# Simulation of communication channels and Cognitive radio using spectrum sensing

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# Overview

# Inverse laplace transform

- Moment generating function and pdf are laplace transform pairs.
- Generation of random variable using it's mgf.
- conversion of mgf to pdf can be done by the expression

$$P_X(x; A, N, Q) = \sum_{q=0}^{Q} 2^{-Q} \binom{Q}{q} \frac{e^{\frac{A}{2}}}{x} \sum_{n=0}^{N+q} \frac{(-1)^n}{\beta_n} \Re\left\{ P_X\left(\frac{A + 2\pi j n}{2x}\right)\right\} + E(A) + E(N, Q)$$

$$E(N, Q) \approx \frac{e^{\frac{A}{2}}}{x} \sum_{q=0}^{Q} 2^{-Q} \, (-1)^{N+1+q} \binom{Q}{q} \Re\left\{ P_X\left(\frac{A + 2\pi j(N + q + 1)}{2x}\right)\right\}$$

$$E(A) = \; e^{-A}$$

# simulation results

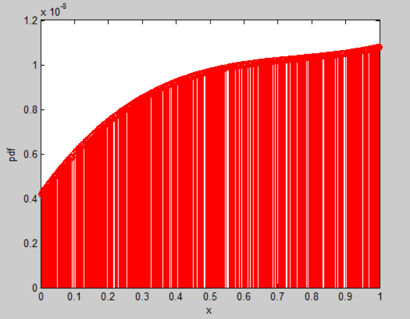


Figure: pdf of gamma function $\alpha = 7, \beta = 8$

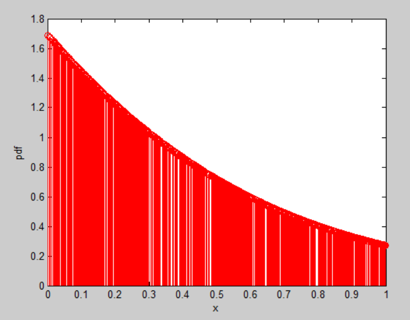


Figure: pdf of exponential function $\alpha = 1, \beta = 0.5$

# conclusion

1. Applicable only for the function which has $X$ as a positive random variabl
2. Probability density function of $X$ is real.
3. 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.

# Maximal Ratio Combining

Maximum-ratio combining (MRC) is a method of diversity combining in which:

1. The signals from each channel are added together.
2. The gain of each channel is made proportional to the rms signal level and inversely proportional to the mean. square noise level in that channel.
3. different proportionality constants are used for each channel.
4. Maximum-ratio combining is the optimum combiner for independent additive white Gaussian noise channels.
5. MRC can restore a signal to its original shape.

Theoritical BER for MRC is

$$\frac{1}{(2\mathrm{SNR})^N}\binom{2N-1}{N}$$

N = number of antennas.

# MRC block diagram

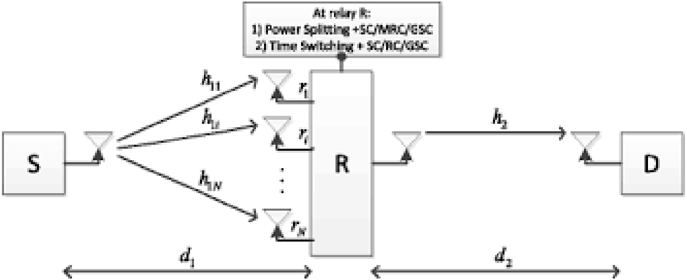


Figure: block diagram of MRC

# Simulation reslts

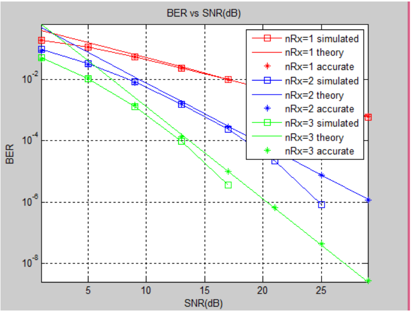


Figure: BER of MRC for different no.of antennas

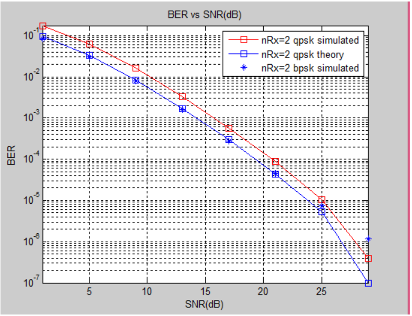


Figure: BER of MRC for QPSK and BPSK

# conclusion

1. If no.of receiving antennas increases then bit error rate decreases.
2. BER of QPSK is greater than BER of BPSK.
3. If number of antennas are increasing then signal will be received exactly.

# Multiple Input Multiple Output

1. MIMO is highly used in 3G and 4G technologies.
2. MIMO can increase reliability.
3. MIMO increases the data transmission rate.
4. Using MIMO we can send more data in less time.

The theoritical BER of MIMO is same as theoritical BER of MRC .But the no.of antennas are taken as $N = R - T + 1$. Where
$T$ =no.of transmitting antennas
$R$ =no.of receiving antennas
So BER of MIMO is

$$\frac{1}{(2\mathrm{SNR})^N}\binom{2N-1}{N}$$

Where $N = R - T + 1$

# Simulation results

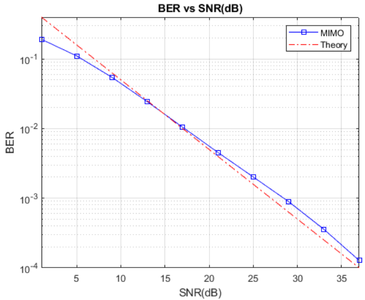


Figure: BER of MIMO Channel

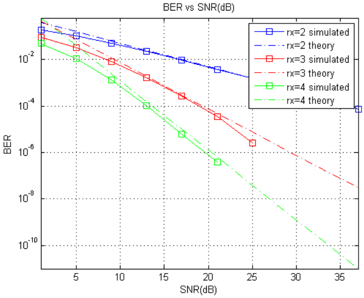


Figure: BER of of MIMO with increasing no.of receiving antennas

# Conclusion

1. The BER of MIMO channel decreases with increasing number of transmitting antennas.
2. installation Cost is high.

# Orthogonal Frequency Division Multiplexing

OFDM is a method of encoding a digital data on multiple carrier frequencies,orthogonal sub-carrier signals with overlapping spectra are transmitted to carry data in parallel.
Genarally in FDM guard bands are required to protect the leakage adjacent interference,where as in OFDM we overlap the sub carriers orthogonally which consumes low bandwidth.
Theoritical BER of OFDM is

$$BER = \frac{1}{2}(1 - \sqrt{\frac{\frac{L}{N}\mathrm{SNR}_{Tx}}{2 + \frac{L}{N} text SNR_{Tx}}})$$

$$\mathrm{SNR}_{Tx} = \frac{P}{\sigma^2}$$

$$\mathrm{SNR}_{Rx} = \frac{LP}{\sigma^2}$$

# Block diagram of OFDM

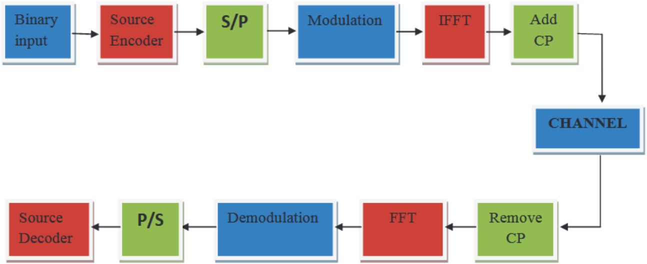


Figure: block diagram of OFDM

# Simulation results

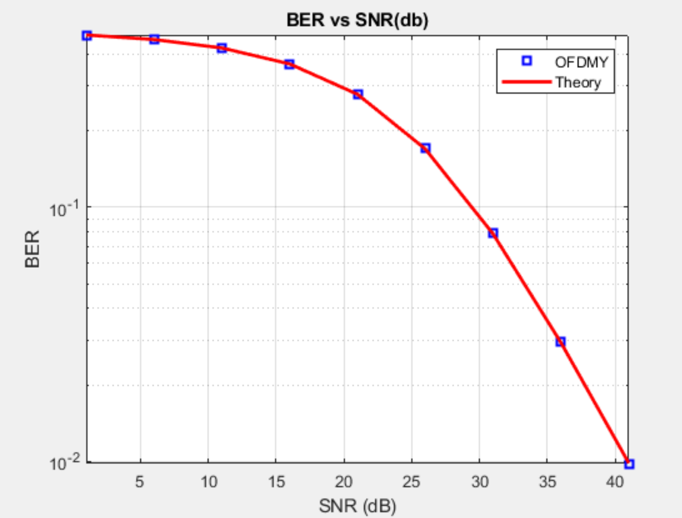


Figure: BER of OFDM Using BPSK

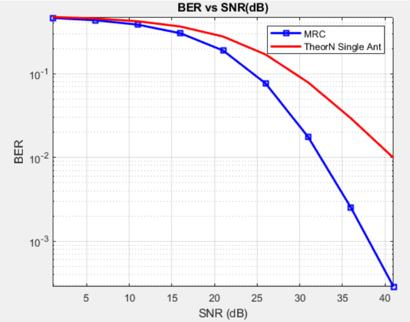


Figure: BER of OFDM with MRC

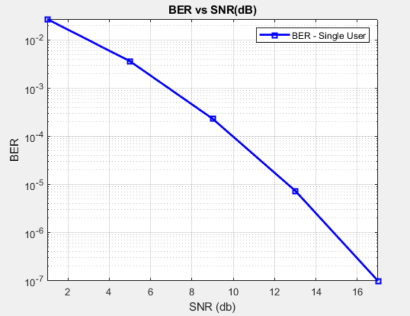


Figure: BER of OFDM with MIMO

# Conclusion

1. By using OFDM we can decrease the bandwidth.
2. Inter Symbol Interference (ISI) is reduced.
3. Storage decreases.
4. we will have Effective data transmission in OFDM.

# Cognitive Radio

In general Radio Spectrum is categorised into two types
1. licensed - assigned exclusively to operators for independent usage.
2. unlicensed - assigned to every citizen for non-exclusive usage subject to some regulatory constraints.
The spectrum hasn't been utilized efficiently and most of the frequency bands are only used for a short time and left unused for the rest of the time. To overcome this problem we go through Cognitive Radio.

# Introduction to cognitive radio

The main motto of CR is to provide spectrum access to secondary users through dynamic spectrum access to improve spectrum efficiency.

CR can operate in 3 modes

1. Underlay
2. Interweave
3. Overlay

In the Cognitive Radio concept, spectrum sensing plays a vital role in improving the spectrum efficiency by giving information on to what extent the spectrum is being utilized.

# Spectrum Sensing

Spectrum sensing is used to provide the information on the RF spectrum, i.e., whether the spectrum is free or occupied.
Spectrum sensing regularly monitors the spectrum and finds out the underutilized spectrum to allocate it to a user.
Spectrum sensing can be done using two methods. They are

- Matched filter Detector
- Energy detector

Matched filter detector uses the knowledge of channel state information(CSI) which is not available at all given times. Moreover, energy detector is very easy to implement.

# Spectrum Sensing using Energy Detector

The energy detector measures the energy of the received signal. At the energy detector, a binary hypothesis test is used to formulate the received signal, $y(t)$. The hypothesis test is as follows

$$H_0 \Rightarrow y = n$$

$$H_1 \Rightarrow y = hx + n$$

Hypothesis 0 ($H0$) means the Primary User's signal is absent and Hypothes is 1 ($H1$) means the Primary User's signal is present.
Let $|\bar{y}|^2$ be the energy of the $\bar{y}$. This value is compared with the threshold value, $E_t$, to decide the outcome of the energy detector.

$$|\bar{y}|^2 < E_t \Rightarrow H_0$$

$$|\bar{y}|^2 \geq E_t \Rightarrow H_1$$

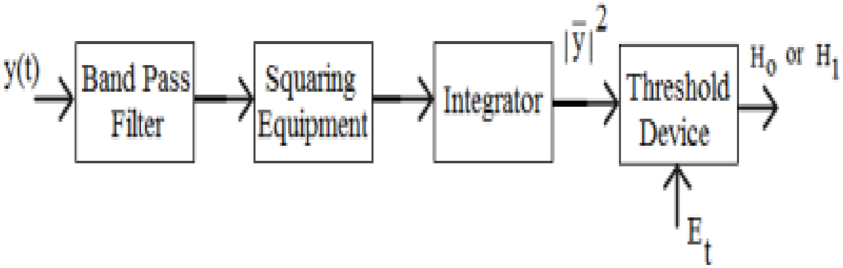


Figure: Block diagram of Energy Detector

# Performance Parameters of Energy Detector

- Probability of Detection ($P_D$)
  The probability of detection indicates the probability that the signal is detected by the energy detector when the spectrum actually contains the signal. It is the probability that $H_1$ is detected as $H_1$.
- Probability of False Alarm ($P_{FA}$)
  The probability of false alarm indicates the probability that the signal is detected by the energy detector when the spectrum is empty. It is the probability that $H_0$ is detected as $H_1$.

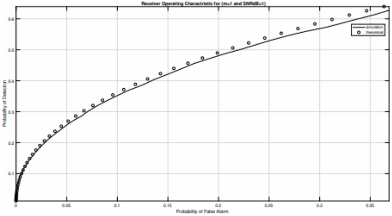


Figure: Characteristics of the energy detector for m=1 and SNRdB=1

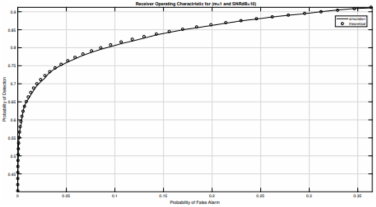


Figure: Characteristics of the energy detector for m=1 and SNRdB=10

# Conclusion

1. A better insight into the need of the spectrum sensing process is given.
2. The energy detector correctly detectsthe spectrum if the SNR of the received signal is high.

# References

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Thank you