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Abstract	This document contains a new downlink preamble structure for cell search that provides fast performance with low computational complexity in cellular operation of 802.16 OFDMA.	
Purpose	To propose a new downlink preamble and cell search scheme for cellular operation of 802.16 OFDMA	
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Cell Search for Cellular Operation of 802.16 OFDMA

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1. Introduction

It is desirable for proper cellular operation of 802.16 to use a cell search scheme that can provide fast performance in multi-cell environment with low computational complexity. In this contribution, we propose an improved cell search scheme for 802.16 OFDMA system. Section 2 describes a new preamble structure for fast cell search. Section 3 describes the operation of the proposed cell search scheme. The performance of the proposed cell search scheme is verified by computer simulation in Section 4. Finally, conclusions are summarized in Section 5.

2. Proposed downlink preamble structure

Consider a downlink (DL) preamble transmitted at the beginning of each frame. As depicted in Figure 1, the proposed preamble comprises four periods of a periodic signal with period N_p in a symbol time and a guard interval with zero power in the time domain.

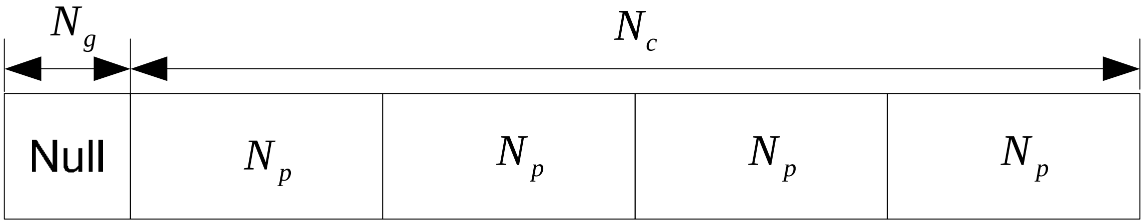

Figure 1 The proposed DL preamble structure in the time domain

Assume that each cell uses one of n_{cell} distinct preamble patterns distinguishable from other cells. The preamble signal can be designed in the frequency domain as

$$P\left[k,n_c\right]=\begin{cases}2\sqrt{2}q\left[k/4,n_c\right], & k=0,4,8,\cdots,N_c\\ 0 & ,\ otherwise\end{cases} \tag{1}$$

where $q\left[m,n_c\right]$ is an extended PN sequence of length N_p, n_c denotes the cell code number belonging to $\Phi_c \in \left\{0,1,2,\cdots,n_{cell}-1\right\}$, N_c $(=4N_p)$ is the number of subcarriers and N_g is the number of samples in the guard interval. After being processed by inverse discrete Fourier transform (IDFT), $P\left[k,n_c\right]$ is a periodic signal with period N_p in the time domain as depicted in Figure 1. Note that the constant $2\sqrt{2}$ in (1) is used to make both the DL preamble and OFDMA symbol have the same average power.

3. Proposed cell search scheme

We propose a three-step cell search process as shown in Figure 2. The frame timing is first acquired and then the symbol timing is coarsely acquired. Finally, the cell is identified with fine synchronization of the symbol time.

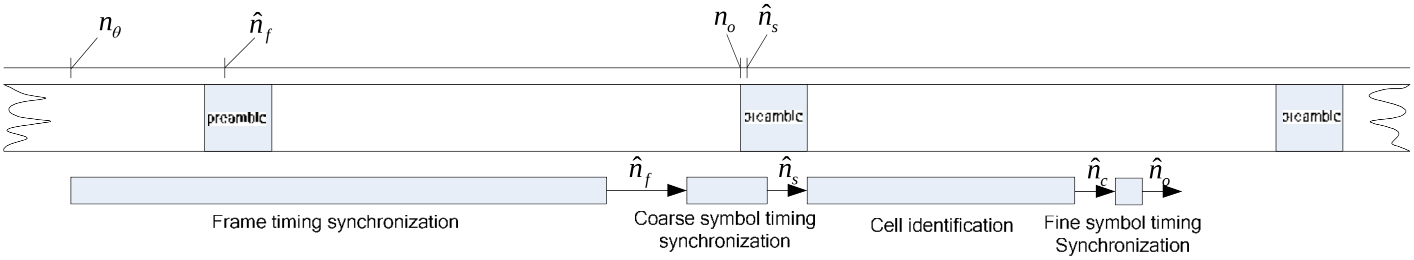

Figure 2 Proposed cell search operation

A. Frame time synchronization

To acquire the frame time, we first detect the preamble symbol. Define a timing index set by

$$\Phi_f \triangleq \left\{ n : n = n_\theta + 2N_p \cdot i, i = 0,1,\cdots,I_\theta \right\}, 0 \le n_\theta \le N_f - 1 \tag{2}$$

where N_f is the number of samples per frame, n_θ is initial timing offset and $I_\theta = \left\lfloor N_f/(2N_p) - 1 \right\rfloor$. Here $\lfloor x \rfloor$ denotes the largest integer less than or equal to x. The set Φ_f contains the instants of the correlation from time n_θ

To obtain the frame timing, the receiver performs a block-wise correlation defined as

$$c_f[n] = \sum_{i=0}^{N_p-1} r[n+i] r^*[n+i+N_p], \; n \in \Phi_f . \tag{3}$$

The frame timing can be found by selecting the timing index $\hat{n}_f$ such that

$$\hat{n}_f = \arg\max_{n \in \Phi_f} \left| c_f[n] \right|, \; if \;\; \max \left| c_f[n] \right| \ge \lambda_f \tag{4}$$

where λ_f is a threshold to be determined.

B. Coarse symbol time acquisition

After the frame time $\hat{n}_f$ is obtained, the timing ambiguity is reduced within a symbol interval. Then, we find out the symbol time in a coarse manner. The receiver performs the correlation $c_s[n]$ defined as

$$c_s[n] = \sum_{i=0}^{2N_p-1} r[n+i] r^*[n+i+2N_p], \; n \in \Phi_s \tag{5}$$

where $\Phi_s \,\square\, \left\{ \hat{n}_f - N_c + 1, \hat{n}_f - N_c + 2, \cdots, \hat{n}_f \right\}$. The symbol timing can be found by selecting the timing index $\hat{n}_s$ such that

$$\hat{n}_s = \arg\max_{n \in \Phi_s} \left| c_s[n] \right|, if \;\; \max \left| c_s[n] \right| \geq \lambda_s \tag{6}$$

where λ_s is a threshold to be determined.

If there is no multi-path propagation and interference, $c_s[n]$ has a peak value at exact symbol time n_o. However, since the received signal is transmitted over a multi-path channel with interference, the estimated symbol timing $\hat{n}_s$ is shifted by Δ_e from n_o, i.e.,

$$\hat{n}_s = n_o + \Delta_e \tag{7}$$

C. Cell identification and fine symbol time synchronization

When $N_p \geq N_g$, $2N_p$ samples apart by N_p samples from time index $\hat{n}_s$ are not affected by the delayed signal due to multi-path delay. Taking $2N_p$-point DFT of these samples, we have

$$R_{\hat{n}_s + N_p}[k] = \sum_{n=0}^{2N_p - 1} r\left[n + \hat{n}_s + N_p \right] e^{-j2\pi kn/(2N_p)} . \tag{8}$$

$2N_p$-point DFT of the pilot pattern at exact symbol time n_o is

$$P^{'}[k, n_c] = \sum_{n=0}^{2N_p} \left(\sum_{k=0}^{N_c - 1} P[k, n_c] e^{j2\pi kn/N_c} \right) e^{-j2\pi kn/(2N_p)} . \tag{9}$$

The time delay can be represented by phase rotation in the frequency domain. Thus, $R_{\hat{n}_s + N_p}[k]$ can be expressed as a phase-rotated version of $P^{'}[k, n_c]$,

$$R_{\hat{n}_s + N_p}[k] = P^{'}[k, n_c] e^{j2\pi \Delta_e k/(2N_p)} \tag{10}$$

Define $c_c[n]$ by

$$c_c[n] = \sum_{k=0}^{N_p - 1} \left\{ P^{'}[2(k+1), n] R_{\hat{n}_s + N_p}[2(k+1)] \right\} \left\{ P^{'}[2k, n] R_{\hat{n}_s + N_p}[2k] \right\}, n \in \Phi_c \tag{11}$$

where the superscript $*$ denotes complex conjugate. We can find the cell code number by selecting the timing index $\hat{n}_c$ such that

$$\hat{n}_c = \arg\max_{n \in \Phi_c} \left| c_c[n] \right|, if \;\; \max \left| c_c[n] \right| \geq \lambda_c \tag{12}$$

where λ_c is a threshold to be determined.

Once the cell code number is obtained, the preamble code sequence is known. Using Eq. (11), we can estimate the timing error Δ_e. The phase rotation can be obtained by

$$\begin{aligned}\theta &= arg\left(c_c\left[n_{id}\right]\right)\\ &= \frac{2\pi\hat{\Delta}_e}{N_p}\end{aligned} \tag{13}$$

The timing error can be estimated as

$$\hat{\Delta}_e = \left\lfloor \frac{N_c\theta}{8\pi} \right\rfloor. \tag{14}$$

Finally, the symbol time can be found by correcting the timing error as

$$\hat{n}_o = \hat{n}_s - \Delta_e . \tag{15}$$

Let P_{D_i}, P_{M_i} and P_{F_i} be the probability of correct detection, miss detection and false detection in the *i*-th step of the proposed three-step search process, respectively. Note that

$$P_{D_i} + P_{M_i} + P_{F_i} = 1 \tag{16}$$

It can be shown that the mean acquisition time is represented as

$$E\left\{t_{acq}\right\} = t_f \frac{2 - P_{M_1} - P_{M_2}}{\left(1 - P_{M_1}\right)P_{D_2}} + t_p \frac{P_{F_2}}{P_{D_2}} \tag{17}$$

where t_f is the frame duration and t_p represents the penalty time due to a false detection. Similarly, the mean search time can be represented as

$$E\left\{t_{search}\right\} = t_f \frac{2 - P_{M_1} - P_{M_2} - P_{M_3} + P_{M_2}P_{M_3}}{\left(1 - P_{M_1}\right)\left(1 - P_{M_2}\right)P_{D_3}} + t_p \frac{P_{F_3}}{P_{D_3}} \tag{18}$$

4. Performance evaluation

The performance of the proposed cell search scheme is verified by computer simulation when applied to 802.16 OFDMA system. The simulation parameters are summarized in Table I [2].

Figure 5 depicts the timing acquisition performance of the proposed cell search scheme. For comparison, we also consider the performance of Cox's scheme with the use of preamble in [1]. The threshold λ_f and λ_s are set to a value equal to 3dB lower than the maximum correlation. The penalty time by a false alarm is set to 1000msec in each scheme. It can be seen that the proposed scheme can obtain the timing synchronization much faster than the Cox's scheme and quite consistent for a wide range of the CIR.

Figure 6 depicts the performance of the proposed cell search scheme in terms of the mean cell search time. The threshold λ_f, λ_s and λ_c are all set to a value equal to 3dB lower than the maximum correlation. It can be seen that the proposed cell search scheme can find the cell in less than 16msec over -5dB CIR and quite robust to the variation of CIR. Due to reduction of the false detection by cell identification step and fine symbol time synchronization step, mean cell search time is shorter than the timing acquisition time.

Table 2 summarizes the computational complexity of the two schemes in unit of million instructions per second (MIPS). The Cox's scheme uses an iteration method to reduce the computation complexity of the correlation [1]. It can be seen that the proposed cell search scheme requires significantly lower computational complexity than the Cox's scheme when applied to 802.16 OFDMA.

5. Conclusion

In this contribution, we have proposed a new cell search scheme with the use of a new preamble for 802.16 OFDMA system. Simulation results show that the proposed cell search scheme can provide fast cell search performance over the conventional one in 802.16 OFDMA operation environment, while significantly reducing the implementation complexity.

Table 1 Simulation parameter

Parameter	Value
BW (MHz)	10 MHz
N_c	2048
Frame Duration (ms)	5
CP time(μs)	12.8
Useful symbol time(μs)	102.4

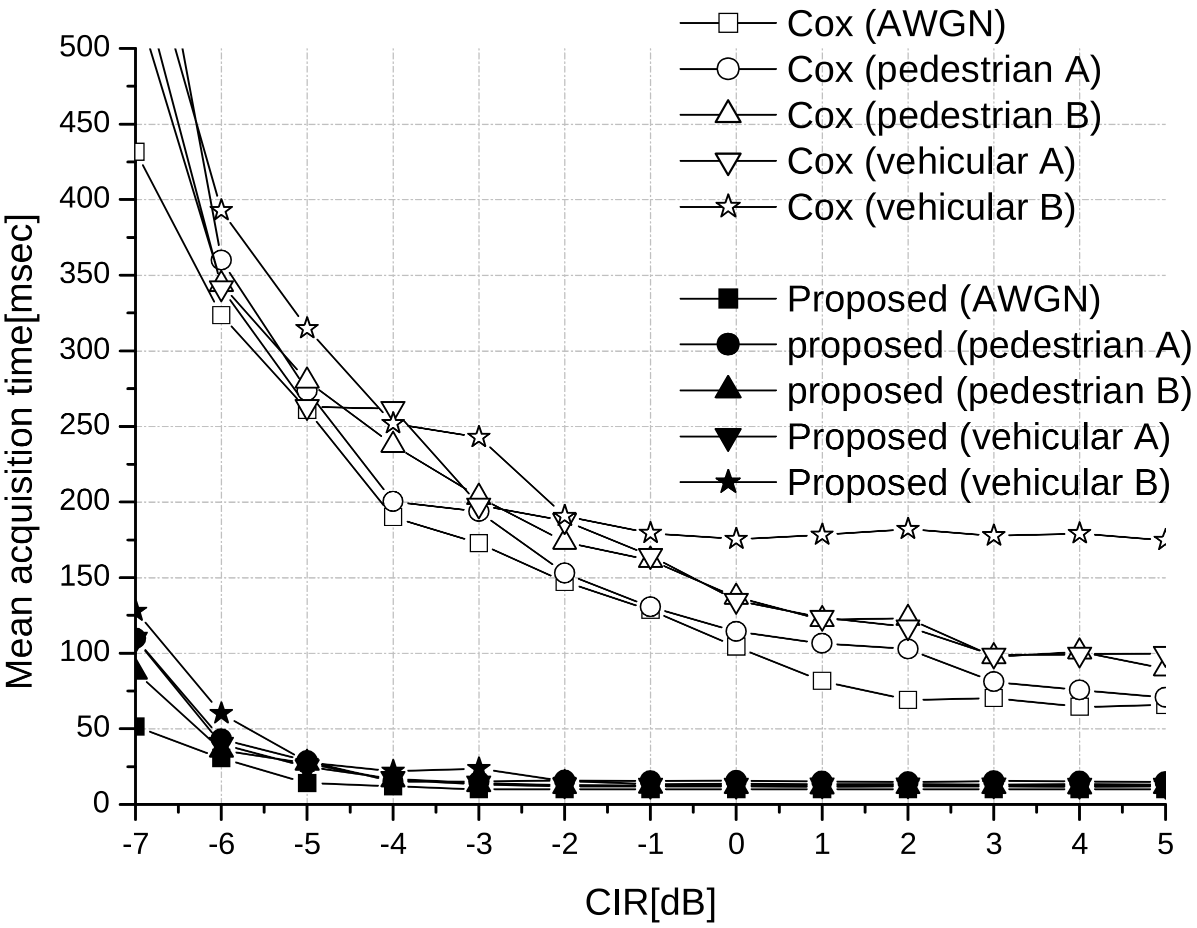

Figure 5 Mean acquisition time of the proposed scheme

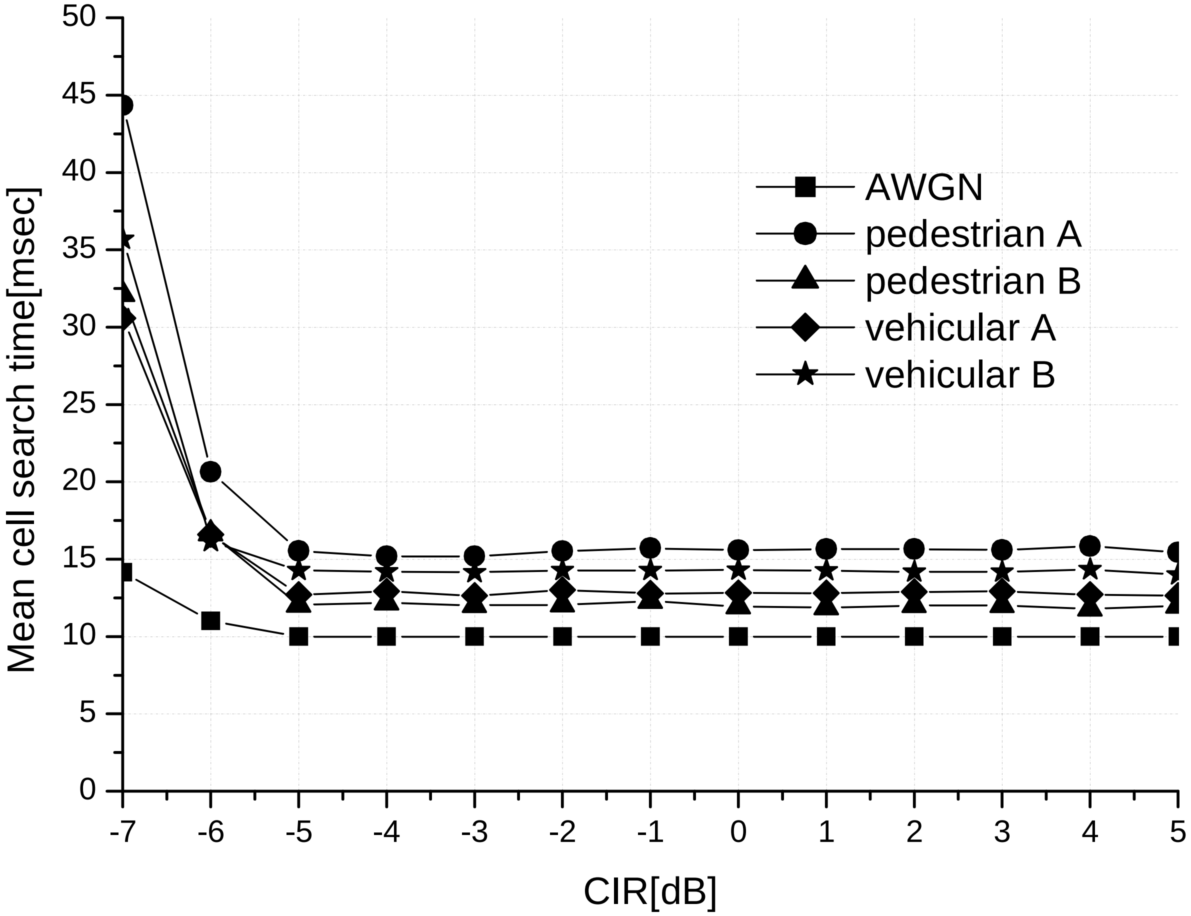

Figure 6 Mean cell search time of the proposed scheme

Table 2 Computational complexity for timing acquisition

	Proposed scheme	Cox’s scheme
Multiplication	20.5820	78.2328
Addition	26.1197	136.4978
Total	46.7017	214.7306

References

[1] T.M. Schmidl and D.C. Cox, “Robust frequency and timing synchronization for OFDM,” *IEEE Trans. Commun.*, vol. 45, pp1613-1621, 1997.

[2] *Specifications for 2.3GHz band portable internet service*, June 2004, TTA_PG302.

Appendix: Text changes

[Replace section 8.4.6.1.1]

8.4.6.1.1 Preamble

The first symbol of each frame in the downlink transmission is the preamble comprising four periods of a signal and a guard interval with zero power in the time domain. A time domain structure of the DL preamble is shown in Figure 1.

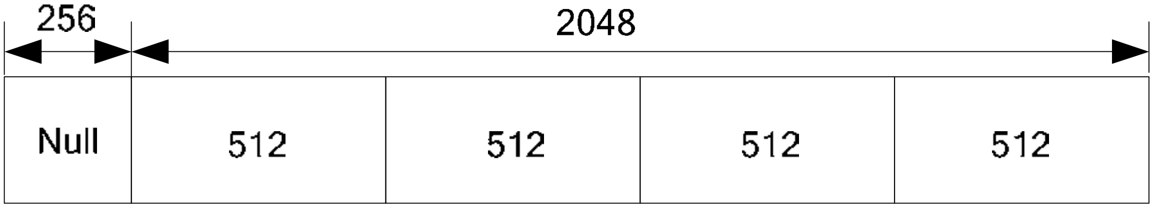

Figure 1 The proposed DL preamble structure in the time domain

128 distinct preamble patterns are used to distinguish a cell (or sector) from others. The preamble can be designed in the frequency domain, which is BPSK modulated as follows,

$$P[k,n_c] = \begin{cases} 2\sqrt{2}q[k/4,n_c], & k = 0,4,8,\cdots,2048 \\ 0 & , \mathit{otherwise} \end{cases} \quad (1)$$

where $q[m,n_c]$ is an extended PN sequence of length 512, n_c denotes the cell code number belonging to $\{0,1,2,\cdots,127\}$, the number of subcarriers is 2048 and the guard interval has 256 samples. After being processed by inverse discrete Fourier transform (IDFT), $P[k,n_c]$ has four periods of a signal of length 512 samples in the time domain as depicted in Figure 1. Note that the constant $2\sqrt{2}$ in (1) is used to make both the DL preamble and OFDMA symbol have the same average power.