MATLAB Simulation of IEEE802.11p Technology on High User’s Mobility

abderrahim mountaciri (yahyamountaciri@gmail.com)
Université Hassan 1er de Settat: Universite Hassan 1er de Settat
https://orcid.org/0000-0001-7604-290X

Research Article

Keywords: Mobility, phenomena, Doppler, Orthogonal Frequency Division Multiplexing

DOI: https://doi.org/10.21203/rs.3.rs-540883/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
MATLAB Simulation of IEEE802.11p Technology on High User’s Mobility

MY Aberrahim Mountaciri
Laboratoire d’Ingénierie, de Management Industriel et d’Innovation (LIMII), Faculté des Sciences et techniques (FST), Hassan First Université of Settat, Settat, Morocco

abstract— In this article proposed IEEE 802.11p Physical layer (PHY). A MATLAB simulation is performed to analyze the baseband processing of the transceiver. Orthogonal Frequency Division Multiplexing (OFDM) is applied in this project according to the IEEE 802.11p standard, which allows data transmission rates from 3 to 27 Mbps. Separate modulation schemes, bit phase shift modulation (BPSK), quadrate phase shift modulation (QPSK), and quadrate amplitude modulation (QAM), are used for different data rates. These schemes are combined with time interleaving and a convolutional error correction code. A guard interval is inserted at the start of the transmitted symbol to reduce the effect of intersymbol interference (ISI). This article studies the PHY physical layer of the IEEE 802.11p vehicular communication standard. An IEEE.802.11p PHY model, with many associated phenomena, is implemented in the V2V vehicle-to-vehicle, and the vehicle-to-vehicle ad hoc network (VANET) provides convenient coordination between moving vehicles. A moving vehicle could move at a very high speed, producing a Doppler effect that damages the OFDM symbols and also causes inter-carrier interference (ICI). This article has discussed VANET technology versus 802.11a technology, as they have many differences when it comes to user mobility. The Doppler effect resulting from the mobility of the user with a high speed of 25 to 400 km/h has been studied as the main parameter, the estimation of the channel based on the LMS algorithm has been proposed in order to improve the performance of the physical physical chain

I. INTRODUCTION
Short Range Communications Dedicated Receiver (DSRC) has been established in a 5.9 GHz band [1]. For services involving vehicle-to-vehicle and vehicle-to-road communications. Even though the standard is not yet complete. The DSRC system is one of the fundamental building blocks. The US Department of Transportation’s “Vehicle Infrastructure Integration” (VII) initiative [2]. VII is considering a national system in which intelligent vehicles communicate with each other and with the transport infrastructure. The aim is to enable a number of new services that provide security, mobility and business benefits. In many ways, the deployment of VII could reduce the number of fatalities on highways and improve the quality of life. The DSRC physical layer (IEEE 802.11p) [3] was originally adopted from the IEEE 802.11a [4] standard, which uses orthogonal frequency division multiplexing (OFDM) physical layer. Through the use of a guard interval, OFDM can mitigate inter symbol interference due to multipath fading. However, IEEE 802.11a was designed for stationary indoor environments with low propagation delay Wireless Access Vehicle (WAVE) environments involve dense urban centers, which tend to have significant delays that would exceed the length of the guard interval in IEEE 802.11a. For this reason, the duration of the symbol was doubled, and so inherently the guard interval was also doubled from 0.8 to 1.6 ms. Another major drawback of IEEE 802.11a is that it was designed for stationary environments. Conventional IEEE802.11a receivers initially estimate the channel response based on known preamble in the packet header. The channel response is assumed to be relatively static for the entire packet duration; therefore the entire packet is compensated based on the initial channel estimate [5]. The performance study in [6] indicated that conventional channel estimation is not a suitable choice for DSRC applications. In order to improve the performance of DSRC systems, it’s necessary to track the rapid fluctuation of the channel response within the packet duration. In this paper, a 5.9 GHz DSRC receiver is designed to improve the performance in harsh vehicular channel conditions. In section 2, the current specifications of the DSRC physical layer are presented. Section 3 gives a brief overview of the channels, the Conventional environmental models are reviewed, Section 4 provides a description of the IEEE 802.11p physical couche, Section 5 presents the simulation results which illustrate the performance improvements of the proposed DSRC receiver design over the conventional DSRC receiver. section 6 proposes the simulation of the LMS estimator of the channel as well as the results of the simulations as well as their interpretations section 7 concludes the paper.

Table 1 comparison IEEE 802.11 p AND IEEE 802.11 a

| Parameter                           | DSRC 802.11p | 802.11a |
|-------------------------------------|--------------|---------|
| Information Data Rate               | 3 – 27 Mbps  | 6 – 54 Mbps |
| Modulation Type                     | BPSK, QPSK,  | BPSK, QPSK,  |
|                                    | 16 QAM, 64 QAM | 16 QAM, 64 QAM |
| Coding Rate                         | 1/2, 1/3, 3/4 | 1/2, 1/3, 3/4 |
| Number of Subcarriers               | 52 (48+4)    | 52 (48+4) |
| OFDM Symbol Duration                | 8 µs         | 4 µs |
| Guard Time                          | 1.6 µs       | 0.8 µs |
| FFT Period                          | 6.4 µs       | 3.2 µs |
| Preamble Duration                   | 32 µs        | 16 µs |
| Bandwidth                           | 10 MHz       | 20 MHz |
| Subcarrier                          | 0.156 MHz    | 0.3125 MHz |
TABLE 2 requirements off IEEE 802.11 p

| Parameter                      | Relevant channel parameters | Criteria for phi parameter |
|--------------------------------|-----------------------------|----------------------------|
| guard interval (GI)            | Maximum excess delay (be)   | GI > (be)                  |
| Carrier spacing Do             | Coherence band (BC)         | BC > Do > BD               |
| Interval between channel       | Coherence time ($T_c$)      | Top < $T_c$                |

TABLE 3: summary devices of different environment in DSRC

| ENVIRONMENT | SEPARATION (m) | rm15 (μs) | D1 (μs) |
|-------------|----------------|-----------|---------|
| Highway LOS | 0-50           | 21.09     | 567.88  |
|             | 50-200         | 95.02     | 2714.29 |
|             | 200-500        | 112.33    | 1520.39 |
|             | >500           | 50.38     | 1248.61 |
| Highway NLOS| 0-150          | 382.01    | 382.01  |
|            | 150-300        | 3750.94   | 3750.94 |
|            | >300           | 3289.93   | 3289.93 |
| Urban LOS  | 0-75           | 10670.13  |         |
|            | 75-150         | 3347.11   | 1700.61 |
|            | 150-250        | 5232.32   | 2309.40 |
|            | 250-350        | 3188.55   | 2309.40 |
|            | 350-450        | 3396.36   | 1700.61 |
|            | >450           | 10933.88  | 1700.61 |
| Urban NLOS | 0-150          | 1739.39   |         |
|            | 150-250        | 2174.24   | 2374.21 |
|            | 250-500        | 2310.61   | 950.23  |
|            | 500-800        | 2370.63   | 1146.29 |
|            | 800-1000       | 2227.27   | 491.92  |
| Rural LOS  | 0-120          | 3132.87   | 783.59  |

III. V2V CHANNEL

Multipath causes the propagation of radio signals transmitted from one antenna to another through two or more paths. In urban areas, fading arises due to the different height of the transmitting and receiving antennas as there is no particular line of sight (NLOS) to propagate the signal from one antenna to another [7]. But fading may happen even there is a presence of a Line of Sight (LOS) due to the reflection, scattering etc. of the transmitted signal from the ground and surrounding area objects. The receiving antenna will get a resultant signal which can vary widely in amplitude or even in phase based on the distribution of the intensity and the bandwidth of the transmitted signal. The amplitude variations of multipath fading signals are followed by Rayleigh and Rician distributions. Multipath propagation can be categorized as large scale and small scale fading. Small scale fading can be expressed as rapid fluctuations of the amplitude or phase of the transmitted radio signal over a very short period of time or short travel distance. Large scale fading is the consequence of signal attenuation due to the propagation over long distances and diffraction around large objects. Multipath small scale fading effect causes few rapid changes in radio channels media such as rapid channel fading in channel strength level, time dispersion produced by multipath propagation path delays and random frequency modulation due to varying Doppler shifts of different multipath signals [8]. The small scale fading can be expressed as a linear filter with the time varying impulse response of a wireless channel. Time variation is introduced due to the receiver motion in space and filtering nature is introduced due to the summation of amplitudes, delays of multiple arriving waves at any instant of time. However based on the time delay spread small scale fading can be categorized as flat fading and frequency selective fading. As per Doppler spread small scale fading can be categorized

3.1. wave channel

A wireless medium between two Omni-directional antennas is usually made up of a secural component, namely line-of-sight (LOS) and scatter (non-LOS) components. The multipath channel is characterized by the power delay profile, which is used to obtain the delay spread. The movement of the vehicle introduces a time varying channel in addition to the multipath fading. The time varying nature of the channel is quantified by the coherence time, $T_c$, which is obtained from the relation [2] $T_c = \frac{1}{2\gamma} = \frac{2}{\sin^2(\pi f d)}$ (2) where $v$ is the relative velocity in meters per second (m/s), $c$ is the carrier frequency in Hertz (Hz), and $c$ is the speed of light in m/s. The WAVE channel can be modeled using statistical models presented in [9]. Rayleigh fading channels represent 2D isotropic scattering environments without a LOS component. Under Rayleigh fading, the received complex envelope is treated as a wide-sense stationary Gaussian random process with zero mean. When a LOS component exists, the envelope becomes a non-zero mean Gaussian random process. This type of fading is called Rayleigh fading, where the Rice factor, $K$, is defined as the ratio of the secular to sum of scatter power. According to [10], a wireless channel can be considered static over a period of $T$ if $T < T_c$. Therefore at a 5.9 GHz band, the channel could have static characteristics over the packet duration, Top, only if it satisfies the following relation $T_p = T_c < \frac{5.9}{3}$ GHz.
fades per packet will also increase. Appendix 3 gives MATLAB program

3.2 Environment comparisons

With regards to the proposed DSRC standard, examining Table 2 suggests that the proposed design parameters of 802.11p should account for many, but not all, of the channel impairments. We start by comparing the guard interval with the delay spreads to determine the degree to which multipath will introduce ISI. For 802.11p, the guard interval (GI) is 1.6 μs, which is twice as long as 802.11a’s GI of 0.8 μs. Among the high-speed environments (LOS / NLOS highway and rural), we see that the rural environment is the least hostile among the three due to its low delay, spread resulting from a lack of diffusers. Closely followed by the LOS motorway environment, which has higher average excess delays (32 ns more) but lower RMS delays (91.23 ns less). Short distance (0 to 50 m), LOS highway the channels have the most favorable performance compared to the others in case of delay and the Doppler characteristic are both taken into account. On the other hand, the NLOS motorway channel’s performance of the channels is much worse. Although the average and RMS delays exceed the LOS highway equivalents of only 151 ns and 184 ns, respectively, Doppler diffusion is much higher at 3515.03 Hz, i.e. a gain of 2291 Hz on the LOS highway equivalent an examination of Table 3 shows that all environments should have coherence bandwidths larger than the spacing between pilot tones. If the figure of merit is changed to sum delay propagation, 802.11p has an average sum delay spread of 507.02 ns (1.972 MHz), while urban LOS/NLOS environments are at 748.91 ns (1.335 MHz) and 704.9 ns (1.419 MHz), Table 3 shows that all environments should have higher consistency bandwidths as the spacing between pilot tones. If the merit number is replaced by a sum delay. However, only propagate highway LOS and rural LOS environments consistently have a sufficiently large coherence bandwidth. Highway NLOS has an average sum delay propagation of 507.02 ns (1.972 MHz), while urban LOS / NLOS environments are at 748.91 ns (1.335 MHz) and 704.9 ns (1.419 MHz), static environments in which 802.11 systems often operate.

IV. CONVENTIONNEL SYSTEM

Figure 4 gives the diagram of the transmitter. Forward Error Correction (FEC) coding is used to detect and correct errors due to channel fading and noise. The FEC code used in this system 

Fig. 3 Examples of fading envelopes for 5.9 GHz DSRC (Ts = 0.8 ms) over a packet duration of 0.8 ms (Nap 100)

Fig. 4a: transmitter in IEEE 802.11 p

Fig. 4b: receiver in IEEE 802.11 p

Fig. 5 comparing IEEE 802.11 a and IEEE 802.11 p with BER versus SNR BPSK

4.1 Comparing IEEE 802.11 a and IEEE 802.11 p

The latest technologies, such as 802.11p, are based on OFDM PHY, as OFDM based transmission systems can provide high speed transmission and high spectral efficiency in channel environments. Fig. 4.1: The OFDM 802.11p system model. The configuration of the model prepared in accordance with the recommendations of the IEEE 802.11a standard [87]. A simulation model was implemented using MATLAB. The structures of transmitters and receivers for 802.11p and 802.11a correspond to the blocks in block 4.4 The simulation model includes the following signal processing steps: transmitter, channel, receiver, transmitter:

- Convolutional coding with a coding rate, R = 1/2 and R = 3/4;
- BPSK modulation scheme;
- Inverse Fast Fourier Transform (IFFT) for 64 samples;
- Addition of a cyclic prefix (CP) of a length of a quarter of the duration of the symbol; The channel:
- Signal transmission with a duration of 8 µs (for 802.11p) and 4 µs (for 802.11a) on the fading channel HIPERPLAN / 2; The receiver:
- Removal of the CP;
- Fast Fourier transform (FFT) for 64 sub-carriers;
- Estimation of the least mean squares (LMS) channel;
- BPSK demodulation;
- Decoding of error codes using Viterbi’s hard decision algorithm. To obtain precise results, ten thousand bits are transmitted. More Data
transmission was simulated to vary $Eb / N0$ on Rayleigh fading channels: model A, shown in Figures 6, two BER curves were obtained: for IEEE 802.11a and IEEE 802.11p standards. For low values of mean $Eb / N0$, the errors are the same. The mean $Eb / N0$ required for a BER of $10^{-4}$ is 2 dB we notice the weak ber that presents ieee 802.11 p compared to ieee 802.11 a

V. MATLAB SIMULATION OFDM IEEE 802.11 P

Doppler shift in IEEE 802.11 p

Doppler shift when a source vehicle and a receiver vehicle move relative to each other, the frequency of the received signal will not be the same as the source. [13] When they get closer to each other, the frequency of the received signal is higher than the source, and it decreases when they get closer as seen in [9]. The Doppler effect has a great effect on vehicle networks due to the errors are the same. The mean signal is higher than the source, and it decreases when they get closer as seen when they get closer.

MATLAB SIMULATION OFDM IEEE 802.11 P

MATLAB simulation model

The MATLaB simulation model see APPENDIX 1 is made for a vehicle speed variation of 25.75, 125, 175, 225 and 400 km / h, the SNR varies from 1 to 40 dB. Figure 2 gives the result of parameters as defined by the IEEE 802.11a is between 0 and 250 km / h, therefore the amount of frequency deviation varies between approximately ± 7.708 kHz. The amount of offset can be very small, however, this offset causes significant problems in PHY transmission because the transmission technique (OFDM) is very sensitive to carrier frequency offset In IEEE 802.11p, the subcarrier spacing has been halved because the WAVE OFDM receiver is more sensitive to carrier frequency offset and Doppler shift. V2V and V2I communications are sensitive to much faster fading and higher Doppler frequency propagation and wave propagation. Multi-path delay higher than any other wireless system. In addition, it must be extremely robust in abnormal situations as collisions and accidents rarely occur under normal conditions. Depending on the limitation of the 802.11p standard, the channel used is a combination of a Rayleigh and an AWGN. For BER 10e-3 value if the moving speed is 30 km / h, no communication can be made when the SNR is less than 10 dB; for communication to be effective at SNR = 16 dB, the maximum relative speed must be less than or equal to 175 km / h. Figure 6a describes the impact of the Doppler effect in the IEEE 802.11 p standard due to the high mobility of the channel, it is observed that the BER decreases if the speed increases which discourages transmission
Figure 6 b gives a Per (packet error rate) as a function of the SNR for different types of of modulation and different value of code K. we conclude that the BPSK modulation and K = 1/2 gives the best performance (ber the most) which is why these parameters have been fixed in all the previous mb simulations. In order to give a realization of the physical layer of the IEEE 802.11 p similar to the IEEE 802.11 layer, the program given in appendix 2 performs this task, the encoding process consists of several steps, the transmitted bits are generated with the data source component. These data are modulated using phase shift modulation (BPSK or QPSK) or amplitude modulation (16-QAM or 64 QAM) the transmitted signal rate which can vary by 3 Mb/s (with BPSK and 1/2 code speed) at 27 Mb/s (with 64-QAM and code rate 3/4. Figure 7 and figure 8 compare the modulation, M-ary, we find there respectively the BER the qam 4 and the qam 64, that we can see that 4 QAM has a low BER compared to 64 QAM. Figures 9 and 10 respectively give the constellations which are the distance between the points I and the modulation system Q for M = 4 and M = 64. 4-QAM was found to provide the best performance (lowest BER) compared to 16-QAM and 64-QAM. The comparison results also included a modulation scheme with a lower constellation value at better BER performance due to the higher bit rate, we note the influence of the Rayleigh-type channel as in the form of noise on the constellation of modulations. We also validate the communication performance of OFDM systems in summary, the simulations see the negative effect of the Doppler effect on the performance of the transmission, namely he degradation of the cradle when the speed of the mobiles increases Table 5 summarizes the situations channel operation.

| Table 5: results simulation fading in wave channel |
|-----------------------------------------------|
| **FLAT FADING** | **FREQUENCY SELECTIVE FADING** |
| **SLOW FADING** | | |
| \(0 \leq r_{RMS} \leq 20\,\text{ns} \) | \(0 \leq r_{RMS} \leq 320\,\text{ns} \) |
| \(0 \leq f_{d} \leq 595,2\,\text{Hz} \) | \(0 \leq f_{d} \leq 595,2\,\text{Hz} \) |
| \(0 \leq v \leq v \leq 109\,\text{km/h} \) | \(0 \leq v \leq v \leq 109\,\text{km/h} \) |
| **FAST FADING** | | |
| \(0 \leq r_{RMS} \leq 20\,\text{ns} \) | \(20\,\text{ns} \leq r_{RMS} \leq 320\,\text{ns} \) |
| \(595,2 \leq f_{d} \leq 595,2\,\text{Hz} \) | \(595,2 \leq f_{d} \leq 2185,2\,\text{Hz} \) |
| \(109\,\text{km/h} \leq v \leq 400\,\text{km/h} \) | \(109\,\text{km/h} \leq v \leq 400\,\text{km/h} \) |

Fig. 7 | BER Vs SNR 4QAM
---|---
Fig. 8 | BER Vs SNR 64QAM
---|---
Fig. 9 | received constellation 4 QAM
---|---
Fig. 10 | received constellation 64 QAM
VI. ADAPTIVE FILTERING (AF) FOR CHANNEL EQUALIZATION

Adaptive Filtering (AF) describes how it has been shown to be an effective filter in channel equalization using self-adjusting channel impulse response coefficients (CIR) based on an adaptation algorithm such as least mean squares (LMS), recursive least squares (RLS) and Kalman (KF) filtering. The LMS algorithm is a simple algorithm among them to implement it practically with less computation cost and it changes the CIR coefficients \( h(n) \) with an effort to reduce the mean square error (MSE) which is the cost of the function. Different variations of the adaptive LMS algorithm such as Fixed Step Size LMS (FSS), Variable Step Size LMS (TVS) and Adaptive Step Size LMS (ASS) to improve the analysis of convergence by modifying the step size parameter [14]. A. Variants of LMS Algorithms FSS-LMS Algorithm The LMS algorithm for updating the CIR coefficients is as follows.

\[
\begin{align*}
    y(n) &= h^T(n) x(n) \quad (4) \\
    e(n) &= d(n) - y(n) \quad (5) \\
    h(n+1) &= h(n) + \mu e(n) u(n) \quad (6)
\end{align*}
\]

where \( x(n) \) is the input of the channel, \( e(n) \) is the error calculated by the AF, \( d(n) \) being the desired output and \( \mu \) is the convergence parameter or the step size for the update. day of the CIR coefficients which decides the stability of the mathematical equation described for the update of the CIR coefficients can be better explained by the block diagram which is shown in Fig.11

![Fig. 11 adaptatif filtre lms](image)

a matlab script for simulation isgiven in appendix 4

ASS-LMS AF for updating CIR filter coefficients with inclusion of gradient vector, which is basis for improvement in convergence rate, adaptability made a way to rapid varying channels ease of channel estimation and equalization. Convergence Analysis of FSS-LMS came from the adatation in step size with inclusion of gradient vector

To evaluate the performance of the proposed ASS-LMS the convergence analysis of different step size algorithms are evaluated with reference to number of iterations as shown in Fig. 12. the effect of the pitch (\( \mu \)) on the constellation of the signal received from the physical chainshawn in fig 13

![Fig. 12: error in lms algorithm](image)

\( a \) constellation for received signal for \( \mu = 0.00001 \)

\( b \) constellation for received signal for \( \mu = 0.0001 \)

VII. CONCLUSION

While much emphasis has and will deservedly be given to DSRC as a mechanism for increasing safety and efficiency on public roadways, its viability rests on the usage of a robust, low-latency physical layer. Decisions regarding DSRC’s projected benefits should always take into account the capabilities of its physical layer technology and the ground truth of the environment under which it operates. Measurements of this ground truth, by the authors and others, have shown the current DSRC standard to be sufficient, but not necessarily optimal, for its intended environment. Although the proposed standard may perform acceptably for short transmissions, longer transmissions may be subject to higher error rates in the absence of further processing. Analysis of our measurements also suggests the need to examine topics such as reduced coherence bandwidths, power control, and angle-of-arrival. All of these items impart challenges that will affect higher layers of the DSRC protocol stack. Conversely, their presence also provides fertile ground for further research and innovation. The authors hope that this chapter has brought sufficient attention to these issues and has encouraged readers to further appreciate how physical layer issues play a driving role in DSRC’s capabilities and future applications.

References

[1] http://grouper.ieee.org/groups/scc32/dsrc, accessed September 2006
[2] Fazel, K., & Kaiser, S. (2008). Multi-carrier and spread spectrum systems: from OFDM and MC-CDMA to LTE and WiMAX. John Wiley & Sons.
[3] http://grouper.ieee.org/groups/802/11/Reports
[4] IEEE Std. 802.11a: “Wireless LAN medium access control (MAC)
[5] Lu, J., Leithead, K. B., Chuang, J. I., & Liu, M. L. (1999). M-PSK and M-QAM BER computation using signal-space concepts. IEEE
%----------------------------???---------------------------------------------
%---------------------IFFT-----------------------
Rx_data_carrier=ifft(Rx_data_carrier,FFT_size); %---------------------------------------------
%---------------------BPSK---------------------
%--------------------------FFT-------------------
FFT_ofdm=fft(DeCP_ofdm,FFT_size,2);  
%----------------------------------------------------
DeCP_ofdm(:,1:carrier_num)=Rx_SP(:,CP_size+1:carrier_num+CP_size); %---------------------------------------------
DeCP_ofdm(:,CP_size+1:carrier_num+CP_size)=IFFT_ofdm;  
Tx_ofdm=reshape(DeCP_ofdm(:,1:carrier_num+CP_size))'; %symbol_num+training_symbol_num);

%-------------------------------------------------------------------------------
% clear all;

if s=1:length(SNR)
    for i = 1 + d4:length(Tx_ofdm)
        copy1(i) = a1*Tx_ofdm(i - d4) ;
        %--------------------------------------------------
        Rx_SP=reshape(Rx_ofdm,Symbol_num_carrier_num+training_symbol_num+carrier_num+CP_size); %----------------------------FFT---------------------------------------------
        FFT_ofdm=fft(Rx_ofdm,FFT_size,2);  
        Rx_training_symbols=fft(Rx_data_carrier,FFT_size);  
        Rx_data_carrier_PS=reshape(Rx_data_carrier,1,N_num); %---------------------------------------------
        Rx_data_carrier_PS=q=1:length(Rx_data_carrier_PS)
        if abs(Rx_data_carrier_PS(q)-1)>abs(Rx_data_carrier_PS(q)+1)<0
            demod_out2(q)=1;
            else
            demod_out2(q)=0;
        end
    end
    BER2=ber_count2/N_num;
    end
    %-------------------------------------------------------------------------------
    %-------------------------------------------------------------------------------
    %-------------------------------------------------------------------------------
appendix 2

%% program to simulate the ieee 802.2 ofdm
clear all; close all; clc;
% OFDM simulation
% By: MOUNTACIRI ABDERRAHIMr
% Initializing parameters
Nsc = input('OFDM symbol size (Number of subcarriers).');
M = input('Modulation order M = ');
EbNo=10^(EbNodB/10);
sigma=sqrt(Eb/(2*EbNo));

 stehen = randn(length(str:stp:Esnr),Nsc);
speed = 20; km/h
fd = (speed/3.6)*5.9e9/3e8;

figure(4)
scatterplot(r);title('constellation for receiver data with rayleigh channel');
savestr=stp:Esnr;
figure(4)
semilogy(snr,berRslt,-g,'linewidth',2,'markerfacecolor','g','markersize',8,'markeredgecolor','g');
grid;
title('OFDM Bit Error Rate vs SNR');
ylabel('Bit Error Rate');
xlabel('SNR [dB]');

legend(['BER, N = ', num2str(Nsc), ',num2str(M),',ht.type]);
n_results=Nc;
EbNodB=40;
k=log2(M);
EbN=10^((EbNodB/10); y = Dmod;
%% Channel
E_theta=mean(abs(y)).^2/k;
sigma=sqrt(Eb/(2*EbNo));
w=sigma*(randn(Nsc,1)+1i*randn(Nsc,1));
h=1/(sqrt(2))*((randn(Nsc,1)+1i*randn(Nsc,1)));h1=transpose(h);
r=h1.*y+transpose(w);

figure(4)
scatterplot(r);title('constellation for receiver data with rayleigh channel');
savestr=stp:Esnr;
figure(4)
semilogy(snr,berRslt,-g,'linewidth',2,'markerfacecolor','g','markersize',8,'markeredgecolor','g');
grid;
title('OFDM Bit Error Rate vs SNR');
ylabel('Bit Error Rate');
xlabel('SNR [dB]');

legend(['BER, N = ', num2str(Nsc), ',num2str(M),',ht.type]);

appendix 3

%% channel model

close all; clc; clear; N0 = 20;

% Number of scatters
NFFT = 2048;

-th scatter(40??) generator
speed = 2; km/h
num_path = 40;
NFFT = 4*256;
Nsamples = NFFT; 4096;
Tslot = 16=6; %1e-2/15;
Tchip = Tslot/1500;
Tchip = 333e-6;
Tslot = Tchip*256;
Tslot = Tchip*256;
sample = length(star);=
fs = 1/Tslot;
td = fs/td;

figure
for n=1:length(star);=
plot(tdat, (abs(flat_seq))); grid on;
xlabel('Velocity = 120km/h')
title('Velocity = 2km/h')

speed 40
figure
subplot(3,1,1)
plot(tdat, (abs(flat_seq))); grid on;
xlabel('Time ')
ylabel('Amplitude ')
title('Velocity = 2km/h')

speed 60

figure
plot(tdat, (abs(flat_seq))); grid on;
xlabel('Time ')
ylabel('Amplitude ')
title('Velocity = 120km/h')

speed 200
speed = 400;
fs = (speed/3.6)*5.9e9/3e8;

appendix 3
flat_seq = flat_fadingl(1,N0,fd,tdat,tau,1,constant_seed); subplot(3,1,3) plot(tdat, (abs(flat_seq))); grid on; xlabel('Time (sec)'); ylabel('Amplitude'); title('Velocity = 40km/h') hold on; plot(xdat1, 10*log10(flat_spec), '-x'); hold on; plot(xdat2, ideal_curve2, 'r-', 'linewidth', 2); xlabel('Frequency normalized by max. Doppler shift'); ylabel('amplitude (dB)'); set(gca, 'ylim', [-120 40]); set(gca, 'xlim', [-2 2]); grid on; legend('Flat fading', 'Ideal', 3)

[pwr freq] = psd(flat_seq(1,:), NFFT, fs); flat_spec = abs(fftshift(pwr(:,1)));

xdat1 = (freq-freq(length(freq)/2+1))/fd;

ideal_curve2 = [1 1]/(2*fd);

% speed 200
speed = 400;
fd = (speed/3.6)*2.45e9/3e8;

plot(tdat, 10*log10(abs(flat_seq)/max(abs(jakes_seq))));
grid on;
xlabel('Time (sec)'); ylabel('Amplitude'); title('Velocity = 400km/h') axis([0 0.09 -30 10]);
[pwr freq] = psd(flat_seq(1,:), NFFT, fs); flat_spec = abs(fftshift(pwr(:,1)));

xdat2 = [-1 1];
ideal_curve2 = [1 1]/(2*fd);
figure(); plot(xdat2, ideal_curve2, 'r-', 'linewidth', 2);
xlabel('Frequency normalized by max. Doppler shift'); ylabel('amplitude (dB)'); set(gca, 'ylim', [-120 40]); set(gca, 'xlim', [-2 2]); grid on;
legend('Flat fading', 'Ideal', 3)

% speed 80
speed = 40;
fd = (speed/3.6)*5.9e9/3e8;
jakes_seq = flat_fadingl(1,N0,fd,tdat,tau,1,constant_seed);
figure(); subplot(311), plot([1:Nsamples]*Tdslot, num2str(Tslot), 's');
plot(tdat, 10*log10(abs(flat_seq)/max(abs(jakes_seq))));
grid on;
xlabel('Time (sec)'); ylabel('Amplitude'); title('Jakes Model, f_d=' num2str(fd), 'Hz, T_s=' num2str(Tslot), 's');

axis([0 0.05 -20 10]);
plot(xdat2, ideal_curve1, 'r-', 'linewidth', 2);
xlabel('Frequency normalized by max. Doppler shift'); ylabel('Ideal');
set(gca, 'ylim', [-120 40]); set(gca, 'xlim', [-2 2]); grid on;
legend('Flat fading', 'Ideal', 3)

[t_state,1,0];
jakes_seq(1,:) = Jakes_Flat(fd, Tslot, Nsamples, t_state,1,0);

% speed 40
speed = 40;
fd = (speed/3.6)*2.45e9/3e8;

plot(xdat1, 10*log10(jakes_spec), '-x'); hold on;
plot(xdat2, ideal_curve2, 'r-', 'linewidth', 2);
xlabel('Frequency normalized by max. Doppler shift'); ylabel('Ideal'); set(gca, 'ylim', [-120 40]); set(gca, 'xlim', [-2 2]); grid on;
legend('Flat fading', 'Ideal', 3)

Axes axes(ax)

fd = (speed/3.6)*5.9e9/3e8;
jakes_seq = flat_fadingl(1,N0,fd,tdat,tau,0,constant_seed);
figure(); subplot(31,1,2) plot(tdat, 10*log10(abs(jakes_seq)/max(abs(jakes_seq))));
grid on;
xlabel('Time (sec)'); ylabel('Amplitude');

[x State,1,0];
jakes_seq(1,:) = Jakes_Flat(fd, Tslot, Nsamples, t_state,1,0);

% speed 120
speed = 120;
fd = (speed/3.6)*5.9e9/3e8;

plot(xdat1, 10*log10(jakes_seq(tslot), 's');
plot(xdat2, ideal_curve2, 'r-', 'linewidth', 2);
xlabel('Frequency normalized by max. Doppler shift'); ylabel('Ideal'); set(gca, 'ylim', [-120 40]); set(gca, 'xlim', [-2 2]); grid on;
legend('Flat fading', 'Ideal', 3)

% QAM is a European space for a distance of
M=16;
%The hexadecimal numbers QAM
mapping=[-3*d 3*d;-d 3*d; d 3*d;-3*d d; d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;-d d; d d; 3*d d; -3*d -d; d -d;-3*d -3*d;-d -3*d; d -3*d; 3*d 3*d;-3*d d;
