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Interference Free Window (IFW) in Las Cdma System and Comparison with Traditional CDMA

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Abstract: Large area synchronous code-division multiple access (LAS-CDMA) is a proposed fourth generation cellular standard. The feature that distinguishes LAS-CDMA from traditional CDMA is the new set of codes used to separate users. LAS code has zero cross-correlation in the "Zero Interference Window" and has only an impulse auto-correlation in the "Zero Interference Window". These excellent features of the technique help to eliminate interference and give better performance.

Keywords: LA Code, LS Code, Auto-correlation, Cross-correlation, IFW

1 INTRODUCTION

In Code Division Multiple Access (CDMA) systems, all users transmit in the same bandwidth simultaneously. Communication systems following this concept are "spread spectrum systems". The frequency spectrum of a data-signal in this transmission technique is spread using a code which is uncorrelated with that signal resulting in the bandwidth occupancy much higher than the required bandwidth. These codes are unique to every user and have low cross-correlation values. That is why a receiver having knowledge about the code of the intended transmitter is capable of selecting the desired signal. Two transmission techniques need to be considered to utilize spectrum efficiently: a) Multiple access scheme b) Duplexing system. Multiple access schemes can be of three types namely TDMA, FDMA and CDMA. The industry has already established the best multiple access scheme, code-division multiple access (CDMA), for 3G systems. LAS-CDMA (Large Area Code Division Multiple Access) employs a novel multiple access scheme which is different from all the known traditional CDMA. The auto-correlation functions of all LAS-CDMA codes are ideal having an IFW (Interference Free Window) and cross-correlation functions of its access codes have a "zero correlation zone" (ZCZ) around the origin. This is the reason that LAS-CDMA system have a much higher system capacity and spectral efficiency than that of a traditional CDMA.Assume that eight smart codes are transmitted and arrive at the receiver of Code *C*1 at different times because of the multipath caused by different reflectors. Due to the cross-correlation property, the desired code to be received is *C*1 but many *C*1 codes can be received due to multipath effect. This does not occur though; due to the auto-correlation property, only Code *C*1 at time *t*1 is received, as shown in Fig. 1. We do not need the strength of more than one path signal to be added for increasing carrier-to-interference ratio (C/I) since we are only receiving carrier-to-noise ratio (C/N), not C/I. The rest of the signals from different paths do not cause any interference, and there is no need to use any means to collect them for the purpose of reducing interference. Hence, with this smart code property we can effectively eliminate interference, and we do not need other technologies.

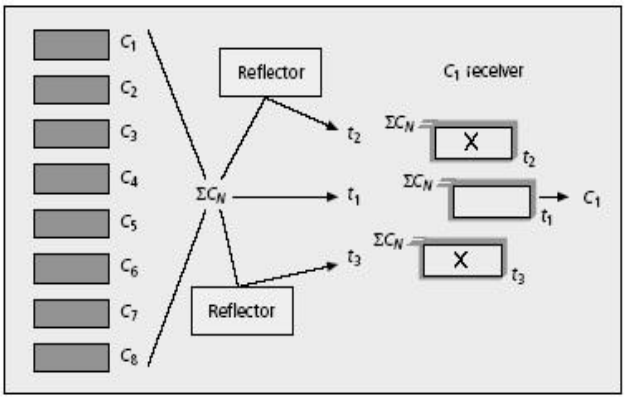

Fig 1: Merit of smart codes

Three types of interference are usually considered:

i) ISI (Inter-Symbol Interference) ,created by the multi-path replica of the useful signal itself.

ii) MAI (Mutual Access Interference) ,the interference created by the signals and their multi-path replica from the other users onto the useful signal.

iii) ACI (Adjacent Cell Interference) ,all the interfering signals from the adjacent cells onto the useful signal.

The LAS- CDMA implements LAS codes which are a set of smart codes exhibiting zero correlation values, when the relative delay-induced code offset is in the so-called Zero Correlation Zone (ZCZ) or Interference Free Window (IFW) of the spreading code. The Large Area Synchronized (LAS) CDMA spreading sequences is constituted by the combination of Large Area (LA) codes and Loosely Synchronous (LS) codes. The resultant LAS codes exhibit an IFW, where the off-peak aperiodic autocorrelation values as well as the aperiodic cross-correlation values become zero, resulting in zero ISI and zero MAI, provided that the time-offset of the codes is within the IFW.

2. ZERO CORRELATION ZONE(ZCZ)

LAS code is made up of LA code and LS code which are called as two poles codes and it is new code using the Design of orthogonal and complemented codes, which has Zero Correlation Windows (ZCW). The most important Feature of this code is that it has biggest auto-correlation value at zero offset and other auto-correlation values are all zero at other offsets. Among all codes family, the cross correlation is also zero at the around of zero offset.

Specifically, Loosely Synchronized (LS) codes exploit the properties of the so-called orthogonal complementary sets .

Considering two group of LS codes:

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LS1 = [1,1,1,-1,1,1,-1,1,0,0,0,0,0,0,0,1,-1,1,1,1,-1,-1,-1]
LS2 = [1,1,1,-1,-1,-1,1,-1,0,0,0,0,0,0,0,1,-1,1,1,-1,1,1,1]
The auto-correlation curve of LS1 code can be obtained by simulation using MATLAB as shown:

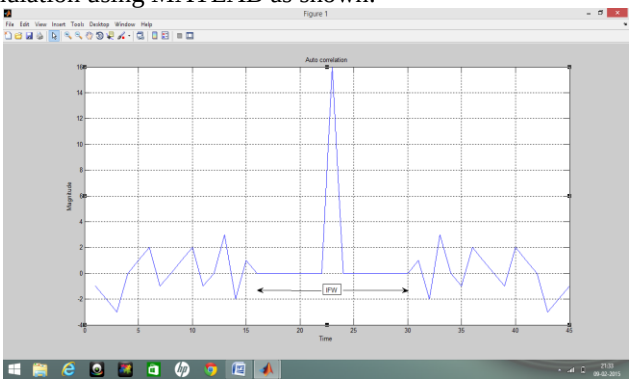

Fig 2: Auto-correlation of LS code

Similarly, cross-correlation curve for two group of LS codes mentioned above can be obtained as shown:

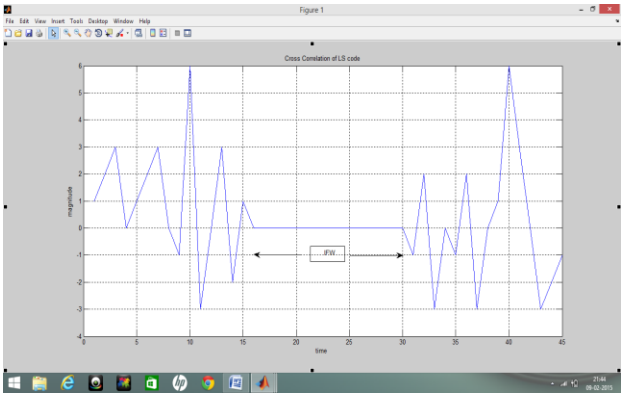

Fig 3: Cross-correlation of LS codes

LA codes are a family of pulse train with carefully designed pulse intervals. LA codes are mainly used to reduce the ACI (Adjacent Cell Interference). The pulses of LA code are formed by passing through a LS code to its matched filter at the required pulse positions. LA code is a ternary code and identified by three parameters LA(L,M,N), in which L is the number of pulses, M is the minimum pulse interval, and N is the total LA code length. Similar curves for two group of long string of LA codes can be obtained using MATLAB having an IFW (A zone where correlation has its value equal to zero) as shown:

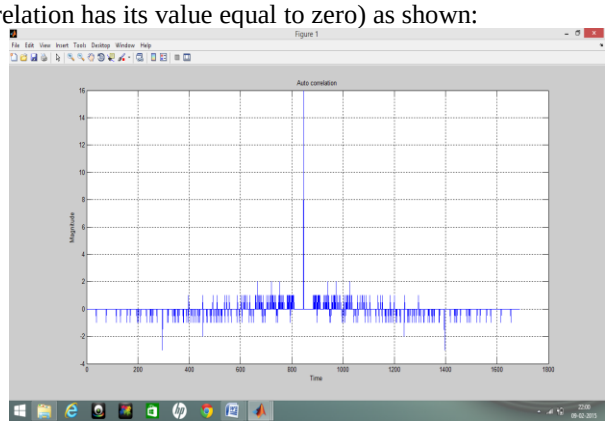

Fig 4:Auto-correlation of LA code

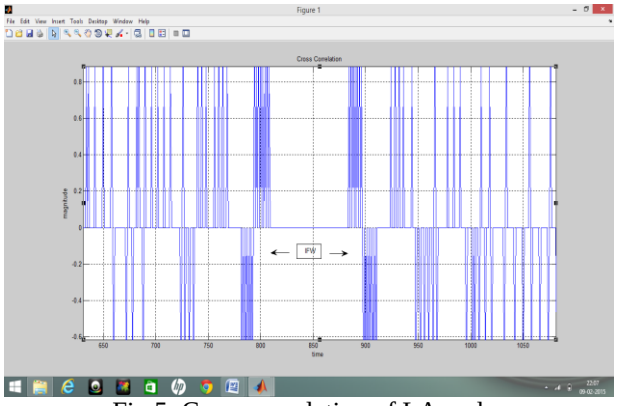

Fig 5: Cross-correlation of LA codes

3. COMPARISON WITH WALSH CODES (TRADITIONAL CDMA)

From the theoretical point of view, if the signals used within a multiple access system are mutually orthogonal, the interference within channels users respectively is zero. In real life, due to signals coming from multiple propagation paths, and those coming from adjacent cells, that are not temporally aligned with the ones in the main cell and due to because their orthogonal condition is not ensured, a non zero interference appears. Walsh code sequences are fixed power codes and are widely used in multi-user CDMA communications. Walsh code is a group of spreading codes having good auto-correlation properties and poor cross-correlation properties. In particular, the Walsh-Hadamard codes of length N can be defined from the following recurrent rule (the same as the Walsh-Hadamard transform):

$$H_0 = [1];$$

$$H_1 = \begin{bmatrix} H_0 & H_0 \\ H_0 & -H_0 \end{bmatrix};$$

$$H_{i+1} = \begin{bmatrix} H_i & H_i \\ H_i & -H_i \end{bmatrix}, \qquad i = 1, \ldots, \log_2(N) - 1;$$

Considering the two orthogonal codes :
H1= [-1;1;1;-1;-1;1;-1;1;-1;1;-1;-1;-1;1;1;1;1;1];
H2 = [1;1;-1;1;1;-1;-1;1;-1;1;-1;1;-1;1;-1;-1;-1;1;1;1];
Auto-correlation curve for code sequence H1 can be obtained as shown:

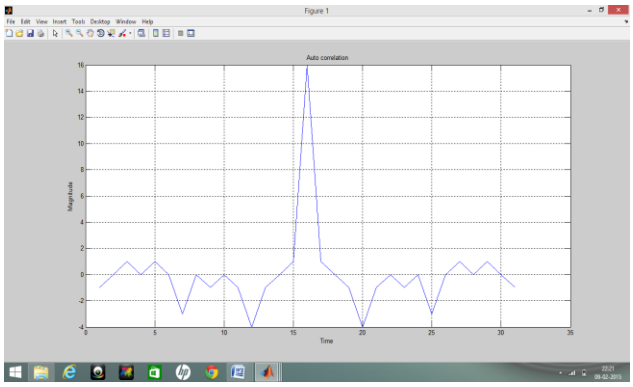

Fig. 6 Auto-correlation of Walsh codes

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Cross-correlation of above two code sequences H1 and H2 can be obtained by simulation as shown:

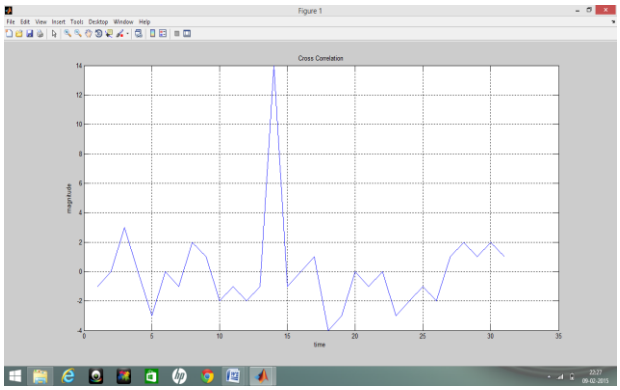

Fig 7 Cross-correlation of Walsh codes

Thus, Walsh codes are fixed length orthogonal codes possesing low cros-corelation properties and no IFW. Thus, the system employing walsh codes exhibit interference.

4. COMPARISON WITH M-SEQUENCE

By using a single shift-register, maximum length sequences (M-sequences) can be obtained. Such sequences can be created by applying a single shift-register with a number of specially selected feedback-taps. If the shift-register size is n, then the length of the code is equal to 2n-1. The number of possible codes is dependent on the number of possible sets of feedback-taps that produce any sequence. The curves for correlation of two such sequences are as shown:

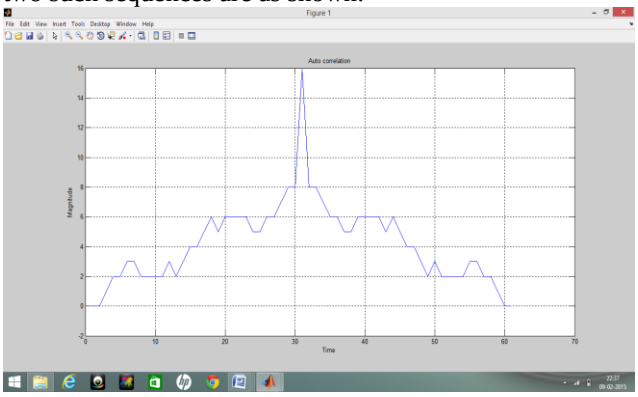

Fig 7 Auto-correlation of m-sequence

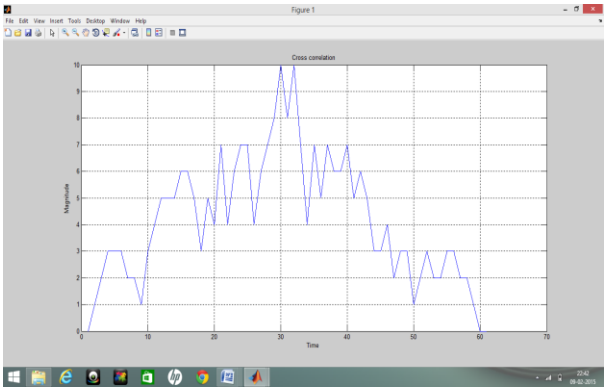

Fig 8 Cross correlation of two m-sequences

5. CONCLUSION

The paper illustrates the comparison of traditional CDMA using walsh codes, m-sequence and LAS-CDMA using LAS codes.The outstanding feature of LAS Code of having "Zero Interference Window" has also been described .Through simulation and analysis, we get to know that cross-correlation values as well as ayto-correlation values can reach to an ideal effect. Thus the excellent correlation feature enables it to be applied to many domains, such as TD-CDMA, FD-CDMA, Public Mobile Communication, Private Mobile Communication, Satellite communication, Navigation exploration etc. When it is applied to different domains, it will bring different technology revolutions.

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