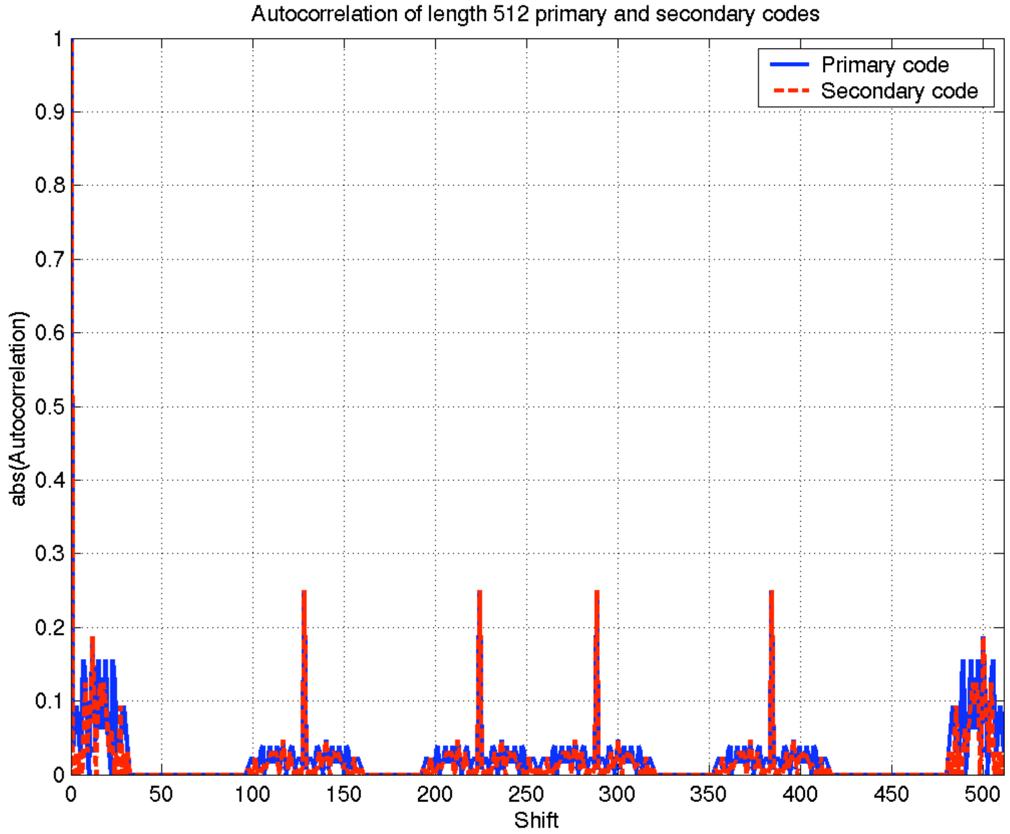
Length 128:
x1 = [1 1 1 1 -1 -1 1 1 -1 -1 1 -1 1 -1 1 1];
x2 = [1 -1 -1 -1 1 1 -1 1];
x3 = [1 -1 -1 -1 -1 -1 1 -1 1 -1 -1 1 1 -1 -1 1];
x4 = [1 -1 1 1 -1 -1 -1 1];

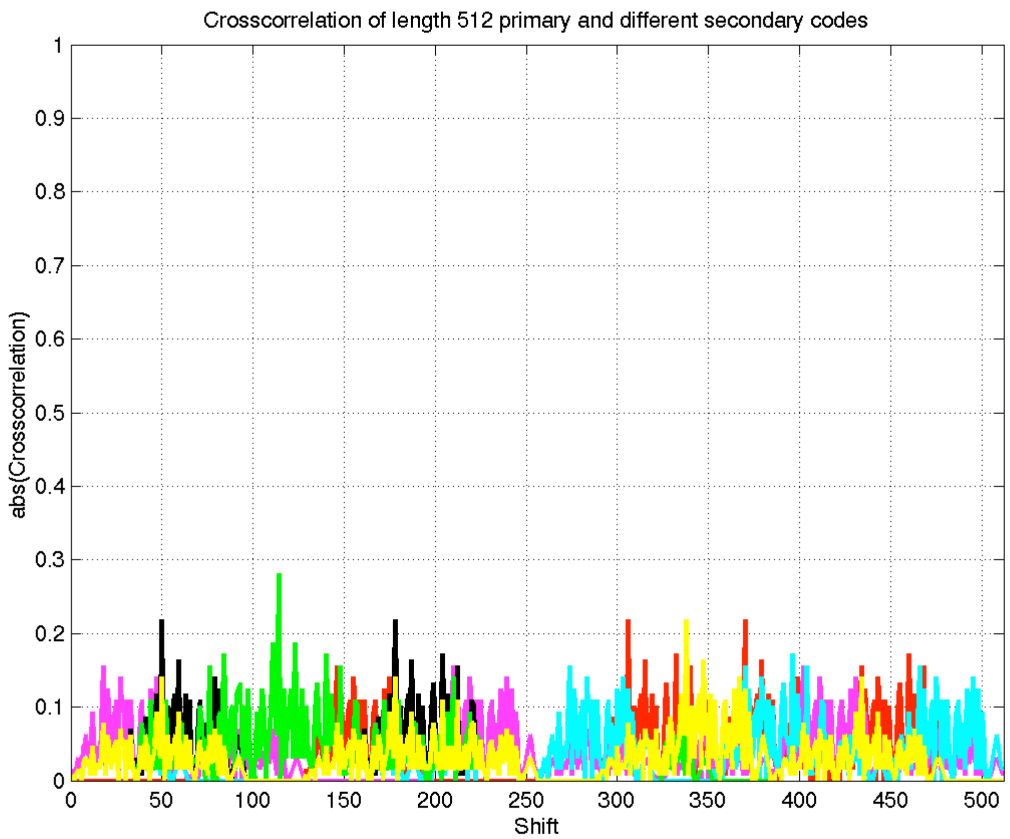
Length 512:
x1 = [-1 -1 -1 -1 1 -1 -1 1 -1 -1 1 1 -1 -1 1 1 1 1 1 -1 -1 -1 1 1 -1 1 1 1 -1 1 -1 1 1];
x2 = [1 1 1 -1 1 1 -1 -1 1 -1 1 -1 -1 -1 -1 1];
x3 = [-1 -1 -1 -1 1 1 -1 -1 1 -1 -1 1 1 1 1 1 -1 1 1 1 -1 -1 -1 1 -1 1 -1 1 1 -1 1 -1];
x4 = [1 -1 -1 -1 -1 1 -1 1 -1 -1 1 1 -1 1 1 1];

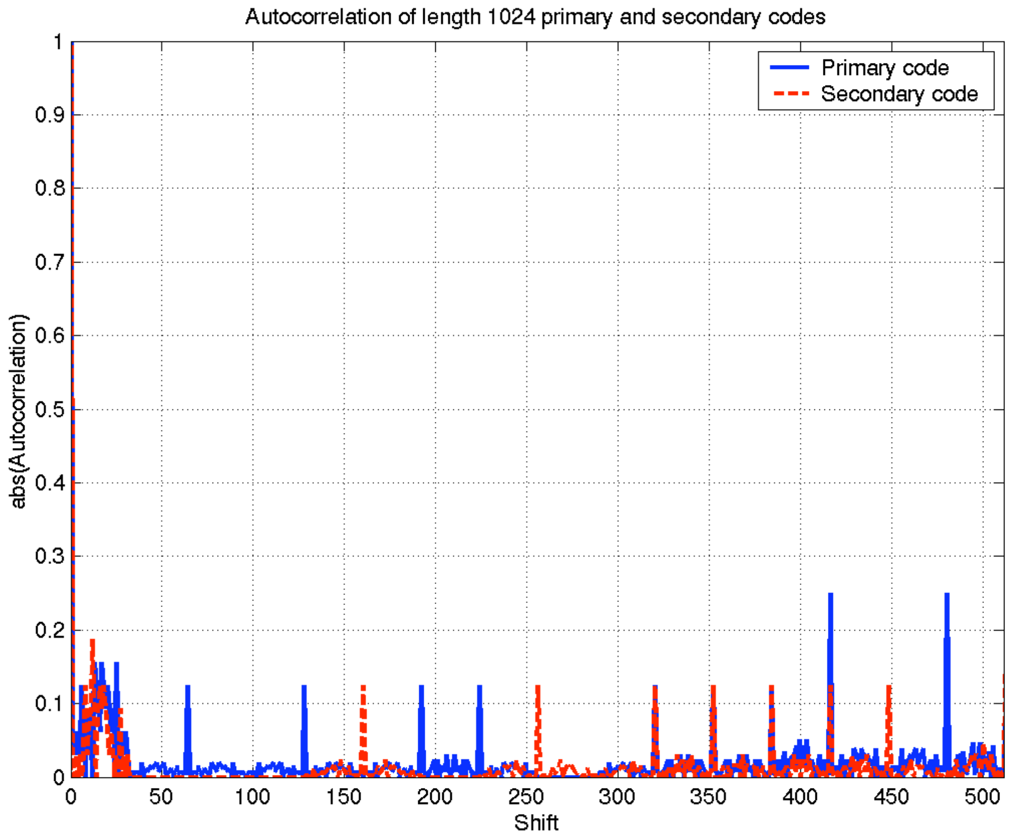
Length 1024:
x1 = [-1 -1 -1 -1 1 -1 -1 1 -1 -1 1 1 -1 -1 1 1 1 1 1 -1 -1 -1 1 1 -1 1 1 1 -1 1 -1 1 1];
x2 = [-1 -1 -1 -1 1 -1 -1 1 -1 -1 1 1 -1 -1 1 1 1 1 1 -1 -1 -1 1 1 -1 1 1 1 -1 1 -1 1 1];
x3 = [-1 -1 -1 -1 1 1 -1 -1 1 -1 -1 1 1 1 1 1 -1 1 1 1 -1 -1 -1 1 -1 1 -1 1 1 -1 1 -1];
x4 = [-1 -1 -1 -1 1 1 -1 -1 1 -1 -1 1 1 1 1 1 -1 1 1 1 -1 -1 -1 1 -1 1 -1 1 1 -1 1 -1];

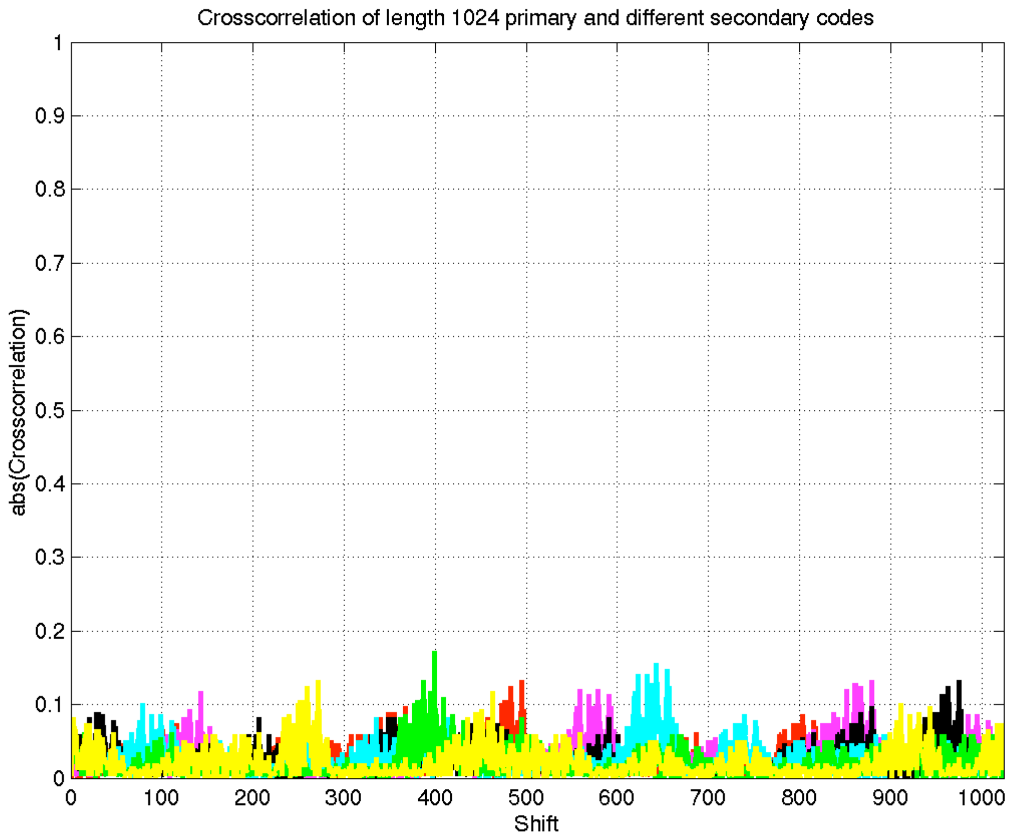

Autocorrelation of length 128 primary and secondary codes
Primary code
Secondary code
Autocorrelation
Shift
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
20
40
60
80
100
120


Crosscorrelation of length 128 primary and different secondary codes
Crosscorrelation
Shift
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
20
40
60
80
100
120


Autocorrelation of length 512 primary and secondary codes
Primary code
Secondary code
abs(Autocorrelation)
Shift
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
50
100
150
200
250
300
350
400
450
500


Crosscorrelation of length 512 primary and different secondary codes
abs(Crosscorrelation)
Shift
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
50
100
150
200
250
300
350
400
450
500


Autocorrelation of length 1024 primary and secondary codes
Primary code
Secondary code
abs(Autocorrelation)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350
400
450
500
Shift


Crosscorrelation of length 1024 primary and different secondary codes
abs(Crosscorrelation)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
100
200
300
400
500
600
700
800
900
1000
Shift

5. Proposed Text Changes

To be determined by the 802.16e Preamble Ad-Hoc committee.

6. References

1. *Draft IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems*, IEEE P802.16-REVd/D5-2004, May 2004.
2.