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Performance Analysis of GDFT with Non Linear Phase on Real Time System

Mr. Umesh Sakhare[1], Prof. Lalit Dole[2]
[1, 2] *Department of Computer Science & Engineering, G. H. Raisoni College of Engineering, Nagpur, Maharashtra, India*

Abstract: *Cellular phone communication (CPC) has been developed throughout the world. During the development of CPC, Quality of Service (QoS) needs to maintain. To maintain QoS the requirement of CPC is to be satisfied. For CPC there are two techniques which are dominating with each other GSM and CDMA. This paper is dealing with CDMA technology and their requirement. CDMA technology uses the spreading code in order to improve frequency band spectrum. CDMA technology is based on wide-band and to improve the band spectrum, spreading code is used. Binary sequence like pseudo random sequence (PN-Sequence), m-ary sequences can be used as spreading code in wireless communication. Spreading codes are used to increase the spread spectrum and proper utilization of the bandwidth. Spreading code is having better result in wireless communication. The various spreading codes like M-ary Binary sequences, Gold codes, Walsh codes and Constant modulus function set (GDFT) used in various applications like Discrete Multi-tone, Orthogonal Frequency Division Multiple Access (OFDM), and Code Division Multiple Access (CDMA).*

This paper deals with simulation of spreading code like Gold, Walsh and Generalized Discrete Fourier Transform codes on real time system by using MATLAB environment. In this model Gold and Walsh and GDFT spreading codes are modulated with voice or speech signal. Performance result can be analyzed in terms of Bit-Error-Rate (BER), Signal-to-Noise ratio (SNR) and Mean Square Value of auto-correlation and Mean Square Value of Cross-Correlation. The experimental result shows the efficient technique used in CDMA.

Keywords: *Generalized Discrete Fourier Transform, Bandwidth, Auto-Correlation function, Cross-Cross Correlation function, Bit Interference, PN Sequence, CDMA, Gold Codes, Walsh Codes, Discrete Fourier Transform*

I. Introduction

CDMA is one of the techniques of cellular phone communication. CDMA provides better voice quality as compare to GSM.

1.1 Gold Code

Combining two m-sequences creates Gold codes. These codes are used in asynchronous CDMA systems. Gold sequences are important class of sequences that allow construction of long sequences with three valued auto-correlation function ACF's. Gold sequences are constructed from pairs of preferred m-sequences by modulo-2 addition of two maximal sequences of same length.

Gold sequences are useful in non-orthogonal CDMA. Gold sequences have only three cross-correlation peaks, which tend to get less important as the length of the code increases. They also have a single auto-correlation peak at zero, just like ordinary PN sequences. The use of Gold sequences permits the transmission to be asynchronous. The receiver can synchronize using the auto-correlation property of gold sequence.

1.2 Gold Theorem

Let $G_1(x)$ and $G_2(x)$ be a preferred pair of primitive polynomials of degree n whose corresponding shift register generate m-sequences of period 2^n-1 and correlation function has a magnitude less than or equal to

$2^{(n+1)/2} + 1$ for *n* odd, or
$2^{(n+2)/2} +1$ for *n* even and n≠0 mod

Then the shift registers corresponding to the product polynomial G1(X).G2(X) will generate 2^n +1 different sequence, with each sequence having a period of 2^n -1 and the correlation sequence are defined in the next section.

1.3 Correlation Properties of Gold Code Sequence

Consider a period of 2^n -1 =127 is considered. To generate such sequence for n=7, it needs a preferred pair of PN sequences that satisfy as $2^{(n+1)}$/2+1 =24+1=17. This requirement is satisfied by the PN sequences with feedback taps (7, 4) and (7, 6, 5, 4). The gold sequence generator is shown in figure-2.A According to Gold's theorem there are a total of $2^n+1=2^7+1=129$ sequences that satisfy $2^{(n+1)}/2+1$. In particular, the magnitude of the cross correlation is less than or equal to 17.

1.4 Walsh Code

Walsh codes are created out of Hadamard is the matrix type from which Walsh created this codes. Walsh codes have just one outstanding quality. In a family of Walsh codes all codes are orthogonal to each other and are used to create channelization within the 1.25 MHz band. Walsh codes of length 2^n can be defined and generated as different rows of a $2^n \times 2^n$ Hadamard matrix. The following recursive equation can be used to generate higher order Hadamard matrices from lower once.

$$H_{2^n} = \begin{bmatrix} H_{2^{n-1}} & H_{2^{n-1}} \\ H_{2^{n-1}} & H_{2^{n-1}} \end{bmatrix}$$

For example starting with a=1×1 matrix H1=[0], one can define Walsh codes of length 4 as follows

H1= [0] $H2 = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}$

$$H_4 = \begin{bmatrix} H_2 & H_2 \\ H_2 & H_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{bmatrix} \rightarrow$$

$$\begin{Bmatrix} W0 = [-1-1\ -1-1] \\ W1 = [-1+1\ -1+1] \\ W2 = [-1\ -1+1+1] \\ W3 = [-1\ +1+1\ -1] \end{Bmatrix}$$

Where W0 W1 are defined as different rows of a 4×4 Hadamard matrix and represented in binary or bipolar format. These rows are mutually orthogonal to each other.

1.5 Generalized Discrete Fourier Transform (GDFT)

An N^{th} root of unity is a complex number z satisfying the polynomial equation.

$z^N - 1 = 0$ $\quad N \in \{1, 2, 3\}$ (1)

All primitive Nth roots of unity satisfy the unique summation property of a geometric series expressed as follows:

$$\sum_{n=0}^{N-1} (z_p)^n = \frac{(z_p)^n - 1}{z_p - 1} = \begin{Bmatrix} 1,\ N = 1 \\ 0,\ N > 1 \end{Bmatrix} \forall p \quad (2)$$

Now define a periodic, constant modulus complex sequence $\{e_r(n)\}$ as the *r*th power of the first primitive Nth roots of unity

$$e_r(n) \triangleq (z_1^r) = e^{j(2\pi r/N)n} \quad (3)$$

Where n = 0,1,2,3,…N-1 and r = 0,1,2,..N-1 The complex sequence III over a finite discrete time interval in a geometric series is expressed as follows [1][2]

$$\frac{1}{N}\sum_{n=0}^{N-1} e_r(n) = \frac{1}{N}\sum_{n=0}^{N-1} (z_1^r)^n = \frac{1}{N}\sum_{n=0}^{N-1} e^{j(2\pi r/N)n} \quad (4)$$

Algorithm:

Step 1: Find N × N DFT

$$A_{DFT} = \left[e^{j(2\pi/N)kn}\right]$$

Step 2: Find G1 and G2 are constant modulus diagonal matrices and written as follows

$$G_1(k,n) = \begin{Bmatrix} e^{j\gamma_{nn}}, & k = n \\ 0, & k \neq n \\ & k,n = 0,1,\ldots N \end{Bmatrix}$$

and

$$G_1(k,n) = \begin{Bmatrix} e^{j\theta_{kk}}, & k = n \\ 0, & k \neq n \\ & k,n = 0,1,\ldots N \end{Bmatrix}$$

Step 3: Calculate GDFT

$$A_{GDFT} = G_1 A_{DFT} G_2$$

Step 4: Find maximum value of out of phase Auto Correlation (dam), maximum value of out of phaes Cross Correlation (dcm), Mean Square Value of Auto Correlation Rac, Mean Square Value of Cross Correlation Rcc and Merit Factor.

Step 5: Simulate using AWGN.

Step 6: Plot BER and SNR

II. Related Work

T.M. Nazmul Huda, Syed Islam analyzed correlation of Gold and Walsh code on the basis of generation of code of little particular lengths. Here, random noise to the generated codes has been added and it tried to find out how Gold and Walsh code act on application of random noise. Correlation is tested for the codes, which shows better result. Here the code is generated on the basis of only a pair of m-sequences of length five. Random noise is based on uniform distribution [1].

Vaishali Patil, Jaikaran Singh, Mukesh Tiwari simulated mathematical model of Gold Codes, Walsh Codes and GDFT and analyzed the result in terms of BER and SNR. It has been observed that GDFT provides better and efficient correlation function which can be exploited in optimum way of asynchronous CDMA communication system rather than Gold and Walsh codes [2].

Ali Akanshu, Handan Agirman-Tosun proposed a mathematical model of Generalized Discrete Fourier Transform (GDFT) to generate spreading code. GDFT can be derived by the definition of Discrete Fourier Transform. GDFT provides a unified theoretical framework where popular constant modulus orthogonal function set including DFT provides foundation to exploits the phase space to improve the correlation property of constant modulus orthogonal set. It is found that GDFT improved correlation over popular DFT, Gold and Walsh as well as Oppermann families, is leading to superior communication performance for the scenario considered in this paper [3][5].

III. Proposed System

The proposed work is the MATLAB simulation of Gold and Walsh on a real time system. Real time system model architecture designed as below

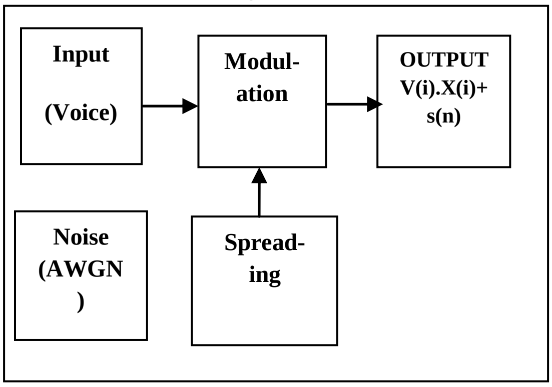

Fig. 1 Real Time System Model at Modulation

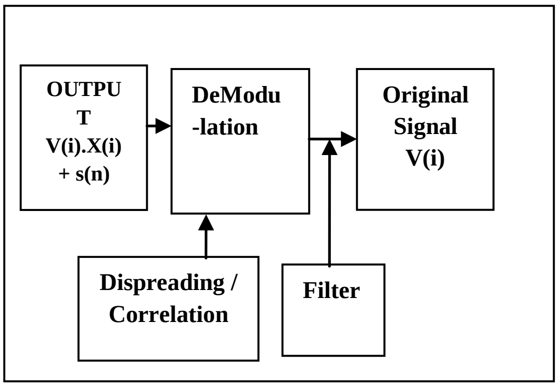

Fig. 2 Real Time System Model at De-Modulation

In this proposed work, system work on input voice signal V(i) recorded by different person. This input signal is modulated by Gold and Walsh code sequence. Same input signal is recovered back. Finally correlate the original signal and recovered signal. The performance of Real Time System can be observed on BER, SNR and Mean Square value. Real Time System approach works on various spreading coding techniques and mentioned in below section.

3.1 Real Time System with Gold Code (RTSGC)

RTSGC uses Gold code as spreading code, here input voice signal V(i) is recorded with sampling frequency (Fs) of 8000 Hz, and Number of samples (ns) is equal to Fs. Gain of input signal GN = 2 * ns. Graph shows the input signal in time as well as frequency domain.

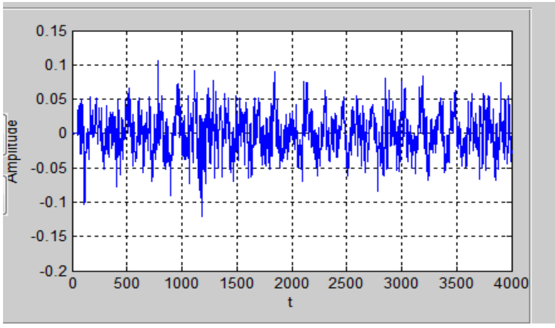

Fig 3. Input Signal in Time

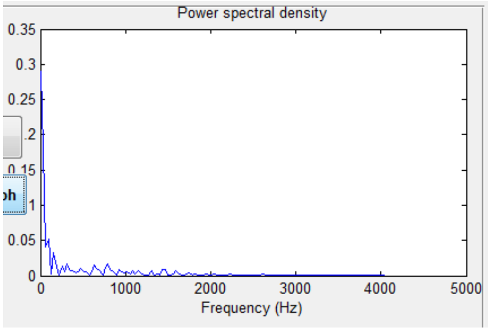

Fig 4. Input & Frequency Domain

A channel noise AWGN is added to input signal. Output after adding AWGN noise is $y_a(i) = v_a(i)$ +AWGN. Fig. Shows the output signal $y_a(i)$.

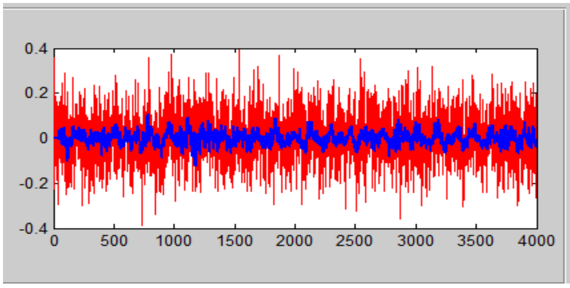

Fig. 5 AWGN noise with input signal

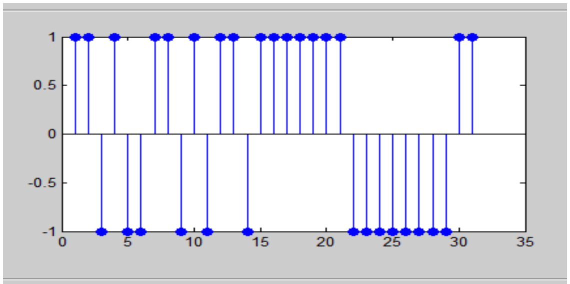

Fig. 6 Gold Code Sample of 31 code length.

Here AWGN noise is varies from 0-40 DB.

Gold code is generated which is of 31 bits code length. Gold code is explained in above section. For example the Gold Code G(x) is 1 -1 -1 -1 1 1 1 1 -1 -1 -1 -1 -1 1 1 1 1 -1 -1 1 1 1 -1 -1 -1 -1 1 1 -1 1 -1. Gold is further used as spreading code, which will also acts as modulating code. Now, modulating signal is $y(x) = [v(i) \times G(x)]$ + AWGN . Fig. shows the modulating signal in Time Vs Amplitude (Time Domain).

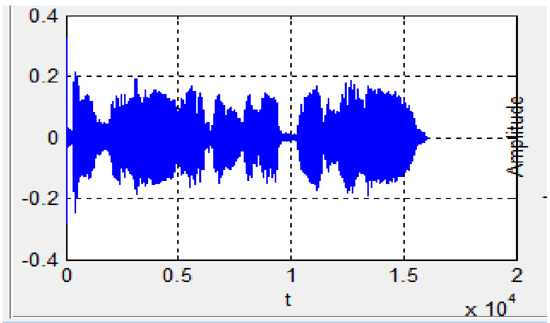

Fig. 7 Modulating Signal in Time Domain

Now, Challenge is to recover the original signal as it is, for that process of demodulation takes place. In the this process, Gold code G(x) of code length 31 bits has been recovered by using correlation function. AWGN noise added by the channel is removed by using filter. Filter removes all the noise samples added to the system. Result of this system is discussed in next section. Original signal is recovered and compared with input signal and both merely same signal. It is observed that in Real Time System, some signal has been lost and not getting 100% pure input signal, due to channel medium. Loss in signal (SNR and BER) is represents in next section of Experimental Results.

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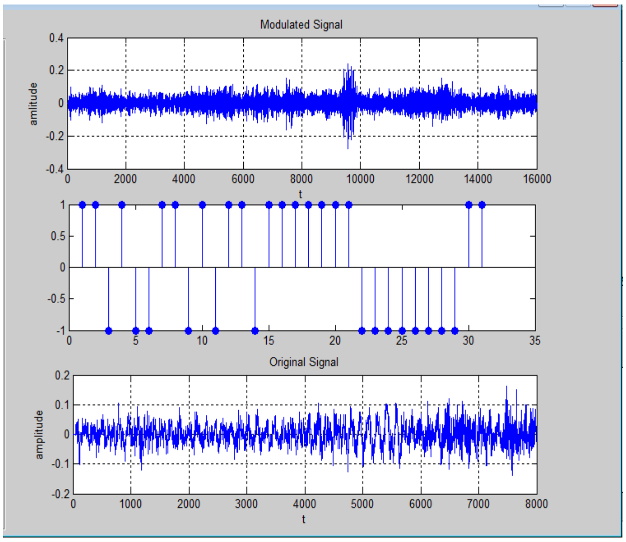
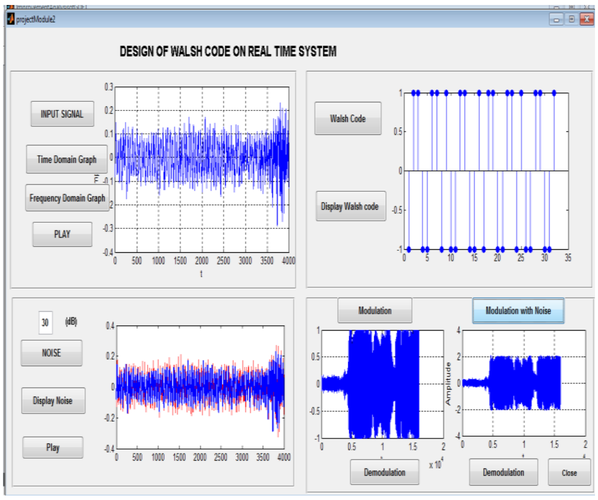


Fig. 8 The process of De-Modulation

3.2 Real Time System with Walsh Code (RTSWC)

In the process of modulation, RTSWC uses Walsh code as spreading code, here again, input voice signal V(i) is recorded with sampling frequency (Fs) of 8000 Hz, and Number of samples (ns) is equal to Fs. Gain of input signal GN=2*ns. Again channel noise AWGN is added to input signal. Output after adding AWGN noise is $y_b(i) = v_b(i) + AWGN$. Fig. Shows the output signal $y_b(i)$. Here AWGN noise is varies from 0-40 DB.

Walsh code is generated which is of 31 bits code length. Every bit of Walsh code is orthogonal to each other. Walsh code is explained in above section. The output signal after process of modulation is $y(x) = v(i) + AWGN \times W(x)$ as shown in fig.



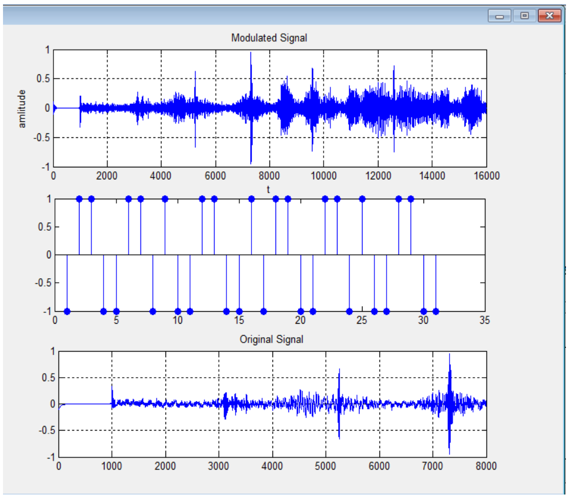


Fig. 9 The process of Modulation

Fig. 10 The process of De Modulation

Now, again same challenge is to recover the original signal from modulated signal, for that, process of demodulation takes place. In the this process, Walsh code W (x) of code length 31 bits has been recovered by using correlation function. AWGN noise added by the channel is removed by using filter. Filter removes all the noise samples added to the system. Here also original signal is recovered and compared with input signal and both merely same signal. It is observed that in Real Time System, some sample of signal has been lost due to noise and not getting 100% pure input signal. Loss in signal (SNR and BER) is discussed in next section of Experimental Results. Above figure shows graph of Modulated signal, Walsh code signal and Original signal.

3.3 Real Time System with GDFT Code (RTSGDFT)

Fig. 10 shows er(n) which is the periodic constant modulus sequence and plays an important role in Generalized Discrete Fourier Transform. It is the complex valued sequence as the r^{th} power of the first primitive Nth root of unity. Hence it has zeros on the unit circle in Z- plane as shown in fig. 11

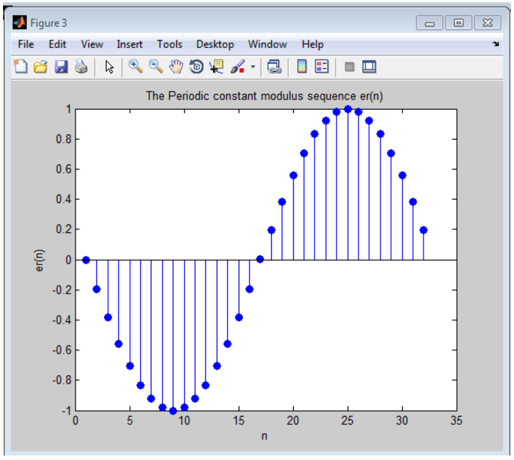


Fig.11 The periodic constant modulus sequences $e_r(n)$

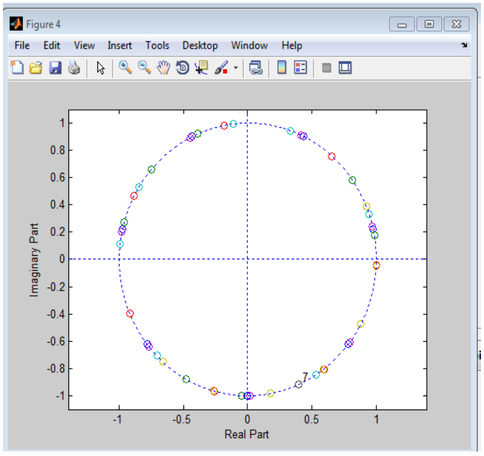


Fig. 12 Pole/Zero plot for primitive Nth root of unit

GDFT spreading code is used for the process of modulation. The fig. shows the process of modulation where the AWGN channel noise is added with input signal. Output after modulation process is Y(x) = [V(i) × GDFT] AWGN. In DeModulation process spreading codes are to be dispread after transmission, the correlation function is required for it. Noise is filter out by using wide band filter.

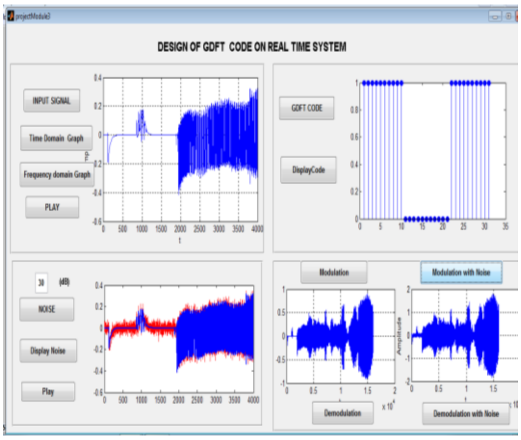


Fig. 13 The process of GDFT Modulation

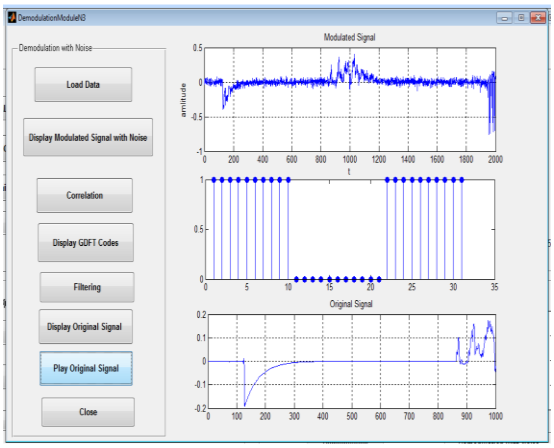


Fig. 14 Process of GDFT demodulation

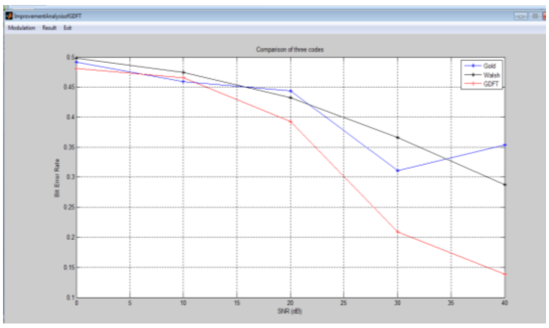


Fig. 15 Performance Comparison of Spreading

IV. Result

Performance of Gold code, Walsh, and GDFT code families and their correlation is analyzed in terms of Signal to Noise ratio (SNR) and Bit Error Rate. As SNR is increases the BER is decreases. The figure shows the analysis of Gold code, Walsh and GDFT on Real time system. From the figure it is clear that GDFT having better result. However, due to its lower cross correlation functi on value it gives the better result in Multipath fading.

Again in order to compare performance of code families several objective performance metrics codesare used. Table 1. Shows comparative results of Gold, Walsh and GDFT spreading family of their out of phase Auto correlation (dam), out of phase cross correlation (dcm), Mean Square value of Auto Correlation ($R_{AC)}$, Mean Square value of cross correlation (R_{CC}).

Table 1: Performance Comparison of spreading code

Code	dam	Dcm	R_{AC}	R_{CC}	F
Gold	**1**	**0.0312**	**0.442**	**0.00021**	**2.213867**
Walsh	**1**	**0.3605**	**0.127**	**0.00979**	**0.637889**
GDFT	**0.342616**	**0.4545**	**0.454**	**0.01414**	**0.006053**

V. Conclusion

In this paper we have implemented spreading code Gold, Walsh and GDFT. GDFT Spreading code can be used in CDMA which is having better result and effective correlation function as compare to Gold, Walsh and any other M-Ary binary sequences on real time system. The low value of R_{AC} is desired to magnitude multipath effect of the channel. Maximum Value of Merit Factor is best for CDMA communication. GDFT code can improves QoS for CDMA. Especially Gold code is used in asynchronous data transmission in CDMA.

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