Simulation of communication channels

A mini project report submitted in fulfilment of the requirements

for the completion of MATLAB

by

T. Asha Jyothi, N150740

L. Sowmya, N150313

Department of Electronics and Communication Engineering

Rajiv Gandhi University of Knowledge Technologies

Nuzvid,India-521202

Certificate

It is certified that the work contained in this mini project entitled “ simulation of communication channels ” has been carried out under my supervision and that it has not been submitted elsewhere for a degree.

Project guide

Mr.SK.Riyaz Hussain

Department of ECE

Asst.professor

RGUKT Nuzvid

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Contents

Abstract:

Nowadays Simulation plays a key role due to its ease.while simulating we have to generate symbols at the input .Generating symbols manually is a difficult task.so we use random number generation techniques to generate them.One of the random number generating technique is transform methods in that technique we used inverse transform sampling.But we can't apply this method to the distributions which didn't have analytical expressions for their cumulative distribution functions .so we go for inverse laplace transform and can obtain most of the random variables with different distributions.using these random numbers bit error rates of relay channel ,AWGN channel,Relay fading system can be simulated and are compared with their theoretical expressions.

keyword- inverse transform sampling, inverse laplace transform, MATLAB.

Introduction:

Simulation modeling solves real-world problems safely and efficiently. It provides an important method of analysis which is easily verified, communicated, and understood. Across industries and disciplines, simulation modeling provides valuable solutions by giving clear insights into complex systems.To do simulation we have to generate huge no.of symbols at the receiver side then only channel can be effectively characterized.so in order to generate huge symbols we use random number generation techniques.There are six techniques to generate random numbers

1.Physical sources:In this method we generate random numbers using physical objects like throwing dice,flipping a coin.But doing large number of experiments for more random numbers is difficult

2.Empirical resampling:In this method we store the physical outputs in a table and use the table to generate random numbers instead of doing the experiments.But it also needs effort.

3.pseudo random generators:generates random numbers that follows a function .

4.simulation/Gameplay:

In this method to get a single result we will take the input in different ways. Combining of many random variables generates random numbers

5.rejection sampling:

In this method we generate the random numbers by taking their pdf but in an approximate manner.we will take only a few x values we will reject the remaining values.

6.transform methods:

A transform method is used when we have the ability to generate instances of a random variable according to one distribution and we would like instances according to another distribution

Among different methods of random number generation using transform methods.we dealt with inverse transform sampling and inverse laplace transform.

2 Simulation

simulation is to imitate one or more aspects of reality in a way that is as close to that reality as possible.The advantages of simulation are

2.1 simulation uses:

1. risk-free environment

Simulation modeling provides a safe way to test and explore different scenarios. It's nothing but making the right decision before making real-world changes.

2. save money and time

Virtual experiments with simulation models are less expensive and take less time than experiments with real assets.

3. visualization

Simulation models can be animated in 2D/3D, allowing concepts and ideas to be more easily verified, communicated, and understood. Analysts and engineers gain trust in a model by seeing it in action and can clearly demonstrate findings to management.

4. insight into dynamics

simulation modeling allows the observation of system behavior over time, at any level of detail.

5. increased accuracy

A simulation model can capture many more details than an analytical model, providing increased accuracy and more precise forecasting.

6. handle uncertainty

Uncertainty in operation times and outcome can be easily represented in simulation models, allowing risk quantification, and for more robust solutions to be found. In logistics, a realistic picture can be produced using simulation, including unpredictable data.

3 Random numbers

3.1 random numbers

Random numbers are numbers that occur in a sequence such that two conditions are met. The values are uniformly distributed over a defined interval or set. It is impossible to predict future values based on past or present ones. Random numbers are important in statistical analysis and probability theory.

We have six fundamental methods to generate random numbers .They are

1. Physical sources
2. Empirical resampling
3. Pseudo random generators
4. Simulation/Game_play
5. Rejection sampling
6. Transform methods

3.2 Methods

3.2.1 Physical sources

This is the most basic way to generate random variables.the flip of a real coin, shuffle actual cards, mix numbered balls or count the number of ticks from an actual radioactive source. In all of these the randomness comes from physical principles.

3.2.2 Empirical resampling

This is used to be called “tables” which were themselves often generated from physical processes. principle of empirical resampling is that you can approximately generate new samples by taking samples with repetition or replacement from an old sample.

3.2.3 Pseudo random generators

In the computer age, to avoid the need for external tables or expensive and slow peripherals we tend to use pseudo random generators. That is the output of deterministic iterative procedures as equivalent to true random sources.

The most basic form of a sequential pseudo random generator is a sequence of states s(1), s(2), s(3) … . Where s(i+1) = g(s(i)) where g() is our deterministic function that maps state to state. The observed random variables are then h(s(i)) where h() is some deterministic function maps state to observables.

3.2.4 Simulation/Game-play

Another fundamental method is direct simulation or game play. If we wanted a random variable that was 1 with probability equal to the odds of being dealt a full house from a standard shuffled deck of cards (and zero otherwise). We can generate such a variable by simulating shuffling a deck, drawing a hand and returning 1 if the hand draw is a full house (and returning 0 otherwise). Notice in this case we are combining many random variables to get a single result.

One of the most important simulation techniques is Markov chain Monte Carlo methods related to Gibbs sampling, simulated annealing and many other variations. These methods implement a complex procedure over a stream of random inputs to generate a more difficult to achieve sequence of random outputs.

3.2.5 Rejection sampling

Rejection sampling is another way to convert one sequence of random variables into another. If we assume we can generate a random variable according to the distribution p(x) we can “rejection sample” to a new distribution using an “acceptance function” q(x) which returns a number in the interval [0,1].

Our procedure is to generate x with probability p(x), generate a random variable y with uniformly in the interval [0,1] if $y \leq q(x)$ accept x as our answer.

3.2.6 Transform methods

A transform method is used when we have the ability to generate instances of a random variable according to one distribution and we would like instances according to another distribution. This method is used when we have access to the inverse of the cumulative distribution function of the function we are trying to generate.

In this we can use this function to convert uniform variants from the interval [0,1] into our target distribution. The cumulative distribution function is the function cdf() where cdf(x) is the probability a random variate generated according to our distribution is less than or equal to x.

Inverse transform sampling is one of the methods in transform methods to generate random variables. Our work is in inverse transform sampling.

4 Inverse transform sampling

The probability integral transform states that if X is a continuous random variable with cumulative distribution function F_x,then the random variable Y = F_x(X) has a uniform distribution on [0,1]. The inverse probability integral transform is just the inverse of this. If Y has a uniform distribution on [0,1] and if X has a cumulative distribution F_x , then the random variable F_x^{-1}**(Y)** has the same distribution as X**.**

Inverse transformation sampling takes uniform samples of a number **u** between 0 and 1, interpreted as a probability, and then returns the largest number x from the domain of distribution P(X)such that P(-∞<X<x)<=**u.**

The inverse transform sampling method works as follows :

1. Generate a random number **u** ,from the standard uniform distribution in the interval [0,1], e.g. from U~Unif[0,1].
2. Find the inverse of the desired CDF, e.g. F_x^{-1}**(x).**
3. Compute X=F_x^{-1}(u). The computed random variable X has distribution F_x**(x)**.

Example:

Suppose we have a random variable U~Unif(0,1) and cumulative distribution function F(x) = 1- exp(-√**x**).

Solution

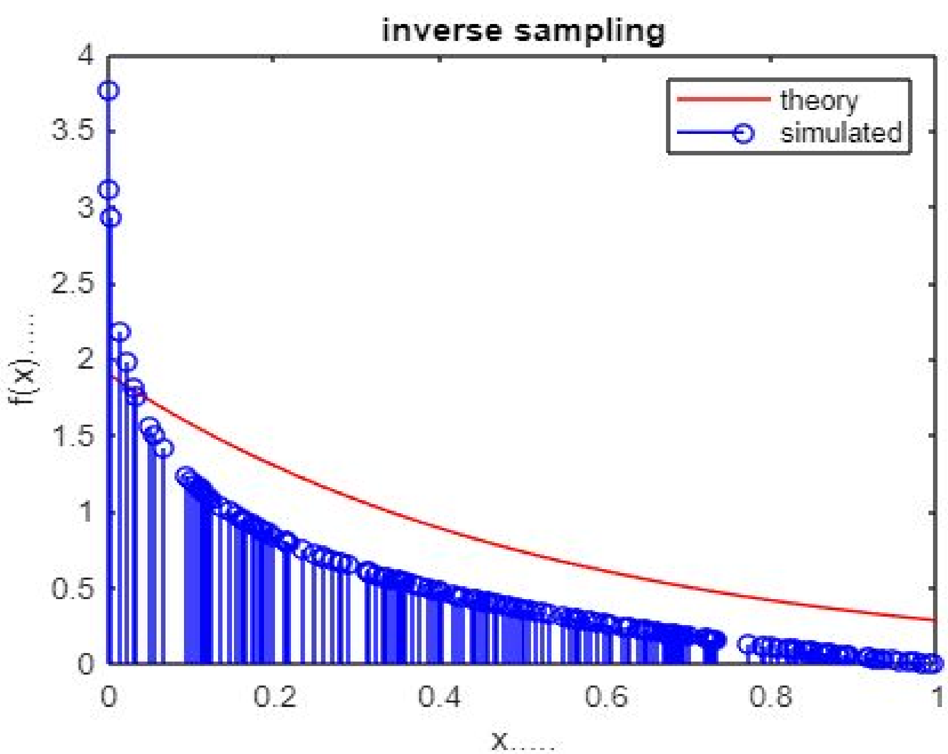
In order to perform an inversion we want to solve for F(F^{-1}(u))=u

$$
\begin{aligned}
F(F^{-1}(u)) &= u \\
1-\exp\left(-\sqrt{F^{-1}(u)}\right) &= u \\
F^{-1}(u) &= (-\log(1-u))^2 \\
&= (\log(1-u))^2
\end{aligned}
$$

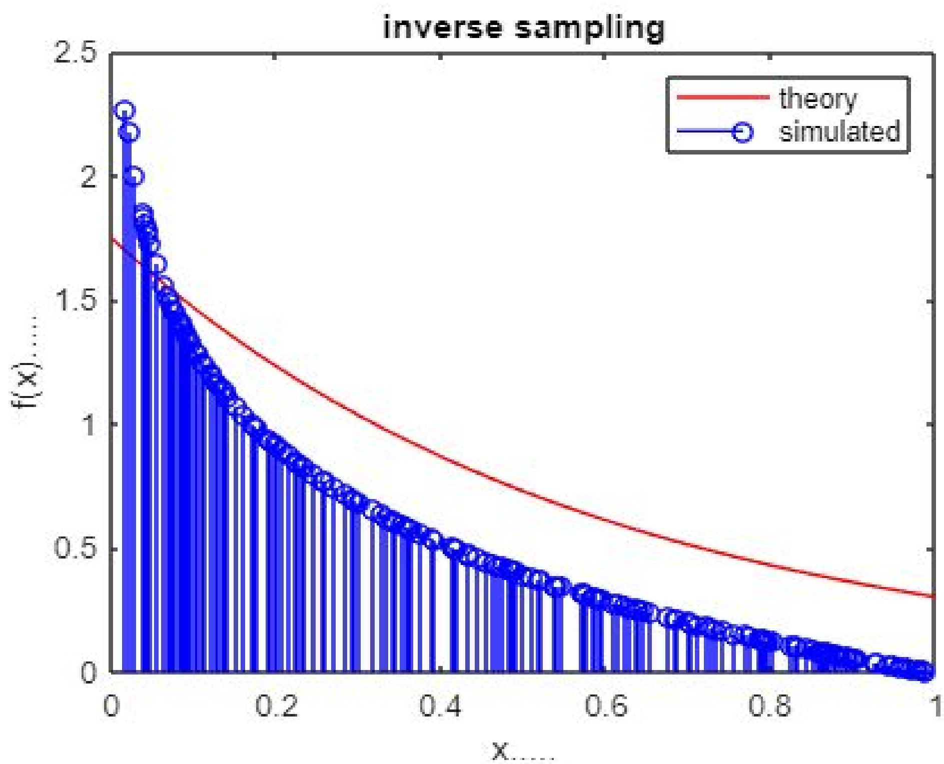
4.1 inverse sampling simulation results

Blue colour represent the inverse sampling simulation performance, Red colour represent the theory. Simulation performance is following closely to the theory. We can observe that when lambda value is increasing the error between theoretical graph and simulation is increasing.

For lamda=1.9



For lamda=1.75



4.2 Conclusion

1. Need analytic form or approximation of inverse cdf.
2. Doesn't work with unnormalized entities
3. Doesn't work for high dimensional problems.
4. used in univariant problems.
5. And finding cdf of all distributions is difficult.

so we go for inverse laplace transform sampling method.

5 Inverse laplace transform sampling

The inverse Laplace transform of the function Y(s) is the unique function y(t) that is continuous on [0 , ∞) and satisfies L[y(t)]= Y(s). If all possible functions y(t) are discontinuous one can select a piecewise continuous function to be the inverse transform.

$$L^{-1}[Y(s)]=y(t)$$

We know that PDF and MGF are laplace transform pairs.in the previous method of generating random variables we ensure some drawbacks to avoid it we will use this inverse laplace transform sample,ng method.in this method we will take the moment generating function and find it;s inverse laplace transform thus gets probability distribution function.but finding inverse laplace transform is a difficult task .To overcome it we have used an approach of finding inverse.The derivation follows as

$$\begin{cases} \hat{P}_X(s) = \int_0^{\infty} P_X(x) e^{-sx}\, dx \\ P_X(x) = \frac{1}{2\pi j} \int_{a-j\infty}^{a+j\infty} \hat{P}_X(s) e^{sx}\, ds \end{cases}$$

On considering these conditions

1. x is a positive random variable
2. Probability density function of x is real
3. Frequency spectrum of real part in s-domain is even

By solving we got

$$
\begin{aligned}
&P_X(x; A, N, Q) \\
&\quad = \sum_{q=0}^{Q} 2^{-Q} \binom{Q}{q} \\
&\qquad \cdot \left[\frac{e^{A/2}}{x} \sum_{n=0}^{N+q} \frac{(-1)^n}{\beta_n} \mathcal{R} \left\{ \hat{P}_X \left(\frac{A + 2\pi jn}{2x} \right) \right\} \right] \\
&\qquad + E(A) + E(N, Q)
\end{aligned}
$$

where the overall truncation error E(N,Q) term can be estimated by

$$
\begin{aligned}
E(N, Q) \simeq \frac{e^{A/2}}{x} \sum_{q=0}^{Q} 2^{-Q} (-1)^{N+1+q} \binom{Q}{q} \\
\cdot \mathcal{R} \left\{ \hat{P}_X \left(\frac{A + 2\pi j(N + q + 1)}{2x} \right) \right\}.
\end{aligned}
$$

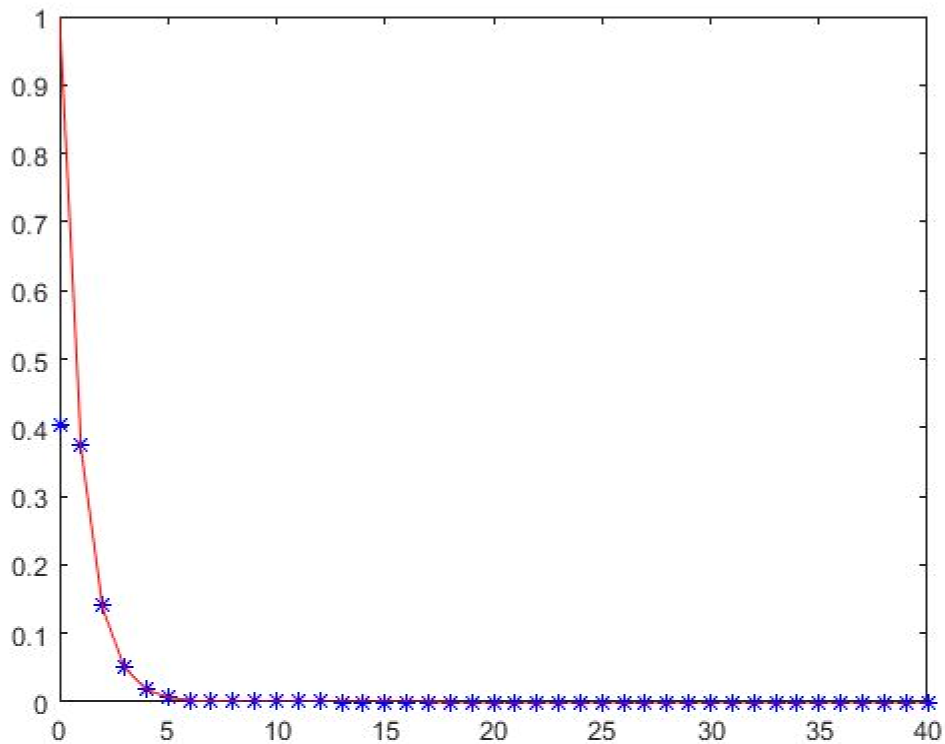
Overall discretisation error E(A) term can be estimated by

E(A)=exp(-A)

Using the above equation we can calculate the inverse laplace transform in matlab.

5.1 Simulation results

Blue colour represents the simulated performance, Red colour represent the theory. Simulated performance is following closely to the theory



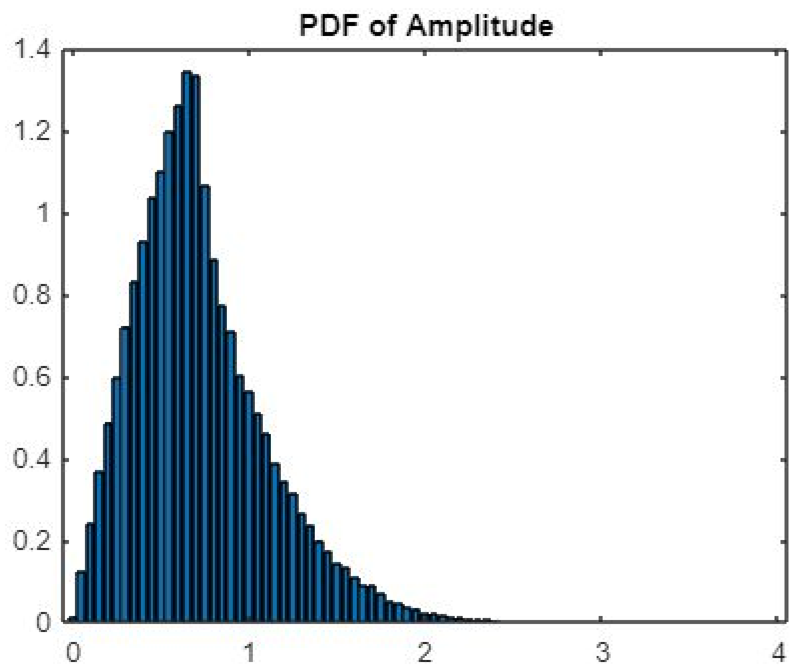
5.2 Conclusion

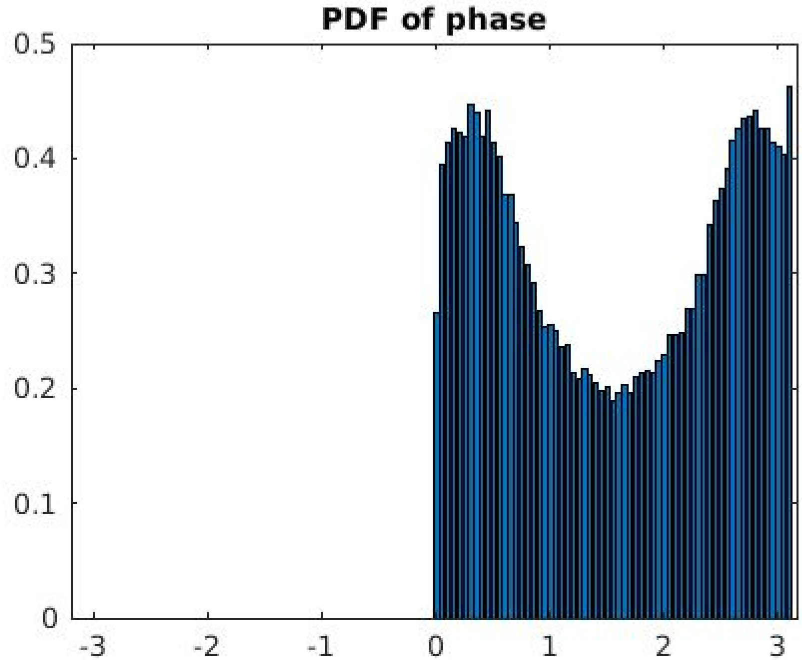
Inverse laplace transform sampling is applicable for only for the function which has x is a positive random variable.Probability density function of x is real.Frequency spectrum of real part in s-domain is even. So we can not apply this to those functions which do not satisfy these conditions

6 Relay channel

Bit error rate of relay channel is the number of bit errors per unit time in a channel between a sender and a receiver.

6.1 simulation results



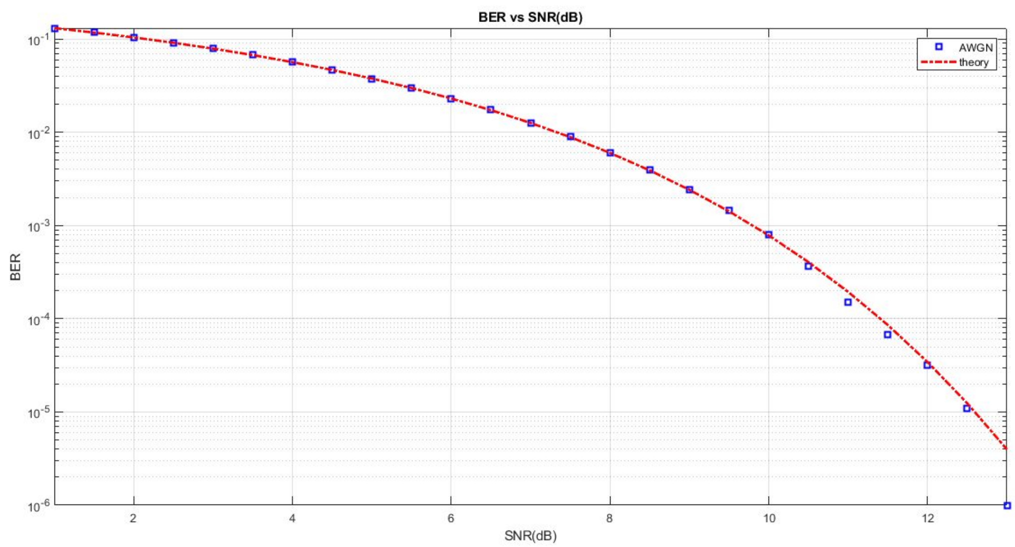

PDF of phase
0.5
0.4
0.3
0.2
0.1
0
-3
-2
-1
0
1
2
3

7 Bit error rate of AWGN channel

1. Additive gaussian noise will effect AWGN channel.
2. AWGN channel noise distribution.

7.1 simulation results

Blue colour represent the bit error rate of BPSK simulation performance, Red colour represent the theory. Simulation performance is following closely to the theory.

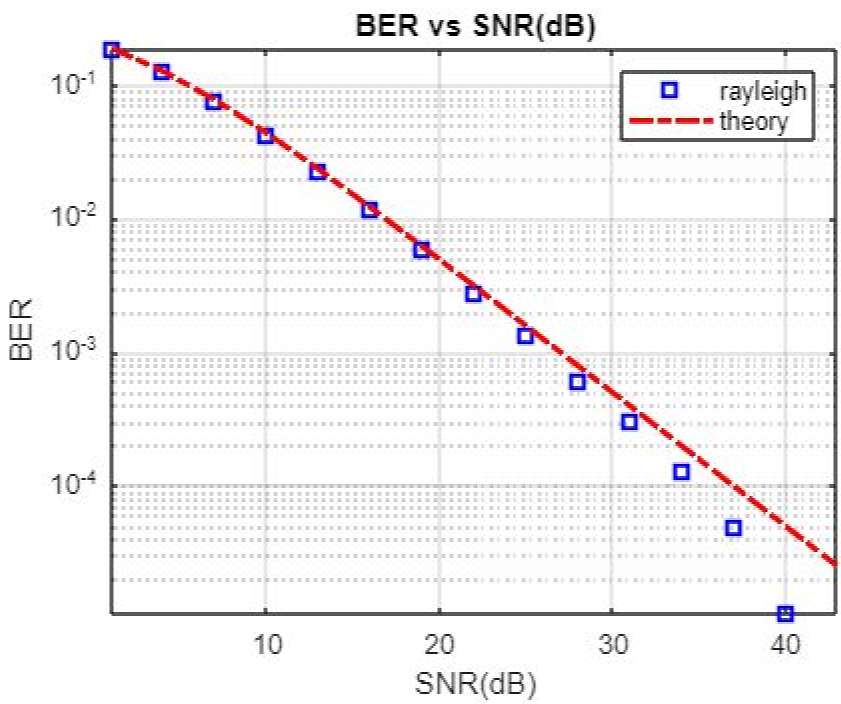


8 bit error rate of rayleigh fading system

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices.Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. Rayleigh fading channel is the combination of relay channel which is affected with white gaussian noise.

8.1 simulation result

Blue colour represent the rayleigh bit error rate of BPSK simulation performance, Red colour represent the theory. Rayleigh Simulation performance is following closely to the theory.



9 Conclusion

Bit error rate of fading system is more compared to AWGN channel. This is due to in wireless communication more noise is added and the line of site component is low so error is high.

10 References

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