6G Vision and Challenges: Complexity Analysis of M-MIMO Rate-less Based System with Various Pre-Coding Schemes

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Research Article

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6G Vision and Challenges: Complexity Analysis of M-MIMO Rate-less Based System with Various Pre-Coding Schemes

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Abstract

Due to the expected essential role of the rate-less digital fountain codes and Massive-Multi-Input Multi-Output (M-MIMO) techniques in the 5G and 6G mobile wireless networks, this paper investigates the performance of M-MIMO enhancing system employing the Raptor code. The proposed M-MIMO-Raptor code based system has been tested over the different wireless communications channel conditions with respect to the various Frequency Doppler (FD). The various promising technologies for the beyond 5G and 6G have been presented with focusing on the advanced error control techniques. The flexible adaptive interleaved pre-code based on the channel conditions is suitable for 6G mobile wireless networks which integrates the various environments of the communications. The complexity of the advanced and fixed code rate schemes is discussed. Several computer simulation experiments are carried out for evaluating the performance of M-MIMO-rate-less code system. These experiments prove the superiority of the presented wireless rate-less system compared to the fixed rate wireless system due to the improved results of BER and the throughput values which are utilized as a performance evaluating metrics. Theoretical analysis of the M-MIMO throughput proves the enhancing of M-MIMO utilizing the rate-less Raptor code and its applicability for the next mobile wireless networks generations.

Keywords:- Beyond 5G, 6G wireless Networks, Fountain codes, M-MIMO system, Raptor codes, Truncated Codes, Interleaving techniques, Equalizers, Performance metrics.

1. Introduction

The mobile wireless communications systems utilize the MIMO to improve its performance and achieve available maximum capacity. On the other hand, the adaptive encoding packet technique is a tool for enhancing the performance of the wireless communications systems. This tool depends on employing the different error control schemes for encoding the transmitted packets with the different code rate according to the channel conditions. The adaptive packet approach can achieve good error performance, optimizing the capacity and low power consumption. Hence, the adaptive packet technique represents the idea of fountain codes, where it provides a variable code rate but with more complexity. The adaptive code rate concept achieves the rate-less code error control schemes. The rate-less fountain code is error control scheme with a variable code rate is applied within the MIMO system for enhancing the performance of the mobile wireless communication systems [1].

In the M-MIMO system, there are several antennas are employed for transmitting and receiving processes for improving the quality of the wireless link and increasing its capacity. The reliability of the wireless systems utilizing the MIMO can be enhanced by the spatial diversity achieve significant capacity gains over conventional single antenna systems. There are many approaches are employed for improving the MIMO system performance such as the OFDM combining within the MIMO to enhance the capacity, employing the error control technique for improving the error performance and interleaving techniques [2-3].

In this research paper, the merging between the classical-fixed code rate error control schemes and the variable code rate fountain code schemes is proposed. Also, the proposed combined error control schemes are performed with the different interleaving techniques. The rate-less fountain codes are suitable for enhancing the error performance over the real-time signals transmission, these error control schemes are tested with the chaotic interleaving. The chaotic interleaving is an efficient data randomizing tool, it is built and designed based on the 2-D Baker map, the randomizing mechanism is carried out by secret key. This secret key is flexible length, which is determined according to the size of transmitted packets [4].

Therefore, the proposed technique aims to improve the M-MIMO systems error performance and enhance the system security through the different secret keys of the chaotic interleaving, it can be changed for every transmitted packet. Utilizing the erasure error control codes achieves improving the real-time signals quality over the noisy and unreliable fixed and mobile communications channels. On the other hand, the unequal-error protecting techniques leads to enhance the power efficiency of the wireless communication systems due to the automatic adjusting of the code rate based on the communication channels conditions [5].

In this paper, the channel coding schemes overview are presented in section 2. In section 3, related work overview is presented. Section 4 describes the computational complexity of the various FEC techniques. Overview of the promising technologies of next mobile generation are presented in Section 5. The proposed model of rate-less based M-MIMO system is described in section 6. related works and recent Raptor code research are presented. In section 7, the simulation results of the proposed rate-less based M-MIMO system with different error control schemes and interleaving techniques are discussed. Simple throughput analytical analysis with considering the rate less features is presented. The conclusion is presented in section 8.

2. Channel Coding Techniques Overview

In this section, the different types of the error control schemes are discussed. Also, the computational complexity of the various Forward Error Correction (FEC) techniques has been described for the classical FEC schemes which have fixed code rate and the advanced rate-less FEC schemes which have variable code rate. Figure 1 shows the various error control schemes.

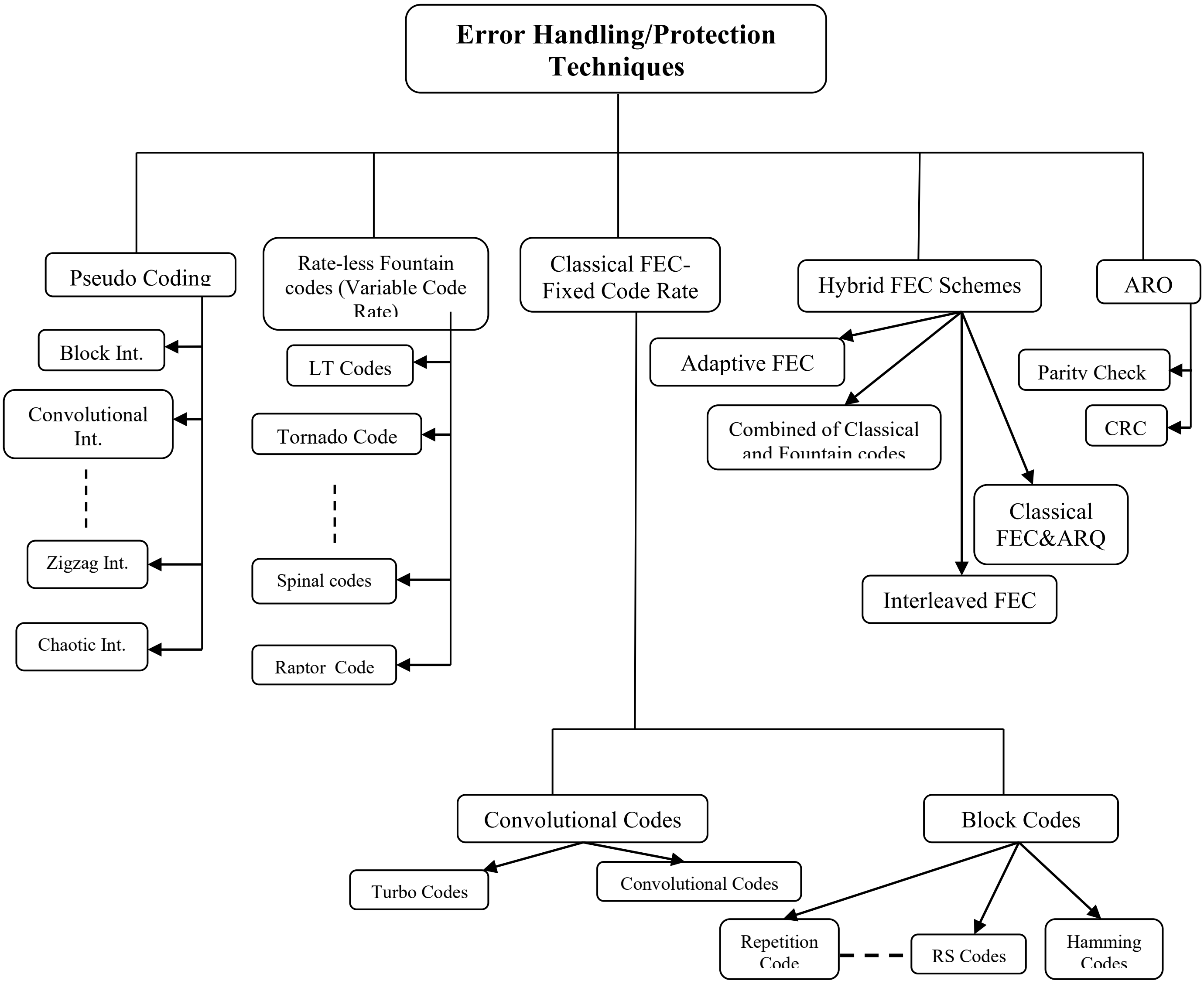


Figure 1 Channel coding techniques categories with respect to the code rate.

- Fixed Code Rate:- Classical FEC Techniques

The classical FEC schemes are an efficient tool for Quality of Service (QoS) the wireless communication systems. These error control techniques have fixed code rate, it contains two main categories, the block codes and the convolutional codes [6].

- Rate-less Fountain Codes

The advanced FEC schemes are an efficient tool for enhancing the real-time signal transmission quality over the unreliable wireless channel. It can be considered hybrid FEC and embedded adaptive packet techniques [7].

- Automatic Repeat reQuest (ARQ)

The ARQ approach is simpler error control schemes, it depends on received data checking at the receiver by parity check bits or CRC schemes. The ARQ utilizes these techniques for detecting the error only, in case of error detecting, the receiver requests retransmitting the corrupted packet again. This error handling method is not suitable for real-time wireless signal transmission. The rate-less fountain codes includes in its mechanism the ARQ concepts.

- Pseudo Coding techniques

The pseudo coding techniques is lower complex scheme performed by randomizing the processed data. It is an efficient for the image and audio over the correlated fading channels.

- Hybrid Techniques

The hybrid techniques are built based on merging and combining the different techniques. there are different types of hybrid techniques, the simpler [8].

- Adaptive Techniques

The adaptive technique includes the adaptive FEC and adaptive packet approaches. The adaptive technique achieves the flexibility for choosing the best choice of encoding tool and transmitted packets format based on the wireless link channel condition for enhancing the throughput and error performance. also, the adaptive packet can be employed for reducing the consumed power and decreasing the ARQ times [9].

3. Related Works Overview

The rate-less error control schemes are considered promising tool for combating the errors and improving the error performance of the next generations of the mobile wireless networks. In this section, the related works of the research papers which are discussed the utilizing of the digital rate-less fountain codes and its advantages in the MIMO and the 5G network.

The digital rate-less fountain code is used for enhancing the performance of the OFDM-based Raptor code utilizing in [10]. In this research paper, the Raptor rate-less code is used with the various modulation techniques to improve the OFDM system error performance. Also, the different types of the digital fountain codes are discussed. The complexity of the rate-less codes compared to the traditional and classic fixed code rate channel coding schemes has been presented [10].

In [11], the near future 5G "Fifth generation" of the mobile wireless network is considered. This research paper discussed the expected eavesdropping threats in 5G mobile wireless network. This threats can be combated by the classical cryptography techniques, these classic approaches are not efficient due to its overhead complexity. The physical-Layer Security (PLS) based is an efficient approach for resisting the eavesdropping over the 5G networks. The PLS-based approach is utilized to achieve improving in the security and error performance of the 5G mobile wireless networks using fountain code within the massive MIMO system. In this research paper, the risks of intruder are reduced using the rate-less raptor code and data punctuation for retrieving the transmitted packets before the attacker. The Raptor code is utilized for enhancing the security and reliability of the massive-MIMO system [12].

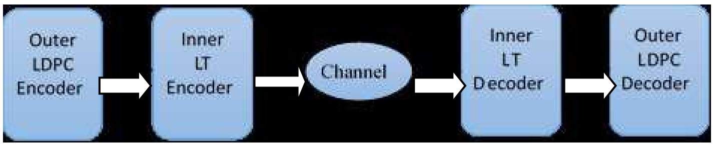
In [13], application of the advanced Forward Error Correction (FEC) techniques such as rate-less Raptor codes with the inner LT code and outer LDPC codes are studied and investigated. The first type of fountain codes is the LT code, it is also, the main partition in Raptor codes structures as shown in Figure 2-a. There are various parameters determine the code rate and the decoding algorithm, these parameters are studied for choosing the suitable for Raptor codes with respect to the systematic property and various code rates. Also, the different modulation techniques are utilized with the Raptor codes and code rate variation. The experiments in this paper revealed that the Raptor code performs better with the BPSK than the QPSK scheme with considering the same code rate and decoding algorithm.

The rate-less Raptor coding technique has been proposed for reducing the interference and protecting the transmitted video signals in [14]. The proposed scheme is evaluated over the multipath and varying conditions communication channels, Raptor code is implemented in this paper by LDPC and LT codes. Also, the rate-less error control schemes are proposed for achieving the reliability and enhancing the efficiency of the mobile wireless 5G communications. The multi-links method has been presented utilizing the rate-less error control technique to improve the wireless link reliability and efficient usage of the network resources [15].

Enhancing the performance of the Wireless Body Area Network (WBAN) is proposed in [16], this paper proposed utilizing Raptor code as an efficient error control scheme. The proposed technique based on the rate less code is used for improving the life time of the network. The WBAN is a Wireless Sensor Network (WSN) specified for the medical applications. Hence, the power source is the main constraint of the WBAN, this research paper enhances the energy efficiency and reliability of this wireless networks by utilizing Raptor code .

3.1 Raptor Codes Description

The structures of Raptor code are given in Figure 2-a, It contains two error control schemes are merged for achieving the Raptor code. The process of decoding is shown in Figure 3.



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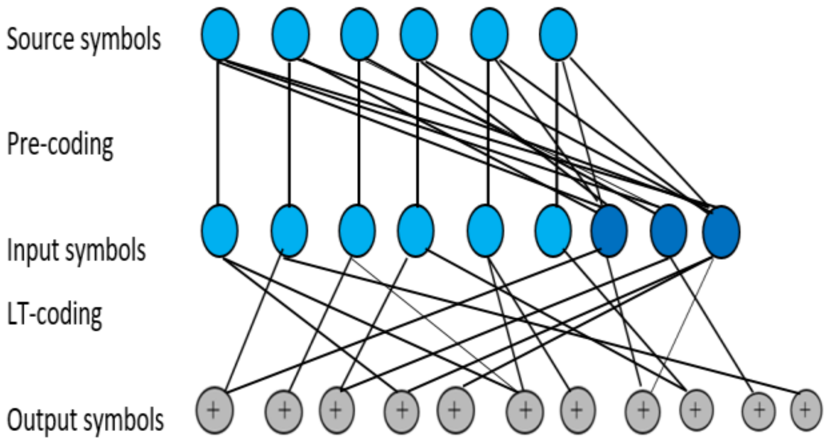


b

Figure 2 Contents and Generating the output symbols of the Raptor codes, a-Block diagram of Raptor code, b-Output symbols generating.

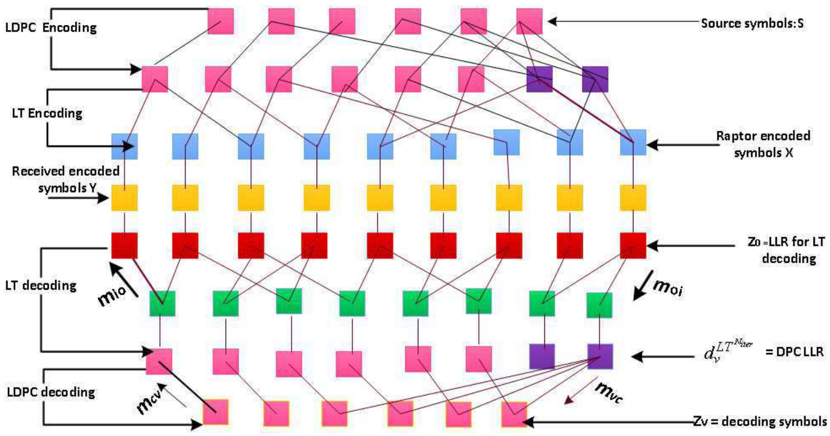


Figure 3 Steps of the Raptor codes Decoding process.

3.1.1 Raptor Coding Process

The encoding process of the rate-less Raptor cod includes two cascaded encoding process utilizing the inner and outer encoder. The coding process stages can be described as follows [17]:

Firstly, the input symbol which is represented by S symbol, it is the source symbol 'original user data' and expressed as in Eq. (1):-

$$S=[s_1, s_2, s_3, s_4, \ldots\ldots\ldots\ldots S_k] \qquad s_i \in \{0,1\} \tag{1}$$

These i/p symbol are encoded by pre-encoder using the LDPC code for producing k′ symbol. k′ denotes to the intermediate symbol. The output of the outer code is represented by U symbol, as expressed in Eq. (2):-

$$U = [u_1, u_2, u_3, \cdots\cdots, u_{k'}] \qquad U_i \in \{0,1\} \qquad where, k' > k \tag{2}$$

The intermediate symbol (k') is the encoded form of source symbol (k'), it is also, input the second encoding process.

The second step is encoding the k′ symbols by the inner LT code. for generating the output symbols (O/S), these encoded symbols is denoted by (C), it is expressed by Eq. (3):

$$C = [c_1, c_2, c_3, \cdots\cdots, c_n] \qquad C_i \in \{0,1\} \qquad where, n > k' \tag{3}$$

Notes that:- k is the original/ source symbol

U is the intermediate symbol, encoded k' and input of inner code, $k' > k$

C is the output symbols and encoded k', $n > k'$.

3.1.2 Channel Effects Investigating

In this section, the effects of the wireless communications channel is presented on the transmitted encoded packets. Suppose that the received signal (y_i) is expressed by Eq. (4), where, x_i refers to the codeword, and n_i represents the Gaussian noise.

$$y_i = x_i + n_i \tag{4}$$

The LLR is calculated using the formula of Eq. (5):-

$$L(C_j) = Ln \frac{P(C_j = {}^{0}/_{y_j})}{P(C_j = {}^{1}/_{y_j})} = \frac{2y_j}{\sigma^2} \tag{5}$$

where, σ^2 is the variance of Gaussian noise, $n \sim N(0, \sigma^2)$, it is the noise of the communication channel, its mean = 0 and the variance equals σ^2.

3.1.3 Decoding Process

The decoding processes of the Raptor code are presented in this section. This process contains two decoding steps as previous described in encoding process, which are the inner and outer decoding. The Sum Product Algorithm (SPA) is used for decoding the inner and outer encoded symbol utilizing Tanner graph. The LLR of the received encoded symbol is given in the formula Eq. (6) [18]:-

$$LLR_{C_jV_i} = 2tanh^{-1}\left(\left(tanh\frac{L(C_j')}{I^2}\right)\prod_{i'\in\ N_c(j)-\{i\}} tanh\left(\frac{L_{i'}C_j}{2}\right)\right) \quad (6)$$

where:-
VN_s : is the variable Node, its symbols are denoted by (V/S).
CN_s : is the check nodes (CN_s), it is the output symbols of the (VN_s).

$$L_{V_iC_j} = L(v_j) + \sum_{j'\in N_v(j)-\{i\}} L_{C_jV_i} \quad (7)$$

$Notes: -$
$N_c(j)$ *is the collected of NVs which are linked to the* j^{th} *check nodes (CNs).*
$N_v(i)$ *is the CNs set, which is connected to the* i^{th} *variable nodes (VNs).*

$$R_{outer} = \frac{k}{k'} \quad , \textit{It is the code rate of the outer encoder} \quad (8)$$

$$R_{inner} = \frac{k'}{N} \quad , \textit{It is the code rate of the outer encoder} \quad (9)$$

Hence,

$$R_{Raptor} = R_{outer}R_{inner} \quad , \quad \textit{It is the code rate of the Raptor Coding}$$

$$R_{Raptor} = \frac{k}{N} \quad (10)$$

Let's, there are one codeword, with the E_b/N_o, R, hence, its energy can be calculated by :-

$$E_b/N_o = 10\ log_{10}\left({}^{1}\!/_{2R\sigma^2}\right) \quad (11)$$

Raptor codes can be represented by :-Raptor Code $(k, C, \Omega(\varepsilon)$, where, the k is the source symbol, C is the output of outer encoded, and Ω(ε), where, *C* is the pre-code with message length k, n is the block length and Ω(ε) is a degree of distribution of LT code, it is determined by ε.

3.1.3 Throughput Analysis Utilizing Fountain Codes

The throughput analyzing has been discussed with presence the rate-less fountain codes, in this section. The fountain codes have the positive effects, which are cleared through the simple presented theoretical analysis. The previous section presents the computer simulation experiments and its results. These experiments are carried out using the Zero forcing equalizer, it evaluated the proposed technique over the M-MIMO system with the modulation technique variation [35].

The throughput is important metric for measuring the wireless communications systems performance. It is defined as the amount of corrected data success to received at a time interval. According to the throughput definition, it mathematical expression is given in Eq. (20) as follows:-

The throughput is affected by the Packet Error Probability (PEP) and the packet length as shown in Eq. (20) [35].

$$T = \frac{N_i(1-PEP)}{T_{trans}} \tag{20}$$

The throughput can be expressed also, as in Eq. (21), It can be expressed as follows:

$$T = \frac{I\left(1-p_J\right)}{T_s(N_1+\sum_{j=2}^{J} N_j p_{j+1})} \tag{21}$$

The T_s symbol is the period, the symbol I is the length of transmitted data, and p_j is the probability of failure decoding 1 through j times. It is given in Eq. (22).

$$p_j = P\left[\bigcap_{k=1}^{j} \text{Decoding failure in the } kth \text{ transmission}\right] \tag{22}$$

$$= P\left[\text{Decoding failure in the } jth \text{ transmission}\right] = \text{BLER}_\text{j} \tag{23}$$

where the BLER denotes the block error rate achieved after the jth transmission.

The average packet delay, δ, is the expected time that elapses from the moment the packet is first transmitted over the channel to the moment the packet is successfully decoded. It is given by:

$$\delta = T_{trans} + T_{wait} = T_s \frac{N_1 + \sum_{j=2}^{J} N_j p_{j-1}}{1-p_J} + \frac{T_r \sum_{j=2}^{J} p_j}{1-p_J} \tag{24}$$

The T_{wait} symbol refers to the average cumulative time of the transmitted of packet for performing the decoding successfully, and T_r represents the time period between transmissions.

Reduction the number of retransmissions processes increases throughput due to the Raptor code. Based on the fountain codes idea, the transmitted messages won't be accepted to retransmitted. It is transmitted many times based on the channel conditions, if the Q is the retransmission times, the throughput decreases to be [(I/(Q.T_{trans})].

4. Computational Complexity of the Various FEC Techniques

The complexity of the error protection systems is the amount of its required operations and its additional memory, logic and arithmetic which are needed for performing the encoding and decoding processes. Therefore, the computational complexity of these systems affects the amount of power consumption and the required time. Also, there are another terms refer to the complexity of the error corrections schemes which are the time complexity, hardware and power complexity. In this section, some simple notes about the complexity parameters of the various error control schemes are presented.

The block codes is represented by this form "Code (n, k, t), where k is the length of data-word 'encoder input' (number of bits in data-word), n is the length of codeword 'encoder output'(number of bits in the codeword)and t refers to the number of correctable error bits which are can be corrected by this code, for example Hamming code (7, 4, 1). On the other hand, the convolutional codes can be represented by "Convolutional code (n, k, K), where, K is the number of shift register in the encoder + 1. It is known as the constraint length, which is the number of inputs 'processed' controls the encoder outputs. The complexity of the bloc and convolutional coding schemes depends on the k, n, t, K and $\Omega(\varepsilon)$ according to the type of this encoder. The computational complexity of various error control schemes depends on some parameters. In general, the complexity of all error control techniques is related to the length of input and output of the encoders. The convolutional codes have complexity higher than the block codes. On the other hand, complexity of the fountain codes depends on its message length and the degree of the distribution [18].

The complexity of the convolutional coding and Turbo coding can be calculated by the formula as given in Eq. (12).

$$\begin{aligned} Complexity &= O[(2^{\Phi\ =\text{Encoder input}})(2^{\Gamma=\text{Memory length}})(\Psi+\Gamma)] \\ &= O[(2^{\Phi_{\text{Encoder input length}}+\Gamma_{\textit{Memory}\ \text{length}}})(\Psi+\Gamma)] \end{aligned} \tag{12}$$

In Eq. (12), the symbol (Γ) refers to the memory length (K-1),The input of encoder is represented by (Φ) symbol and the (Ψ) is the amount of processed data.

While the complexity of Reed-Solomon coding can be calculated by the mathematical formula in Eq. (13):-

$$O[k(n-k)\cdot\log(n)] \tag{13}$$

In Eq. (13), k symbol refers to the source message symbols and n represents the output of the encoder length.

In Eq. (14), the complexity of Raptor code is given:-

$$O[k \cdot \log(1/\varepsilon)] \tag{14}$$

The Raptor code complexity is gien in Eq. (14), It gives the needs average number of the operations for decoding k source blocks, while the formula ($O[\log(1/\varepsilon]$) gives required process for encoding k [18].

5. Promising Technologies and Challenges of Next Mobile Generation

As mentioned about the Bluetooth technology in [19], "Bluetooth is considered the engine of the personal wireless communications", the engine of developing the wireless networks to reach the expected vision of 6G is the artificial intelligent and the nano-science and nanotechnology. The promising technologies and the challenges of the next mobile wireless networks are discussed in the following sub-sections.

5.1 The promising Technologies of 6G Mobile Wireless Networks

In this section, the different promising technologies for the 5G and 6G mobile wireless are presented with focusing on the error protection scenarios. The advanced digital fountain codes are one of these technologies due to its features compared to the fixed code rate schemes. Also, these rate-less codes have number of advantages such as it is applied within the real-time applications, where it is generated on-line. Also, the truncation of the rate-less codes mechanism can be applied in wireless network. Also, the fountain codes can be suitable for the 5G, 5G beyond and 6G next mobile wireless networks, these networks require high data rate, the rate-less codes reduce the latency due to decreasing the retransmission processes [18].

the 5 G is the next mobile cellular generation networks, the advanced technologies will be utilized for the 5G and the beyond. In [19], MMSE and raptor code are merged or enhancing performance of M-MIMO technology in 5G. The large (M-MIMO) is one of thee promising technologies which are specified and proposed for 5G mobile net. In [23], the Raptor codes are used for estimating channel with the minimum mean square error scheme. Based on this combination as shown in Figure 4, there is no need to sending sensing packets 'pilot symbol' to sense the channel conditions to save the power and achieve high power efficiency. the MMSE technique and Raptor code are employed for achieving the ideal perfect channel case for M-MIMO, ZF tested with the pilot contamination.

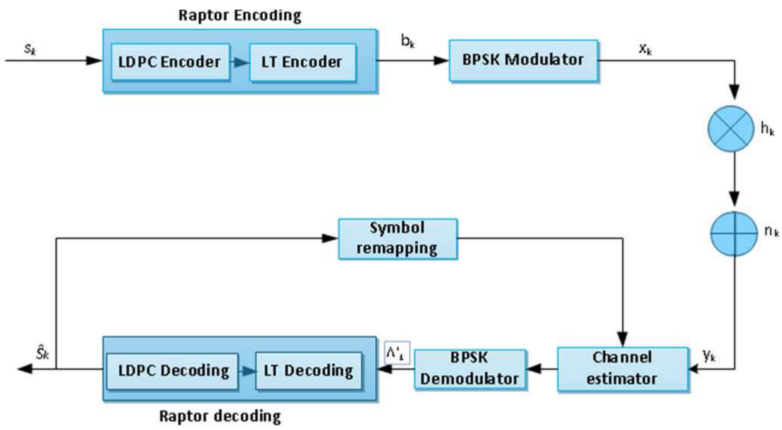


Figure 4 Raptor code block diagram for estimating the symbols with MMSE.

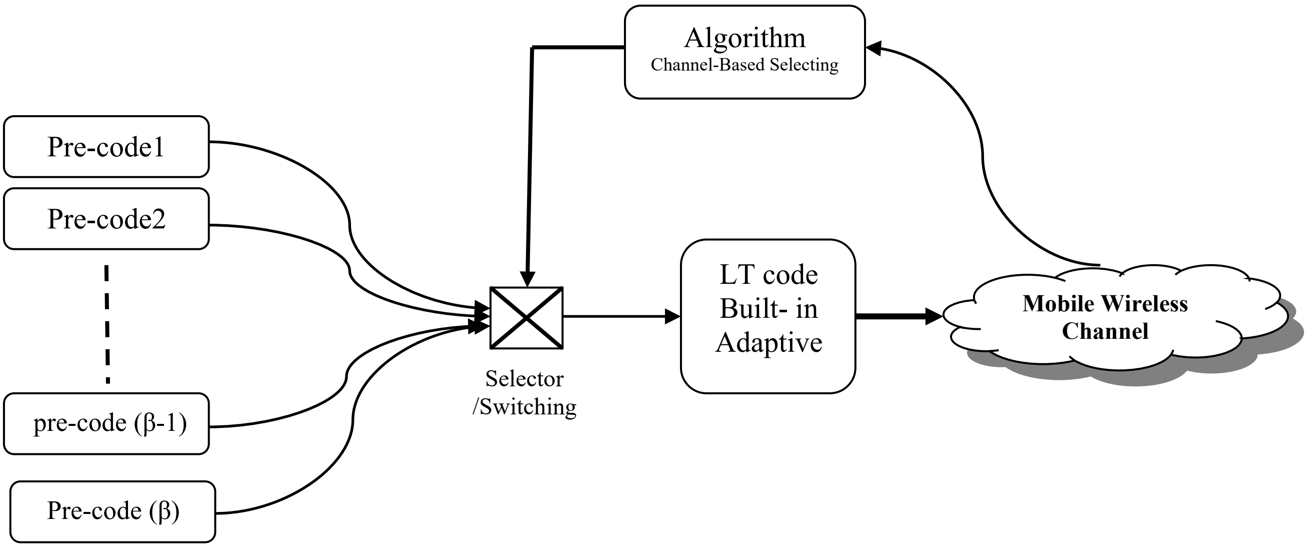
The rate less based error control schemes, fountain codes can be considered one from the promising error protection and QoS tools in the 5G and the expected 5G+. Recently, several papers presented the Rate-less codes as an applicable and efficient error protection technique for the next mobile wireless generations. The rate-less space-time codes (RSTBC) are proposed for 5G mobile wireless network generation, it is utilized for M-MIMO wireless system over the noisy/lossy wireless communications channel [20].

The block codes schemes with the rate-less coding are employed for M-MIMO wireless system, also, concepts of the fixed and rate-less coding techniques are discussed. The channel path losses/pilot contamination cause data lost, the M-MIMO is proposed for the next mobile/cellular wireless generation, where its spectrum and energy are high efficient. The RSTBC scheme is combined with the M-MIMO for enhancing the reliability of the data transmission over the noisy/mobile channel. the results of the simulation experiments proved that the M-MIMO-RSTBC based system is suitable for the next mobile 5G networks [21].

The Internet of Things (IOT) and Internet of Nano-Things (IONT) can be considered one of the promising technologies for the beyond 5G and 6G fixed/mobile wireless networks also, the rate-less coding schemes are considered one of these promising technologies. In [22], the Analog Fountain Code (AFC) is proposed for encoding the small packets transmission. The optimized parameters of the AFC are determined by analyzing the probability density function (PDF) of the data between the variable Node (VN) and Check Nodes (CN) for the fountain code with respect to the BER according to the SNR of the communication channel [22].

The complexity of the rate-les codes is mainly characterized by the weight set, the source message length and degree distribution function as cleared in Eq. (14). The AFC has linear-complexity encoding and decoding processes in terms of the block length. The code is rate-less in nature and can generate a potentially limitless number of coded symbols; thus, achieving any desired rate on the-fly. The coding and decoding of rate-less code are explained for the Raptor code rate-less scheme which is considered the widely fountain code technique [23].

The idea of adaptive per-code of Raptor code technique is proposed in this research paper for beyond 5G and 6G mobile wireless networks. This presented technique reduces the power consumption and enhancing the whole throughput of the wireless system with good error performance. The proposed technique also presents the idea of adaptive interleaving scheme. The selecting of suitable outer encoder and randomizing tool are determined by the communication channel conditions as shown in Figure 5a - b [24].



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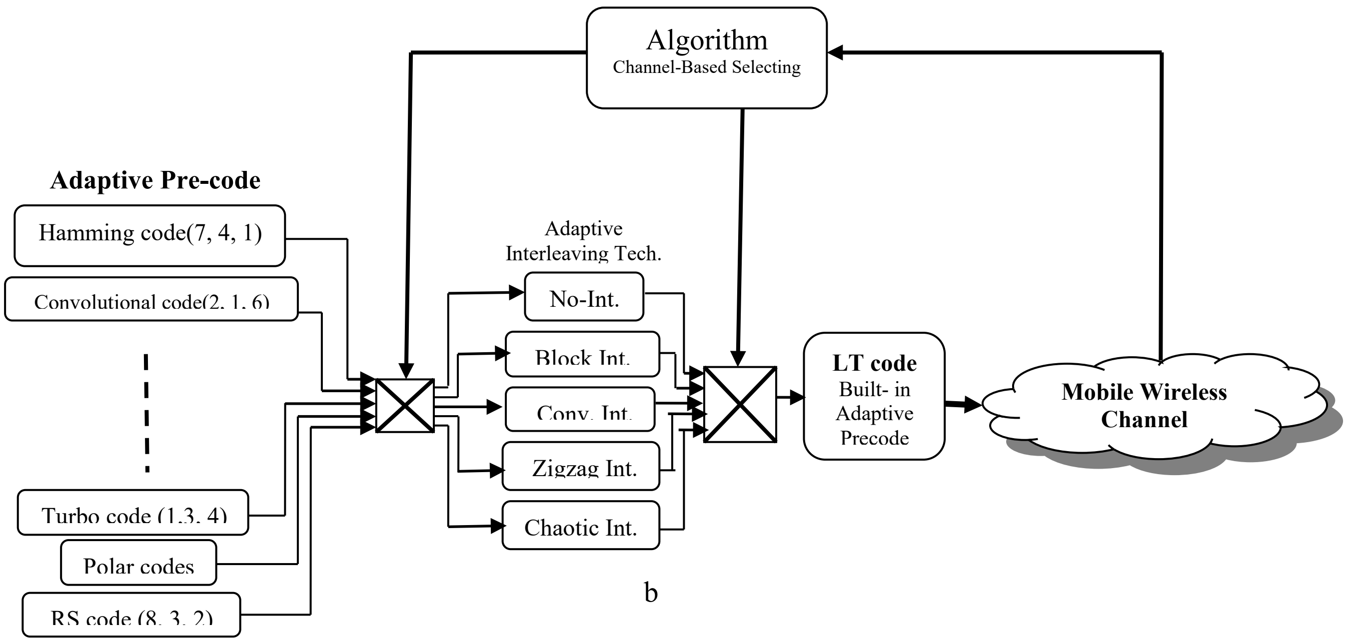
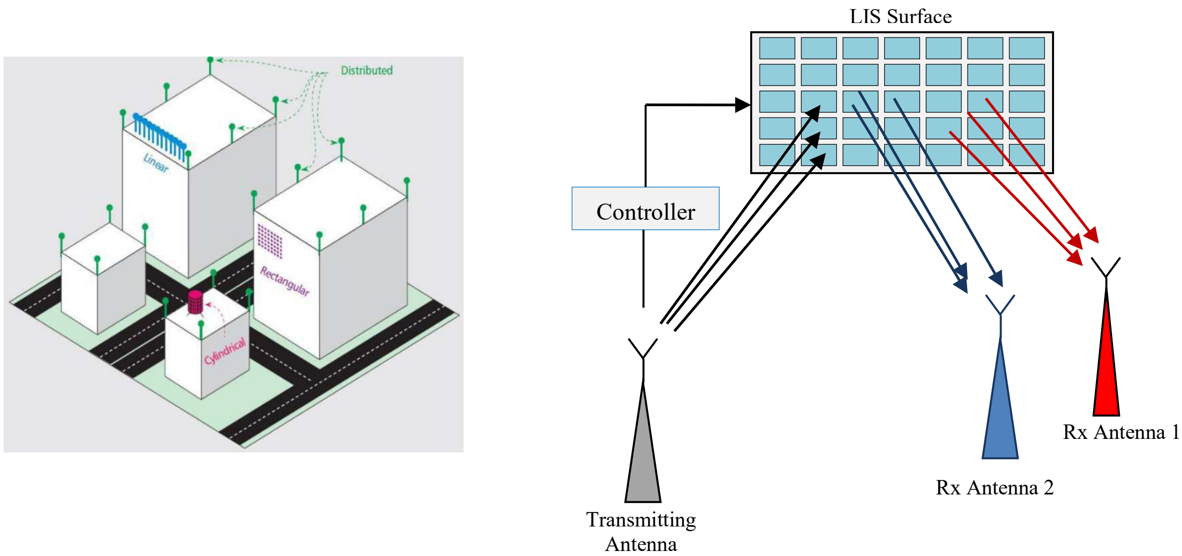


b

Figure 5 Adaptive rate-less Raptor codes for 6G wireless mobile networks, a- Adaptive Pre-code based on channel conditions, b-Adaptive Interleaved Pre-code based on the wireless link.

The 6G technology will integrate the different communications environments such as the terrestrial, air, water (sea), space and desert/mountains environments. These environments lead to high variations in the wireless communications channel, this variation needs efficient flexible error protection technique. The flexibility of the error protection technique work and compatible with the rapid variation in the communications channel [25].

The capabilities of known traditional technologies are not suitable for the requirements the 5G, beyond 5G and 6G generations, where these expected mobile wireless networks generations require high performance, perfect power efficiency, ultra data rate and etc. There are promising technologies can be employed for these next generations such as the Large Intelligent Surface (LIS), Holographic Beam forming (HBM), Laser communications, Visible Light Communications (VLC) and etc. The LIS can be considered the advanced M-MIMO as shown in Figure 6 [26].



a b

Figure 6 Promising 6G technologies, a- Simple M-MIMO example , b- The LIS system for smart wireless environment.

Low latency and high data rate are considered the main specifications of the mobile broadband 5G networks. Beyond 5G 'intermediate G' and 6G attracted many researchers to expect the suitable technologies and specifications these promising mobile generations. The 6G requires special and advanced potential technologies such as the THz communications and Orbit Angular Momentum (OAM) and advanced coding based on rate-less schemes. The Rate-less fountain codes can be employed for avoiding the latency due to the retransmission process. The systematic Raptor code is presented for enhancing the data transmission latency through avoiding the retransmission process. Due to the requirements of the intermediate mobile wireless network generation and 6G, the known and classical communications and data processing technologies are not suitable. LIS can be considered advance of the m-MIMO system [27-29].

5.1 The promising Technologies of 6G Mobile Wireless Networks

Due to the experts and researchers visions toward the beyond 5G and 6G specifications and capabilities, there are several challenges restricts this vision and requirements. Although, the big difference between 2G mobile/cellular network and the present 4G&4G+ mobile/cellular network, the variation between the next mobile generation (6G) and the present network is not expected, where "the end of cellular starts with the beginning of 6G establishing". On the other hand, the developing of mobile wireless networks will jumping several jumps, every jump represents step and wall in the 6G world. Really, based on the vision and promising and the expected capabilities of 6G system, it will be considered the new "6G world".

In this section, some of the expected challenges of 6G vision are mentioned, as in the following:-

- Security:- The back bone of the 6G will be the open environment, with this transmission media and the advances in the DSP and software the security risks and threats will be increased. Hence, the security tools must be developed to be more effective and efficient. The AI is the main key in the data analysis for discovering the original and false data. Also, the AI can be employed to generate smart data can resist and detect any attacker by intelligent encryption technique not the traditional encryption tools.

- Power Consumption:- the second constraint is the required power for the different terminals of the 6G networks. The main key for this issue is the nano-electronics for designing and manufacturing ultra-low power circuits. The adaptive systems such as adaptive error control schemes, adaptive modulation and adaptive packets techniques can be used for indoor and terrestrial stations for providing the QoS and consumed power trade-off.

- Hash environments:- The different environments integration will be performed in the 6G platform networks. It will perform the communications underwater 'submarine', terrestrial, space, indoor, outdoor, satellite and other communications channels. This variations in the communication channel conditions needs flexible and adaptive systems for choosing the suitable data transmission scenario which insures perfect QoS and good error performance. Also, the AI can be employed for choosing the best transmission options based on the channel sensing.

-The intermediate nodes design:- The 6G integrates the various environments such as the underwater communications, air space communication, visible light communications and satellite communications. These different media communications require intermediate nodes which receive the signals and regenerate, adapt it to be suitable for transmitting over the another communications environments. The design of these nodes and its power is a challenge. The intermediate nodes include the sea/land intermediate node 'floating node', 'the flying node', this node covers the far area such as mountain areas and desert, these node must be low power consumption and fast.

The previous challenges are not all the 6G mobile wireless networks generation, it is some of expected challenges. The most of the 6G challenges can be solved by the Artificial Intelligent (AI) algorithms which can be more smart to learn from the practical situations and modify itself based on the present scenario.

6. Rate-less Fountain Code based M-MIMO System

In this section, the expected technology which is recommended for the 5G and beyond 5G mobile wireless networks generations is presented with the adaptive concept. The Large Intelligent Surface (LIS) is considered the advances of traditional diversity techniques and MIMO techniques. It can provide good error performance better than the traditional transmission scenarios. The description of the proposed M-MIMO rate-less based system is presented in this section. Figure 7 shows the contents of the proposed system with the modified block of Raptor encoder in the transmission stages. In the receiving process the Raptor decoder in the presented block diagram is appeared before the convolutional decoder. The presented system of the rate-less M-MIMO system is evaluated by the proposed model as shown in Figure 7. In this figure, the processing steps of the transmitted signals are mentioned.

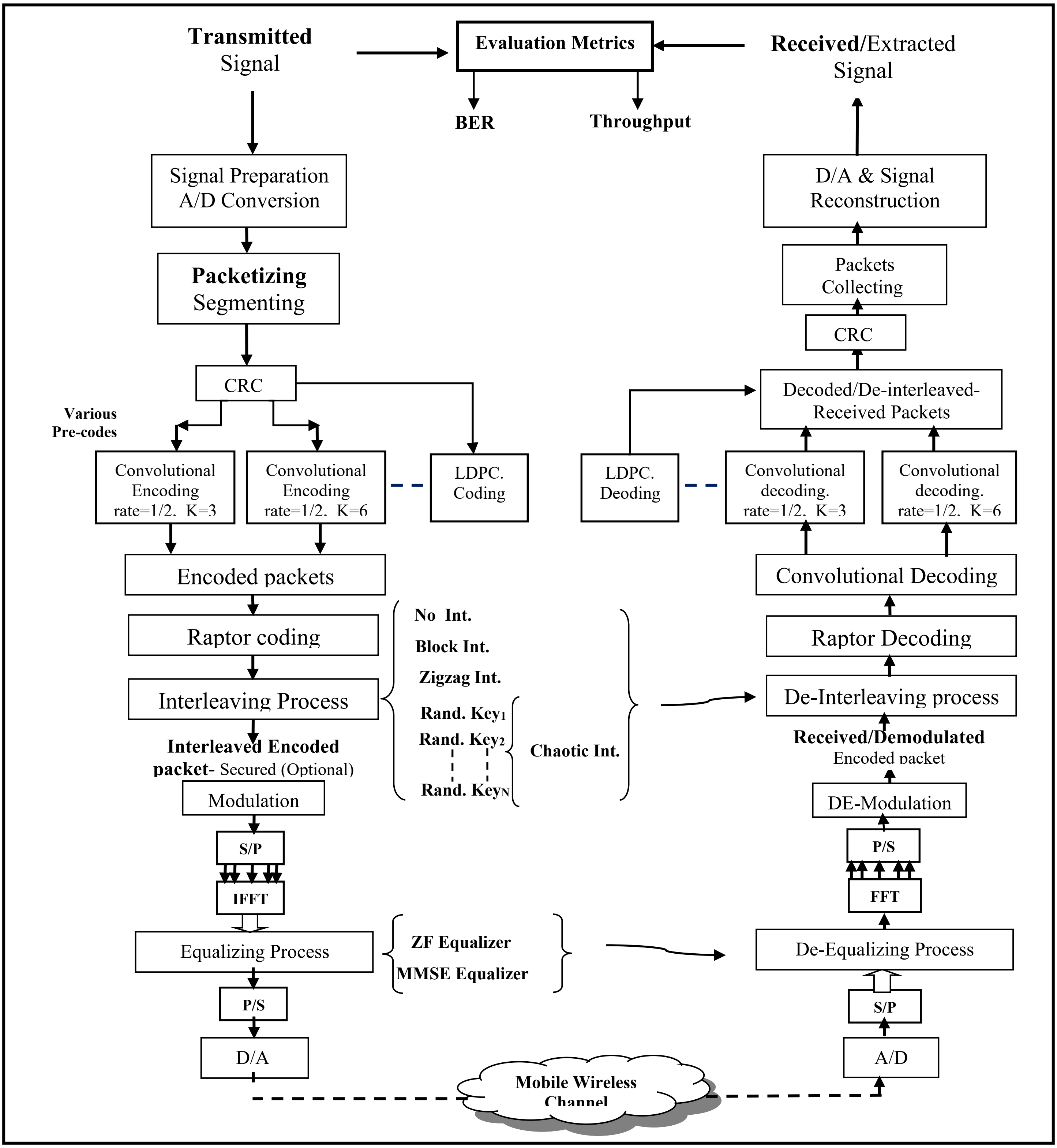


Figure 7 Block diagram of the proposed Raptor Code OFDM-MIMO System model.

6.1 The Proposed Model Description

The model starts with the original signal preparation step and generating the binary version. the second step is data packetizing and segmenting. After the CRC encoding, the convolutional encoding with the various constraint length (K= shift registers in the encoder+1) is performing on the input packet-by packet. The next step is executing the Raptor code mechanism by the LT code. The packet randomizing process is performed by the different techniques, no-int., block int., zigzag int. and chaotic int. The interleaved encoded packets and its images are modulated by QPSK modulation. The modulated-interleaved encoded packets are transformed form serial top parallel (S/P) for performing the IFFT transforming. After the transforming, the output is equalized by Zero Forcing Equalizer (ZFE) or MMSE Equalizer. the parallel to serial (P/S) process is performed and followed by the D/A conversion. The wireless communications channel is utilized for transmitting the data is simulated by Jake's model.

6.2 Description of M-MIMO System

In this section, the M-MIMO system contents and its constructions have been discussed, also, the setting of the MIMO which is utilized in the computer simulation is presented. In Figure 6, the M-MIMO and the expected promising LIS technology are given. In Figure 8, the simple block diagram of the M-MIMO contents are given, as shown in this figure, the number of antennas at the transmitting side is denoted by (N_t), it can be expressed as a matrix contains one column as in Eq. (15). In the other side the number of antennas at the receiver are represented by (N_r) and expressed as a matrix contains one column [30].

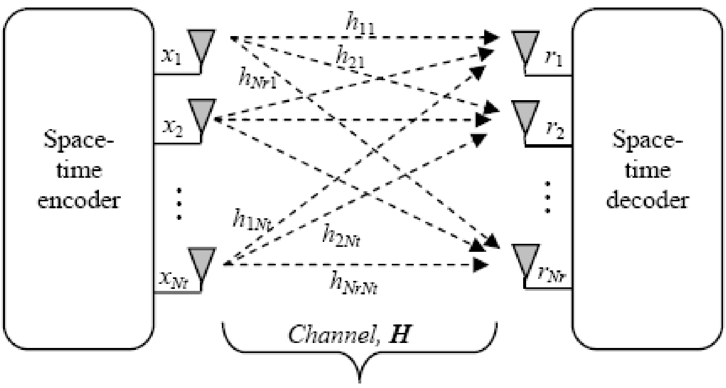


Figure 8 Simple contents of the MIMO.

The MIMO signals can be expressed mathematically as follows: Eq. (15) gives the received signal, H symbol represents the channel functions, it contains (number of receiving side antennas (N_r) × number of transmitting side antennas (N_t)) elements and (n) symbol represents the noise. Also, the expression in Eq. (15) can be reformulated as in Eq. (17) for considering the matrix form of MIMO signals.

$$\boldsymbol{Rr = HX + n} \tag{15}$$

$$\mathrm{H}=\begin{bmatrix} \boldsymbol{h_{11}} & \cdots & \boldsymbol{h_{1N_t}} \\ \vdots & \ddots & \vdots \\ \boldsymbol{h_{N_r1}} & \cdots & \boldsymbol{h_{N_rN_t}} \end{bmatrix} \tag{16}$$

$$\begin{bmatrix} \mathbf{r_1} \\ \mathbf{r_2} \\ \cdot \\ \cdot \\ \cdot \\ \mathbf{r_{N_r}} \end{bmatrix} = \begin{bmatrix} \boldsymbol{h_{11}} & \cdots & \boldsymbol{h_{1N_t}} \\ \vdots & \ddots & \vdots \\ \boldsymbol{h_{N_r1}} & \cdots & \boldsymbol{h_{N_rN_t}} \end{bmatrix} \begin{bmatrix} \boldsymbol{x_1} \\ \boldsymbol{x_2} \\ \cdot \\ \cdot \\ \cdot \\ \boldsymbol{x_{N_t}} \end{bmatrix} + \begin{bmatrix} \boldsymbol{n_1} \\ \boldsymbol{n_2} \\ \cdot \\ \cdot \\ \cdot \\ \boldsymbol{n_{N_r}} \end{bmatrix} \tag{17}$$

The SNR of the MIMO channel is expressed as given in Eq. (18), hence the capacity of the system (*C*) can be calculated by the formula in Eq. (19) [31].

$$\mathrm{SNR} \approx \frac{N^2M^2.E_S}{N.M.(n)} \tag{18}$$

$$\mathrm{C}=Blog_2[1 + MN(SNR)] \tag{19}$$

The M-MIMO system capacity (C) is used as metric for evaluating the proposed rate-less based M-MIMO system, through measuring the throughput of the different transmission scenarios. The error performance of the standard and proposed rate-less M-MIMO system is measured by the BER. The computer simulation experiments results prove improving in the capacity and capacity of the proposed rate-less based M-MIMO system [31].

6.3 Spatial Diversity and Multiplexing

The spatial diversity and spatial multiplexing are considered in this section. These techniques are employed in the presented M-MIMO scenario for improving the performance and overcoming the multipath fading. The multipath fading is considered the critical constraint in the mobile wireless communications. The diversity tools are built based on utilizing multiple-copies of the transmitted signal and send it through different paths. There are several types of diversity, frequency, time and space. Hence, the received signals can compensate the loss due to utilizing the different path [32].

On the other hand, the spatial multiplexing technique provides linear increasing in the rate of the data transmission with no need B "bandwidth" or extra power. The spatial multiplexing leads to increase the transmission rate with the same number of antennas at the receiving side and transmitting side. It works based on sending the different symbols through each antenna. At the receiver, these signal symbols are discriminated with considering the advantage of each antenna at the transmitter has a unique spatial signature. Hence, suppose, MIMO system have (*Nt)* and (*Nr),* the system capacity increases with min (*Nt*, *Nr*) [33].

7. Simulation Experiments and Results

In this section, computer simulations are performed to evaluate the performance of the proposed technique on the M-MIMO Raptor code based. The transmission channel is AWGN channel and Rayleigh fading channels. Simulation Program using Matlab 2014 is done for evaluating the BER reduction and throughput due to the proposed Raptor code based OFDM-MIMO system. This experiment uses ZF, MMSE equalizers for diversity (MIMO system) and non-diversity. This experiment is repeated for no interleaves and the three interleaving techniques (block interleaving, chaotic interleaving, and zigzag interleaving) [34].

Table I Simulation Parameters of rate-less Raptor code based MIMO-OFDM System

Parameters	**Setting of Simulation**
Communications channels	AWGN, Rayleigh fading
Simulation Model	Jake's model
Frequency Doppler shift (FD)	0, 50, 100 Hz
No of source symbol (k), Symbol size	260, 2024, 4048 symbol
Utilized Equalizer	ZF, MMSE
Interleaving mechanisms	No, Block, Various Chaotic with k1, k2, k3, and Zigzag
Coding	Raptor codes by Conv. encoding
Modulation	OFDM, QPSK
FFT, Cyclic prefix	2048, 512
No of intermediate symbols	10920 OFDM symbol
Conv.block size	43008
Conv. Code rate, K	0.5, 3 and 6
SNR	0 to 10 dB
Performance parameter	BER, Throughput

In this section, simulation experiments are carried out to demonstrate the performance of the Raptor code based M-MIMO system, when no, block, chaotic and zigzag interleaving is applied in the system. Using the same simulation parameters described in Table I.

It is clear that the proposed system has a BER reduction using QPSK modulation. The simulations also evaluate the Throughput Vs SNR & FD for Raptor with QPSK for different interleaving techniques. This experiment is repeated also over AWGN and different fading channels. The proposed system is able to receive any changes occur in the channel.

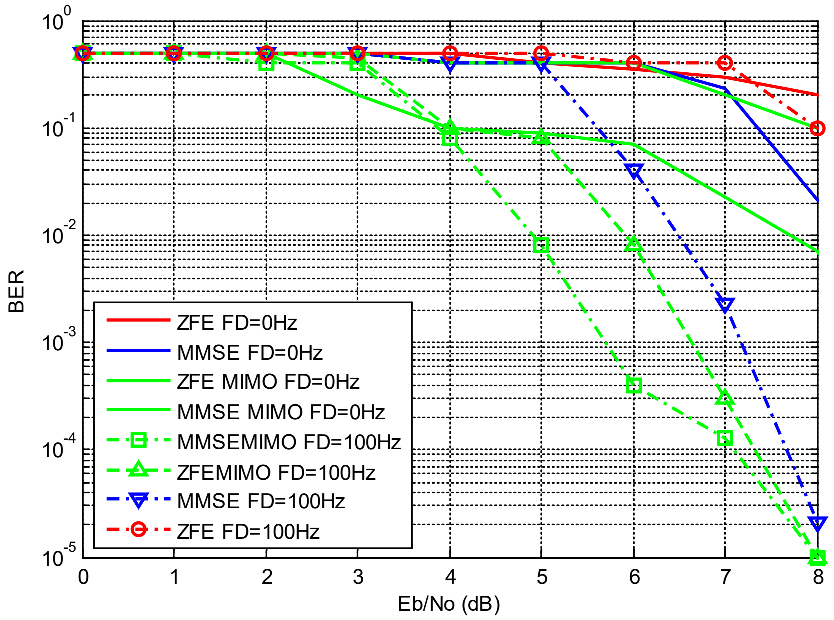


Figure 9 BER Vs E_b/N_o for fountain code based M-MIMO System No Interleaving with respect to the Equalizing and various FD.

Figure 9 shows the BER performance of the proposed Raptor-OFDM system with no interleaving using ZF and MMSE frequency domain equalizers. The results show that, the MMSE equalizer outperforms ZF. For example, at BER = 1e-5, MMSE with diversity (MIMO-System) outperforms MMSE without diversity, ZF with diversity and ZF without diversity by 0.75 dB, SNR=7.5, 8.25, 9, 9.75 dB respectively for FD=0 Hz. Figure 9, also, shows the results of the first experiment with the FD=100 Hz, the MMSE with and without diversity are almost congruent to give BER = 1e-5 at SNR=7.5. The ZF equalizer with diversity outperforms ZF without diversity by 0.75, BER = 1e-5 at SNR=8.25 and 9 dB respectively. Note, The result improved for FD=100 from FD=0, then the proposed system is capable to mitigate the effects of fading in mobile communication systems.

Figure 10a shows the BER performance of the proposed Raptor-OFDM system with chaotic interleaving using ZF and MMSE frequency domain equalizers. The results show that, the MMSE equalizer outperforms ZF. For example, at BER = 1e-5, MMSE with diversity (MIMO-System) outperforms MMSE without diversity, ZF with diversity and ZF without diversity by 0.75 dB, SNR=7.5, 8.25, 8.25, 8.25 dB respectively for FD=0 Hz. For

FD=50 Hz, as shown in Figure 10b, the proposed system containing MMSE equalizer with diversity is constant, give the same result for FD=0. The ZF equalizer with and without diversity are almost congruent to give BER = 1e-5 at SNR=8.25 dB. The MMSE equalizer without diversity degraded to reach the BER = 1e-5 at SNR=9 dB.

Figure 11a shows the BER performance of the proposed Raptor-OFDM system with Zigzag interleaving using ZF and MMSE frequency domain equalizers. The results show that, the MMSE equalizer outperforms ZF. For example, at BER = 1e-5, MMSE with diversity (MIMO-System) outperforms MMSE without diversity, ZF with diversity and ZF without diversity by 0.75 dB, SNR=7, 8, 8, 8 dB respectively for FD=0 Hz. Figure 11b, the BER of MMSE-diversity is improved to give 1e-5 at SNR=6.75 dB at FD=100 Hz. The MMSE without diversity and ZF with diversity are almost congruent to give BER = 1e-5 at SNR=8.25. The ZF equalizer without diversity give BER = 1e-5 at SNR= 9 dB. The proposed Raptor codes for MIMO-OFDM system with Zigzag interleaving achieves a significant performance gain over the other systems.

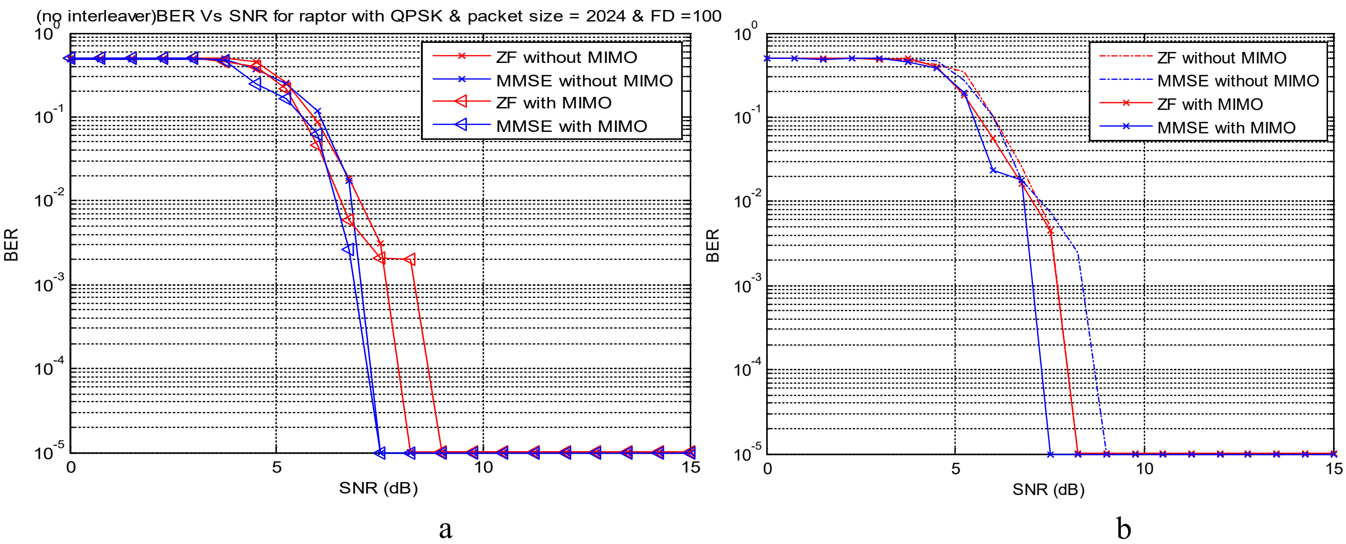
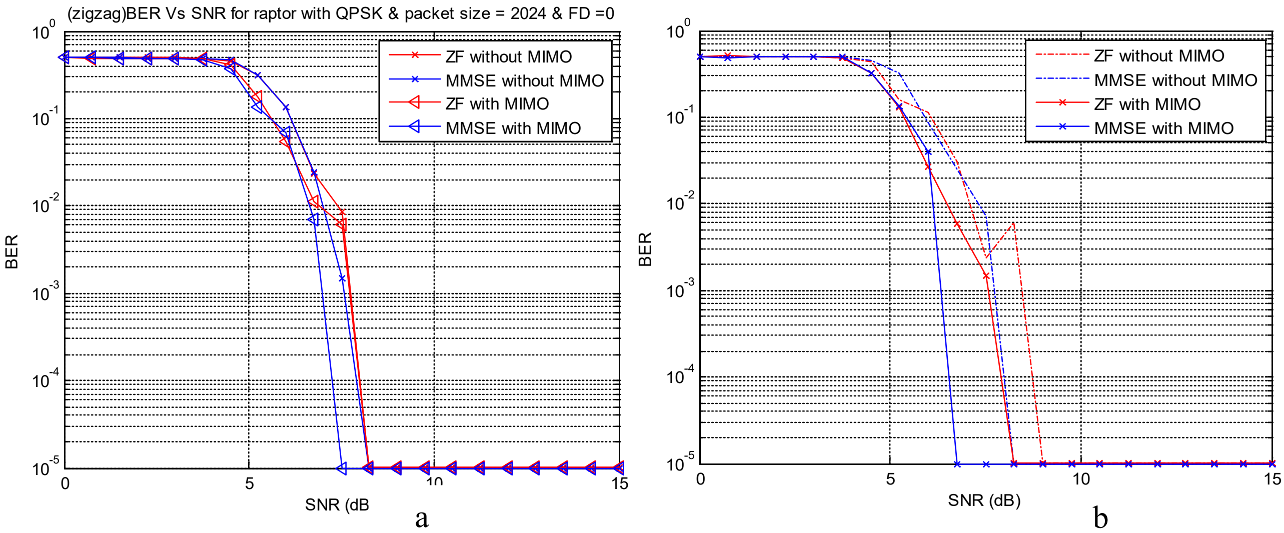


Figure 10 BER Vs SNR for Raptor Based-MIMO System uses
a- No interleaving-FD= 100 Hz, b- Chaotic Interleaving- FD=50 Hz.



a b

Figure 11 BER Vs SNR for Raptor OFDM-MIMO System, a- Zigzag Int. - FD=0 Hz, b- Zigzag Int. - FD=100 Hz.

Figure 12, shows a performance comparison of the throughput for proposed Raptor code based on M-MIMO-OFDM System uses no interleaving. The results show that, the proposed Raptor code with diversity (M-MIMO-System) outperforms the system without diversity.

- Performance analysis :-

Table V tabulates the results of the throughput the different used transmission scenario for evaluating the Rate-less Raptor code based MIMO system

Table V Throughput of the proposed system with respect to the different randomizing tools with respect to the various pre-code schemes.

Diversity Technique	FD (Hz)	Throughput of The Proposed Raptor based MIMO system at SNR=10 dB					
		Pre-code: Conv. (1,2, 3)		Pre-code: Conv. (1,2, 3)		Pre-code Hamming (15,11)	Pre-code:- Hamming (15,11)
		Chaotic Int.	Block Int.	Zigzag Int.	No Int.	Chaotic Int.	Zigzag Int.
Non	0	0.9410	0.8234	0.9507	0.8088	0.9110	0.9007
	50	0.9261	0.9117	0.9251	0.8529	0.9161	0.9151
	100	0.9503	0.8323	0.9352	.8824	0.9303	0.9252
Utilized	0	0.9804	0.9703	9705	0.97	0.9604	9505
	50	1.00	0.9402	1.00	0.930	0.9583	0.9603
	100	1.00	0.8539	0.9703	0.9506	0.9729	0.9690

Table V Throughput of the proposed system with respect to the different pre-codes

Diversity Technique	FD (Hz)	Throughput of The Proposed Raptor based MIMO system at SNR=8 dB			
		Pre-code: Conv(1,2, 6)		Pre-code: Conv (1,2,3)	
		Chaotic Int.	Block Int.	Zigzag Int.	No Int.
Non	0	0.9412	0.8235	0.9506	0.8088
	50	0.9265	0.9118	0.9253	0.8529
	100	0.9506	0.8329	0.9353	.8824
Utilized	0	0.9806	0.9708	9706	0.97
	50	1.00	0.9412	1.00	1.00
	100	1.00	0.8529	0.9706	0.9706

Table V discuss the throughput of the proposed system with zigzag interleaving. The table shows the improvement in throughput of the proposed Raptor-OFDM system, with zigzag interleaving. For example, at SNR of 9dB and *FD*= 50 Hz, the proposed Raptor-OFDM system, give throughput=0.9853 and 1.0 without and with diversity respectively.

8. Conclusions

The promising technologies of 5G and 6G mobile wireless networks are discussed in this paper with focusing on the advanced error protection techniques. Signals transmission over various environments is the main challenge in the 6G generation, due to the 6G will integrate the terrestrial, space, underwater and mountains environments. In this research paper, the flexible adaptive interleaved rate-less coding technique based on the channel conditions is proposed for the beyond 5G and 6 G wireless networks generations. The M-MIMo Raptor code based system is presented for improving the error performance and throughput enhancing utilizing the interleaving techniques. The proposed system improves the BER and the throughput. The performance of the proposed Raptor code based M-MIMO system with the convolutional codes (1, 2, 6) and the chaotic interleaving over a multipath fading channel is better than the traditional system with respect to the MMSE equalization. The experiments prove the superiority of the presented wireless rate-less system compared to the fixed rate wireless system due to the improved results of BER and the throughput values which are utilized as a performance evaluating metrics. Theoretical analysis of the M-MIMO throughput proves the enhancing of M-MIMO utilizing the rate-less Raptor code and its applicability for the next mobile wireless networks generations.

-No conflict of interest exists.

Authors wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Also, they confirm that there is no funding was received for this work.

-Data Availability:

The data associated with a paper and support the findings of research work are available from the corresponding author upon reasonable request.

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Figures

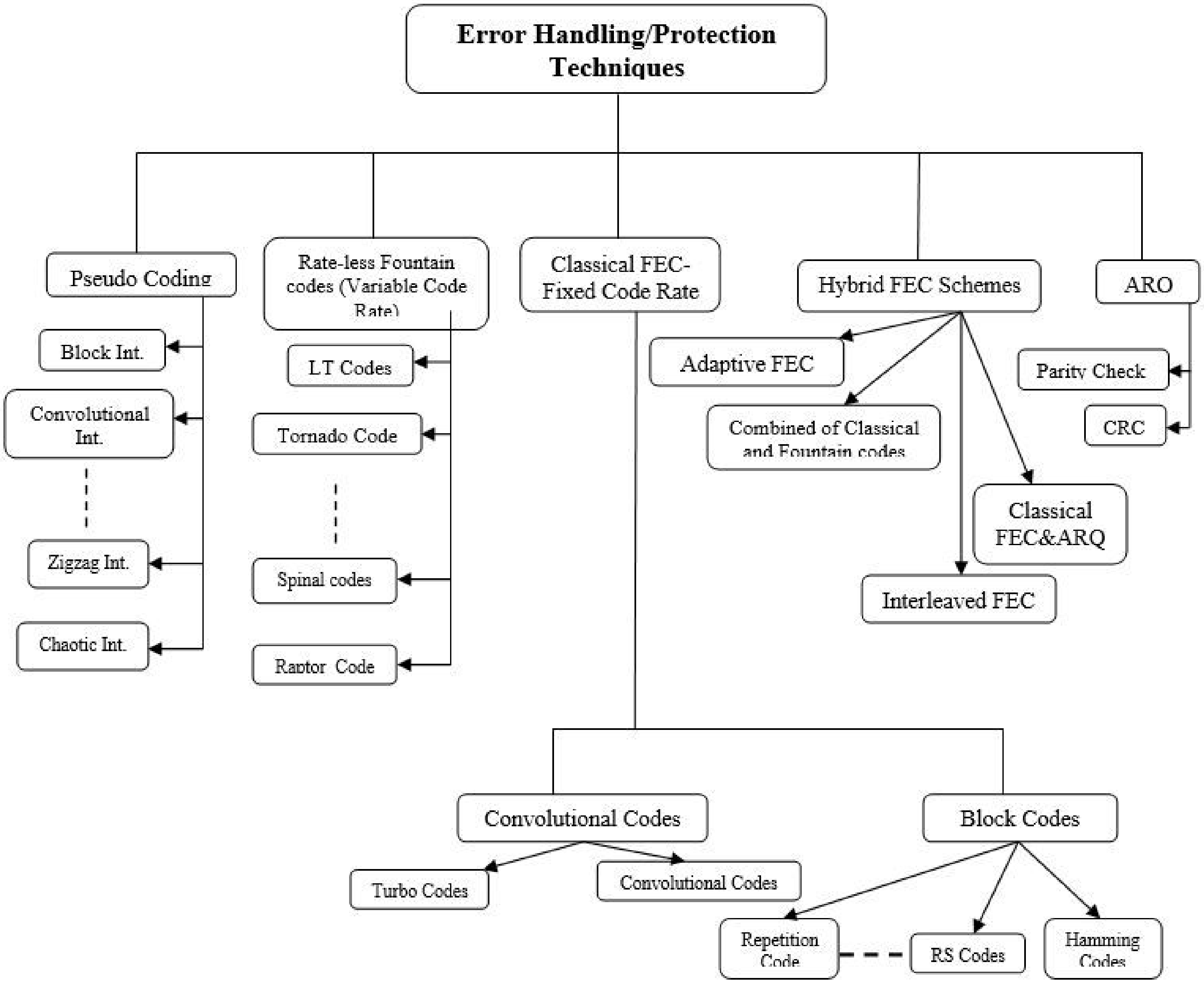

Figure 1

Channel coding techniques categories with respect to the code rate.

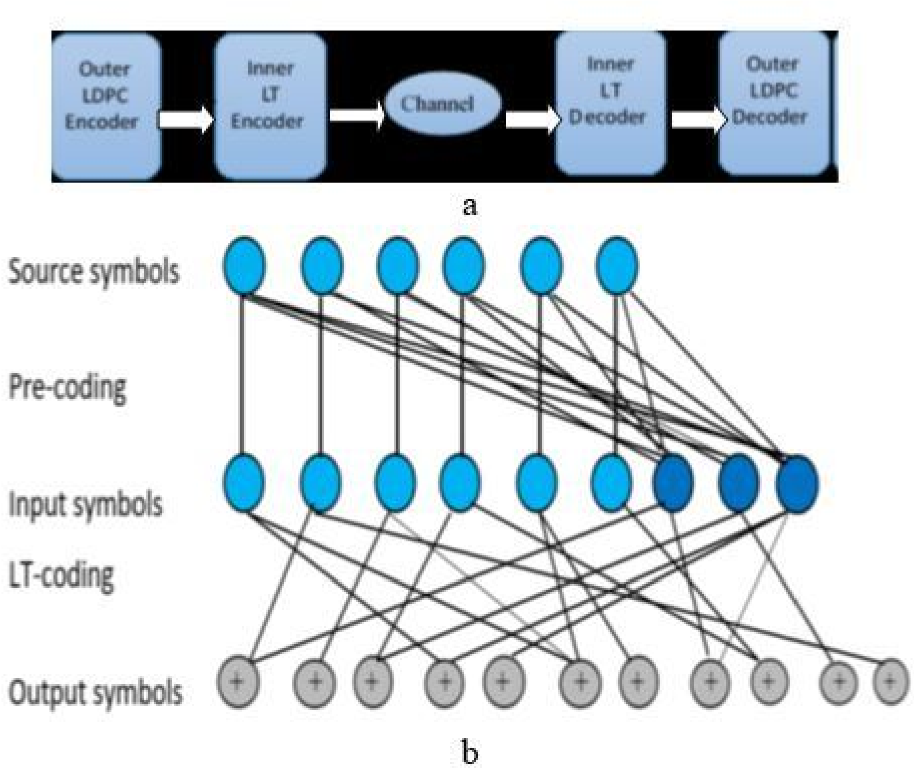

Figure 2

Contents and Generating the output symbols of the Raptor codes, a-Block diagram of Raptor code, b-Output symbols generating.

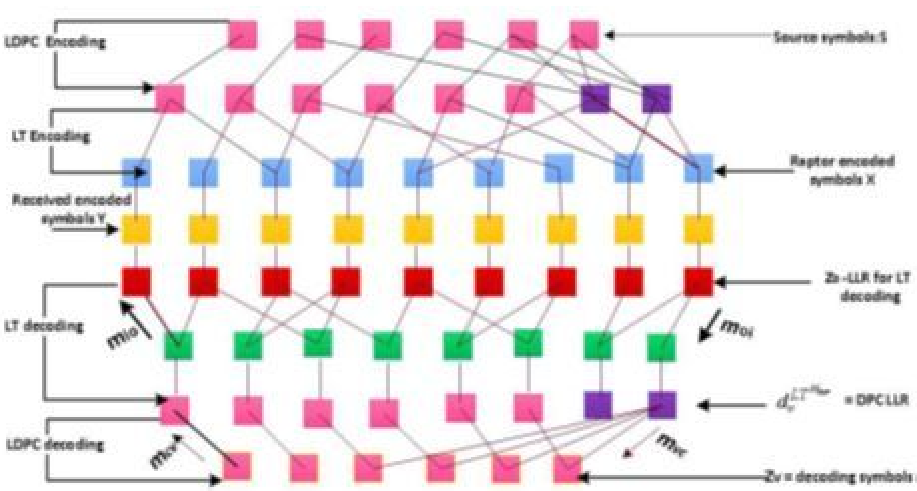

Figure 3

Steps of the Raptor codes Decoding process.

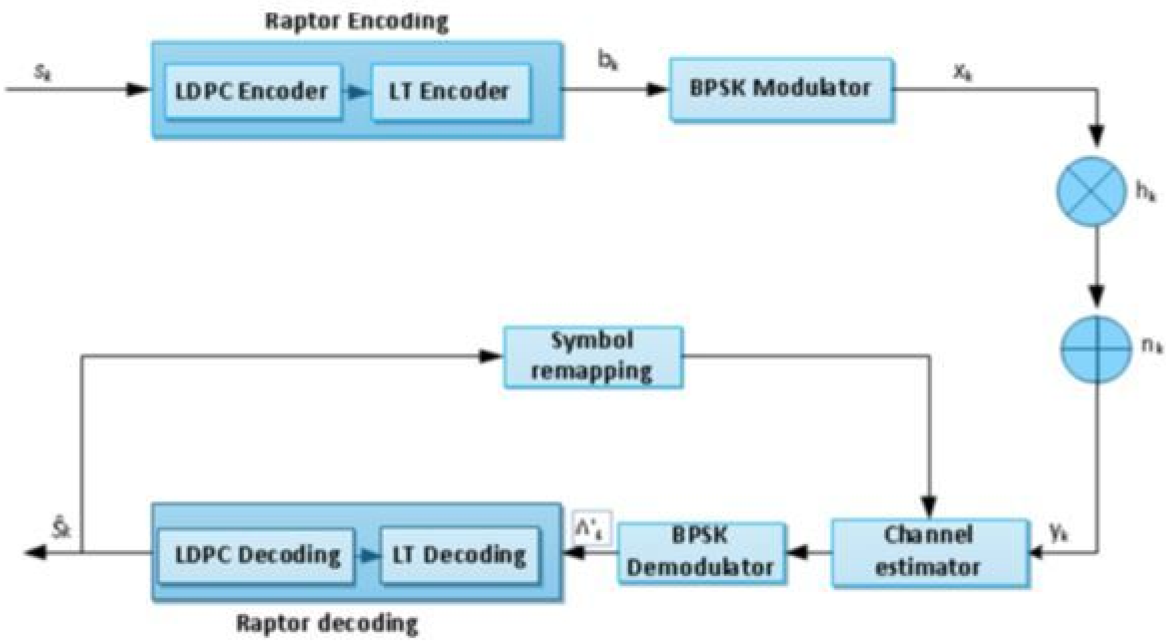

Figure 4

Raptor code block diagram for estimating the symbols with MMSE.

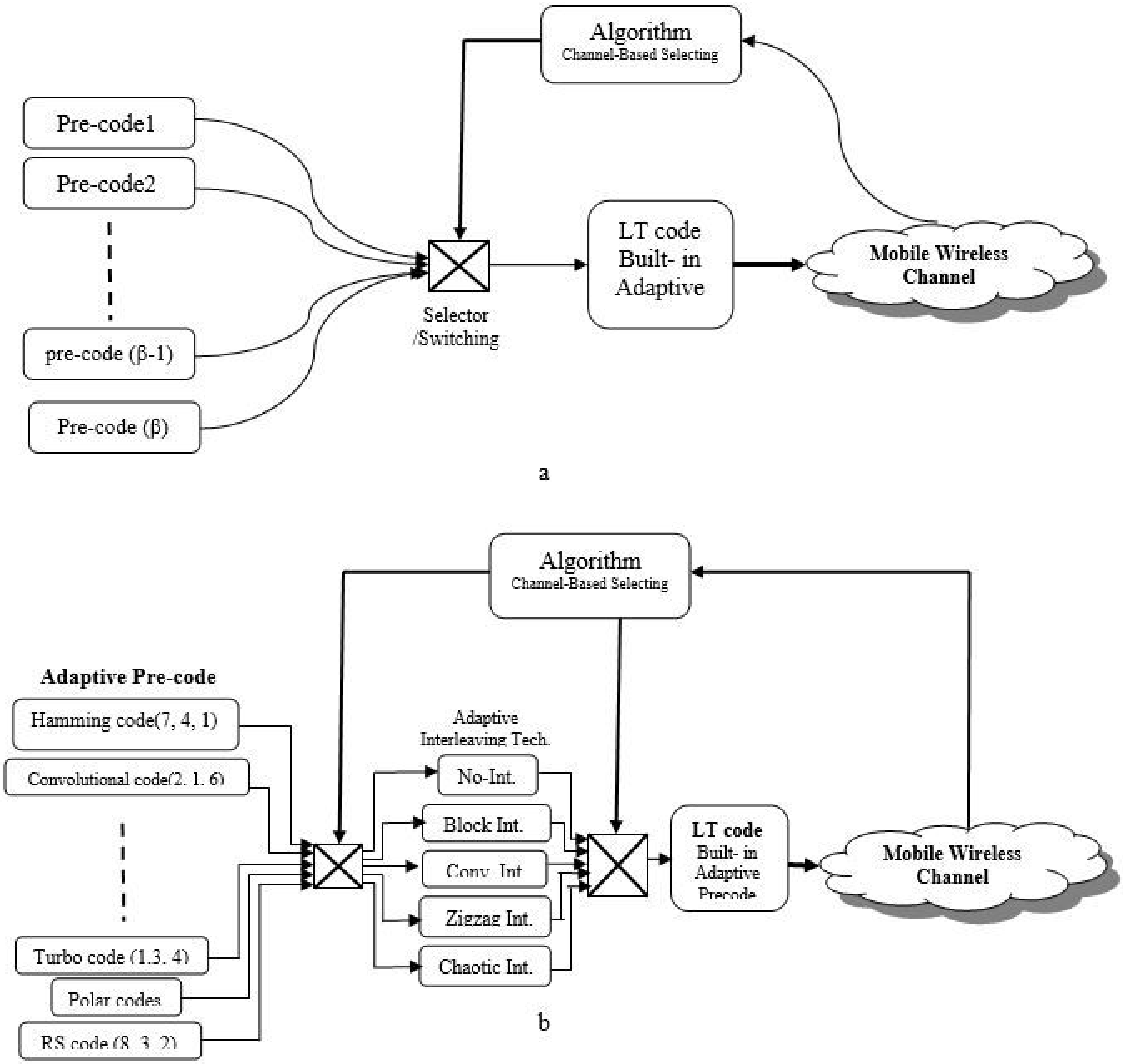

Figure 5

Adaptive rate-less Raptor codes for 6G wireless mobile networks, a- Adaptive Pre-code based on channel conditions, b-Adaptive Interleaved Pre-code based on the wireless link.

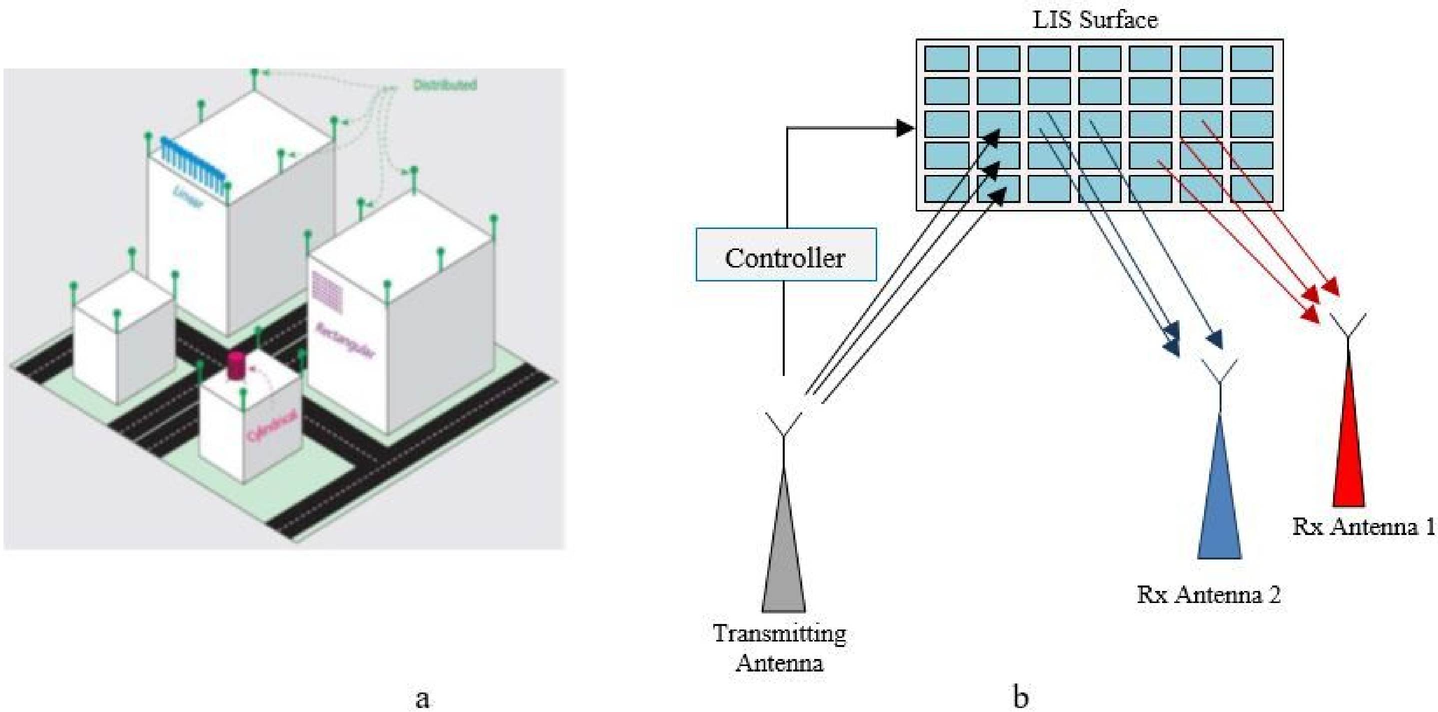

Figure 6

Promising 6G technologies, a- Simple M-MIMO example , b- The LIS system for smart wireless environment.

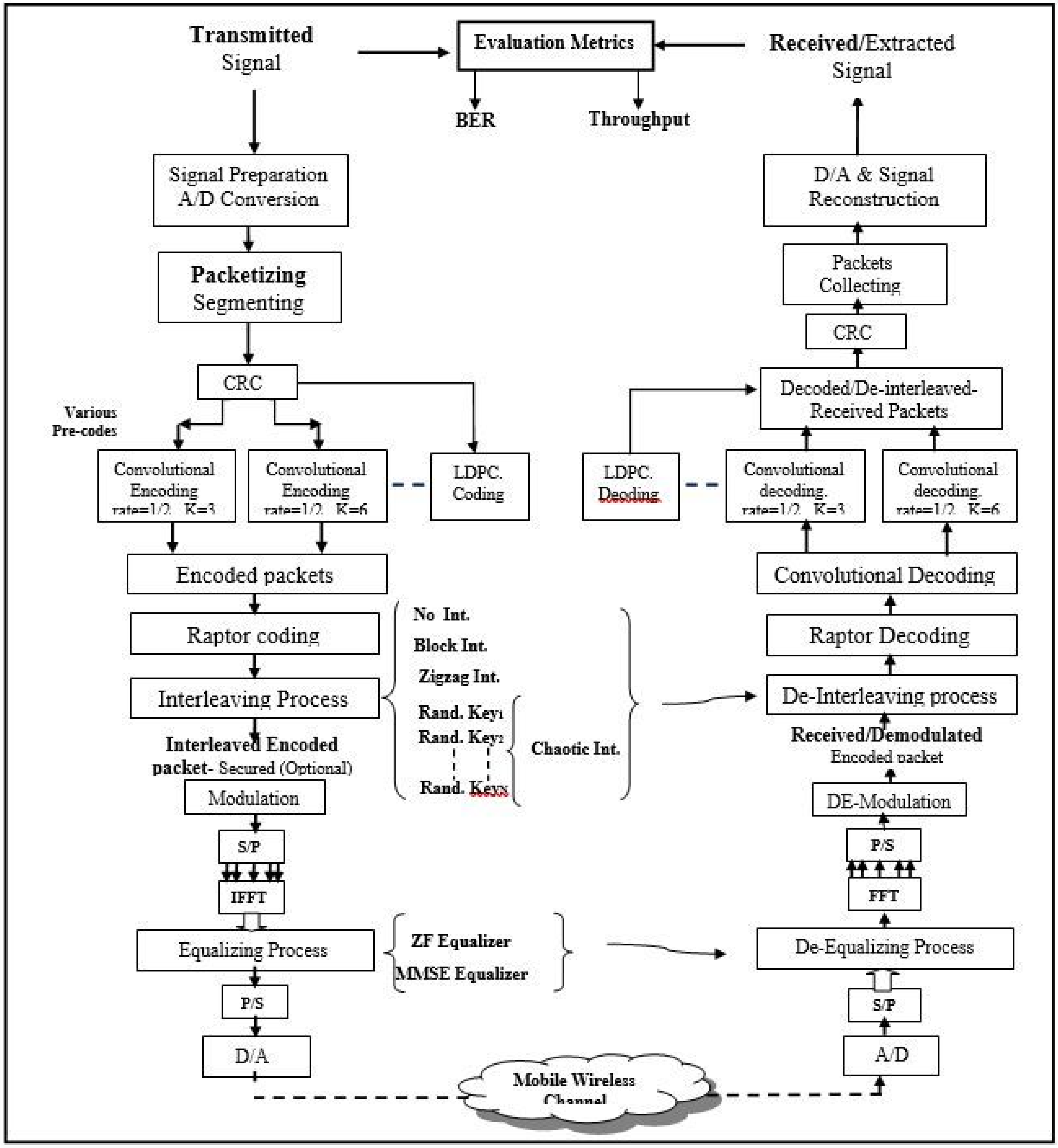

Figure 7

Block diagram of the proposed Raptor Code OFDM-MIMO System model.

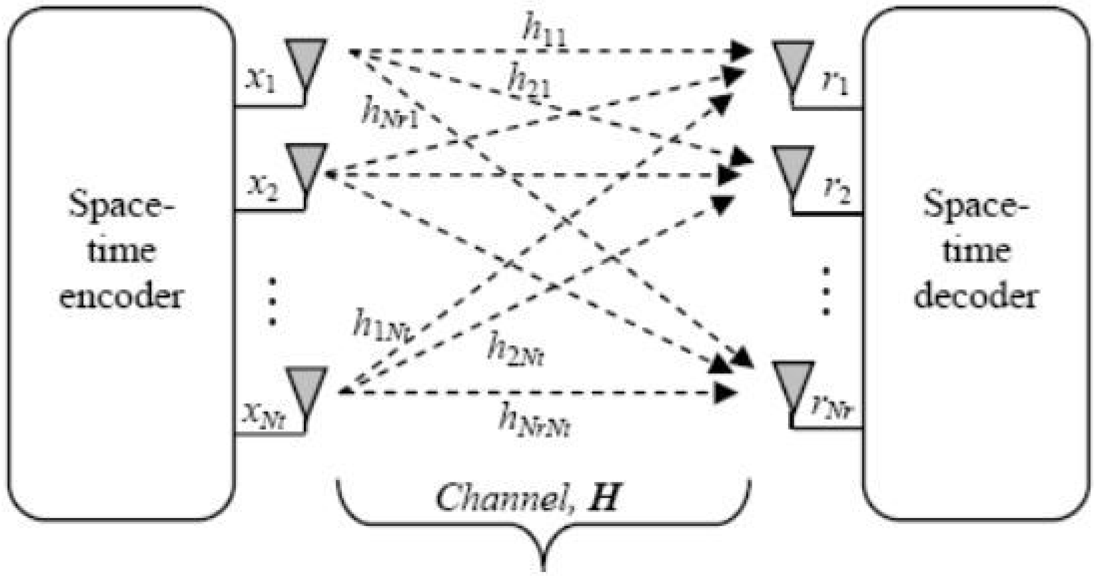

Figure 8

Simple contents of the MIMO.

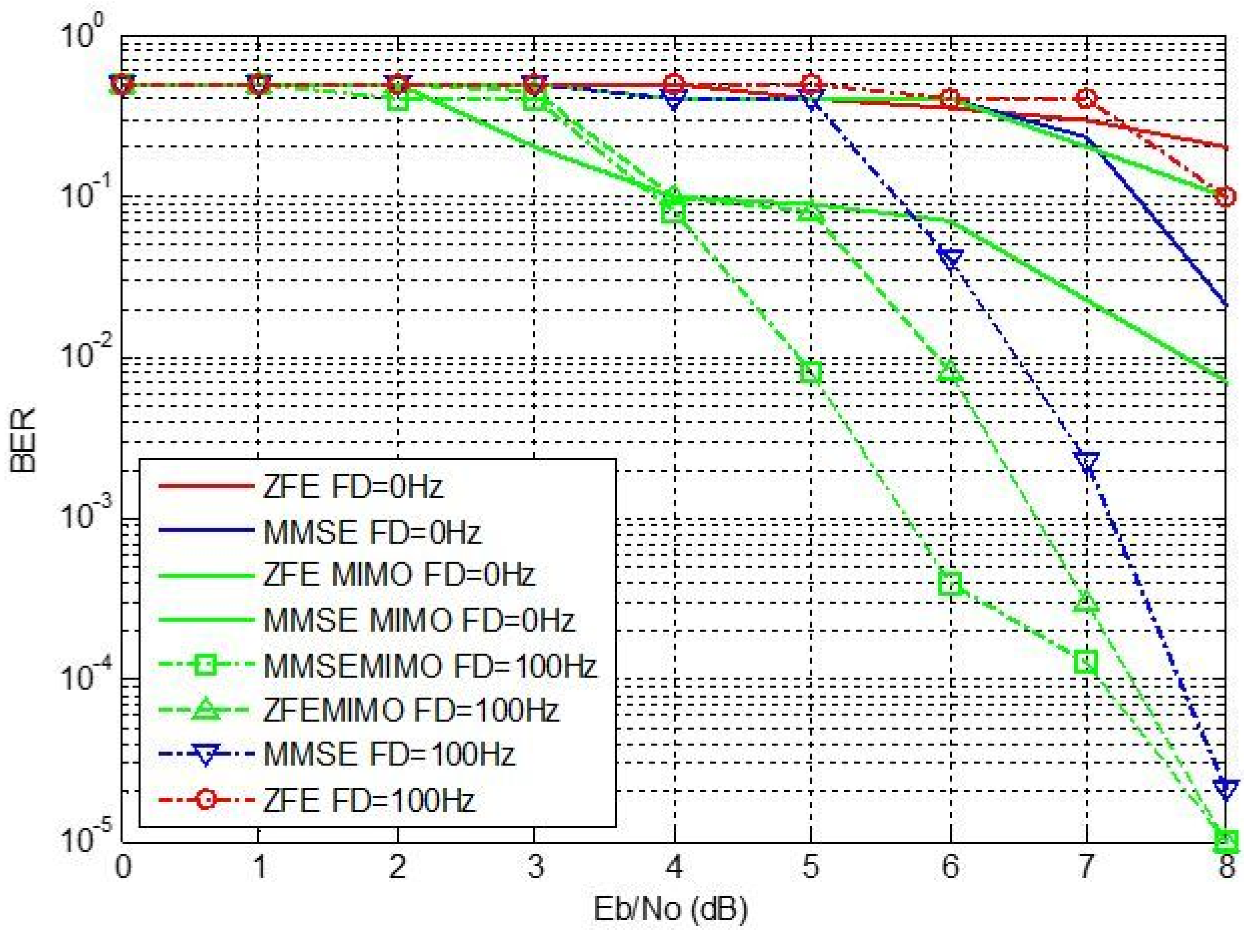

Figure 9

BER Vs Eb/No for fountain code based M-MIMO System No Interleaving with respect to the Equalizing and various FD.

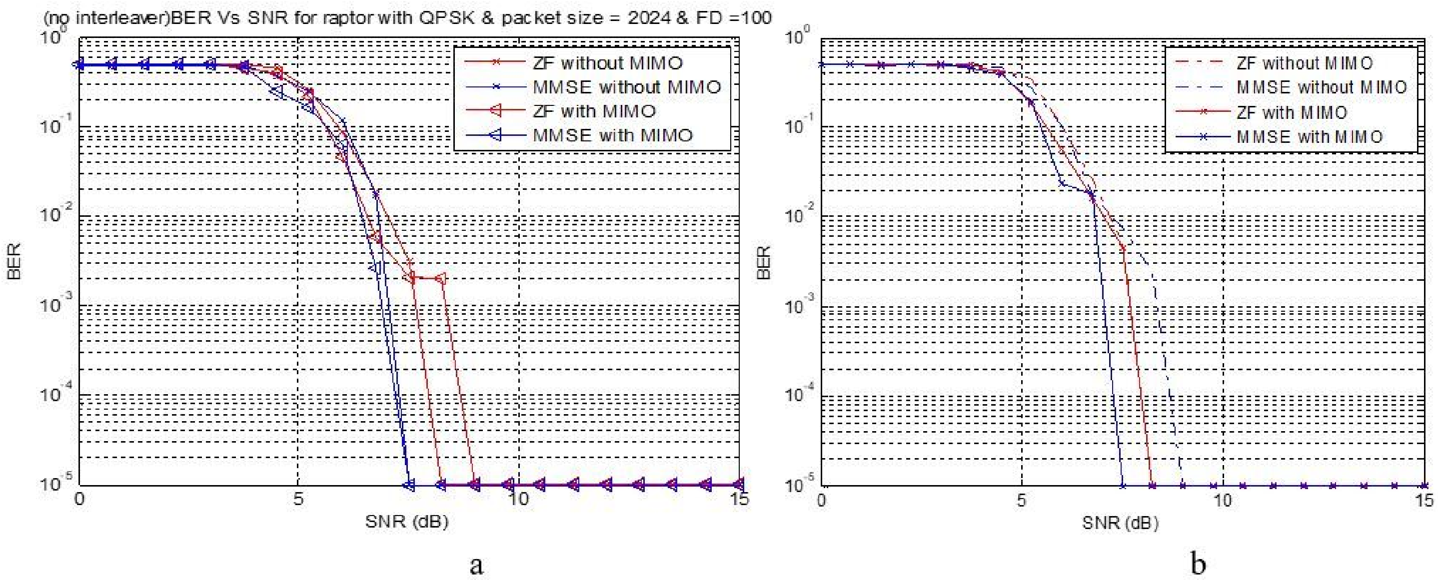

Figure 10

BER Vs SNR for Raptor Based-MIMO System uses a- No interleaving-FD= 100 Hz, b- Chaotic Interleaving-FD=50 Hz.

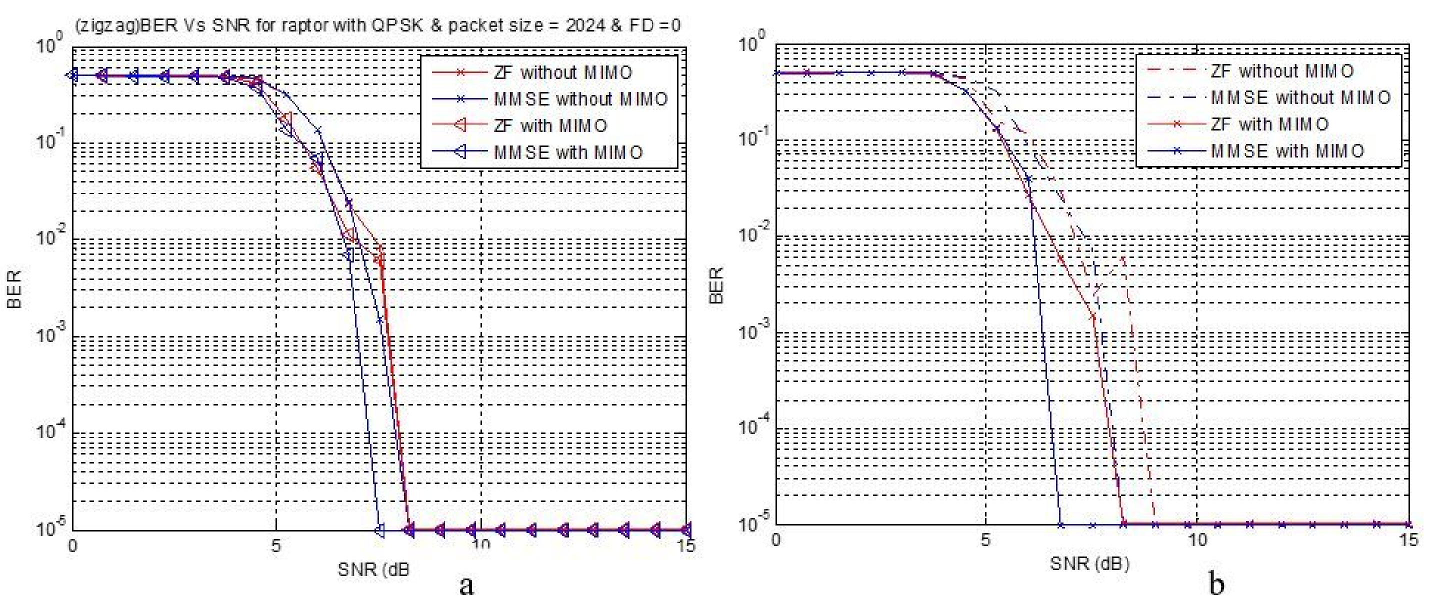

Figure 11

BER Vs SNR for Raptor OFDM-MIMO System, a- Zigzag Int. - FD=0 Hz, b- Zigzag Int. - FD=100 Hz.

Figure 12

Figure 12 not available with this version.