

A New Approach for Frequency Domain Equalizer Against Channel Impairment in Single-carrier Communications for Vehicle to Vehicle Communication

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Abstract—The use of vehicle-to-vehicle (V2V) communication will be an integral part of intelligent transport systems (ITSs) and lots of work has been done for ITS channel modeling. In order to establish communication between vehicles-to-vehicles and between vehicles and roadside stations for surveillance and proper navigation, a reliable wireless channel is needed. But the strength of the received signal can change significantly depending on the absorbing, diffracting and scattering effects from the surrounding environment and high Doppler velocity making channel estimation even more difficult. Frequency domain equalization (FDE) is a very effective tool to resist frequency selective fading in high speed communications system, but its performance will be greatly degraded when suffering serious Doppler impact due to rapidly time varying channel condition. Based on the single-carrier system with FDE (SC-FDE), a FDE scheme is proposed in this paper to resist high Doppler spreading effect.

Index Terms— LMS, FDE, Multipath fading, ITS, V2V.

I. INTRODUCTION

The term intelligent transportation system (ITS) refers to efforts to add information and communications technology to the transport infrastructure and vehicles in a way to manage factors that are typically odds with each other, such as vehicles, loads, and routes to improve safety and reduce probability of vehicle collisions , transportation times, and fuel consumptions. The use of vehicle-to-vehicle (V2V) communication will be an integral part of intelligent transport systems (ITSs) , and work on ITS has been growing significantly in recent years [1].The information flowing between vehicles will likely be multimedia means data, images, video, and voice. Vehicular ad hoc networks are also gaining importance for V2V communications, because they allow vehicles in close proximity to communicate without depending on other systems, e.g., the cellular network. There are lots of advantages regarding the V2V communication such as-

1. Dedicated vehicles send warning messages to other road users.
2. On board equipment receives these messages.
3. Driver is made aware of such events and can react accordingly.
4. Vehicles can send messages to other vehicles by using Point-to point or meshed communications

As for examples Accidents, Congestions, Road conditions, Blind spot warning, therefore other vehicle get informed well in advance before it is too late [2].

For wireless communication system multipath fading is a severe problem and inter symbol interference (ISI) is the major reason for erroneous reception of information in high mobility wireless vehicular communications [3]. In order to get rid of these problems an efficient adaptive equalizer needed. Equalization gives a way through which received signals can be resolved through and can be received without any error.

II. CHANNEL CHARACTERIZATION

In order to establish communication between vehicles-to-vehicles and between vehicles and roadside stations for surveillance and proper navigation, a reliable wireless channel is needed. However characterization of the channel in the V2V environment, as shown in Fig 1 [3], of the channel is of current interest to understand propagation behavior. The strength of the received signal can change significantly depending on the absorbing, diffracting and scattering effects from the surrounding environment which is

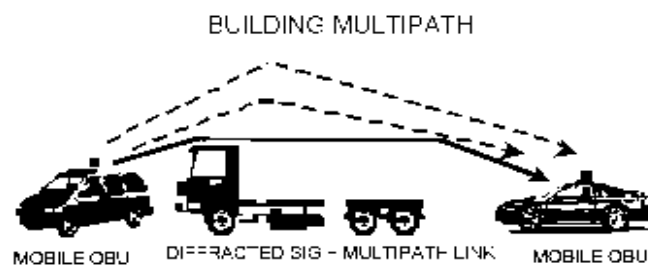


Fig 1: V2V link with multipath reflection.

more significant for reliable communication in the presence of channel dispersion because of multipath effect. Thus, the signal qualities in V2V communications becomes very poor due to the multipath fading, the shadowing, and the Doppler shifts caused by the high mobility of vehicles [3], [4]. Therefore wireless channels are inherently unreliable and vulnerable to transmission technique. Those above mentioned problems are observed by authors, which are depicted in figure below [5].

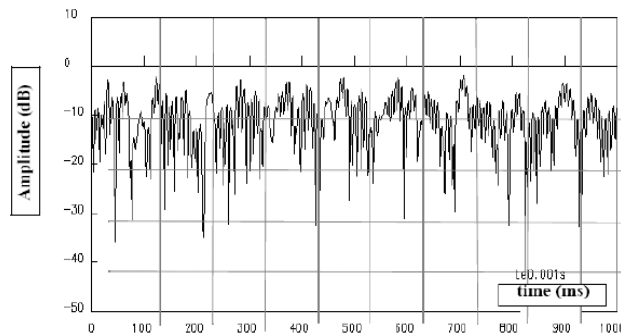


Fig 2: Variation in received signal due to fading effect.

III. FREQUENCY DOMAIN EQUALIZER

Generally, equalizers are used as filters in time & frequency domain. An equalizer in which the coefficients are dynamically configured in order to approximate the optimum results is an adaptive equalizer.

Several convergence algorithms exist for updating these coefficients, and each represents a different trade-off between the computational complexity required to compute the taps at each step and the speed with which the coefficients come close to the optimum values. Hence, convergence speed is one of the most important and deciding factors for the use of different types of algorithm used in adaptive equalizer which depends upon the requirements. Here authors have given emphasis on LMS algorithm and have implemented it in the designed model for mitigation of multipath effect in V2V communication.

In all cases, the convergence algorithms require the knowledge of the current error at the output of the equalizer, and appropriate means must be provided. It is clear that the correct signals are not known at the receiver in general, as this would require knowledge of the transmitted sequence. The usual approach is depicted in Fig 3.

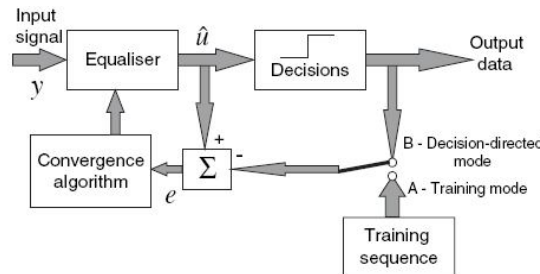


Fig 3: Basic structure of an adaptive equalizer.

The whole working of the adaptive equalizer is mainly divided into two parts:

- i) First is the Training Mode for known sequence code,
- ii) Second is the Decision-Directed Mode for unknown transmitted data.

By iterative process and with the knowledge of reference sequence the equalizer computes the error and simultaneously equalized the received signal [7].

IV. LMS ALGORITHM

LMS: adaptive filtering algorithm having two basic processes.

- 1) Filtering process, producing
 - a) Output signal
 - b) Estimation error
- 2) Adaptive process, i.e., automatic adjustment of filter taps weights.

Let input signal (vector), desired response and output of the filter are represented by $u(n)$, $d(n)$ and $y(n)$ respectively. And filter tap weight is represented by $w(n)$. Where n represent n^{th} sample of the signal.

The filter output $y(n)$ is given by

$$y(n) = \sum_{k=0}^{M-1} w_k^* u(n-k) = w^h(n)u(n) \quad (1)$$

The estimated error $e(n)$ is calculated as given below

$$e(n) = d(n) - y(n) \quad (2)$$

The weights of the tap of the filter are adapted by an iterative process and represented by a simple equation as given below

$$W(n+1) = w(n) + \mu u(n)e^*(n) \quad (3)$$

Where, μ is the step size which is directly related to the rate convergence of the algorithm [8] [9].

V. SIMULATION RESULTS

The objective of a frequency domain equalizer (FDE) is to eliminate the ISI by correcting the channel response distortions [6]. A frequency domain equalizer attempts to do this by equalizing the amplitude and phase of the channel response over the bandwidth of the interest using a process that operates on a frequency domain representation of the signal. Authors are successful in designing an efficient FDE, as shown in Fig 4, for mitigation of fading problem in V2V communication in MATLAB Simulink environment. Here we send the training symbol as for reference and to estimate the channel properly the training symbol have the knowledge of the modulation that is used in transmitter side. Taking the advantage of using the known training symbol we estimate the channel frequency response as given below.

The received training symbols R_k is a product of the training symbol L_k and the channel H_k plus the additive noise W_k ,

$$R_k = H_k L_k + W_k \quad (4)$$

Since the training sequence L_k is known, we compute the Channel Frequency response as following:

$$H_k^* = R_k + W_k L_k \quad (5)$$

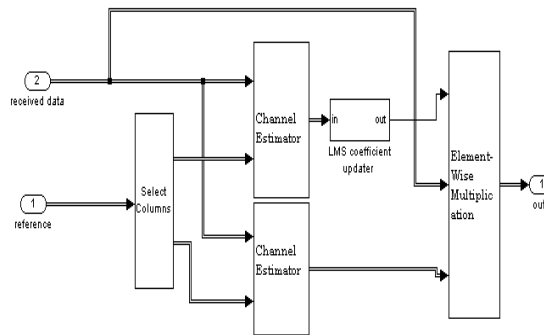


Fig 4: FDE block diagram

Here for betterment of the link quality between the vehicle to vehicle and also in order to enhance the performance of the equalizer, we estimated the channel twice for getting a continuous stable SNR level at the output of equalizer. As shown in figure the upper Channel estimator block estimated the error in received signal with respect to a known training symbol. Depending upon the errors, the weights of the LMS filter updated. Similarly the Lower Channel estimator block estimated the error in signal. The performance of the channel estimator is depicted in Fig. 5 which is plotting SNRs (in dB) with respect to different path losses (in dB).

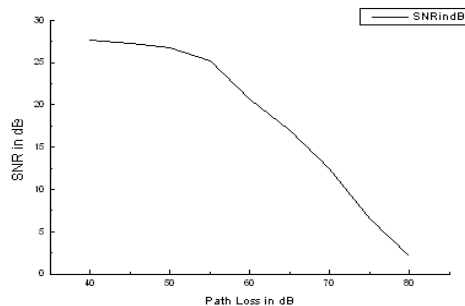


Fig 5: Plot of SNRs (in dB) w.r.t. Path Losses (in dB)

The simulated result shows an improvement in the received signal and is represented by a comparative study between the signal before (Fig: 6, 8, 9) and after equalizer (Fig: 7, 10).

Because of the multipath effect the phase and amplitude of the received signal changes frequently. That is why the scatter plot of the received signal is random in nature as in figure below.

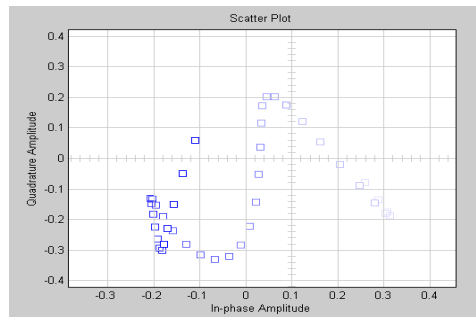


Fig 6: Scatter plot of received signal before equalizer.

This problem is successfully resolved by using FDE which stabilizes the phase and amplitude. The improvement in the received signal is clearly visible in figure below (Fig: 7).

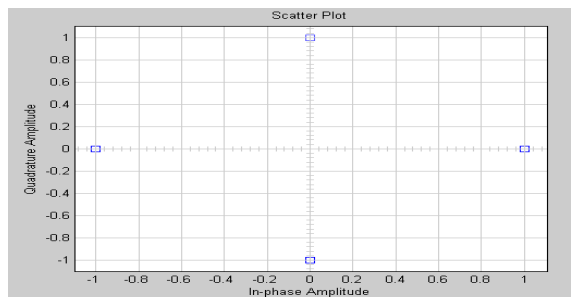


Fig 7: Scatter plot of received signal after equalizer

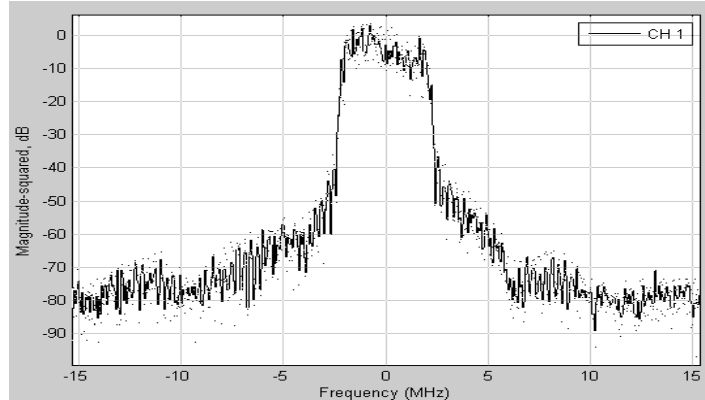


Fig 8: Spectrum plot of the received signal before equalizer with Doppler= 0.1 Hz

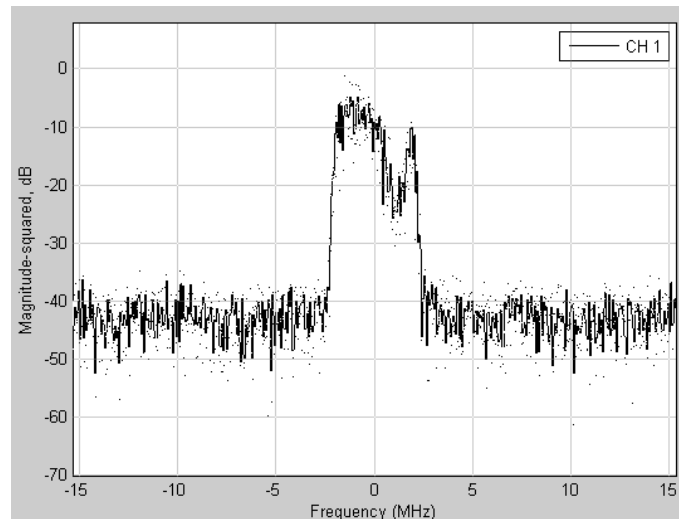


Fig 9: Spectrum plot of the received signal before equalizer with Doppler= 40 Hz

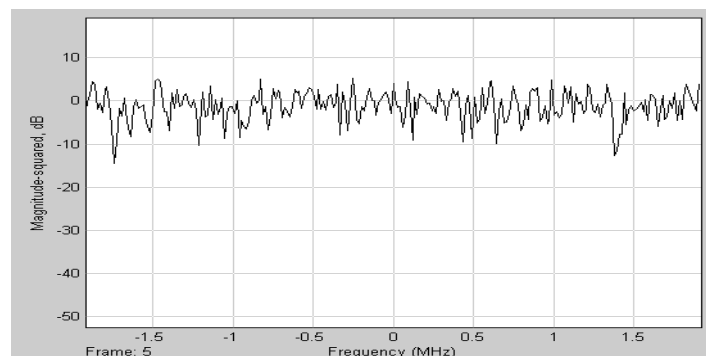


Fig 10: Spectrum plot of the received signal after equalizer

Fig 8 and Fig 9 are the spectrum plots of the received signal after channel. The signal level variation clearly depicts the Doppler effects on the received signal. Due to this dispersion in channel, the signal level of the received varies continuously. Therefore the received signal SNR level varies accordingly and we get a poor V2V communication link. This SNR level fluctuation is minimized by using designed FDE at the receiver side and we get an equalized (in phase and amplitude level) received signal as depicted in Fig 10.

CONCLUSION

With the above results, authors firmly believe that frequency domain equalizer is a power tool to create an ideal channel for V2V communication in presence of multipath effects.

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