"Heaven's light is our guide"

Rajshahi University of Engineering & Technology

Lab Report

Course No: EEE 4184

Course Title: Digital Communication Sessional

Experiment No: 02

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Experiment No.: 02

1.Problem Statement: The probability density function of the signal-to-noise ratio of Rayleigh Fading SISO is given by

$$f_\gamma(\gamma) = \frac{1}{\bar{\gamma}} e^{-\frac{\gamma}{\bar{\gamma}}}, \qquad \gamma > 0$$

(a) Mathematical Derivation: Derive the expressions of the outage probability of Rayleigh fading SIMO channel.
(b) write the Computer Program: Using Matlab, write the programs of the outage probability of Rayleigh fading SIMO channel.
(c) Explain the Numerical Results: Explain the numerical results of the outage probability of Rayleigh fading SIMO channel

2. Derivation of the outage probability of Rayleigh fading SIMO channel:

Let ,
γ= Signal to noise ratio (SNR) of Combiner output.
γi = SNR of each branch (i = 1, 2, . . . , nR).
nR = Number of Antennas at the Receiver.
γth = Threshold SNR.
Probability Density Function of γi:

$$f_{\gamma_i}(\gamma_i) = \frac{1}{\overline{\gamma_i}} e^{-\frac{\gamma_i}{\overline{\gamma_i}}},$$

where γi = E[γi].
Probability Density Function at γth:

$$f_{\gamma_i}(\gamma_{th}) = \frac{1}{\overline{\gamma_i}} e^{-\frac{\gamma_{th}}{\overline{\gamma_i}}}$$

Cumulative Distribution Function (CDF) at γth:

$$F_{\gamma_i}(\gamma_{th}) = Pr\left(\gamma_i < \gamma_{th}\right) = \int_0^{\gamma_{th}} \frac{1}{\overline{\gamma_i}} e^{-\frac{\gamma_{th}}{\overline{\gamma_i}}} d\gamma_{th} = 1 - e^{-\frac{\gamma_{th}}{\overline{\gamma_i}}}.$$

Cumulative Distribution Function (CDF) of γP at γth:

$$\begin{aligned} F_{\gamma_\Sigma}(\gamma_{th}) &= Pr\left(\gamma_\Sigma < \gamma_{th}\right) = Pr\{max\left(\gamma_1, \gamma_2, \ldots, \gamma_{n_R}\right) < \gamma_{th}\} \\ &= \prod_{i=1}^{n_R} Pr\left(\gamma_i < \gamma_{th}\right) = \prod_{i=1}^{n_R} F_{\gamma_i}(\gamma_{th}). \end{aligned}$$

Outage Probability of Rayleigh fading SIMO channel.:

$$P_{out}(\gamma_{th}) = F_{\gamma_{\Sigma}}(\gamma_{th}) = \prod_{i=1}^{n_R}\left(1 - e^{-\frac{\gamma_{th}}{\gamma_i}}\right) = \left(1 - e^{-\frac{\gamma_{th}}{\gamma_i}}\right)^{n_R}$$

3.Program for the outage probability of Rayleigh fading SIMO channel:

```
In[192]:= (********** outage probability *********)

SNRADB = 3;
snra = 10^(SNRADB/10);
nr = 2;
strm = OpenWrite["D:\Outage Probability.txt"];
For[SNRdB = 0, SNRdB < 20.1, SNRdB++,
  ThSNR = 10^(SNRdB/10) // N;
  OutageProbability = (1 - Exp[-ThSNR/snra])^nr;
  Print["SNR=", SNRdB, "dB\t", OutageProbability];
  Write[strm, OutageProbability];
 ];
Close[strm];
```

4.Numerical results of the outage probability of Rayleigh fading SIMO channel:

a) Numerical data

snr	outage probability value at SNRADB=3	outage probability value at SNRADB=5	outage probability value at SNRADB=10
0	0.155384973	0.073498781	0.009055917
1	0.218947095	0.107853096	0.013992621
2	0.300430389	0.155384973	0.021482155
3	0.399576401	0.218947095	0.032718032
4	0.512714711	0.300430389	0.049339242
5	0.632073203	0.399576401	0.073498781
6	0.74653405	0.512714711	0.107853096
7	0.844349502	0.632073203	0.155384973
8	0.917133324	0.74653405	0.218947095

9	0.963017156	0.844349502	0.300430389
10	0.986727485	0.917133324	0.399576401
11	0.99636569	0.963017156	0.512714711
12	0.999290048	0.986727485	0.632073203
13	0.999909202	0.99636569	0.74653405
14	0.999993183	0.999290048	0.844349502
15	0.999999738	0.999909202	0.917133324
16	0.999999996	0.999993183	0.963017156
17	1	0.999999738	0.986727485
18	1	0.999999996	0.99636569
19	1	1	0.999290048
20	1	1	0.999909202

b) Graphical representation:

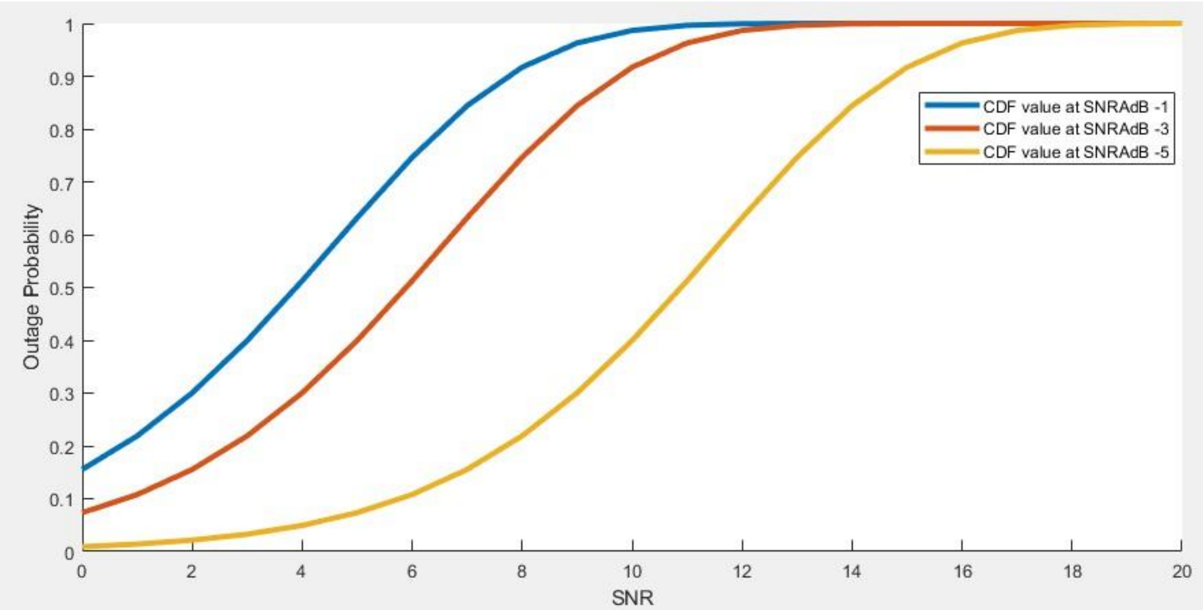

Figure 2.1. outage probability vs signal to noise ratio plot for Rayleigh fading SIMO channel

c) Description of Figure 2.1:

This is a plot of outage probability as a function of Signal to Noise Ratio (SNR or γ) for selected values of average value of SNR (SNRADB). This figure describes the effects of SNR on outage probability. The outage probability of a Rayleigh fading Single-Input Multiple-Output (SIMO) channel represents the probability that the instantaneous channel capacity falls below a certain threshold (e.g., a target data rate). The resulting plot will show how the outage probability changes with the signal-to-noise ratio (SNR) in a Rayleigh fading SIMO channel. As the SNR increases, the outage probability should decrease, indicating a more reliable communication link. Conversely, at lower SNR values, the outage probability will be higher, showing that the channel struggles to meet the target data rate and experiences more outages.

5.Discussion and Conclusion

Discussion:

Signals in wireless communication undergo erratic amplitude fluctuations as a result of the multipath components' fluctuating phase and magnitude. In LOS-free situations, the Rayleigh fading model is frequently employed to explain this behaviour. This study will examine the effects of SNR on the outage probability for the Rayleigh Fading SIMO channel, which has a single broadcast antenna and a single receiver antenna.

Figure 2.1 shows the effect of SNR on outage probability. Effect of SNR on Outage Probability:
Higher SNR (γ): As the SNR increases, the outage probability decreases. This is intuitive because a higher SNR means a stronger and more reliable signal relative to the noise, making it less likely for the communication link to experience an outage.

Lower SNR (γ): Conversely, a lower SNR leads to a higher outage probability. When the SNR is low, the received signal becomes weaker in comparison to the noise, making it more susceptible to fading and potential communication outages.

Impact of N (Number of Receive Antennas): Increasing the number of receive antennas (N) at the receiver reduces the outage probability. With multiple antennas, the receiver can employ diversity techniques, such as selection combining or maximal ratio combining, to improve the overall reliability of the communication link, especially in fading environments

Conclusion:

It's important to note that Rayleigh fading is a stochastic process, and its statistical properties are captured by the CDF of the SNR. Therefore, outage probability is a probabilistic measure, and specific outage events may vary randomly with channel realizations.

In summary, the SNR significantly affects the outage probability in a Rayleigh fading SIMO channel, where higher SNR and/or more receive antennas result in lower outage probability and better communication reliability.