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Comparative Analysis of MIMO OFDM System Using Different Fading Techniques

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Abstract: The MIMO technology utilizes different antennas at each terminal of a wireless link and greatly improves the link reliability and spectral efficiency of future wireless communication systems. This technology integrated with Orthogonal Frequency Division Multiplexing (OFDM), which is particularly proving a propitious entrant for upcoming next generation wireless systems including both mobile and fixed systems. Itprovides an attractive air-interface solution for next-generation wireless/cellular systems. In this paper Waterfilling algorithm has been used to optimize transmit power for maximizing the capacity. The Waterfilling algorithm successfully solved the problem of power allocation for MIMO-OFDM wireless network and adaptively allocate power to minimize BER performance and increasing the capacity in order to maintain the QoS requirements for a network. The proposed work is investigated by using Matlab tool.

Keywords: Multiple Input Multiple Output Orthogonal Frequecny Division Multiplexing(MIMO-OFDM),Waterfilling Algorithm, Signal to Noise Ratio(SNR),Bit Error Rate(BER),Quality of Service (QoS),Channel State Information(CSI).

I. INTRODUCTION

The vital requirements of a future cellular wireless communication includes the high data rate access with high QoS, assuming the bandwidth spectrum as a limited resource with hostile propagation conditions due to fading caused by multipath components and interference from other users. The requirements therefore, demand the challenging spectral efficiency with improved reliable transmission link.

The growing demand for broadband internet access has to meet the challenging parameter of QoS, as broadband channel is a non-LOS channel undergoing impairments like time and frequency selective fading (Hos and Visser, 2004) (Andrea, 2005). The solution to these impairments is MIMO-OFDM technology.

MIMO technology is a well-known high data rate interface with promising fact of dynamically enhanced capacity by implication of a proper budget allocation in a particular wireless cellular network. Its unification with a multipath based technique like OFDM, can eliminate Inter Symbol interference (ISI) (Jaya and Mandal 2015) and can drastically improve the capacity and spectral efficiency of wireless cellular networks. In this paper we measure the performance of MIMO-OFDM system using the waterfilling algorithm.

A MIMO-OFDM system utilizes the multiples antennas at transmitter (T_x) and receiver (R_x) side. The OFDM modulated data is transmitted from various antennas at T_x side and is extracted at R_x side after the OFDM demodulation and MIMO decoding. Under the MIMO-ODFM system, each user occupies one subcarrier at a time with finest channel gain for that subcarrier and transmit power (P_t) is distributed over the subcarriers using the Waterfilling algorithm. When the perfect CSI is available at the nodes, P_t allocation improves the BER performance and channel capacity and also tends to improve the performance of indoor power line communication system (Yang, *et al.,* 2015).

The paper shows the optimize solution of power allocation in MIMO-OFDM system for LTE Advance using stochastic adaptive Waterfilling algorithm utilizing imperfect channel estimates in a non-stationary fading channels and evaluates the performance of the MIMO-OFDM system with different configuration i.e. antenna spacing and number of transmit and receive antennas, in terms of channel capacity (White Paper, 2019) (Mahmood, and Ghazal. 2016).

The paper contains the analysis the impact of power optimization on channel capacity with the help of capacity and CCDF graphs. The MIMO-ODFM is system is evaluated first without Waterfilling algorithm and then with the Waterfilling algorithm and comparative graphs of capacity and CCDF were obtained on three small scale fading distribution models i.e. Nakagami-m and Rayleigh (Andrea, 2005) (Jaya and Mandal 2015) (Wellner, 2003).

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For implementing the Waterfilling algorithm, certain conditions need to be meet, including the Channel State Information (CSI)at transmitter side, as it increases the cost and complexity of the transmitter. The conditions are stated after the deep analysis of MIMO-OFDM with different parameters of antenna spacing and number of transmit and receive antennas under simulation and result study section (Kusuma, *et al.*, 2016) Hemangi *et al.*, 2013).

2. PROPOSED METHODOLOGY

A. MIMO-OFDM

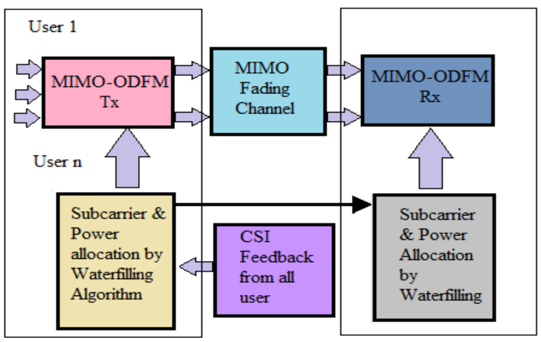

Fig.1. MIMO-OFDM System

The expression for MIMO-OFDM system is shown by the equation 2.1.

$$Y_i = \sum_{i=1}^{T} C_{ij}[n,k] I_i[n,k] + N_j[n,k] \qquad (2.1)$$

For j=1…,R and k=0,……K-1,

Where Y_i isthe received signal at the k^th^ sub-carrier

$I_i[n,k]$ is the symbol transmitted from the i^{th} transmit antenna(T_x)

$C_{ij}[n,k]$ is the channel's frequency

$N_j[n,\ k]$ is additive (complex) Gaussian noise (Jianxuan and 2003)..

B. Waterfilling Algorithm

The well-known Waterfilling algorithm provides the solution and optimization of channel capacity and maximizing the mutual information between the input and output of a channel. The principle of water filling algorithm is to optimally allocate the power that helps to increase the capacity of MIMO-OFDM system. The Waterfilling algorithm allocates power amongst the subcarrier in such a way that a greater portion of power goes to the sub channel with high gain and less or even no to the channels with lower gain. This power allocation is subject to the power constraint, which means the individual power of a sub channel should be less than or equal to the total power of the system as shown in equation 2.2:

$$\sum P_k \leq P_t \quad (2.2)$$

The Water filling technique is used to determine the powers (p_i) transmitted in each channel to achieve greatest possible capacity. Consider a MIMO communication link with a shared total power budgeti-e transmitted power(p_t.), then the Shannon channel capacity for MIMO-OFDM is given as:

$$C = \sum_{i=1}^{T} \log_2(1 + \frac{\sigma_i^2 p_i}{\sigma_n^2}) \text{ Bp/Hz} \qquad (2.3)$$

Where,

σ_i =Gain

σ_n=Noise Variance

P_i = Power of i^{th} Channel

To achieve the greatest possible capacity ρ_i should be chosen in such a way that for every mode i

$$P_i = \left(\frac{1}{\lambda} - \frac{\sigma_n^2}{\alpha_i^2}\right)^2 (2.4)$$

If the value of Pi is less than zero, then i^{th} channel has been assigned zero power level, then for i-1 channel we obtain threshold value, for that threshold value i-1 channel will be evaluated, if it is greater than zero so i-1 channel has been assigned that value of power and if it is less than zero so same process will be repeated. This iteration will continue until all the sub channels have been assigned with the power level.

3. SIMULATIONS AND RESULTS STUDY

a. Capacity Curves

For simulation purpose, the capacity of MIMO-OFDM system channel is analyzed with different combination of antennas spacing (λ) and order of MIMO-OFDM system on Nakagami-m, Rayleigh and Rician fading channel. The used parameters are shown in **(Table 1).** The performance is displayed in terms of SNR (db) versus the average capacity (bits/sec/Hz) plots.

Table 1. Performance parameters

Parameter	Value
Channel(s)	Nakgami-m, Rayleigh, Rician fading.
Antenna Spacing(λ)	0.3-0.5
Radio Technology	ODFM
Order(s)	2x2,4x4,8x8

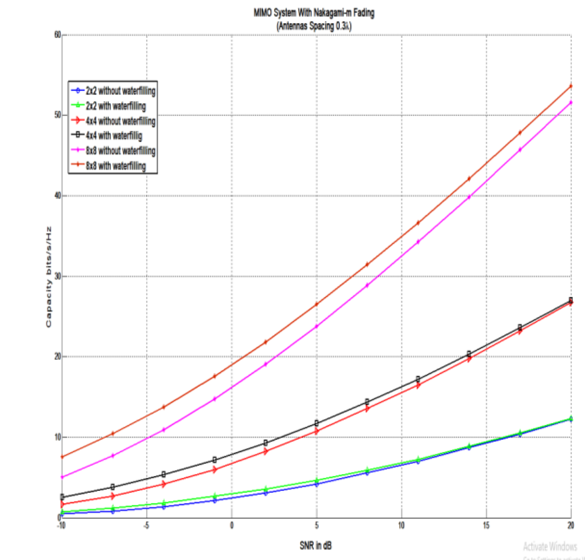

Fig.2: Capacity Curves at λ=0.3 antennas spacing with Nakagami-m Fading Distribution

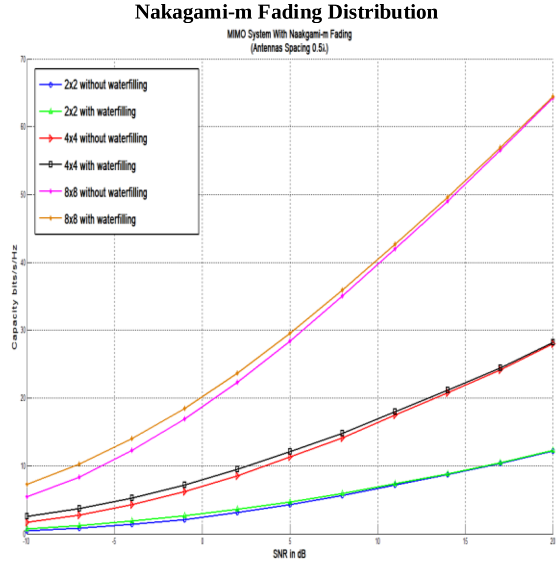

Fig. 3: Capacity Curves at λ=0.5 antennas spacing with Nakagami-m Fading Distribution

The Capacity Curves of MIMO-OFDM System at λ=0.3 and λ=0.5 antennas spacing with Nakagami-m fading distribution is shown in **(Fig. 2)** and **(Fig. 3)** respectively. Clearly depicted in **(Fig. 2)** the capacity of a MIMO-OFDM system increases exponentially with the SNR. Moreover power optimization (Waterfilling) at higher order for MIMO-OFDM system has greater impact on channel capacity. Increasing the order from 2x2 to 8x8, gradually increases the gap between the capacity curves of MIMO-OFDM with and without Waterfilling algorithm. The gap is minimized by using a good value of SNR for MIMO-ODFM system. Therefore if the SNR is good than there is no significance in using Waterfilling at MIMO-OFDM transmitter.

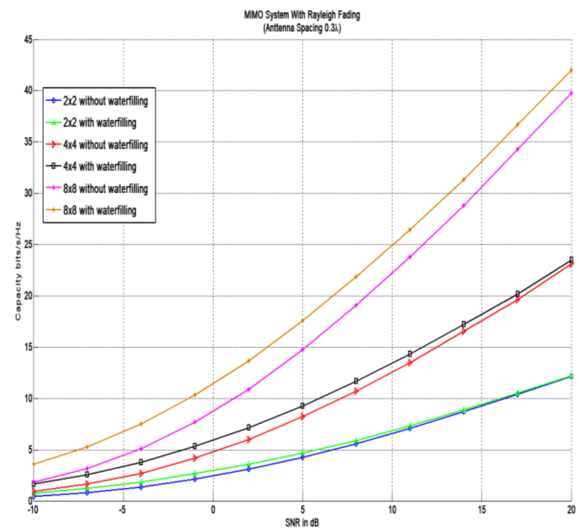

Fig. 4: Capacity Curves of λ=0.3 antennas spacing with Rayleigh Fading Distribution

(Fig. 3) shows the antennas spacing from λ=0.3 to 0.5, increases the average channel capacity of the system by 18%. The same parameters from **(Table 1)** were analyzed using the Rayleigh fading distribution channel. The capacity curves were plotted and analyzed for changing the λ=0.3 to 0.5 and order of MIMO-OFDM system in **(Fig. 4 and 5)** respectively.

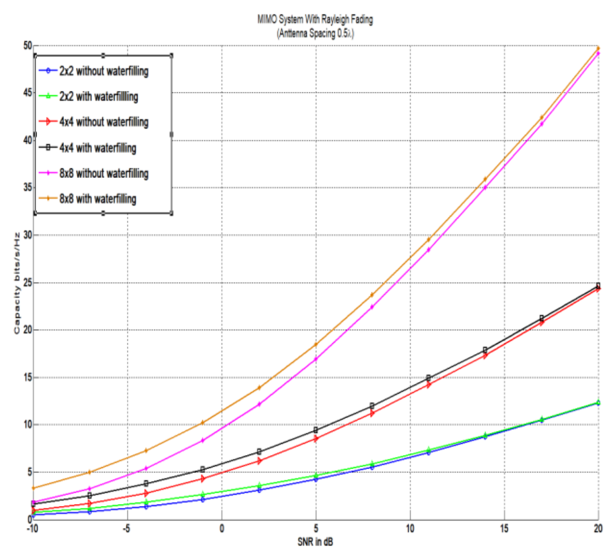

Fig. 5: Capacity Curves of λ=0.5 antennas spacing with Rayleigh Fading Distribution

It is analyzed from **(Fig. 4 and 5)** that Waterfilling algorithm at lower order MIMO-OFDM system is not a good choice at all as the capacity curves are similar with and without Waterfilling algorithm. Moreover the antennas spacing formλ=0.3 to 0.5 increases the average channel capacity of the system by 19%.

The MIMO-OFDM system is again simulated using parameters mentioned in table 1 with Rician Distribution channel. The capacity curves were plotted and analyzed for changing theλ=0.3 to 0.5 and order of MIMO-OFDM system in **(Fig. 6 and 7)** respectively.

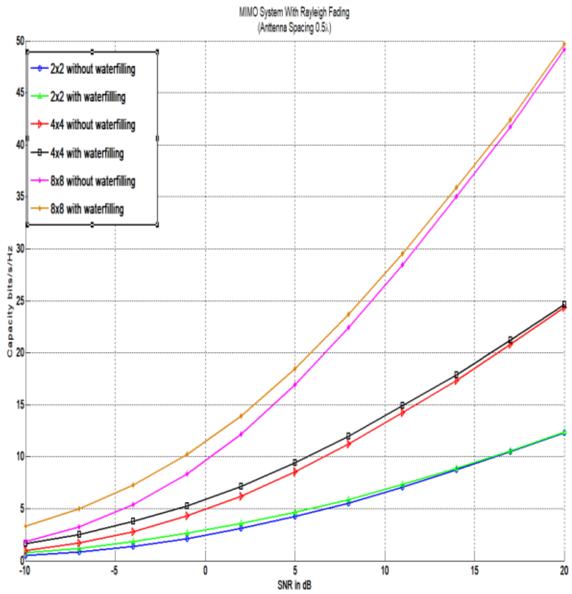

Fig. 6: Capacity Curves at λ=0.3 antennas spacing with Rician Distribution

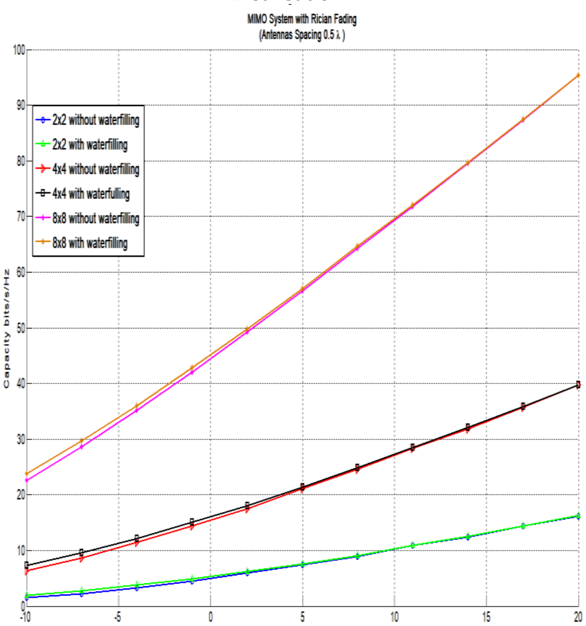

Fig. 7: Capacity Curves at λ=0.5 antennas spacing with Rician Distribution

From **(Fig. 6)** it is analyzed, that the channel capacity of MIMO-OFDM system with Rician distribution fading is almost linear at higher order. The use of Waterfilling algorithm is suitable at higher order, as the gap between channel capacity curves is negligible at lower order. The **(Fig. 7)** shows, as we increase the antennas spacing from λ=0.3 to 0.5, the capacity curves with or without Waterfilling becomes equal. Hence at λ=0.5 with Rician distribution fading, there is no need of power optimization through Waterfilling algorithm. Moreover the channel capacity is increased by 18.75%.

b. CCDF Curves

CCDF curves of MIMO-OFDM system with 2x2, 4x4 and 8x8 using Rayleigh fading distribution are shown in **(Fig. 8, 9 and 10)** respectively. The performance is displayed in terms capacity of channel (bps/Hz) versus the probability. These curves are helpful in finding the probability to achieve a particular data rateat different values of SNR.

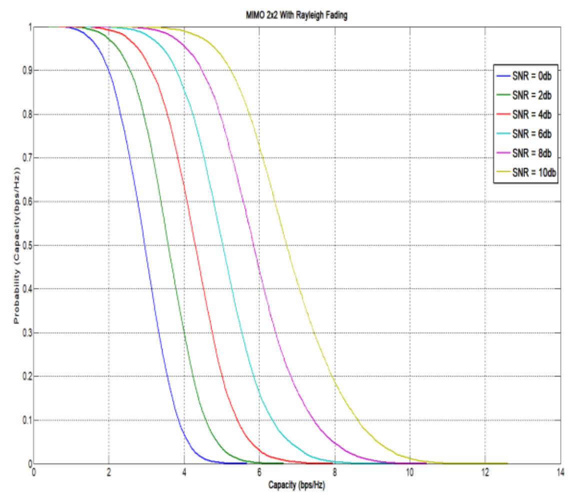

Fig. 8: CCDF Curve of MIMO-OFDM2x2 with Rayleigh Fading

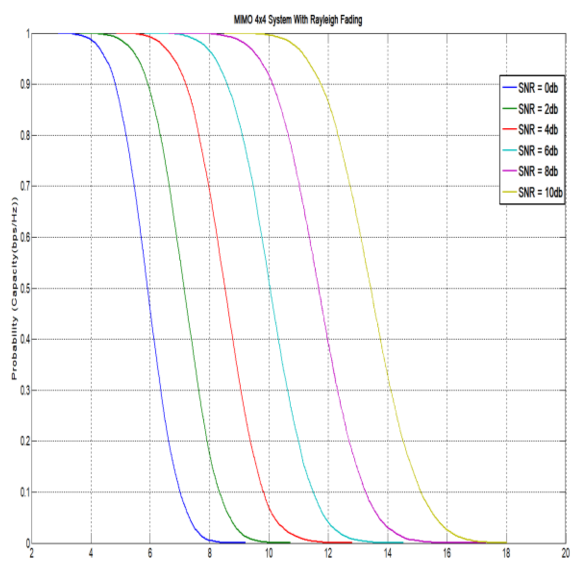

Fig.9: CCDF Curves of MIMO-OFDM 4x4 with Rayleigh Fading

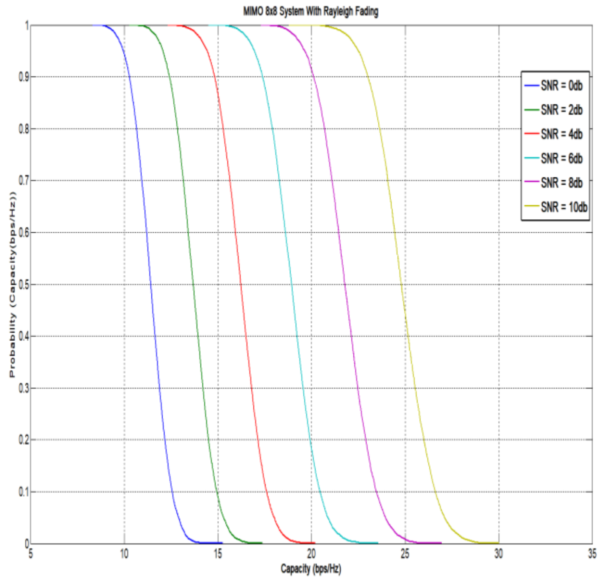

Fig.10: CCDF Curves of MIMO-OFDM 8x8 Rayleigh Fading

From **(Fig. 8, 9 and 10)**, it is analyzed that as the value of SNR increases the probability of getting higher data rate is greater and also by increasing the order of MIMO system at fixed value of probability, 13.7% of increment of channel capacity was visible while using the MIMO-OFDM with Rayleigh distribution fading.

Similarly the CCDF curves of MIMO-OFDM 2x2, 4x4 and 8x8 with Nakagami-m fading distribution were obtained as shown in **(Fig. 11,12 and 13)**.

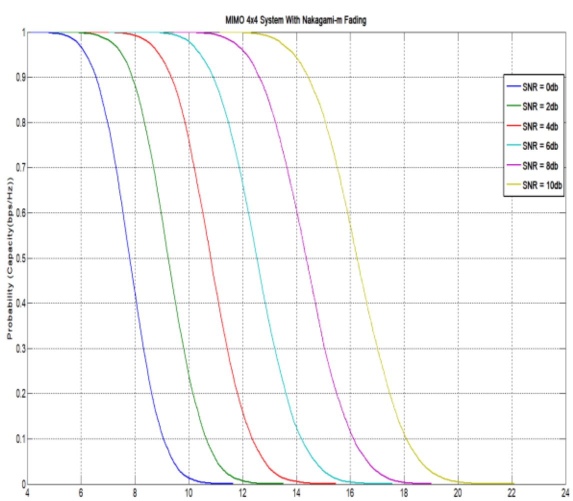

Fig. 11: CCDF Curves of MIMO-OFDM Nakagami-m fading

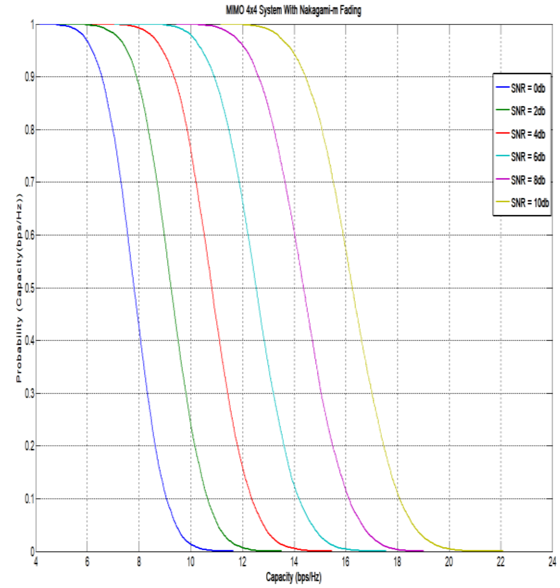

Fig. 12: CCDF Curves of MIMO-OFDM 4x4 Nakagami-m fading

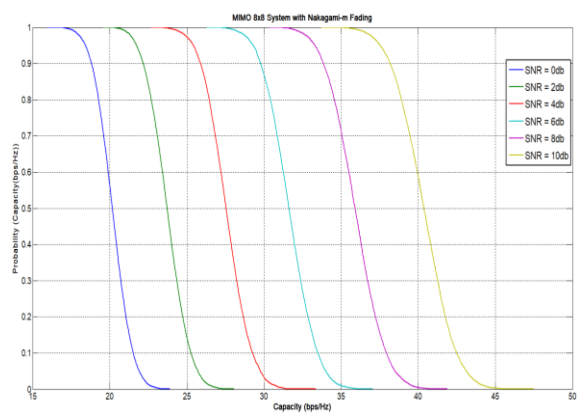

Fig. 13: CCDF Curves of MIMO-OFDM 8x8 Nakagami-m fading

Simulation results from above **(Fig. 11, 12 and 13)** shows that as the value of SNR increases, the probability of getting higher data rate is greater and also by increasing the order of MIMO system at fixed value of probability, 22% of increment of channel capacity was achieved while using MIMO-OFDM with Nakagami-m distribution fading.

4. CONCLUSIONS

In this paper, the power optimization scheme at the communication system which has low SNR results in very high gain in channel capacity is presented. Antenna spacing is very important factor because it also effects the overall average channel capacity at same value of SNR. At Rician fading channel, Water filling algorithm does not have any significant effect on channel capacity While on Nakagami-M and Rayleigh Fading Channel Water filling has very significant rise in Channel Capacity. Rician Fading Channel has highest data rates at the same value of SNR as compare to Nakagami-M and Rayleigh fading Channels.

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