Homework : 04
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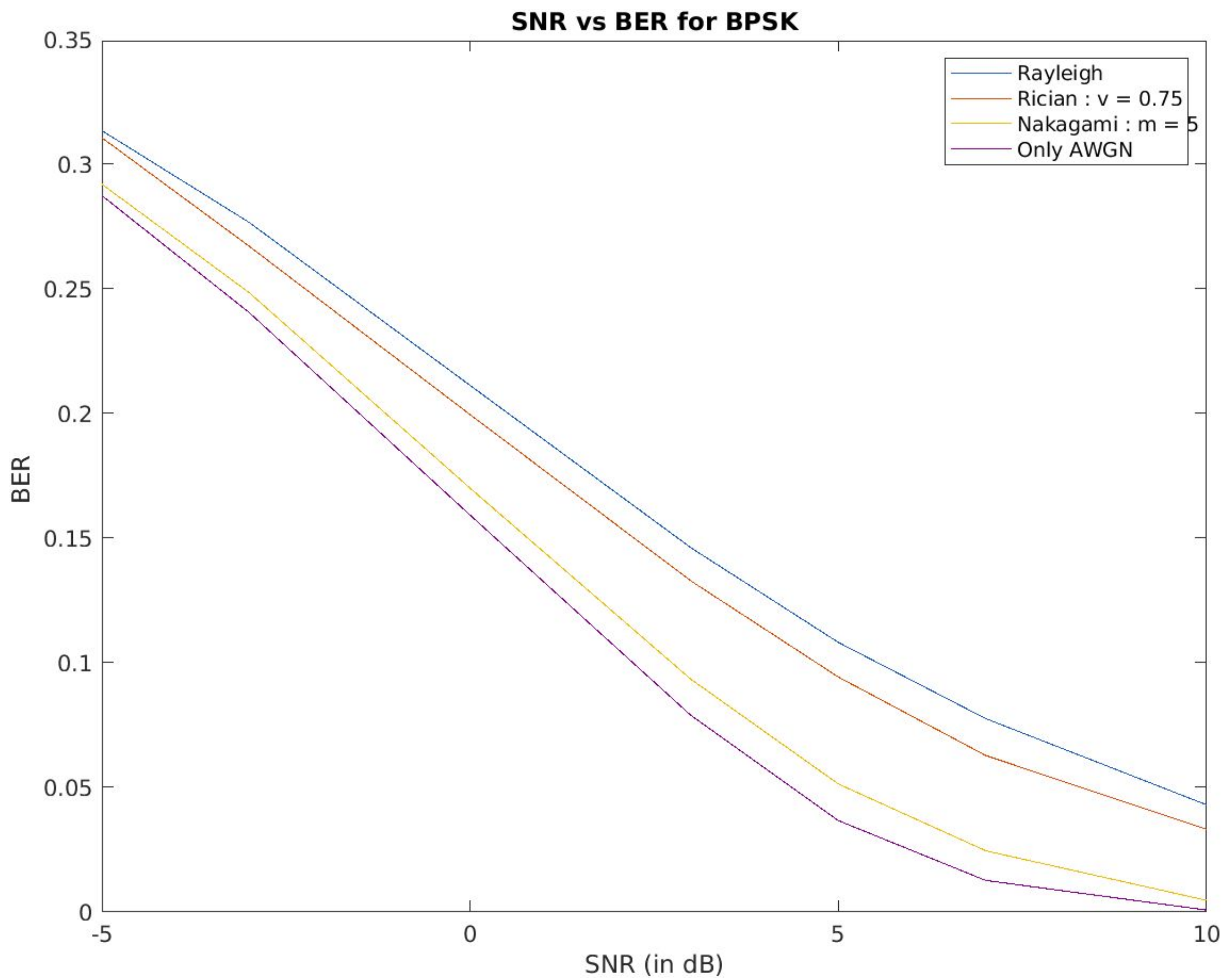
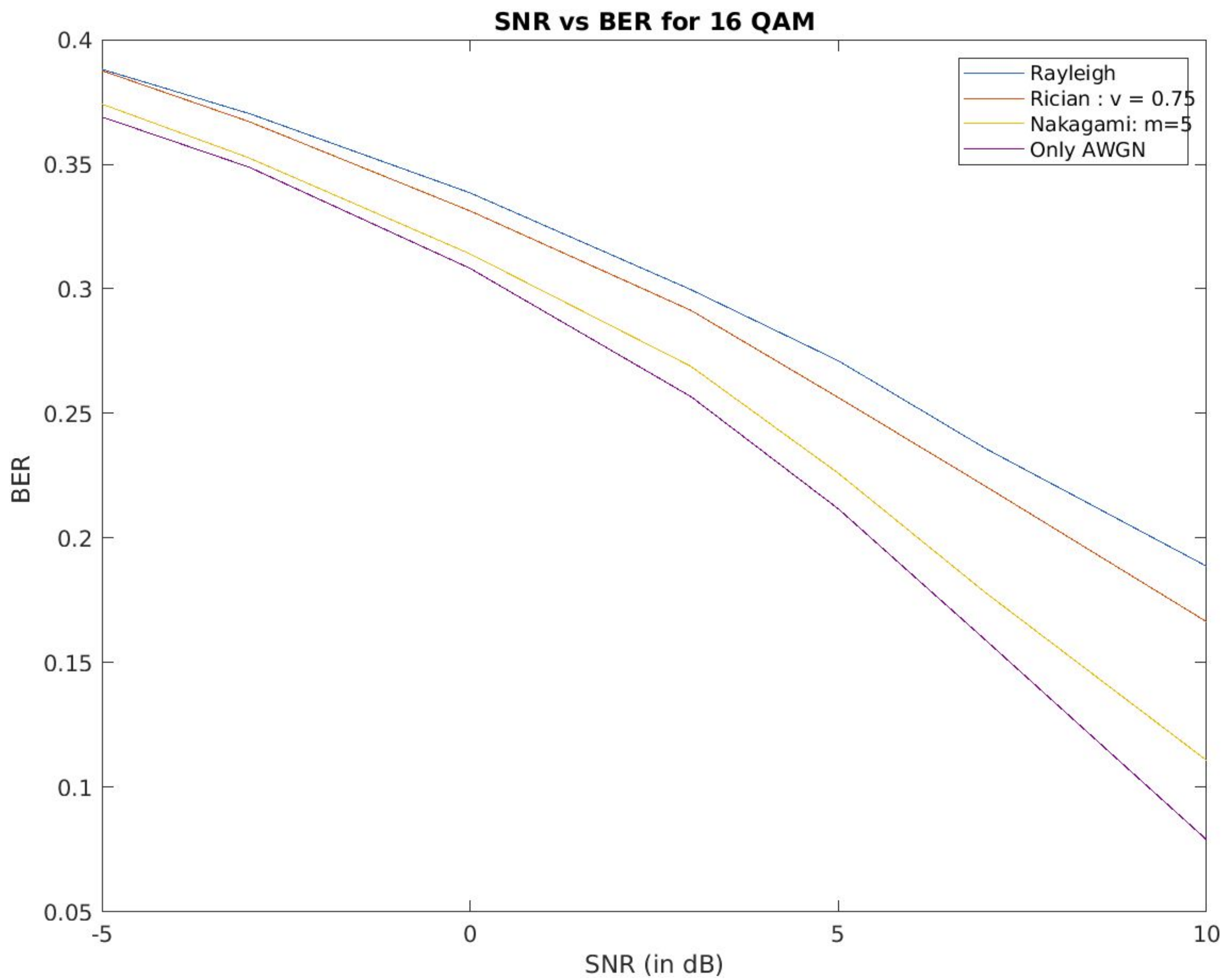
Simulating BPSK and 16 QAM modulations and examining the BER for different fading.

Before comparing BER for different fading , we need to ensure that the power is the same.i.e;

$$y_k = h_k x + n$$

Where h_k defines the fading, which is a random process.




SNR vs BER for 16 QAM
BER
SNR (in dB)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
-5
0
5
10
Rayleigh
Rician : v = 0.75
Nakagami: m=5
Only AWGN

Observations & Analysis

$\Rightarrow$ $y_k = h_k x + n$

where n: AWGN $\sim \mathcal{N}(0, N_0)$

N_0 is decided by SNR.

* h_k: Random process which models the fading environment.

For Rayleigh: $h : \underline{X} \sim \text{Rayleigh}(\sigma_x)$

For Rician $\Rightarrow$ $h : Y \sim \text{Rician}(v_y, \sigma_y)$

For Nakagami $\Rightarrow$ $h : Z \sim \text{Nakagami}(m_z, \Omega_z)$

For comparing BER for same SNR between different fading environments Power should be constant

$\Rightarrow E(X^2) = E(Y^2) = E(Z^2) = 1$ (constant

$E(X^2) = 2\sigma_x^2 \Rightarrow \boxed{\sigma_x = \frac{1}{\sqrt{2}}}$

$E(Y^2) = 2\sigma_y^2 + v_y^2 = 1$

Let $v_y = 0.75$

$\Rightarrow \sigma_y = \sqrt{\dfrac{1-(0.75)^2}{2}}$

$E(Z^2) := \Omega_z = 1$

Here m_z is considered as '5'

* For just AWGN:

$y_k = x_k + n_k \Rightarrow \boxed{h_k = 1}$

The paramaters are set to constant while simulating and comparing BER.

a) Analysis for BPSK :

SNR = (-5dB, 10dB)

⇒ BER gradually decreases ⇒ as SNR ↑

This is evident since as SNR ↑

signal strength is relatively high compared to noise

→ Hence, we can decode bits more reliably.

b) Analysis for 16 QAM:

The same holds true.

For a given SNR, for any fading

$$(BER)_{16QAM} > (BER)_{BPSK}.$$

* c) Analysing different variants of the same fading channel.

→ It is evident that a single AWGN channel has better BER, when compared to other fading channels.

→ Fading also induces random-ness, which makes it even more harder to decode when applying thresholding rule.

* For ~~Rician~~: rician.

It has two dependendent parameter

$\sigma^2 + v^2 = 1$

As $v : 0 \rightarrow 1$

The BER for rician moves from Rayleigh curve → Only AWGN curve reason:-

A Rician R.V. with $v=0 \Rightarrow$ resembly a Rayleigh distribution, since

$R_1 \sim \text{Rayleigh}(\sigma)$

$R_1 = \sqrt{X_1^2 + X_2^2}$; $X_1, X_2 \sim N(0, \sigma^2)$.

$R_2 \sim \text{Rician}(v, \sigma)$

$R_2 = \sqrt{X_1^2 + X_2^2}$; $X_1 \sim N(v\cos\theta, \sigma^2)$

$X_2 \sim N(v\sin\theta, \sigma^2)$

$\therefore$ for $v=0$

$\boxed{R_1 \simeq R_2} \Rightarrow$ Hence will be similar to rayleigh curve

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& for Nakagami (m, Ω)

we need to have $\boxed{\Omega = 1}$

As $m: 1 \rightarrow \infty$

(BER) curve nakagami reaches AWGN curve at very high 'm'

with $m=1$

Nakagami $(m=1, \Omega) \simeq \text{Rayleigh}(\sigma)$

where $\boxed{\Omega = 2\sigma^2}$

$\therefore$ For $m = 1$ BER curve is similar to that of rayleigh

as $m \uparrow \Rightarrow$ BER curve reaches 'only AWGN'