Implementation of Digital Video Broadcasting Codec Using FPGA

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Abstract

This paper is concerned with transmitting signals of Digital Video Broadcasting (DVB) properties using Field Programmable Gate Array (FPGA) using Verilog code to achieve this goal. DVB is a technique used an outer code (Reed-Solomon), inner code (convolutional code) and interleaver in between them. the properties of Reed-Solomon is (204, 188), convolutional code is a 1/2 and interleaver of depth I=12. The method used to programming the FPGA is schematic and Verilog code.

Keywords: Communications, Concatenation, FPGA, DVB

الخلاصة

تختص هذه الدراسة بمجال الاتصالات الرقمية و باستخدام نظام بث الفيديو الرقمي لغرض ارسال معلومات من نقطة الى نقطة اخرى وذللك بواسطة برمجة مصفوفة البوابات القابلة للبرمجة عن طريق لغة(Verilog) حيث يستخدم مشفر ريد–سلمون و مشفر لافوفي ويستخدم بينهما مبعثر.

الكلمات المفتاحية: بث الفيديو الرقمي،مصفوفة البوابات القابلة للبرمجة.

1. Introduction

In communication, channel coding is a method used for correcting errors in data transmission over noisy channel the basic idea is to encode the message in a way by using an error correcting code. The mathematician Richard hamming pioneers this field in the 1940s and invented the first error correcting code in the 1950s. The earlier codes (Hamming codes) were far from Shannon limits of transmitting data over a noisy channel .The problem is how to decrease the bit error rate without increasing the code word length and decoding complexity, Forney in his doctoral thesis presented to MIT stated that a hard decision code and a soft decision code which are Reed Solomon and convolutional code respectively can decreases the bit error rate without the need of increase the codeword length and decoding complexity. By doing so Forney invented Concatenation which is a combination of two codes an inner code and outer code. This technique was invented in 1965 by Dave Forney as a solution of problem mentioned above. Later this technique became the corner stone of coding theory it was used first time in 1971 Mars orbiter mission, because of its success it was used in Voyager program deep space explorer in 1977 since then the concatenation codes are an essential way of coding. The use of Reed Solomon code and convolutional code is very common but other codes like low density parity check code (LDPC) and Bose chaudhuri Hocquenghem (BCH) code can be used. The latest application of concatenation is the DVB-T or DVB-S which represent very important standards in communication now days. The type of concatenation mentioned above is called serial concatenation there is another type invented in 1993 called parallel concatenation its use two convolutional codes in parallel called (turbo codes). Digital Video Broadcasting (DVB) it's a standard published by Joint Technical Committee (JTC) of the European Telecommunication Standard Institute (ETSI) and others, this std. gives the physical layer and data link layer to the transmission process [Forney,1965].

2. Concatenated Code

Shannon said in his theory that ((a probability of error exponentially small in the block length at any information rate below channel capacity)) [Forney, 1965]. After Shannon about 40 years, codes is invented with small codeword and simple enough to build. The idea of concatenation is that if we have a large system it's difficult to build

this system entirely but breaking this system into sub systems can achieve this system work with less difficulty.

In coding theory concatenation is a technique used two types of codes serially to achieve work only can be achieved with complex codes as shown in fig(1), Forney use a hard decision code and a soft decision code, Forney attempts to combine two or more codes this can achieved by three types namely serial and parallel this technique implemented in digital video broadcasting with all of its types like DVB-T(Digital Video Broadcasting Terrestrial), DVB-S(Space) and DVB-H(Handheld) with different types of codes.

3. Digital Video Broadcasting (DVB)

DVB is a functional which block contains processes on the bit stream from the output of the MPEG2 to the channel shown in fig (1) is illustrated with the following steps:

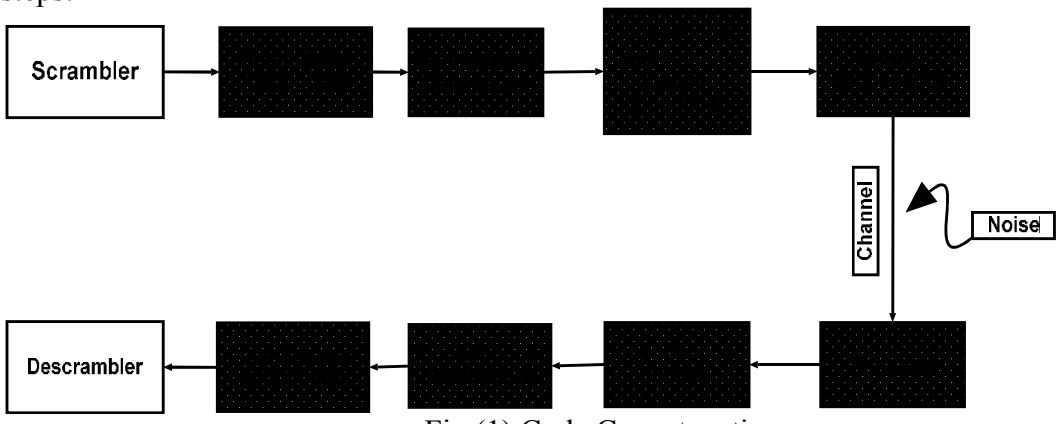


Fig (1) Code Concatenation

a- Multiplexer for energy dispersal.
b- Outer coding (Reed-Solomon).
c- Convolutional interleaver.
d- Base band shaping for modulator.
e- Modulation.

i- Reed-Solomon Code

In 1959 Irving Reed and Gus Solomon presented a paper to the journal of the society for industrial and applied mathematics this paper was published in 1960 it was a five papers under the name (Polynomial Codes over Certain Finite Fields) describing a new error-correcting code called today Reed-Solomon codes, this code played an important role in communication and used in application like compact discs players and space communications. Reed-Solomon is one of techniques called error correcting codes which concerns with data transmission over a noisy channel these techniques used to reduce the bit error rate of a certain channel. The channel capacity causes a change in the information sent or delete in this information the error correcting techniques will treat this problem. In coding theory Reed-Solomon is a part of the non-binary error correcting codes and able to correct errors that came in bursts [ETSI, 1997]. Reed-Solomon codes are encoded and decoded by the use of finite field arithmetic which a discovery of a French mathematician Evariste Galois, these fields is called Galois fields. Reed –Solomon code is special case of BCH [Bose chaudhuri Hocquenghem] code [Clarke,2002].

Reed-Solomon operates at Galois fields$GF(2^m)$. RS (n, k) can encode m bit symbols into a block consist of $n = 2^m - 1$ symbols the encoder expand the k bit symbols into n bit symbols as shown in eq. (1to4).In our design RS(188,204) is used. RS (n, k) has a minimum distance of n-k+1and have the following properties

$$n = 2^m\text{-}1 \quad (1)$$

$$n - k = 2t \quad (2)$$

$$k = 2^m - 1 - 2t \quad (3)$$

$$d_{min} = 2t + 1 = n - k + 1 \quad (4)$$

Where n is number of output symbols from the encoder.

k is number of output symbols to the encoder.

t is Error Correcting Capability.

d is Hamming Distance.

GF Galois Field.

The decoder of Reed-Solomon corrects a (t) symbols with (m) bits it replaces the corrupted one with another correct byte doesn't matter whether one bit is corrupted or all bits of the symbol so these features give Reed-Solomon an advantage over binary codes[Clarke,2002].

ii- Convolutional Code

Convolutional code was of the earlier code where the soft decision decoding is developed whereas block codes depend on the k inputs to give n outputs convolutional codes can be said to give stream codes, however they can still rate as R=k/n codes as an example of convolutional encoder furthermore they were among the earlier code where soft decision decoding developed the convolutional encoder is similar to a finite state machine work with information in a serial manner, our design used a convolutional code with constraint length of 7 G1=171,G2=133 [I. A. Glover, 2010].

iii- **Interleaving**

In communication system errors occur due to many factor like noise, small channel band width, interference between channels and sources to avoid these errors channel coding is developed but sometimes error correction codes shall not be able to correct these errors if they came in groups so called bursts . Interleaving is a technique used to beat that burst errors due to the channel this is can be done by spreading the errors over more than symbol in block codes and over time in convolutional code so this technique is very useful to overcome the burst ,convolutional interleaver is used with I=12 [Yun Q. Shi.2004].

4. Field Programmable Gate Array (FPGA)

FPGA is a configurable device used to implement digital circuits with various tasks; this device makes the design of digital circuits easier than before [Spartan-3A/3AN FPGA Starter Kit Board User Guide,2008].

5. Implementation of Digital video Broadcasting

Implementation of proposed digital video broadcasting (DVB) using Matlab and Xilinx ISE10.1 will give a good vision of the circuit and its work shown in fig (2).

i- Using MATLAB

The first step to implement the design is using Matlab to prove circuit works. It can be shown in fig (3) the circuit of concatenation of two codes convolutional code as an inner code, Reed-Solomon code as an outer code and interleaver. Fig (4) shows the transmitted and received picture. When this circuit implemented in Matlab it can be seen that the input and output will be as shown in figs (5) and (6). It can be shown that when the signal to noise ratio equal to 7dB then there is an errors in the received signal, while in 10 dB signal to noise ratio the signal is received correctly.

ii- Using Field Programmable Gate Array(Xilinx Spartan)

Concatenated codes implementation using Xilinx 10.1 with schematic and Verilog code simulation so as they give the results shown in figs (11) and (12).

a. Encoder

Implementation of code concatenation by using FPGA is different from using Matlab,it can be done either by schematic or by HDL language, in this paper we used both schematic and verilog code to implement our design.

b- Decoder

Decoder is implemented using Verilog code which is an HDL language that used to implement and simulate digital circuits. Verilog code contains modules to simulate our codes and give the results shown in figs (11) and (12).

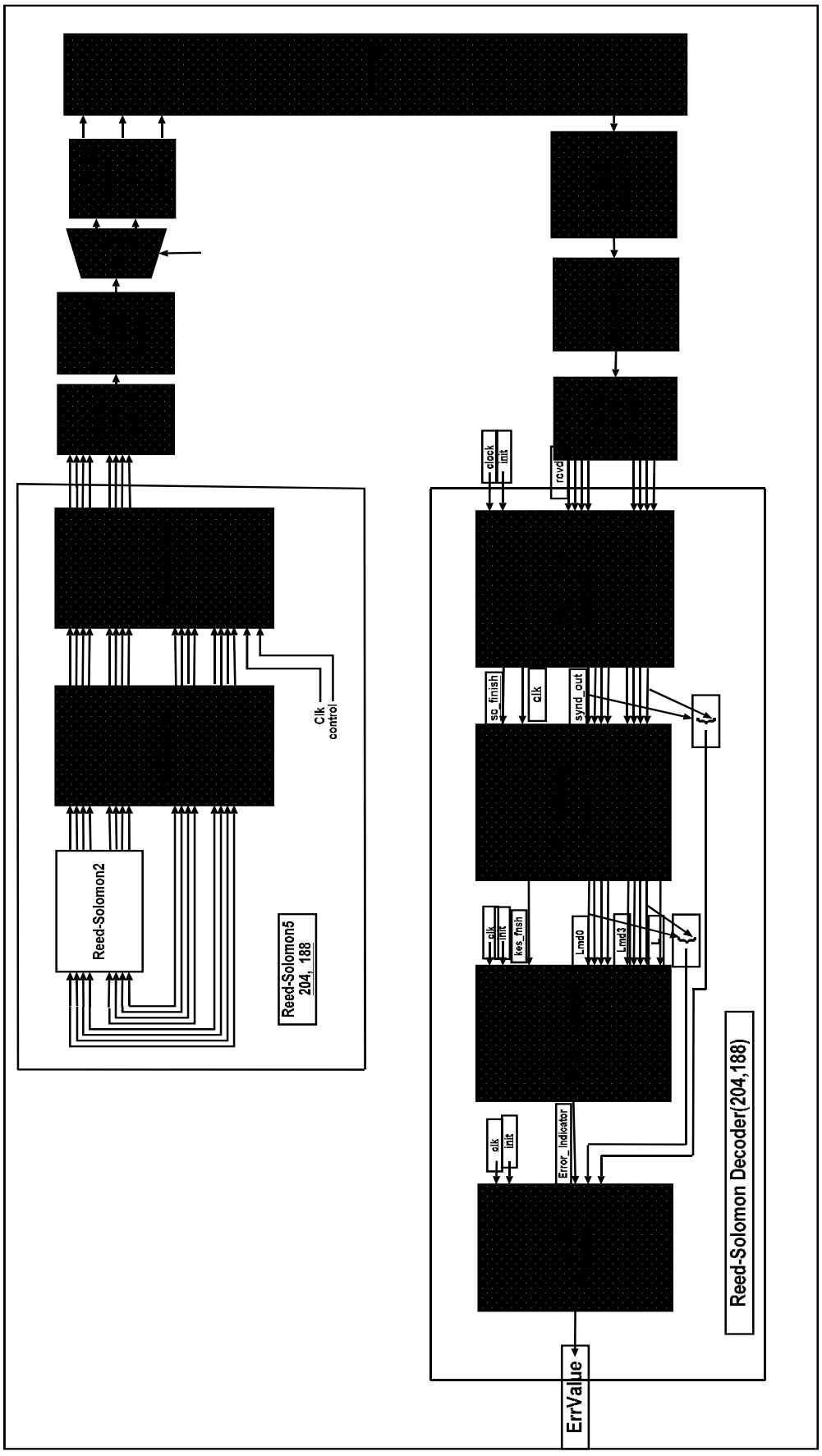


Fig (2) Concatenated Codes DVB Encoder and Decoder using Xilinx 10.1

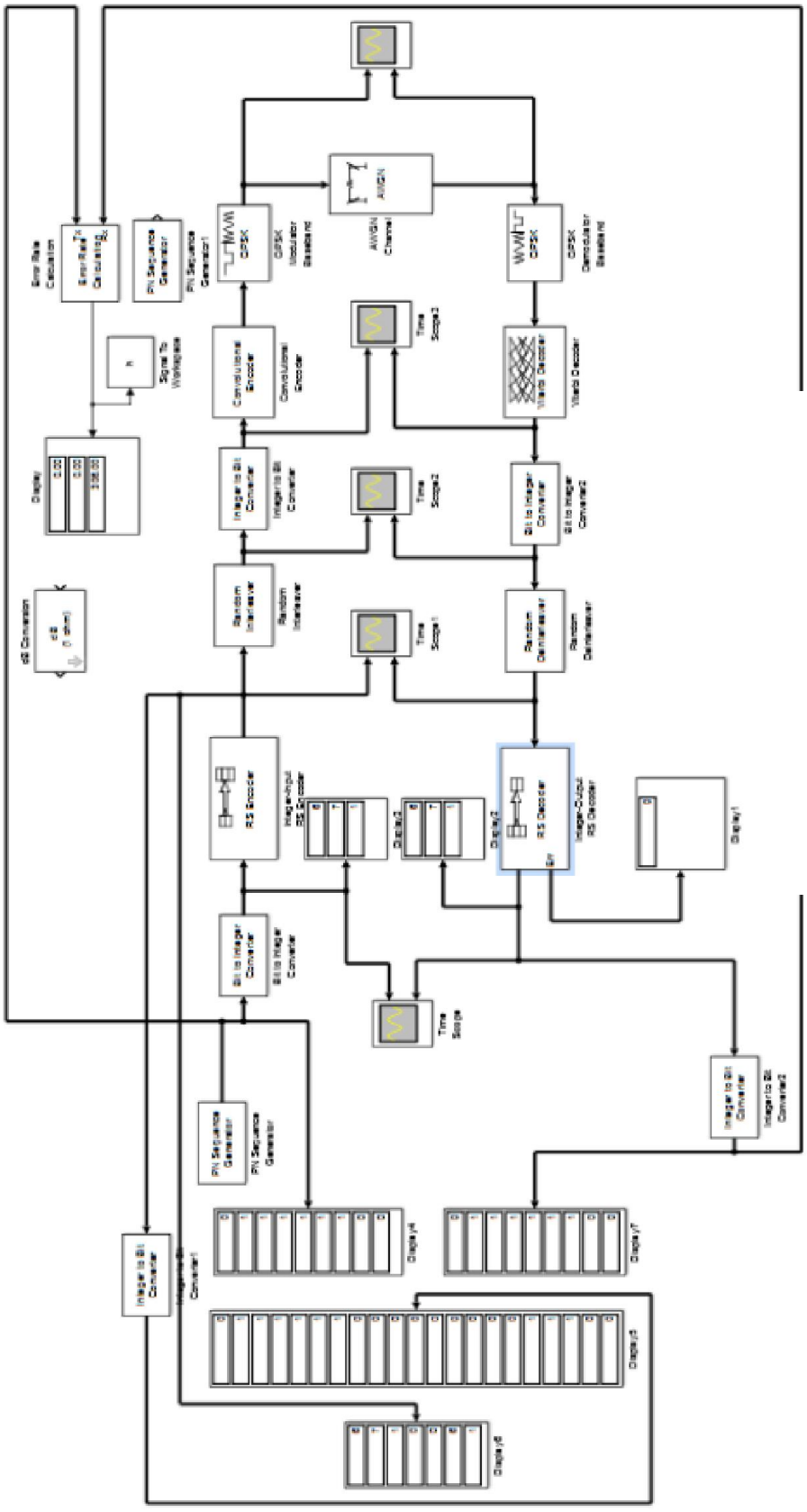
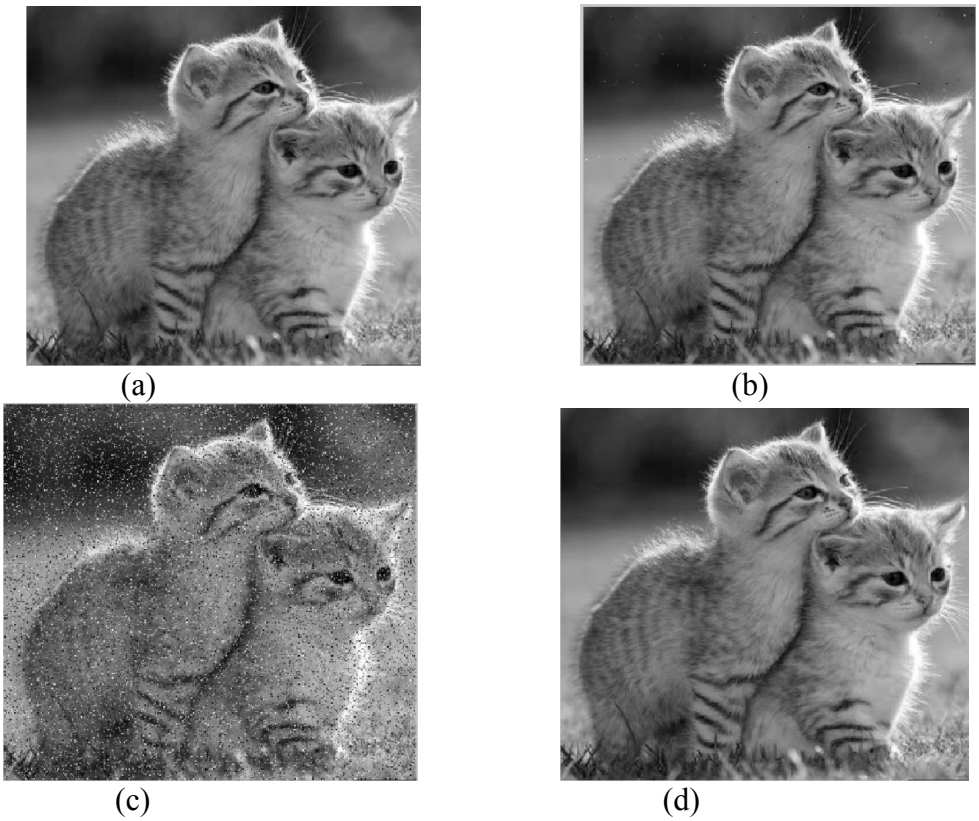


Fig (3) Concatenated Code



(a) (b)

(c) (d)

Fig (4) Transmitted Image a-Original Image b-Received Image with SNR=12 dB c-Received Image with SNR=10dB d- Received Image with SNR =13 dB

The images shown in fig (4) were transmitted with concatenated codes and interleaver with various signals to noise ratio are simulated by using Matlab.

6. Results and Discussions

The results from implementation of the concatenated codec are obtained by using Matlab so that Input and output of the Reed-Solomon, Convolutional code and Interleaver are shown in figs (5), (6), (7) , (8), (9) and (10) respectively.it can be seen that When the signal to noise ratio less than a certain number errors will occur during retrieving the sent signal.

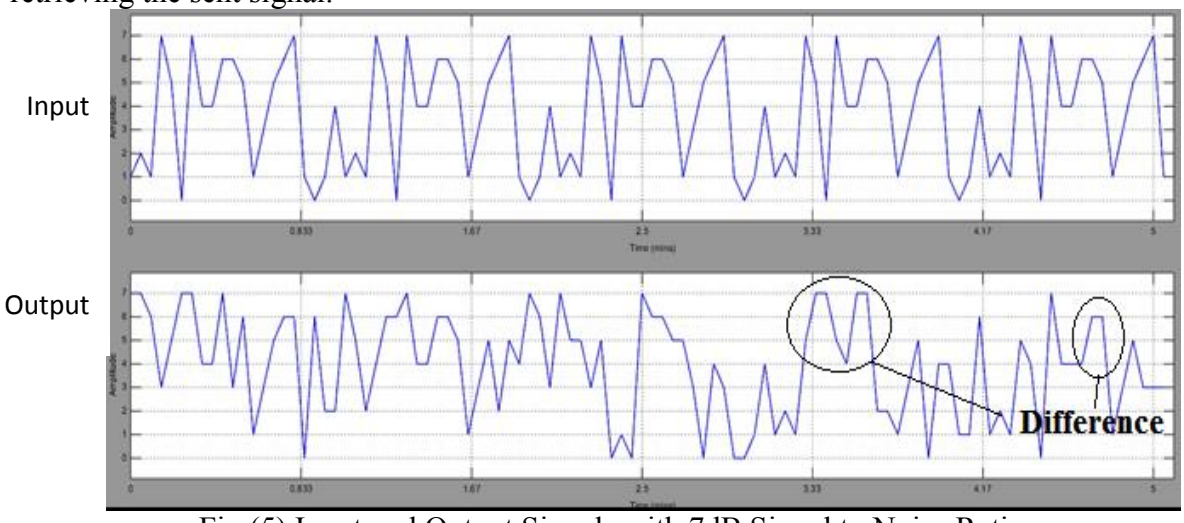


Fig (5) Input and Output Signals with 7dB Signal to Noise Ratio

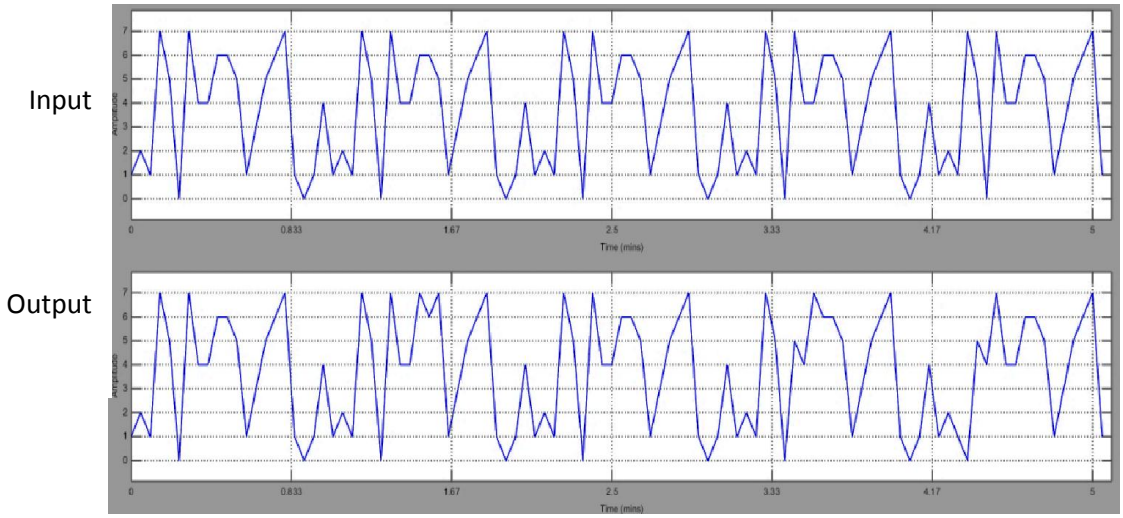


Fig (6) Input and Output Signals of Fig (3) with 10dB Signal to Noise Ratio.

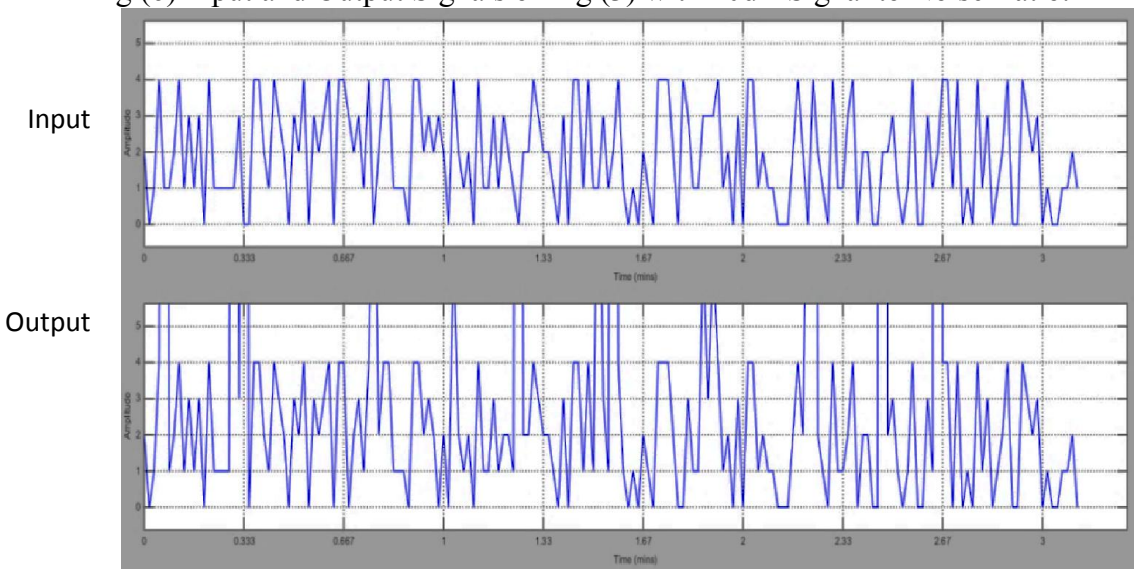


Fig (7) Input and Output Signals of Reed-Solomon with 10dB S/N (204, 188)

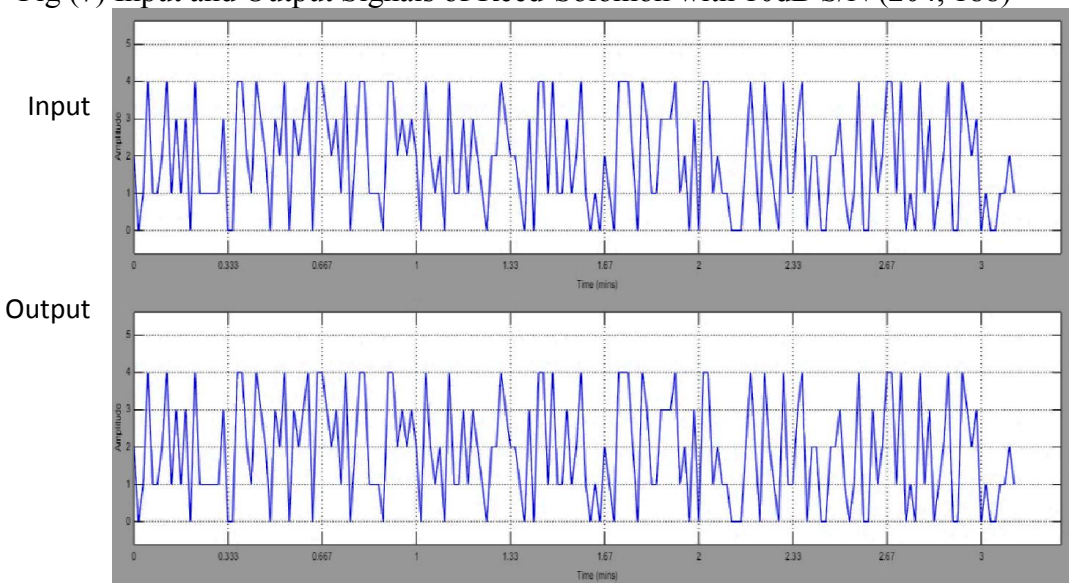
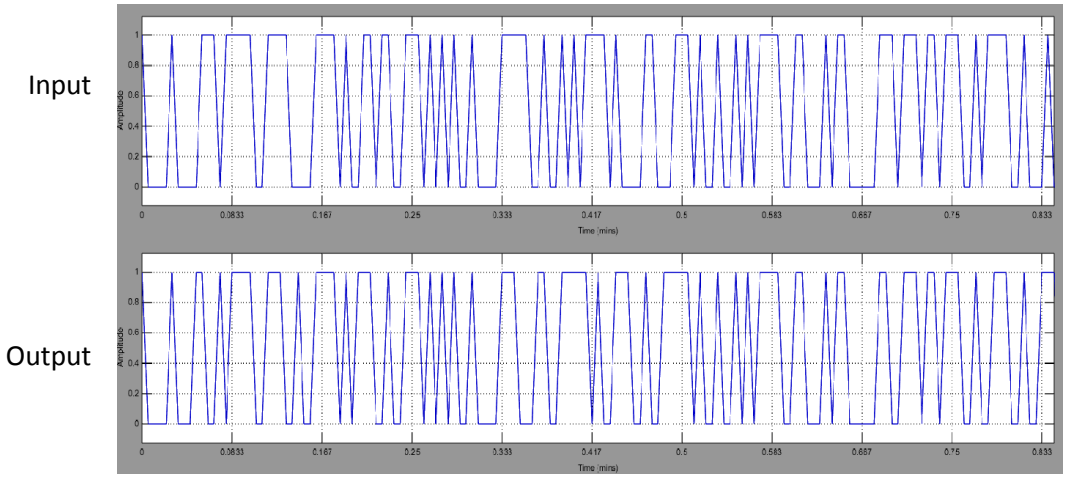


Fig (8) Input and Output signals of Reed-Solomon (204, 188) with 12 dB S/N



ıput and Output Signals of Convolutional Encoder and Viterbi Decoder

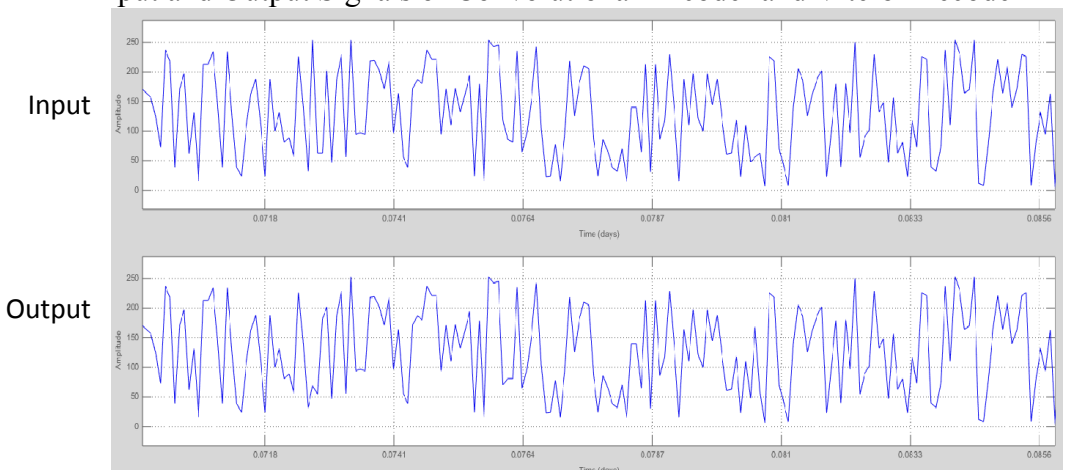


Fig (10) Input and Output Signal of Interleaver and Deinterleaver

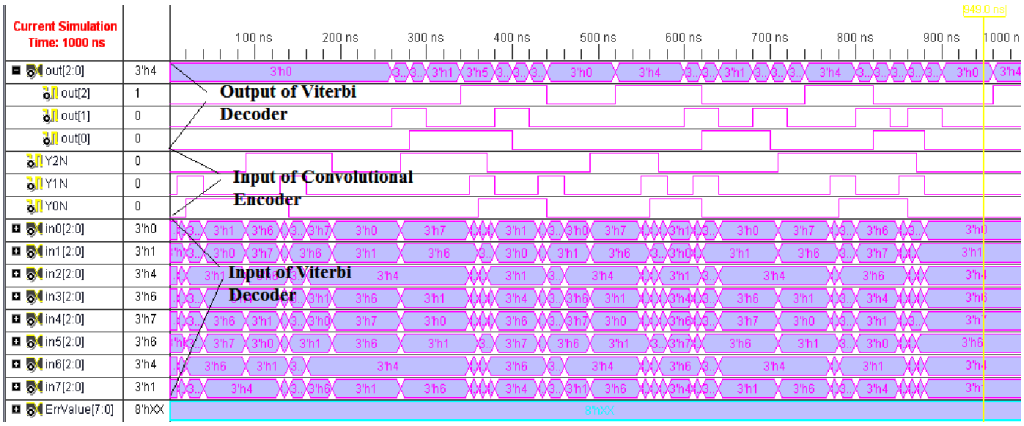


Fig (11) Input and Output of Convolutional Encoder and Viterbi Decoder

The input and output signals of convolutional encoder and viterbi decoder is show in fig (11), you can see the delay of the signal (out) due to the calculation process, also the signals (in0,….,in7) which is the input to the viterbi decoder, While the calculation of the Reed-Solomon can be depicted in fig (12).

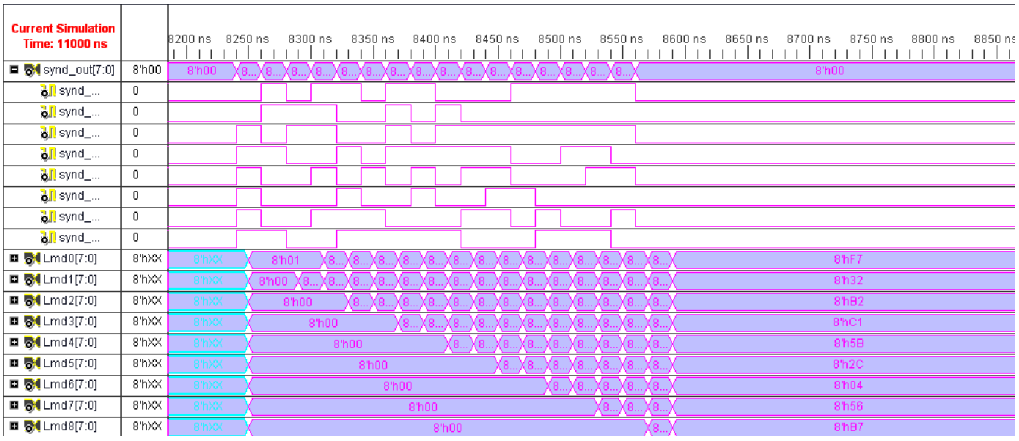


Fig (12) Reed-Solomon Output

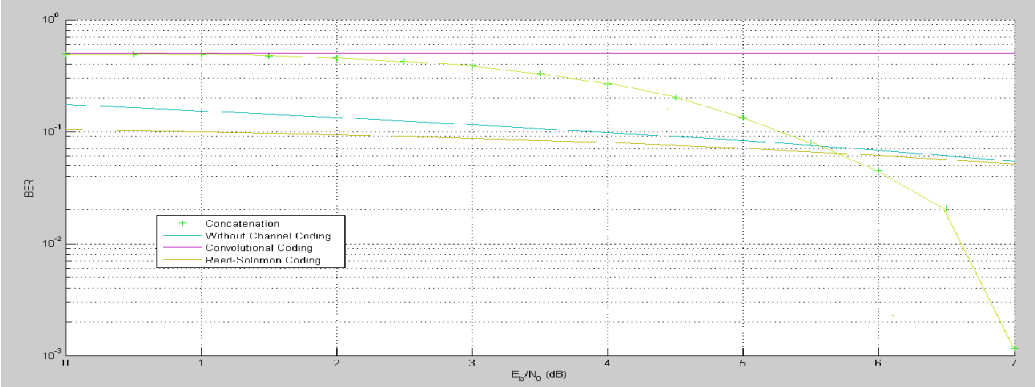


Fig (13) Signal to Noise Ratio versus Bit Error Rate of proposed design.

7. Conclusions

FPGA is a very fast, reliable and economic in cost device to use in communication projects, so it has a very effective performance in executing coding processes, since it uses a parallel bus. Reed-Solomon is an excellent code that able cope a massive amount of data like images with high definition (HD) due to its parallel properties. Convolutional code is a simple code in both coding and decoding. Combining Reed-Solomon and convolutional codes will overcome the disadvantages of the two codes to perform a near perfect code that works near Shannon limits as shown in fig (13).also it can be seen that when SNR=7 there was errors but if it rises to SNR=10 the errors are vanishes.

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