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# High Data Rate of Wireless Vehicular Communication System Based on Error Bits Cancellation

**Ebaa Abdul Zahra Jafar[1]*** **Ashwaq Q. Hameed [2]***

[1]*College of Engineering, University of Babylon, Babylon, Iraq*

*E-Mail: eng.ebaa.jafar@uobabylon.edu.iq

[2] Electrical Engineering *Department, College of Engineering,* University of Technology, Baghdad, *Iraq**

*E-Mail: 50058@uotechnology.edu.iq

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**Abstract**

Road safety can be substantially improved by the deployment of wireless communication technologies for vehicular networks, which enables new services and further facilitates communication among moving vehicles. In this paper, we study the performance of vehicular communication systems under various conditions by using MATLAB simulation. Then we improved the performance of the system by employing LMS equalization, which reduced the error and obtained higher data transfer rates. A multipath time-varying channel model with a 100 ns delay spread is used in the simulation. The OFDM system is applied in this paper according to the IEEE 802.11p standard. BPSK, QPSK, 16-QAM, and 64-QAM modulation schemes are used. Which is then combined with a time interleaver and a convolutional encoder. An LMS decision feedback equalizer is used to reduce the impact of inter symbol interference. The decoder utilizes the Viterbi algorithm in order to decode the received signal. A comparison between IEEE802.11p and IEEE802.11a standards has been created to investigate which is more suitable for vehicular communication systems. The performance of different modulation schemes and coding rates for SNR in the range of (0-16) dB was investigated. Then the simulation model has been improved by using LMS equalization and comparing the results of the model with and without the LMS equalizer for different frame sizes and different vehicle velocities. Throughput measurement was used to study system performance in the range of SNR (0-16) dB for unpunctured QPSK over time variant channel with different velocities and different frame sizes. A compression of previous work was executed to show the enhancement that is obtained in this work. The best BER obtained at 50 km/h vehicle speed is $4.3 * 10^{-4}$ at a SNR of 16 dB by using an unpunctured QPSK modulation scheme and an LMS algorithm with (0.01) and 10 frame size.

**Key words:** IEEE 802.11p, V2V, Dedicated Short Range Communication (DSRC), Vehicular Communication System

## 1. Introduction

A vehicular communication system is a communication network where roadside units and vehicles can exchange information with each other [1]. Vehicular communication systems are important because of their effectiveness in reducing traffic congestion and accidents due to

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their applications that provide safety. Several papers study V2V communication systems, such as [2], which focuses on the performance of vehicle-to-vehicle (V2V) communication by studying an analytical model for IEEE 802.11p in periodic broadcast mode to analyze the Dedicated Short Range Communication (DSRC) performance. [3] proposes the Narrowband Internet of Things to enhance the robustness of the vehicular communication system. While the target of [4] is how to apply machine learning and get enhanced PER values in V2V communication, the channel estimation problem encountered in V2V communication systems was discussed in [5]. [6] investigated the physical layer of a multi-antenna for vehicular communication channels. [7] simulated to plain IEEE 802.11p, a MIMO-extended PHY layer based on IEEE 802.11p offers significantly higher robustness against short-term fading. [8] described IEEE802.11p and IEEE802.11a standards and made a comparison between them. In this paper, we studied the performance of vehicular communication systems for different conditions, then improved this performance by using LMS equalization. By comparing the results of the model with and without the LMS equalizer for different frame sizes and different vehicle velocities, we showed the enhancement that we got. This paper is arranged as follows: in Section 2, the wireless vehicular communication system model is described. The time-varying channel model and adaptive equalization algorithm are portrayed in Sections 3 and 4, respectively. Simulation results are given in Section 5. Section 6 concludes this paper. Finally, the references are written in Section 7.

## 2. Wireless vehicular communication system

IEEE 802.11p is the standard that chosen for the Wireless access in Vehicular Environment (WAVE) architecture. It is an improvement to the well-known IEEE 802.11a by decreasing the signal bandwidth from 20 MHz to 10 MHz in IEEE 802.11p that makes the communication more effective for high mobility vehicular channel, such as decreasing inter symbol interference (ISI) caused by multipath channel with a doubled guard interval. This implies that the parameters in the time domain are doubled in comparison with the parameters of IEEE 802.11a [9]. Some different contrasts between IEEE 802.11p and IEEE 802.11a standards are underlined in Table 1.

**Table 1**. Comparisons between parameters of IEEE 802.11a and IEEE 802.11p [10]

| Parameter | IEEE 802.11a | IEEE 802.11p |
|---|---|---|
| Bitrate Mb/s | 6,9,12,18,24,36,48,54 | 3,4,5,6,9,12,18,24,27 |
| Modulation Type | BPSK, QPSK, 16QAM, 64QAM | BPSK, QPSK, 16QAM, 64 QAM |
| Code Rate | 1/2, 1/3, 1/4 | 1/2, 1/3, 1/4 |
| Number of Subcarriers | 52 | 52 |
| Symbol Duration | 4 µs | 8 µs |
| Guard Time | 0.8 µs | 1.6 µs |
| FFT Period | 3.2 µs | 6.4 µs |
| Preamble Duration | 16 µs | 32 µs |
| Subcarrier Frequency Spacing | 0.3125 MHz | 0.15625 MHz |
| Error Correction Coding | K = 7 (64 states) | K = 7 (64 states) |

The IEEE 802.11p frame structure is displayed in **Fig. 1**. Every frame consists of a preamble, DATA field, and SIGNAL field. The preamble is located at the beginning of each frame, and it consists of ten short symbols ($t_1$) to ($t_{10}$), each with 1.6 us duration, and two long symbols each with 6.4 us duration, which are used for channel agreement. The SIGNAL field carries information about the coding rate, the modulation type, etc. Finally, the DATA field is used to carry the main data. The guard interval (GI) is used in order to reduce inter symbol interference (ISI).

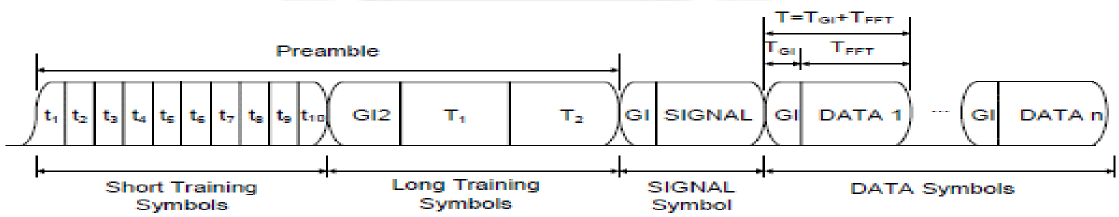


**Figure 1. Packet structure [10]**

The wireless vehicular communication system model consists of the transmitter, channel, and receiver, as shown in **Fig. 2**. On the transmitter side, the data is encrypted with several stages, including encoding, interleaving, and puncturing. Then, the data will be modulated with a certain signal constellation. Then the pilot subcarriers are inserted between the data subcarriers, and training symbols are added for channel estimation. Then the IFFT block is used to transform the frequency domain subcarriers into the time domain, and at last, a cyclic prefix is added with a length equal to one-fourth of the duration of the symbol. Hence, the signal is ready for transmitting over the channel. In the receiver, the signal goes through the same transmission stages but in reverse, with channel estimation and equalization to compensate for the effect of the fading channel

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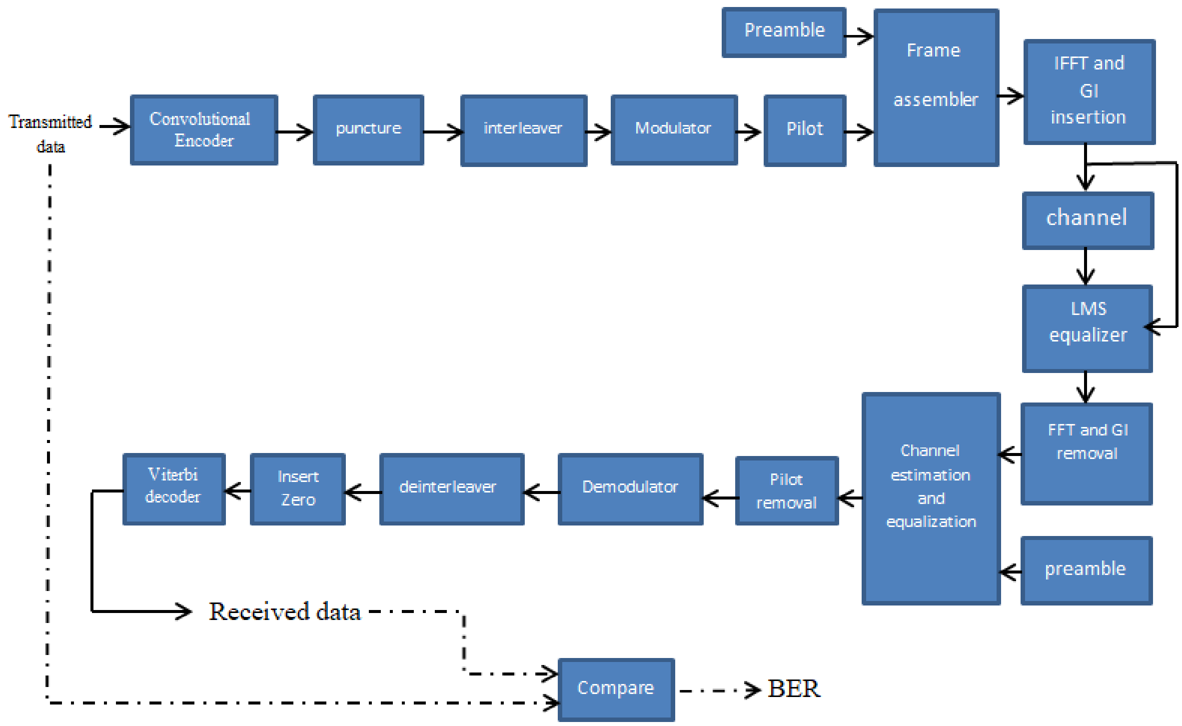


**Figure 2. The wireless vehicular communication system model**

A Vehicular communication system was created using Simulink from Mathworks, as shown in Fig. 3. Each car shown in this figure consists of several submodels, such as the Car Dynamic Model and the Detection System Model.

The car dynamic model calculates the position of the car by using integration blocks. It is also possible to determine which system should be activated the blind spot warning system or the adaptive cruise control system by using the detection system. The position of the first car is then transmitted and received over the IEEE 802.11p PHY layer using varied modulation schemes and coding rates that are combined with the convolution encoder, which has a 1/2 coding rate as a mother code. By using puncture block, other code rates can be obtained, such as (2/3) and (3/4), and then the interleaving process can be utilized in digital transmission to reduce the impact of burst errors.

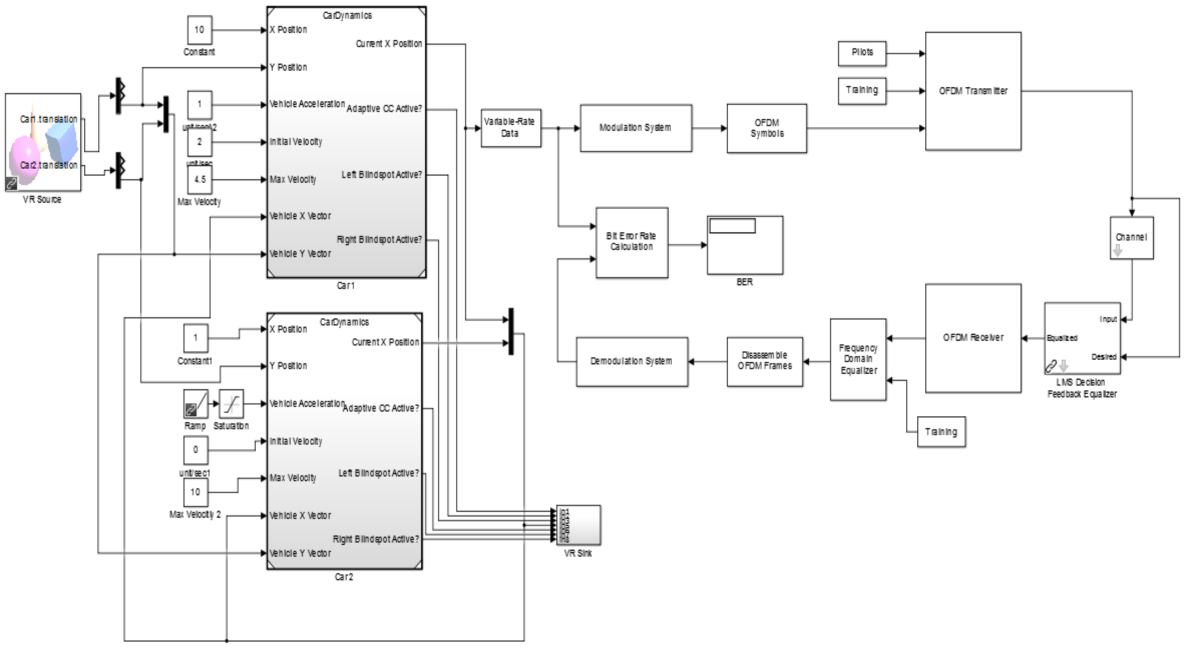


**Figure 3. Wireless vehicular communication system**

For the IEEE 802.11p standard, the interleaving process is characterized by two modifications. The first one is executed with the matrix interleaver, and the second one is executed with the general block interleaver [9].

The first modification is defined by the rule [11]:

$$j = (N_{CBPS}/16)\,(i\ mod\ 16) + floor(i/16) \qquad (1)$$

$$i = 0, 1, \ldots, N_{CBPS} - 1$$

While the second modification is defined by the rule [11]:

$$k = s \times Floor\left(\frac{j}{s}\right) + (j + N_{CBPS} - Floor\ (16 \times j/N_{CBPS}))\ mod(s) \qquad (2)$$

Where $N_{CBPS}$ denotes the number of code bits in one OFDM symbol. That depends on the modulation scheme used, as given in table (2), j = 0, 1, …, $N_{CBPS} - 1$ and s is a parameter that is defined in Eq. (3).

$$s = max\left(\frac{N_{BPSC}}{2}, 1\right) \qquad (3)$$

| Modulation | Coding rate (R) | Coded bits per Subcarrier ($N_{BPSC}$) | Coded bits per OFDM symbol ($N_{CBPS}$) | Data bits per OFDM symbol ($N_{DBPS}$) | Data rate (Mb/s) |
|---|---|---|---|---|---|
| BPSK | 1/2 | 1 | 48 | 24 | 3 |
| BPSK | 3/4 | 1 | 48 | 36 | 4.5 |
| QPSK | 1/2 | 2 | 96 | 48 | 6 |
| QPSK | 3/4 | 2 | 96 | 72 | 9 |
| 16QAM | 1/2 | 4 | 192 | 96 | 12 |
| 16QAM | 3/4 | 4 | 192 | 144 | 18 |
| 64QAM | 2/3 | 6 | 288 | 192 | 24 |
| 64QAM | 3/4 | 6 | 288 | 216 | 27 |

**Table 2. Modulation-dependent parameters [11].**

IFFT block with 64 points are used, which realizes OFDM modulation; however, only 52 subcarriers are used. From these 52 subcarriers, 48 are used to carry the actual data, while the remaining 4 subcarriers, which are called pilots, are used to ignore phase and frequency offset on the receiver side and are situated on subcarriers −21, −7, 7, and 21 [9]. The least square (LS) estimation is used to estimate the channel coefficients, and these coefficients are compensated by using the zero forcing (ZF) equalizer. In addition, LMS decision feedback equalizer is used to reduce (ISI). A viterbi decoder is applied in order to decode the received signal.

## 3. Channel model

The transmission medium in all forms of wireless communications is the radio channel between the transmitter and receiver. In addition to the multipath problem, the signal transmitting over vehicular communication networks suffers from Doppler shift, caused by relative velocities between the transmitter and the receiver. These problems are addressed by the time-variant channel model, which explains the behavior of the model in propagation environments with strong paths and fast movements. The spectral properties of the channel are specified by the delay spread that causes the smearing and spreading of the signal over time.

The reciprocal of delay spread is a measure of channel coherence bandwidth. The coherence bandwidth BC is the maximum frequency difference for which the signals are still strongly correlated [12].

The effect of Doppler spread in a multipath propagation environment is to enlarge the bandwidth of the multipath waves. Hence, reinforcing the bandwidth of the signal. This phenomenon is called Doppler spread [13], [14].

The baseband signal that transmits over the channel is assumed to be x(t). Then, the passband signal is given as [12]:

$$\tilde{x}(t) = \mathrm{Re}\left[x(t)e^{i2\pi f_c t}\right] \tag{4}$$

The received signal after propagating over the channel of various Doppler shifts and propagation paths can be represented as:

$$\tilde{y}(t) = \mathrm{Re}\left[\sum_{i=1}^{I} C_i e^{j2\pi(f_c+f_i)(t-\tau_i)}\, x(t-\tau_i)\right] = \mathrm{Re}\left[y(t)e^{j2\pi f_c t}\right] \quad (5)$$

Where $C_i$, fi, and $\tau_i$ are the channel gain, Doppler shift, and delay for the $i^{th}$ path, respectively. For the λ wavelength and the ν mobile speed, the Doppler shift is given as:

$$f_i = f_m \cos\theta_i = \frac{v}{\lambda}\cos\theta_i \quad (6)$$

Where $f_m$ is the maximum Doppler shift and $\theta_i$ is the angle of the access $i^{th}$ path. The received baseband signal in Eq. (5) is given as:

$$y(t) = \sum_{i=1}^{I} C_i e^{-j\Phi_i(t)} x(t-\tau_i) \quad (7)$$

Where $\Phi_i(t) = 2\pi\{(f_c + f_i)\tau_i - f_i t\}$ according to Eq. (7); therefore, the corresponding channel can be modeled as a linear time-varying filter with the following impulse answer:

$$h(t,\tau) = \sum_{i=1}^{I} C_i e^{-j\Phi_i(t)} \delta(t-\tau_i) \quad (8)$$

The effect of multipath propagation is presented by Rayleigh channel coefficients. Besides, the Doppler shift caused by relative movement in the channel changes each multipath component with time.

## 4. **Adaptive equalization algorithm**

Time varying channels corrupt the transmitted signal, and then error bits will be obtained at the receiver. ISI caused by multipath has been specified as the major problem for transmission via the radio channel of mobile communications. Equalization is a technique that is utilized to combat ISI [15].

Since the mobile fading channel is random and time changing, equalizers must track the time changing characteristics of the mobile channel and are thus named adaptive equalizers.

The adaptive algorithm is dominated by the error signal ($e_k$). This error signal is formed by comparing the output of the equalizer ($\hat{d}_k$). With signal ($d_k$), that is an exact scaled replica of the transferred signal. The adaptive algorithm uses ($e_k$) to decrease the mean square error and updates the equalizer weights in a mode that iteratively reduces the mean square error [16]. The structure of the adaptive equalizer is demonstrated in **Fig. 4.**

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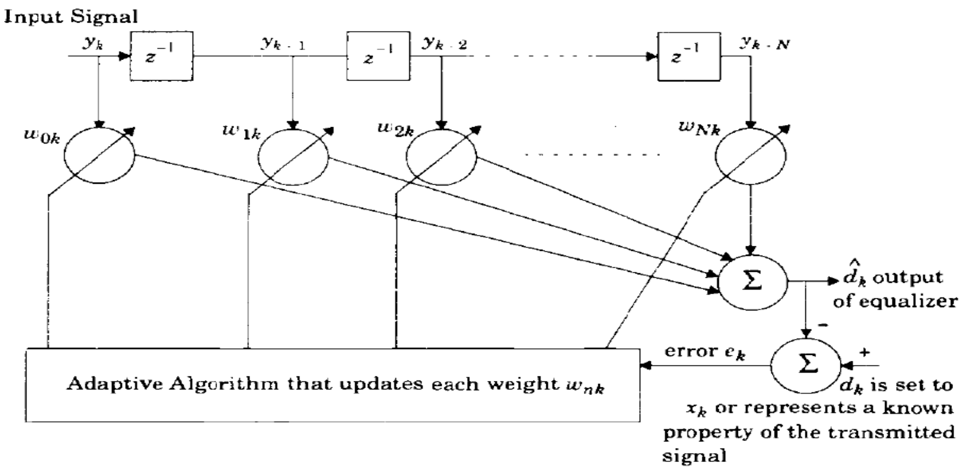


**Figure 4. A basic linear equalizer during training [15].**

Assume that the equalizer input signal is a vector ($y_k$) [17], where:

$$y_k = [y_k \quad y_{k-1} \quad y_{k-2} \quad \dots \quad y_{k-N}]^T \tag{9}$$

The equalizer's output is given by:

$$\hat{d}_k = \sum_{n=0}^{N} w_{nk} y_{k-n} \tag{10}$$

A weight vector can be given as:

$$W_k = [W_{0k} \quad W_{1k} \quad W_{2k} \quad \dots \quad W_{Nk}]^T \tag{11}$$

The Least Mean Squares (LMS) algorithm seeks for the optimum or near-optimum filter weights through performing the following iterative operation [16]:

$$\text{New weight} = \text{previous weight} + (\text{constant}) * (\text{previous error}) * (\text{current input vector})$$

$$w_N(n+1) = w_N(n) - \alpha e_k^*(n) y_N(n) \tag{12}$$

where

$$\text{previous error} = \text{previous desired output} - \text{previous actual output}$$

$$e_k(n) = x_k(n) - \hat{d}_k(n) \tag{13}$$

Where the subscript N indicates the number of delay stages in the equalizer, and α is the step size that controls the convergence rate and firmness of the algorithm.

Because the channel distortion is too sharp for a linear equalizer to handle. A feedback equalizer can be used for better performance. The basic concept behind DFE is that the ISI that influences future symbols can be evaluated and subtracted out before detection of subsequent symbols [18].

DFE consists of a feed forward filter (FFF) and a feedback filter (FBF). The **Fig. 5** exhibits the block diagram of the decision feedback equalizer.

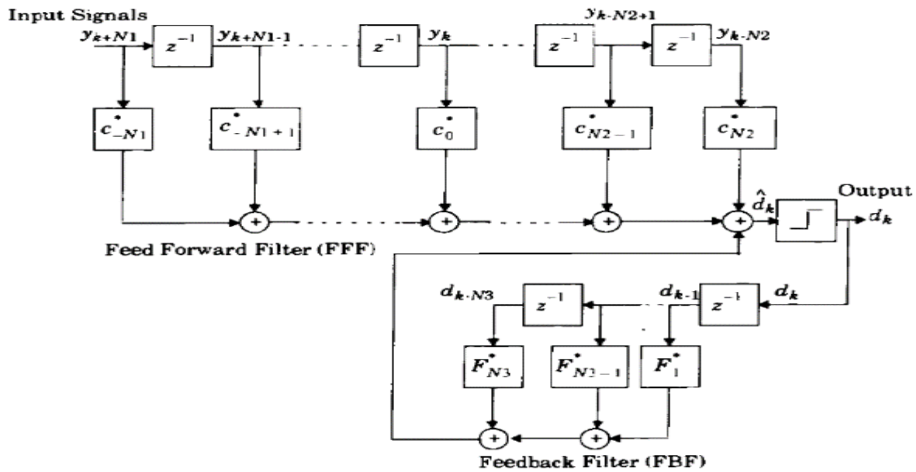


**Figure 5. Decision feedback equalizer (DFE) [15]**

The feed forward section is nothing but a linear equalizer. The FBF coefficients can be modified to skip the ISI on the current symbol from past symbols. The equalizer has N1 + N2 + 1 taps in the feed forward filter and N3 taps in the feedback filter, and its output is expressed as

$$\hat{d}_k = \sum_{n=-N_1}^{N_2} C_n^* y_{k-n} + \sum_{i=1}^{N_3} F_i d_{k-i} \tag{14}$$

Where $C_n^*$ and $y_n$ are tap gains and the inputs, respectively, to the forward filter, $F_i$ are tap gains for the feedback filter, and $d_i$ ($i < k$) is the previous symbol [16].

## 5. Simulation results

This section first investigates the robustness of the 802.11p physical layer when compared with the 802.11a. For similar link parameters. Then it presents the system performance over a time-variant channel without the LMS decision feedback equalizer, then with the LMS decision feedback equalizer and two different step sizes using different scenarios with unpunctured QPSK, 100 ns delay spread, and ZF equalization. **Fig. 6** demonstrates the model performance for the unpunctured QPSK modulation scheme, propagating over a time-varying channel. With ZF equalization, the speed of the vehicle is 50 km/h, and DS = 15. The cyclic prefix of 802.11p has a value of 16 samples, which is longer than the cyclic prefix of 802.11a, where it is equal to eight samples. The longer cyclic prefix duration for 802.11p operation mitigates the larger delay spread of the channel and offers increased robustness for outdoor operation. This fact can also be proved by using throughput measurement, which measures the rate at which messages arrive at their destination successfully, as displayed in **Fig. 7** which state that IEEE 802.11p has a throughput value equal to (0.983), which is larger than that in the IEEE 802.11a standard, which is equal to (0.855) at 16 dB SNR for the same channel and vehicle speed.

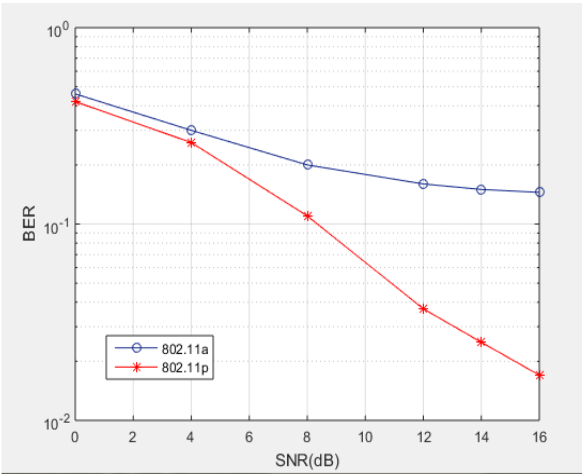


**Figure 6. The performance of unpunctured QPSK modulation scheme, propagates across a time-varying channel. With ZF equalization, DS = 15, the speed of the vehicle is 50 km/h.**

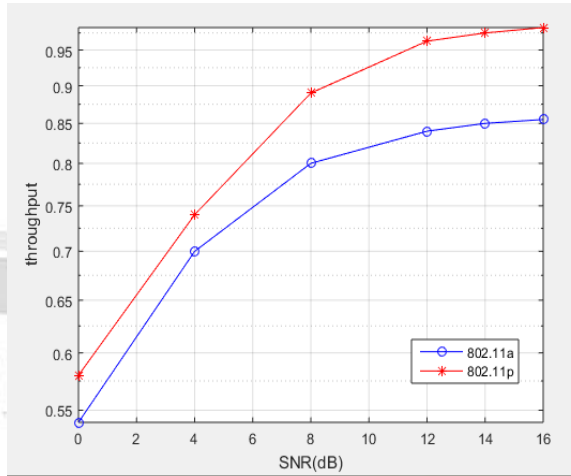


**Figure 7. The throughput for coded unpunctured QPSK over time-varying channel, vehicle speed of 50 km/h, ZF equalization and DS = 15.**

**Fig. 8** demonstrates the model's performance for different modulation schemes and coding rates, propagating across time-varying channel. With ZF equalization, the speed of the vehicle is 50 km/h, DS = 1, and 20 OFDM per frame. From this figure, it can be observed that BPSK and QPSK have better performance than 16 QAM and 64 QAM. The reason for this fact is that the symbols of the QPSK and BPSK constellations are less densely spaced than the 64QAM and 16 QAM constellations, respectively. The figure also shows a comparison between the 1/2 code rate and other code rates, where 3/4 and 2/3 code rates require higher SNR compared with the 1/2 code rate for similar constellations at the same BER performance. This is because the redundancy of 1/2 code rates is less than that of other code rates; therefore, the error correction capability of the decoder with 2/3 and 3/4 code rates will be less than that with 1/2 code rates. Finally, QPSK with a 1/2 coding rate is preferred because it has better performance than all other modulation schemes. In spite of this, it has approximately the same BER curve as BPSK with a 1/2 coding rate because of its higher spectral efficiency whereas the distance between QPSK symbols is the same as that between BPSK symbols. However, QPSK is two-dimensional; therefore, the spectral efficiency will be increased without decreasing the minimum distance among symbols.

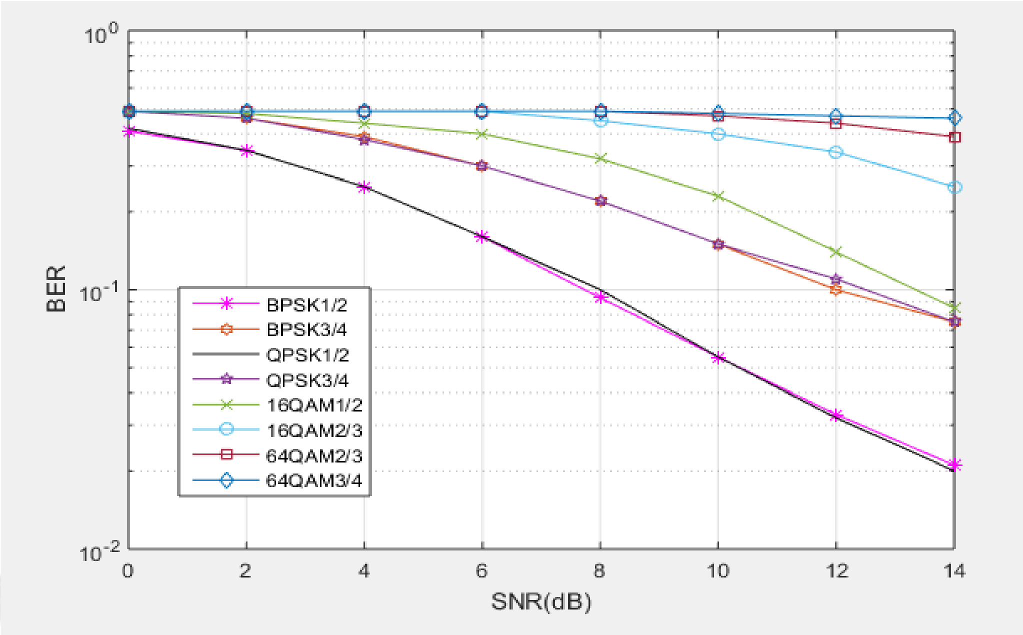


**Figure 8. Model performance for different modulation schemes and coding rates propagating over time-varying channel with ZF equalization, speed of vehicle is (50 km/h), 20 OFDM symbol per frame, and DS = 1.**

For the first scenario, the number of OFDM symbols per frame is set at 20 with three different vehicle speeds of 30 km/h, 50 km/h, and 80 km/h. The results of the vehicle at 30 km/h are shown in **Fig. 9**, where the value of BER has an evident improvement when using the LMS equalizer in comparison with that without it. This is due to the LMS equalizer, which mitigates ISI that arises from the multipath effect of the channel. **Fig. 10** shows an enhancement in the throughput curves where, at 16 dB SNR, the value of the throughput rises from 99.3% to 99.96 % after using the LMS equalizer.

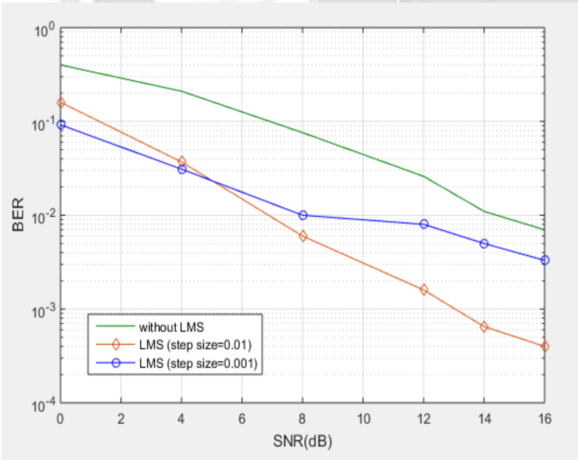


**Figure 9. The performance of QPSK with a 1/2 coding rate over a time-variant channel with 20 OFDM symbols per frame, vehicle speed of 30 km/h, ZF, and LMS equalization.**

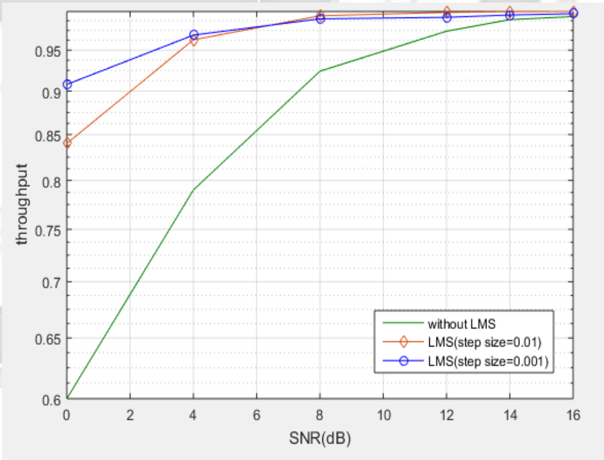


**Figure 10. The throughput of unpunctured QPSK over a time-variant channel with 20 OFDM symbols per frame, vehicle speed = 30 km/h, ZF, and LMS equalization**

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**Fig. 11** displays the performance of the system when the vehicle is moving at a speed of 50 km/h. It can be noted that the LMS equalizer improved the performance from (0.011) to ($8.5*10^{-4}$) at a 16 dB SNR value. At the same time, it is clear that the results are worse than those shown in **Fig. 9**, which means that the effect of Doppler is still present. This is also shown by the throughput measurement in **Fig. 12:** An increase in throughput from (98.9%) to (99.915%) will be obtained for the same SNR by using the LMS algorithm.

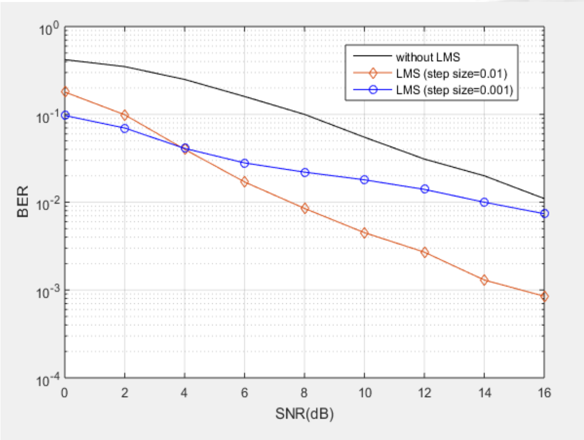


**Figure 11. The performance of the unpunctured QPSK modulation scheme over time-variant channel with 20 OFDM symbols per frame, a vehicle speed of 50 km/h, ZF and LMS equalization**

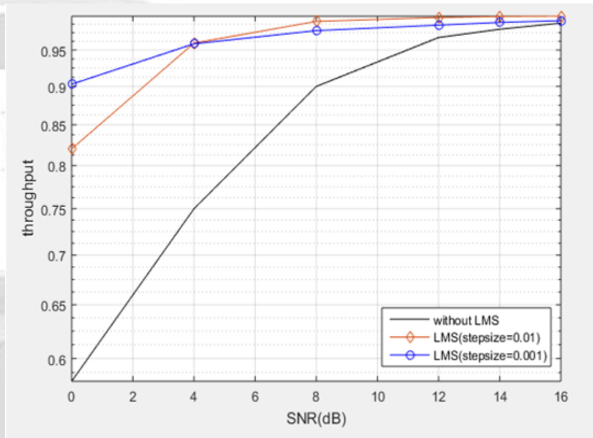


**Figure 12. The throughput of unpunctured QPSK over a time-variant channel with 20 OFDM symbols per frame, vehicle speed = 50 km/h. ZF and LMS equalization**

The performance of the system at 80 km/h vehicle speed is shown in **Fig. 13.** The effect of motion at a higher speed on performance can be observed, where **Fig. 13** shows the worst performance in comparison with **Figs. 9 and 11**. At (16 dB) SNR, the BER of the system has a value of (0.002) with the LMS equalizer, while this value is reduced to ($4*10-4$) and ($8.5*10-4$) for **Figs. 9 and 11,** respectively. However, the system was improved by adding an LMS equalizer, and hence an ISI reduction will be obtained. The data bits that were received correctly are about 99.8% of the total transmitted bits when using the LMS algorithm, while this value is reduced to 97.3% for the system without the LMS equalizer at 16 dB SNR, as shown in **Fig. 14**.

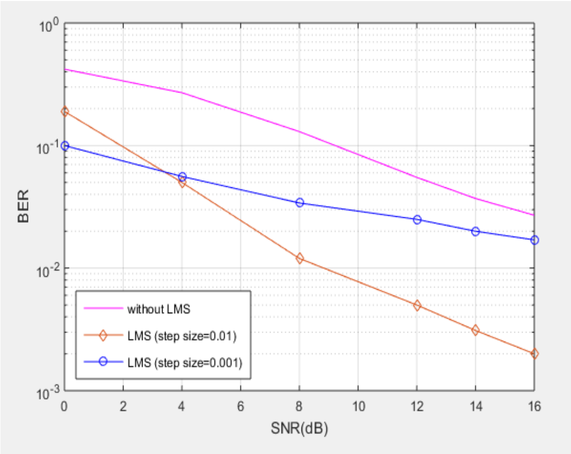


Figure 13. BER performance of QPSK with 1/2 coding rate over a time-variant channel with 20 OFDM symbols per frame, vehicle speed of 80 km/h, ZF, and LMS equalization.

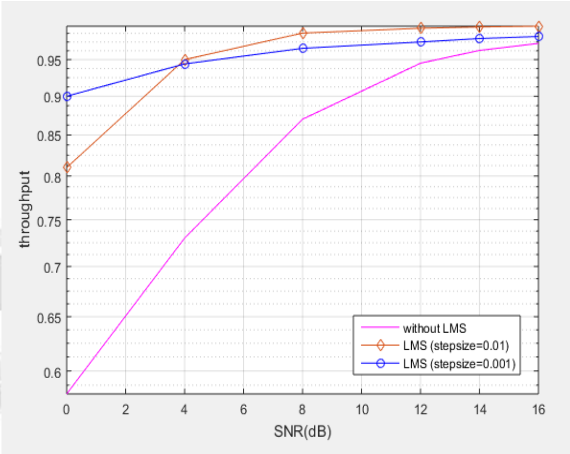


Figure 14. The throughput of unpunctured QPSK over a time-variant channel with 20 OFDM symbols per frame, vehicle speed of 80 km/h, ZF, and LMS equalization

The performance of the system over a 50 km/h vehicle speed with different OFDM symbols per frame was studied in the second scenario. **Fig. 15** shows the effect of using the LMS equalizer on the system performance when using 10 OFDM symbols per frame. It can be observed that the LMS algorithm improves the system performance widely, where at 16 dB SNR, the BER of the system reaches ($4.3*10^{-4}$) by using the LMS equalizer, while it has a value of (0.0056) without the LMS equalizer at the same SNR. Throughput measurement in **Fig. 16** shows that (99.44%) of total transmitted bits are received correctly for the system without an LMS equalizer at 16 dB SNR, while (99.957%) of total transmitted data are received correctly when using an LMS equalizer at the same SNR.

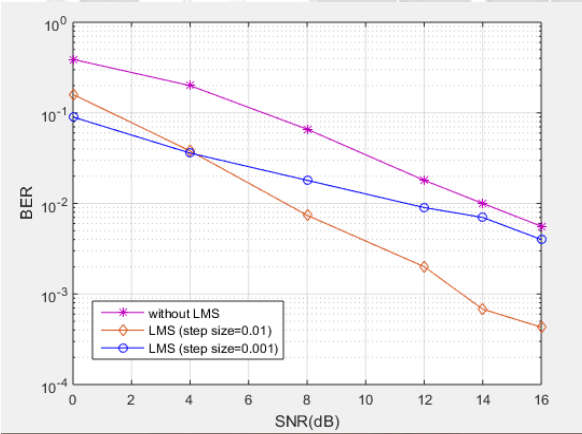


Figure 15. BER performance of the unpunctured QPSK modulation scheme over a time-varying channel, vehicle speed of (50 km/h), ZF equalization, LMS equalization, and 10 OFDM symbols per frame.

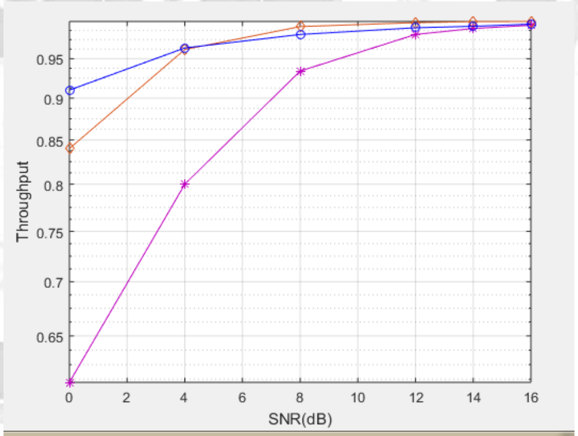


Figure 16. The throughput of the unpunctured QPSK modulation scheme over a time-varying channel, vehicle speed (50 km/h), ZF equalization, LMS equalization, and 10 OFDM symbols per frame.

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The system performance with 50 OFDM symbols per frame is shown in **Fig. 17.** It can be noted that at 16 dB SNR, the curve of BER with LMS equalization has a value of 0.0016, which is the worst in comparison to the same curve in the **Figs. 15 and 11** at the same SNR. The increase in OFDM symbols per frame shows a marked decrease in performance in spite of the enhancement in the performance of the system with the LMS equalizer in comparison to that without it. Which means that the LMS equalizer could not solve the problem of the system that uses a large frame size. However, this enhancement is obtained by using the LMS equalizer because of ISI cancellation by this algorithm. This enhancement in performance is also shown by the throughput measurement in **Fig. 18** where it has a value of (94%) and (99.84%) for the system before and after using the LMS algorithm, respectively, at the same SNR. The throughput decreases with increasing OFDM symbols, where the value of throughput is about (99.957%), (99.915%), and (99.84%) of the system with 10, 20, and 50 OFDM symbols per frame, as shown in **Figs. 16, 12, and 18,** respectively.

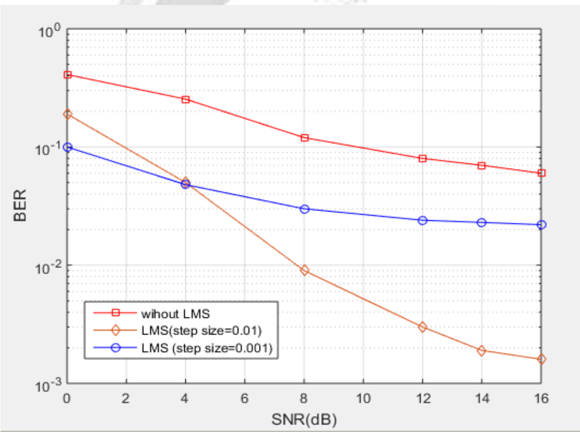


**Figure 17. BER performance of the unpunctured QPSK modulation scheme over a time-varying channel, speed of the vehicle (50 km/h), with ZF equalization, LMS equalization, and 50 OFDM symbols per frame.**

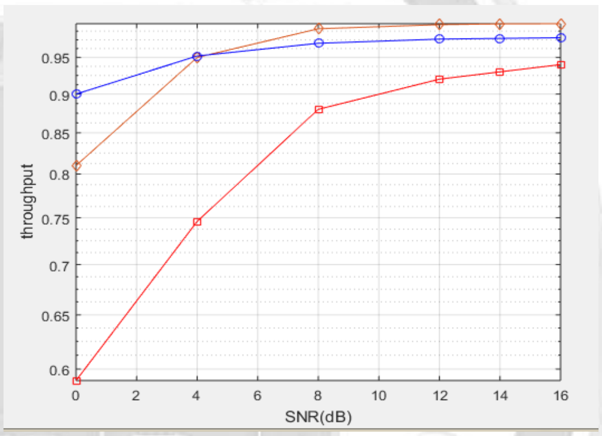


**Figure 18. The throughput of the unpunctured QPSK modulation scheme over a time-varying channel, speed of the vehicle (50 km/h), ZF equalization, LMS equalization, and 50 OFDM symbols per frame.**

Finally, a comparison with reference [5] results was carried out in order to show the enhancement amount that is obtained in this work. The comparison shown in Fig. 19 for the same DS, which equals four, vehicle speed at 40 km/h, with LS estimation. It's clearly seen that at the same SNR, the result of this work is much better than those in [5]. For example, the 16 dB SNR reference [5] has a BER equal to 0.5, while this work has a BER value of 0.009. This enhancement is due to the reduction in the number of OFDM symbols transmitted in the frame, which makes the LS estimate of the channel coefficients, depending on the preamble, accurate enough for the equalization of the remaining OFDM symbols in the frame. Then the LMS algorithm is used in this work for equalization, which gives much better performance. As can be noted in Fig. 19 the curve of BER reaches 5.7∗ 10-4 at 16 dB SNR. This is due to ISI cancellation by the LMS algorithm.

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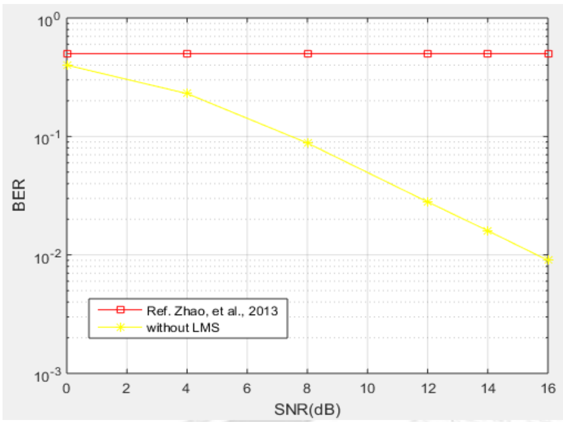


Figure 19. Comparison between the results obtained in this work and [5] without using

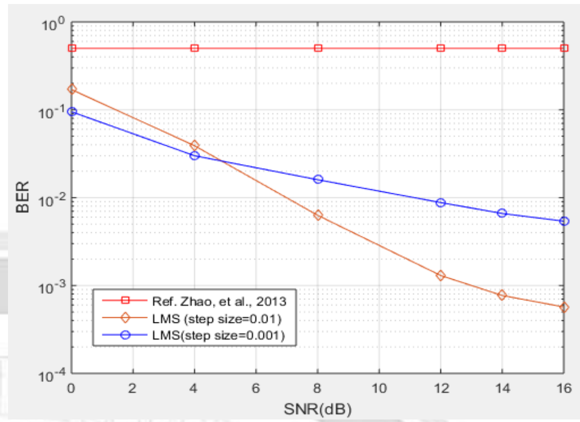


Figure 20. Comparison between the results obtained in this work with [5] with LMS algorithm

## 6. Conclusions

This work focuses on the performance of vehicular communication systems for different conditions. Firstly, we can conclude that the IEEE 802.11p standard is more suitable for vehicle communication systems than IEEE 802.11a. The performance over time varying channel with different modulation schemes and coding rates shows that QPSK and BPSK with a 1/2 coding rate have the best performance in comparison with other modulation schemes. The performance of the system is also affected by vehicle speed, where the best results are at low speeds and the worst performance is at high speeds. The results of the simulation for the QPSK modulation scheme with a (1/2) coding rate over time variant channel at a 50 Km/h vehicle speed and a 100 ns delay spread show that the performance of the system decreases with the increase in frame size. Where the 10 OFDM symbol per frame gives the best performance, the 50 OFDM symbol per frame gives the worst performance. The best result obtained for wireless vehicular communication system simulation over a multipath time variant channel with a 100 ns delay spread is 4.3∗10-4, and it's obtained when using the LMS algorithm with a (0.01) step size and QPSK with a 1/2 coding rate for 10 frames and 50 km/h vehicle speed at a SNR of 16 dB.

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# رفع معدل البيانات لأنظمة اتصالات المركبات اللاسلكية عن طريق تقليل البيانات الخطأ

اباء عبد الزهرة جعفر[1] أشواق قاسم حميد[2]

[1] *كلية الهندسة، جامعة بابل، بابل، العراق*

*E-Mail: eng.ebaa.jafar@uobabylon.edu.iq

[2] *قسم الهندسة الكهربائية، كلية الهندسة، الجامعة التكنولوجية، بغداد، العراق*

*E-Mail: 50058@uotechnology.edu.iq

**الخلاصة**

ان الزيادة الهائلة في تدفق حركة المرور أدت إلى زيادة الطلب على التكنولوجيات المبتكرة التي يمكن أن تحسن سلامة وكفاءة انظمة نقل المركبات. ويمكن تعزيز السلامة على الطرق بشكل كبير عبر نشر تكنولوجيات الاتصالات اللاسلكية للمركبات التي تتيح خدمات جديدة وتسهل الاتصال بين المركبات المتحركة. في هذا البحث قمنا بدراسة أداء أنظمة اتصالات المركبات في ظل ظروف مختلفة باستخدام محاكاة MATLAB. ثم قمنا بتحسين أداء النظام من خلال استخدام LMS equalization، مما أدى إلى تقليل الخطأ والحصول على معدلات نقل بيانات أعلى. كما تم استخدام نموذج وسط ناقل متعدد المسارات ومتغير مع الزمن بتأخير انتشار قدره (100 ns). تم استخدام نظام التجميع التعامدي بتقسيم التردد وفقا لمعيار 802.11p مع مخططات التشكيل BPSK, QPSK, 16QAM و64QAM، حيث يتم دمج هذه المخططات مع (Time interleaving) و(Convolution encoder). وقد استخدم LMS equalizer من أجل تقليل تأثير التداخل بين الرموز. اما في جهاز فك الشفرة فقد استخدم خوارزمية Viterbi لفك تشفير الإشارة المستلمة. تم إنشاء مقارنة بين المعيارين IEEE802.11p و IEEE802.11a للتحقيق في أيهما أكثر ملاءمة لأنظمة اتصالات المركبات. أيضا تم التحقيق في أداء مختلف أنظمة التشكيل ومعدلات الترميز لمختلف قيم (SNR) ضمن المدى(16−0) dB. بعدها تم تحسين نموذج المحاكاة باستخدام LMS equalization ومن ثم مقارنة نتائج النموذج مع وبدون LMS equalization على مختلف السرعات للمركبات وبقيم مختلفة لحجم Frame المستخدم. استخدم قياس كمية نقل البيانات لدراسة أداء النظام بالنسبة إلى SNR ضمن المدى (16−0) dB من أجل Unpunctured QPSK عبر الوسط المتغير مع الزمن باستخدام سرعات مختلفة وأحجام Frame مختلفة.كما تم انشاء مقارنة مع عمل سابق ليظهر مقدار التحسين الذي تم الحصول عليه في هذا العمل. أقل BER تم الحصول عليها عندما سرعة السيارة 50 كم / ساعة هي $4.3*10^{-4}$ عندما قيمة SNR تساوي (16 dB) وذلك باستخدام مخطط التشكيل Unpunctured QPSKوخوارزمية LMS ذات حجم خطوة (0.01) و حجم Frame يساوي 10.

**الكلمات الدالة:**− IEEE 802.11p، V2V، تخصيص اتصالات قصيرة المدى، نظام اتصال المركبات.