Analysis of PSS Detection Scheme in Long Term Evolution Systems

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***Abstract*-A cell search procedure is used by User Equipment (UE) to acquire time and frequency synchronizationwithin a cell and to detect the cell identity.Cell search in LTEis performed using the Primary Synchronization Signal (PSS) and Secondary Synchronization Signal (SSS) in a hierarchical manner. Thus PSS detection forms a vital part of cell search.**

In this paper we have simulated the generation of PSS by using complex Zadoff Chu (ZC) sequence. We also simulate the scheme for PSS detection of cell identity using Linear Correlation. The spectral analysis of the same has been performed. The probability of detection for the proposed scheme is evaluated for various white Gaussian noise channels.

Keywords-Cell search, LTE, PSS, ZC sequence.

I. INTRODUCTION

Long Term Evolution (LTE) systems offers transmission rates up to 50 Mbps on the Uplink (UL) and 100 Mbps on the Downlink (DL) [1]. In this system, a scalable transmission bandwidth is designed to allow user mobility up to 350 kmph, with slight reduction of performance.LTE uses Orthogonal Frequency Division Multiple Access (OFDMA) for the downlink transmission and Single Carrier Frequency Division Multiple Access (SCFDMA) for the uplink transmission [2-4].

Cell Search is a basic function of any cellular system, during which cell identity of LTE radio cell is obtained by the mobile unit. The celldetection in LTE is tightly linked to the Primary Synchronization Signal (PSS) and the Secondary Synchronization Signal (SSS) [2, 3].

A length-63 Zadoff-Chu (ZC) sequence, whichoccupies the central six Resource Blocks (RBs) of the systembandwidth, is used to generate the PSS. Since the SSS detection can be performed only after the PSSis successfully identified, the overall DL synchronizationperformance is therefore heavily dominated by a robust PSSdetection.

Synchronization and cell search in 3rd Generation Partnership Project(3GPP) LTE systems based on thefrequency-domain identification of PSS and SSS are discussedin [5]. In [6], a robust time and frequency synchronizationscheme in 3GPP LTE is proposed.The PSS detection depends on a cross-correlationoperation being performed between the received and localZC sequences and has a relatively high complexity. In [7] the essential central-symmetric property of the ZC sequences have been exploited to improve the PSS detection performance, and based on this property, three high-performancePSS detectors have been proposed.

This paper proposes Linear Correlation scheme to detect physical layer identity from PSS. The property of zero autocorrelation has been exploited for the same. The scheme is applied for channels with varying Signal to Noise Ratio (SNR). The probability of PSS detection is estimated under various conditions. The performance of the scheme is evaluated using simulations.Thegraph showing Power Spectral Density (PSD) for ideal PSS detection is also presented.

The paper is organized as follows. In Section II the radio frame structure and cell searchin LTE is explained. Section III describes generation of PSS.PSS detection using linear correlation scheme is explained in Section IV.Section V describes the spectral analysis. The probabilistic analysis is explained in section VI. Finally, theconclusionsaredrawnin Section VII.

II. LTE RADIO FRAME AND CELL SEARCH

A Time Division Duplex (TDD) and Frequency Division Duplex (FDD) frame structures (type 1 and 2 respectively) in LTE, are organized in radio frames units of length 10 ms. Each radio frame is divided into 10 sub frames of length 1 ms, which are further divided into two slots of length 0.5 ms. Each slot either contains 7 OFDMA symbols with short Cyclic Prefix(CP) or 6 OFDMA symbols with long CP.

The synchronization signals are transmitted periodically, twice per 10 ms radio frame. In a FDD frame the PSS is always located in the first and eleventh slots independently of the CP length. The SSS is located in the symbol immediately preceding the PSS.This design enables coherent detection of the SSS relative to the PSS. [2,3]

LTE defines 504 unique physical layer cell identities. To accommodate and manage this large amount, the cell identities are divided into 168 unique physical layer cell layer identity groups. Each group further consists of three physical layer identities. The cell identity is delivered to UE using Broadcast Channel.

PSS is used to detect one of three physical layer cell identity, represented by $N_{ID}^{(2)} = 0, 1, 2.$ SSS is used to determinethephysical layer cell identitygroup,given by $N_{ID}^{(1)} = 0,\ 1,\ \dots, 167.$ The complete cell search procedure consists of calculating the cell's identity, after the detection of synchronization sequences, by applying the equation,

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$$N_{ID}^{cell} = 3N_{ID}^{(1)} + N_{ID}^{(2)} \quad (1)$$

LTE uses a hierarchical procedure for cell search. The detection of physical layer cell identity group from SSS can only be performed after successful detection of PSS. Thus successful PSS detection is vital for cell search in LTE.

III. PSS GENERATION

The PSS is constructed from a frequency-domain polyphaseZC, with the middleelement punctured to avoid transmitting on the d.c.subcarrier.A ZC sequence is a complex-valued mathematical sequence which exhibits the useful property that, cyclically shifted versions of it are orthogonal to each other.In particular, these sequences have a low frequency-offset sensitivity, defined as the ratio of the maximum undesired autocorrelation peak in the time domain to the desired correlation peak computed at a certain frequency offset. This allows a certain robustness of the PSS detection during the initial synchronization.

The mapping of the PSS sequence to the subcarriers is shown in Figure 1.

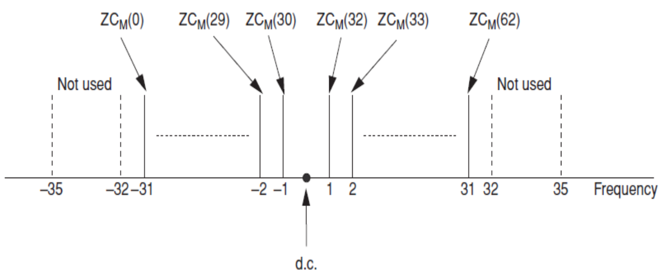

Figure 1. PSS sequence mapping in the frequency domain.

Three ZC sequences are used in LTE forgeneratingPSS.They are generated in frequency-domain according to the equation [3],

$$ZC_u^{N_{ZC}} = e^{-j2\pi u \frac{n(n+1)/2 + ln}{N_{ZC}}} \; ; n = 0,1,2 \ldots, N_{ZC} - 1 \quad (2)$$

WhereN_{ZC} = 63, is the length of the sequence. In LTE, l = 0and$u$ is the root index selected from the set {25,29, 34}.

The three values of $N_{ID}^{(2)}$ = 0, 1, 2 are represented by the PSS with three different ZC root indices u = 25, 29, 34 respectively.

We have generated PSS sequence of length 63 using equation (2) for each root index. [8] The generated sequence has constant amplitude.

IV. PSS DETECTION

The PSS signal is transmitted in Time Domain. To obtain time domain sequence IDFT is applied to the generated ZCsignal.The transmitted signal gets distorted due to noise present in the channel. The channel is modeled as Additive White Gaussian Noise (AWGN). The effect of AWGN on the received signal can be studied using Signal to Noise Ratio (SNR).

SNR is calculated using following formula,

$$SNR = \mu/\sigma \quad (3)$$

Where μ= Signal Mean

σ= Standard Deviation of the Noise

Block diagram for PSS detector is as shown in figure,

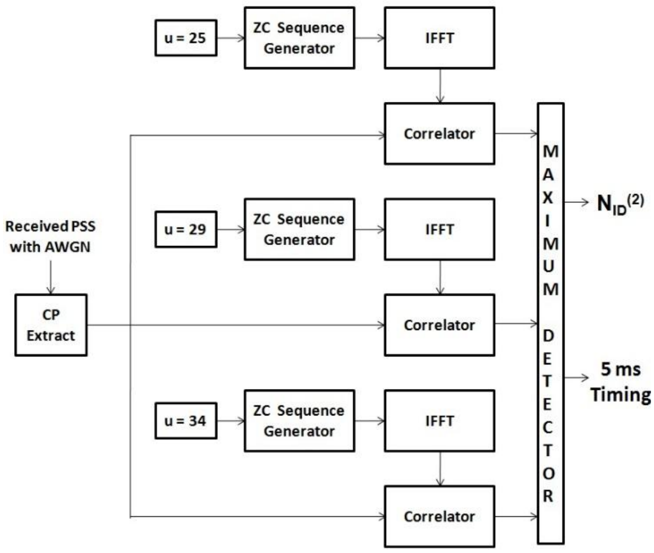

Figure 2.Block diagram for PSS detector.

Figure 2 shows that the received PSS is correlated with the three ZC sequences of each of the rootsu = {25, 29, 34}.The correlator block can be implemented using Linear correlation.

Linear Correlation is given by the following equation,

$$r_{xh}(k) = \sum_{n=0}^{N-1} x(n-k).h^*(k) \quad (3)$$

Where k = Time Lag, and
N = length of the sequence.

The linear autocorrelation function is given by,

$$r_{xx}(k) = \sum_{n=0}^{N-1} x(n-k).x^*(k) \quad (4)$$

Where k= Time Lag, and
N= length of the sequence.

The autocorrelation peak is detected by the maximum detector.By using the zero autocorrelation property, it returns the corresponding root index andthus the physical layer identity is detected from the received PSS. Thus PSS is detected successfully. [8]

V. SPECTRAL ANALYSIS

The correlation used to detect the PSS is performed in time domain. The energy distribution in the frequency domain can be studied by spectral analysis. The graph showing the PSD is shown in Figures 3-5.

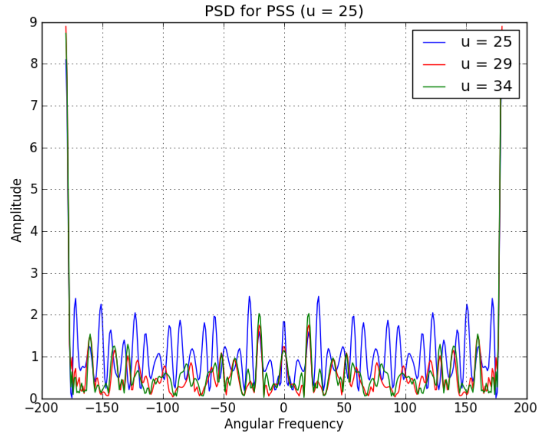

Figure 3.PSD for detection of PSS with root 25.

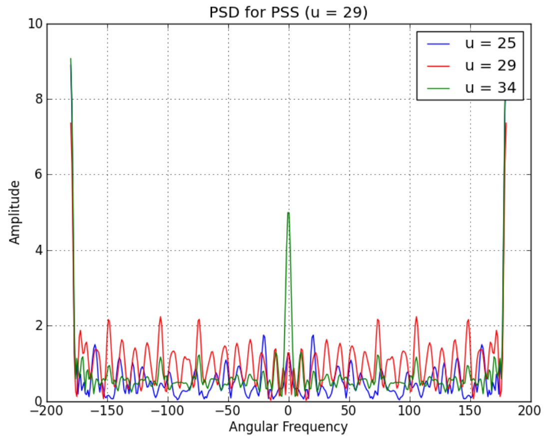

Figure 4.PSD for detection of PSS with root 29.

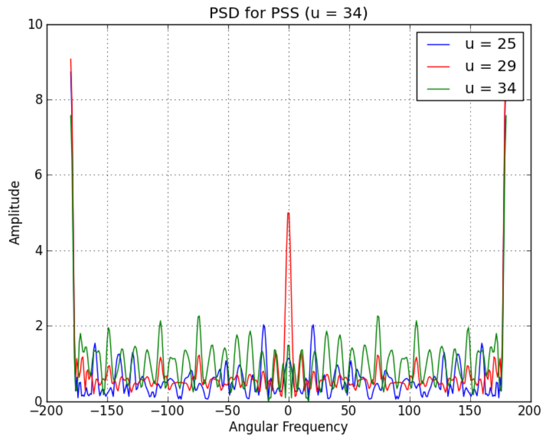

Figure 5.PSD for detection of PSS with root 34.

The area under the PSD plot shows the energy present in the signal. Figure 3 shows that the energy contained in correlation of PSS for root u = 25 is more than that of u = 29 and u = 34. Similar observations can be made from Figures 4 and 5. Thus the energy contained in the autocorrelation signal is more than the cross-correlation signal.

VI. PROBABILISTIC ANALYSIS

The PSS detection using the proposed schemes has been simulated for noisy channels.Monte Carlo simulations using 10000 trials were used to estimate the probability of detection for various values of SNR, for each scheme.

Probabilityofphysical layer identity detection using linear and circular correlation for various values of SNR is shown in Figure6.

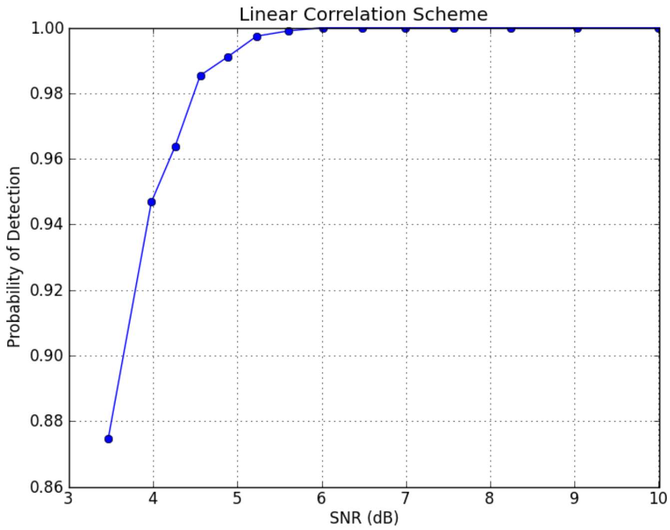

Figure 6.PSS Detection Probability.

Figure 6shows that the probability of PSS detection is constant up to SNR of 6 dB. As SNR reduces, the performance of the scheme degrades gradually.The computation of linear correlation requires appending of zeros to the received signal.

VII. CONCLUSION

This paper describes schemes for generation and detection of PSS, of LTE systems,using linear correlation.Theschemeis designed to determine the physical layer identity correctly.Spectral analysis of the proposed scheme shows the energy content of the correlation signals. The area under power spectral density curve is equal to total signal power which is more for autocorrelation signal.

The performance of PSS detection is evaluated by calculating probability of detection for various SNR values. The scheme performs well up to SNR of 6dB. As cell search largely relies on PSS detection, the linear correlation scheme proves to be advantageous. This enables a robust connection to base station.

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