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Channel Capacity Improvement of MIMO Communication Systems using Different Techniques

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ABSTRACT

The modern communication systems require high data, and this rate cannot be achieved in Single input- Single out put (SISO) systems. This prosperity can be gained by improving the channel capacity using systems for Multiple Input-Multiple output (MIMO). In this paper the parameters effecting channel capacity are studied, these include (antennas numbers, antennas distribution, and Signal to Noise Ratio (SNR)) using multiplexing, diversity and beamforming techniques. The results showed that the channel capacity for multiplexing technique increased semi-linearly with antennas number when the antennas at transmitter side and receiver side are equal. While the increase in capacity became less when the antennas distribution is different. Increasing the antennas ate the receiver side gives better capacity than increasing the antennas ate the transmitter side. The multiplexing techniques give the best performance from diversity techniques and beamforming when (SNR) greater than (10 dB). While the beamforming technique gives the best performance for (SNR) less than (10 dB).

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تحسين سعة القناة لنظم الاتصالات متعدد الإدخال – متعدد الإخراج باستخدام تقنيات مختلفة

الخلاصة

إن نظم الاتصالات ألحديثه تتطلب معدل بيانات عالية، وهذا المعدل العالي من البيانات لا يمكن تحقيقه بالا نظمه التي يكون نظامها (أحادي الإدخال – أحادي الإخراج) بل إن الانظمه التي تعمل بتقنية (متعدد الإدخال – متعدد الإخراج) هي ألتي تلبي المطلب أعلاه. في هذا البحث تم دراسة العناصر التي تؤثر على سعة القناة (عدد الهوائيات، توزيع الهوائيات، نسبة الاشاره إلى الضوضاء) وباستخدام تقنيات تعدد الإرسال والتنوع وتعديل الشعاع. أظهرت النتائج بان سعة القناة وباستخدام تقنية تعدد الإرسال تتزايد بصوره شبه طرديه مع عدد الهوائيات إذا كان عدد الهوائيات في جهتي الإرسال والاستلام متساو. بينما تكون الزيادة في السعه اقل عندما يكون توزيع الهوائيات غير متساوي في الطرفين.ان زيادة عدد الهوائيات في طرف الاستلام يعطي سعه أفضل مما لو كانت الزيادة في طرف الإرسال. ان تقنية تعدد الإرسال تعطي أداء أفضل من تقنيتي التنوع وتعديل الشعاع عندما تكون نسبة الإشارة إلى الضوضاء اكبر من (10dp) ، بينما يكون أداء تقنية تعديل الشعاع هو أفضل أداء في حالة كون نسبة الاشاره إلى الضوضاء أقل من (10dp).

1. INTRODUCTION

Communication systems have witnessed tremendous growth toward high speed data transmission over different channels. Since it was difficult to reach the high-speed transfer of information using a single input- single output (SISO) system, Because the increased channel capacity in these systems requires either increasing the bandwidth (BW) or increase (SNR) and that it is often difficult to change [1], As a result of these requirements multiple input-signal output (MISO) and (SIMO) systems were founded.

The term (MIMO) servers is used to define the system jointly processing signals captured by several receive antennas from several transmitting antennas [2], the channel capacity of (MIMO) system with transmit (N_T) and receive (N_R) antennas can be improved without increasing transmit power or spectral bandwidth. The channel capacity depends on the statistical and antennas numbers [3]. Recently the commercial company using these systems that consist technology such as wireless local

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Nomenclature

BF	beamforming technique
DIV	diversity technique
d_r	distance between received antennas
d_t	distance between transmitted antennas
H	channel matrix order($N_r \times N_t$)
h	fading coefficient
MIMO	multiple input-multiple output
MISO	multiple input-single output
MUX	multiplexing technique
N	noise matrix
Q	signal to noise ratio per symbol
SIMO	single input- multiple output
SISO	single input-single out put
SNR	signal to noise ratio
X	received signal matrix
Y	transmitted signal matrix
α	attenuation
λ	wavelength

area and modern generation network. Four varieties of classified communication systems in both the transmitter and receiver depending on antennas number. Single Input-Single Output(SISO) Systems contains a single antenna in the transmitter and a signal antenna in the receiver as shown in Fig. 1.

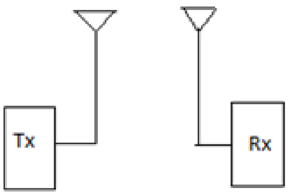

Fig. 1. SISO system.

The channel capacity is represented by Eq. (1)[1]:

$$C = BW \ log \ 2(1 + \rho) \ bits/s/Hz \tag{1}$$

where is BW- bandwidth, ρ- signal to noise ratio for received antenna.

Single Input-Multiple Output(SIMO) Systems contains a single antenna at the tip of a transmitter and antennas group in the receiver as shown in Fig. 2:

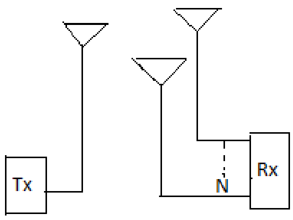

Fig. 2. SIMO system.

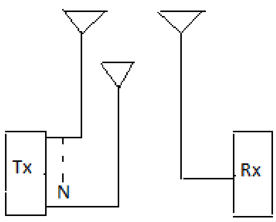

Fig. 3. MISO System

Multiple Input- Single Output (MISO) Systems contains an antennas group antenna at the tip of a transmitter and a single antenna in the receiver as shown in Fig. 3.

Multiple Input- Multiple Output(MIMO) Systems using antennas matrix at both the transmitter and receiving systems (MIMO) as shown in Fig. 4.

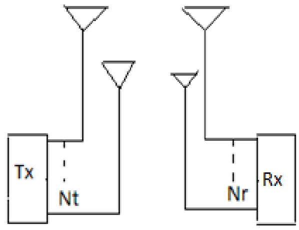

Fig. 4. MIMO system.

These systems may be the best solution to the problem of the growing demand for high-rate data transmission, as the channel capacity of data in these systems is directly proportional to the number of antennas used [4].

2. LITERATURE REVIEW

Transmitter and receiving techniques can be classified into MIMO system into three main Techniques: Diversity Technique (DIV), Beamforming Technique (BF) and Multiplexing Technique (MUX)

2.1. Diversity Technique (DIV)

This technique is based on making some ciphers on the information signal before sending process from Matrix of antennas and these ciphers are many and varied [5]. The most advantage of the cipher, this transmission process does not need any additional bandwidth, by observing the circuit in Fig. 5. some mathematical equations were written, which was used in the transmitter 2 antennas (N_t = 2) and 2 antennas in the receiver (N_r = 2) and if we assume that the signals received during the period(i) and (i+1)is r(i)and(i+1) respectively, this will appear as a vector y(i) [5]:

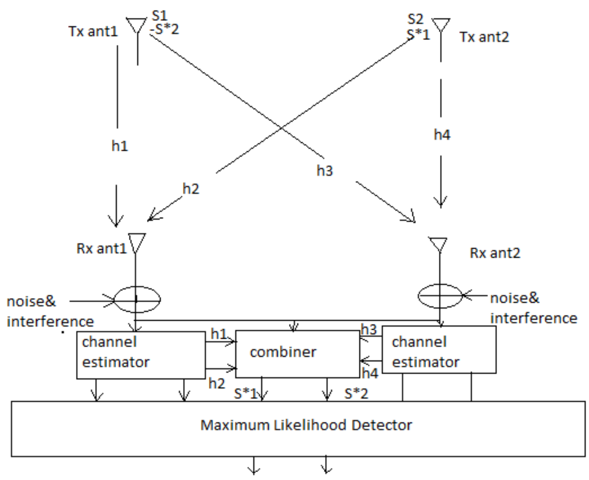

Fig. 5. Block Diagram for circuit of transmitter & receiver (N_t = 2, Nr = 2)

$$y = \begin{bmatrix} r(i) \\ r(i+1) \end{bmatrix} \tag{2}$$

$$y(i) = \sqrt{\frac{q}{N}} \begin{bmatrix} h1 & h2 \\ h2 & -h1 \end{bmatrix} \begin{bmatrix} S1 \\ S2 \end{bmatrix} + \begin{bmatrix} n(i) \\ n(i+1) \end{bmatrix} \quad (3)$$

q- Signal to noise ratio per symbol
h_1 , h_2 - fading coefficient
n(i) , n(i+1) –random noise for Gauss distribution at period (i) and (i+1).
Previous equation can be written as:

$$Y(i) = \sqrt{\frac{q}{N}} .H .b\,(i) + n(i) \quad (4)$$

During the first period of the transmitting (i), the signals S_1, S_2 from the first and second antenna are send, During the period which followed (i+1) send S^*_1 , S^*_2 from antenna of the first and second, respectively. But at receiving the transmitted signal from the first antenna passed conditions different from those transmitted signal through second antenna, which will lead to a change in the phase and attenuation according to the equations [5]:

$$h1 = \alpha 1 e^{j\theta 1} \quad (5)$$

$$h2 = \alpha 2 e^{j\theta 2} \quad (6)$$

α_1, α_2 – Attenuation at first and second path respectively.

θ_1 , θ_2 – Different of phase first and second path, respectively.

And it can be expressed the reached signal to the receiving antenna through two periods (i) and (i+1) can be expressed as following equations [5]:

$$r1 = h1 \quad S1 + h2 + S2 + n1 \quad (7)$$

$$r2 = -h1\, S^*2 + h2\, S^*1 + n2 \quad (8)$$

r_1, r_2 – Received signal through period (i) and(i+1)
n_1, n_2 –random noise

At the receiving side computes, the fading coefficient h_1, h_2 by channel estimator, then generate two signals $S1$, S_2 by combiner circuit as:

$$S-1 = h^*{}_1 r1 + h_2 r^* 2 \quad (9)$$

$$S-2 = h^*{}_2\; r1 - h^* r^*{}_2 \quad (10)$$

2.2. Beamforming Technique (BF)

The term beamforming knows that collecting the signal from more Sensor in order to increase (SNR). The changes that occur in the channel can be described as a change in phase in attenuation as in Eqs. (5) and (6). So the noise at the first antenna is different from the second antenna. to get the transmitted signal is calculated fading coefficient h_1, h_2 by channel estimator, then extracted output signal from each antenna. And then to the circuit to collect the signal from the first and second antenna. Consider Beamforming technique of the specifics of SIMO systems, but it is applied to the (MIMO) systems, and the treatment of an antennas array at the tip of a single transmitter and an antenna gain (N_t) from a single antenna gain. The (SNR) has been found in these systems is proportional with the sum of the elements square of the matrix [6]:

$$\rho \propto \sum / hij /^2 \quad (11)$$

ρ- signal to noise ratio

h_{ij} -value of attenuation and phase difference which affect to the signal when moving from the transmitting antenna(j) to the receiving antenna(i).

2.3. Multiplexing Technique (MUX):

Multiplexing technique specializes in (MIMO) systems where the sent data divided across the channel using data distributor (Demultiplexer) [7]. And then it is on the data encryption process and the process of transmission. Where it is given a special frequency for both transmitter and receiver opposite him. But in point of receiving it is being quite the opposite, as is the receipt of information across a range of antennas circuits receiving the necessary treats each recipient of the rest of the signals as noise. And then be transferred serial to parallel data using (Multiplexer). This technique has proven its outstanding performance in improving the communication channel capacity compared to other technologies, since the transmission and receiving accomplish at (1/N) a time of transmission time if completed from a single antenna. Fig. 6. shows the scheme of sending and receiving using a multiplexing technique.

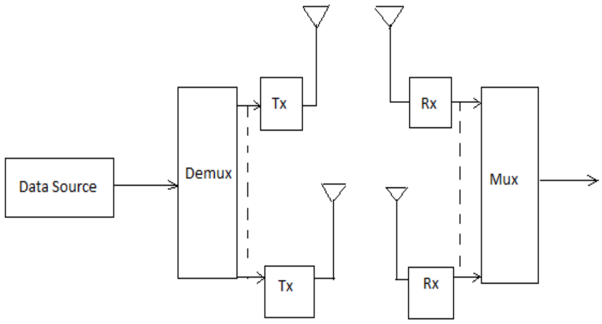

Fig. 6. Block Diagram for transmitter & receiver using multiplexing technique.

2.4. Channel Capacity and Channel Matrix

The channel capacity is known as the upper limit of the transmitted data per unit time through the channel, with a stay on the specific value of the (SNR), and measured by unit (bit/sec). Calculated using Shannon's Eq. [7]:

$$C = BW\; Log2(1+\rho) \quad (bit/sec) \quad (12)$$

The increase in capacity requires either increasing the bandwidth or increase the Signal to Noise Ratio, increasing of bandwidth is limited or is not allowed, either increase of Signal to Noise Ratio requires increasing the transmitted power, But the difficulty of finding a signal amplifiers operate a linear pattern at the high levels of power, and also cannot increase the value of the transmitted power because of the limitations of interference between systems. Therefore, the possibility of improving the channel capacity in the (SISO, SIMO, MISO) systems was limited, which led to the use of (MIMO)Systems [8].

Expresses the relationship between the transmitter and receiving systems in the form of a matrix mm called channel matrix, which depends on the properties of the channel as well as the number of antennas, the channel matrix is written as [7]:

$$H = \begin{bmatrix} h11 & \cdots & h1Nt \\ \vdots & \ddots & \vdots \\ hNr1 & \cdots & hNrNt \end{bmatrix} \quad (13)$$

The order of matrix($N_r \times N_t$), The channel capacity in (MIMO) systems vary according to technology used to send and receive the signal, as shown in the following equations:

$$C = BW.Log2(1 + \rho\lambda max) \ \ (Beamforming) \qquad (14)$$

$$C = BW.Log2(1 + \frac{\rho}{Nt} \sum_{i=1}^{z} \lambda\ i) \ \ (Diversity) \qquad (15)$$

$$C = BW.Log2[det[INr + \frac{\rho}{Nt} HHIC]] \ (Multiplexing \qquad (16)$$

I_{Nr} – Identity matrix with order (N_r*N_r)
tc- conjugate composite of transpose matrix
λ_I – Eigen value with sequence (i)
λ_{max} –Maximum of Eigen value
Z- Value of matrix Rank (HH^{tc}),
The value(Z) calculated by equation

$$/\lambda . I - HHtc/ = 0 \qquad (17)$$

It is possible to write an equation of channel capacity, which uses multiplexing technology in terms of Eigen values, as in the following formula:

$$C = BW . \sum_{i=1}^{z} Log\ 2\ (1 + \frac{\rho}{Nt} \lambda i) \qquad (18)$$

3. METHODOLOGY

Suppose that medium be propagation without fading, and line of side, symbolized transmitter side (T) and the receiving side (R), as number of transmitting antennas equal to the number receiving antennas (N_t=N_r =N). The distance between adjacent antennas regular (d_t =d_r) as shown in Fig. 7, the carrier frequency (f_c), the resulting matrix is the (H = H_{LOS}), and each element of the matrix is calculated from the following formula [9]:

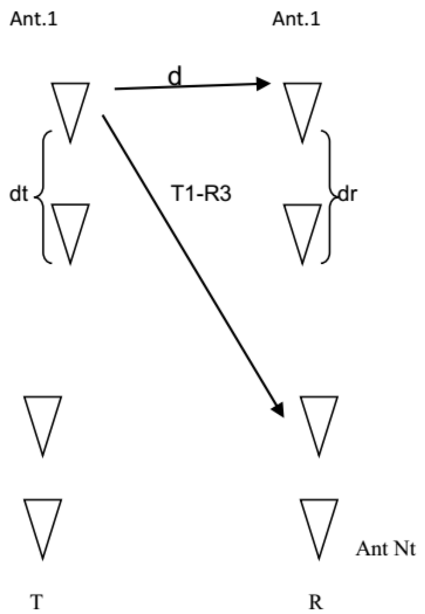

Fig. 7. Radiation tracking method.

$$hij \ = \ /T1 - R1/ \quad \frac{exp(\frac{-j2\pi}{\lambda} /Ti - Rj/}{/Ti - Rj/} \qquad (19)$$

$/T_i$-$R_j/$ - vector length from transmitting element (i) to receiving element (j)
$/T_1$-$R_1/$ - vector length from transmitting element (1) to receiving element (1)

If the distance (d_t,d_r) lees than (0.5 λ) It will be the equation:

$$Hij = exp\ (j\theta ij) \approx exp\ (j\theta) \qquad (20)$$

when (θ) is constant for every values (i, j)

$$HHtc = N \quad , \ HHtc \approx NI \qquad (21)$$

When substitution in equation of channel capacity we will get:

$$C = BW.\log_2 det\left[IN + \frac{\rho}{N} NIN\right] = BW .\log_2\left[det[(1 + \rho)IN]\right] \qquad (22)$$

$$C = BW . N .\log_2(1 + \rho) \qquad (23)$$

$$C \propto Min\ (Nt\ , Nr) \qquad (24)$$

Thus, the channel capacity increases directly proportional to the increase in the number of antennas**,** for the purpose of calculating the channel capacity of the (MIMO) systems and the effect of the number of antennas on the capacity has written a set of programs using MATLAB [8].

3.1. System Model

It can be described as the communications system, which has been studied model by equation [5]:

$$Y = HX + n \qquad (24)$$

$$Y\begin{bmatrix} 1 \\ \vdots \\ \vdots \\ Nr \end{bmatrix} = \begin{bmatrix} h_{11} & \cdots & h_{1N_t} \\ \vdots & \ddots & \vdots \\ h_{N_r1} & \cdots & h_{N_rN_t} \end{bmatrix} \begin{bmatrix} X(1) \\ \vdots \\ \vdots \\ X(N_t) \end{bmatrix} + \begin{bmatrix} n(1) \\ \vdots \\ \vdots \\ n(N_r) \end{bmatrix} \qquad (25)$$

Y- Matrix of received signal order (N_r×1)
H- Channel matrix order (N_r×N_t).
X- Matrix of transmitted signal order (N_t×1).
n- Noise matrix for random distribution order (N_r×1)

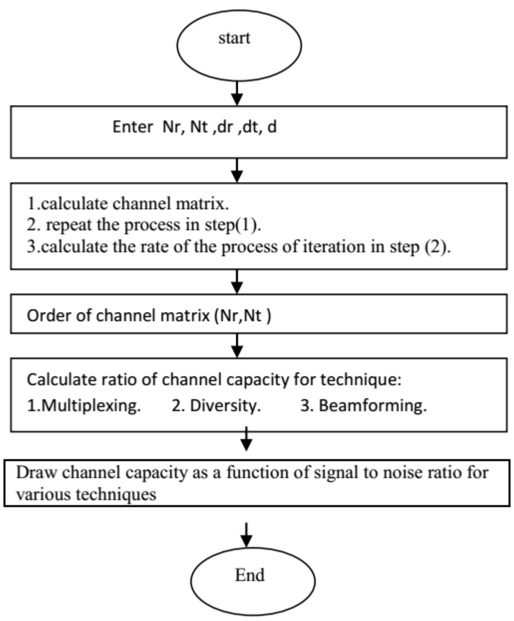

Fig. 8. Basic configuration of computer simulation.

The change of the number of antennas at both the transmitter and receiving part can get to any system (SISO, SIMO, MISO, MIMO), The program calculates the capacity of the channel in terms of the signal-to-noise ratio at the receiving end and in different conditions and techniques based on Eqs. (14) -(16), as well as Shown in Fig. 8. The number of antennas is used to calculate the channel matrix, so that the size of the matrix is determined by counting the number of antennas at both ends of the transmitter and receiver. Here the channel capacity is calculated in the case of MIMO and the three different techniques (MUX, BF, and DIV). So draw Channel capacity as a function of signal to noise ratio for techniques various.

4. RESULTS AND DISCUSSION

The distance between the transmitter and receiving are selected, as well as the interfaces distances between antennas at both the transmitter and receiver. The number of antennas for several cases are shown below:

4.1. Number of Transmitting and Receiving Antennas are Equal

Implemented simulation of the system in case of an equal number of antennas (N_t=N_r=N), Figs. 9 and 10 shows average channel capacity when the (N = 2) and (N = 3), respectively, using the techniques (Diversity, Beamforming, Multiplexing). We conclude from the two Figs. 9 and 10 that the channel capacity increases with the number of antennas (when the (SNR) is fixed) of the various technologies and this increase will be greater for the technology (MUX) as shown in Fig. 11, and smaller increase for Beamforming and Diversity techniques as shown in Figs. 12 and 13, respectively.

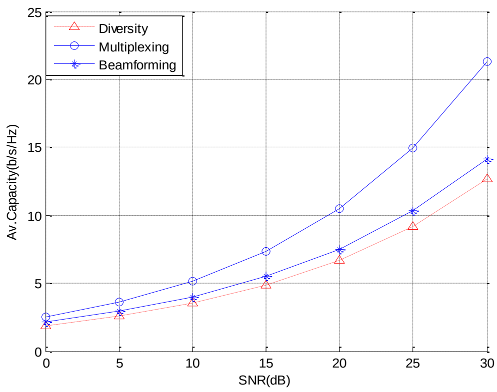

Fig. 9. Change the channel capacity vs. signal to noise ratio, when (N = 3), (d_t = d_r = 0.5λ).

4.1. Number of Transmitting and Receiving Antennas are Not Equal

Implemented simulation of the system for two cases, first case when the number of transmit antennas is equal (N_t = 2), and number of receiving antennas (N_r = 4). second case when (N_t=4 , N_r=2). The results were as shown in Figs. 14 and 15 for techniques (MUX. BF. DIV). We conclude from the Figs. 14 and 15 the increase in the number of antennas in the receiving side gives a larger increase in channel capacity, which corresponds to the increase in the

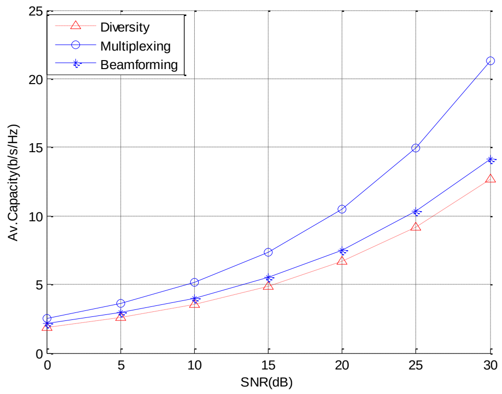

Fig. 10. Change the channel capacity vs. signal to noise ratio, when (N = 2), (d_t = d_r = 0.5λ).

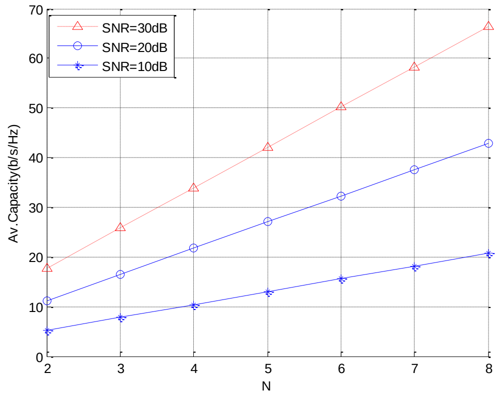

Fig. 11. Effect of antennas number on ratio of channel capacity for MUX (when SNR is Fixed) d_t = d_r = 0.5λ.

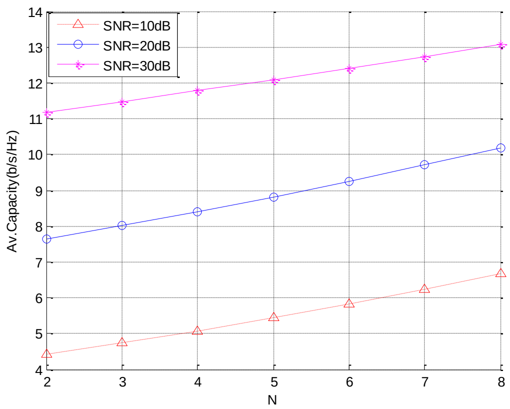

Fig. 12. Effect of antennas number on ratio of channel capacity for BF , when SNR is Fixed) d_t=d_r=0.5λ.

number of antennas by the transmitter because the difference in the number of antennas makes the channel capacity change with the least number of antennas as shown in Eq. (24). Many researchers have tried to study the factors that affect the channel capacity in the MIMO systems. The telatar researcher pointed out that the dimness that occurs in the signal leads to a decrease in the signal to noise ratio, thus reducing the of the channels capacity, which makes a large the error probability. It affects the number of antennas in the transmission and receiver and also depends on the bonding factor. When comparing these studies with the results obtained, it was found that the number of antennas has a clear effect on the channel capacity and within a certain level of the (SNR). These limits varied between 10-15 dB. in this study it was found that the limit of the signal to noise ratio is (10 db) When the ratio is more than this limit, the technology of the (MUX) is better and the channel capacity is increasing.

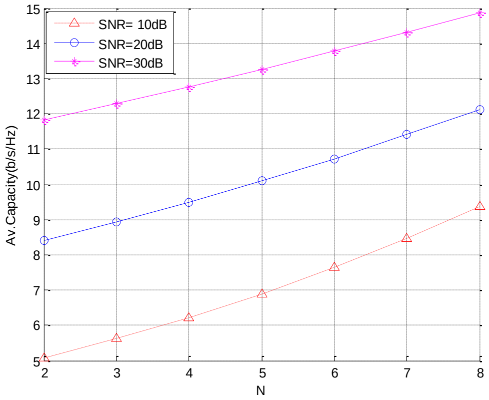

Fig. 13. Effect of antennas number on ratio of channel capacity for DIV (when SNR is Fixed) d_t=d_r=0.5λ.

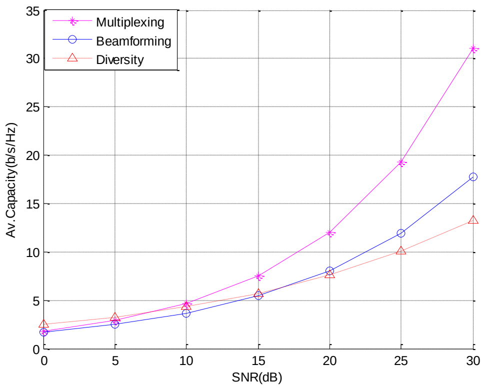

Fig. 14. Change the channel capacity vs. signal to noise ratio, when (N_t=2 ,N_r=4), (d_t=d_r=0.5λ)

5. CONCLUSIONS

In this paper the effect of the number of antennas at the transmitter and receiving in the (MIMO) system are studied from the results obtained it can be concluded the following:

- The(MUX) technology gives better performance than the (BF) and (DIV) techniques, when the (SNR) of more than (10 dB) as shown in Fig. 15. while giving (BF) technique better performance of (MUX) technique and diversity When the (SNR) is less than (10 dB) as shown in Fig. 15.
- Receiving Increasing channel capacity in (MIMO) systems almost directly proportional to the number of antennas when the number of antennas equal in both the transmitter and. As if the number of different antennas the increase in channel capacity determined by the side with a number of antennas least.
- Better to have an equal number of antennas at both the transmitter and receiving because it gives the channel capacity greater than if the number of antennas between the different points of contact. Also, increasing the number of antennas in the receiving side gives the larger capacity from increased of antennas number at the transmitter part.

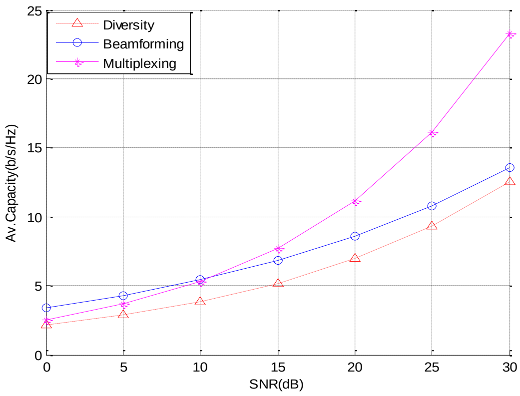

Fig. 15. Change the channel capacity vs. signal to noise ratio, when (N_t = 4 ,N_r = 2),(d_t = d_r = 0.5λ).

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