On Channel capacity for IMT-A in different fading environment

Jay K Popat, Dr. Paresh M. Dholakia, V.V.P Engineering College,Rajkot, India.
Email:jaypopat93@gmail.com, pmdholakia@gmail.com

***Abstract*—Nowadays use of Information and communication technologies are increase, meanscommunicating devices like mobiles phone, computer, laptops, extra. Thing is that there is demand of not only service of voice and data but also speed of data. Problem is that by increasing technology users of voice and data increase also it is now used for business purpose, education, broadband etc. so load is occur on the system and performance is degraded as bandwidth is limited. To fulfill this requirements of higher rate data to users International Telecommunications Union (ITU) gives standards of International Mobile Telecommunications-Advanced (IMT-A) which is 4G standards. Key features of IMT-A will be Compatibility of services, enhanced peak data rates to support advanced services,worldwide functionality & roaming and some other applications, Interworking with other radio access systems. In this paper this requirement is going to be full filled. Also analysis of channel capacity in different fading environment has been done and comparison as well.**

***Keywords*—Diversity, Multiplexing, Rayleigh distribution, Rician distribution, Nakagami distribution,**

I. INTRODUCTION

Use of data and voice is increasing such as mobile internet user, broadband user and internet for industrial purpose. Few years ago there were only less number of user who are using voice and data. But now it is basic need, According to Morgan Stanley's report entitled "Internet Trends" (June 2010), in a survey among of human needs, voice and data connection is now ranks third, behind food and shelter [8]. So the need of is not only just quality data but also speed of data or channel capacity. Channel capacity of any wireless communication system is depends on 3 parameters as per Shannon-Hartley's theorem [3] which are signal to noise ratio (SNR), number of antenna at transmitter side and receiver side and Bandwidth. The requirements of IMT-A is give in below Table 1.

A per this theorem if SNR increase then channel capacity is also increase, SNR is the ratio of signal power and noise power either signal power has to be increase or noise power has to be reduce. It is not possible to always higher power to signal and noise power cannot controlled. In case of bandwidth it is directly proportional to channel capacity, but same thing is here bandwidth is fixed in wireless communication system, so to improve channel capacity this factor cannot be consider and last one is by changing number of antennas at transmitter end as well as receiver end. This is quite efficient way to increase channel capacity. In wireless communication two things are most important for evaluation of any wireless system first one is Bit error rate (BER) and second is its capacity.

Table 1: Requirements of IMT-A

Item	Category	Target
Spectral efficiency	-	>40 MHz
Peak data rate	Downlink	1 Gbps
peak data rate	Uplink	500 Mbps
Peak Spectral Efficiency	Downlink	15 bps/Hz (4x4)
Peak Spectral Efficiency	Uplink	6.75 bps/Hz(2x4)

II. EVALUATION OF SYSTEM BY BER

In real time communication whatever data has been sent from transmitter, it cannot 100% received by receiver. In digital system, sometimes data have to be send for long distance. If it has been not done then there is error occurs in the received stream. So communication cannot be done effectively and efficiently. Just because of this, there is need of other higher frequency signal which can carry this information data for long distance. This is called digital modulation. Some digital modulation technique is mentioned in below Table 2.

Table 2: Digital Modulation techniques and error probability equations

Digital Modulation	Error Probability
BPSK	(1/2)*erfc(√Y)
QPSK	(1/2)*erfc(√Y)
M-PSK	(1/2)*erfc(sqrt ((log$_2$M)*sin^2(π/M)*Y))
M-QAM	(2/√M)*(1-(1/√M))*erfc(sqrt ((3log$_2$M/2(M-1)*Y)))
D-BPSK	(1/2)*e^(-Y)

Here, Y is signal to noise ratio and M is modulation index. Values are 4, 16, 64 etc. In M-PSK value of M is 4 then it will be QPSK.

III. Evaluation of System by Channel Capacity

In wireless communication two terms are most important which are Diversity and Multiplexing. By changing in diversity channel capacity cannot increase or decrease if diversity branches are same, this term is only used to make strong path between transmitter antennas and receiver antennas. Also it is independent from the SNR. While multiplexing is dependent upon SNR. By this term channel capacity can be increase or decrease. Equation of receives signal can be given by,

$$y = Hx + n \qquad (1)$$

Where y is received signal, H is defined as channel matrix and n represent white Gaussian noise of channel.

In single input single output (SISO) system there is only one antenna at transmitter and one antenna at receiver side. It is also known as conventional radio system. Channel capacity for SISO can be given equation (2),

$$C = \log_2(1+SNR) \qquad (2)$$

Figure 1: SISO

Single input multiple output (SIMO) include one antenna transmitter side while 2 or more number of antennas receiver side. It is also known as receiver diversity and equation for SIMO capacity is given below,

$$C = \log_2\left(1+SNR\left(\sum_{i=1}^{Nr}|h_{i1}|^2\right)\right) \qquad (3)$$

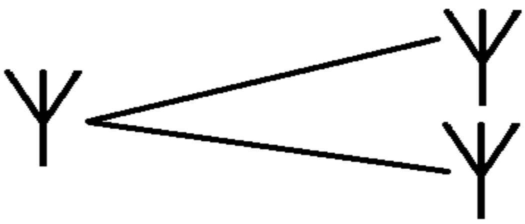

Figure 2: SIMO

By changing diversity means by transmitter diversity, there are more number of antennas at transmitter side while one antennas at receiver side called multiple input multiple output.. By the result it has been proven that Channel in SISO is lower than MISO and SIMO, but channel capacity if same for MISO and SIMO for same number of antennas.

$$C = \log_2\left(1+\frac{SNR}{Nt}\left(\sum_{j=1}^{Nt}|h_{1j}|^2\right)\right) (4)$$

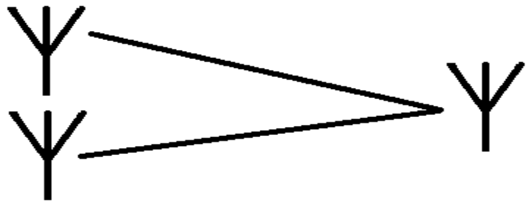

Figure 3: MISO

Spatial multiplexing or multiple input multiple output is used to increase channel capacity of system this is combination of receiver and transmitter side diversity. Channel capacity is more than SISO, SIMO and MISO due to higher number of antenna. Channel capacity equation is,

$$C = E\left\{\sum_{i=1}^{r} log_2\left(1+\frac{SNR}{Nt}\lambda_i\right)\right\} \qquad (5)$$

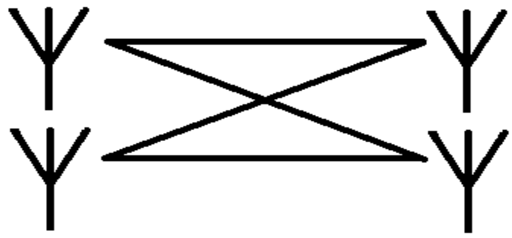

Figure 4: MIMO

Here SNR is signal to noise ratio, Nt is number of transmitter antennas, Nr is number of received antennas and λ_i is eigenvalues of channel matrix H calculate by SVD.

Comparison of all this system capacity can be done in below figure 5. As per that conclusion carried out is that diversity does not affect the channel capacity that's why SIMO and MISO has almost same channel capacity while it has higher than SISO but if spatial multiplexing is there than it has higher channel capacity than other.

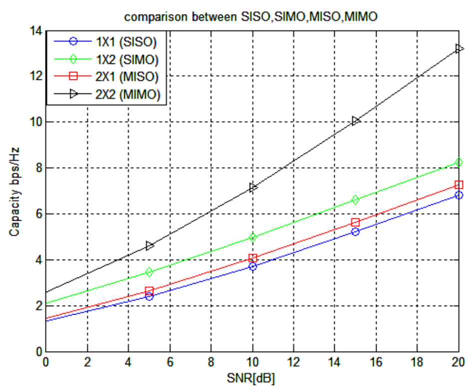

Figure 5: Comparison of SISO, SIMO, MISO and MIMO

Not only number of antennas, bandwidth and SNR effect on channel capacity but also environment does or fading. This will study in following section.

IV. FADING ENVIRONMENTS

A. *Rayleigh Distribution*

In wireless communication when signal is transmitted from the source then to reach at receiver it will follows multiple path called fading. This signal may reflected, diffracted,scatter from any walls, edges, building or any other obstacles. Due to this its strength is degrade. The Rayleigh distribution has a probability density function (pdf) given by,

$$\text{P(r)} = \frac{r}{\sigma^2}\exp(-\frac{r^2}{2\sigma^2})(\, 0 \le \text{r} \le \infty) \qquad (6)$$

Where σ is define as the rms value of the received voltage signal before envelope detection and σ2 is define as the time average power of the received signal before envelope detection.

Rayleigh fading models assume that the strength or magnitude of a signal that has passed through such a transmission medium (communications channel) will fade, or vary randomly, according to a Rayleigh distribution. Rayleigh fading is viewed as a reasonable model for ionospheric and tropospheric signal propagation as same as the effect of highly built-up urban environments on radio signals. Rayleigh fading is most useful when there is no dominant propagation along a LOS (line of sight) between the transmitter and receiver. The channel capacity analysis in Rayleigh fading environment by different number of antennas at transmitter and receiver can be done by the Figure 6.

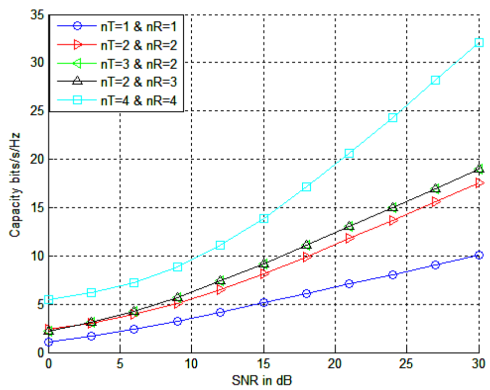

Figure 6: Channel capacity in Rayleigh Distribution

B. *Rician distribution*

The pdf of Rician distribution can be given by,

$$\text{P(r)} = \frac{r}{\sigma^2}\exp(-\frac{r^2+A^2}{2\sigma^2})\ \text{I}_0\,(\frac{Ar}{\sigma^2}) \qquad (\text{A} \ge 0\,,\ \text{r} \ge 0) \qquad (7)$$

Where A is peak amplitude of dominant signal and $\text{I}_0\,(\frac{Ar}{\sigma^2})$ is modified Bessel function of zero order and first kind. If there is comparison of Rayleigh and Rician PDF, then there is only one factor which need to consider is A. which is also known as Rician factor. As per [2], if value of A is zero then it Rayleigh distribution. So only difference is of line of sight component. In Rician due to this one stronger path is there which gives the results that channel capacity is higher rather than in Rayleigh for the same number of antennas at transmitter as well receiver side.

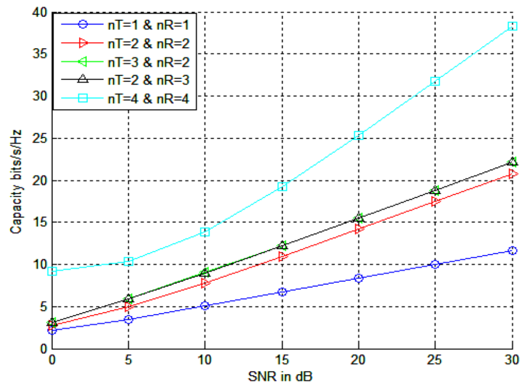

Figure 7: Channel capacity in Rician Distribution

C. *Nakagami distribution*

The pdf of Nakagami distribution can be given by,

$$\text{P(r)} = \frac{1}{\Gamma(\text{m})}\left(\frac{m}{\gamma}\right)^m r^{m-1} exp\left(-\frac{m}{\gamma}r\right) r \ge 0 (8)$$

As per above equation, Nakagami is in between distribution of Rayleigh and Rician. Here, m is known as Nakagami parameter, γ is average and $\Gamma(.)$ is Gamma function. [1] If value of m=1 then it is Rayleigh distribution while for value of m>1 it is near to Rician. In urban area there is no any line of sight path in general situation just because of height of building. But maybe there one reflected, scattered or diffracted component which value is more than Rayleigh component.

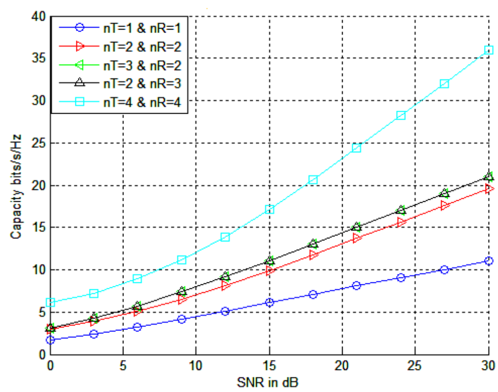

Figure 8: Channel capacity in Nakagami Distribution

This all analysis in fading environment is done by applying water filling algorithm. Comparison with earlier sectionchannel capacity and by water filling channel capacity with same number of antennas can be done by as below figure 9.

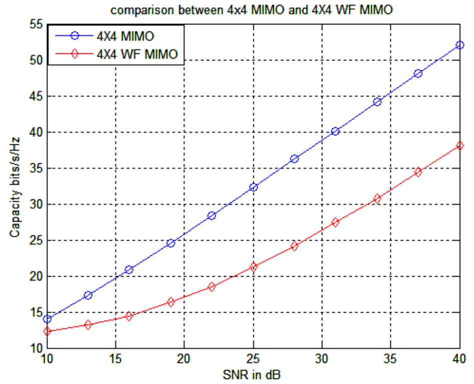

Figure 9: Comparison of simple 4x4 MIMO and 4x4 WF MIMO

Reason for this change is just because in simple MIMO all channel is behaved as ideal, while in water filling some channels which has power more than threshold has been eliminated. Comparison of channel capacity in Rayleigh, Rician and Nakagami can be given in following figure 10.

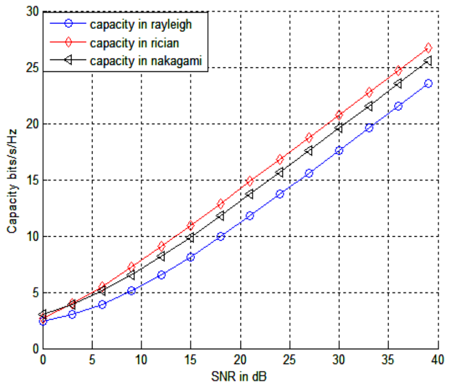

Figure 10: Comparison of channel capacity in Rayleigh, Rician and Nakagami Distribution

V. CONCLUSION

After all this analysis in Rayleigh, Rician and Nakagami of its channel capacity by changing number transmitter and receiver antenna and Bandwidth which are allocated in IMT-A, its requirement can be full filled. Peak data rate for uplink and downlink can be achieved. Also channel capacity is higher in Rician Fading rather than Rayleigh or Nakagami. By changing Rician Factor value Capacity is changed and for zero it will be same as Rayleigh. Same thing for Nakagami, it will switch in Rayleigh and Rician by Nakagami parameter m.

REFERENCES

[1]Yoora Kim; Sungoh Kwon, "Capacity Analysis of Opportunistic Scheduling in Nakagami- m Fading Environments," in Vehicular Technology, IEEE Transactions on , vol.64, no.11, pp.5379-5384, Nov. 2015

[2]Nyarko, J.K.N.; ango Mbom, C.; Rugui Yao; Ling Wang, "Asymptotic capacity of Rician fading Channel for large scale antenna systems," in AFRICON, 2015 , vol., no., pp.1-5, 14-17 Sept. 2015

[3]Lee, W.C.Y., "Estimate of channel capacity in Rayleigh fading environment," in Vehicular Technology, IEEE Transactions on , vol.39, no.3, pp.187-189, Aug 1990

[4]Arar, M.; Yongacoglu, A., "Contribution of multiplexing and diversity to ergodic capacity of spatial multiplexing MIMO channels at finite SNR," in Information Theory (CWIT), 2011 12th Canadian Workshop on , vol., no., pp.155-158, 17-20 May 2011

[5] Paresh M. Dholakia · Sanjay Kumar · C. H. Vithalani, “Performance Analysis of 4 × 4 and 8 × 8 MIMO System, to Achieve Higher Spectral Efficiency in Rayleigh and Rician Fading Distributions.” Springer, November 2014, volume 79, issue 1, pp 687-701

[6]Kuldeep Kumar1, Manwinder Singh2, “Proposed Water filling Model in a MIMO system,”International Journal of Emerging Technology and Advanced Engineering , ISSN 2250-2459, Volume 1, Issue 2, December 2011

[7]Yanqing Zhu; Jie Chen; Wei Yang; Pengbo Wang, "Analysis of channel capacity for MIMO SAR model," in Geoscience and Remote Sensing Symposium (IGARSS), 2012 IEEE International , vol., no., pp.4003-4005, 22-27 July 2012

[8]Amit Kumar,Dr. Yunfei Liu,Tanvir Singh,Dr. Sawtantar Singh Khurmi, “IMT-Advanced: The ITU standard for 4G Mobile Communication,” INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY VOL. 2, ISSUE 1, MARCH 2011

[9]Tse, D., & Viswanath, P. (2005). *Fundamentals of wireless communication*. Cambridge: Cambridge University Press.

[10] J.G. Proakis, M. Salehi, Digital Communications, 5th ed., McGraw-Hill, Boston, 2008.