Ministry of Comminations (MoC)
Iraq - Baghdad
Issued: November 2021

Analysis of Wireless Channel Capacity Increasing Through Using MIMO System

Mahmood A. Mahmood, Firas A. Ajeel, Sa'ad M. Shebeeb & Isra'a T. Lateef
Directorate of Space & Communications
Communication Research Center / Radio Networks

ABSTRACT:-

MIMO (multiple-input, multiple-output) wireless technique has been illustrated to allow dramatic increase in the efficiency of the use of the radio spectrum. The principle of MIMO system employing the necessary mathematical analysis to consider the achieved capacity performance. The capacity of MIMO channel is functionally correlated to the SNR and frequency changes based on Shannon equation. This paper analyzes this issue for 2x2 MIMO system within range of 4-5 Ghz. It has been proved analytically that the MIMO capacity channels have finite upper capacity limit for the frequency and SNR. It appears that the channel capacity of MIMO is reach to certain limit in correlation with both SNR and frequency changes. However, MIMO is set to play a major role in future wireless systems, including future developments of third generation mobile systems, enhanced wireless LAN (WiFi) systems and the potential fourth generation "gigabit wireless" systems.

KEYWORDS:- MIMO, Channel Capacity, SNR, Frequency Bandwidth & Matrix.

I. INTRODUCTION

In the recent wireless systems, the designers are facing number of challenges. These include the limited deviations theory and incorporates the statistical constraints by capturing the rate of decay of the buffer occupancy probability for large queue lengths. In addition, there is an increasing demand for higher data rates, better quality of service and higher network capacity. In recent years, MIMO systems have emerged as a most promising technology in these measures. Hence,

additional dimension, which needs to be modeled on its

effective capacity can be regarded as the maximum throughput of a system operating under limitations on the buffer violation probability. This formulation is tightly linked and in a sense dual to the concept of effective bandwidth that is employed in the analysis of how much resource in terms of service rates is needed to support a given time-varying arrival process. The analysis of the effective capacity in various wireless communication settings has been conducted in several recent studies [1]. Figure (1) illustrates block diagram of the generalized MIMO system channel. Unlike the classical channel model, the transmitter distortion generated by physical transceiver implementations is included in the model.

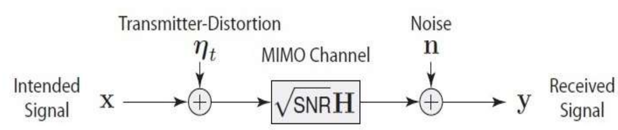

Fig.1 MIMO system concept

MIMO refers to the RF propagation channel. The multiple inputs are the two or more transmit antennas radiating signals into the RF channel and the multiple outputs are the two or more receive antennas collecting signals from the RF channel. With multiple antennas at both ends of the link comes the ability to exploit other leverages than diversity and array gains. It is now possible to increase the transmission throughput via the spatial multiplexing capability of MIMO channels. However, it is not possible to maximize both the spatial multiplexing and the diversity gains [2].

When dealing with MIMO channels, space comes as an

that the receiver 'Rx' and the transmitter 'Tx' are equipped own in the same way as time and frequency variations have been modeled for wideband SISO systems.

With the emergence of MIMO systems, multipaths were effectively converted into a benefit for the communication system. MIMO indeed takes advantage of random fading, and possibly delay spread, to multiply transfer rates. Paulraj and Kailath [3] introduced a technique for increasing the capacity of a wireless link using multiple antennas at both ends. The prospect of dramatic improvements in wireless communication performance at no cost of extra spectrum was further illustrated in the now famous paper by Telatar [4].

Having multiple antennas at the transmitter and receiver has been shown to improve the performance significantly in terms of both reliability and throughput when the channel fading coefficients are known at the receiver and/or transmitter. Due to these promising gains in the performance, information-theoretic analysis of MIMO channels has attracted much interest in the research community. In particular, considerable effort has been expended in the study of the capacity of MIMO wireless channels [5]. In most studies on MIMO channel capacity, ergodic Shannon capacity formulation is employed as the main performance metric. In [1], effective capacity is proposed as a metric that can be employed to measure the performance in the presence of statistical limitations. Effective capacity formulation uses multi-dimensionality should always be kept in mind when modeling MIMO channels or when designing space-time codes.

II. THEORY OF MIMO SYSTEM AND PRINCIPLE OF OPERATION

The mathematical representation of the MIMO system is performed through a complex matrix, which depends on the scenario considered each time (i.e., flat or selective spatial fading). The capacity achieved by the MIMO channel in all cases is studied with the use of the Shannon extended capacity formula. The capacity performance results, developed from the simulations performed, are related to the number of the multiple antenna elements

rate. For the case of multiple antennas at both the receiver with, the distance between them and the degree of correlation evidenced.

More philosophically, multiple antennas also challenge the way that should consider the propagation channel. With MIMO techniques, signal processing is able to benefit from the channel, rather than having to remove its impact. The consequence is that channel models have to be accurate, avoiding conservative rules without being too optimistic. In this respect, mathematical representations are required, while physical models reproduce the properties of the MIMO channel by specifying the locations of obstacles and the array configuration, so called analytical models provide a mathematical representation of the channel matrix. For this research, we'll consider a MIMO channel model and assume that the transmitter and receiver are equipped with nT and mR antennas respectively, the channel input-output relation is expressed as:

$$y = Hx + n \quad \ldots\ldots\ldots\ldots\ldots\ (1)$$

Above, x denotes the nT dimensional transmitted signal vector, and y represents the nR dimensional received signal vector. In équation (1), H denotes the NxM dimensional random channel matrix whose components are the fading coefficients between the corresponding antennas at the transmitting and receiving ends. Unless specified otherwise, the components of H are assumed to have arbitrary distributions with finite variances. Hence, Shannon's capacity formula approximated theoretically the maximum achievable transmission rate for a given channel with bandwidth B, transmitted signal power P. To eliminate the effect of shadow fading, the capacity is normalized to the average capacity with single side noise spectrum No, based on the assumption that the channel is white Gaussian (i.e., fading and interference effects are not considered explicitly).

$$C = B \cdot \log_2\left(1 + \frac{P}{N_o B}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \mathbf{(2)}$$

In practice, this is considered to be a SISO scenario (single input, single output) and equation (2) gives an upper limit for the achieved error-free SISO transmission and the transmitter ends, the channel exhibits multiple inputs and multiple outputs and its capacity can be estimated by the impulse response of the channel between the ith transmitter element and the jth receiver element denoted as H matrix [1]:

$$\mathbf{H}(\tau,t)=\begin{bmatrix} h_{1,1}(\tau,t) & h_{1,2}(\tau,t) & \cdots & h_{1,n_t}(\tau,t) \\ h_{2,1}(\tau,t) & h_{2,2}(\tau,t) & \cdots & h_{2,n_t}(\tau,t) \\ \vdots & \vdots & \ddots & \vdots \\ h_{n_r,1}(\tau,t) & h_{n_r,2}(\tau,t) & \cdots & h_{M_R,n_t}(\tau,t) \end{bmatrix}$$

……………………………………………. (3)

The matrix elements are complex numbers that correspond to the attenuation and phase shift that the wireless channel introduces to the signal reaching the receiver with delay (τ), The input-output notation of the MIMO system can now be expressed by the following equation [1] & [6]:

$$\mathbf{y}(t)=\mathbf{H}(\tau,t)\otimes\mathbf{s}(t)+\mathbf{u}(t)$$ ………………… (4)

Complex channel measurement: H = [Hij] for the ith transmit and jth receive antenna capacity (instantaneous and averaged over 1 second) for 2 nT by 2 mR:

$C = \log2(\det[I + (\rho/2)H\dagger H]) = \sum \log2(1 + (\rho/2)\lambda i)$ ……(5)

where ρ is the total signal-to-noise ratio per antenna and λi is the eigenvalues of $H\dagger H$

$Cn = \sum \log2(1+(\rho/2)\lambda i) / (1/4) \sum \log2(1+\rho Hij)$ ………………………………………………………(6)

we have defined H†H matrix is equal to the product of its eigenvalues, i.e., det(I+nRSNR) in fact is equal to the sum of the logarithms of the terms in the product.

III. METHODOLOGY

The methodoloy applied in this research is based on the letirature review that provide theoritical framework for the MIMO channel capacity system. Initially, the MIMO system is represented by the vectors of channel matrix H, and each élément in this matrxi have certain hybrid charactéristics and statistical properties of the antenna matrix. The originality of MIMO techniques lies in the exploitation of the spatial or double directional structure of the channel. In the first stage, these charactéristics are calculated by the Computer Simulation Technology 'CST' software [7]. Where the obtained results illustrate the technical charactéristics of MIMO. In the second stage: the obtained [Hij] values are re-accessed into the MATLAB software (Version.12) in order to provide the technical performance results of MIMO. Thus we will have a consolidated simulation for the MIMO channel capacity. This methodolgical structure is also largely responsible for the performance of MIMO systems. Therefore, it does make sense to introduce a technical way to characterize the spatial properties of a multi-antenna channel, or more specifically, the space-only correlation of the channel [6].

IV. RESULTS DISCUSSION AND CONCLUSION

In this paper, the channel capacity in MIMO wireless system environment is investigated with present of frequency change and SNR effect under statistical constraints, which are formulated as limitations on frequency bandwidth of interest that is ranged from 4Ghz to 5Ghz with step of 0.1 Ghz increasing for practical purpose. We have employed effective capacity as the performance metric that provides the throughput under such constraints.

We have obtained the following results based on the research methodology in the previous section:

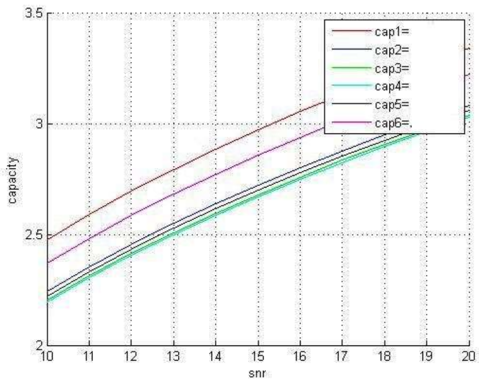

Fig.2 Capacity of 2x2 MIMO channel over déterminists SNRs

From the results in figure (2), it is found a logicl increment of channel capacity with increasing in the SNR in the presence of the frequency change. Moreover, the channel capacity is found to show almost a linear varing with respect to the SNR change. Nevertheless, it can be predicted from the presented results in fig.1, the jump in the MIMO channel capacity reaches the saturation after frequency 4.5 Ghz in order to show that no any more effect of the freqnccy on the channel capacity. This perspective reflect the effect of MIMO on the channel capacity inceasing in the wireless systems by excluding the effect of the frequecy bandwidth on the capacity of the channel.

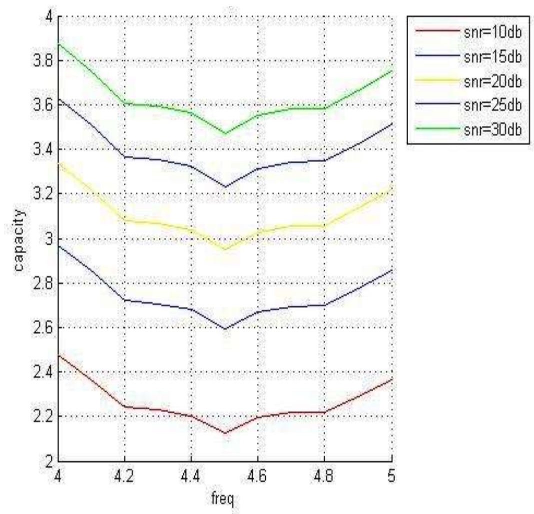

Fig.3 Capacity of 2x2 MIMO channel over déterminists frequencies

In fig.3, the effect of the frequency changes on the channel capacities is studied with respect to different SNR values. The change of frequencies shows non-linear variation in the channel capacity at an individual values of the SNRs; however, the jump steps between each consécutive channel capacity enveloppe is found to be relatively not constant. In other word, the channel capacity enveloppe is seemed to be closed to each other after certain increasing in the SNRs. Finally, it is found that the MIMO channel capacity enveloppe is the same for all SNRs values, but not the same amplituses. So whatever increasing in the SNR values will be considered, we will not get more growth in the MIMO system capacity.

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