CHAPTER ONE

Introduction

1.1 Introduction:

Long Term Evolution is the latest advancement in the field of wireless communication system. Wireless communication has travelled a long journey from the first Generation to fourth Generation. Starting in the 1980's, the first commercial wireless technology that served basic voice communication used analog narrow band FM modulation. The multiple access mechanism of the first generation used Frequency Division Multiple Access (FDMA), having transmission bandwidth in 20 – 30 KHz range.

Third generation (3G) wireless systems were extended version of the second-generation systems designed to increase wireless data rates. European and American started their own projects for third generation mobile phone system called 3rd Generation Partnership Project (3GPP) and 3rd Generation Partnership Project 2 (3GPP2).

3GPP started evolving into the Universal Mobile Telecommunications System (UMTS), it is an extension to GSM. 3GPP2 starting working on Code Division Multiple Access 2000 (CDMA2000), evolved from Code Division Multiple Access (CDMA). Both technologies were based on CDMA. UMTS uses Wideband CDMA (WCDMA) as radio access technology, which uses Direct Sequence CDMA (DS-CDMA) and occupies 5 MHz of bandwidth [1].

The 3GPP standard started from Global System of Mobile/General Packet Radio Service GSM/GPRS, which was based on TDMA and FDMA access technology, then moved towards Code Division Multiple Access, that used both circuit switched and packet switched technology. Finally, it moved towards mobility and high-speed wireless mobile broadband system long Term Evolution (LTE) is the advanced version of the 3GPP for fulfilling transmission targets of four generation (4G) mobile communication system [1].

The link LTE system:

- Adopts orthogonal frequency division multiple access (OFDMA) technique both for combating the multipath effect of frequency selective channel and for achieving high data rates.
- The LTE specification provides downlink peak rates of at least 100 Mbps, and uplink of at least 50 Mbps.
- LTE supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz and supports both frequency division duplexing (FDD) and time division duplexing (TDD).

The long term evolution (LTE) is based on Single-Carrier Frequency-Division Multiple Access (SC-FDMA) in up-link and orthogonal Frequency-Division Multiple Access (OFDMA) in down-link. LTE is offers favorable features such as reduced delay for connection establishment, robust performance in frequency selective channel, lower latencies, simpler and cost effective system, high spectral efficiency, and simple receiver architecture [2].

1.2 Problem statement:

If the sector identity is detected fast and correctly by the Primary Synchronization Signal (PSS), the correctly cell identification is detected. Detection of PSS may be inaccurate if the object is moving with a high speed the channel can vary from symbol to symbol performing accurate detector of the PSS will reduce the synchronization and cell search delay time.

In this project we built stable receiver sub-system use the symmetry property samples of the PSS detection of the LTE to reduce the computing complexity to be fast and accurate.

1.3 Aim and Objectives:

The aim of this project is to improving fast synchronization scheme detection for LTE.

The objectives are:

1-To study the PSS & SSS and its calculations in LTE.

2-To improving the cell search procedure in terms of lower complexity and increased detection probability.

3-To reduce the time delay performing fast and accurate detector of the PSS will reduce the Synchronization &cell search delay time.

1.4 Methodology:

In identifying the sector with the highest signal level first perform a cross-correlation of the received symbols on the 62 centered subcarriers with replicas of the PSS signals.

Detect the orthogonal frequency division multiplexing symbol time by maximize time offset, primary synchronization signal, secondary synchronization signal and its calculations from given equations.

The calculations and results will introduce from given data and using MATLAB program for simulation.

1.5 Thesis outline:

The outline of the thesis is as follows:

Chapter Two provides a description of Orthogonal Frequency Division Multiple Access (OFDM), and discusses cell search in LTE.

Chapter Three describes methodology access procedure and design challenges for stability of system, provides detailed insight into cell search procedure, sequence generations and detection of synchronization signals.

Chapter Four the simulation parameters and results carried out by using MATLAB

Chapter Five will give conclusions and recommendations.

CHAPTER TWO

Literature Review

2.1 Introduction:

OFDM is a method of encoding digital data on multiple carrier frequencies. OFDM is a frequency division multiplexing FDM scheme used as a digital multi-carrier modulation method. Wireless is a high speed application wanted at the cost of minimizing losses and limited RF channel bandwidth. The OFDM technique was used in several high frequency military systems. The concept of OFDM has been around as early as 1960's. In 1980's OFDM was studied for high speed modems [1].

A large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintaining total data rates similar to conventional single carrier modulation schemes in the same bandwidth. OFDM is a specialized FDM, the additional constraint being all the carrier signals are orthogonal to each other.

OFDM is transmits a large number of narrow band carriers, closely spaced in frequency domain, to avoid a large number of modulators and filters at the transmitter and complementary filters and demodulators at the receiver it is wanted to be able to use modern digital signal processing techniques, such as FFT Fast Fourier Transform Figure 2.1 show basic block diagram of OFDM transmitter and receiver.

The serial to parallel transformation is used to partition the high data rate signal into a number of low data rate signals, keeping the overall data rate of the system constant, Fast Fourier Transform (FFT) transforms a cyclic time domain signal into its equivalent frequency spectrum. This is done by finding the equivalent waveform; it was generated by a sum of orthogonal sinusoidal components. The amplitude and phase of the sinusoidal components represent the frequency spectrum of the time domain signal.

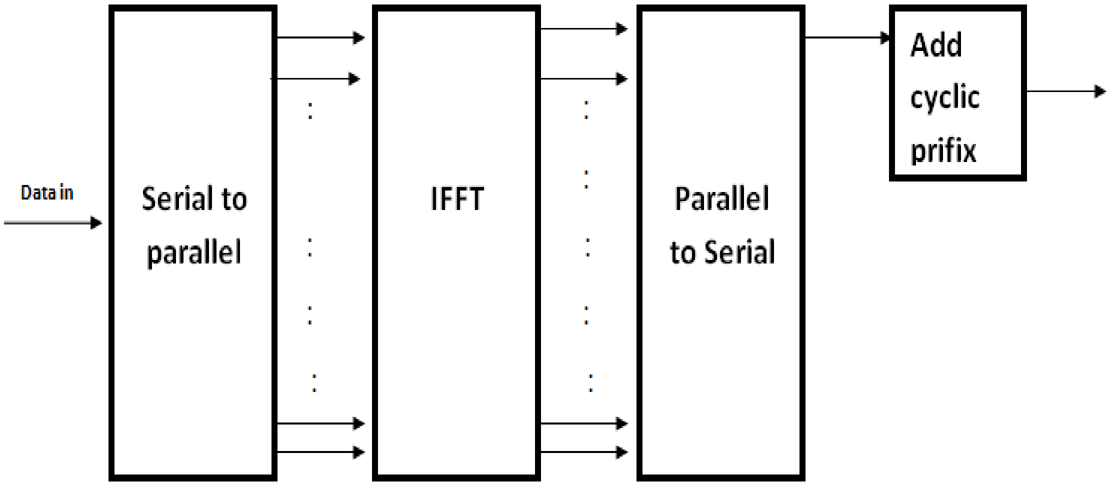

Figure 2.1: OFDM transmitter

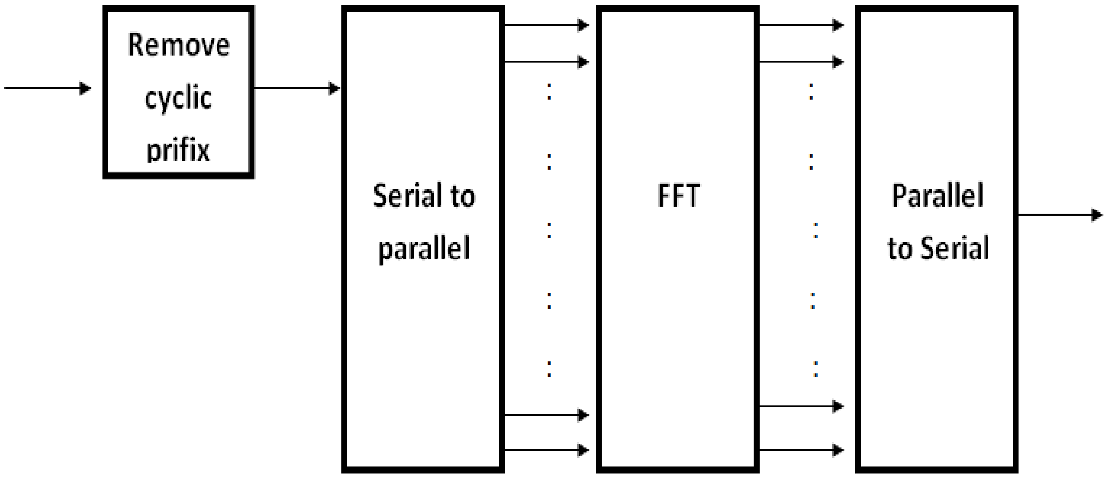

Figure 2.2: OFDM receiver

The IFFT performs the reverse process, transforming a spectrum amplitude and phase of each component into a time domain signal. An IFFT converts a number of complex data points, of length that is a power of 2, into the time domain signal of the same number of points. Each data point in frequency spectrum used for an FFT or IFFT is called a bin. The cyclic prefix (CP) acts as a guard interval to help mitigate the effects of the Inter Symbol Interference (ISI) and Inter Carrier Interference (ICI) caused by multipath propagation.

By add the cyclic prefix in the front of the symbol absorbs the transient response related to propagation and multipath propagation through the channel and when discarded at the receiver preserves the orthogonality of the signals at the receiver see Figure 2.4. The basic approach is to divide the available bandwidth of a single physical medium into a number of smaller, independent frequency channels. Figure 2.3 shows spectral occupancy in a basic FDM system [3].

One of the disadvantages of using the cyclic prefix is that it was uses a some part of bandwidth of the system, which could be used and can use this bandwidth to transmit more data. The cyclic prefix required in the transmission channel was a multipath component. Which the cyclic prefix is used to know the channel has more delay spread the length of the cyclic prefix. The cyclic prefix length is chosen and depends on the longest delay spread so that the smearing caused by the longest delay spread is confined to the cyclic prefix.

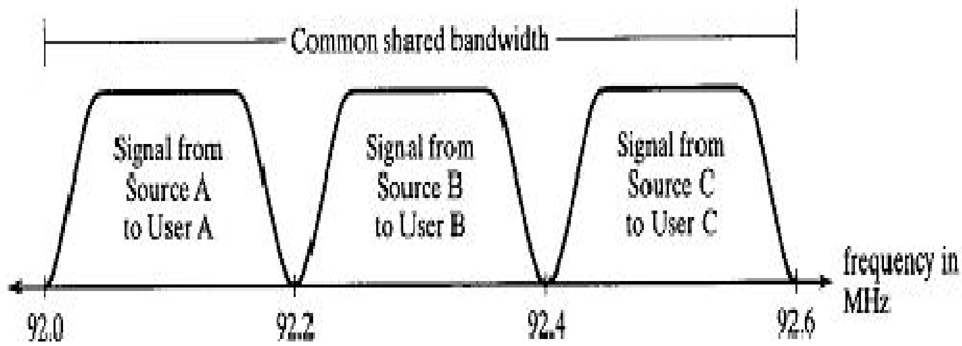

Figure 2.3: Spectral occupancy in OFDM system

2.2 Frequency and Time Synchronization in OFDM System:

To demodulate an OFDM signal the receiver needs to perform two important synchronization signals .Time synchronization and frequency synchronization, time synchronization is timing offset of the symbol need to be properly determined. Frequency synchronization in receiver must align its carrier frequency. The timing synchronization requirements are kind of relaxed when compared to single carrier systems since OFDM structure is designed to accommodate optimal level of error. Frequency synchronization is importance since orthogonality of signals depends on individual recognizable in frequency domain. Version of the symbols is received and undesired energy from subsequent symbol is added to this symbol resulting erroneous detection [5].

2.2.1 Frequency Synchronization:

The commonly represented form of subcarriers in OFDM is the sinc form which is represented as

$$sinc(x) = \frac{\sin(x)}{x} \qquad (2.1)$$

sinc is the sine function,

x is variable in x axis.

since the zero crossing of the frequency domain sinc pulses all line up as the frequency offset $\delta=0$ there is no interference between the carriers .in fact due mismatched oscillators at transmitter and receiver end the offset is never zero [5].

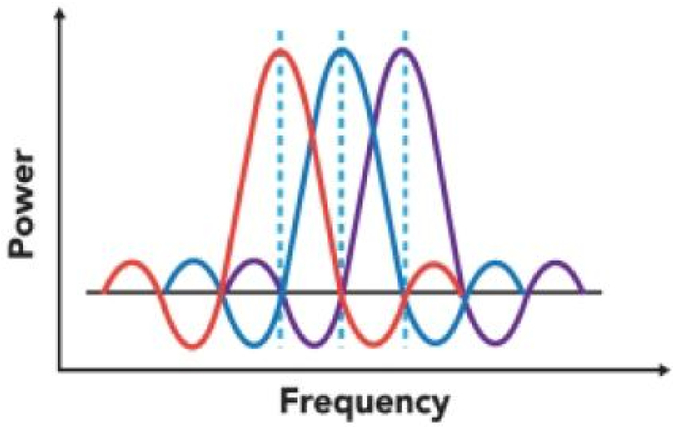

Figure 2.4 OFDM orthogonal subcarriers.

2.2.2 Time Synchronization:

The cyclic prefix minimizes the effect of timing errors in OFDM. If synchronization is not maintained is still possible to tolerate timing offset without any degradation in performance $0 \leq \tau \leq T_m - T_s$ where T_s is the guard time (cyclic prefix duration) and T_m is the maximum channel delay spread. Where $\tau<0$ corresponds to sampling earlier than ideal instant whereas $\tau>0$ is greater than the ideal instant .The timing offset can be included by channel estimator in the complex gain estimate for each sub channel and the phase shift can be applied without any loss in performance [5]. If the timing offset is not within the window ISI occurs regardless of whether the phase shift is appropriately accounted for the case where $\tau>0$ the receiver loses some of energy since only a delayed.

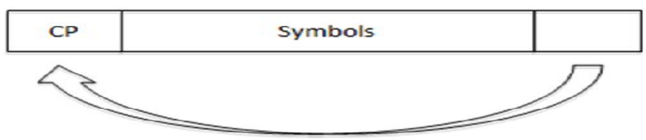

Figure 2.5: Cyclic prefix.

2.2.3 Obtaining Synchronization:

Synchronization is obtained in OFDM communication systems using cyclic prefix and pilot symbol. Pilot symbols are transmitted at periodical intervals and the receiver knows what transmitted, attaining time and frequency synchronization is easy, but the cost of surrounding some throughput. In absence of pilot symbols cyclic prefix which also be used to obtain time and frequency synchronization.

2.3. Long Term Evolution (LTE):

Long term evolution is the brand name for emerging and developed technologies that comprise the existing 3G and 4G networks. In cellular communication systems the process of initial cell search is the UE must be able to perform search and initial synchronization for a base station to set up the downlink access. For the broadband wireless access, it is very important that the UE has to perform time and frequency synchronization procedures, containing searching for a cell base station and detecting frame arrival which is come to serve the UE when setting up the downlink transmission. To accomplish those operations, primary synchronization signal and secondary synchronization signal are transmitted periodically from base station to use the system of Long Term Evolution (LTE). There are 504 cell identities defined and packed into 168 cell identity groups such that each cell identity group contains three sectors it will be mentioned down in details. Generally after PSS and SSS detection UE will determine the radio cell identity and it is synchronized in time and frequency with the radio cell. Then the UE is will be ready to receive the radio cell downlink from broadcast data.

Next step that user equipment (UE) extract System Information Block (SIB) which it is broadcasted through Physical Broadcast Channel (PBCH), then UE acquire the Physical Random Access Channel parameters (PRACH) is used to generate PRACH preamble.

2.4 Cell Search in LTE:

The access procedure is happens firstly that the UE must be identified within the network. This access procedure is called the cell search and includes synchronization between UE and the cell and acquiring the information about cell.

OFDM system is sensitive to time and frequency offsets, which requires more timing and frequency synchronization for a data to be received. In order to send or receive data, the mobile unit must be synchronized with the network, when a user equipment mobile unit is powered on, it search the available radio cells and lock to one of them to continue communication, more than one mobile unit users simultaneously try to access the set of radio cells and also the user equipment mobile unit start it search without any knowledge of bandwidth it has allocated.

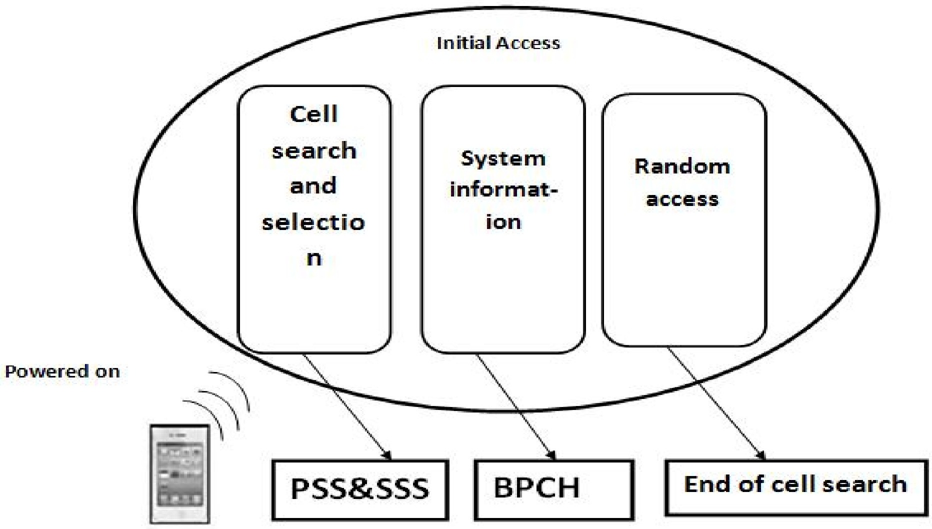

Figure 2.6: LTE access procedure.

Hence the initial cell search procedure must be implemented in timing and frequency synchronization. Here we present how a LTE mobile unit perform cell search and identifies the strongest radio cell near it. The timing and frequency synchronization that is required as part of this cell search procedure also performed.

Cell search is a basic function of cellular system, during which frequency and timing synchronization is obtained between mobile unit and network. Good execution of the cell search and selection procedure as well as acquire initial system information essential for UE before taking steps to communicate with the network.

2.4.1 Initial Cell Search:

Initial cell search is done in steps start when User Equipment (UE) is powered on in cellular mobile system, it is very important to perform time and frequency synchronization procedure to correctly determine the start of the signal and select best possible base station for a given UE it must perform cell search and synchronization with the base station to sending or receiving data.

This procedure is known as initial cell search. It is supporting the mobility of the base station with UE to search for signal called Received Signal Strength Indicator (RSSI) from the other cells or in doing handover.

Cell search includes:

- The Synchronization (frequency and time with base station and UE).
- Frame arrival on the channel in downlink frame structure.
- Identify Physical layer Cell Identitifier (PCI).

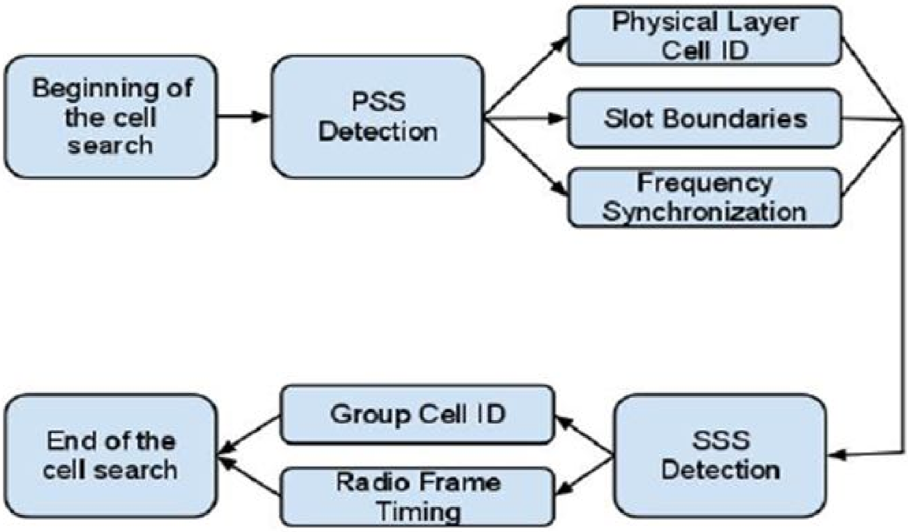

Figure 2.7: Cell search and synchronization signals.

The main signals used in LTE cell search synchronization process are synchronization signals of the cell from base station to mobile, Primary Synchronization Signal (PSS), and Secondary Synchronization Signal (SSS).

These two signals provide information about:

- Physical layer ID.
- Frame slot boundaries.
- Frequency synchronization.
- Group cell ID.
- And radio frame timing.

With all information about it, time, frequency synchronization and physical layer cell identities (PCI) can be extracted. LTE systems uses a hierarchical cell search procedure, the physical layer cell identity is consist of 504 unique physical layer cell identities. To accommodate and manage this large amount these cell identities can be derived using a hierarchal scheme which consists of 168 different physical layer cell identity known as group numbering from 0 to 167, and each group consists of three physical layer identities known as cell identity numbering from 0 to 2.

The physical layer cell identity hierarchy is shown in Figure 2.8 this is usually represented as N_g =0….167, N_s =0, 1, and 2 and cell identity N_c

$$N_c = 3N_g + N_s \qquad (2.2)$$

Where:

Nc is a number of cell identification

Ng is a number of group identification

Ns is a number of sector identification

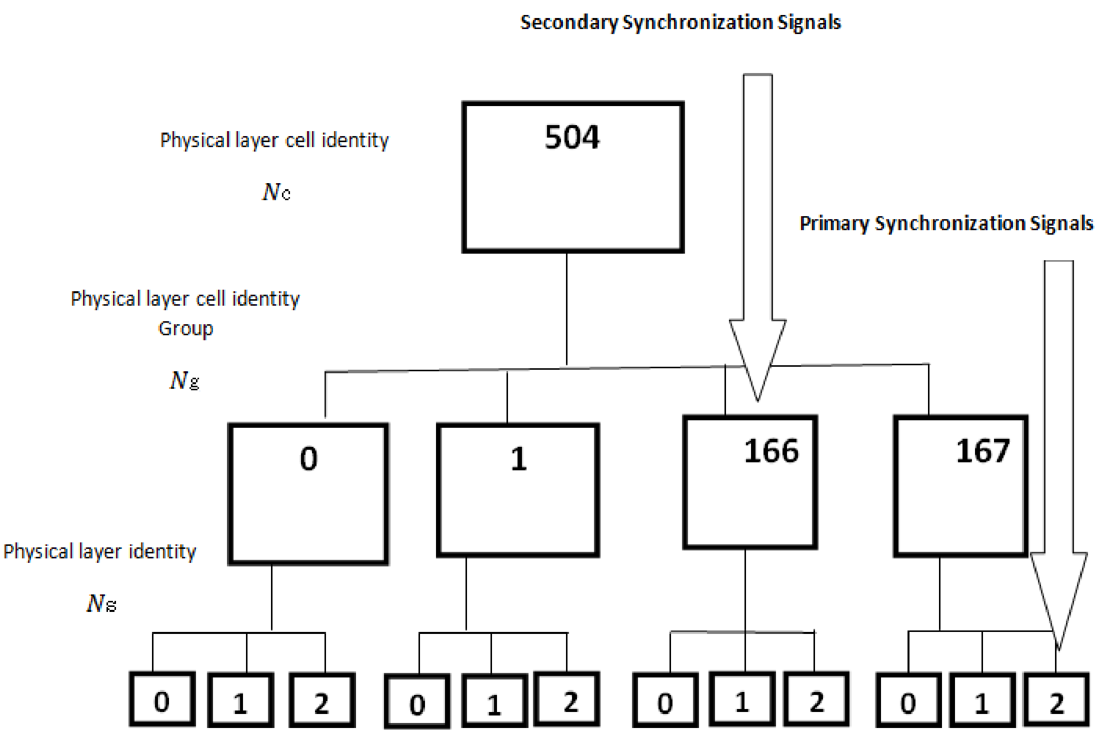

Figure 2.8: Primary Synchronization Signal and Secondary Synchronization Signal hierarchy.

2.5. Synchronization Signal:

In cellular network several targets must be achieved before first higher level connection can established. First UE needs to fined carrier frequency offset between the UE and base station. Then the OFDM symbol timing must be estimated. Finally the beginning of LTE frame needs to be found.

The long Term Evolution is specified a number of synchronization signals to allow timing and frequency synchronization and cell identity. They are now will describe in details as a knowledge is require to understand the synchronization and cell search procedure.

Hierarchical cell search procedure is performed in two steps using two signals primary synchronization signal and secondary synchronization signal. In general the synchronization signals have 72 subcarriers reserved for these signals, but they use only 62 of the 72 subcarriers. The reason of this only 62 sub carrier is used because it enables the UE to perform 64 point FFT and lower sampling rate [6].

The primary synchronization signal first it determine one of three cell identities (0, 1, 2), also represented by N_s. The secondary synchronization signal is used to determine a cell-ID between 0 and 167 represented by number N_g are shown in Figure 2.9.

The primary synchronization signal is based on sequence called zadoff-chu sequence is a complex–valued mathematical sequence which exhibits the useful property that cyclically shifted versions it is orthogonal to each other.

2.5.1 Downlink Frame Structure:

The discussion of the radio frame structure used in LTE. The radio frame is (10 ms) , each (1 ms) have 10 sub frames, each sub frame is subdivided into 2 slots each slot is(0.5ms), each slot has 6 OFDM symbols or 7 OFDM symbols depending on the length of cyclic prefix.

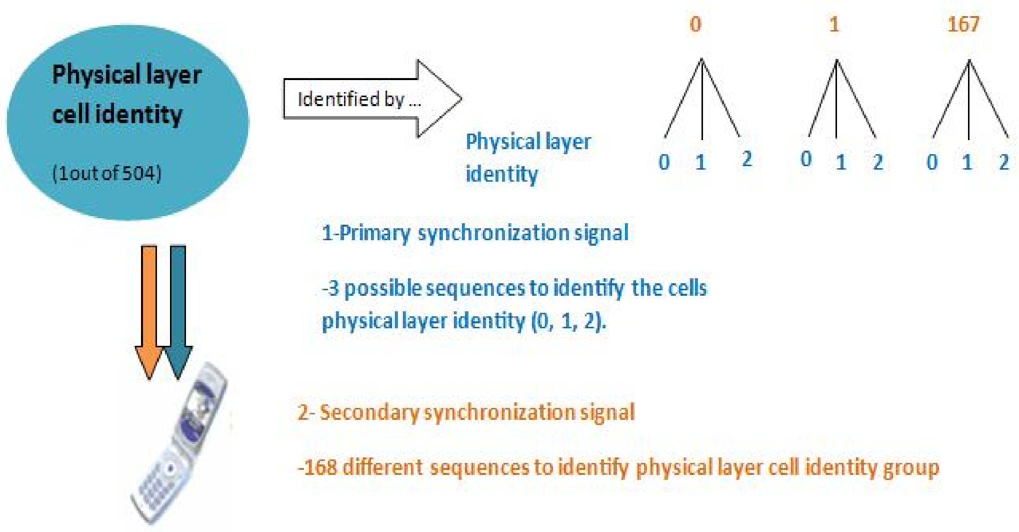

Figure 2.9: Representation of hierarchical cell search

If extended cyclic prefix is used, 6 OFDM symbols are used in 0.5ms slot, if normal cyclic prefix is used, 7 OFDM symbols are used in 0.5ms slot Figure 2.10 [6].

In Frequency Division Duplexing (FDD), in (LTE) the two signals are found in first sub-frame and sixth sub-frame, it also found in zero and tenth slot in 10ms frame of LTE frame.

In the OFDM symbol PSS is transmitted in last of the in first sub-frame and sixth sub-frame; both are identical to each other. With PSS detection, is achieving Physical Layer Identity (0-2).

SSS is transmitted prior to PSS. It is happen two times in .5ms slot and it is different in each slot. This difference of SSS is to differentiate between the first and second half of the radio frame for frame synchronization [2]. With detection of SSS, physical cell identity group (0 - 167) is determined.

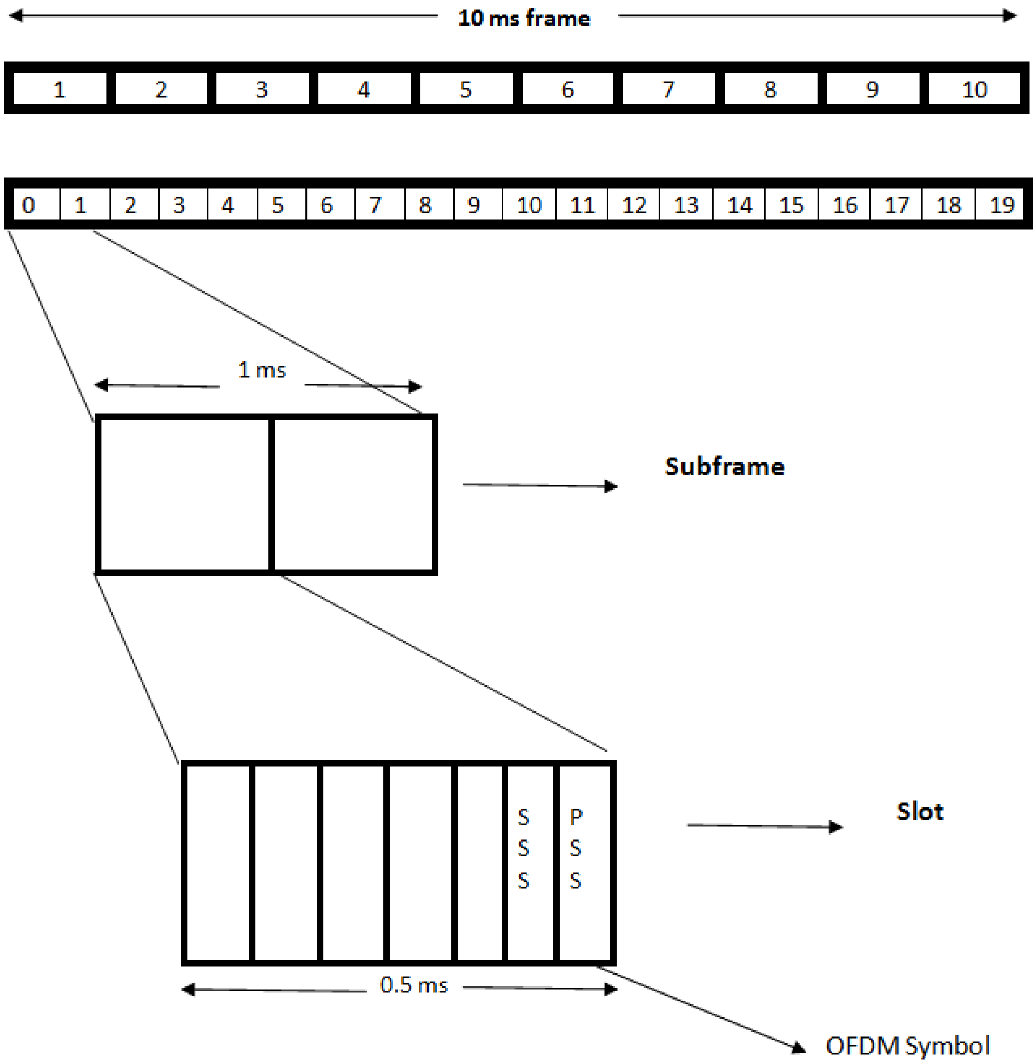

Figure 2.10: Downlink frame structure.

The primary and secondary synchronization signals are length 62 sequence. PSS and SSS are mapped to the 62 subcarriers around zero frequency subcarrier.

To avoid direct current injection the zero frequency subcarrier is set to be unused at the receiver. The two signals are transmitted in 72 subcarriers around DC subcarrier in central and used 62 subcarriers.

The remaining ten sub carriers, five subcarriers on each side are zero padded. Of the 72 subcarriers 62 subcarriers are used for transmission, and the 10 remaining subcarriers are zero padded. These 72 subcarriers occupy 1.08 MHz bandwidth [6].

The UE scans the bandwidth of the available frequencies to extract the basic information of the LTE cell such as transmission bandwidth, normal or extended cyclic prefix used multiple access, system frame number and physical channel cell identifier.

PSS uses special modulation sequence known as the Zadoff- Chu sequence for its generation. In the next chapter, the Zadoff- Chu sequence, PSS and will be introduced and described.

CHAPTER THREE

Methodology

Methodology

3.1 Overview:

In this chapter we will describe a concept for synchronization and cell search in 3GPP LTE downlink systems. It contains a full frequency synchronization and time synchronization of the cell identification and UE. The estimated cell identity is verified by a cell confirmation.

3.2 Access Procedure in Cell Search and Synchronization:

3.2.1 Introduction:

In the beginning the UE calculates the three sequences by Zadoff-Chu sequence and to do the DC zero forcing to obtain the Primary sequences. Then do cross correlation to the received signal with the sequences, by result of correct correlation sector identification can be estimated.

The orthogonal frequency division multiplexing symbol time can detected by maximize time offset .The correlation result with strongest signal is chosen for analysis.

This selection yields the sector-ID as there is a fixed relation to the family of the Zadoff-chu sequence. The correlation peak is proportional to time position gives the time offset to the start of radio frame between first and sixth sub frame.

In identifying the sector with the highest signal level first we perform a cross-correlation of the received symbols on the 62 centered subcarriers with replicas of the PSS signals in Figure (3.1) according to [11]:

$$Q_i(n) = \sum_{k=-31,k\neq 0}^{31} d_i(k)R(n+k) \qquad (3.1)$$

Where:

Q_i (n) is a cross-correlation of the received symbols
d_i (k) is the ith primary synchronization signal sequence.
R (n) is the received symbols.

The magnitude of the cross correlation output that gives the sector with the highest signal that shows a large peak result.
Thus the estimated sector identity is given by:

$$N_{S_{max}} = \arg\max\left(|Q_i(n)|\right) \tag{3.2}$$

$|Q_i(n)|$ Is the magnitude of the cross correlation output.

Next step, must extract the Secondary Synchronization Signal and separated into even subcarrier and odd subcarrier entries by $d(2n)$ and $d(2n+1)$ by equations mentioned in previous chapter.

When entries are even it dived through C_0 only. It depends only on the detected and estimated correctly the sector-ID. The result reference is afterwards using autocorrelation to obtain m_0 and achievement the cyclic shift. With m_0 can be compute the second scrambling sequence z_1^{m0} and afterwards divide the odd subcarrier entries $d(2n+1)$ through z_1^{m0} and c_1. The cross-correlation of the result with S reference shows a significant maximum, which indicates m_1. The pair of estimated m_0 and m_1 identifies the group identity N_g. The cell identity can then be calculated with
$N_c = 3N_g + N_s$

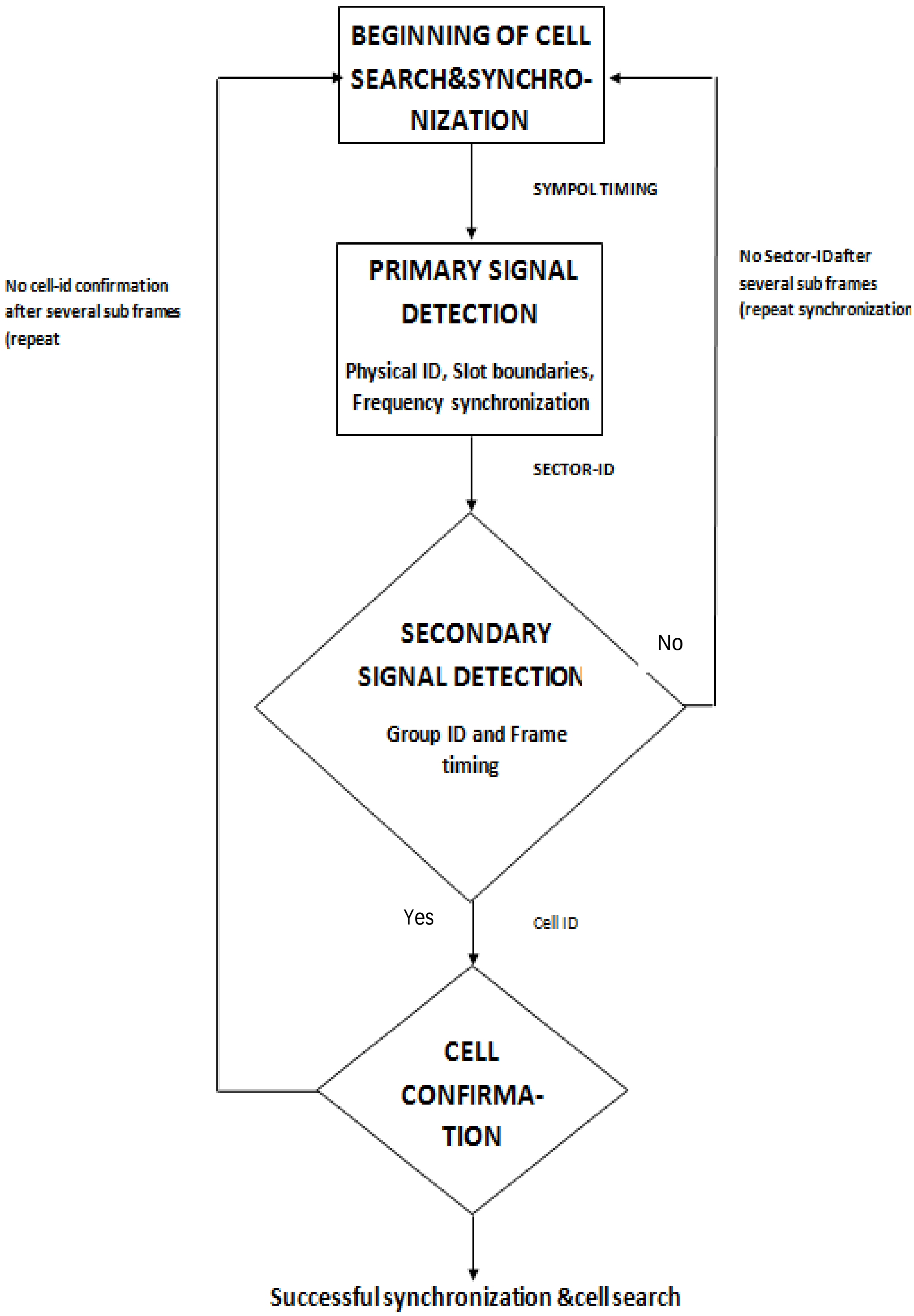

Figure 3.1: Synchronization and cell search procedure.

The cell search procedure is achieved for several cyclic shifts of the received signal $d(n)$, and give accurate primary synchronization signal.

After cell identity estimation finished the cell signal can be calculated in the receiver using the correct sector identity N*s* for the initialization of the sequence. The cell identity can be verified and calculated results by cross-correlation with the received signal. A significant peak show a successful synchronization and cell identification Figure 3 .1.

3.3 Cell Search Procedure:

In this chapter we will describe in detail the two synchronization signals that used in cell search and synchronization. The detailed procedure of performing cell search and synchronization using the PSS and SSS signals is described in this section. Firstly the UE (User Equipment) is switched on; it calculates all three possible Zadoff-Chu sequences and performs the DC zero forcing to obtain the three PSS then it send to base station to starts searching for a strongest cell in the downlink band. The capability of the bandwidth of the UE, it generally searches in the central part of the bandwidth. When the UE it has found a good candidate with the required 72 subcarriers (which are possibly the synchronization signals), the UE initially performs a rough frequency synchronization. Since the PSS (Primary Synchronization Signal) is mapped to resource elements after puncturing the DC element, the UE can look for the DC component and its surrounding subcarriers to perform the rough synchronization. The problems that the UE encounters and overcomes during initial startup are simulated in this section and the UE has to determine symbol start, it has to look for a cell and perform rough synchronization, it has to determine the carrier frequency, it has to perform timing synchronization, and has to perform fine frequency synchronization [14].

3.4 Zadoff- Chu Sequence:

Zadoff-chu sequence is widely used in the LTE system. The Zadoff-Chu sequence is also called a (CAZAC) sequence [7], It is defined as samples of a complex exponential function. The sequence is formed as a quadratic phase modulated sinusoid, which is responsible for the constant time domain. The constant envelope also purvey low Peak to Average Power Ratio (PAPR) to the time sequence, which is a desirable property for any sequence. The low PAPR permits the transmitter power amplifier to operate in a high efficiency regime. The parameters of Zaddoff-chu is responsible that it is good auto correlation, has one peak in correlation and without side lobes. With these auto correlation functions being an impulse, we can infer that its spectrum is a constant, a very desirable property of frequency domain channel estimation [7].
The Zadoff-Chu is complex exponential function with quadratic phase given by equations [8]:

$$\mathrm{Xu(m)} = e^{-\frac{j\pi u m^2}{\mathrm{Nzc}}} \quad \textit{When Nzc is even} \tag{3.3}$$

$$\mathrm{Xu(m)} = e^{-\frac{j\pi u (m+1)^2}{\mathrm{Nzc}}} \quad \textit{When Nzc is odd} \tag{3.4}$$

$$m=0,1,\ldots\ldots,(N\mathrm{zc}-1)$$

Where N_{zc} is length of the Zadoff-Chu sequence, and u one of 3 selected integers called the root index.

The following properties are set of the Zadoff-Chu (CAZAC) Sequence each sequence must has ideal autocorrelation, amplitude is fixed, it has good correlation of sequences with another function at zero side lobes, cyclic cross correlation at any sequences, it is amplitude fixed and the main property of the Zadoff-Chu sequence is that it does not need Discrete Fourier Transform DFT operation as its in frequency domain.

3.5 Primary Synchronization Signal (PSS):

The primary synchronization signal in LTE is designed to use one out of three possible Zadoff-chu sequences. They have length 63 and differ in family. The specification allows root index u {25, 29, and 34}. There is a mapping applied to construct the PSS in frequency domain out of a Zadoff-chu sequence**.**

Primary Synchronization Signal downlink frame appears twice, first in slot 0 and then in slot 10. Both the slots carry the same sequence. PSS provides information about sector, it have 3 different values from 0 to 2 depending [9]. Upon the root index of the Zadoff-Chu sequence (see Table 3.1). Once UE decodes PSS, it gets information about 5ms frame timing (sub frame timing) see Figure 3.2 [9].

PSS is uses 62 subcarriers of 72 subcarriers transmitted on the resource blocks and round the DC frequency index subcarrier, with the 5 subcarriers on each side are zero padded.

From now we will denote the physical cell identity as Nc, physical layer identity sector (PSS) as N_s and physical cell identity group (SSS) as Ng is generated using Equation 3.5 and 3.6 [9]:

The sequence d(n) used for primary synchronization signal is generated from a frequency domain Zadoff-chu sequence according to:

$$du(n) = e^{-j\frac{\pi un(n+1)}{63}} \quad n=0,1,\ldots,30 \tag{3.5}$$

$$du(n) = e^{-j\frac{\pi u(n+1)(n+2)}{63}} \quad n=31,32,\ldots,61 \tag{3.6}$$

Where the Zadoff-chu sequence root sequence index *u* is given by Table 3.1 [10].

Table 3.1: Zadoff-Chu Root Index (*u*) corresponding to primary synchronization signal [10]:

N_S	Root index (u)
0	25
1	29
2	34

The Zadoff-Chu sequence of length 62 is centered in the DC zero frequency index subcarrier to avoid DC injection. The roots used to generation the PSS with physical layer identity in table 3.1. The three roots are selected due to good cross correlation and autocorrelation properties, resulting in better frequency and time offset sensitivity. Primary synchronization signal can detect up to ±7.5 KHz of frequency offset due to the frequency domain autocorrelation and low frequency offset sensitivity [7]. The UE uses non-coherent detection, as it detects PSS without prior knowledge of channel.

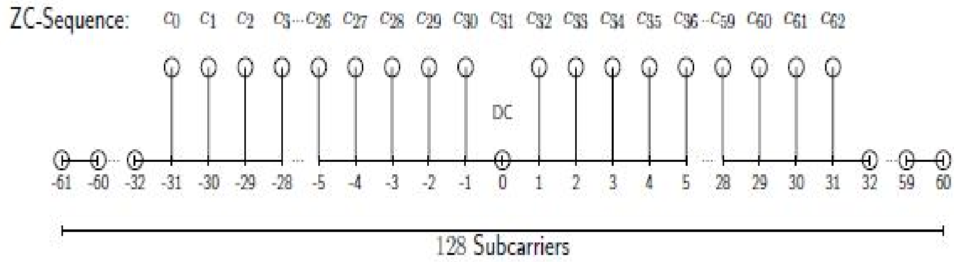

Figure 3.2: PSS mapping of a Zadoff-Chu sequence

3.6 Secondary Synchronization Signal (SSS):

The Secondary Synchronization Signal (SSS) is used by the UE to determine the cell-ID of the serving cell. As the PSS it does not directly catch the beginning of a LTE radio frame the UE can only estimate it using the SSS. Therefore the SSS must be differing between sub frame index 0 and sub frame index 5. The following section will describe how this is achieved and how the UE can find the cell-ID through the SSS.

Secondary synchronization signal helps to detect radio frame timing and physical cell identifier group. SSS uses interleaved maximal length sequence (m-sequence of length 31) to form a sequence of length 62. The SSS sequence of length 62 is mapped to resource block in the same manner as PSS transmitting the frequency domain signal around the DC. zero frequency index .The SSS signal depends on the group-ID and the sector-ID. To each group-ID a pair of numbers m_0 and m_1 is assigned. Through those numbers there can be generated two sequences s_0 and s_1 using length 31 linear feedback shift register. Those maximum-length sequences are than interleaved in frequency domain as shown in Figure 3.5 [9].

There is a scrambling applied on the even and the odd subcarrier entries separately in SSS. For the scrambling it has two additional sequences c_0 and c_1 are generated that are both based on a base scrambling code $\tilde{c}$. The shift values between the sequences indicate the sector-ID N_s. Further the information about the generation of the base scrambling can be found in the 3GPP specification.

A second scrambling is applied using the codes z_1^{m0} and z_1^{m1} that are also based on $\tilde{c}$. This time the shift depends on the group-ID Ng. However, this scrambling only applied to the odd subcarrier entries of the SSS. SSS can also be detected with frequency offset up to +/- 7.5 kHz [9]. When UE starts decoding SSS it has knowledge about the channel as PSS is already known. SSS detection is coherent in nature, as the channel information is known.

S:

$$d[2n] = s_0^{m0}[n]c_0[n] \;\; in\, subframe\, 0 \qquad (3.7)$$

$$d[2n] = s_1^{m1}[n]c_0[n] \;\; in\, subframe\, 5 \qquad (3.8)$$

$$d[2n+1] = s_1^{m1}[n]c_1[n]z_1^{m0}[n] \;\; in\, subframe\, 0 \qquad (3.9)$$

$$d[2n+1] = s_0^{m0}[n]c_1[n]z_1^{m1}[n] \;\; in\, subframe\, 5 \qquad (3.10)$$

The indices m_0 and m_1 are derived from the physical-layer cell-identity group N_g according to:

$$m_0 = m' mod\, 31$$

$$m1 = \left(m0 + \left\lfloor \frac{m'}{31} \right\rfloor + 1\right) mod 31$$

$$m' = Ng + \frac{q(q+1)}{2}$$

$$q = \frac{\left\lfloor Ng + \frac{q'(q' + 1)}{2} \right\rfloor}{30}$$

$$q' = \left\lfloor \frac{Ng}{30} \right\rfloor$$

Where the output of the above expression is listed in Table 3.2:

Table 3.2: Mapping between Physical Cell identity group N_g, m_0 and m_1

N_g	m_0	m_1	N_g	m_0	m_1	N_g	m_0	m_1	N_g	m_0	m_1	N_g	m_0	m_1
0	0	1	34	4	6	68	9	12	102	15	19	136	22	27
1	1	2	35	5	7	69	10	13	103	16	20	137	23	28
2	2	3	36	6	8	70	11	14	104	17	21	138	24	29
3	3	4	37	7	9	71	12	15	105	18	22	139	25	30
4	4	5	38	8	10	72	13	16	106	19	23	140	0	6
5	5	6	39	9	11	73	14	17	107	20	24	141	1	7
6	6	7	40	10	12	74	15	18	108	21	25	142	2	8
7	7	8	41	11	13	75	16	19	109	22	26	143	3	9
8	8	9	42	12	14	76	17	20	110	23	27	144	4	10
9	9	10	43	13	15	77	18	21	111	24	28	145	5	11
10	10	11	44	14	16	78	19	22	112	25	29	146	6	12
11	11	12	45	15	17	79	20	23	113	26	30	147	7	13
12	12	13	46	16	18	80	21	24	114	0	5	148	8	14
13	13	14	47	17	19	81	22	25	115	1	6	149	9	15
14	14	15	48	18	20	82	23	26	116	2	7	150	10	16
15	15	16	49	19	21	83	24	27	117	3	8	151	11	17
16	16	17	50	20	22	84	25	28	118	c4	9	152	12	18

Ng	m0	m1	Ng	m0	m1	Ng	m0	m1	Ng	m0	m1	Ng	m0	m1
17	17	18	51	21	23	85	26	29	119	5	10	153	13	19
18	18	19	52	22	24	86	27	30	120	6	11	154	14	20
19	19	20	53	23	25	87	0	4	121	7	12	155	15	21
20	20	21	54	24	26	88	1	5	122	8	13	156	16	22
21	21	22	55	25	27	89	2	6	123	9	14	157	17	23
22	22	23	56	26	28	90	3	7	124	10	15	158	18	24
23	23	24	57	27	29	91	4	8	125	11	16	159	19	25
24	24	25	58	28	30	92	5	9	126	12	17	160	20	26
25	25	26	59	0	3	93	6	10	127	13	18	161	21	27
26	26	27	60	1	4	94	7	11	128	14	19	162	22	28
27	27	28	61	2	5	95	8	12	129	15	20	163	23	29
28	28	29	62	3	6	96	9	13	130	16	21	164	24	30
29	29	30	63	4	7	97	10	14	131	17	22	165	0	7
30	0	2	64	5	8	98	11	15	132	18	23	166	1	8
31	1	3	65	6	9	99	12	16	133	19	24	167	2	9
32	2	4	66	7	10	100	13	17	134	20	25	-	-	-
33	3	5	67	8	11	101	14	18	135	21	26	-_	_-	-_

.

The two sequences $s0^{m0}(n)$ and $s1^{m1}(n)$ are defined as two different cyclic shifts of the m-sequence s~ (n) according to:

$$s0^{m0}(n) = s^{\sim}((n + m0) mod 31)$$
$$s1^{m1}(n) = s^{\sim}((n + m1) mod 31)$$

Where $s^{\sim}(i) = 1 - 2x(i), 0 \le i \le 30$ is defined by:

$$x(i' + 5) = \left(x(i' + 2) + x(i')\right) mod 2, 0 \le i' \le 25$$

With initial condition

$$x(0) = 0,$$
$$x(1) = 0,$$
$$x(2) = 0,$$
$$x(3) = 0,$$
$$x(4) = 1$$

Where s_0 and s_1 denote the group-ID shifted base sequence that was interleaved in time domain. The primary scrambling sequences c_0 and c_1 has a shift depending in the sector-ID, whereas z_1^{m0} and z_1^{m1} describes the second scrambling sequences.

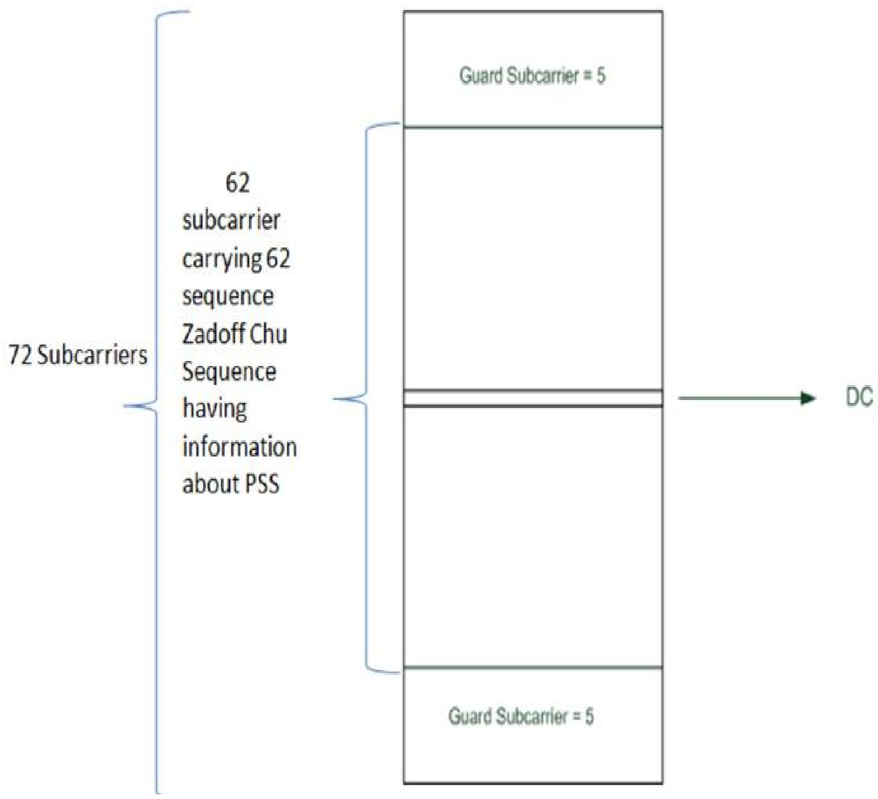

Figure 3.3: Resource mapping of Primary Synchronization Signal

3.7 Broadcast Channel (BCH):

The Broadcast channel (BCH) in wireless is used to broadcast the cell system information to the cell that allows channels to be configured and operated. Therefore it is significant to decode the Physical Broadcast channel to get system information. Physical channel carries information of Master of Information Block (MIB). MIB contains limited and important information needed for initial cell access for UE.

Information carried by master information set up cell bandwidth in terms of resource block, which are continuously broadcasted to the cell. The PBCH is designed in a way that it does not need system bandwidth to decode the broadcasted information, it has little latency time and power is consumed by UE, it can be decoded reliably at the edge of cell site and system overhead should be low.

Physical broadcast channel can be decoded when the system is unknown bandwidth, as it is centered on a DC subcarrier as in PSS and SSS.

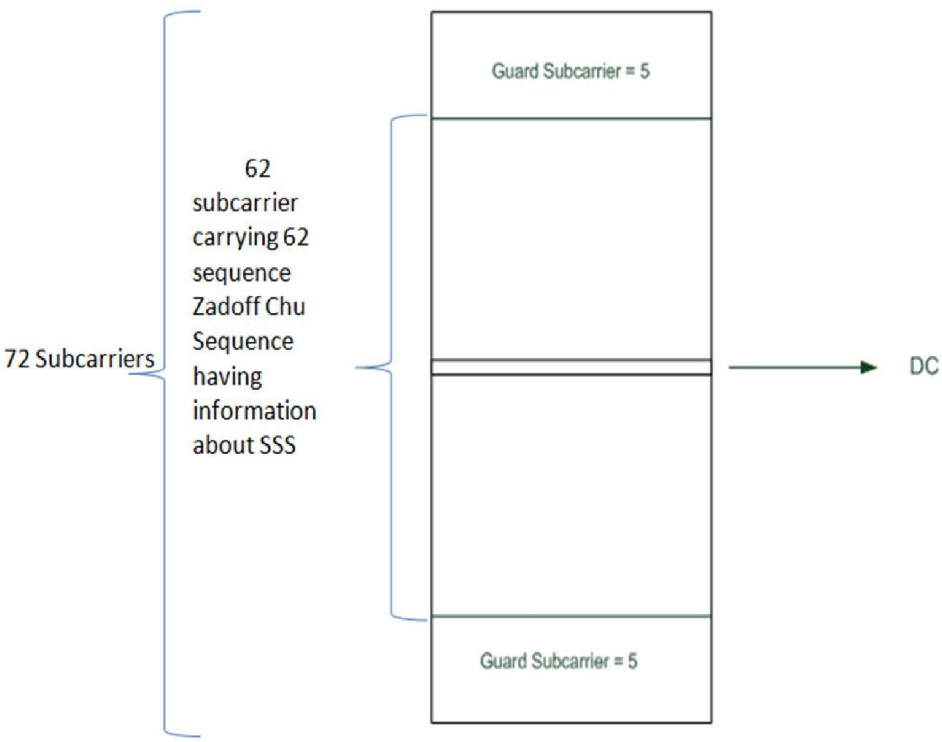

Figure 3.4: Resource mapping of secondary Synchronization Signal

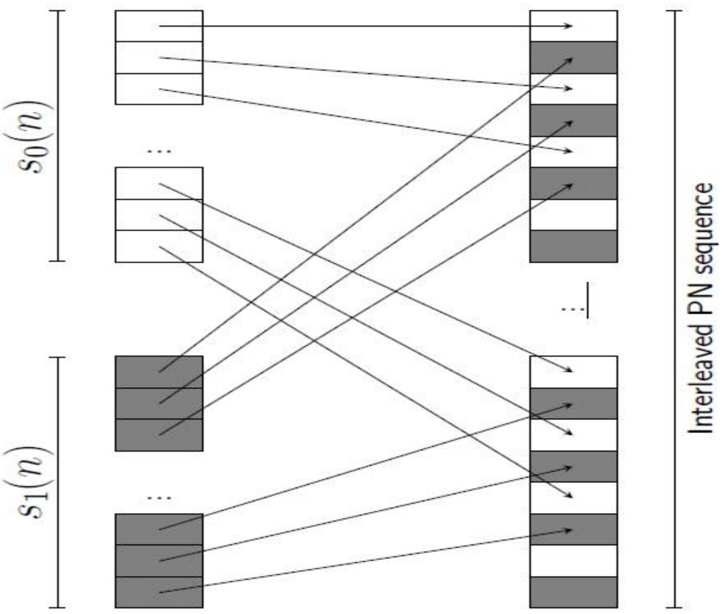

Figure 3.5: Mapping of Secondary Synchronization Signal [14].

The PBCH also uses 62 subcarrier of72 subcarriers; it can work when search is done at minimum bandwidth of system. The frequency of DC is previously known. The physical channel channel uses frames spread on time interval with one sub frame in each 10ms frame. System overhead is being low by providing the minimum information for the initial access of cell.

Master information Block is sent over PBCH. MIB is 14 bits long sent over of 40ms [3].

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Chapter Four

Results

Chapter 4:

Results

4.1 Overview:

This chapter discusses the implementation and simulation of cell search procedure using MATLAB.

The process of the downlink synchronization can be summarized into the flow diagram shown in Figure 4.1.

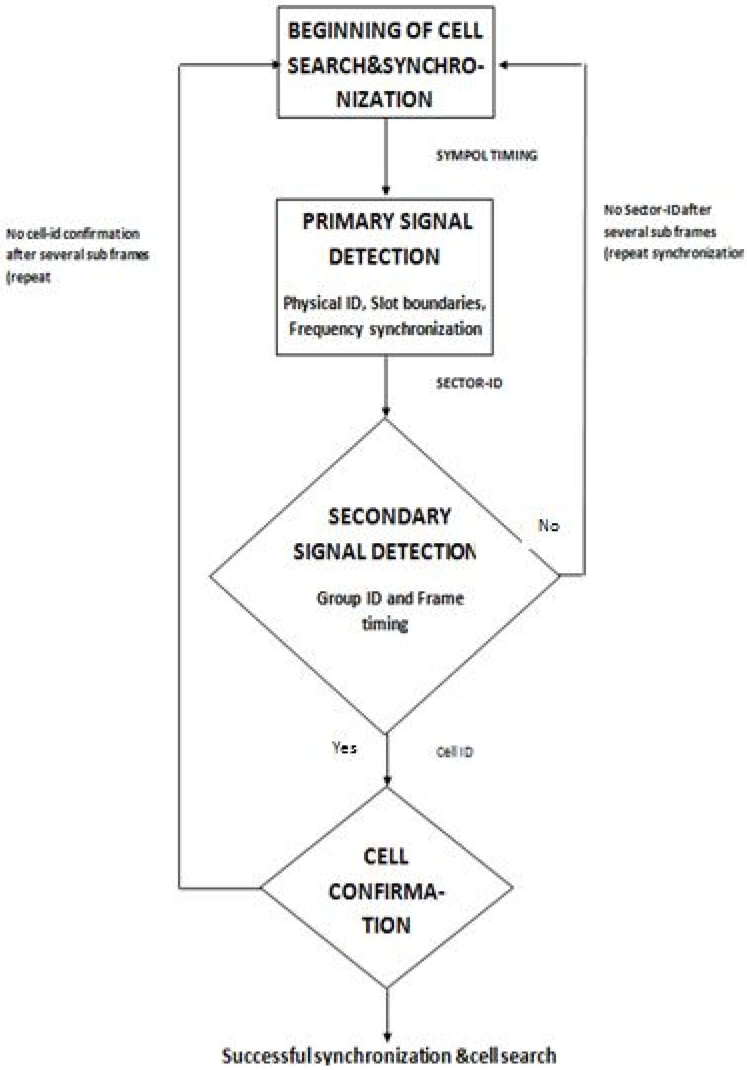

Figure 4.1: Cell search procedure.

In this scheme we assumes an FDD transmission, these issues are encountered and resolved is schematically explained.

4.2 PSS Detection:

When UE is powered on. The UE has in its memory a copy of the three possible primary synchronization signals. UE monitors the central part of the spectrum regardless of its bandwidth capability. The first step is the determinations of the symbol start that a UE has to perform before proceeding with further signal processing. The UE performs this detection by using a sliding window method with a delay length of symbol length. In this method, the received signal is processed with a delayed version of itself the ratio of the aggregated cross correlation between the input to the delay line and the output to the delay line to the aggregated auto correlation at the output of the delay over a set of samples helps in detecting the symbol start.

The representation by MATLAB of the three primary synchronization signals in Figures 4.2, 4.3 and 4.4. As described in previous chapter, the PSS signals are Zadoff-chu sequences with their center made zero to represent DC.

The start of symbol is determined by checking the peak triangle in the ratio of the cross and auto correlations are described in Figures 4.5 and 4.6.

The parameters used for PSS sequence generation

Transmitted bandwidth = 1.08 M

Number of available subcarrier = 72Hz

Utilized subcarrier = 62 (centered around d.c. zero frequency index subcarrier)

Guard subcarrier = 5 (either sides of PSS)

Length of PSS sequence = 62

PSS is transmitted from base station to UE. Downlink uses OFDM modulation technique, as the received signal is demodulated affectively using frequency based equalizer at UE

$$N_c = 3N_g + N_s \quad (4.1)$$

$$N_g = 0...168 \quad (4.2)$$

$$N_s = 0, 1, 2 \quad (4.3)$$

Each one has amplitude different from another on the unit circle at different cyclically shifted phases. Figures 4.2, 4.3 and 4.4 represent the real and imaginary parts of the three sequences used in Primary Synchronization Signals. It can be seen that each are located at different phases, but has constant amplitude. The Center element representing DC can also be seen.

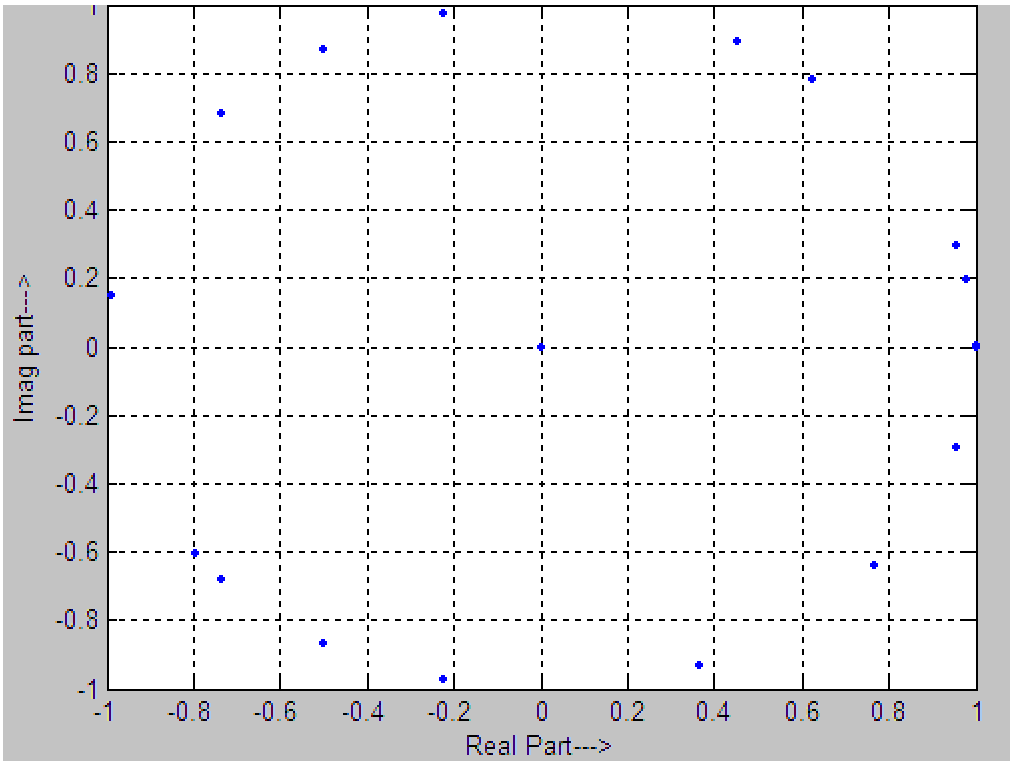

Figure 4.2: Zadoff-chu sequence of PSS sequence of length 63 and root 25

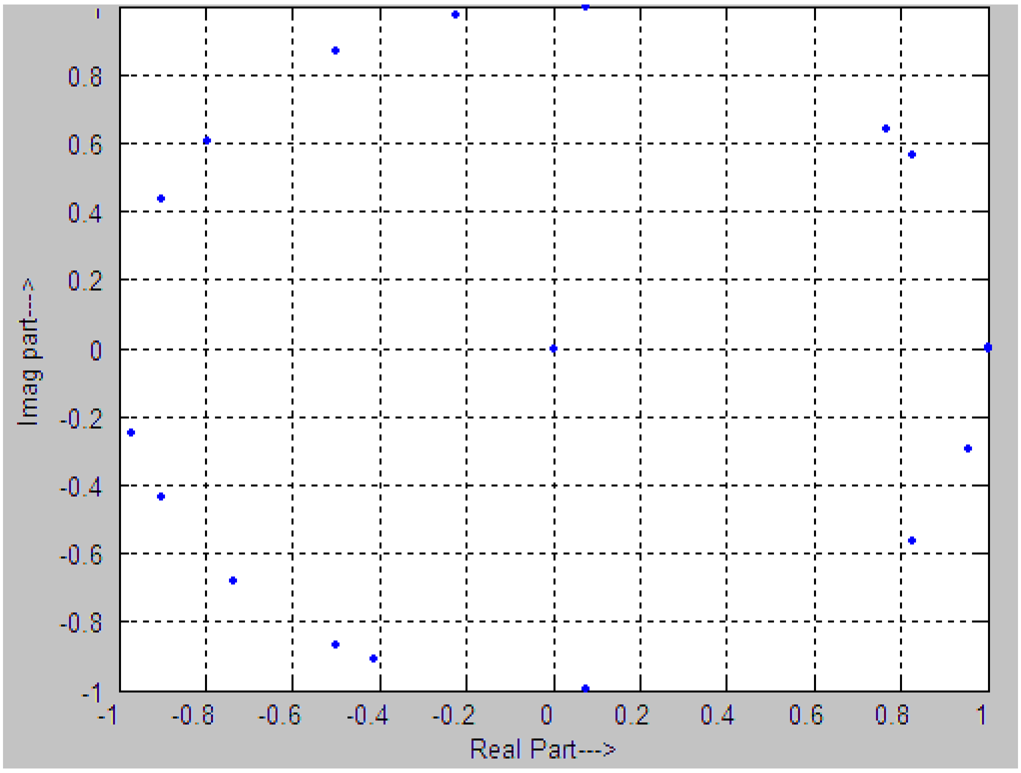

Figure 4.3: Zadoff-chu sequence of PSS sequence of length 63 and root 29

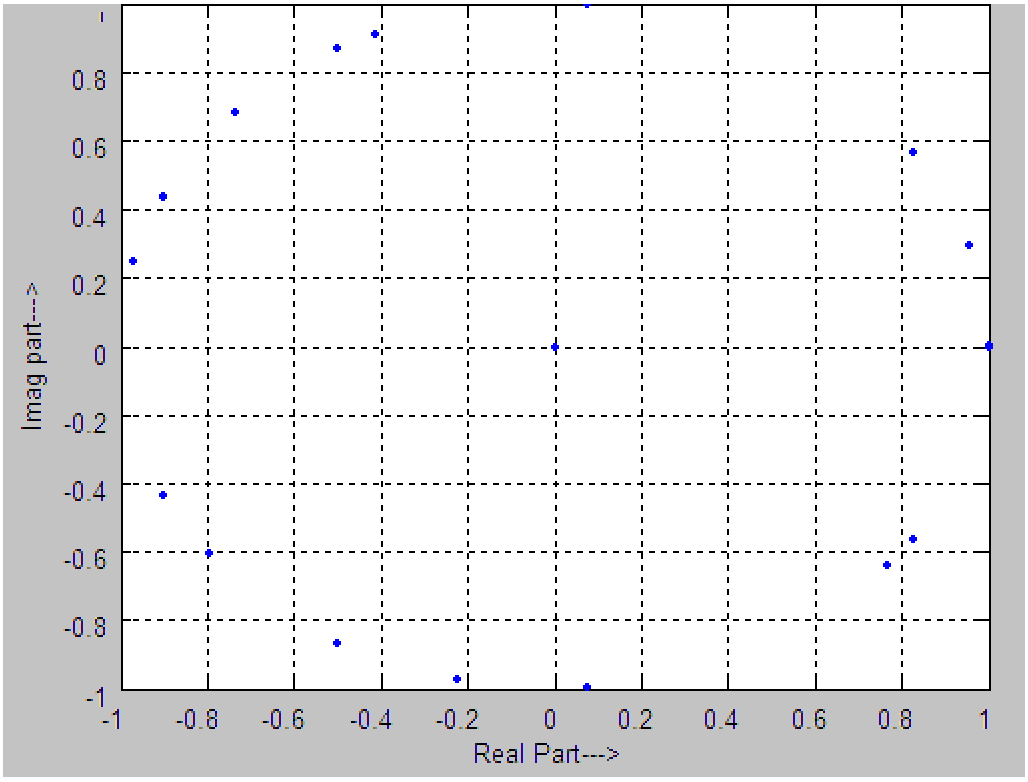

Figure 4.4: Zadoff-chu sequence of PSS sequence of length 63 and root 34

From figures above it can be seen that the three sequences with different roots have constant amplitudes, but at different phases.

The autocorrelation Figure for these three sequences are represented in Figure 4. 5. It can be seen that the side lobes are present because the sequence is not a perfect zadoff-chu sequence due to DC puncturing.

And the value of physical layer ID corresponds to root index of the ZC sequence = 25, 29 and 34.

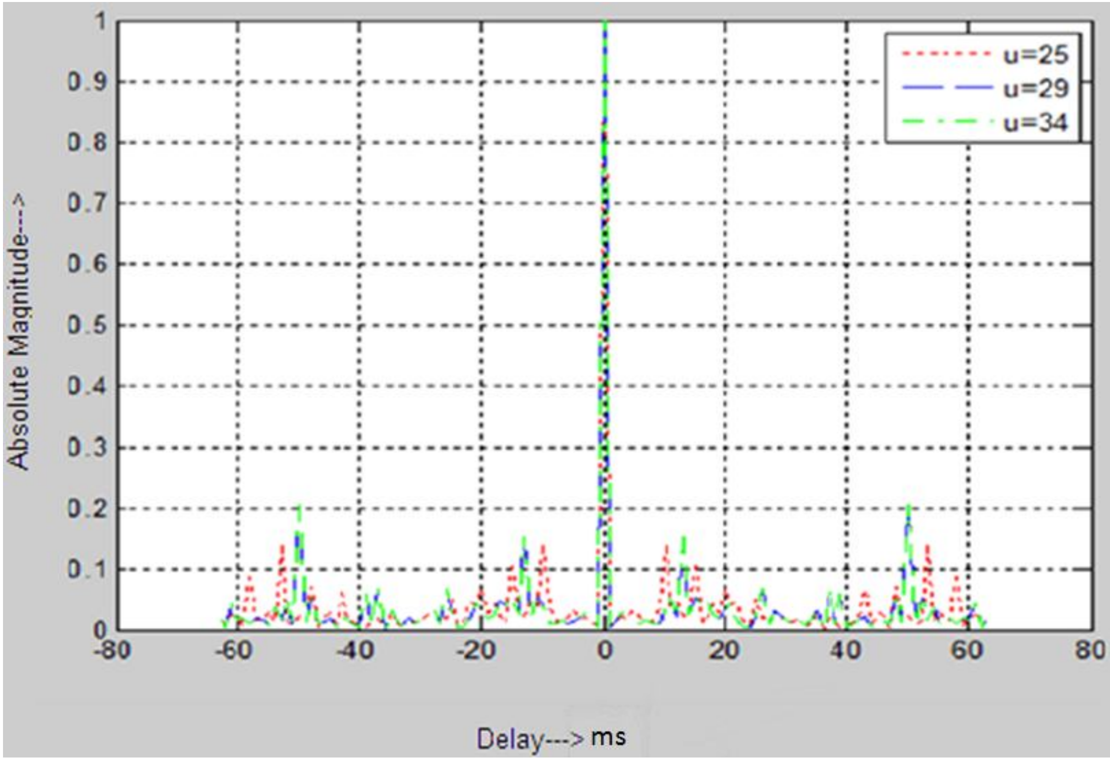

Figure 4.5: Autocorrelation of PSS with Root index (u) = 25, 29 and 34.

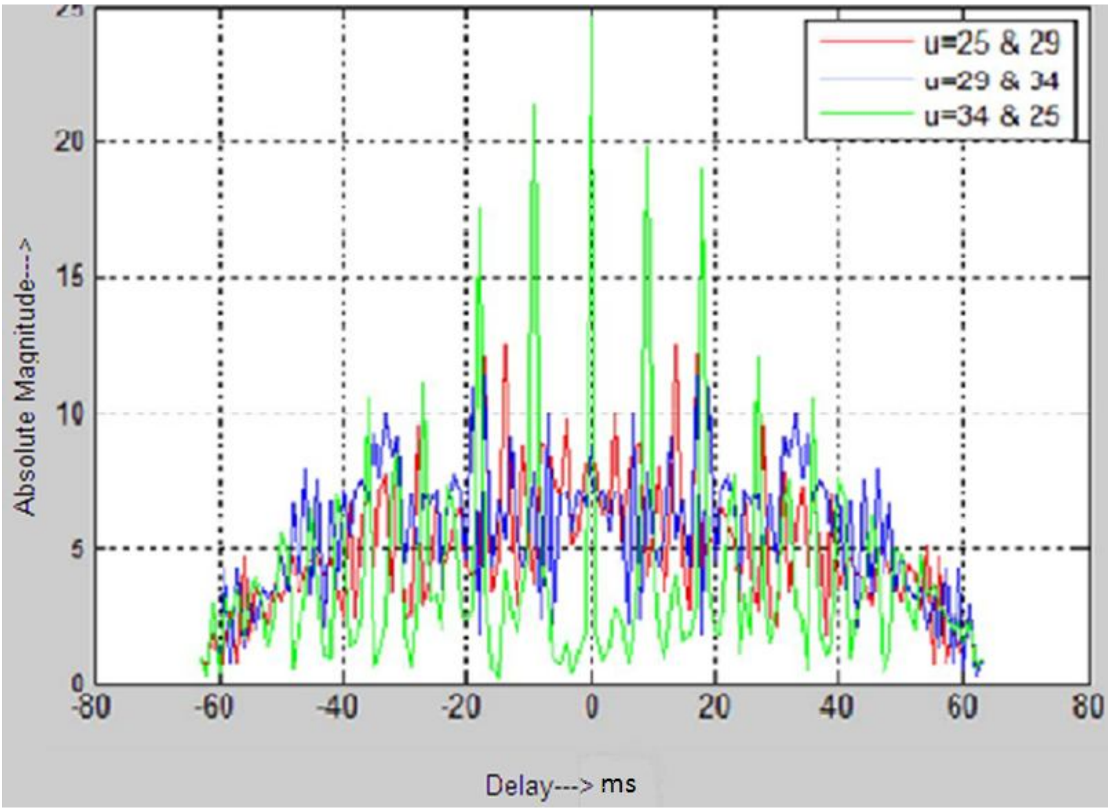

Figure 4.6: Cross correlation between pair of PSS root index (u) 25&29, 29&34 and34&25.

The cross correlation property between pairs of the Zadoff-Chu sequences in LTE system can be seen in Figure 4.6 Refer to the Appendix for MATLAB implementation of the cell search.

From Figure 4.6, the cross correlation property is good for pair 25, 29 and 29, 34 but is not so good for pair 34, 25.

4.2: SSS Detection

The procedure is performed for several cyclic shifts of $d(n)$ (for instance a shift of −2 to +2 sub-carriers), in order to detect the integer CFO part. The received signal is de-interleaved signal into the odd part and the even part d(2n) and d(2n+1).When Ng is known from the PSS , the scrambling code $c_0(n)$ is already known to the UE and can descrambled from the received signal . If the received sequence $d(n)$ is positioned on the correct frequency grid then Significant peaks will only be generated. Figures 4.7 and 4.8 shows an example of correlation magnitudes for estimating integer's m_0 and m_1. Side peaks located outside the detection interval are not considered as main peaks.

Significant peaks clearly indicate the case of correct *Ng*, sub-frame index. When the cyclic prefix is removed accordingly and the FFT is applied After having retrieved the orthogonal frequency division multiplexing symbol timing,. For the PSS cross-correlation, there is a miss rate when using an energy threshold to give incorrect correlation at low peaks.

The parameters used for SSS sequence generation:

Transmitted bandwidth = 1.08 MHz

Number of available subcarrier = 72

Utilized subcarrier = 62 (centered around d.c. zero frequency index subcarrier)

Guard subcarrier = 5 (either sides of SSS)

Length of SSS = 62

Ng= 0...168

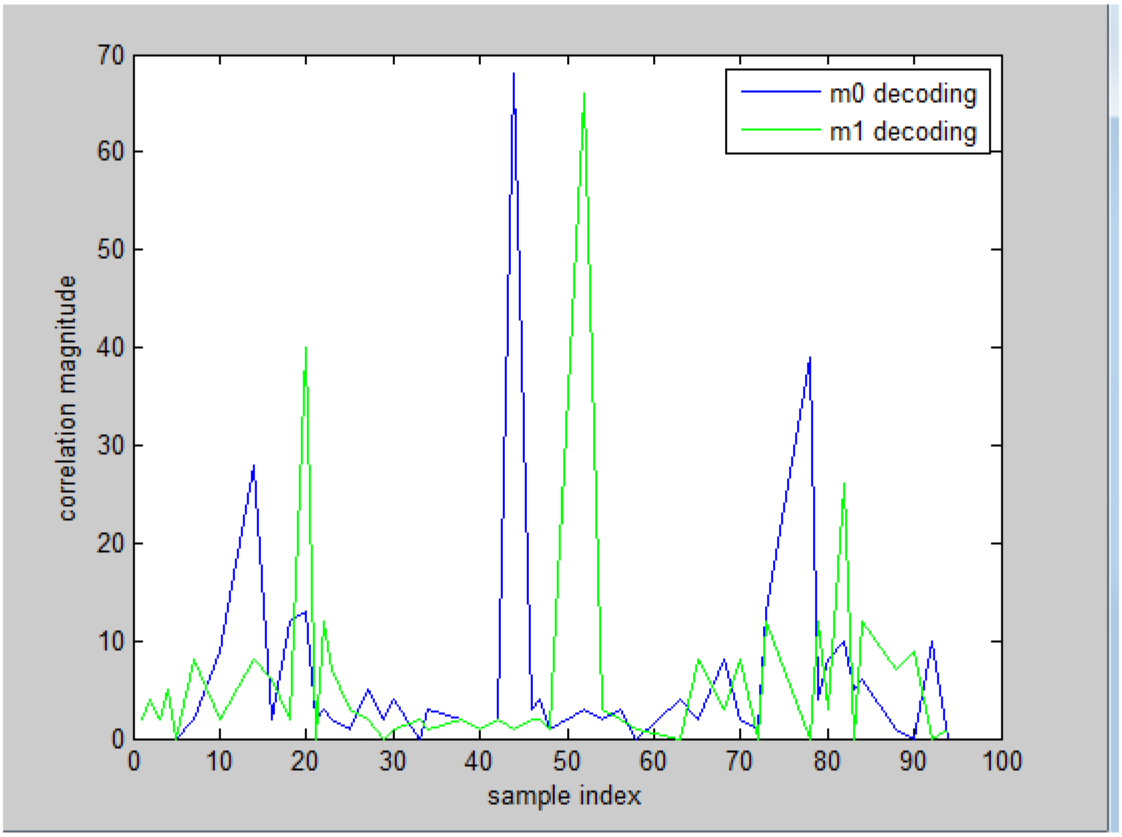

Figure 4.7: Correct SSS detection significant peaks clearly indicate the case of correct using Correlation magnitude

The higher the probability, the higher the threshold that the peak is correct may be not reaching this threshold level. When an isolated sector/cell environment is considered this miss rate is almost equal to the sector fail rate, as the possibility that one of the other correlation terms generates a peak higher than the peak corresponding to the actual sector is very small. For the sector fail rate we employed a threshold equal to 0.023 of the 62- Length received PSS sequence.

The fail rate in cell search is depending on the sector and the group fail rate, when the sector is found false, the group is automatically estimated wrongly, it depend on sector. Further, it might be possible that the group identity is estimated wrongly, even when the sector identity was correctly estimated.

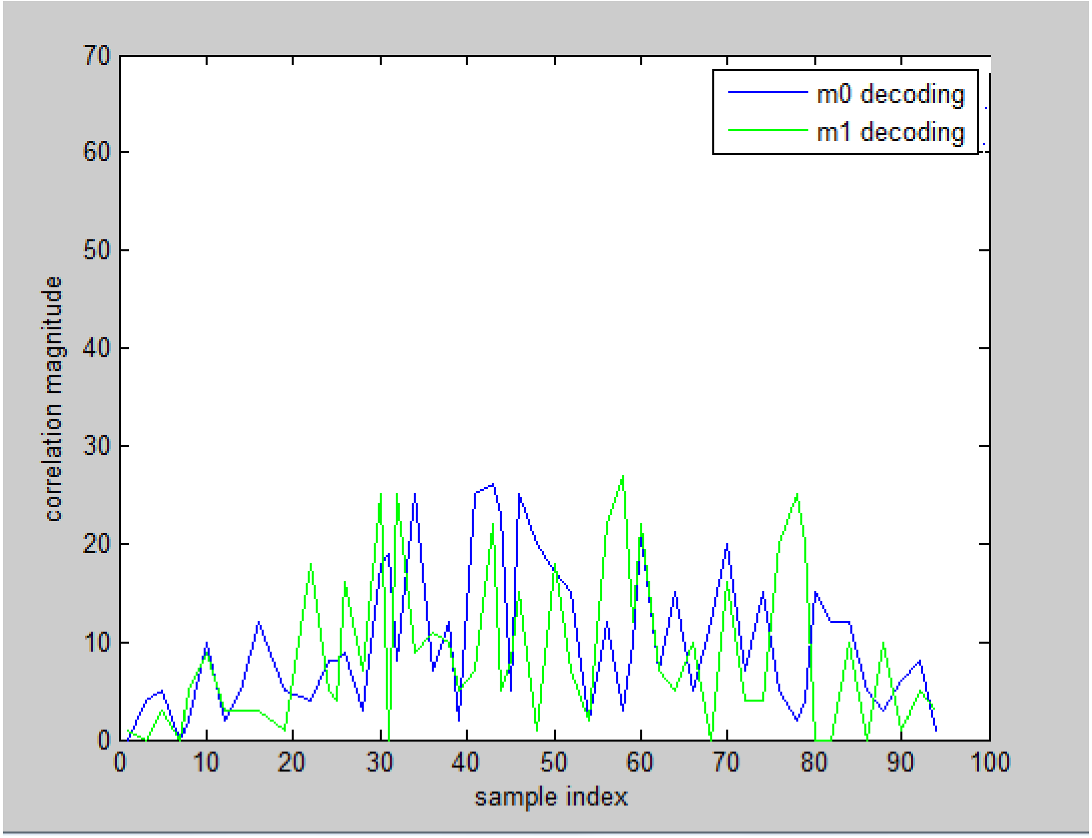

Figure 4.8: wrong SSS detection correlation magnitude in case of inappropriate cyclic shift.

4.4 Overall system design:

The fail rate of the overall cell-ID should must be at least as high as the sector miss rate. Figure 4.9 illustrates all the rates; we can see where the group fail rate appears to be very small. This means that the SSS decoding process is successful, even under conditions of multipath channel and realistic time and frequency synchronization. If sector information is correctly acquired by the PSS signal, the cell is estimated correctly in most cases.

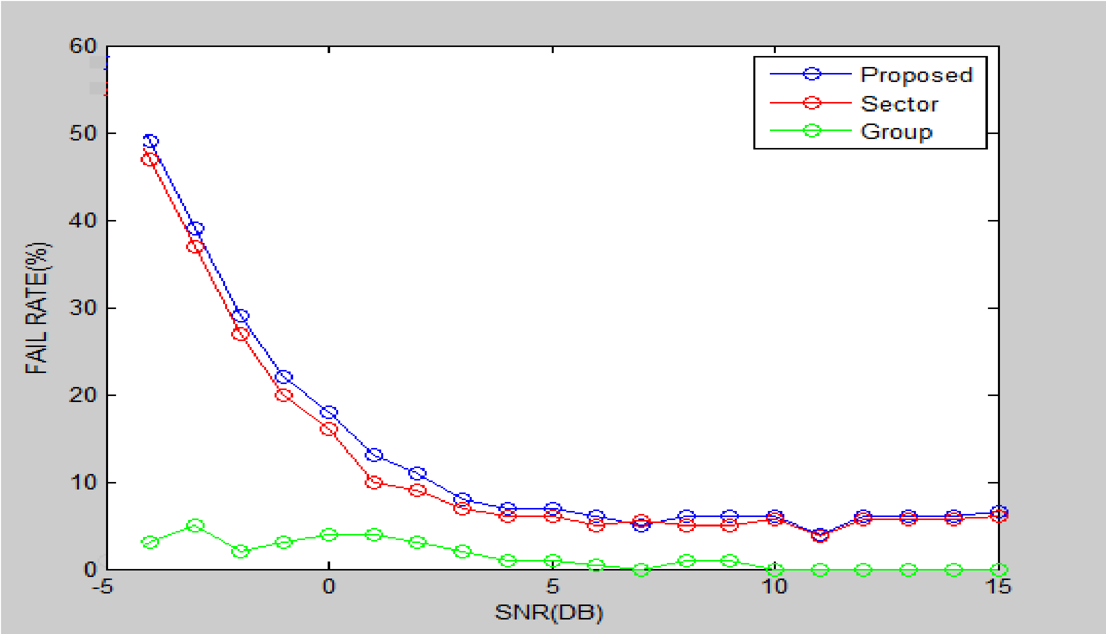

Figure 4.9: Fail rate of the received PSS sequence, of SSS signal decoding (group) and PSS (sector).

Fail rate of PSS signal when threshold equal to 0.023 of the received PSS sequence energy, fail rate of SSS signal decoding (group miss rate) and cell fail rate. When sector information is correctly acquired, the cell is estimated correctly in most cases, the proposed sector identity is more accurate than normal sector identity.

4.3: Chapter Summary:

We construct a procedure including sector and cell search, cell identification, and time and frequency synchronization procedure, as illustrated in Figure 4.1. Blocks in flow chart are adjusted to each other and feedback control signals guarantee the stability of the receiver sub-system. If the SSS signal decoder fails several times, the synchronization will be refreshed, as a wrong sector identity or large synchronization errors occur.

Similarly when the estimated cell is not confirmed after several iterations, which mean that sector or group, were estimated falsely, the complete process is performed from the beginning.

The complete procedure enables connection to the base station. For LTE receiver, we need to perform cross-correlation to estimate the sector identity and acquire cell identification. It also provides a reliable estimate of the beginning of frame.

The results of our scheme show that the fail rate of the overall cell-ID should must be at least as high as the sector miss rate .If sector information is correctly acquired by the PSS signal; the cell is estimated correctly in most cases.

A significant peak indicates a successful synchronization and cell identification.

Chapter 5

Conclusion and Recommendations:

5.1: conclusion:

In this research the two synchronization signals used in the cell search have been presented in details the primary synchronization signal and secondary synchronization signal. These two signals provide information about physical layer identity, frame slot boundaries, frequency synchronization, group cell identity, and radio frame timing. Where the PSS carries the physical layer identity sector and SSS is carries the physical layer cell identity group.

The detection of these two signals not only enables time and frequency synchronization, but also informs the UE whether the cell uses Frequency Division Duplex (FDD) or Time Division Duplex (TDD) and provides the UE with the physical layer identity of the cell and the cyclic prefix length. Synchronization sequence is more important because its detection affects not only search time but also performance of demodulation.

For a 3GPP LTE receiver, cross-correlation needs to be performed to estimate the sector identity and enable cell identification.

Finally, we construct a procedure including sector and cell search, cell identification, and time and frequency synchronization procedure, as illustrated in Figure 4.1. Blocks in flow chart are adjusted to each other and feedback control signals guarantee the stability of the receiver sub-system. If the SSS signal decoder fails several times, the synchronization will be refreshed, as a wrong sector identity or large synchronization errors occur. Similarly when the estimated cell is not confirmed after several iterations, which mean that sector or group, were estimated falsely, the complete process is performed from the beginning.

The results of our scheme show that the fail rate of the overall cell identity should must be at least as high as the sector miss rate.

5.2 Recommendations:

After estimating primary and secondary synchronization signal the next step will be to choose sector information is correctly acquired by the PSS signal, then the cell will be estimated correctly in most cases and significant peak indicates a successful synchronization and cell identification.

7

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Appendix: A

Implementation of Cell Search Procedure:

```
close all

clear all

%%%Primary Synchronization Signal%%%%%%



%PSS is selected and Matched randomly%%%%


du_flag_25 = 0;
du_flag_29 = 0;
du_flag_34 = 0;

Ns = floor(3*rand); % Selects Ns--- 0,1,2
switch Ns
case 0
du_flag_25 = 1;
case 1
du_flag_29 = 1;
case 2

du_flag_34 = 1;
end

u25=25;

for n= 0 : 30

duu_25(n+1) = exp(-j*pi*u25*n*(n+1)/63);

end

for n= 31 : 62
duu_25(n+1) = exp(-j*pi*u25*(n+2)*(n+1)/63);

end
```

```
du_25(1:31) = duu_25(1:31);
du_25(33:64) = duu_25(32:63);
for n=0:63

shift_25(n+1) =du_25(n+1) *exp((j*2*pi*0*n)/63);

end

[corr_25 lag_25] = xcorr((du_25));%,shift_25);

%%

u29=29;
for n= 0 : 30

duu_29(n+1) = exp(-j*pi*29*n*(n+1)/63);

end

for n= 31 : 62

duu_29(n+1) = exp(-j*pi*29*(n+2)*(n+1)/63);
end

%%Putting off data from dc zero frequency index subcarrier %%%


du_29(1:31) = duu_29(1:31);
du_29(33:64) = duu_29(32:63);
for n=0:63

shift_29(n+1) =du_29(n+1) *exp((j*2*pi*0*n)/63);

end

[corr_29 lag_29] = xcorr((du_29));%,shift_29);
corr_29=corr_29/max(corr_29);%corr_29);
%%

%u34=34;
for n= 0 : 30
duu_34(n+1) = exp(-j*pi*34*n*(n+1)/63);
```

```
end

for n= 31 : 62

duu_34(n+1) = exp(-j*pi*34*(n+2)*(n+1)/63);

end

%%%Putting off data from dc zero frequency index subcarrier %%

du_34(1:31) = duu_34(1:31);
du_34(33:64) = duu_34(32:63);

for n=0:63

shift_34(n+1) =du_34(n+1) *exp((j*2*pi*0*n)/63);

end

[corr_34 lag_34] = xcorr((du_34));%,shift_34);
corr_34=corr_34/max(corr_34);%(corr_34);

%%
figure(1)
subplot(3,1,1)
plot(lag_25,abs(corr_25));
title('u=25');

grid on
subplot(3,1,2)
plot(lag_29,abs(corr_29));
title('u=29');
grid on
subplot(3,1,3)
plot(lag_34,abs(corr_34));
title('u=34');
grid on
figure(2)
plot(lag_25,abs(corr_25),':r');
grid on
hold on
plot(lag_29,abs(corr_29),'--b');
hold on
```

```
plot(lag_34,abs(corr_34),'-.g');
hold off
legend('u=25','u=29','u=34');
figure(3)
[cross_25_29 lag_25_29] = xcorr(shift_25,shift_29);
cross_25_29 = cross_25_29 / max(corr_25);%(cross_25_29);
plot(lag_25_29,abs(cross_25_29),'-r');
grid on
hold on
[cross_29_34 lag_29_34] = xcorr(shift_29,shift_34);
cross_29_34 = cross_29_34 / max(corr_25);%(cross_29_34);
plot(lag_29_34,abs(cross_29_34),'-b');
hold on
[cross_25_34 lag_25_34] = xcorr(shift_34,shift_25);
cross_25_34 = cross_25_34 / max(corr_25);%(cross_25_34);
plot(lag_25_34,abs(cross_25_34),'-g');
hold off
legend('u=25 & 29','u=29 & 34','u=34 & 25');
xlabel('Delay--->ms');
ylabel('Absolute Magnitude--->');



% Secondary Synchronization Signal is an interleaved
concatenation of two
% length 31 sequences
% d(2n)= s0m0(n)c0(n)
% d (2n+1) = s1m1(n)c1(n)z1m0(n); in subframe 0
% d(2n)=s1m1(n)c0(n) % d(2n+1)=s0m0(n)c1(n)z1m1(n); in
subframe 5
% where 0<=n<=30
% for our case, say N1=25, mo=25, m1=26 (m0 and m1 can be got
from the % table)
% Say, N2=0, as obtained from primary synch signal

clear all;

Signal_rotated_ofdm_channel_64point;
 Receiver_Match_Signals;

%SSS_generation;
 N2=0;
 m0=25;
```

```
 m1=26;

% Generate signals z1m0 and z1m1
xz(1)=0; xz(2)=0; xz(3)=0; xz(4)=0; xz(5)=1;

 for i=1:26
 xz(i+5)=mod((xz(i+4)+xz(i+2)+xz(i+1)+xz(i)),2);

 end

 for n=1:31

zbar(n)=1-(2*xz(n));

 end

 for nn=1:2:61

 z1m0(nn)=zbar((mod((nn+mod(m0,8)),31))+1);
z1m1(nn)=zbar((mod((nn+mod(m1,8)),31))+1);

 end


 % Generate the signals c0(n) and c1(n)

 xc(1)=0; xc(2)=0; xc(3)=0; xc(4)=0;xc(5)=1;
 for ii=1:26
xc(ii+5)=mod((xc(ii+3)+xc(ii)),2);

 end

 for j=1:31 cbar(j)=1-(2*xc(j));

 end

 for k=1:2:61
      c1(k)=cbar((mod((k+N2+3),31))+1);
 end

 for l=2:2:62

c0(l)=cbar((mod((l+N2),31))+1);
```

```
 end

 % Generate signals s0m0(n) and s1m1(n)
 xs(1)=0; xs(2)=0; xs(3)=0; xs(4)=0;xs(5)=1;

 for jj=1:26

xs(jj+5)=mod((xs(jj+2)+xs(jj)),2);

 end

 for kk=1:31 sbar(kk)=1-(2*xs(kk));

 end

for m=1:62

s0m0(m)=sbar((mod((m+m0),31))+1);

 end

 for p=1:62
s1m1(p)=sbar((mod((p+m1),31))+1);

 end

 % Generate the signals d(2n) and d(2n+1)
 % Consider subframe 0 first
 % d(2n)= s0m0(n)c0(n);
 % d(2n+1)=s1m1(n)c1(n)z1m0(n) d0=zeros(1,62);
 for q=2:2:62
 d0(q)=s0m0(q).*c0(q);

end

 for q=1:2:61
 d0(q)=s1m1(q).*(c1(q)).*(z1m0(q));

 end


 % Now, Consider subframe 5
```

```
 % d5(2n)= s1m1(n)c0(n);
 % d5(2n+1)=s0m0(n)c1(n)z1m1(n)
d5=zeros(1,62);

 for qq=2:2:62

d5(qq)=s1m1(qq).*c0(qq);

 end
 for qq=1:2:61
 d5(qq)=s0m0(qq).*(c1(qq)).*(z1m1(qq));

 end
```