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Research Article

Design the MC-CDMA System with LS-PSO Channel Estimation Based FPGA

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Abstract: The aim of study, providing the best BER performance in channel estimation for Multi Carrier-Code Division Multiple Access (MC-CDMA) system and flexible manner, FPGA design, is using a combination of the SIMULINK family of products, XILINX system generators, XILINX and MATLAB which is suitable for rapid design and verification. In MC-CDMA system, channel estimation is a very important method to work around the influence of channel fading's which jamming pilot symbols and caused BER degradation. That the market for wireless communications infrastructure matures equipment vendors are under increasing pressure to provide low cost solutions for operators and reduce wireless technology complexity. In this study new MC-CDMA channel estimate schema suggested that was based on a combination of Local Search and Particle Swarm Optimization. The proposed channel estimator tested under channel fast fading for different situations. In particular, the transmitter design focus on the 64-QAM system and spreading gold code.

Keywords: Channel estimation, FPGA, LS-PSO, MC-CDMA

INTRODUCTION

The increase in consumer demand and the exponential growth of wireless systems, which enable consumers to communicate anywhere through the information, has in turn led to the emergence of many portable wireless communications products (Joseph and Kumar, 2012). This research works mainly to the integration of targets as far as signal processing applications in a one device. Since integration through software applications concessions speed of the system, integration through hardware will be the better compliment. CDMA is a completely new idea in the field of wireless communications, Multi-carrier communications as MC-CDMA is usually to provide the ability to transfer high with high efficiency in bandwidth wireless communication systems by De Angelis *et al*. (2010).

From the channel has suffered from the time of the various factors and frequency selective fading to improve mobile communication systems. So channel estimation is the most critical factor need to do with inserting pilot symbols which is necessary before the demodulation MC-CDMA signals reduce the BER and achieve less distortion of the output data. It was used in wireless standards, especially for broadband multimedia wireless facilities. Moreover, the most cases are implemented mainly in ASICs (Lee and Ha, 2003; Andreev *et al*., 2004) and not sliced FPGA. The main reason for this is the concern designers to reduce energy consumption of the system. FPGAs have the feature of configurability, which gives the ability to test several plans very easy. In addition, the likelihood of automatic for a radio channel that is usually involved as real when combined with real Pseudo Noise (PN) sequence is used to spread the signal, it leads to a signal received from the real value. But a more accurate representation of the results and realistic wireless channel transfer function in the complex, which refers to a radio channel, was magnitude change and phase rotation exists. The channel estimation of an MC-CDMA system based on Least Square Estimator (LSE) algorithm and linear interpolation in frequency domain over multipath fading channels was proposed in Iraji *et al*. (2003). Different detection receivers for MC-CDMA were also introduced; their algorithms include Maximum Ratio Combining (MRC), Minimum Mean Square Error (MMSE) and Parallel Interference Cancellation (PIC) and interference cancellation based on Expectation-Maximization (EM) algorithm. It was proved that MMSE algorithm provides significant performance gain compared to that with MRC algorithm and the system performance can be further improved by using PIC and EM algorithms. Edfors *et al*. (1998) is the comb-type based channel estimation in which pilot symbols are transmitted on some of the sub carriers of each OFDM symbol. This method

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usually uses different interpolation schemes such as linear, time domain interpolation, spline cubic and low-pass. Some different methods have been developed to reduce the complexity and improve the performance of the MMSE estimation such as modified MMSE and singular value decomposition. Trivedi and Gupta (2007), the performance of an MC-CDMA system employing MMSE multiuser detection at the receiver was evaluated using two pilot symbol assisted channel estimation schemes, the Maximum Likelihood (ML) estimation and the MMSE estimation. It was shown that the MMSE estimator significantly outperforms the ML estimator in non-sample-spaced channels where path delays are closely spaced with respect to the timely resolution of the system. Moreover, Amsavalli and Kashwan (2012) have taken place in which some of the design and implementation elements of the CDMA decoder were carried out. It was decided that the CDMA decoder should be implemented on an FPGA and the relevant frequencies for the carrier wave and the underlying modulated data as well as the interconnection between peripherals in SOC'S. Oyerinde and Mneney (2013) provided the optimal threshold value obtained based on wavelet decomposition and therefore they could improve the channel estimation. Local search make PSO algorithms accurately and fast convergence to the Pareto optimal front, such as multi-objective local search by Xu *et al*. (2013). Amiri *et al*. (2014), evolutionary algorithm PSO developed in which searches for optima by updating generations for random particles. In this study, FPGA proposed and implementation of channel estimation using Local Search PSO for MC-CDMA. The objective of the study, the computational complexity of the proposed LSPSO algorithm is proven to be as low complexity as close to the correlate with a substantial comparable performance gain like PSO algorithm. This approach is also investigating that objective function based BER calculate by LSPSO Algorithm to obtain pilot coefficients. As a final point, Design and implementation proved that the signals with LSPSO channel estimate become much better.

METHODS AND ALGORITHM

The PSO algorithm: Particle swarm optimization is a population based stochastic optimization similar to simulate the social behavior of swarms of the birds. A swarm of particles, "fly", in PSO algorithm, through research that the area of research in n-dimensional space the globally optimal. Kennedy and Eberhart established for the first time a solution to the problem of optimization of nonlinear complex by imitating the behavior of flocks of birds. They are produced the concept of function, optimized by a swarm of particles (Zambrano-Bigiarini *et al*., 2013). There are some parameters in the PSO that may affect performance. For any problem, optimize certain, some of these parameter values and choices have a significant impact on the efficiency of the method of PSO and other parameters have an impact small or non-existent. Parameters PSO core is a swarm size or number of particles, the number of iterations, the components of velocity and acceleration coefficients bellow pictured. Moreover, influenced by PSO similar weight, inertia, speed clamping and the speed of construction and these standards.

All particles of the two advantages related velocity and position. Each particle is also the best memory location that is found to the point (*p*-best) and finds the best site found so far by all particles in the population (*l*-best). In each step of the algorithm, particles are moved from the current situation through the application of transmission (He and Guo, 2013). The magnitude, velocity versus direction, is affected by the velocity in the prior redundancy and the location of the particles to compare its *P*, *l*-best. Therefore, each iteration algorithm and the direction and magnitude of movement of each particle is the purpose of its own history and social influence of the group. Overall, the PSO algorithm can be described as follows:

1. Initially, velocity and position of particles are produced randomly in search space. Each particle i has $x_i = (x^1{}_i, x^2{}_i \ldots x^O{}_i)$ position vector and velocity vector $v_i = (v^1{}_i, v^2{}_i, \ldots, v^O{}_i)$, where O is length of solution space.
2. Calculate the fitness value of every particle and location of the particle according to the highest fitness. If the present value of fitness is greater than the value of the best fitness found in the particle so far, then *p*-best is updated and updated *l*-best.
3. Estimate the velocity, for each particle, based on the following equations:

$$V_i^d \; (1+t) W V_i^d(t) + (p - best_i^d(t) - x_i^d(t)) + c_2 \; r^2{}_i(t)(l - best_i^d(t) - x_i^d(t)) \tag{1}$$

$$W = W_{\max} - \frac{W_{\max} - W_{\min}}{iteration} \times iteration \tag{2}$$

where, c_1 and c_2 are constants that weigh the influence of individual learning and social influence, respectively and r_i are the random variables, between 0 and 1, representing the movement freedom of any particle and W is the inertia of the system:

4. According to the next equation update the position (x) of every particle:

$$x_i^d(t+1) = x_i^d(t) + v_i^d(t+1) \tag{3}$$

5. Repeat the steps between 2 to 4 until it reaches the event of termination either precision or the number of iterations. The PSO pseudo code has been applied.

The pseudo code of the method is as followings:
For each particle
Initialize: parameters of PSO
END
DO
For each particle
Indentify: calculate fitness value
If: the fitness value is better than the best fitness value (p-best) in history
Set: current value as the new (p-best)
End If
While: Choose the particle with the best fitness value of all the particle as the (l-best)
For each particle
Identify: calculate particle velocity according equation
Set: update particle position according equation
End While
While maximum iterations or minimum error criteria is not attained

Local search PSO algorithm: The MSE function of LSE can be used to achieve the optimal level of pilot tones the objective of obtaining to the algorithm LSPSO. For the improving the quality of the solution is to implement a scheme of Local Search (LS), where it intends to explore the area less crowded in the current archive perhaps to get more non-dominated solutions. In this section, an amended local search scheme MLS is provided, which is a modification of the Hooke and Jeeves (1961) method to deal with the MOP. General procedure for the MLS scheme can be described by next steps:

Step 1 : Start with a randomly chosen point ($X_m \in R_n$) $\in E^t$ and the set step lengths Δx_i in all of the coordinate directions, u_i, $i = 1 \ldots n$. Set $m = 0$, shoulder that m is the size of E^t.

Step 2 : Set $m = m + 1$ and $k = 1$ where k is the number of test $(s.t., k = 1, \ldots, k_{max})$ to obtain a more favored solution than X_m.

Step 3 : The variable x_i is perturbed around the present provisional base point X_m to get the new temporary base point X'_m as:

$$x'_m = \begin{cases} x_m + \Delta x_i u_i \ if\ f^+(.) > f \\ x_m - \Delta x_i u_i \ if\ f^-(.) > f(.) \cap f^+(.) \\ \\ x_{m\ if\ f(.) > (f^+(.) \cap f^-(.))} \end{cases} \quad (4)$$

$\forall_i = 1, 2, \ldots\ldots, n$

where, $f(.) = f(X_m)$, $f^+(X_m + \Delta x_i u_i)$ and $f(.) = f(X_m - \Delta x_i u_i)$. Assume $f(.)$ is the evaluation of the objective functions at a point.

Step 4 : If the point X_m is unchanged.

While the number of trial k not satisfied, reduce the step length Δxi using the following dynamic equation:

$$\Delta x_i = \Delta x_i (1 - (r)^{k/k_{max}}) \quad (5)$$

where, r is a random number $r \in [0, 1]$ and go to step 3.

Step 5 : Else, if x'_m is preferred than, x_m, (i.e., $(x'_m) > f(x_m)$ then the new base point is x'_m and go to step 6.

Step 6 : With the help of the base points x_m and x'_m, establish a pattern's direction S as follows:

$$S = x'_m - x_m \quad (6)$$

Find a point x''_m:

$$x''_m = x'_m + \lambda S \quad (7)$$

where, λ is the step length, which could be taken as λ = 1.

Step 7 : If $f(x''_m) > f(x'_m)$ set $x_m = x'_m$, $x'_m = x''_m$ and go to 6.

Step 8 : If $f(x''_m) \leq f(x'_m)$ set $x_m = x'_m$ and go to 4.

These steps apply to all non-dominated solutions in E^t, which enables the algorithm to realize the less congested region in the external archive. The pseudo code of the proposed.

LSPSO pseudo code algorithm:

```
Initialize Parameters for PSO
Identify local set = {}.
Identify global set
The nearest member in G^{t=o} to the i-th particle is GP^{t=o}
Set the external set
While travel not completed PSO algorithm
    While sub-travel not completed
    Generate
    Evolve the infeasible particle until they can be feasible
    Upload
    Indentify and GP_t^{t+1}
    Upload E'.
    End while
End Travel
LS scheme
Start whit
Generate
While stopped criterion satisfied) DO
    If =
        Reduce
End
    Establish a pattern direction
      If
      Set
      Else if
    End If
End
```

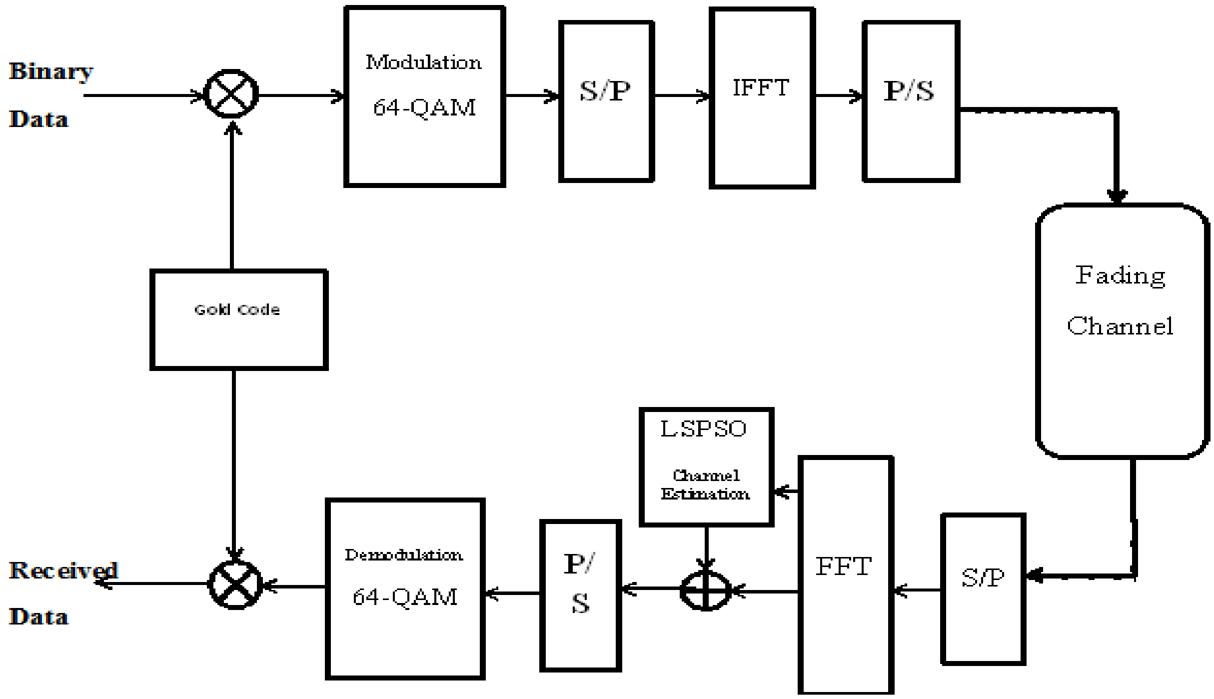


Fig. 1: MC-CDMA system based LSPSO channel estimation method

MC-CDMA system: The MC-CDMA system model consists of two parts, the transmitter and the receiver. On the transmitter side there is the number of blocks programmed and tested separately first, then connected together to form the transmitter part, Fig. 1, shows MC-CDMA system block diagram. All parts of the system have been designed in VHDL; programmed parts have all been tested separately to verify correctness of operation and functionality.

The information data are modulated using a 64-QAM modulator. The data modulated symbols are represented by:

$$D\,(n) = [\,d_1, d_2, d_3, \ldots d_n] \tag{8}$$

The user specific gold code cg is generated from a PN generator, PN code sets can be generated from linear feedback shift registers, by changing its initial conditions (Kushwah and Manglasheril, 2014):

$$C(g) = [c_1, c_2, c_3, \ldots, c_g] \tag{9}$$

where,

$$C_g = C_{N1} \text{ x or } C_{N2} \tag{10}$$

and,

$$C_N(n) = P_1 + P_4 + \ldots\ldots + P_{n-1},\ n = 1, 2 \ldots g,\ P = 1 \tag{11}$$

Spreading data symbols are converted from serial-to-parallel (s/p) vector Y_s of length $N_d = n \times g$.

The pilot vector Y_P of length N_p is signified by:

$$Y_p N_p = [y_1, y_2, \ldots. y_{np}] \tag{12}$$

where,

$$y_n = y_{n-1} + y_{n-3} + \ldots. y_2, n = 1,2, \ldots.. N_p \tag{13}$$

Y_P is generated by varying the initial conditions using the PN code generator given in (11) and then this vector is concatenated with the vector Y_s to form a concatenated vector Y_{sp} of length N_c:

$$Y_{sp} = [Y_s Y_p] \tag{14}$$

$N_c = N_d + N_p$ is the number of sub-carriers of Inverse Fast Fourier Transform (IFFT). Next parallel-to-serial (p/s) convertor, after this, the transmitted signal will pass through the paths frequency selective fading channel. The channel is modeled by Jake's classical, where it's discrete impulse response h_n is defined as:

$$h_n = \sum_{l=1}^{L} h_l \ sinc\left\{\frac{\tau_l}{T_s} - n\right\} \tag{15}$$

where,

T_s = The input sample period to the channel
τ_l = The set of path delays
L = The total number of propagation paths and is the *l-th* path gain

At the receiver, (s/p) conversion, the received signal is sent to the FFT block which transforms it into a frequency domain vector $QAM\ (k)$ of length NC:

$$QAm(k) = Y_{Spr}(k)H(k) + F(k) \quad (16)$$

Let $Y\ (k)\ =\ Y_{SPr}$ for minimalism, $H\ (k)\ =\ FFT\ \{h\ (n)\}$ and $F\ (k)\ = FFT$ {Fading channel}. Also, $QAm\ (k)$ is de-interleaved, the received pilot signals P (k) of length N_p are extracted and used to estimate the channel impulse response for the data sub-channels in the channel estimation block. The LSPSO channel estimator is used:

$$H_{LSPSO} = \frac{P(k)}{Y_p} \quad (17)$$

H_{LSPSO} is included channel estimation using local search PSO methods, which were in above section, the received data from the $QAM\ (k)$ of length, N_d is multiplied H_{LSPSO} with to find the estimated data vectors. The estimated data vectors, each of length N_d are summed and p/s is converted and applied to a de-spreader to obtain the estimated output data.

RESULTS AND DISCUSSION

In this section, the first part, MC-CDMA system is implemented in Hardware Description Language (HDL). VHDL is used to code the Register Transfer Level (RTL) of the designs. All parts of the system have been programmed in VHDL; programmed parts have all been tested separately to verify correctness of operation and functionality. The designs are entered as a component in the system and the signal flow between these components and the implementation by using the package Xilinx FPGA version 14.1. And then, as a second part, we take the results of the performance of Channel Estimation using an algorithm LSPSO. LSPSO algorithm is written in MATLAB and converts to Xilinx FPGA, as a block, by turning to the black box in the process of representation. Moreover, the specification of the model parameters for MC-CDMA, which was used in Table 1.

MC-CDMA based on VHDL: Figure 2 shows some various MC-CDMA parts such as Gold code, IFFT, 64-QAM and LSPSO. Where, spreading code is done by using Gold code as spreading code; Gold codes are constructed from a modulo-2 addition of two PN code sequences as shown in Fig. 2a. In addition, IFFT operation used the butterfly method computation in programming the 8 paths show in Fig. 2b. Also in transmitted and received, 64-QAM mapping, which is used here was real and imaginary, illustrate in Fig. 2c, DATA (5:0) is represented by the symbol I (3:0) and Q (3:0) as output. However, in receiver side only, LS-PSO channel estimation as shown in Fig. 2d.

In Fig. 3a to e, show behavioural Simulation for gold code, IFFT, serial to parallel, 64-QAM and LSPSO channel estimation respectively. Very of MC-CDMA parts can be connected as components in the system and all the system then tested as one unit. After it passes all the tests, it can be saved as a source code to the system. We tested sending two bits from the transmitter to the receiver, then the program indicates that the design can be implemented according to Table 2 and it is implemented successfully as shown in Fig. 4.

MC-CDMA system based on MATLAB: In addition to the construction of the proposed design in VHDL, we have been building and testing the proposed system of

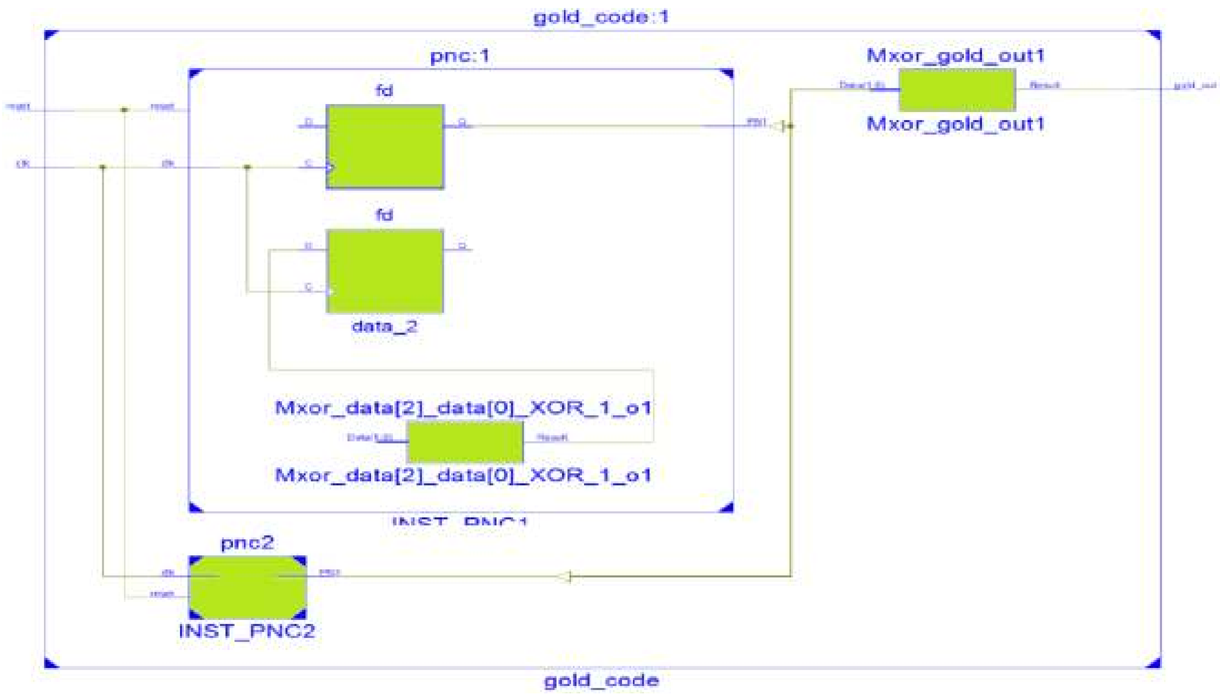
Table 1: MC-CDMA simulation parameters

Parameters	Value
Number of transmitting bits	300000
Modulation	64 QAM
FFT and IFFT size	128
Spading code type	Gold code
Length code	8
Additive noises	20 dB
Channel estimation	LSPSO
Inertia weight	0.4
PSO iteration	10.0
Cognitive parameter	2.3
Social parameter	1.3

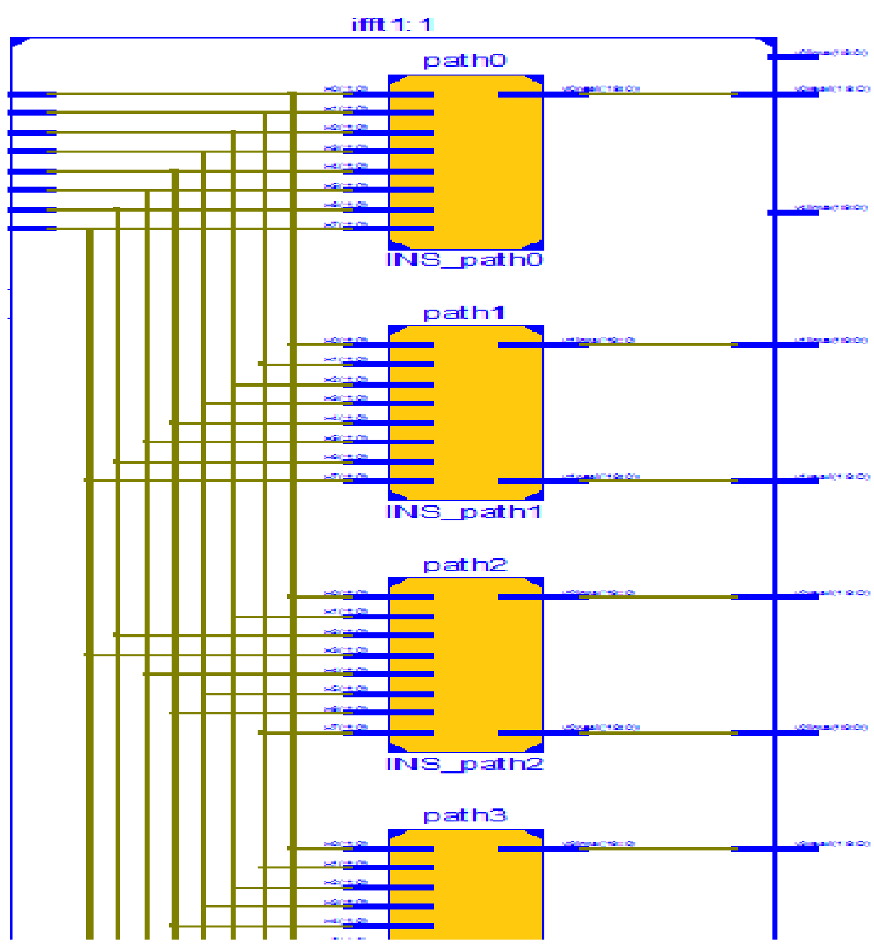
Table 2: Final design summary of MC-CDMA system

Device utilization summary

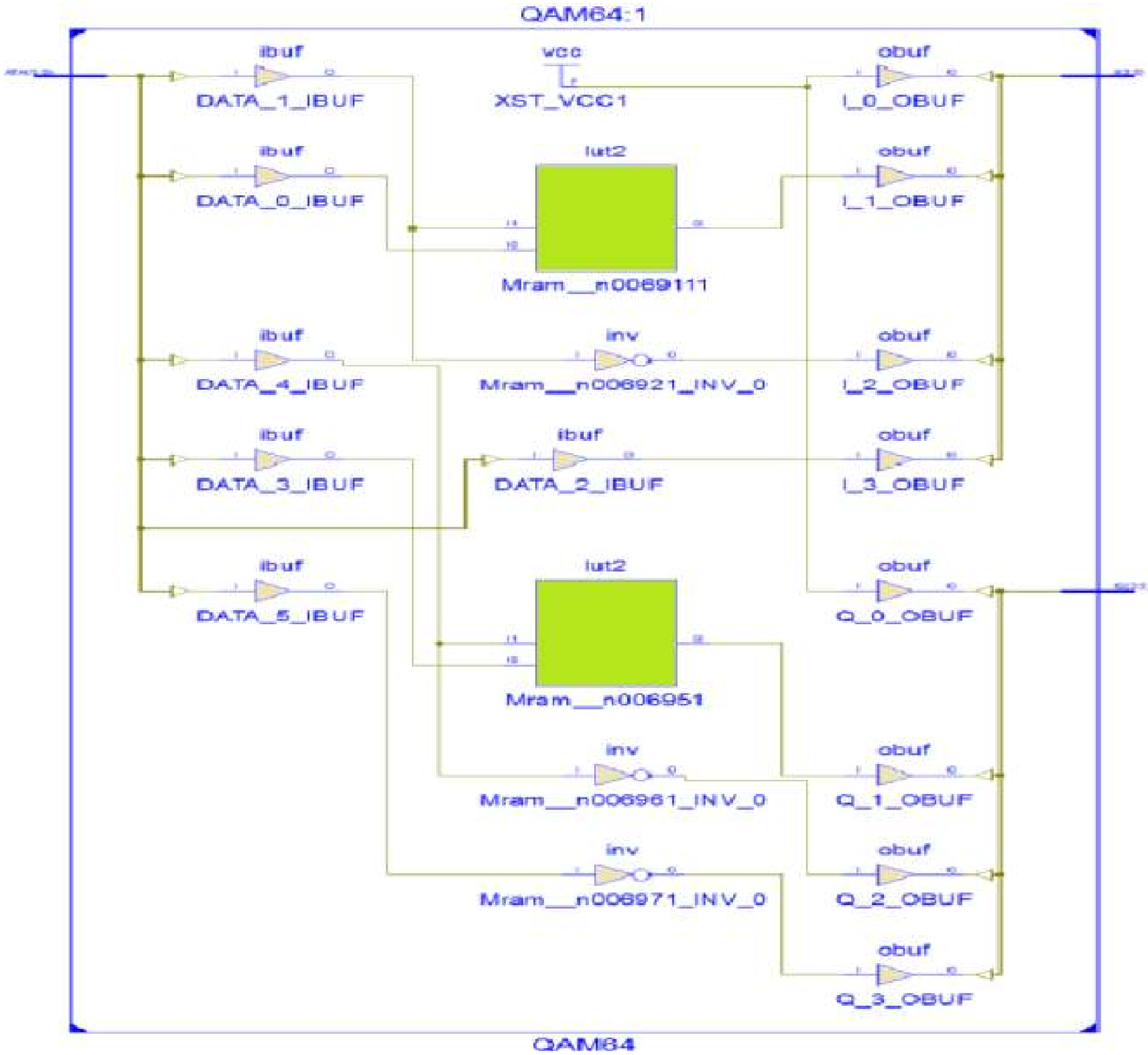
Logic utilization	Used	Available	Utilization (%)	Note (s)
Number of slice flip flops	88.000	11.776	1	
Number of 4 input LUTs	2.271	11.776	19	
Logical distribution				
Number of occupied slices	1.255	5.888	21	
Number of slices containing only related logic	1.255	1.255	100	
Number of slices containing unrelated related logic	0.000	1.255	0	
Total number of 4 input LUTs	2.352	11.776	19	
Number used as logic	2.271			
Number used as a rote-thru	81.000			
Number of bonded IOBs	6.000	372.000	1	
Number of GCLKs	1.000	24.000	4	
Number of MULT 18×18SIOs	20.000	20.000	100	
Total equivalent gate count for design	24.078			
Additional JTAG gate count for IOBs	288.000			


gold_code:1
pnc:1
Mxor_gold_out1
fd
Mxor_gold_out1
fd
data_2
Mxor_data[2]_data[0]_XOR_1_o1
Mxor_data[2]_data[0]_XOR_1_o1
pnc2
INST_PNC2
gold_code

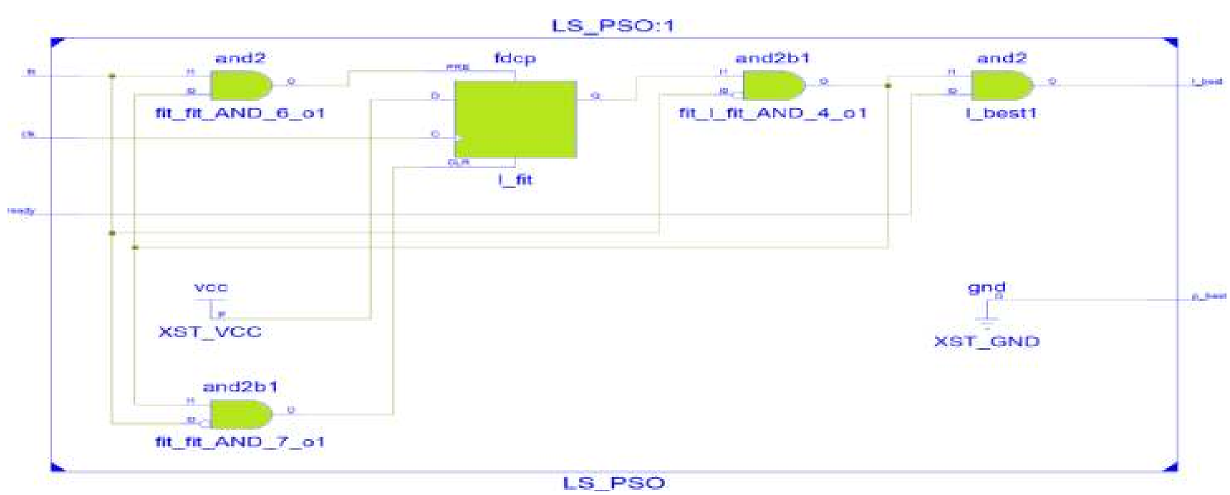
(a)


ifft 1: 1
path0
INS_path0
path1
INS_path1
path2
INS_path2
path3

(b)

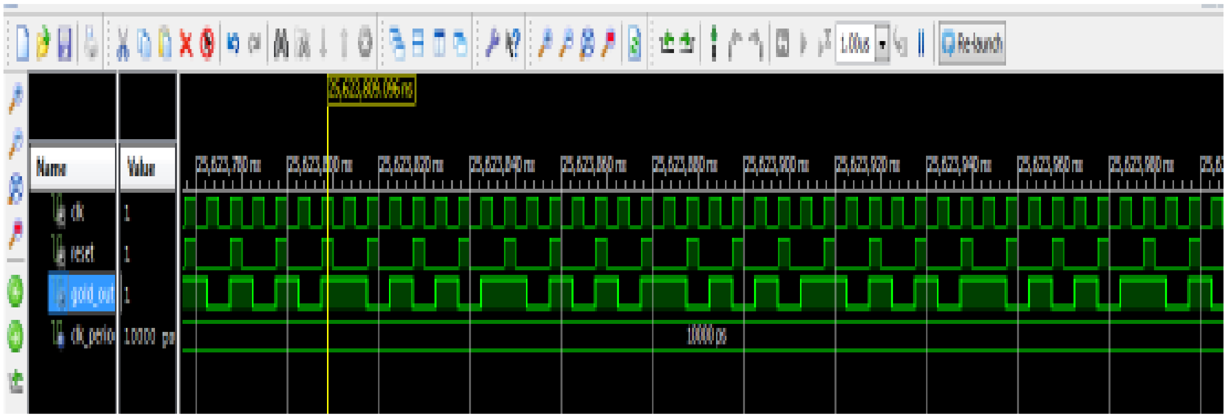


(c)

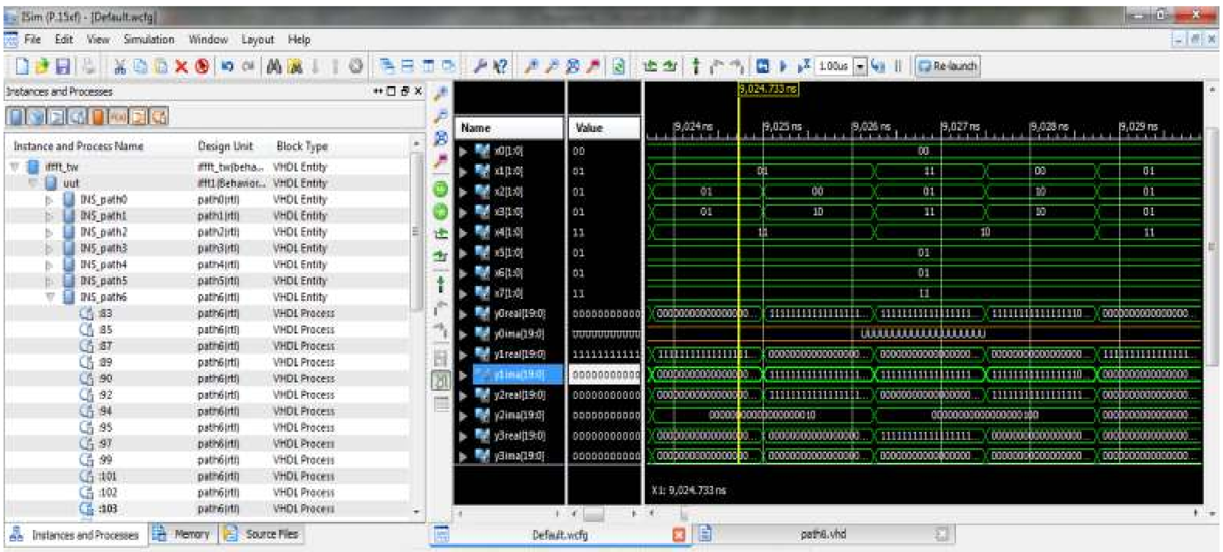


(d)

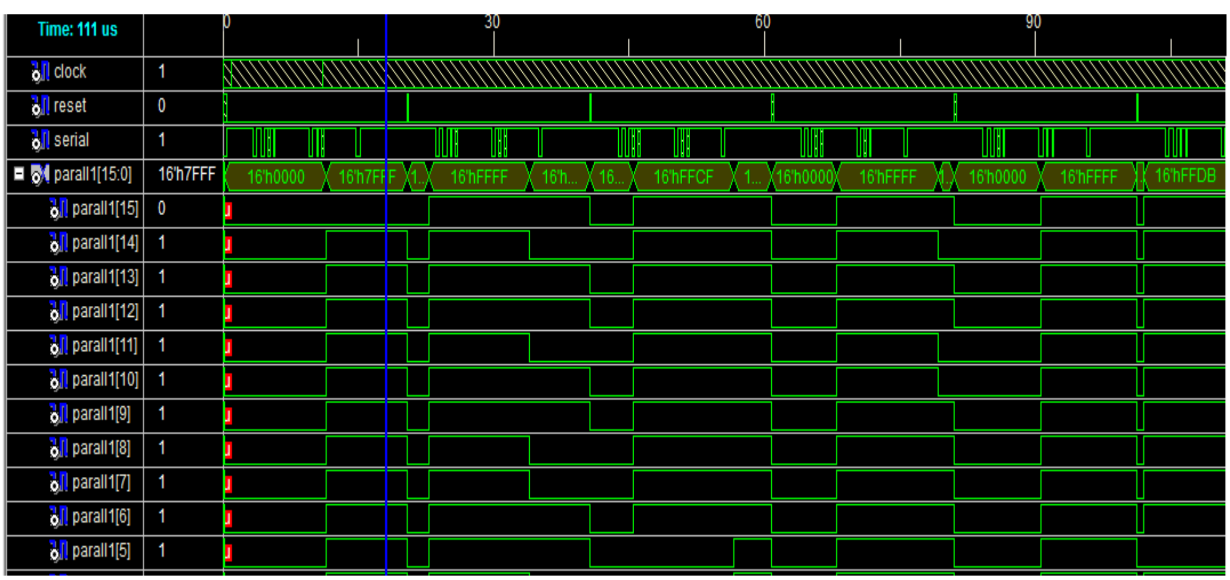
Fig. 2: RTL circuit for some parts of MC-CDMA; (a): Gold code; (b): IFFT; (c): QAM modulation; (d): LS-PSO


Name
Value
clk
reset
gold_out
10000 ps

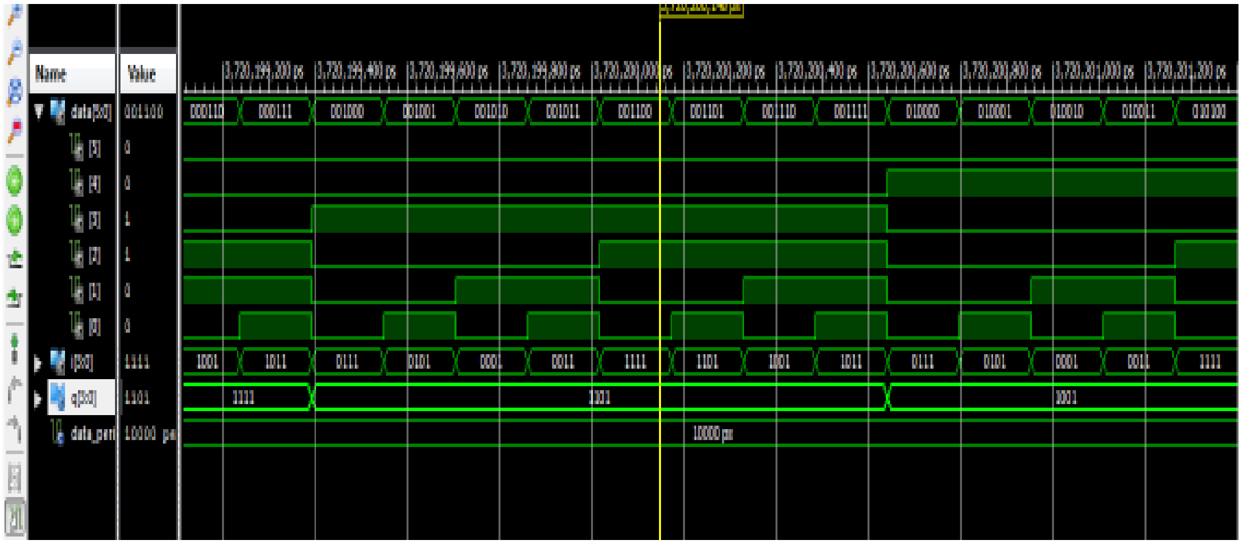
(a)


File
Edit
View
Simulation
Window
Layout
Help
Re-launch
Instances and Processes
Instance and Process Name
Design Unit
Block Type
Name
Value
Default.wcfg
path6.vhd

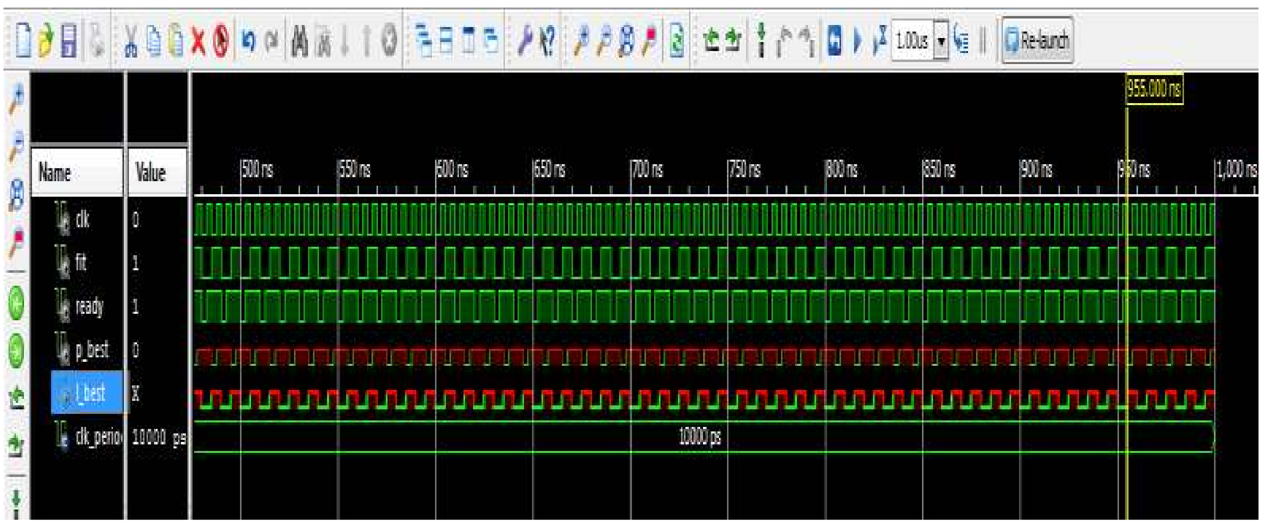
(b)


Time: 111 us
30
60
90
clock
reset
serial
parall1[15:0]
16'h7FFF
16'h0000
16'hFFFF
16'hFFCF
16'hFFDB

(c)



(d)



(e)

Fig. 3: Behavioral simulation for; (a): Gold code; (b): IFFT; (c): Serial to parallel conversion; (d): QAM modulation; (e): Local search-PSO

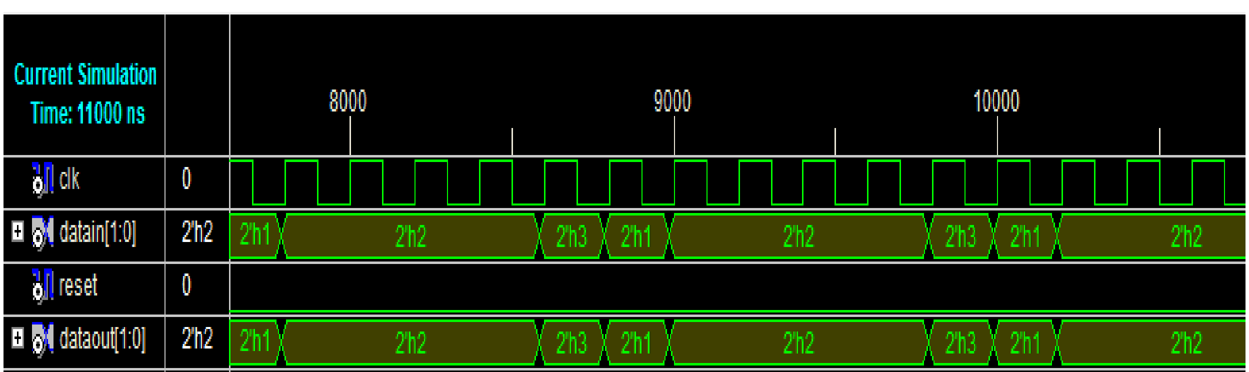


Fig. 4: Behavioral simulation sends 2-bits of MC-CDMA system

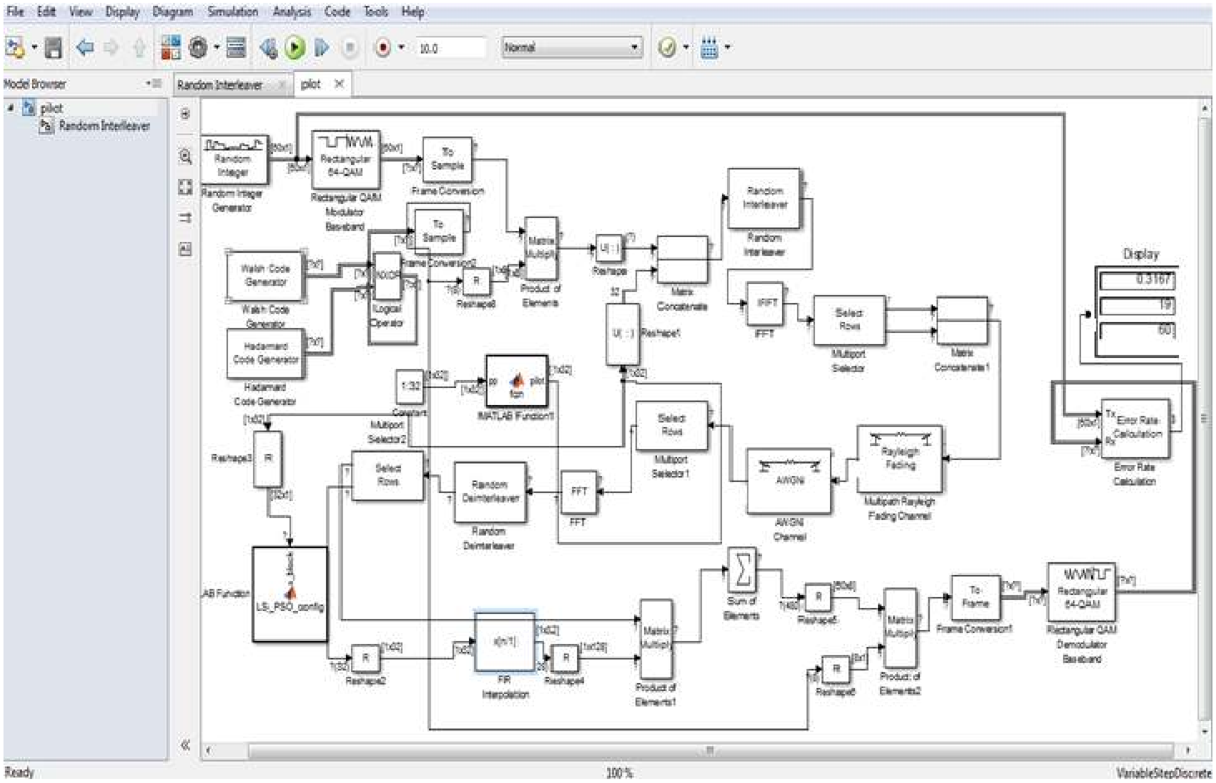


Fig. 5: MC-CDMA system based LSPSO channel estimation using SIMULINK

SIMULINK program, the input is represented by a random integer generator frame based and both the spreading gold code and pilots which are LSPSO based are built as subprograms using MATLAB functions. The LSPSO channel estimation also builds using the MATLAB function the proposed system is tested for SNR = 10 dB in AWGN and 3-paths fast Rayleigh fading channel where the SER is recorded as 0.316 as shown in Fig. 5.

CONCLUSION

In this study, an FPGA implementation of a baseband MC-CDMA receiver was presented with we used a new technique for channel estimation to optimize the power of pilot tones. In this design, estimators were used to estimate the efficiency of the channel in the MC-CDMA system called LSPSO. This algorithm LSPSO is very important to solve the problem when faced with all the molecules of early convergence or stagnation in the search process that outperform orthogonal pilot tones. Simulation results demonstrated that the channel estimation of the MC-CDMA system using VHDL methods and when the pilots are LSPSO channel estimation, signal achieves better performance improvement compared to the same proposed system, conventional MC-CDMA, the proposed system was also built and tested using SIMULINK program. The results of the simulation program in Xilinx some parts of the MC-CDMA system provides increased data transfer speed proportionally. The results also show set of design flexibility and ease of change and development.

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