<u>Mobile and Personal Communications</u>

Homework Assignment – 2019

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1.What is PCS? How is it different from Cellular?

Ans) Cellular is dual-classified as being inclusive of both analog and digital networks. Cellular networks began with analog infrastructures, and over time migrated this infrastructure to digital. In a cellular network, depending upon your location throughout the world, the operation frequencies are 800MHz to 900MHz band. Cellular infrastructure is generally based on a macro cell architecture. Macro cells involve a coverage area with a diameter of around 8 miles, and because of this large coverage area, cellular operates at high power levels, in a range of .6 to 3 watts.

Whereas PCS is a more recent technology, and has been all digital since inception. As with cellular, depending upon where you are located in the world, the frequency band of operation is in the 1.8GHz to 2GHz band. Instead of cellular macro cells, PCS uses two different infrastructures, both microcell and picocell. As these names imply, the coverage areas of these architectures are smaller than macro cells, around 1 mile in diameter. As a result, PCS uses much lower power levels – 100 milliwatts.

So, the key differences between PCS and cellular are the frequencies in which they operate, coverage areas of their different cell architectures, and the power levels each uses to transmit signals. They work essentially the same way, use the same types of network elements, and perform the same functions.

2. Why do we use interleaving? What is the trade-off when using it?

Ans) Interleaving is the reordering of data that is to be transmitted so that consecutive bytes of data are distributed over a larger sequence of data to reduce the effect of burst errors. The use of interleaving greatly increases the ability of error protection codes to correct for burst errors. Basically, most error correction coding techniques are good at suppressing bit-wise errors which are independent and random. However, when channels are not memoryless, there could be burst errors. i.e. several bit errors are likely to see in close by given the first bit error occurs. Hence, in such cases typical ECCs gets much weaker.

Interleaving resolves this very efficient way. Basically, we take a block of bits and interleave it in a particular known order. Now when a burst error occurs, after the de-interleaving at receiver the effected bits are now speared apart much more than the original burst. And hence it improves the work of ECC significantly.

3. Compare the first-generation analog and second-generation digital systems

Ans) First generation is designed for Basic voice service using Analog based protocols. It was deployed in 1970-84 with bandwidth of 2kbps. First generation used Frequency Division Multiplexing (FDMA) with Horizontal Handoff techniques.

However, second gen is also designed for voice service but with improved coverage and capacity. Even the bandwidth is increased up to 14-64 Kbps. 2^{nd} Gen was deployed in Early 1999 using TDMA (time division Multiplexing) and CDMA (Code division Multiple Access). Short messaging is also started through this technology. It also used the same Horizontal handoff techniques.

4. Explain the relationship between cluster size, capacity, and co-channel interference

Ans) To increase the capacity of a system we need to keep the interference to minimum or try to decrease the created interferences. One of it is Co-channel interference. Co-channel interference occurs between two access points (APs) that are on the same frequency channel. To reduce the Co channel Interference, we use a process called “Clustering”. It a process of diving the channel into clusters A **cluster** is group of cells in which no frequency is reused within a cluster. Frequencies used in one cell cluster can be reused in another cluster of cells. If clusters size increases the number of channels per cell decreases, capacity decreases. On the other hand, co channel reuse ratio increases increasing CIR.

5. What are the possible solutions to increase capacity of cellular systems? Explain how and indicate if there are any drawbacks in your solution.

Ans) We have many solutions to increase the capacity of Cellular system. Few of them are adding new channels, frequency borrowing, cell splitting, cell overlay, sectorization and HetNets. Every solution has some disadvantages included in them. Such as

Sectorization is dividing a cell into sectors to reduce the interference and increase the capacity. It also allows low cluster size. It allows transmission in single direction to reduce the wastage of transmission energy. But it has so much complexity, increased handoff and decrement in trunking efficiency.

Cell splitting is dividing the cell into several micro cells with in the own base station. It also increases capacity by giving more frequency reuse. But it comes with more handoff.

Like this every solution have some small drawbacks while every solution improves capacity at huge.

6. Is co-channel interference a function of transmitted power from cell site? Explain

Ans) Yes, it is a function of transmitted power. Transmitter power control, however, can also be used to control cochannel interference, i.e. interference from other users using the same channel. Co channel interference can be present also in systems with perfectly orthogonal signals (for instance "ideal" TDMA, FDMA). By proper power adjustment, the detrimental effects of co-channel interference can be reduced. This allows for a “denser” reuse of resources and thus higher capacities. So, we basically plan to choose the transmitter powers in each base-mobile link such that a sufficient transmission quality (signal-to-interference ratio) is maintained in all communication links.

7. Discuss how to reduce CCI with sectorization.

Ans) Sectorization is dividing a cell into sectors to reduce the interference and increase the capacity. One way to increase the subscriber capacity of a cellular network is replace the omni-directional antenna at each base station by three (or six) sector antennas of 120 (or 60) degrees opening. Each sector can be considered as a new cell, with its own (set of) frequency channel(s).

The base station can either be located at the center of the original (large) cell, or the corners of the original (large) cell.

The use of directional sector antennas substantially reduces the interference among co-channel cells. This allows denser frequency reuse. Sectorization is less expensive than cell-splitting, as it does not require the acquisition of new base station sites. It improves S/I ratio and reduces interference which increases capacity. Main advantages are that it reduces cluster size and provides additional freedom in assigning channels.

8. a. Describe ACI problem and how it effects the communication signal. b. How can we reduce ACI?

Ans) a) Adjacent channel interference is the interference from neighboring carriers. It happens when power of signal transmitter in our channel interferes with the other user's channel. The adjacent-channel interference which receiver A experiences from a transmitter B is the sum of the power that B emits into A's channel known as the "unwanted emission", and represented by the ACLR (Adjacent Channel Leakage Ratio)—and the power that A picks up from B's channel, which is represented by the ACS (Adjacent Channel Selectivity). B emitting power into A's channel is called adjacent-channel leakage. The problem can be particularly serious if an adjacent channel user is transmitting in very close range to a subscriber's receiver while the receiver attempts to receive a base station on the desired channel. This is called Near-far effect. This effects the communication signal as when a mobile close to a base station transmits on a channel close to one being used by a weak mobile. So, the base station may have difficulty in discriminating the desired mobile user from the bleed over caused by the close adjacent channel mobile creating distortion, noise and interference.

B) Adjacent channel interference can be minimized through careful filtering and channel assignments. By keeping the frequency separation between each channel in a given cell as large as possible, the adjacent channel interference may be reduced considerably. Thus, instead of assigning channels which form contiguous band of frequencies within a particular cell, channels which form a contiguous band of frequencies within a particular cell, channels are allocated such that frequency separation between cells should be maximum.

9. a. If the call arriving rate is 10 calls per minute. Average call holding time is 3 minutes. Calculate traffic intensity. b. Define GOS. Is it better to increase or decrease it?

a) The traffic intensity (E)= λt_h where λ = Call Arrival rate (Call/ Hour) ; t_h = Mean holding time (Hours/call)

$$\lambda = 10 \text{ Calls/min} = 600 \text{ calls /hour} ; t_h = 3 \text{ min/call} = 3/60 \text{ hour/ call}.$$

$$E = 600 * (1/20) = 30 \text{ Erlang}.$$

b) Grade of service (GOS) is measure of the ability of user to access trunked system during busiest hour. GOS sometimes called blocking probability (Pb). We need to decrease the Blocking probability as much as possible. We need to keep it minimum so that we can't get our call blocked frequently.

10.What does 3G means, what are some of the main features of 3G?

Ans) 3G means 3rd Generation. It is the upgrade for 2G and 2.5G GPRS networks, for faster data transfer speed. The first commercial 3G networks were introduced in 2000. The main features of 3G are wireless voice telephony, mobile Internet access, fixed wireless Internet access, video calls and mobile TV. 3G telecommunication networks support services that provide an information transfer rate of at least 144 kbit/s. 3rd generation uses Code Division Multiple Access (CDMA) with Horizontal Handoff techniques. It has bandwidth up to 2mbps.

11. Why does the radio channel vary? what is the effect of this variation?

Ans) Radio channels vary because of the variation in land masses from area to area. We have land with mountains, big building, trees which object the channels during the signal flow. Due to interfering of these elements the radio channel varies frequently from place to place. The effect of this variation is that different places need different transmitting powers taking the land masses into account. So during building of channel, we need to take care of all objects interfering the flow of medium and introduce transmitting power according to that.

12. What is the cause of inter-symbol interference (ISI), when do we observe ISI?

In time domain, received signals corresponding to successive transmitted symbols through frequency-selective fading channel will overlap, giving rise to a phenomenon called inter-symbol interference (ISI). ISI degrades transmission performance, which can be overcome by the channel equalization techniques

13. State the difference between long term and short-term fading?

Short-term fading is rapid fluctuations caused by the local multipath (e.g., Rayleigh fading) Long-term fading is long-term slow variation in the mean level of received signal strength (e.g., Lognormal fading) caused by movement over large enough distance

14. Describe delay spread and coherence bandwidth. Explain their relation between each other.

Ans) In telecommunications, the **delay spread** is a measure of the multipath richness of a communications channel. In general, it can be interpreted as the difference between the time of arrival of the earliest significant multipath component (typically the line-of-sight component) and the time of arrival of the last multipath components. The delay spread is mostly used in the characterization of wireless channels, but it also applies to any other multipath channel (e.g. multipath in optical fibers).

Coherence bandwidth is a statistical measurement of the range of frequencies over which the channel can be considered "flat", or in other words the approximate maximum bandwidth or frequency interval over which two frequencies of a signal are likely to experience comparable or correlated amplitude fading.

Coherence bandwidth is related to the inverse of the delay spread. The shorter the delay spread, the larger is the coherence bandwidth. If the multipath time delay spread equals *D* seconds, then the coherence bandwidth W_c in rad/s is given approximately by the equation:

$$\mathbf{W_c = 2\pi/D}$$

15. Describe coherence time and maximum Doppler spread. Explain their relation between each other.

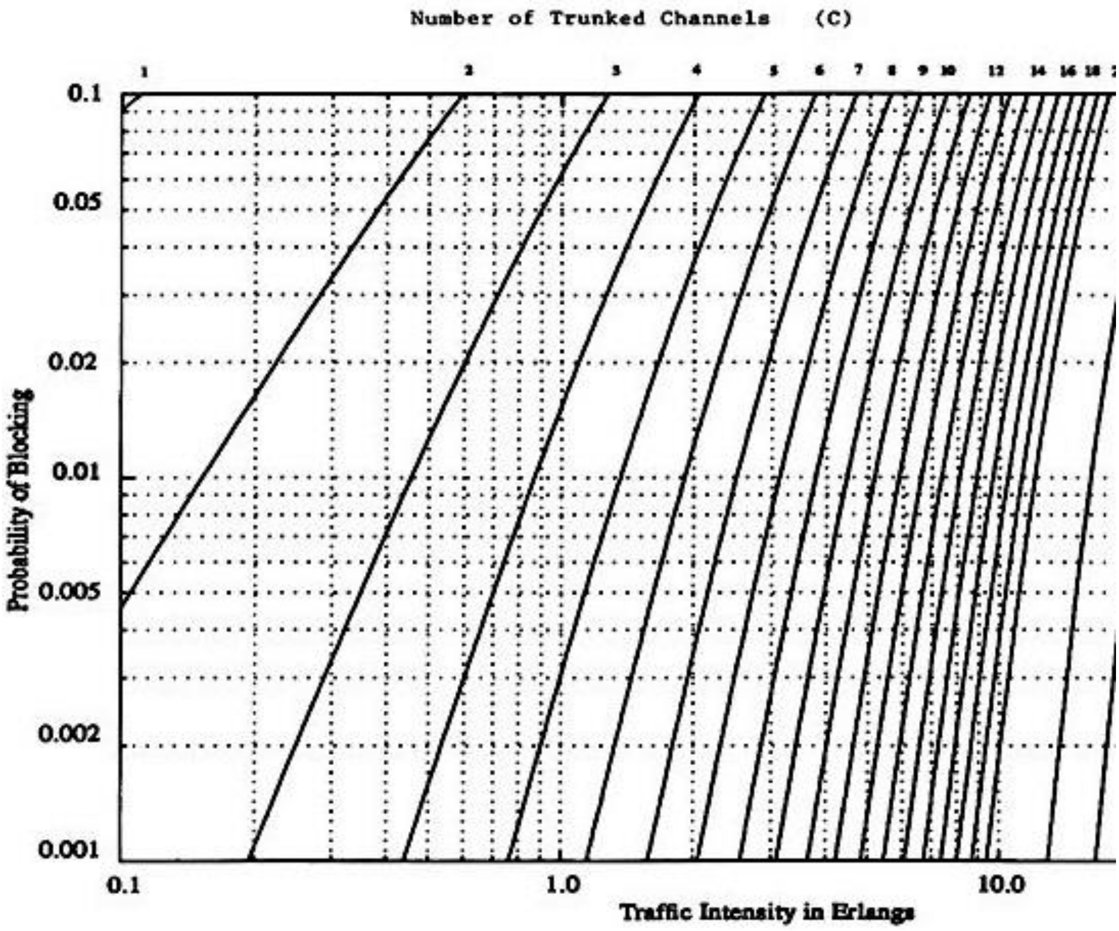
Ans) Coherence time is the time duration over which the channel impulse response is considered to be not varying. Basically, Coherence time is a statistical measure of the time duration over which the channel impulse response is essentially invariant, and quantifies the similarity of the channel response at different times. If the time interval between the signal transmissions is much greater than the coherence time, the channel will likely affect the two signal transmissions differently; otherwise, they will be affected similarly.

Doppler spread B_d is a measure of spectral broadening caused by the time rate of change of the mobile radio channel and is defined as the range of frequencies over which the received Doppler spectrum is essentially nonzero. When the bandwidth of the transmitted signal is much larger than the Doppler spread, the effects of the Doppler spread are negligible at the receiver.

Doppler spread and coherence time are parameters that describe the frequency-dispersion nature of the mobile channel. The Doppler spread is inversely proportional to the coherence time, and we thus have the following:

$$\mathbf{B_d=1/T_c}$$

16. Plot the GOS versus number of channels for 10 Erlang traffic intensity.



17. Following problems require MATLAB coding.

a. AWGN signal analysis

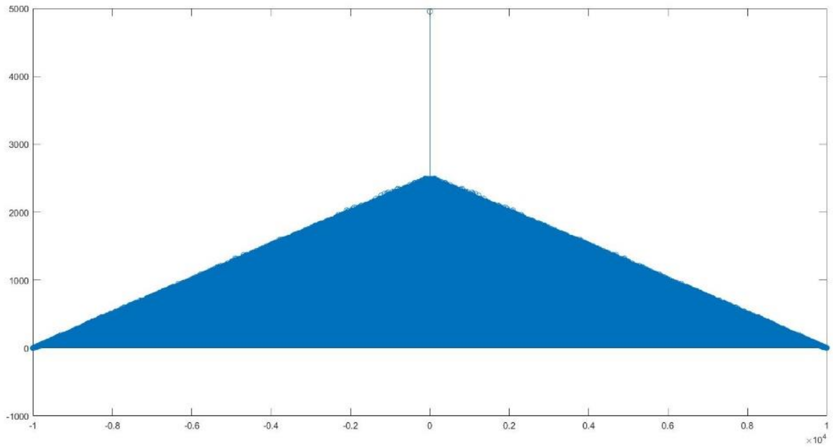
MATLAB CODE :

```
%Generate random bits (10000 bits) with values 1 and 0
rand_bin = round(rand(1,10000));
%Plot the bit correlation values (autocorrelation of bit values)
[c,lags] = xcorr(rand_bin);
stem(lags,c)
%Assume a repetition of 3
s=rand_bin
out=repmat(s,3,1)
out=out(:)'
%Apply block interleaving
st1 = 27221; st2 = 4831; % States for random number generator
n = 7; k = 4; % Parameters for Hamming code
msg = randi([0 1],k*500,1); % Data to encode
code = encode(msg,n,k,'hamming/binary'); % Encoded data
```

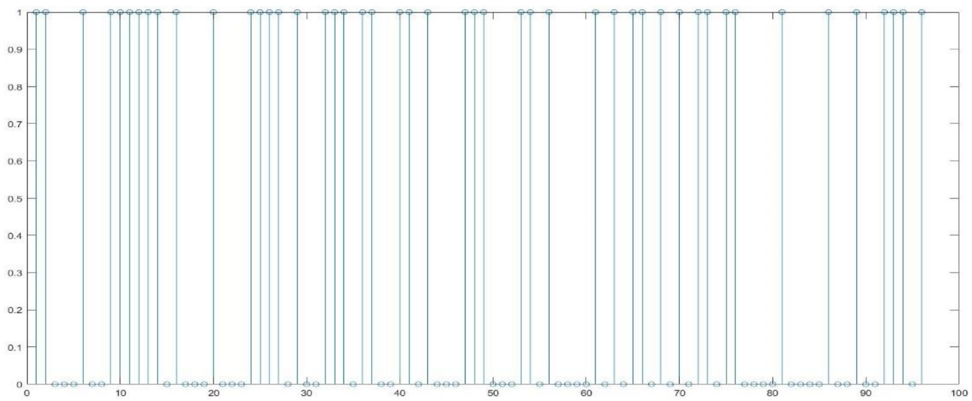
```
% Create a burst error that will corrupt two adjacent codewords.
errors = zeros(size(code)); errors(n-2:n+3) = [1 1 1 1 1 1];
% With Interleaving
%------------------
inter = randintrlv(code,st2); % Interleave.
inter_err = bitxor(inter,errors); % Include burst error.
decoded = decode(deinter,n,k,'hamming/binary'); % Decode.
disp('Number of errors and error rate, with interleaving:');
[number_with,rate_with] = biterr(msg,decoded) % Error statistics
% Create binary data symbols
   data = randi([0 1], 96, 1);
% Create a BPSK modulator System object
   hModulator = comm.BPSKModulator;
% Change the phase offset to pi/16
   hModulator.PhaseOffset = pi/16;
% Modulate and plot the data
   modData = step(hModulator, data);
   scatterplot(modData)
   %Plot the symbol correlation values
   [c,lags] = xcorr(data);
stem(lags,c)
%Generate complex additive white Gaussian noise (AWGN)
t = (0:0.1:10)';
x = sawtooth(data);
y = awgn(x,10,'measured'); %Measuring AWGN
plot(data,[x y])
legend('Original Signal','Signal with AWGN')
%Plot the noise correlation value
[c,lags] = xcorr(y);
stem(lags,c)
%Normalize the noise and find SNR
r = snr(data,y);
% Calculate symbol error rate
[number,ratio]= symerr(data,y);
%Convert symbols to bits
out = lteSymbolDemodulate(x,'QPSK','Hard')
%Apply de-interleaving
deinter = randdeintrlv(inter_err,st2); % Deinterleave.
%calculate bit error rate (BER)
numerrs = biterr(1,data);
%Plot Symbol Error Rate(SER
stem(number,ratio);
%plot BER
stem(numerrs);
%BER versus SNR
plot([number,ratio]);
log([number,ratio]);
```

```
set(gca, 'YScale', 'log');
xlabel("SNR");
ylabel("SER and BER");
% Apply majority voting type
function [result,x]=majority_vote(data,y,numclass)
stem(result)
end
```

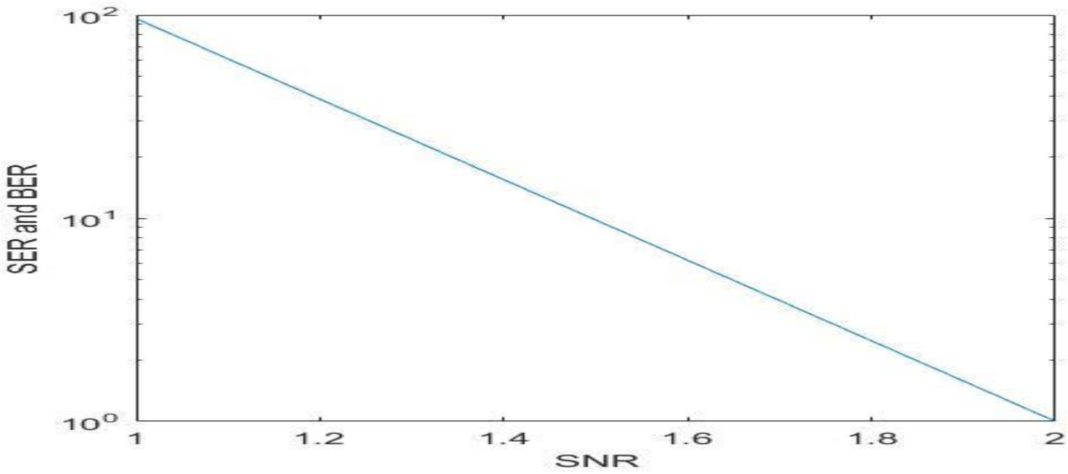
RESULTS: a) Generated Random Bits and their Correalation



b) Loop of SNR with Signal and Noise



C) Final Result



Comments:

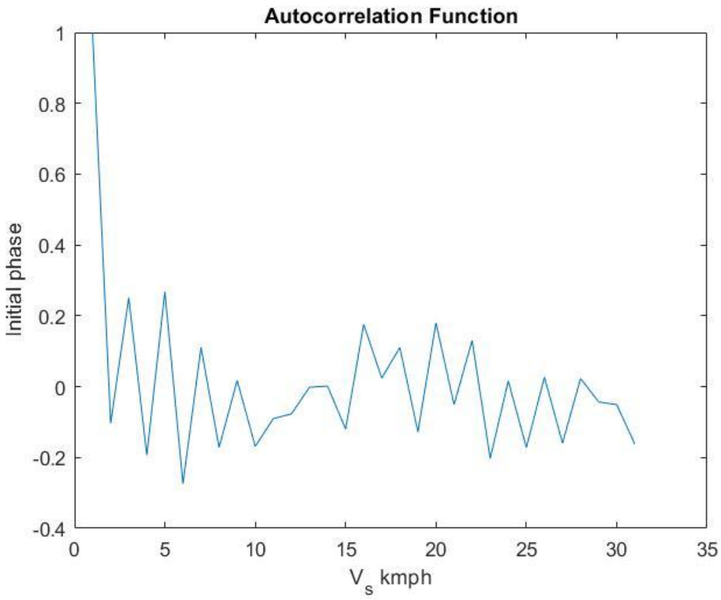
The result shows us the graph of Symbol error rate and Bit error rate versus Signal to noise ratio. It depicts that the increase in signal to noise ratio makes Bit error rate and Symbol error rate to decrease.

After Removing interleaving:

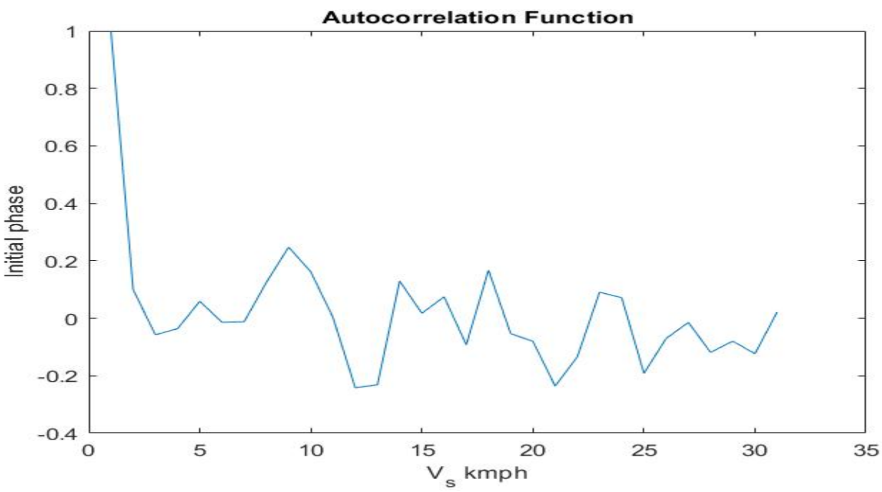
A block interleaver accepts a set of symbols and rearranges them, without repeating or omitting any of the symbols in the set. The number of symbols in each set is fixed for a given interleaver. So when deinterleaving is used the rearrangement is broken and the repetition of symbols may occur.

b. Rayleigh Fading :

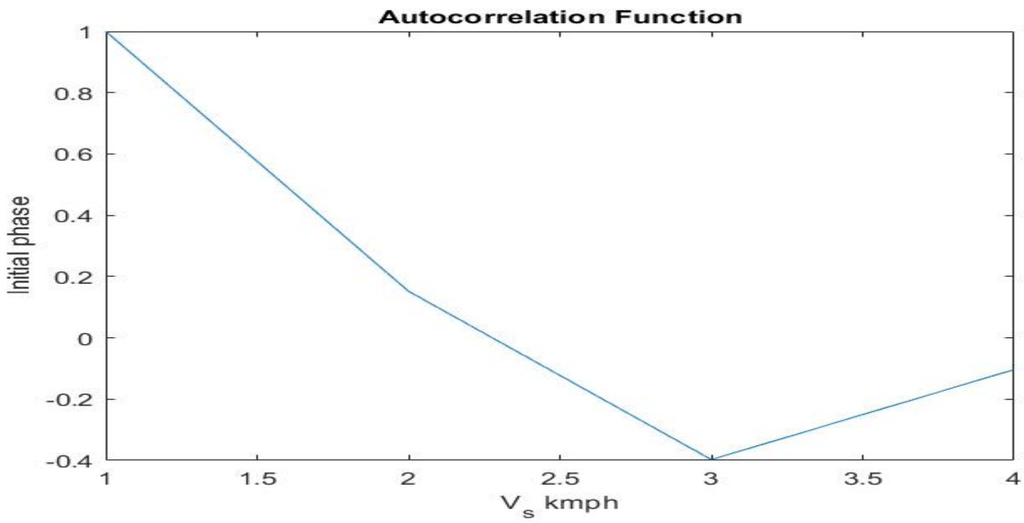
Fc=900e6; vs_kmph=3;



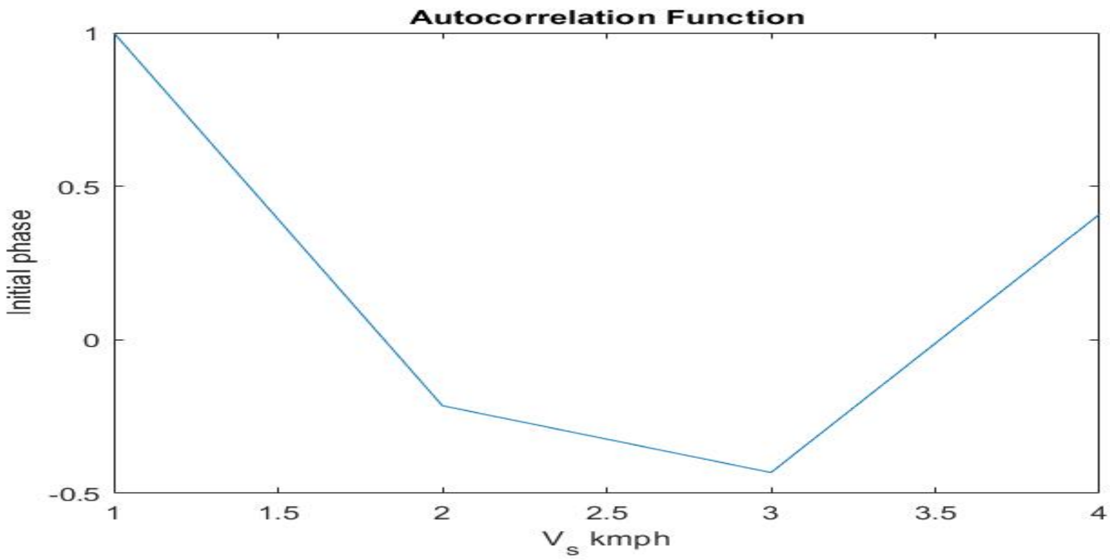
Fc=900e6; vs_kmph=30;



Fc=90000; vs_kmph=30;



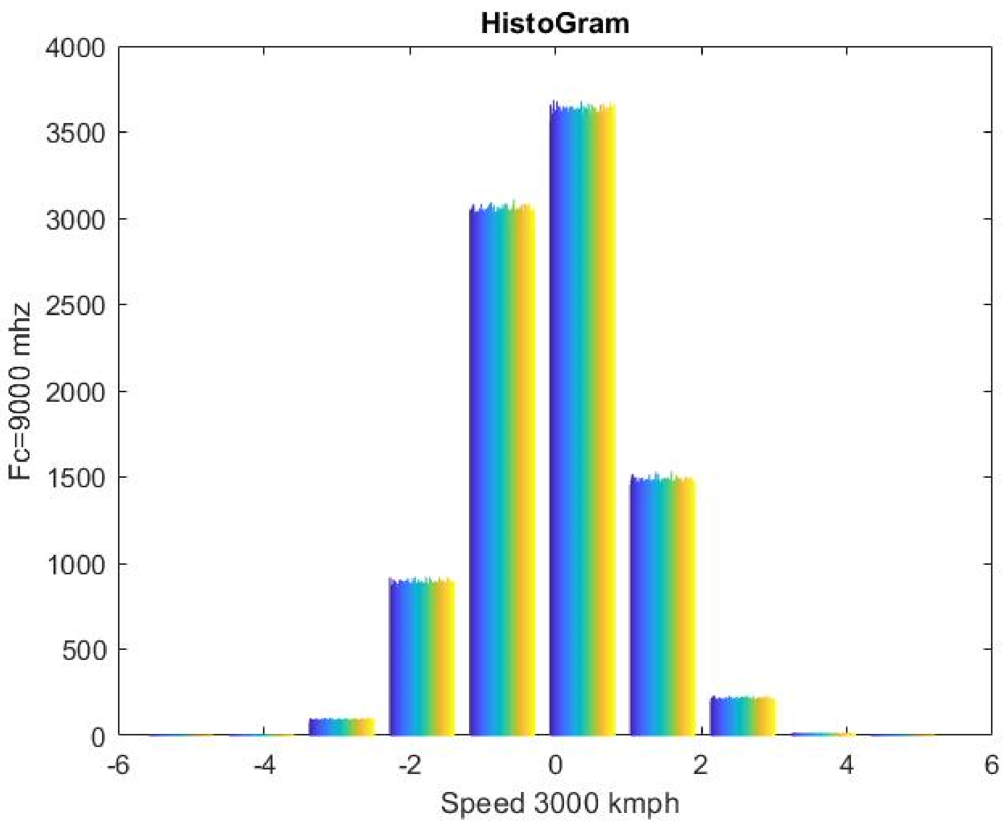
Fc=9000; vs_kmph=3;



HISTOGRAM :

```
Fc=9000;      % Carrier Freq. in Hz (GSM and EDGE
vs_kmph=3000;

x = randn(Fc,vs_kmph);
hist(x)
title("HistoGram")
xlabel(" Speed 3000 kmph")
ylabel("Fc=9000 mhz")
```



<u>Comments:</u>

The result shows us the graph of Speed 3000kmph versus carrier frequency of 9000mhz. It depicts that the variation in speed makes the carrier frequency.

PART 3:

```
Samples_PerSymbol=1;
TSymbol = 1/ (13e6/48); % symbol period (in second) in GSM/EDGE
Fs=(1/TSymbol)*Samples_PerSymbol;  % Sampling frequency of the oversampled rate
No=40; % number of oscillators
initial_phases=2*pi*rand(No,1);
Ns=30000; % number of fading samples
Fc=900e6;      % Carrier Freq. in Hz (GSM and EDGE
```

```
vs_kmph=300;

% With Interleaving
%------------------
inter = randintrlv(code,st2); % Interleave.
inter_err = bitxor(inter,errors); % Include burst error.
decoded = decode(deinter,n,k,'hamming/binary'); % Decode.
disp('Number of errors and error rate, with interleaving:');
[number_with,rate_with] = biterr(msg,decoded) % Error statistics

%Normalize the noise and find SNR
r = snr(Fc,vs_kmph);

%calculate bit error rate (BER)
numerrs = biterr(Fc,vs_kmph);

% Calculate symbol error rate
[number,ratio]= symerr(Fc,vs_kmph);

plot(r,numerrs);
```

Comments:

The result shows us simulation for speed=300 kmph and Fc=900e6 of Symbol error rate and Bit error rate versus Signal to noise ratio. It depicts that the increase in signal to noise ratio makes Bit error rate and Symbol error rate to decrease.

After Removing interleaving:

A block interleaver accepts a set of symbols and rearranges them, without repeating or omitting any of the symbols in the set. The number of symbols in each set is fixed for a given interleaver. So, when deinterleaving is used the rearrangement is broken and the repetition of symbols may occur.