Experiment No: 03

Name of the Experiment: Modelling a Narrowband or Frequency-Flat Fading channel in a wireless communication system by using Rayleigh and Rician multipath fading channel objects and the channel visualization tool.

Objective:

In this experiment we will model a Narrowband or Frequency-Flat Fading channel in a wireless communication system by using Rayleigh and Rician multipath fading channel objects and the channel visualization tool.

Introduction:

Rayleigh fading is a statistical model for the effect of a propagation environment in a radio signal, such as that used by wireless devices. Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium (also called a communication channel) will vary randomly, or fade, according to a Rayleigh distribution — the radial component of the sum of two uncorrelated Gaussian random variables. Rayleigh fading is viewed as a reasonable model for tropospheric and ionospheric signal propagation as well as the effect of heavily built- up urban environments on radio signals. [1] [2] Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. If there is a dominant line of sight, Rician fading may be more applicable. Rayleigh fading is a special case of two-wave with diffuse power (TWDP) fading. Rician fading or Ricean fading is a stochastic model for radio propagation anomaly caused by partial cancellation of a radio signal by itself — the signal arrives at the receiver by several different paths (hence exhibiting multipath interference), and at least one of the paths is changing (lengthening or shortening). Rician fading occurs when one of the paths, typically a line-of-sight signal or some strong reflection signals, is much stronger than the others. In Rician fading, the amplitude gain is characterized by a Rician distribution.

Code:

```
clc;
clear all;

%% Initialization

sampleRate500kHz = 500e3; % Sample rate of 500K Hz
sampleRate20kHz = 20e3; % Sample rate of 20K Hz
```

```
maxDopplerShift  = 200; % Maximum Doppler shift of diffuse
components (Hz)
delayVector = (0:5:15)*1e-6; % Discrete delays of four-path
channel (s)
gainVector  = [0 -3 -6 -9]; % Average path gains (dB)

KFactor = 10; % Linear ratio of specular power to diffuse
power
specDopplerShift = 100; % Doppler shift of specular
component (Hz)



%% Creating Channel System Objects


% Configure a Rayleigh channel object
rayChan = comm.RayleighChannel( ...
    'SampleRate',sampleRate500kHz, ...
    'PathDelays',delayVector, ...
    'AveragePathGains',gainVector, ...
    'MaximumDopplerShift',maxDopplerShift, ...
    'RandomStream','mt19937ar with seed', ...
    'Seed',10, ...
    'PathGainsOutputPort',true);

% Configure a Rician channel object
ricChan = comm.RicianChannel( ...
    'SampleRate',sampleRate500kHz, ...
    'PathDelays',delayVector, ...
    'AveragePathGains',gainVector, ...
    'KFactor',KFactor, ...
    'DirectPathDopplerShift',specDopplerShift, ...
    'MaximumDopplerShift',maxDopplerShift, ...
    'RandomStream','mt19937ar with seed', ...
    'Seed',100, ...
    'PathGainsOutputPort',true);
```

```
%% Modulation and Channel Filtering


qpskMod =
comm.QPSKModulator('BitInput',true,'PhaseOffset',pi/4);

% Number of bits transmitted per frame is set to be 1000.
For QPSK
% modulation, this corresponds to 500 symbols per frame.
bitsPerFrame = 1000;
msg = randi([0 1],bitsPerFrame,1);

% Modulate data for transmission over channel
modSignal = qpskMod(msg);

% Apply Rayleigh or Rician channel object on the modulated
data
rayChan(modSignal);
ricChan(modSignal);



%% Visualization


release(rayChan);
release(ricChan);



%% Wideband or Frequency-Selective Fading


rayChan.Visualization = 'Impulse and frequency responses';
rayChan.SamplesToDisplay = '100%';


% Display impulse and frequency responses for 2 frames
numFrames = 2;
for i = 1:numFrames
    % Create random data
    msg = randi([0 1],bitsPerFrame,1);
    % Modulate data
    modSignal = qpskMod(msg);
```

```
    % Filter data through channel and show channel
responses
    rayChan(modSignal);
end

release(rayChan);
rayChan.Visualization = 'Doppler spectrum';

% Display Doppler spectrum from 5000 frame transmission
numFrames = 5000;
for i = 1:numFrames
    msg = randi([0 1],bitsPerFrame,1);
    modSignal = qpskMod(msg);
    rayChan(modSignal);
end



%% Narrowband or Frequency-Flat Fading

release(rayChan);
rayChan.Visualization = 'Impulse and frequency responses';
rayChan.SampleRate = sampleRate20kHz;
rayChan.SamplesToDisplay = '25%';  % Display one of every
four samples

% Display impulse and frequency responses for 2 frames
numFrames = 2;
for i = 1:numFrames
    msg = randi([0 1],bitsPerFrame,1);
    modSignal = qpskMod(msg);
    rayChan(modSignal);
end

release(rayChan);
rayChan.PathDelays = 0;         % Single fading path with
zero delay
rayChan.AveragePathGains = 0;  % Average path gain of 1 (0
dB)

for i = 1:numFrames % Display impulse and frequency
responses for 2 frames
    msg = randi([0 1],bitsPerFrame,1);
    modSignal = qpskMod(msg);
```

```
    rayChan(modSignal);
end



release(rayChan);
rayChan.Visualization = 'Off'; % Turn off Rayliegh object
visualization
ricChan.Visualization = 'Off'; % Turn off Rician object
visualization

% Same sample rate and delay profile for the Rayleigh and
Rician objects
ricChan.SampleRate = rayChan.SampleRate;
ricChan.PathDelays = rayChan.PathDelays;
ricChan.AveragePathGains = rayChan.AveragePathGains;

% Configure a Time Scope System object to show path gain
magnitude
scope = dsp.TimeScope( ...
    'SampleRate',rayChan.SampleRate, ...
    'TimeSpanSource','Property', ...
    'TimeSpan',bitsPerFrame/2/rayChan.SampleRate, ... % One
frame span
    'Name','Multipath Gain', ...
    'ShowGrid',true, ...
    'YLimits',[-40 10], ...
    'YLabel','Gain (dB)');

% Compare the path gain outputs from both objects for one
frame
msg = randi([0 1],bitsPerFrame,1);
modSignal = qpskMod(msg);
[~,rayPathGain] = rayChan(modSignal);
[~,ricPathGain] = ricChan(modSignal);
% Form the path gains as a two-channel input to the time
scope
scope(10*log10(abs([rayPathGain,ricPathGain]).^2));

%% Fading Channel Impact on Signal Constellation

clear hRicChan hMultipathGain;
release(rayChan);
```

```
rayChan.PathDelays = delayVector;
rayChan.AveragePathGains = gainVector;
rayChan.MaximumDopplerShift = 5;

% Configure a Constellation Diagram System object to show
received signal
constDiag = comm.ConstellationDiagram( ...
    'Name','Received Signal After Rayleigh Fading');

numFrames = 16;

for n = 1:numFrames
    msg = randi([0 1],bitsPerFrame,1);
    modSignal = qpskMod(msg);
    rayChanOut = rayChan(modSignal);
    % Display constellation diagram for Rayleigh channel
output
    constDiag(rayChanOut);
end
```

```
release(rayChan);
release(constDiag);
rayChan.SampleRate = sampleRate500kHz;

for n = 1:numFrames
    msg = randi([0 1],bitsPerFrame,1);
    modSignal = qpskMod(msg);
    rayChanOut = rayChan(modSignal);
    constDiag(rayChanOut);
end
```

Figure:

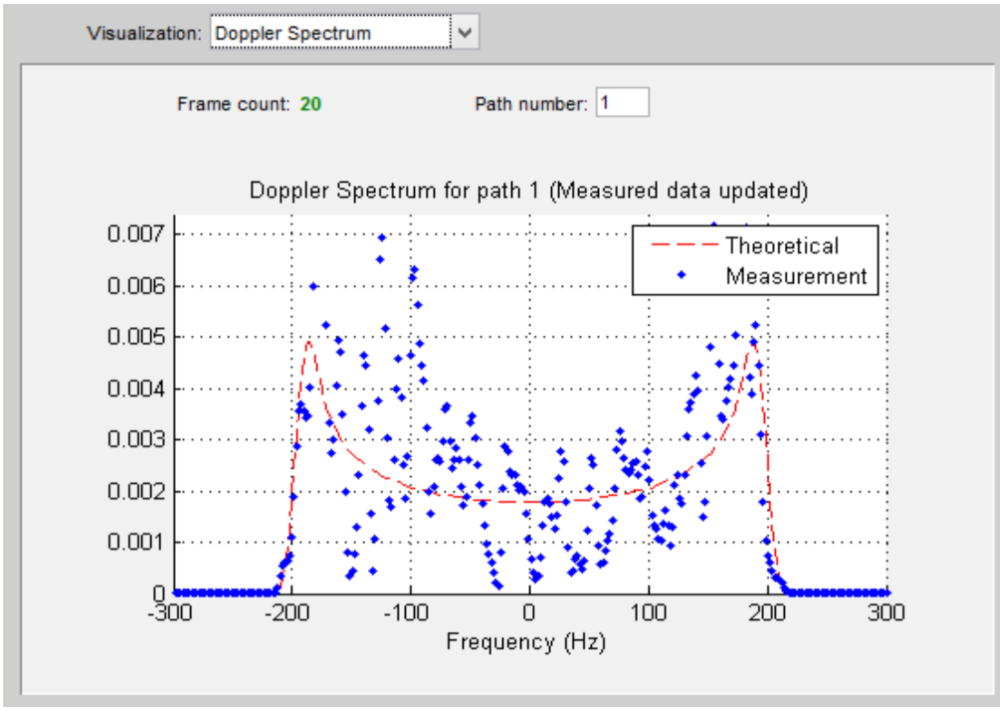

Fig.1(a): Doppler Spectrum QPSK Modulation

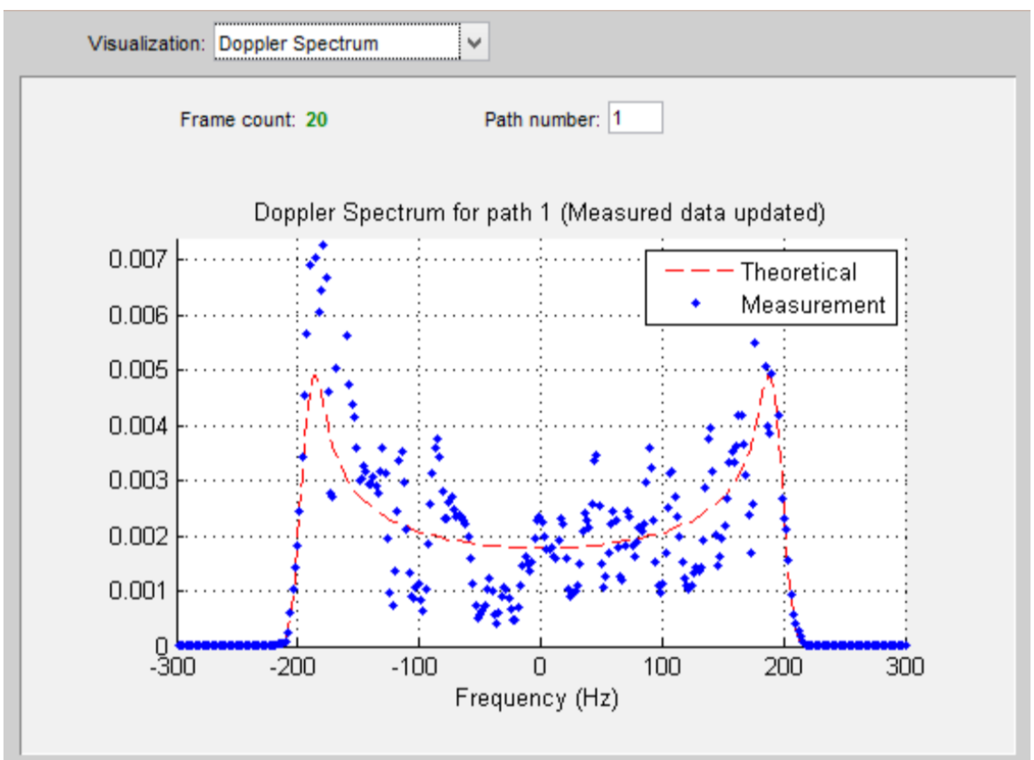

Fig.1(b): Doppler Spectrum 4-QAM Modulation

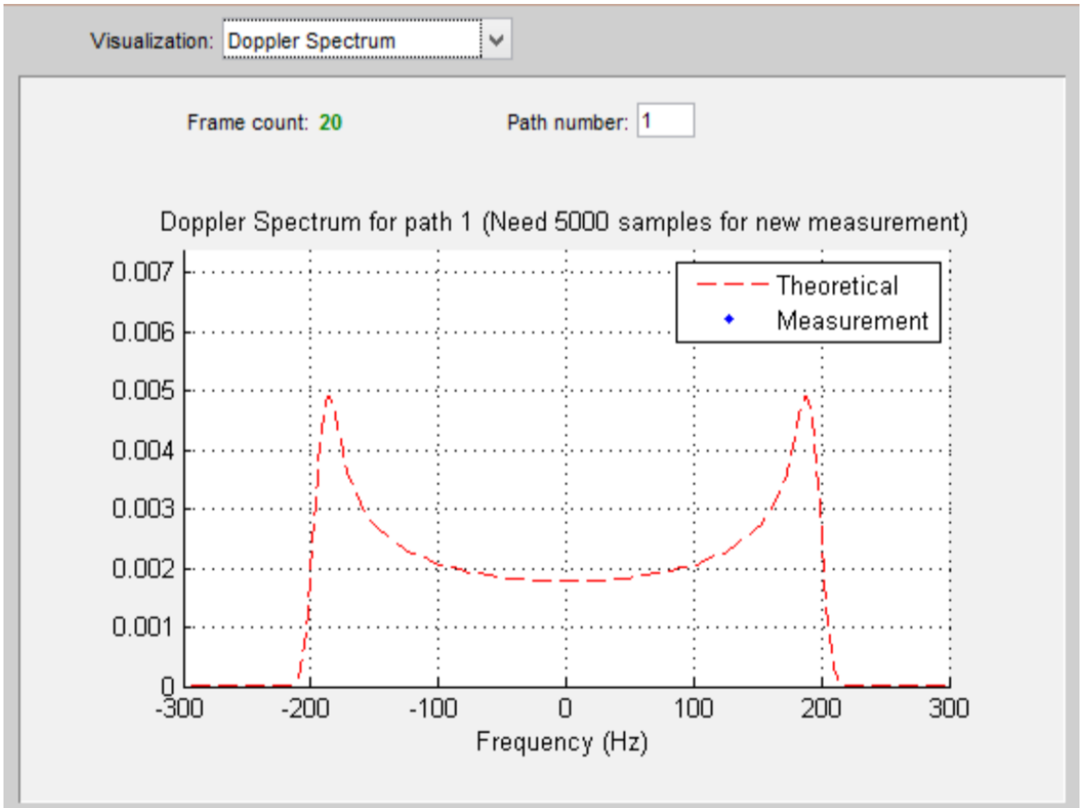

Fig.1(c): Doppler Spectrum 16-QAM Modulation

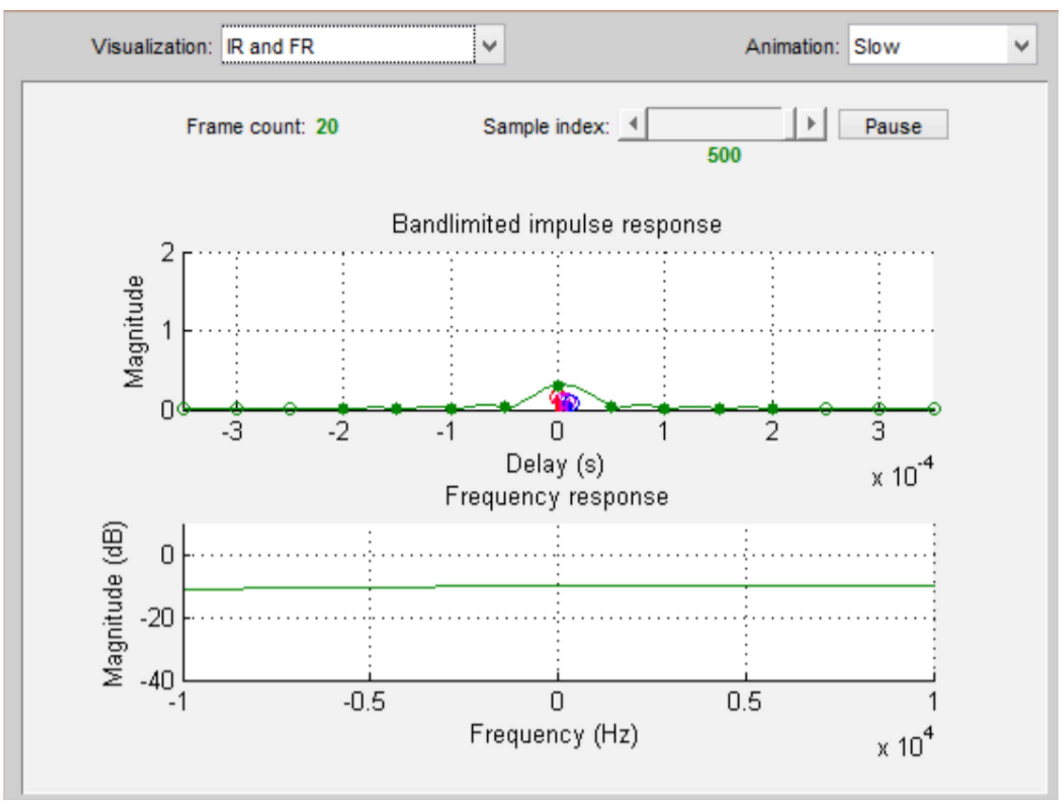

Fig.2(a): IR and FR for QPSK Modulation

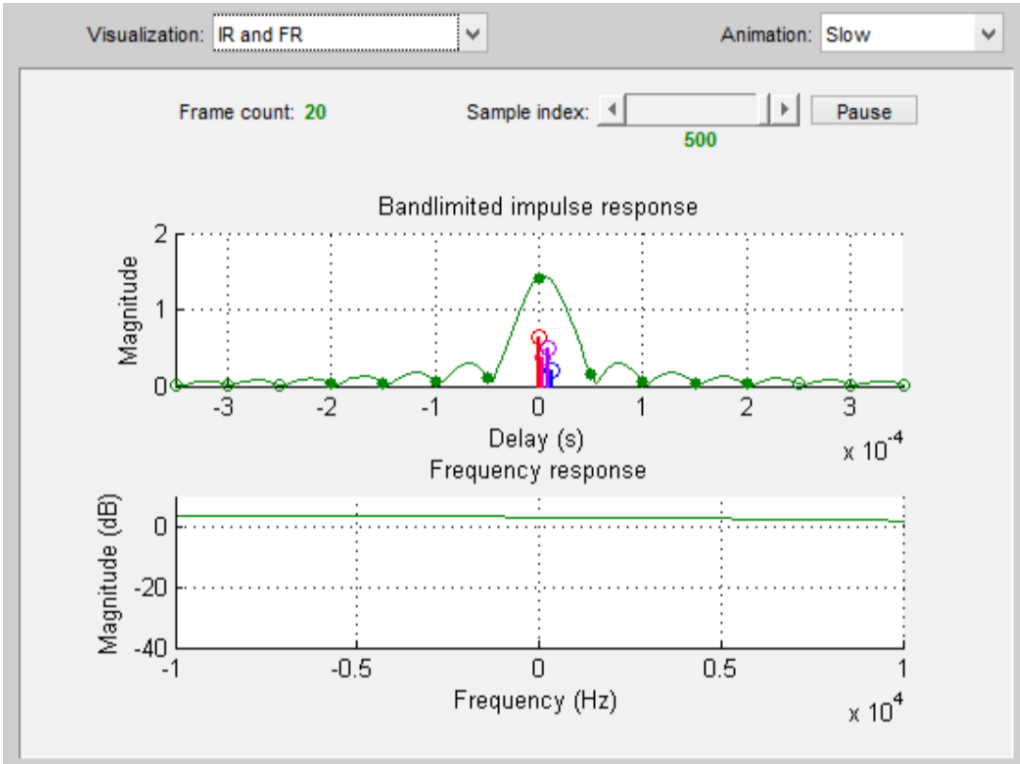

Fig.2(b): IR and FR for 4-QAM Modulation

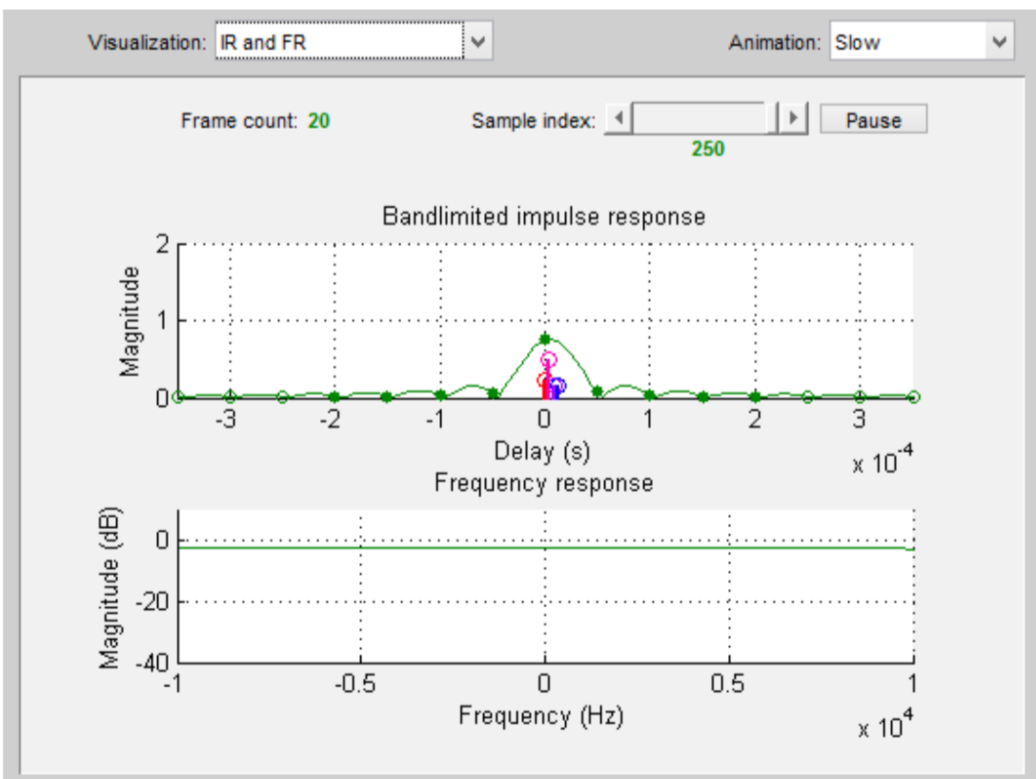

Fig.2(c):IR and FR for 16-QAM Modulation

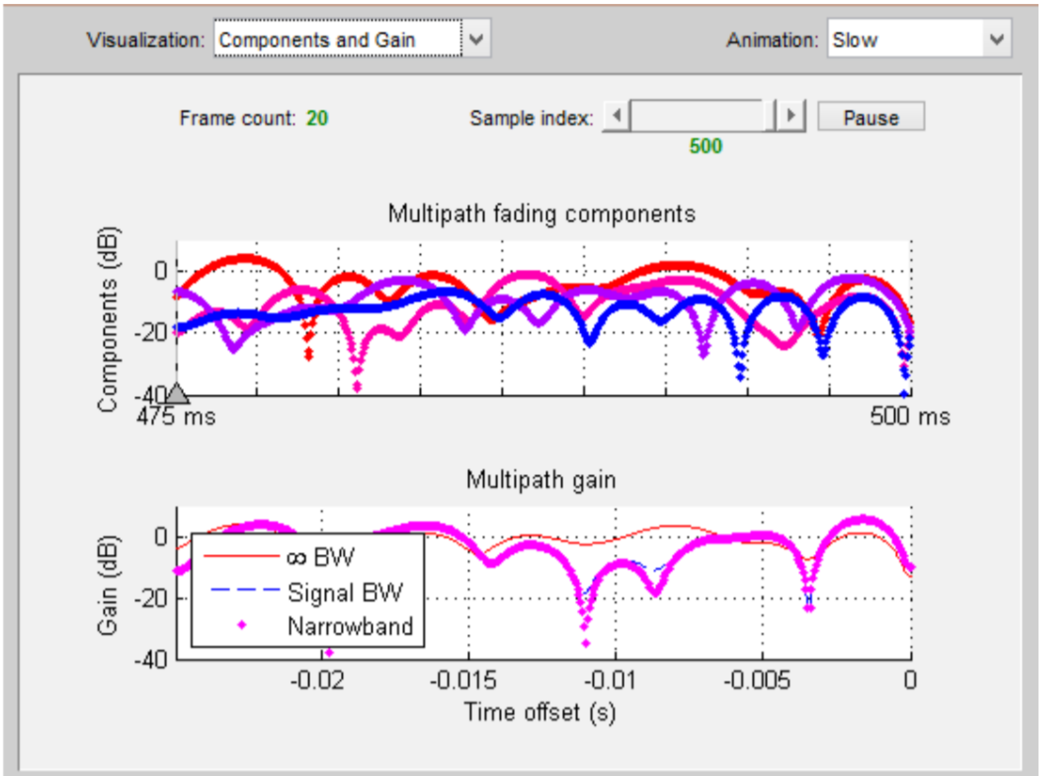

Fig. 3(a): Component and Gain for QPSK Modulation

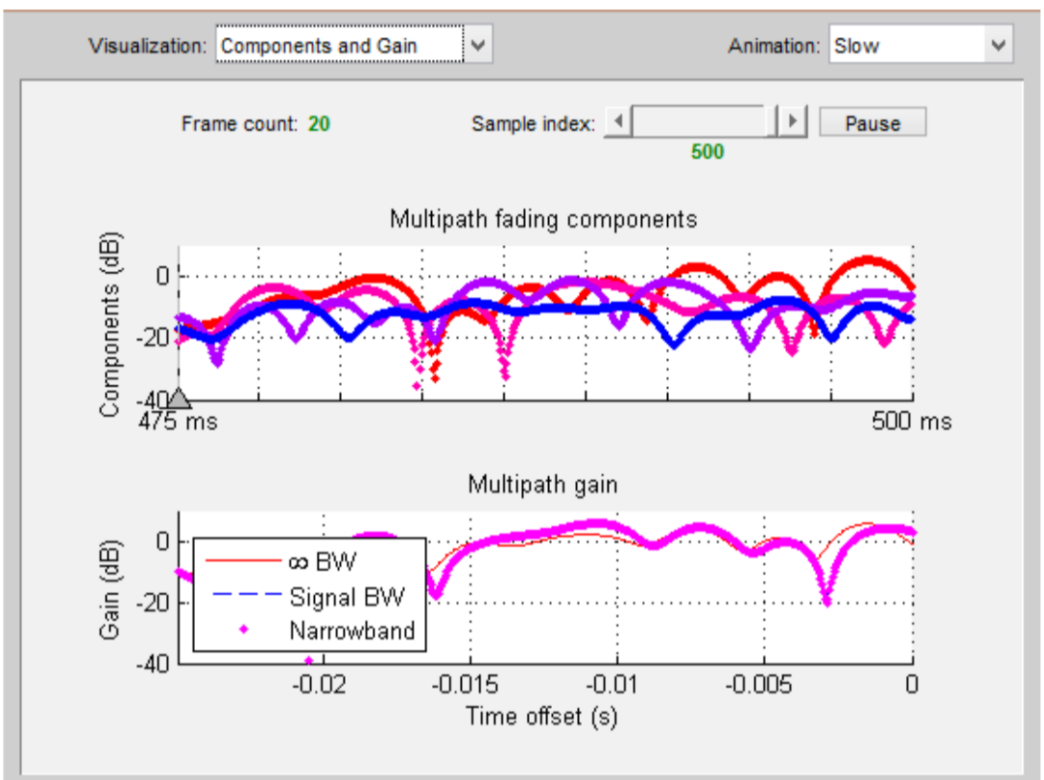

Fig. 3(b): Component and Gain for 4-QAM Modulation

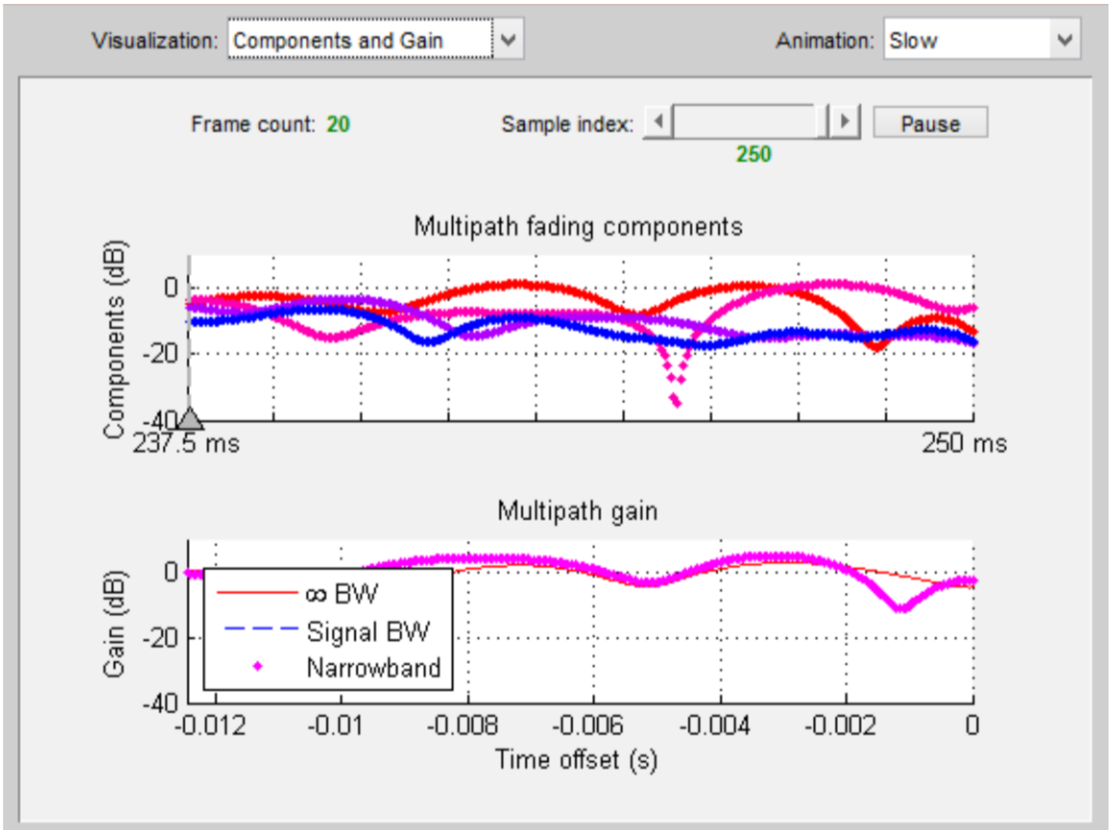

Fig. 3(c): Component and Gain for 16-QAM Modulation

Result Analysis:

Fig.1(a) showed the Doppler spectrum of QPSK modulation where we got both theoretical value and the samples as measured value. For the frequency range -300 Hz to -210 Hz and 210Hz to 300Hz the theoretical value and measured value were same and from -210Hz to 210Hz the theoretical value and measured value were in different. Fig.1(b) showed the Doppler spectrum of 4-QAM modulation. Here both theoretical value and measured value were taken and we got more samples compared with Doppler spectrum of QPSK modulation. For the frequency range -300 Hz to -210 Hz and 210Hz to 300Hz the theoretical value and measured value were same and from -210Hz to 210Hz the theoretical value and measured value were in different. Fig.1(c) showed the Doppler spectrum of 16-QAM modulation but we didn’t get the measured value because 16-QAM modulation need 5000 samples for new measurement. After observing Fig.1(a), Fig.1(b), Fig.1(c), we can say that 16-QAM modulation is better than other two because it can send more samples for the same frequency compared with QPSK and 4-QAM modulation. The

Impulse response and Frequency response of QPSK, 4-QAM and 16-QAM modulation in wireless communication system was depicted in Fig.2(a), Fig.2(b), Fig.2(c). The plot of Impulse response showed magnitude of the multipath response (infinite bandwidth) and the band limited channel response. The component with the smallest delay value was shown in red, and the component with the largest delay value was shown in blue. Components with intermediate delay values were shades between red and blue, becoming bluer for larger delays. The bandlimited channel response was represented by the green curve. This response was the result of convolving the multipath impulse response, described above, with a sinc pulse of period, T For the plot of frequency response frequency was constant but magnitude(dB) was different for QPSK, 4-QAM and 16-QAM modulation. For QPSK modulation frequency response was -10 dB, for the 4-QAM modulation frequency response was above 0dB and for 16-QAM modulation frequency response was -3dB. Fig.3(a), Fig.3(b), Fig.3(c) showed the component and gain of QPSK, 4-QAM and 16-QAM modulation technique of a narrow band using Rayleigh and Rician multipath fading channel. The plot of component showed the magnitudes of the multipath gains over time, using the same color code as that used for the multipath impulse response. The triangle marker and vertical dashed line represent the start of the current frame and the plot of gain showed the collective gains for the multipath channel for three signal bandwidths.

The narrow band (magenta dots) was the magnitude of the narrowband phasor in the above plot. This curve was sometimes referred to as the narrowband fading envelope. Current signal bandwidth (dashed blue line) was the sum of the magnitudes of the channel filter impulse response samples (the solid green dots in the impulse response plot). This curve represents the maximum signal energy that could be captured using a RAKE receiver. Infinite bandwidth (solid red line): was the sum of the magnitudes of the multipath component gains.

Conclusion:

After observing we conclude that 16 QAM modulation is better compared with QPSK and 4 QAM modulation.