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LOW COMPLEX PRIMARY AND SECONDARY SYNCHRONIZATION SIGNAL DESIGN FOR LTE DOWNLINK SYSTEMS

Anagha.T.R[1], **B.Shoba** [2] , **Dr.K.Jayanthi** [3]

[1]*Student, Electronics and Communication Engineering Department,*
Rajiv Gandhi College of Engineering and Technology, (Pondicherry, India)

[2]*Head of Dept., Electronics and Communication Engineering Department,*
Rajiv Gandhi College of Engineering and Technology, (Pondicherry, India)

ABSTRACT

In this paper a low-complex variant of the frequency domain synchronization structure specified in Long-Term Evolution standard is proposed. In the proposed scheme the PSS (Primary Synchronization Signal) is split into four parts; such that each part can be derived from one another. So instead of the whole PSS, it is enough that either of the four parts of the PSS satisfies all the conditions for synchronization. The proposed SSS structure does not use scrambling sequences; but at the same time is free of double collision problem.

***Keywords:* Cell search, LTE, synchronization, synchronization signals, ZC sequence**

I. INTRODUCTION

The Long Term Evolution (LTE) is a mobile communication standard that is specified by the 3rd Generation Partnership Project (3GPP).It uses SC-FDMA in uplink and OFDMA in downlink.

In the downlink, OFDM based radio access was adopted because of its inherent robustness against multipath interference and its affinity to different transmission bandwidth arrangements.

When a mobile station either turns on or experiences a handover process, the mobile station must search for a base station (BS) and determine which sector in the BS can provide satisfactory service. This process, called cell search, usually employs the synchronization signals that are transmitted periodically from surrounding BSs.

Both the FDD and TDD versions of LTE broadcast Synchronization Signals in the downlink directions. There are two types of synchronization signals: Primary Synchronization Signals (PSS) and Secondary Synchronization Signals(SSS). Synchronization Signals are broadcast within every 10 ms radio frame. The UE uses the Synchronization Signals to achieve radio frame, subframe, slot and symbol synchronization in the time domain, identify the center of the channel bandwidth in the frequency domain and deduce the Physical layer Cell Identity (PCI).Detecting the Synchronization Signals is a prerequisite to measuring the cell specific

Reference Signals and decoding the Master Information Block (MIB) on the Physical Broadcast Channel (PBCH).

In [1] the LTE features, architecture and frame structure are explained. In [2],[3] and [4] the detailed study of cell search is made. In [4],[5],[6]and [7] the details of synchronization is specified.[8] to [19] proposes new structures for synchronization signals and detection methods. The concept of splitting the PSS to reduce the complexity is proposed in [19] and a performance evaluation is also made.

The existing system uses 62 subcarriers generated based on the ZC sequence. In [19] the concept of splitting the PSS into two such that the second segment is the conjugate of first segment is introduced. With this concept instead of the whole PSS of length 64, detection and offset compensations can be done with length 32 PSS; thus reducing the complexity of the system. In the proposed work the PSS is split into four segments, such that the other three segments are obtained from the first segment. The proposed PSS is of length 16 ie; approximately one fourth of the existing system. The proposed SSS does not use scrambling sequences for signal generation. Thus to introduce a concept that can reduce the complexity (to about one fourth).

II. SYSTEM DESCRIPTION

2.1 Frame structure in LTE standard

LTE standard supports a scalable transmission bandwidth ranging from 1.4 to 20MHz, which translates to FFT sizes of 128-2048(Table I) and is allocated in terms of resource blocks (RBs) each spanning 180 kHz. The smallest system bandwidth corresponds to 6 RBs. The subcarrier spacing is 15 kHz. Transmission over the subcarriers is arranged into frames. Regardless of the transmission mode, the synchronization channels occupy a 1.25 MHz central frequency band. This frequency band corresponds to 72 central subcarriers, including 62 subcarriers carrying the synchronization signals and 5 null subcarriers reserved at both ends. A downlink frame is 10ms long, having 10 subframes; each 1ms long. Each subframe is divided into two slots of 0.5ms , each having six (Extended CP)or seven (Normal CP)OFDM symbols. In the case of FDD, the PSS is broadcast using the central 62 subcarriers belonging to the last symbol of time slots 0 and 10.In the case of TDD, the PSS is broadcast using the central 62 subcarriers belonging to the third symbol of time slot 2 (subframe 1) and the third symbol of time slot 12 (subframe 6).The SSS is always mapped to the symbol ahead of the PSS signal in the same slot. Detection and analysis of PSS and SSS signals are required to detect the cell ID. To connect to the network successfully, a user equipment requires to detect the cell ID that is composed of cell ID group (NID(1)) and sector ID (NID(2)) as follows:

$$\begin{gathered} \mathrm{NID(cell)} = 3\,\mathrm{NID(1)} + \mathrm{NID(2)}\ , \\ 0 \leq \mathrm{NID(1)} \leq 167,\ 0 \leq \mathrm{NID(2)} \leq 2 \end{gathered} \tag{1}$$

In LTE systems, there are total of 504 different PCI (168 different physical layer cell identity groups numbering from 0 to 167,and each group consists of 3 physical layer identities from 0 to 2).

2.2 PSS and SSS Sequences

The Primary Synchronization Signal (PSS) is broadcast twice during every radio frame and both transmissions are identical. The PSS is a Zadoff-Chu (ZC) sequence which belongs to the class of Constant Amplitude Zero Auto Correlation (CAZAC) sequences. Such sequences are favored for synchronization purposes because they have constant amplitude and exhibit the useful property that cyclically shifted versions of a ZC are orthogonal to one another. Furthermore, the discrete Fourier transform (DFT) of a ZC sequence is another ZC sequence.

PSS is transmitted over six resource blocks but uses only 62 subcarriers around D.C zero frequency index subcarrier, with the remaining 5 subcarriers on each side zero padded.

$$d(n) = \begin{cases} \exp(-j\pi un(n+1)/63) & n=1,2\ldots31 \\ \exp(-j\pi u(1)(n+2)/63) & n=33,32\ldots64 \end{cases} \tag{2}$$

Where the ZC root sequence index u is 25, 29 and 34 for NID(2)= 0,1,2 respectively and d(0)=d(32)=0.

The Zadoff-Chu sequence of length 62 is centered around the d.c. zero frequency index subcarrier to avoid d.c. injection. The roots used to generation the PSS with physical layer identity = 0, 1, 2 are u = 25, 29, and 34 respectively. These sets of roots are selected due to good autocorrelation and cross correlation properties, resulting in better frequency and time offset sensitivity. PSS can detect up to +/- 7.5 KHz of frequency offset due to the frequency domain autocorrelation and low frequency offset sensitivity. The UE uses non-coherent detection, as it detects PSS without prior knowledge of channel.

TABLE I

DEFINED MODES IN LTE

N_{IFFT}	Bandwidth (MHz)	Occupied Subcarriers	Normal CP	Extended CP
128	1.4	76	10/9	32
256	3	151	20/18	64
512	5	301	40/36	128
1024	10	601	80/72	256
2048	20	1201	160/144	512

Like the PSS, SSS is also broadcast twice during every radio frame; but both transmissions are not identical. Like the PSS, SSS is also mapped to the central 62 subcarriers.

Initially, for the generation of SSS, the two basic sequences only were used. This caused double collision problem, as the sequence index of more than one cell group ID were same. To avoid the double collision problem the occurrence of basic sequence was randomized by using scrambling sequences; which increased the complexity.

The sequence used for SSS generation is given by:

$$d(2n) = \begin{cases} s_0^{(m_0)}(n)c_0(n)\ in\ subframe\ 0 \\ s_1^{(m_1)}(n)c_0(n)\ in\ subframe\ 5 \end{cases}$$

$$d(2n+1) = \begin{cases} s_1^{(m_1)}(n)c_1(n)z_1^{(m_0)}(n)\ in\ subfram \\ s_0^{(m_0)}(n)c_1(n)z_1^{(m_1)}(n)\ in\ subfram \end{cases} \tag{3}$$

where, d(n) is the binary value of the nth subcarrier of SSS sequence; c(n) and z(n) are the scrambling sequences; s(n) is the basic sequence useful for distinguishing each cell group IDs.

III. PROPOSED PSS AND SSS STRUCTURES

A PSS structure in which the ZC sequence is divided into two segments is mentioned in [19].As mentioned in [19], the PSS segments are complex conjugates of each other and is as follows:

$$d(n) = \exp(-j\pi u(n+1)n/31) \quad 1 \le n < 32$$
$$d(n) = du^{*}(34-n) \quad 33 \le n < 64$$
$$d(0) = d(32) = 0 \qquad (4)$$

In the proposed signal structure the first segment is the normal ZC sequence; second segment is the complex conjugate of the first; third segment is the negative of the first part; fourth segment is the conjugate of the negative of the first part and is as follows:

$$d(n) = \exp(-j\pi u(n+1)n/15) \; 1 \le n < 16$$
$$d(l) = d(n)^{*} \; 17 \le l < 32$$
$$d(m) = -d(n) \; 33 \le m < 48$$
$$d(o) = d(m)^{*} \; 49 \le o < 64 \qquad (5)$$

The SSS sequence that avoids the double collision problem without using scrambling sequence is given by:

$$d_0(2n) = s(m_0)(n)$$
$$d_0(2n+1) = s(m_1)(n)$$
$$d_1(2n) = s(m_2)(n)$$
$$d_1(2n+1) = s(m_3)(n) \qquad (6)$$

where, $m_0 = x$, $m_1 = m(x+y) \bmod 31$, $m_2 = (1+x+2y) \bmod 31$ and $m_3 = (7+x+3y) \bmod 31$. In (6), $x = (i_G) \bmod 31$, $y = \lfloor i_G/31 \rfloor$, and i_G is the cell group index. $s(m_0)(n)$,$s(m_1)(n)$,$s(m_2)$ and $s(m_3)(n)$ are cyclic shifted sequences of the m-sequence of length 31 with generator polynomial x^5+x^2+1, and m_0,m_1,m_2 and m_3 denote corresponding cyclic shift indices.

The minimum hamming distance between the hopping sequence $\{m_0, m_1, m_2, m_3\}$ and the second order hopping sequence is made three so that no double collision occurs.

IV. PSS AND SSS DETECTION

Time and frequency synchronization is a very important factor in LTE system. Time synchronization tunes the OFDM symbol and LTE frame timing. Frequency synchronization estimates and compensates the Carrier Frequency Offset (CFO).CFO occurs due to the mismatch between the transmitter and receiver oscillators, and the Doppler shift caused by the relative motion between transmitter and receiver. CFO of a received signal consist of an integer multiple of the carrier frequency (called IFO) and a fractional part (called FFO),that is less than the carrier frequency.

The mobile station or user equipment will have the three ZC sequence stored in it. The received signal is cross correlated with the three stored ZC sequences at the UE. There will be three values of result produced; of which one will have a maximum value and the other two will have low values. A peak detector is used to find the peak or maximum value of the three results. Thus the sector ID of the serving cell can be found.

In the proposed PSS structure, each set of 16 subcarriers of the PSS transmitted from ENodeB are cross correlated with corresponding set in the UE ,for each PSS. Of the four sets the one with maximum correlation is used to find the Sector ID. Thus to determine the sector ID the set with less error is used. After the PSS is detected, detection of SSS is done. The odd and even subcarriers of received SSS are cross-correlated with the odd and even subcarriers of the possible 168 SSS sequences respectively to find out (m_0, m_1, m_2, m_3).From the look-up table the cell group ID corresponding to the obtained (m_0, m_1, m_2, m_3) is found out. Using the equation (1) the cell ID is found out.

V. SIMULATION AND PERFORMANCE EVALUATION

The complexity is reduced since the size of ZC sequence to be considered for detection is almost one fourth of the basic ZC PSS sequence. Thus the number of complex multiplications required also decreases significantly.

Fig. 1. shows the constellation of 64-Sequence PSS. The constellation is a unit circle as per the CAZAC property.

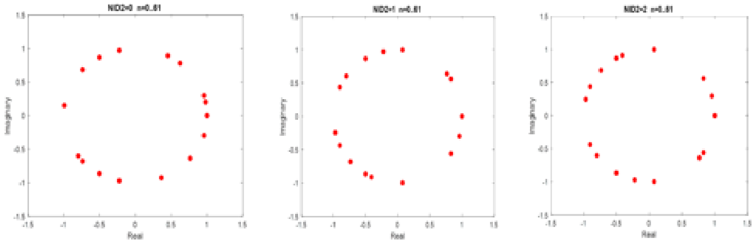

Fig. 1. PSS constellation: 64 Sequence

Fig.2 shows the cross-correlation of the PSS for sector ID zero with all the three possible PSS sequences. The auto-correlation of PSS sequence for sector ID zero shows a maximum value at zero and minimum value at other points.

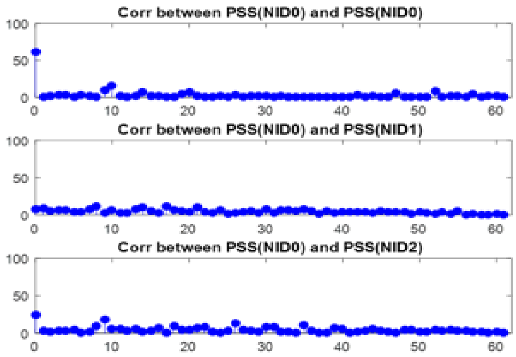

Fig. 2. Cross-correlation between PSS for sector ID=0 and all the three possible PSSs.

Fig.3. shows the PSS constellation for 16-sequence PSS structure. Like the 64-sequence , 16-sequence constellation is also a unit circle.

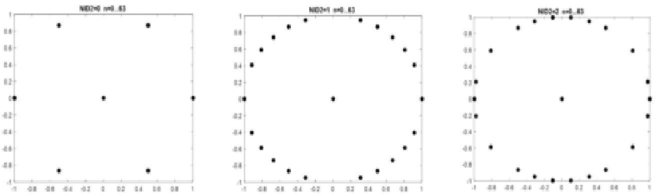

Fig. 3. PSS constellation: 16 sequence

Fig.4. shows the SSS for subframe 0 and subframe 5.The SSS in both the subframes are different.

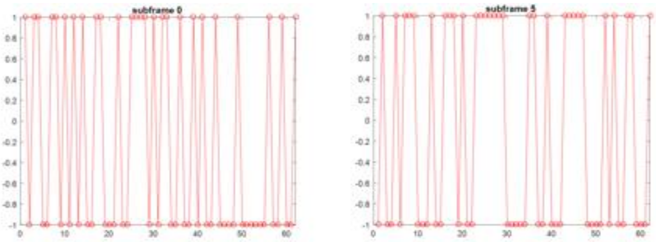

Fig. 4. SSS:Existing

Fig. 5. Shows the modified SSS for subframe 0 and subframe 5.Like the existing SSS, magnitude at different points is one and SSS in both subframes are different.

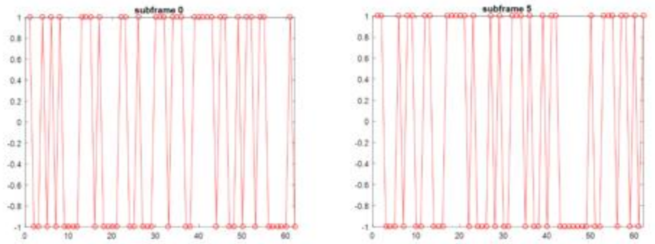

Fig. 5.SSS:Proposed

VI.CONCLUSION

In this paper a low complex PSS and SSS structure is proposed. In the existing system the whole 62 subcarriers were used to find the sector ID. But in the proposed PSS structure only 16 subcarriers is used to find the sector ID, which can reduce the complexity of PSS significantly. The SSS generated without using scrambling sequences also reduces the complexity significantly.

REFERENCES

[1.] "LTE: The evolution of mobile broadband",LTE part 11:3GPP release 8

[2.] Pei-Yun Tsai and Hsiang-Wei Chang ,"A New Cell Search Scheme in 3GPP Long Term Evolution Downlink OFDMA Systems," 2009 IEEE

[3.] Ameneh Golnari," A Low Complexity Architecture for the Cell Search Applied to the LTE Systems," 2012 IEEE

[4.] Konstantinos Manolakis," A Closed Concept for Synchronization and Cell Search in 3GPP LTE Systems," 2009 IEEE

[5.] Na Ding, Chen Chen, Wenhua Fan,Yun Chen and Xiaoyang Zeng, “An Improved Coarse Synchronization Scheme in 3GPP LTE Downlink OFDM Systems” IEEE 2012

[6.] Wen Xu, Konstantinos Manolakis,” Robust Synchronization for 3GPP LTE System ,” IEEE 2010

[7.] Ilgyu Kim,Youngnan Han,Hyun Kyu Chung, “An Efficient Synchronization Signal Structure for OFDM-Based cellular system,” IEEE Transacations on Wireless Communication, Vol.9,No.1,Jan 2010, pp.99-104.

[8.] Leila Nasraouri, “A Simply-Differential Low Complex Primary Synchronization Scheme for 3GPP LTE Systems,”

[9.] L.Taghavifar , B.Kouhi, “Primary Synchronization Signal in LTE/LTE-Advanced Systems,” JWEET,2013,pp.43-46.

[10.] Juan I. Mazarico,Vinod Kumar,” Detection of synchronization signals in Reuse-1 LTE networks ,“ IEEE 2009

[11.] Chixiang Ma, Hao Cao and Ping Lin,”A Low-Power Low-Cost Design of PrimarySynchronization Signal Detection”IEEE Transactions on Very Large Scale Integration (VLSI) Systems, Vol. 20, No. 7, July 2012

[12.] Mohammad H. Nassralla, Mohammad M. Mansour,” A Low-Complexity Detection Algorithm for the Primary Synchronization Signal in LTE,” IEEE Transactions on Vehicular Technology ,Nov, 2015

[13.] Isael Diaz,” A Sign-Bit Auto-correlation Architecture for Fractional Frequency Offset Estimation in OFDM,” IEEE 2010

[14.] Szu-Lin Su, Yung-Chuan Lin, Yun-Jhen Fan,” Joint sector identity and integer part of carrier frequency offset detection by phase-difference in Long Term Evolution cell search process,” IET Commun., 2013, Vol. 7, Iss. 10, pp. 950–959

[15.] Ameneh Golnari, “Design and Implementation of Time and Frequency Synchronization in LTE,”IEEE Transacions on Very Large Scale Inregration(VLSI) Systems.

[16.] Liu Kewen,” An improved ML estimation of frequency and time offset in FDD-LTE initial cell search process,” Procedia Engineering 15 (2011) 2250 – 2254

[17.] Jung-In Kim,Jung-Su Han,Hee-Jin Roh and Hyung-Jin Choi ,“SSS Detection Method for Initial Cell Search in 3GPP LTE FDD/TDD Dual Mode Receiver” IEEE 2009

[18.] I1 Gyu Kim: Keecbeon Kim and ByeongWoo Liin .”A Fast Cell Search Algorithm for Inter-cell Asynchronous W-CDMA System using Code Hopping Method “,IEEE 1998,pp.1373-1377

[19.] Kapseok Chang, “Signal Design for Reduced Complexity and Accurate Cell Search/Synchronization in OFDM-Based Cellular Systems,” IEEE Transactions on Vehicular Technology,Vol.61,No.9,Nov 2012

[20.] Nurul ‘Ain Amirrudin ,Sharifah H. S. Ariffin, N. N. N. Abd Malik, N. Effiyana Ghazali” Mobility Prediction via Markov Model in LTE Femtocell” International Journal of Computer Applications (0975 – 8887) Volume 65– No.18, March 2013