A SIMULINK-BASED MODEL AND ANALYSIS OF THE PHY LAYER IN VEHICULAR COMMUNICATIONS

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Overview

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  - Simulink Design
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  - Simulation Scenarios
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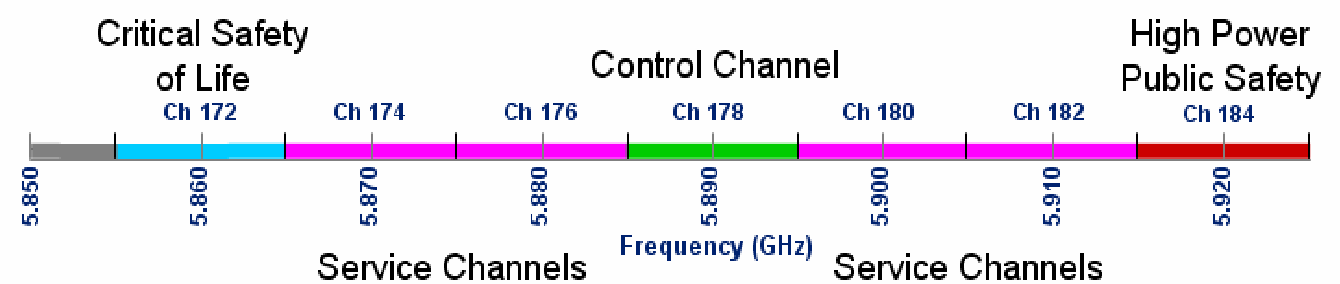
Motivation/Introduction

Motivation

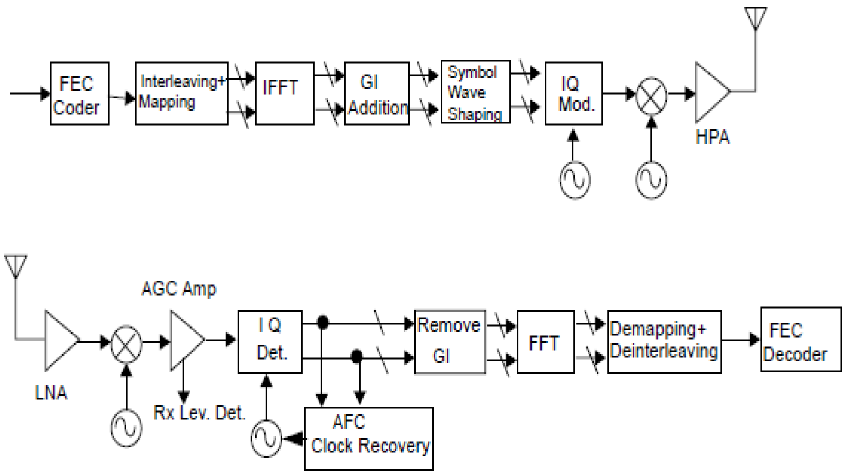
- LTE used widely for vehicular safety applications
- Shift to higher frequencies due to lack of available frequency band
- Most common standard: Dedicated Short Range Communication (DSRC) using IEEE 802.11p protocol
- DSRC: robust in fading, low latency
  - Enormous potential for public safety
  - Possible reference for design of future standards high-frequency communication
- For reference, validated simulator that follows standard is required

Dedicated Short Range Communications (DSRC)

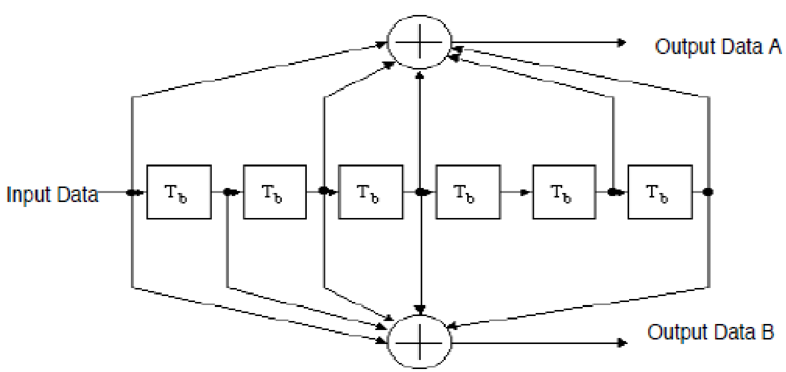
- Centered at 5.9 GHz
- Usually used for Vehicle-to-Vehicle (V2V) or Vehicle-to-Infrastructure (V2I) communication
- Channel 178: Control Channel (CCH) for safety communication
- Either end of band: special uses
- Remaining: Service Channel (SCH)
- PHY: IEEE 802.11a
- MAC: IEEE 802.11e



IEEE 802.11a PHY



Tx/Rx for OFDM PHY



Convolutional Encoder (K=7)

- OFDM PHY for Tx and Rx
- Convolutional Encoder (K=7, R=1/2, 2/3, 3/4)
- Viterbi Decoder
- 48 data, 4 pilot, one null subcarriers, 11 guard subcarriers in one OFDM symbol (64 subcarriers)
- IEEE 802.11p PHY is very similar to IEEE 802.11a PHY

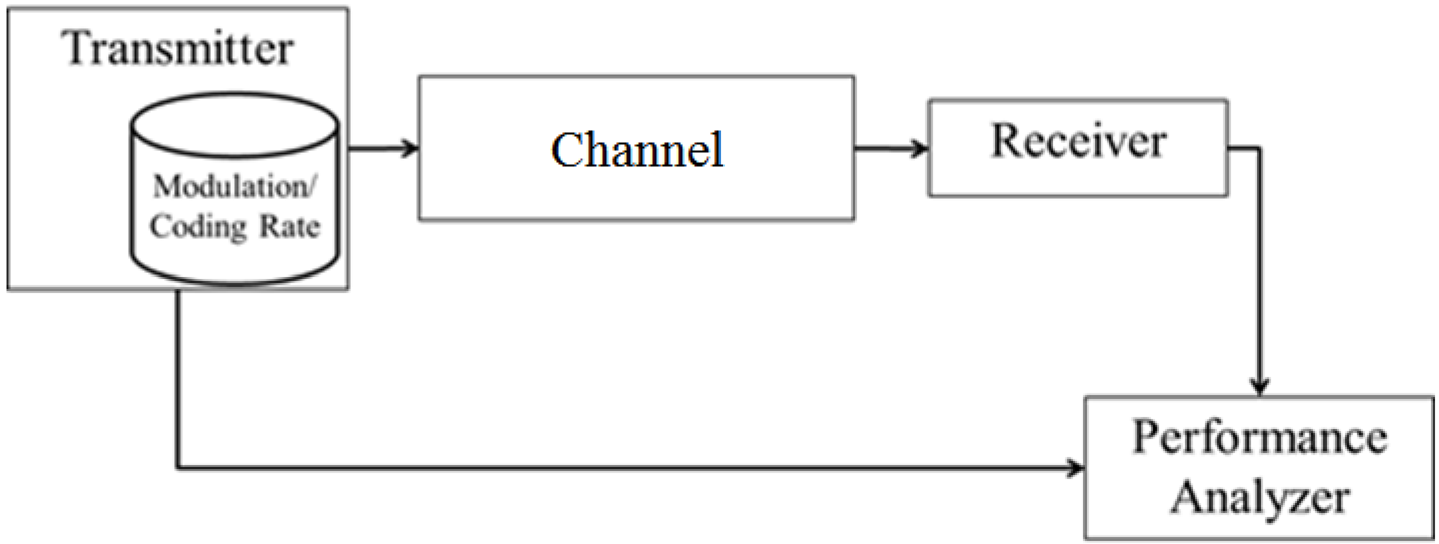
Differences between IEEE 802.11a and .11p

Same
Halved
Doubled

	IEEE 802.11a	IEEE 802.11p
Bandwidth	20 MHz	10 MHz
Bit Rate	6, 9, 12, 18, 24, 36, 48, 54	3, 4.5, 6, 9, 12, 18, 24, 27
Modulation Scheme	BPSK, QPSK, 16 QAM, 64 QAM	BPSK, QPSK, 16 QAM, 64 QAM
Code Rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4
Data bits per OFDM symbols	24, 36, 48, 72, 96, 144, 192, 216	24, 36, 48, 72, 96, 144, 192, 216
# of Subcarriers	52	52
# of Data Subcarriers	48	48
# of Pilot Subcarriers	4	4
Subcarrier Spacing	0.3125 MHz	0.15625 MHz
FFT Period	3.2 µs	6.4 µs
FFT/IFFT Size	64	64
Guard Time	0.8 µs	1.6 µs
Preamble Duration	16 µs	32 µs
Symbol Duration	4 µs	8 µs
Signal Field Duration	4 µs	8 µs
CP Interval	0.8 µs	1.6 µs
OFDM Symbol Interval	4 µs	8 µs

IEEE 802.11p Simulator

Simulator Design

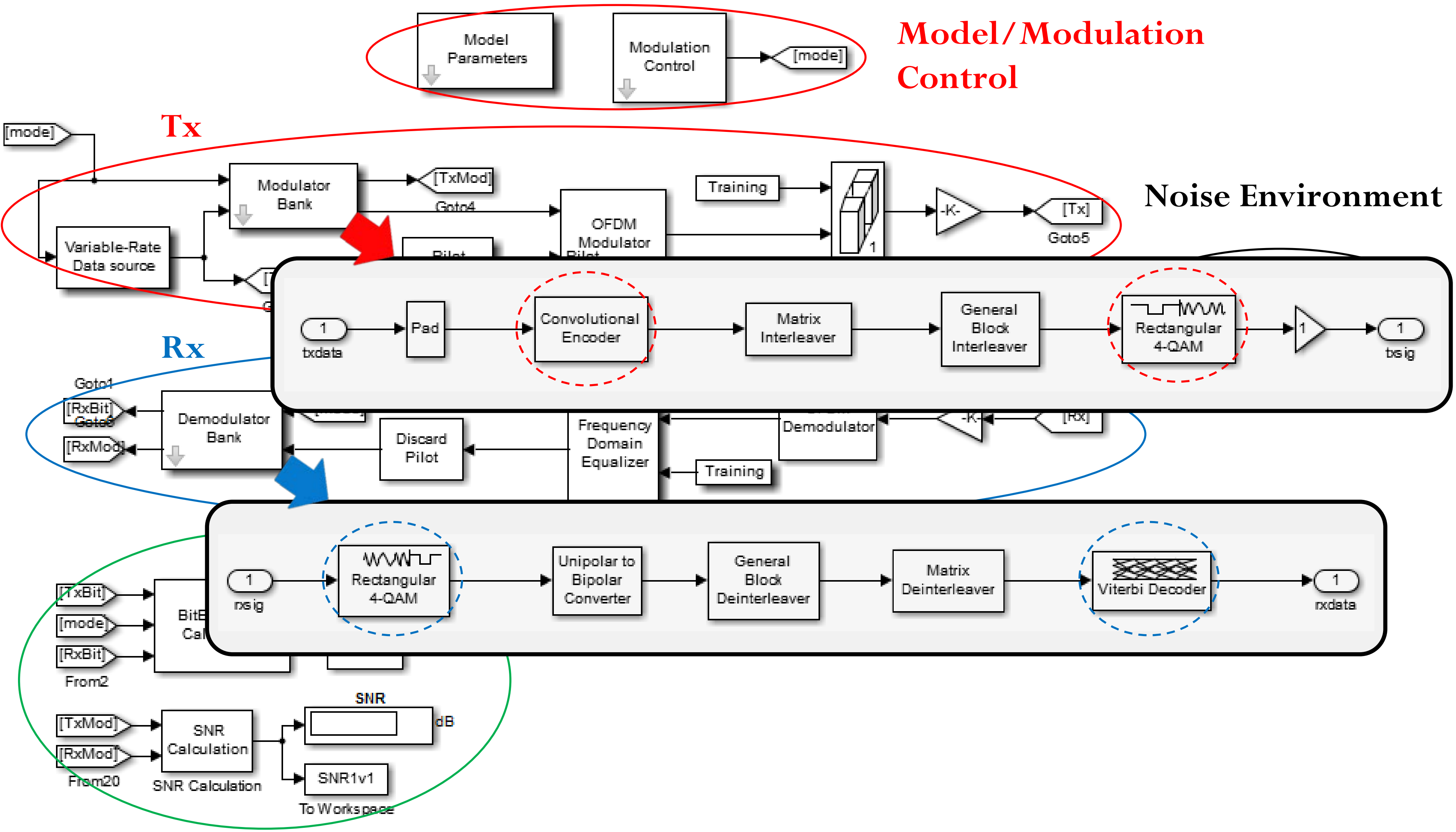


- Transmitter (Initialization included)
- Channel (AWGN, Rayleigh, Rician Fading)
- Receiver
- Performance Analyzer (measures SNR, BER)

Why Simulink?

- Suitable for one-to-one communication (1 Tx to 1 Rx)
- Several relevant communication examples (e.g. IEEE 802.11a PHY, LTE Downlink, etc.)
- Easy to Edit
- Good Visualization
- Toolbox to reduce development time (e.g. modulator, OFDM modulator, noise function, etc.)

Simulink Model (1)



Simulink Model (2)

Modulation/Coding Rate Control Block

Modulation/Coding Rate Control Block (mask)

Select Modulation Scheme/Coding Rate

Parameters

Mode Select: QPSK 1/2

Noise Environment Block

Noise Environment Block (mask)

Select Noise: AWGN, Fading

Parameters

Fading mode: params.fadingMode

K factor

params.K1

Maximum Doppler shift (Hz):

params.Dopplerv1

Initial Phase (rad):

pi

SNR (dB):

params.SNR1

Initialization m file

```
% IEEE 802.11p - fundamental sizes
p.NFFT          = 64; % Number of points on FFT
p.CPLen         = 16; % Cyclic prefix length
p.guardBands    = [6; 5]; % Left and right guard bands
p.pilotIndices = [-21; -7; 7; 21]; % Pilot subcarrier indices

% OFDM symbols
p.OFDMSymPerFrame     = OFDMSymPerFrame;
p.OFDMTrainPerFrame   = OFDMTrainPerFrame;
p.OFDMTotSymPerFrame = OFDMSymPerFrame + OFDMTrainPerFrame;

% Modulator/demodulator banks
p.numModulators = 8;
p.txBitsPerSymbol = [1 1 2 2 4 4 6 6];
p.txBitsPerBlock = p.numTxSymbols * p.txBitsPerSymbol;
p.modOrder = 2.^p.txBitsPerSymbol;
p.codeRate = [1/2 3/4 1/2 3/4 1/2 3/4 2/3 3/4];

% Timing-related parameters
p.OFDMSymbolPeriod = 8e-6;

% Noise-related parameters
p.fadingMode=1; % 1 for No fading 2 for Rician fading
p.K1 = 1; % K-factor parameter for Fading option
p.K2 = 2;
p.Dopplerv1 = 5.463*16;
p.Dopplerv2 = 5.463*40;
p.SNR1 = 26;
p.SNR2 = 25;
```

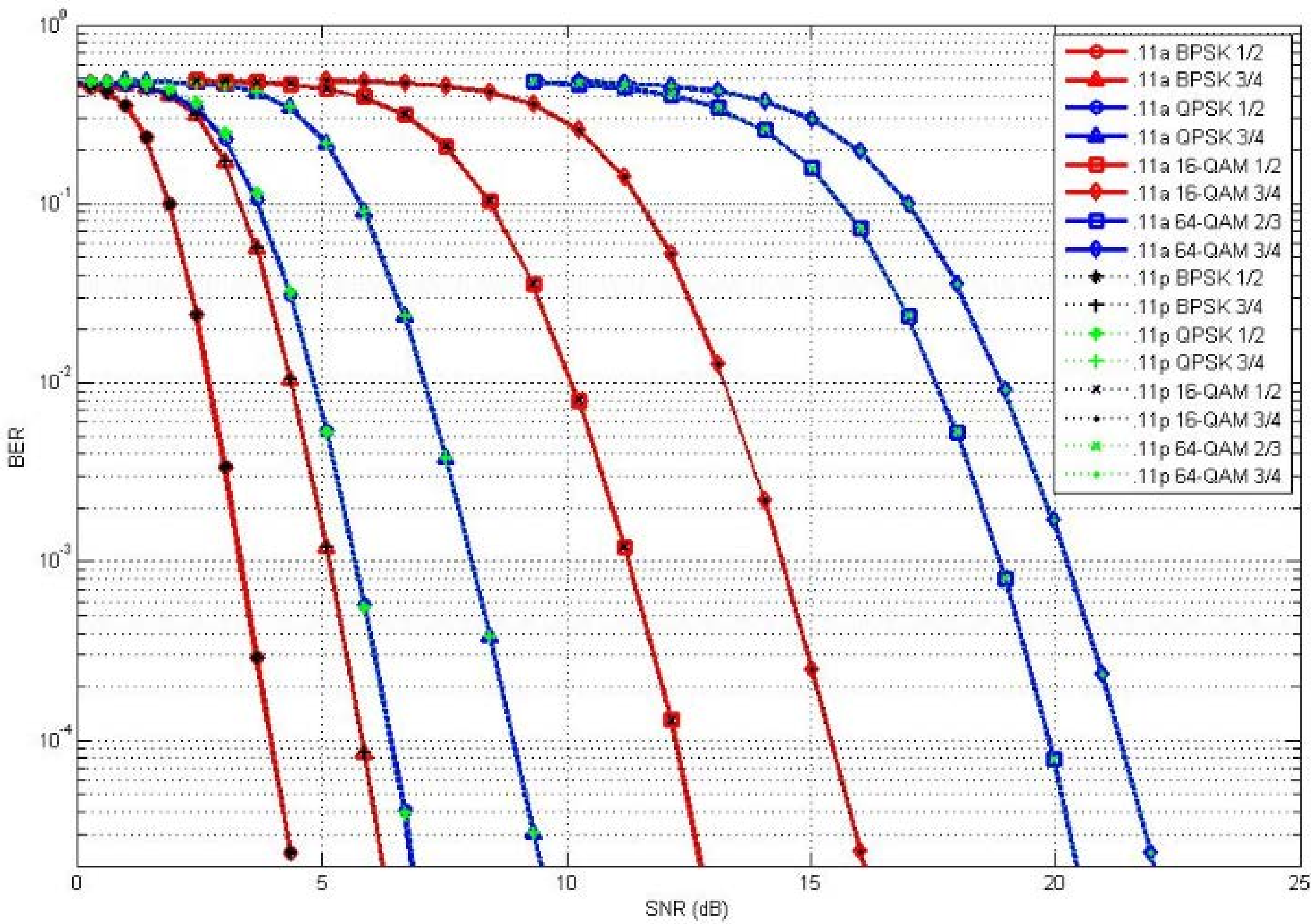
Simulation Scenarios/Results

Simulation Scenarios

- Setup certain parameters to user defined values
  - K-factor, velocity for Doppler Shift, Modulation Schemes, Coding Rate, size of symbols/frames
- Collect SNR/BER and average over whole iterations

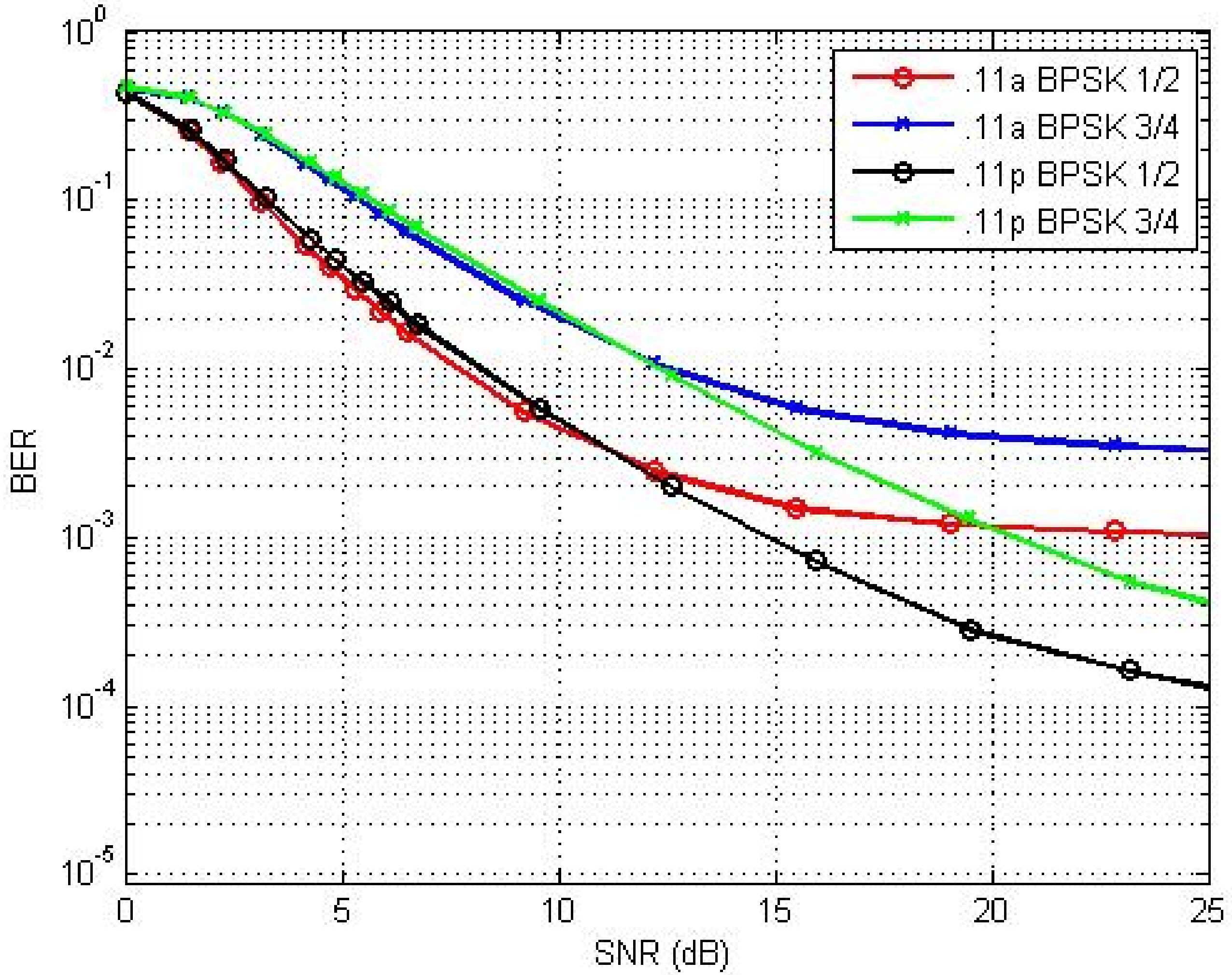
Controllable Parameters	**Selected Values**
Noise Scenarios	AWGN, Rayleigh Fading, Rician Fading
K-factor (Rician Fading)	1, 2, 4, 10, 15, 20 (ratios, not dB)
Velocity for Doppler Shift	10, 25, 45 mph
Modulation Schemes	BPSK, QPSK, 16-QAM, 64-QAM
Coding Rates	1/2, 2/3, 3/4
# of OFDM Symbols/Frames	20 OFDM symbols/10,000 frames

Validation: Comparison between IEEE 802.11a and IEEE 802.11p in AWGN



Matches results in [8]

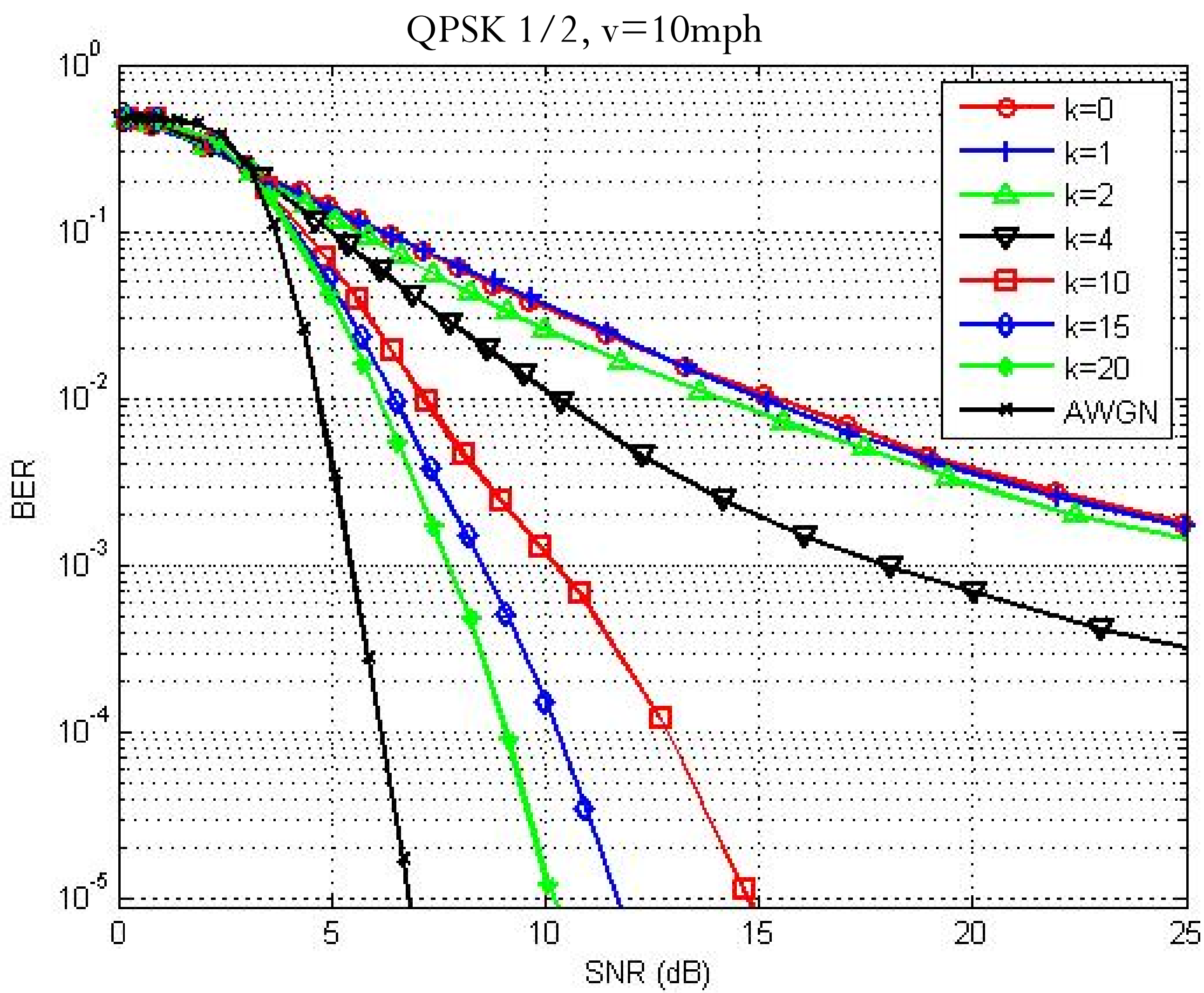
Comparison between IEEE 802.11a and IEEE 802.11p in Rayleigh Fading



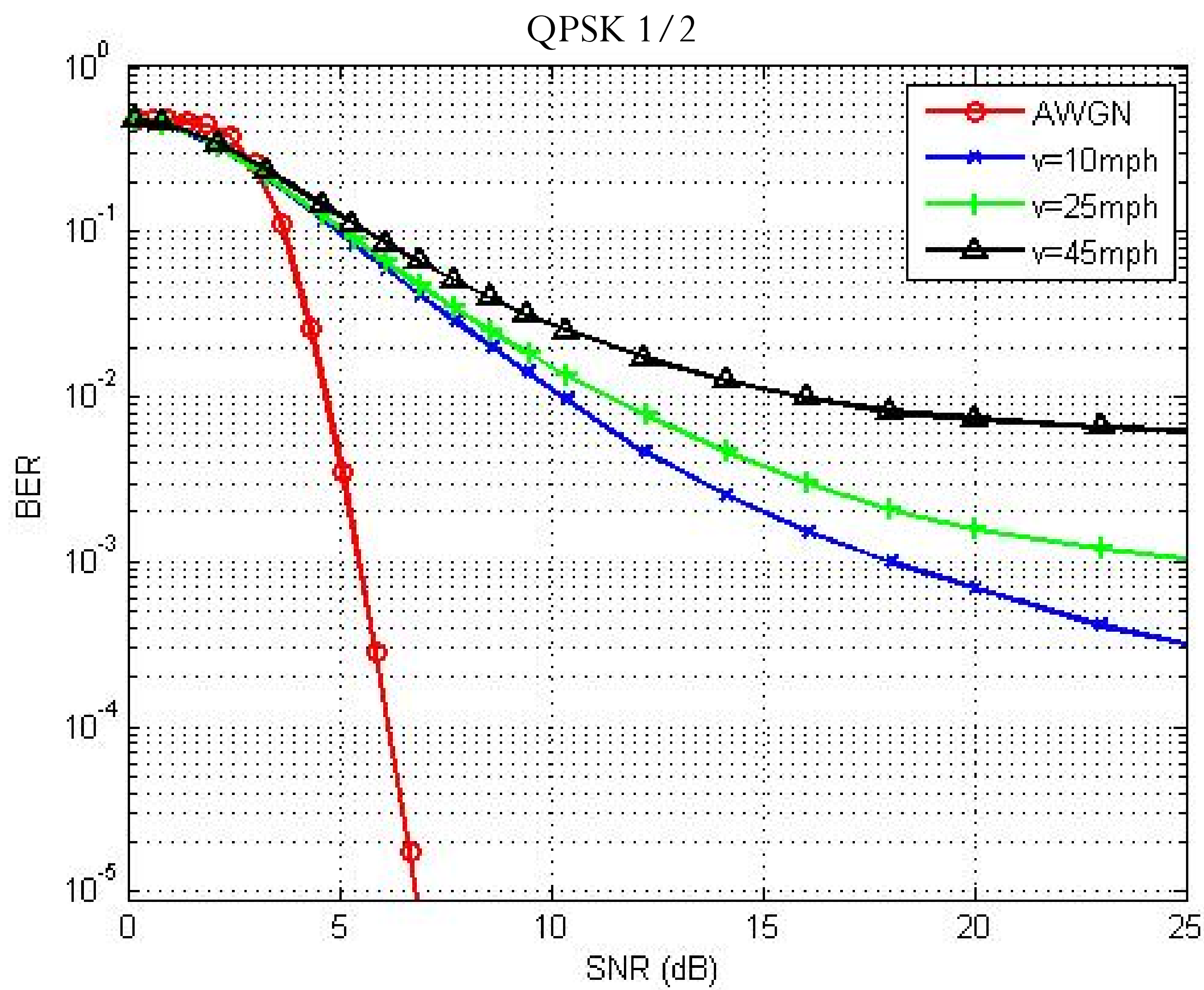
Delay (ns): 0, 10, 20, 40, 70, 100, 140, 190, 240, 320
Path Gain (dB): -4.9, -5.1, -5.2, -0.8, -1.3, -1.9, -0.3, -1.2, -2.1, 0.0

Matches results in [8]

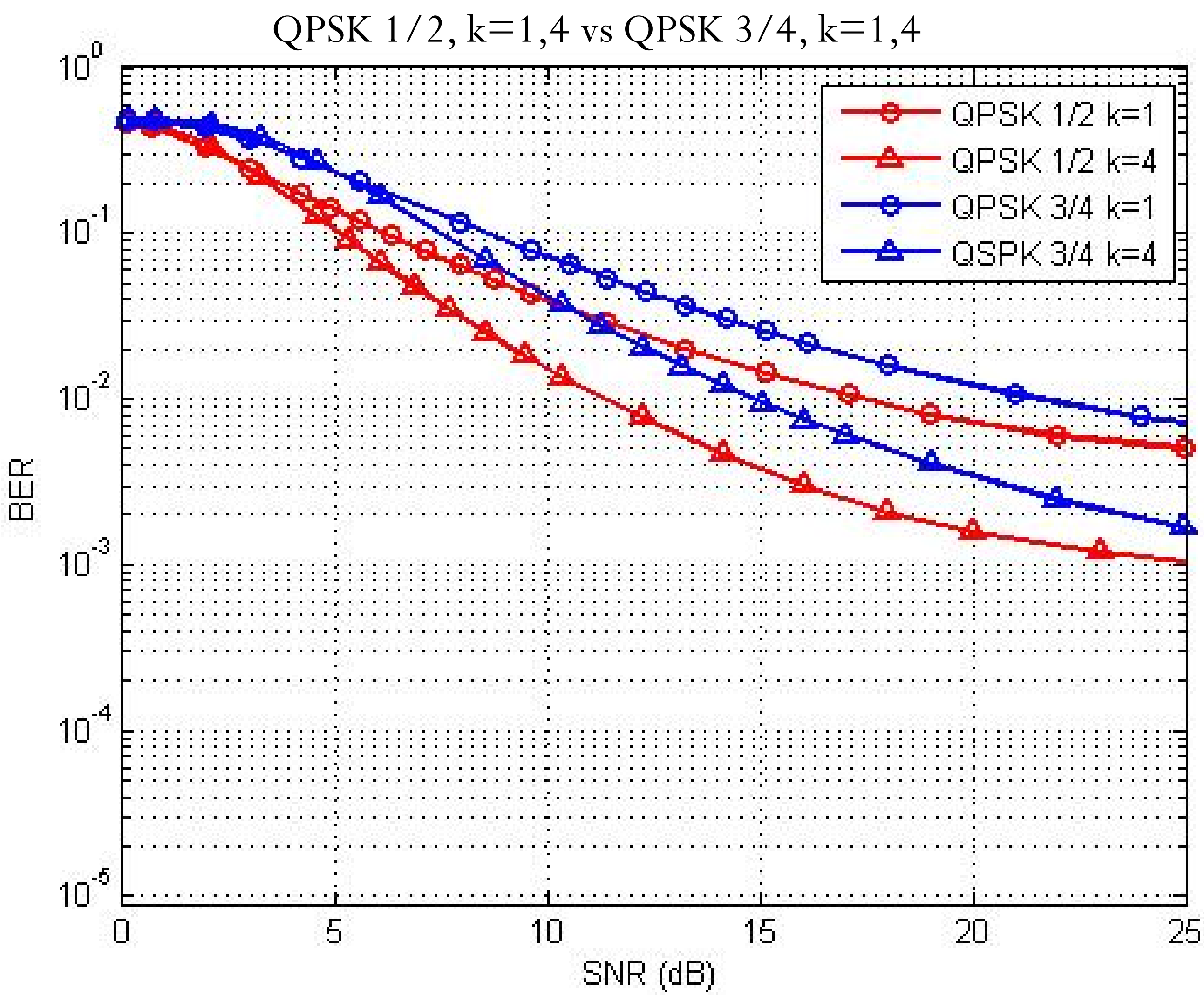
IEEE 802.11p Performance in Rayleigh and Rician Fading



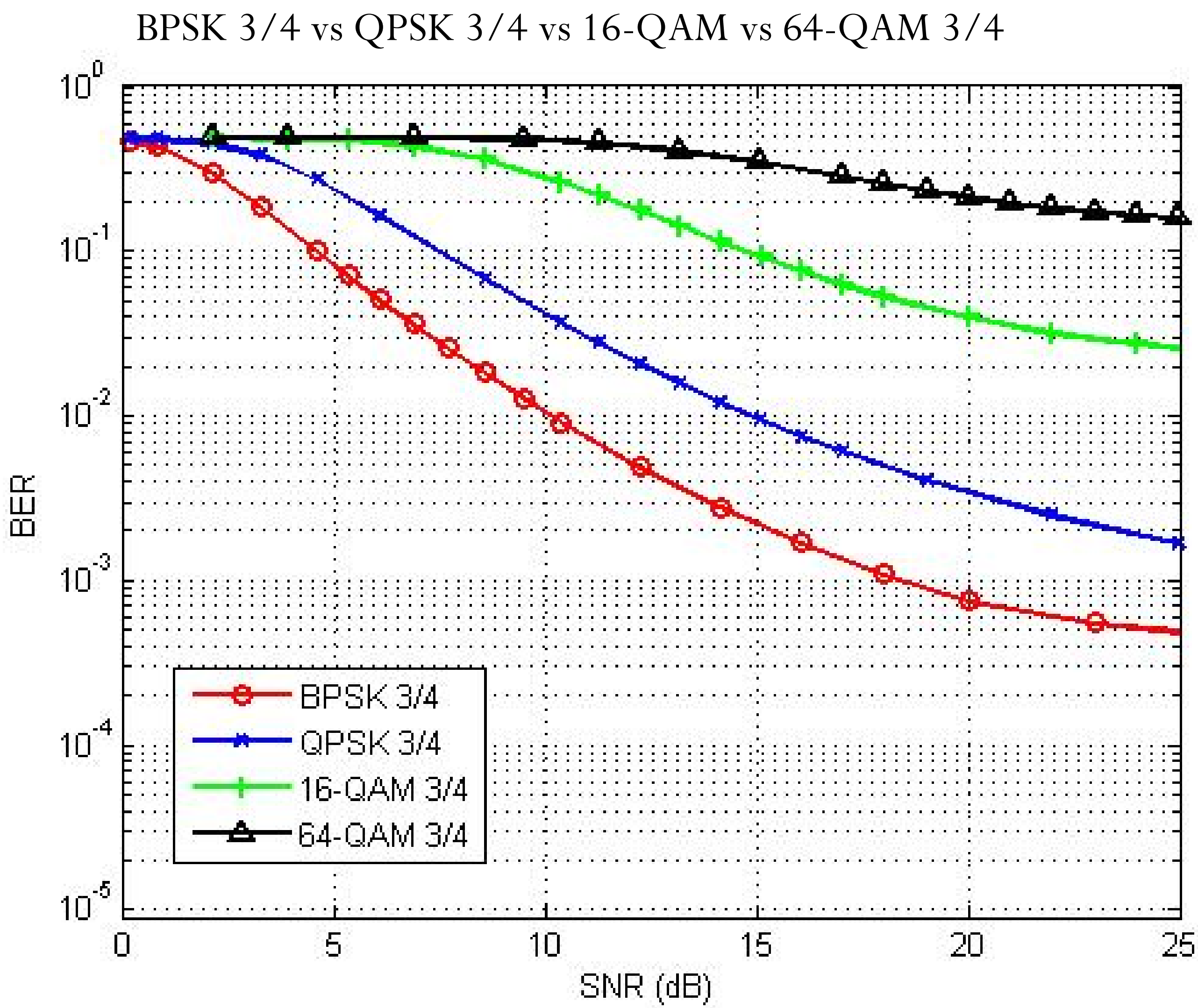
Effect of velocity on 802.11p (Rician fading, k=4)



Effect of coding rate on 802.11p (Rician Fading, v=25mph)



Effect of Modulation Schemes (Rician Fading, k=4, v=25mph)



Future Work

- Extend PHY Simulator capabilities
  - More channels/noise environment scenarios
  - Capability to measure other parameters, e.g. PER, latency, etc.
- Use with Higher layer simulator
  - Convert collected BER to PER and use for MAC
  - Possible Network layer capability

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Thank You!