Wireless Communication - Project 1

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Abstract

In wireless communications, transmitting signals in different places has always been a popular issue since numerous factors would contribute to the received signal and cause distortion. In different location and environment, the reflection of the original transmitted signal varies, therefore greatly effects the received signal. By carefully examine the signal, we could reconstruct the original transmitted signal, simultaneously, obtain the relation of the received signal with the environment and its velocity.

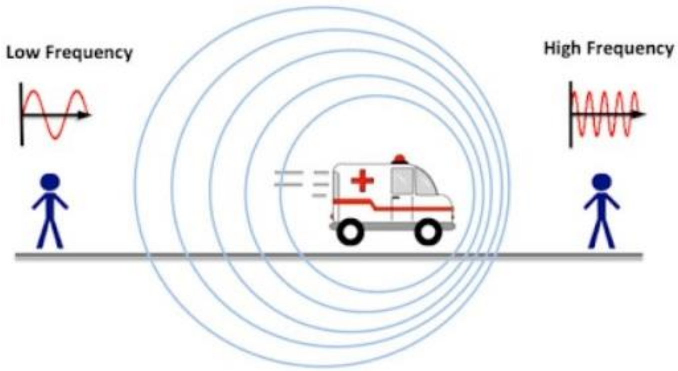
Introduction

The objection of this project is to simulate Rayleigh fading which considers different velocities and compares the differences. With the basic knowledge of Doppler Effect, we could observe the relationships between velocity, doppler frequencies, delay spread and the distribution of the received signal. In this simulation, we compare the two speed which is 20 and 200 and observe the differences and simultaneously plot the distribution and the correlation of the received signal that passes over the Rayleigh Fading Channel.

Methodology

- Doppler Effect (Doppler spread)

  Doppler effect (Doppler spread) is that the frequency changes in relation to the observer who moves toward/away the wave source. The reason for the Doppler effect is that when the source of the waves is moving towards the observer, each successive wave crest is emitted from a position closer to the observer than the crest of the previous wave. Therefore, each wave takes slightly less time to reach the observer than the previous wave. Hence, the time between the arrivals of successive wave crests at the observer is reduced, causing an increase in the frequency. While they are traveling, the distance between successive wave fronts is reduced, so the waves "bunch together". Conversely, if the source of waves is moving away from the observer, each wave is emitted from a position farther from the observer than the previous wave, so the arrival time between successive waves is increased, reducing the frequency. The distance between successive wave fronts is then increased, so the waves "spread out".



The phase shift equation is represented below,

$$\Delta\Phi = 2\pi \frac{v \cdot \Delta t \cdot \cos\theta}{\lambda}$$

And Doppler frequency is represented as

$$f_d = \frac{v \cdot \cos\theta}{\lambda}$$

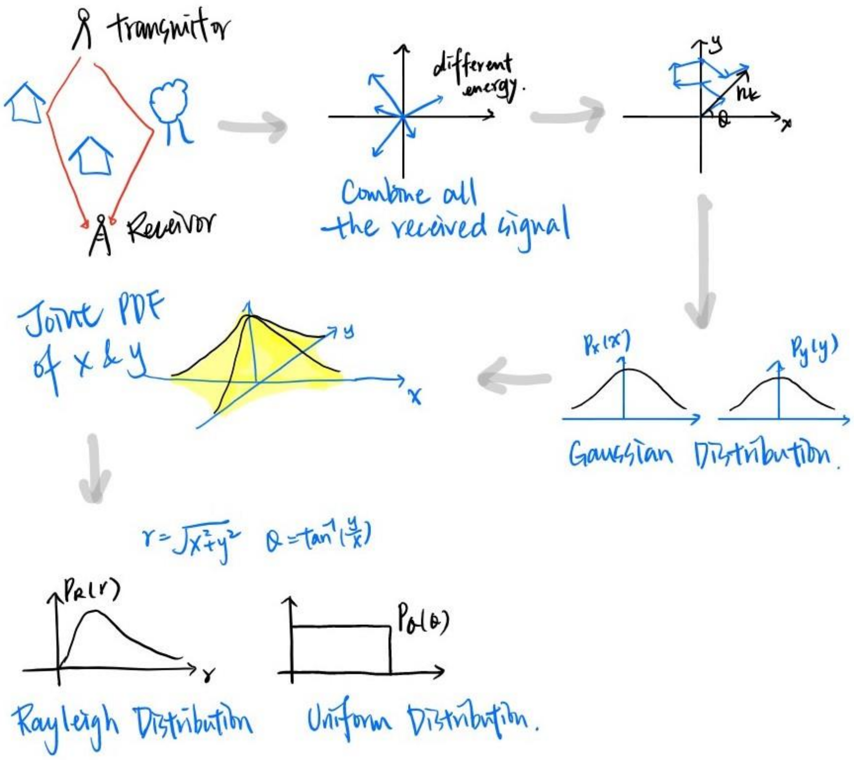
- Rayleigh fading channel

Rayleigh fading can be a useful model in heavily built-up city centres where there is no line of sight between the transmitter and receiver and many buildings and other objects attenuate, reflect, refract, and diffract the signal.

While signals is transmitted in an environment with unknown (usually many) obstacles, reflection would occur and the original signal could be distorted by the reflections which has different phase shift in a particular time. By examining the received signal and draw it into polar form, we could add up all the vectors that obtains the vector h_k. We statistically measure the received signal over time and observed that the imaginary part and real part of the received signal forms a Gaussian Distribution. By combining the two distribution and obtain its joint distribution, we would obtain the radius and phase.

$$\mathrm{r} = \sqrt{x^2 + y^2} \qquad\qquad \theta = \tan^{-1}\frac{x}{y}$$

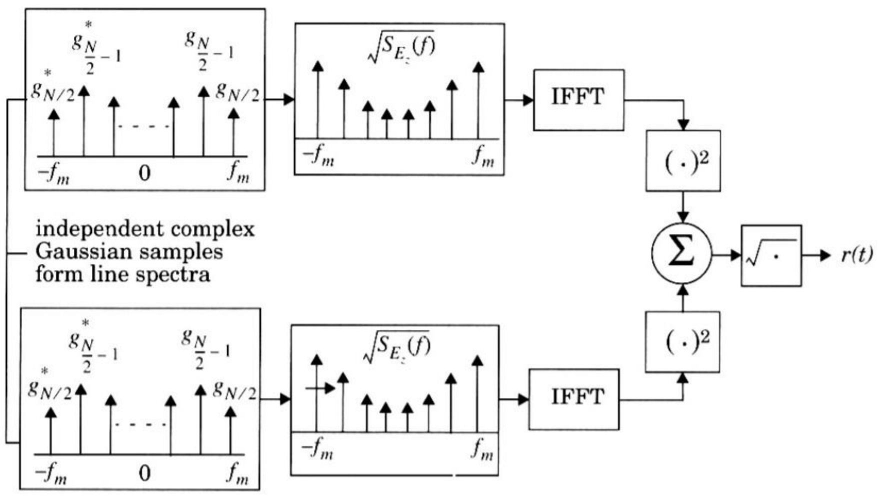
The distribution of the radius is the Rayleigh Distribution and the phase forms a uniform distribution.



Simulation

Since doppler frequency is positive related to velocity from the equation that calculates the phase shift, the by setting the doppler frequency f_d as different value is equivocal to the representation of different speed. Low moving speed is also considered correlated since the signal received over time is likely to be highly correlated with a low moving speed. On the other hand, with high moving speed, the signal received is more likely to change due to the rapid change of environment.

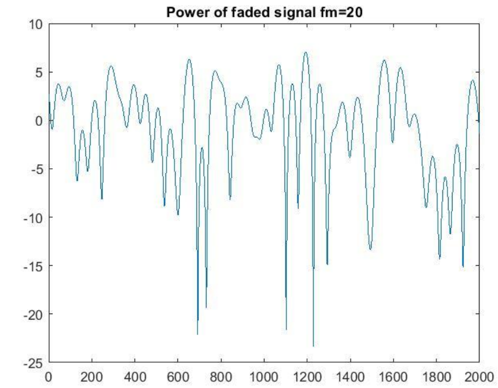
The simulation steps are shown below,

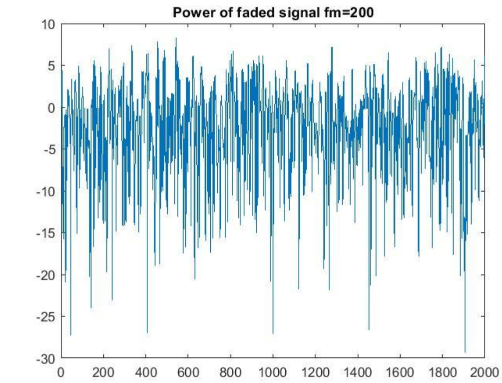


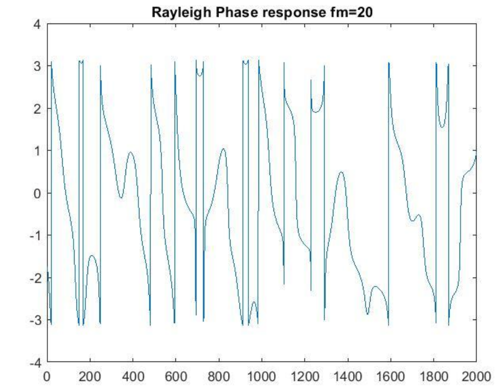
In this simulation result, I set $f_d = 20$ to represent low speed (correlated) and $f_d = 200$ (uncorrelated) to represent high speed and compare the differences

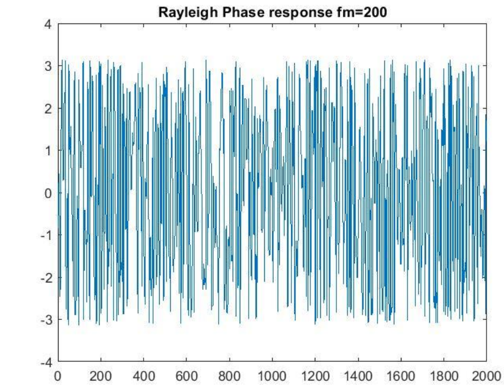
Low speed $f_d = 20$

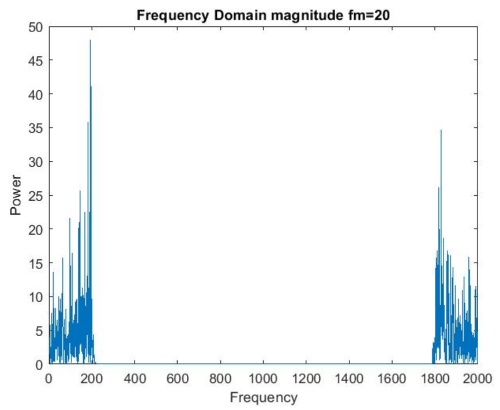
High speed $f_d = 200$

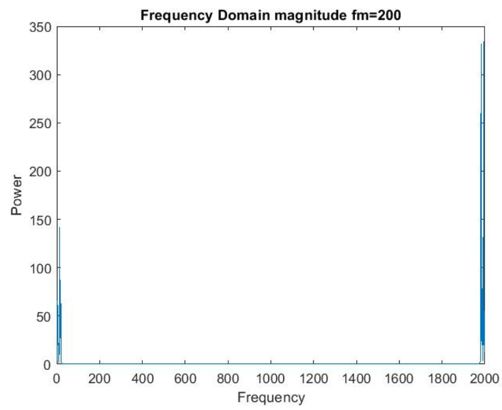


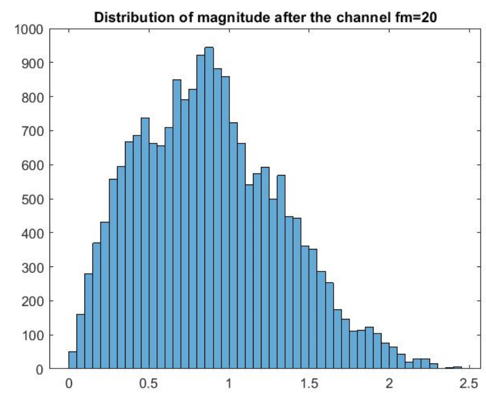


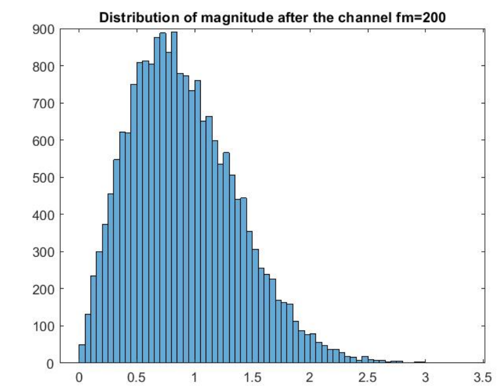


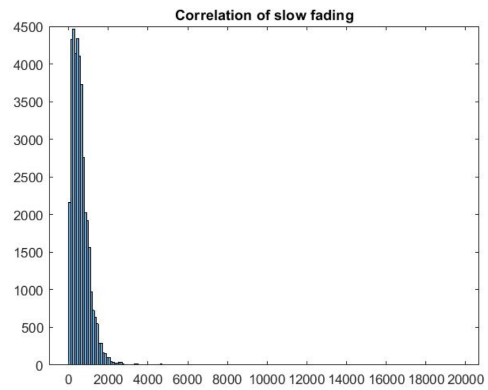


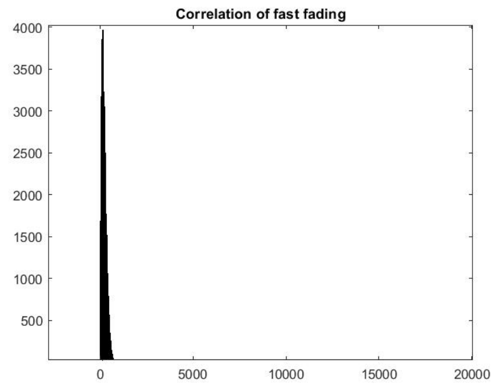












Conclusion

The power of the two different velocities, it is obvious that the power and phase of the fast-moving transmitter drastically change over time in comparison with the slow-moving transmitter. In other words, the received signal is uncorrelated and harder to predict and the environment changes dramatically which matches our assumption. By obtaining the Fast Fourier Transform, the spectrogram matches perfectly with the doppler spectrogram. With a larger U shape means that the frequency is more likely to fluctuate in between the U values. In doppler effect, that range of frequency observed range is larger for high moving speed transmitter which matches our expectations. By statistically count the received signal, the distribution of the radius is a Rayleigh distribution. The correlation of the received signal matches the Clarke theoretical and high speed transmitter signal is less likely to correlate with each other.

Appendix

- Simulation of $f_d = 20$

```
rayChan = comm.RayleighChannel('SampleRate',2000,'MaximumDopplerShift',20);
sig = 1i*ones(2000,1); % Signal
out_low  = rayChan(sig); % Pass signal through channel

%display magnitude and phase
figure(f1);
plot(20*log10(abs(out_low)));
title('Power of faded signal fm=20');
figure(f3);
phase = angle(out_low);
plot(phase);
title('Rayleigh Phase response fm=20');
```

```
%plot spectrogram of the signal
figure(f5);
outlow_freqdomain = fft(out_low);
n = length(out_low);          % number of samples
f = (0:n-1)*(2000/n);     % frequency range
power = abs(outlow_freqdomain).^2/n;    % power of the DFT
plot(f,power)
xlabel('Frequency')
ylabel('Power')
%plot(abs(outlow_freqdomain)/20);
title('Frequency Domain magnitude fm=20');
```

```
%plot distribution of slow fading
figure(f7)
rayChan = comm.RayleighChannel('SampleRate',2000,'MaximumDopplerShift',20);
sig = 1i*ones(20000,1); % Signal
out_low  = rayChan(sig); % Pass signal through channel.
distribution_r_low = abs(out_low);
histogram(distribution_r_low);
title('Distribution of magnitude after the channel fm=20');

%calculate the correlation of the received signal
figure(f9)
%%relation_low = zeros(20000);
%%for c = 1:20000
    %%relation_low(c) = corrcoef(out_low(1), out_low(c));
%%end
distribution_r_low = abs(out_low);
relation_low = xcorr(out_low);
histogram(abs(relation_low));
title('Correlation of slow fading');
```

- Simulation of $f_d = 200$

```
%%%fast fading channel
rayChan = comm.RayleighChannel('SampleRate',2000,'MaximumDopplerShift',200);
sig = 1i*ones(2000,1); % Signal
out_high = rayChan(sig); % Pass signal through channel.
```

```
%display magnitude and phase
figure(f2);
plot(20*log10(abs(out_high)));
title('Power of faded signal fm=200');
figure(f4);
phase = angle(out_high);
plot(phase);
title('Rayleigh Phase response fm=200');
```

```
%plot spectrogram
figure(f6);
outhigh_freqdomain = fft(out_high);
n = length(out_high);          % number of samples
f = (0:n-1)*(2000/n);     % frequency range
power = abs(outhigh_freqdomain).^2/n;    % power of the DFT
plot(f,power)
xlabel('Frequency')
ylabel('Power')
%plot(abs(outhigh_freqdomain));
title('Frequency Domain magnitude fm=200');

%plot distributiion of fast fading
figure(f8)
rayChan = comm.RayleighChannel('SampleRate',2000,'MaximumDopplerShift',200);
sig = 1i*ones(20000,1); % Signal
out_high  = rayChan(sig); % Pass signal through channel.
distribution_r_high = abs(out_high);
histogram(distribution_r_high);
title('Distribution of magnitude after the channel fm=200');

figure(f10)
distribution_r_high = abs(out_high);
relation_high = xcorr(out_high);
histogram(abs(relation_high));
title('Correlation of fast fading');
```

Reference

https://www.mathworks.com/help/matlab/math/basic-spectral-analysis.html
https://www.mathworks.com/help/matlab/ref/fft.html
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