Study the Effect of HARQ and MISO Technique on the EnodeB Performance of LTE System

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ABSTRACT: *Long Term Evolution (LTE) is designed as a wireless broadband technology for a last generation of Universal Mobile for Telecommunication System (UMTS) to provide multimedia services for the users. In order to study the effect of Hybrid Adaptive Repeat and Request (HARQ) procedure with multiple antenna technique on the performance of LTE system, this paper deals with HARQ procedure in case of one and two retransmitting. On the other hand, this paper submits Multiple Input Single Output (MISO) technique using two antenna elements at the transmitter side to improve the capability of the system with low complexity for the system. The results showed that the block error rate (BLER) and the throughput of the system are improved when the HARQ procedure and MISO technique are employed together in a three cases study of the Channel Quality Indicator (CQI) of the user. The results explained that the amount of improvement which offered by the procedure of HARQ with two retransmitting be very slight compared with the case of one retransmitting.*

Keywords: EnodeB, HARQ, LTE, MISO

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1. Introduction

Initially, LTE system which is submitted by 3GPP standard is begun to ensure the competitiveness of UMTS where LTE has many features like higher capacity and low delay as compared with old systems. This system is characterized by its ability to provide high data rate in the DL and UL directions. Consequently, it delivers multimedia services (such as voice, video, interactive game, etc.).

In order to fulfill these requirements, LTE is based on orthogonal frequency division multiple access (OFDMA) in the DL direction and single carrier- frequency division multiple access (SC-FDMA) in the UL direction. The idea of OFDMA technique converts the wide band frequency channel carrier into a set of many narrow mutually orthogonal sub-carriers, as shown in Figure 1.The minimum transmission bandwidth is 180 KHz so each user allocated different bandwidth using different number of sub-carriers. The most benefits for using OFDMA multiple access schemes in the DL direction are larger bandwidth and bandwidth flexibility. The most benefits for using OFDMA multiple access schemes in the DL direction are larger bandwidth and bandwidth flexibility.

On the other hand, the benefit of using SC-FDMA in the UL direction is better power amplifier efficiency for the UE [1] [2].

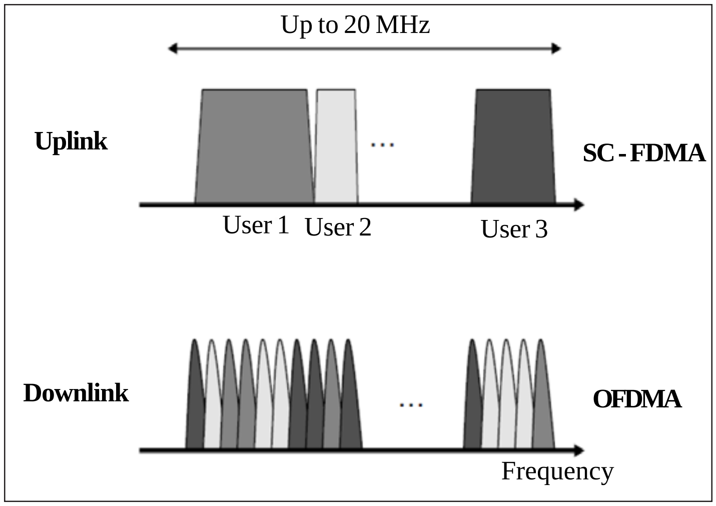

Figure 1. LTE multiple access schemes [2]

The high data rate one of the key features of the LTE. Therefore, it is needed to use efficient techniques to providing efficiency and reliability of data transmission over noisy channel.

HARQ procedure offers attractive solution to compensate the error rate by used a combination of Forward Error Correction (FEC) and automatic retransmission request. It has flexible choices to determine the appropriate number of re-transmitter to deal with the errors. It is worth to mention that there is tradeoff in HARQ procedure between the resources consumption and the number of retransmitted. This paper studies two cases of retransmitting (one and two).

Multiple antennas technique is efficient option to increase the capacity and enhance the coverage area of the system. One of the types of multiple antennas is Multiple Inputs Single

Output (MISO), it has the advantage of applying only one antenna at the subscriber side, and as a consequence simplifying the subscriber implementation procedure while the number of antenna at transmitter side equal of two elements.

K. Chung, A. Doufexi and Si. Armour [3] dealt with HARQ alone where they evaluated the performance of the LTE system after employed the HARQ with different schemes. The difference among these schemes of HARQ depends on the memory requirements, the resources consumption and the delay while M. L. Kawser et.al [4] presented HARQ as a solution to support the performance of LTE system for the weak received signal only. Z. He and F. Zhao [5] intended to calculated the performance of LTE system with HARQ procedure for many cases of modulation and coding schemes alone and together as adaptive modulation. S. Joshi et.al [6] submitted 2∗2 MIMO technique as a spatial correlation to support the LTE system where the paper is evaluated the throughput fraction and the capacity of the system. The mathematical model of ergodic capacity is proposed in [7] for LTE system supporting with MIMO technique to enhance the performance of the system. Al last, the mixing between HARQ and MIMO are submitted by [8] to enhance the LTE system but with high processing due to the retransmitting of HARQ equal of 3 and the complexity at the receiver side because using more than one antenna elements.

It is obvious from the literature review there is tradeoff between the enhancements which is supported the system and the effect of complexity and the delay1. Consequently, this paper engages between HARQ procedure and MISO technique to improve the performance of LTE system with low processing and complexity.

2. Theory

2.1 Backround

The LTE protocol model specifies the protocols terminated between User Equipment (UE) and evolved node base station(eNodeB)[9], this protocol stack defines three layers: layer one, layer two and layer three [10], as shown in Figure 2. The function of HARQ in the standard of LTE is submitted by the layer two with other functions like segmentation and scheduling where this layer is divided into three sub-layers as shown in Figure 2, while layer one (physical layer) provides the bits transmission. Finally, layer three deals with resources control and application layer [10] [11].

2.2 Resource Block

The major concept of resources allocation in LTE system is shown in Figure 3 where the spacing between two sub-carriers is typically 15 kHz and each 12 subcarriers with 6 or 7 OFDM symbols (depending on the size of cyclic prefix) called Resource Block (RB). The RB consists of resource elements (REs) group where the RE represents the basic unit of the resources. The bandwidth for each RB is180kHz (12 ∗ 15 kHz = 180 KHz), so the minimum transmission bandwidth is 180 KHz (one RB), and each user allocated different bandwidth using different numbers of RB.

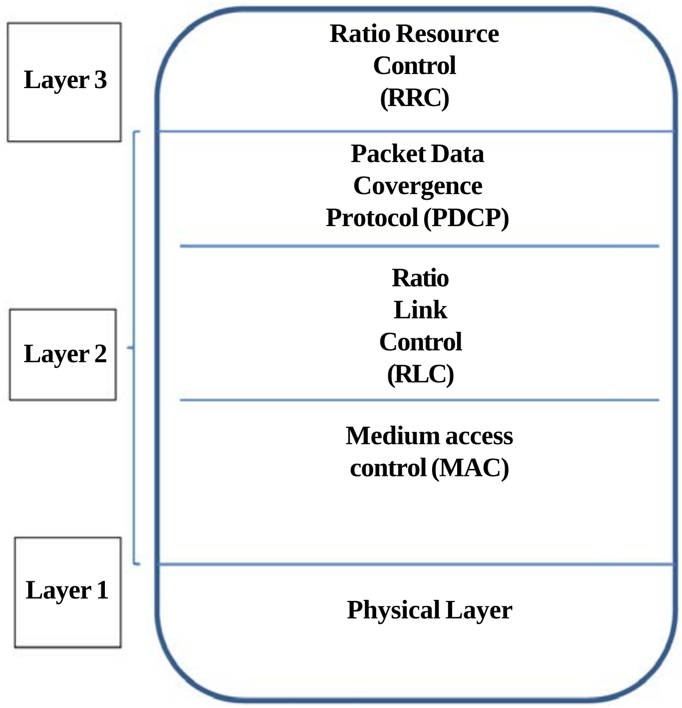

Figure 2.Protocol stack of LTE

The REs in DL direction divide into two kinds, REs for data and REs for control [12]. The REs which is devoted to data are carried by physical downlink shared channel (PDSCH). PDSCH can be modulated depending on channel quality of UE which is used QPSK, 16QAM or 64QAM modulations depending on the channel quality of UE.

The REs for control carried via many channels and physical signals [13]. Physical hybrid ARQ indicator channel (PHICH) is one of the control channels where which deals with the HARQ procedure acknowledgement/negative acknowledgement (ACK/ NAKS). ACKS and NAKS confirm the delivery of data or request the retransmission of data blocks received incorrectly [9].

2.3 Frame Structure of LTE

The frame structure of LTE consists of ten sub-frames, each sub-frame contains two slots where the length of one slot equal of 0.5ms. LTE supports two types of frame structures:

1) **Type 1 Frame:-** Frame devotes to frequency division duplexing (FDD), it is separated UL on DL.

2) **Type 2 Frame:-** Frame devotes to time division duplexing (TDD), Type 2 is dealt with UL and DL together.

2.4 Channel Quality Indicator (CQI)

Channel quality indicator is a technique which provides the eNodeB information's about the link adaption parameters and the data rate that can be received successfully by the UE. The parameters reported by a UE to the eNodeB are signal strength quality, transmission mode, number of antennas and interference situation experienced at the connection time. Based on these parameters, the UE will be supported at the time. The value of the CQI which is received at the eNodeB indicates which type of the modulation and coding schemes will be used for the DL direction, see Table 1 [2] [13].

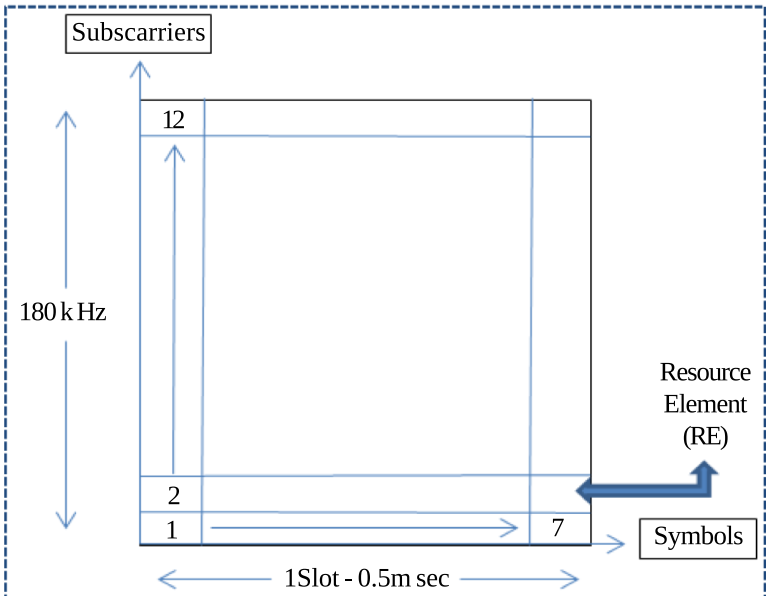

Figure 3. Resource block of LTE

CQI	Modulation	Coding Rate
0	-	-
1	QPSK	78/1024
2	QPSK	120/1024
3	QPSK	193/1024
4	QPSK	308/1024
5	QPSK	449/1024
6	QPSK	602/1024
7	16QAM	307/1024
8	16QAM	490/1024
9	16QAM	616/1024
10	64QAM	466/1024
11	64QAM	567/1024
12	64QAM	666/1024
13	64QAM	772/1024
14	64QAM	873/1024
15	64QAM	948/1024

Table 1. Relationship between CQI and Modulation type [1]

2.5 HARQ Procedure

Hybrid Adaptive Repeat and Request is a technique which used in LTE to reduce the effect of multipath fading channel. It is able to enhancement SNR and throughput performance by reducing the error [14]. The HRAQ based on stop and wait procedure. At the beginning the UE decoded the packet which is transmitted from the eNodeB and send the ACK. For NACK, the eNodeB will send a retransmission. The UE will combine the retransmission with the original transmission and will decoding again. For successful decoding the UE sends positive acknowledgement (ACK) to the eNodeB, then the eNodeB will send a new packet for that HARQ process.

It is worth to mention that due to the stop-and-wait way of operating, one needs to have multiple HARQ procedure to enable a continuous data flow. In LTE the number of processes is fixed to 8 procedures in downlink direction. The minimum delay of the retransmission is 7 ms [1] [2]. The SNR gain which is provided by using HARQ procedure is: [15]

$$SNR_{(i)} = SNR + SNR_{(gain)} \quad (1)$$

Where i represents the i^{th} retransmission.

Figure 4 illustrates the procedure of HARQ in case of a single user continuous transmission.

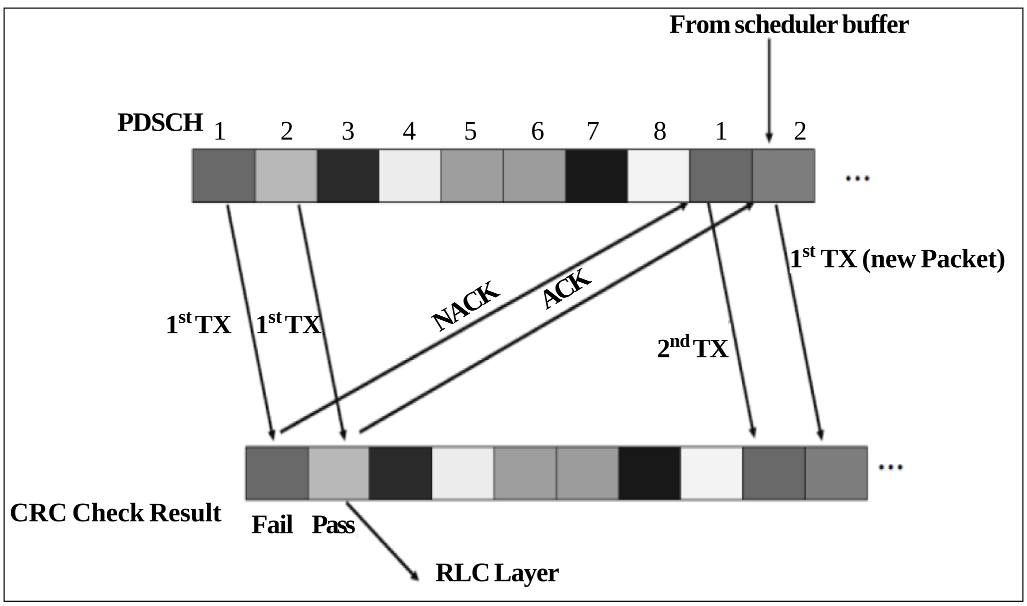

Figure 4. HARQ processes for single UE [13]

2.6 Multiple Antennas Techniques

It is a technique which used multiple antennas at both the transmitter and/or the receiver side. The basic principle of it is sending different data from two or more antennas at the transmitter side while at the receiver the data will be separated with many antennas which lead to increase the peak data rates. Multiple antennas technology considers in the new wireless communications standards such as LTE system to increase the data rate, throughput and the link range without additional bandwidth or transmitted power. On the other hand, the additional antennas will add more processing time and need to more resources for control purposes (overhead) where the multiple antennas need to dedicate reference signals [12].There are many types of multiple antennas depending on the number of antennas at the transmitter, receiver or both such Single Input Multiple Output (SIMO), Multiple Input Single Output (MISO) and Multiple Input Multiple Output (MIMO). In order to reduce the complexity at the receiver side besides the benefit of the transmit diversity technique, MISO is submitted as a solution key, it is used to improve signal robustness under fading conditions [13] [16], see Figure 5.

3. System Simulation

The system under consideration of LTE is built on the following assumptions:

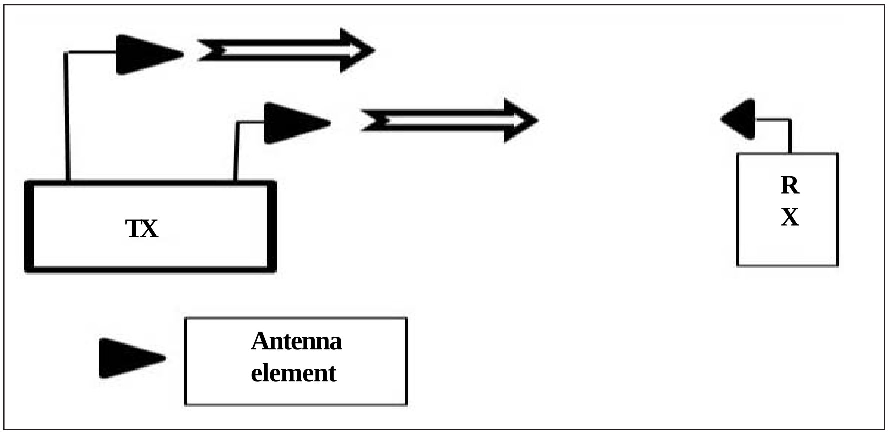

Figure 5. Transmit diversity of MISO technique

a) Single Cell – Single User: - covered the communication between one cell and one user only.

b) The location of user chosen as shown in Figure 6. Location one represents the worst case (i.e.UE at the edge of the cell), location two represents the normal case (i.e.UE in the middle distance between eNodeB and the edge of the cell) and location three represents the perfect case (i.e.UE is near from eNodeB).

c) Table 2 demonstrates modulations and coding schemes which are used by UE depends on the CQI.

d) The details of the system are shown in Table 3 .

The simulation program which is used in this paper is presented by Institute of Communication and Radio-Frequency Engineering in Vienna University of Technology. The program is used to simulate the DL LTE physical layer.

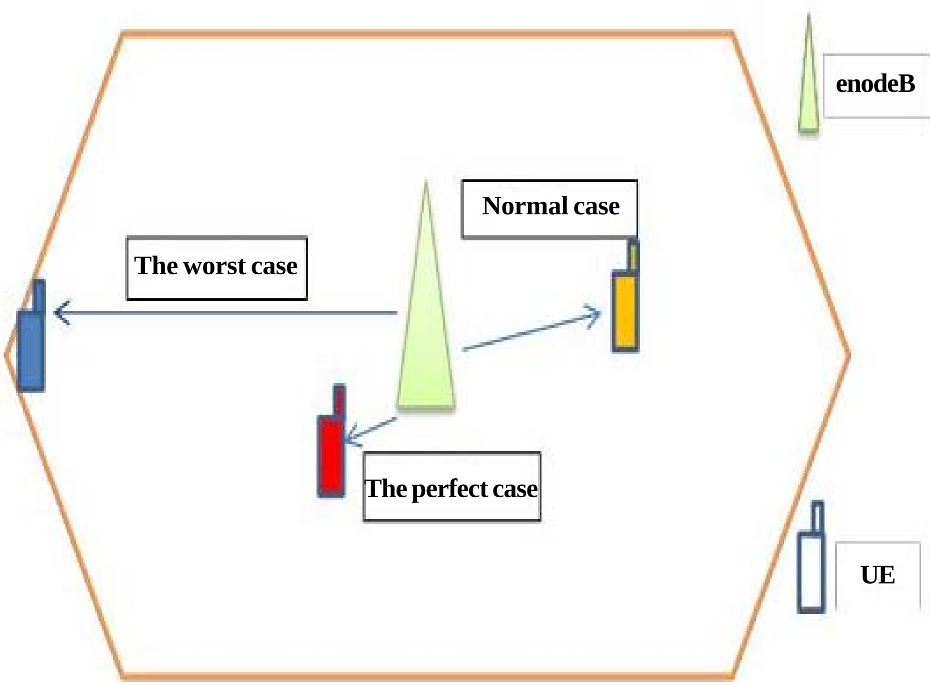

Figure 6. Positions of UE about eNodeB

4. Results and Discussions

Figure 7 and 8 plotted when the UE at the end of the cell, this case represents the worst case (CQI = 3). When the CQI = 3 the

UE will be used robust modulation scheme (QPSK) to compensate the effect of weak signal.

CQI	Modulation type	Coding Rate	The Case
3	QPSK	193/1024	UE at the edge of the cell UE at the middle
8	16QAM	490/1024	distance between eNodeB and the border of the cell
10	64QAM	466/1024	UE is near from eNodeB

Table 2. Modulation and Coding Schemes

Parameter	Value
Bandwidth (MHz)	1.4
The type of frame	FDD
Number of sub-frames	5000
Types of CQI	3, 8, 10
Number of retransmissions	0,1 and 2
Cyclic prefix	Normal
Transmitter and receiver antennas	MISO 2*1
Channel Mode	PedB
Symbol/RB	7

Table 3. The details of system assumptions

The desirable value of SNR is the value which gives BLER less than 0.1. In other words, the appropriate SNR for nominal modulation scheme is the value of SNR which submits BLER value less than 10%. Consequently, it is noted form the Figure8. that the SNR which gives BLER equal of 0.1 is 2.8dB without enhancing techniques while after employed the HARQ procedure and MISO technique SNR equal of 0.4dB. This is related to the transmit diversity which enhances the signal over noise and recover data correctly if the error is occupied.

For Figure 8 which illustrates the relationship between the SNR and throughput, throughput is increased with the increment of SNR. It is obvious from the plot that there is additional of throughput submits with the help of HARQ and MISO. Then, the throughput without and with enhancing the system (HARQ and MISO) is met at SNR equal of 4dB, this is related to additional resource elements which are consumption by HARQ procedure and MISO technique.

The same relationships but for the case of CQI = 8 demonstrate in Figures 10 and 11 respectively. BLER is decreased with the increment of SNR, it is noted form Figure10. There is improvement for the system performance where the SNR which gives BLER less than 0.1 is 11dB approximately after introduced HARQ and MISO while for the case without HARQ and MISO is 13.5dB. With the increment of SNR, the throughput is increased gradually as shown in Figure 11. For the same reason in the case of CQI equal of 3, the curves of without and with HARQ and MISO are met at SNR = 15dB approximately. In general, the throughput of CQI = 8 is greater than the throughput of CQI = 3 because the type of scheme modulation at each case (at CQI = 3, QPSK modulation is used while 16QAM modulation scheme is used at CQI = 8).

Again the relationship between BLER and SNR but for channel quality = 10 for the case of without and with HARQ and MISO

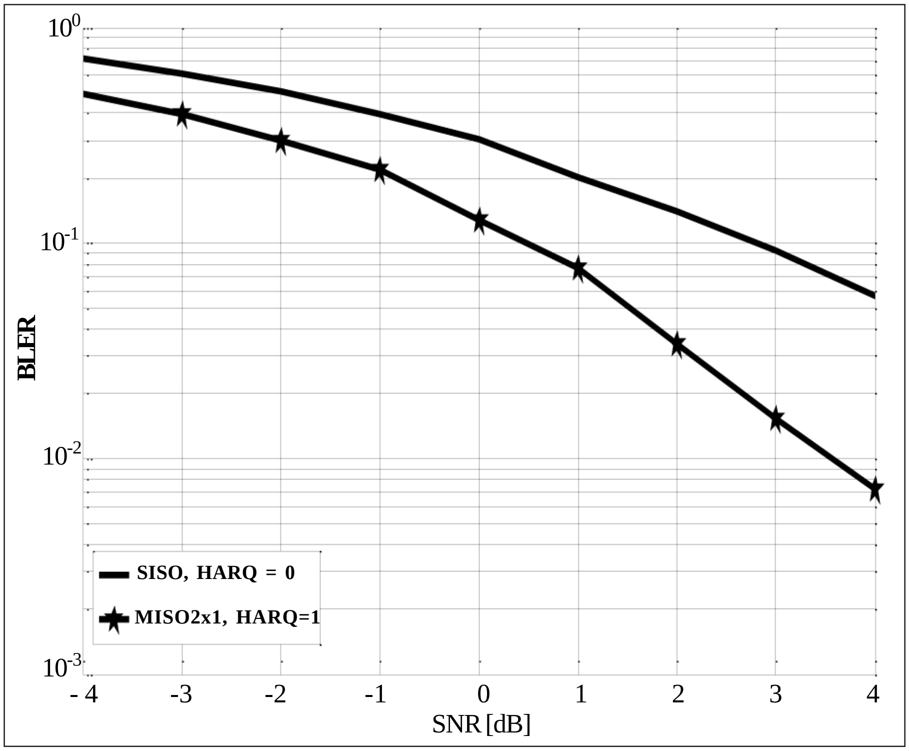

Figure 7. SNR versus BLER when CQI = 3

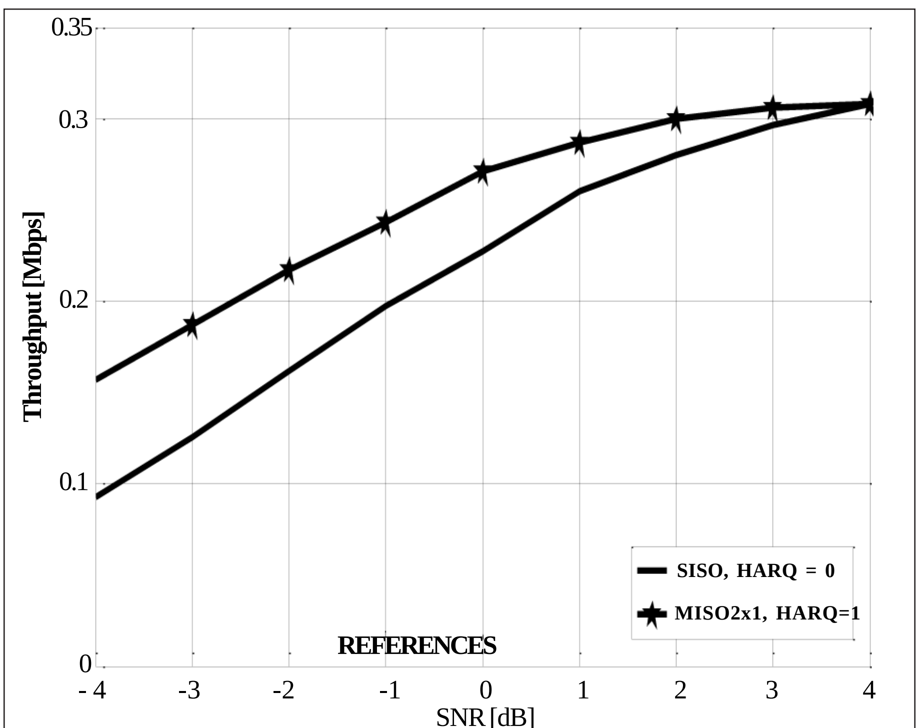

Figure 8. SNR versus Throughput when CQI = 3

explains in Figure 12. The figure reveals that 10% BLER is achieved at SNR = 17.5dB for the system without HARQ and MISO. It is noted from the plot that the performance of the system after introduced HARQ and MISO reaches to 10% BLER at SNR = 14.7 dB approximately, this means that there is an advantage of about 18% of SNR.

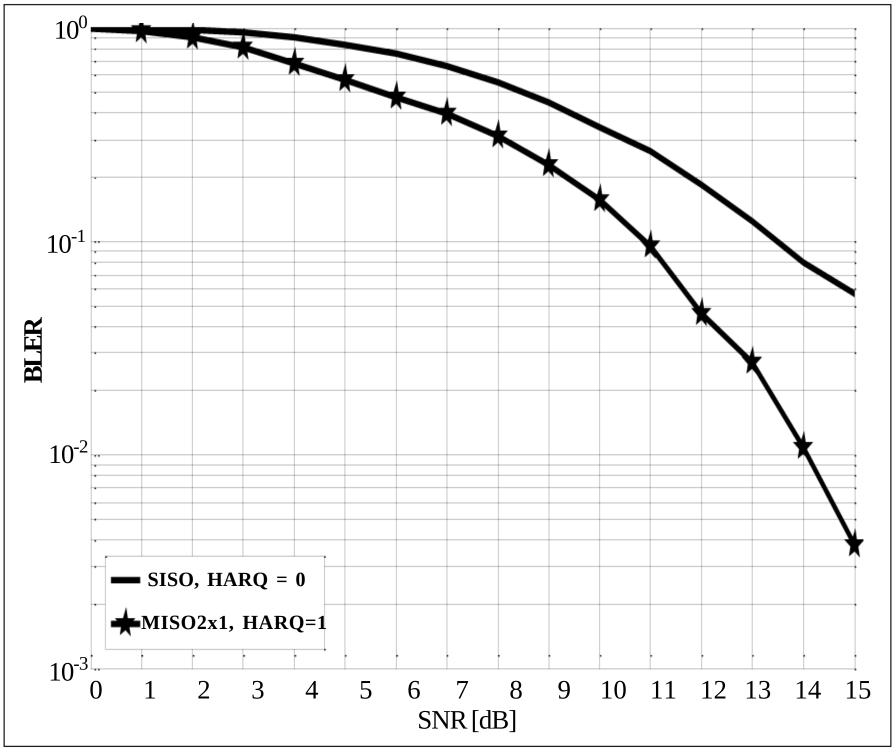

Figure 9. SNR versus BLER when CQI = 8

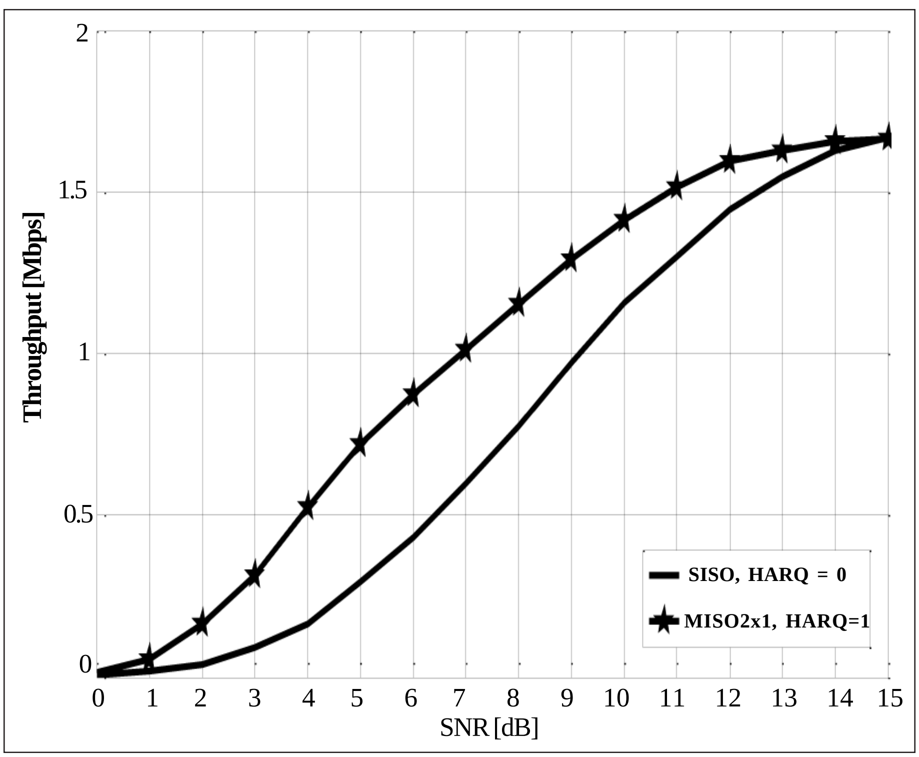

Figure 10. SNR versus Throughput when CQI = 8

Figure 13 demonstrates the relationship between throughput and SNR without and with HARQ and MISO for channel quality equal of 10.

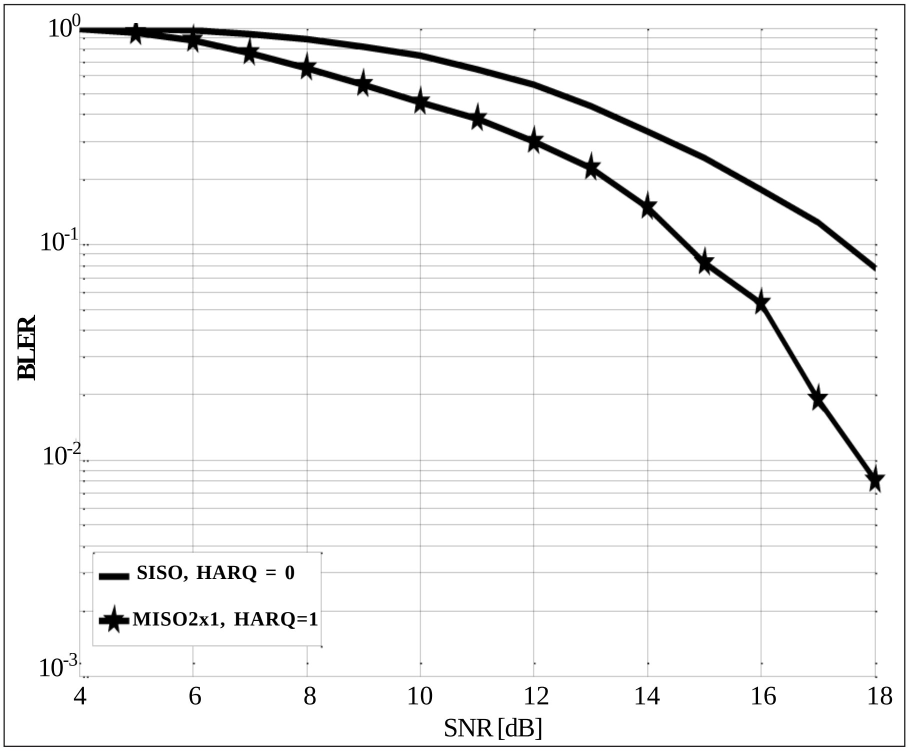

Figure 11. SNR versus BLER when CQI = 10

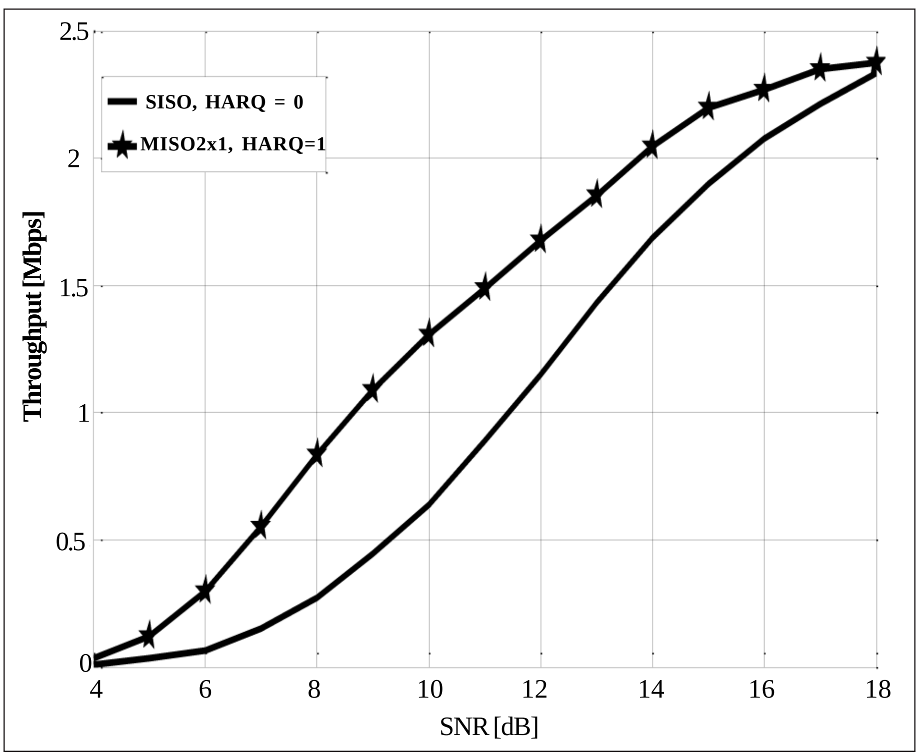

Figure 12. SNR versus Throughput when CQI = 10

For this case, the behavior of throughput is better than the previous cases of channel qualities, this is related to the modulation scheme (64QAM modulation) which is used at this channel quality where six bit is transmitted at each step of transmission. The

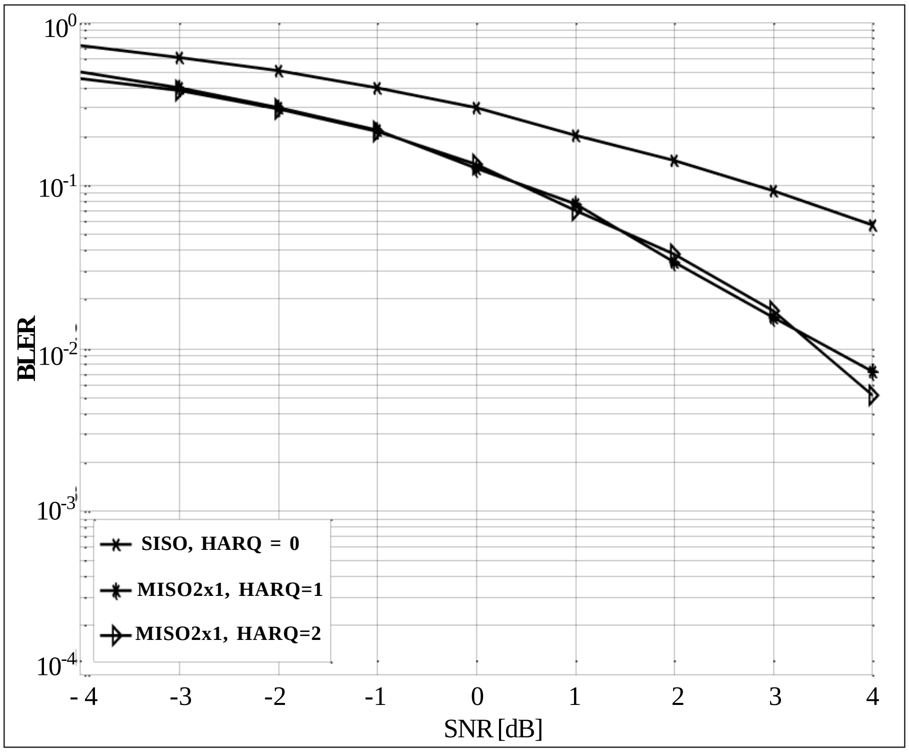

Figure 13. Comparison among different systems from BLER point of view in case of CQI = 3

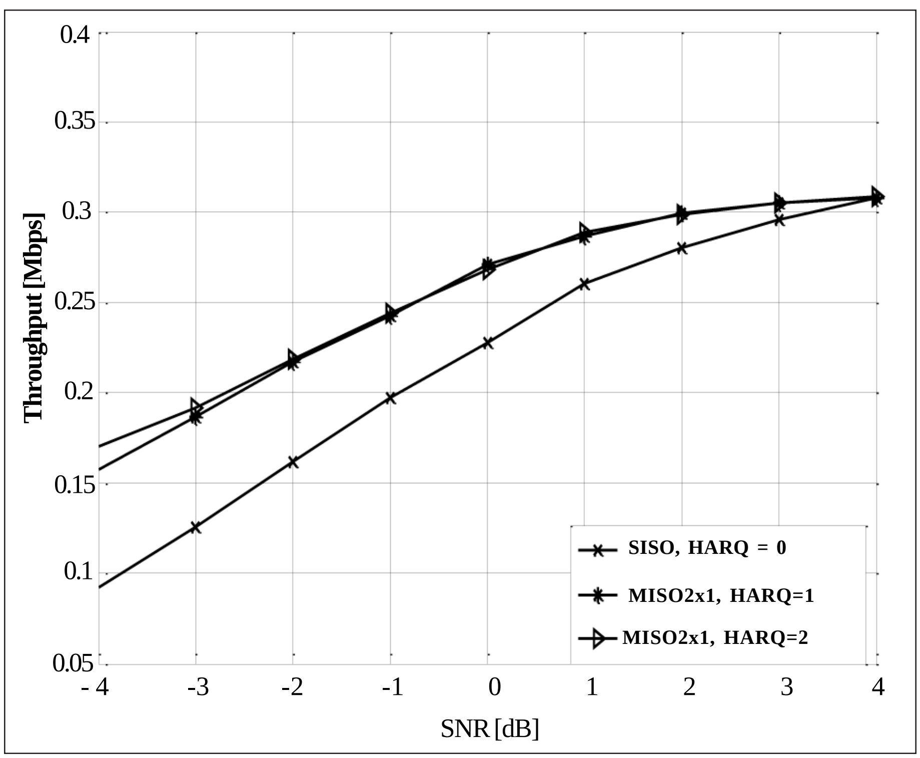

Figure 14. Comparison among different systems from throughput point of view in case of CQI = 3

performance of the system after enhancing the system by HARQ and MISO is improved. On the other hand, this improved is tumbled for the SNR greater than 18dB due to the limiting range of SNR which belongs to 64QAM modulation scheme as well as

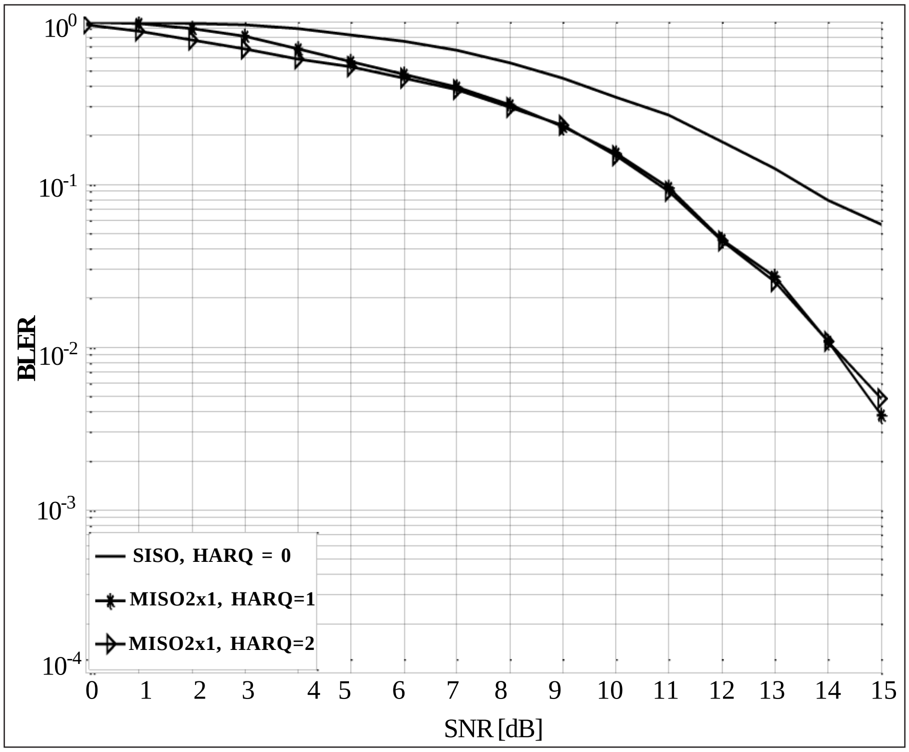

Figure 15. Comparison among different systems from BLER point of view in case of CQI = 8

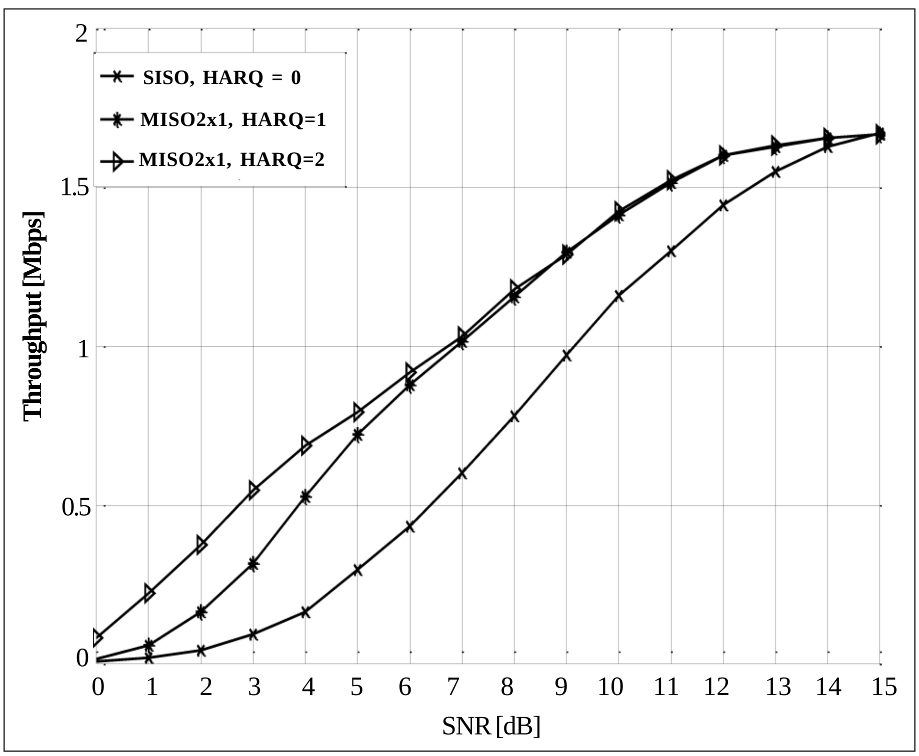

Figure 16. Comparison among different systems from throughput point of view in case of CQI = 8

the resource elements consumption which are needed to implement HARQ procedure and the overhead for multiple antenna (MISO).

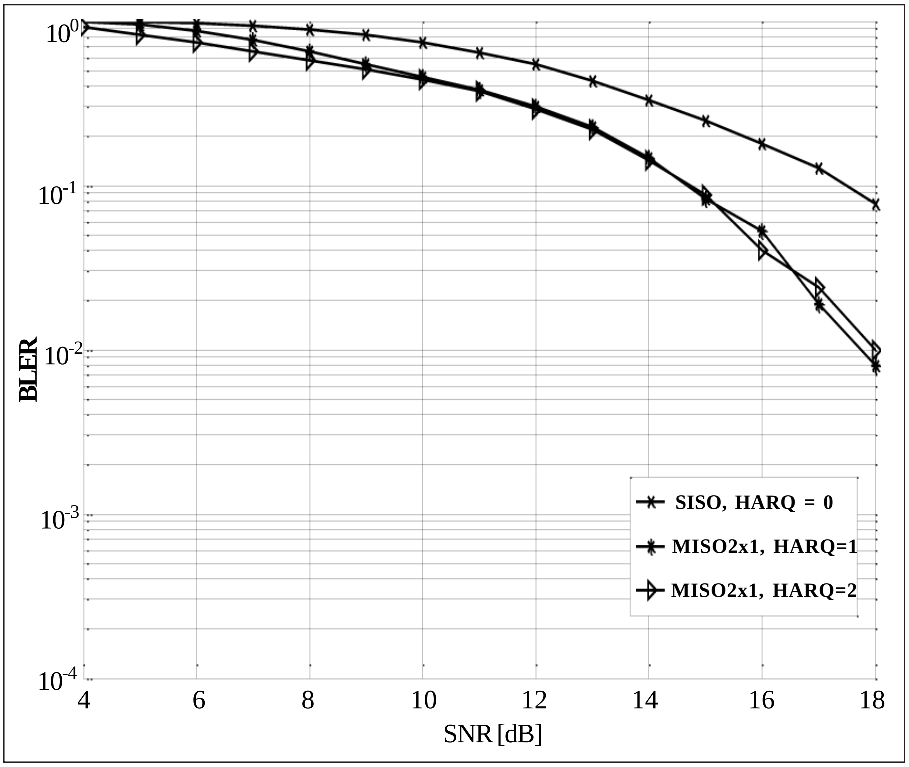

Figure 17. Comparison among different systems from BLER point of view in case of CQI = 10

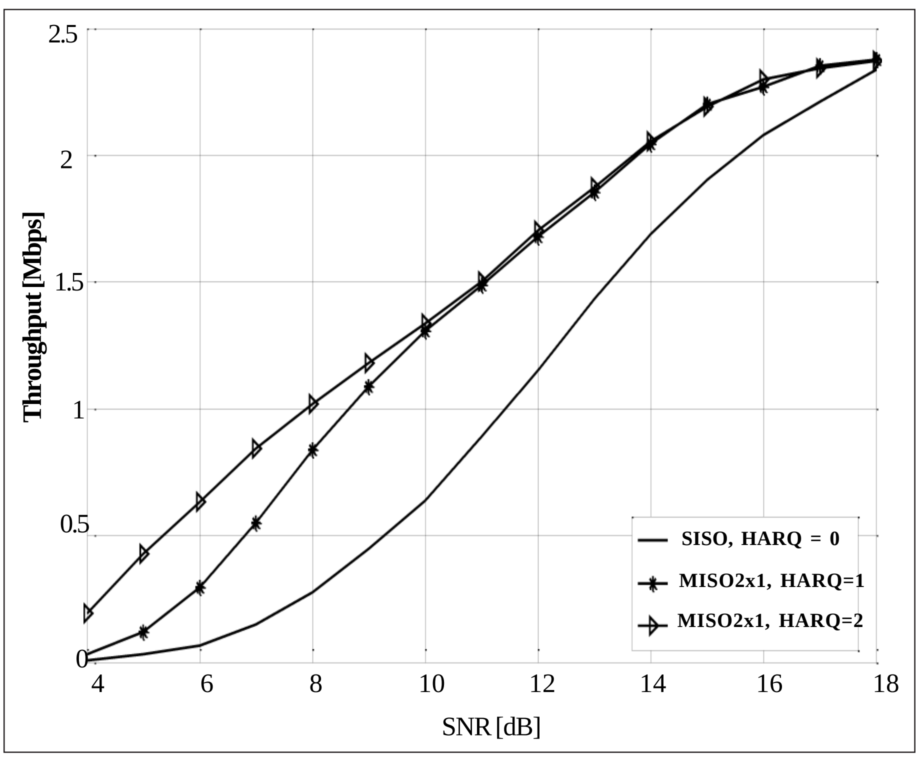

Figure 18. Comparison among different systems from throughput point of view in case of CQI = 10

In order to compare among the following systems performances: the case of single input single output (SISO) technique alone, MISO technique with one retransmitting HARQ procedure and MISO technique with two retransmitting HARQ procedure, Figure 13. explains the relationship between SNR and BLER while Figure 14. explains the relationship between SNR and throughput in case of CQI = 3.

Obviously, the improvement on the performance of system after employ MISO with two retransmitting is slightly better than the case of one retransmitting. This is related to correct more errors by first re-transmitter of HARQ procedure; this applies to the cases of the other channels quality indicator.

It is obvious from Figure 14. that there is an advantage from applies MISO with HARQ procedure on the throughput of the system. But, more precisely, the improvement on the throughput of the system with two retransmitting is not much as compare with the case of one retransmitting.

Figures 15 and 17 demonstrate the relationship between SNR and BLER for the cases of CQI equal to 8 and 10 respectively. While Figures 16 and 18 illustrate the relationship between SNR and throughput for the cases of CQI equal to 8 and 10 respectively.

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