Comparison of BER Performances of MMSE Equalizer and Viterbi Algorithm for the MLSE Solution in 60 GHz Communication Channel

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Abstract

In this paper, Intersymbol Interference (ISI) which is one of the most significant problems for the 60 GHz communication channel is analyzed. 60 GHz indoor channel model is developed by IEEE802.15.3c Task Group. By using this model, variation of Bit Error Rate (BER) with MMSE (Minimum Mean Square Error) equalizer is investigated. BPSK modulated data sequence is transmitted on different Signal-to-Noise Ratios (SNR) and different bit packet lengths. Performance of MMSE equalizer is analyzed in LOS and NLOS environments. As a result, obtained results are compared with output of Viterbi algorithm that is used for the MLSE (Maximum Likelihood Sequence Estimation) solution.

1. Introduction

Wireless communication technologies are playing a very important role in the modern world. Communication networks in indoor environments will be used by a wide variety of multimedia services in the future. This increase of data transfer will need more available bandwidth in the frequency spectrum. The use of 60 GHz channel is one of the solutions would be most effective in solving this problem. Electromagnetic signals in 60 GHz cannot propagate to the long distances because of the oxygen absorption. This phenomenon has resulted in approximately 7 GHz unlicensed bandwidth in 60 GHz communication channel [1].

60 GHz channel has a wide variety of applications areas for using of this large bandwidth especially in indoor communication. Uncompressed high-definition image transmission [2], high rate data communication between peer-to-peer or point-to-point devices [3], intra-car wireless network applications [4] may take place in the future in our daily lives. In particular, studies for use in 5G wireless communication systems are ongoing [5].

In this study, it is presented the analyzed the BER performance of MMSE equalizer in 60 GHz communication channel. Initially, channel model is simulated according to the 60 GHz indoor channel model is developed by IEEE802.15.3c Task Group. Then, a known equalization technique MMSE equalizer is performed to solve Intersymbol Interference (ISI) problem in this channel. Furthermore, BPSK modulated data sequence is transmitted on different Signal-to-Noise Ratios (SNR). Also, number of bits is transmitted in one packet is changed to investigate the effect of this variation. Performance of MMSE equalizer is analyzed on LOS (Line of Sight) and NLOS (Non-Line of sight) environments. Finally, obtained results are compared with the output of Viterbi algorithm that is used for the MLSE (Maximum Likelihood Sequence Estimation) solution.

In section II, channel model, MMSE equalization technique and Viterbi algorithm that is used for the MLSE solution used in this study is described. Simulation results are presented in section III. Finally, a conclusion is drawn in section IV.

2. Channel Modeling and Equalization

2.1. Channel Modeling

The channel modeling for 60 GHz indoor applications is standardized by IEEE.802.15.3c Task Group for WPAN. This group standardized SV channel model [6] for NLOS environments. SV channel model is using not only for 60 GHz communication channel, but also for all mm wave communications. For the LOS channel environments it is necessary to take into the consideration the direct path component. Because of this reason SV model was improved as TSV channel model [7]. TSV model standardized by IEEE.802.15.3c is used for the implementation of the simulations in this study.

Communication channel model is represented in Fig.1.

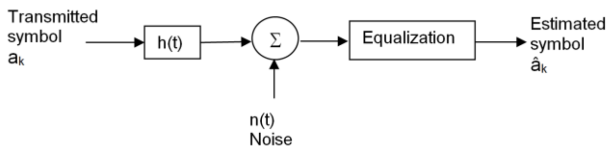

Fig. 1. Communication channel model that is used for the implementation of the simulations

Transmitted symbol sequence is as Ld bits:

$$s_k = \sum_{p=0}^{Ld-1} a_k \tag{1}$$

The signal in the receiver:

$$y_k = \sum_{p=0}^{Ld-1} h_p s_{k-p} + n_k \tag{2}$$

When selecting the sampling period in a digital communication system, the pulse duration for transmitting bits must take into account.

The sampling period (T_s) must be less than the pulse duration for each transmitted bit (T_p). By the provision of the condition $T_s<T_p$, at least once sampling of the each pulse is guaranteed.

When the sampling period is decreased, the bandwidth which requires to transmit the information increases. Therefore, this reduction should be kept in an optimum level. In accordance with the values in the experiments of the task group IEEE.802.15.3c, the sampling period is selected as 1 ns for the simulations in this paper.

2.2. MMSE Equalization

In wireless communication systems, because of the filtering effect of communication channel or effects such as reflections resulting multipath, amplitude or phase distortion occurs depending on the frequency. Correction of the distortion caused by the channel in the receiver is the equalization process.

The basic equalization structure reverses the effect of ISI and rebuilds the ideal channel impulse response (CIR) in the receiver. When ISI occurs, the signal value obtained at the sampling time in the receiver is the sum of the signals that scaled by coefficients which change with desired signal and ISI value of adjacent signals. So the signal in the receiver at the time k is this:

$$y_k = a_k + \sum_{i=-\infty}^{\infty} c_i a_i \,, \quad i \neq k \tag{3}$$

y_k is the signal in the receiver at time k and a_k is the kth value of the bit sequence. Adjacent symbol values are a_i and ISI effect of these symbols are c_i. If impulse response of the channel is known or can be found, c_i coefficients are known. Thus, it is possible to get rid of the ISI effect in the receiver.

MMSE equalizer minimizes the mean square error. It aims to minimize the effects of ISI and also noise. MMSE equalizer, generally, does not eliminate the effect of ISI. On the other hand, MMSE equalizer minimizes the total power of noise and ISI components which effect on output.

For MMSE solution, it needs to find a coefficient set for each sampling time k. These c[k] matrixes must minimize the error between desired signal and equalized signal.

$$E(e[k])^2 = E(s[k] - c[k] * y[k]) \tag{4}$$

e[k] is the error at time k. For MMSE solution, it needs to find c coefficients minimize the $E(e[k])^2$ value.

2.3. MLSE Equalization

Maximum Likelihood (ML) method is an optimal way to obtain the data transmitted correctly in a noisy channel. ML method selects the set of values of model parameters that maximize the likelihood function for a given data set.

MLSE (Maximum Likelihood Sequence Estimation) algorithm selects the input sequence that maximizes the likelihood of the received signal for a certain channel response. MLSE algorithm is used in Viterbi Algorithm (VA) for maximum likelihood sequence estimation [8].

VA gives better BER performance than MMSE equalizer. However, computational complexity of VA is very high. If length of CIR is L and the size of the signal set is M, M^L calculation is required. When the value of L is high, computational complexity is substantially increased. On the contrary, there is no computational complexity at that level in MMSE equalizer. But, BER performances of MMSE equalizer will be never as good as VA.

In 60 GHz communication channel, length of CIR can be 200 ns or more. Because of the sparseness of 60 GHz communication channel, computational complexity of VA is too high [9]. The goal of comparison VA and MMSE is to investigate what level the performance MMSE equalizer to the best solution.

3. Simulation Results

3.1. Analysis of BER Performance of MMSE Equalizer to Variation of Number of Transmitted Bits

BER performance of MMSE equalizer is analyzed to variation of number of transmitted bits in 60 GHz communication channel. BPSK modulated signal is transmitted in NLOS environment as number of bits in one packet as *Ld=300*, *Ld=500* and *Ld=1000*, respectively. In Fig.2, BER performance of MMSE equalizer is shown for *Ld=300*.

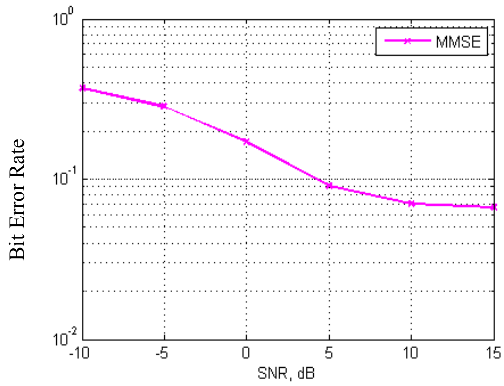

Fig. 2. BER performance of MMSE equalizer for BPSK signal, NLOS environment, Ld=300.

In Fig.3, BER performance of MMSE equalizer is shown for *Ld=500*.

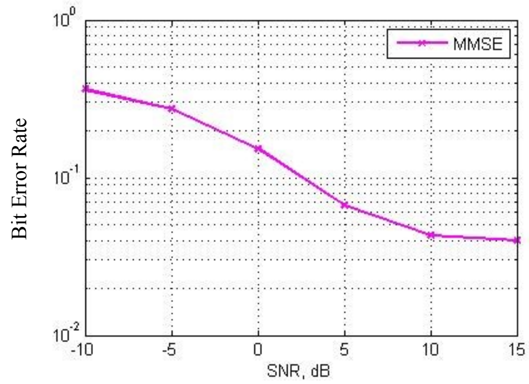

Fig. 3. BER performance of MMSE equalizer for BPSK signal, NLOS environment, Ld=500.

In Fig.4, BER performance of MMSE equalizer is shown for *Ld=1000*.

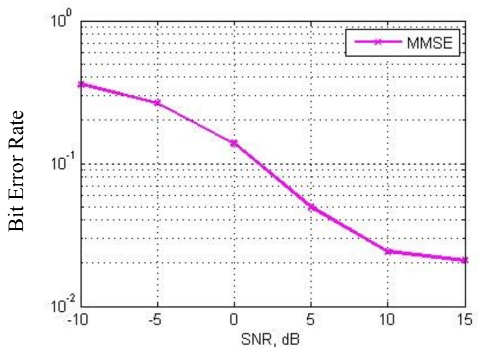

Fig. 4. BER performance of MMSE equalizer for BPSK signal, NLOS environment, Ld=1000.

When the results are investigated in Fig.2, Fig.3 and Fig.4, it is clear to say that if the number of transmitted bits (Ld) in one packet increased, value of BER is decreased. This situation is related with the CIR, because RMS delay spread of 60 GHz communication channel is high. According to the channel model (h(t)), arrival times of the rays can reach to 300 ns. Therefore, it is difficult to eliminate ISI effect for *Ld=300*. The BER performance is better for *Ld=500*, much better for *Ld=1000*.

3.2. Analysis of BER Performance of MMSE Equalizer for LOS and NLOS Environments

In 60 GHz communication channel, BER performance of MMSE equalizer is analyzed for LOS and NLOS environments. BPSK modulated signal is transmitted in as *Ld=1000* in one packet for this analyze. It is easier to see the difference, if the number of bits in one packet is higher. In Fig.5, BER performance of MMSE equalizer is shown for *Ld=1000* and LOS environment.

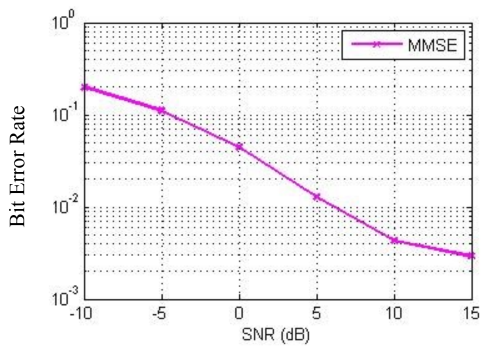

Fig. 5. BER performance of MMSE equalizer for BPSK signal, LOS environment, Ld=1000.

When the results are examined in Fig.4 and Fig.5, it is obvious that BER performance is much better in LOS environments than NLOS conditions. The direct path between the receiver and transmitter improves greatly the quality of the communication as expected. So, ISI effect in 60 GHz channel is significantly decreased in LOS environments by MMSE equalizer.

3.3. Comparison of BER Performances of MMSE Equalizer and MLSE Equalizer

BER performance of MMSE equalizer and MLSE equalizer (Viterbi Algorithm for the MLSE solution) is compared for BPSK modulated signal, *Ld=1000*, NLOS environments in 60 GHz communication channel.

BER performance is much better in LOS environments as expressed in previous subsection. However, it is rare to find LOS usage areas in 60 GHz communication except peer-to-peer or point-to-point devices. Because of this reason, this simulation is done in NLOS conditions.

In Fig.6, comparison of BER performance of MMSE equalizer and MLSE equalizer is shown for *Ld=1000* and NLOS environment.

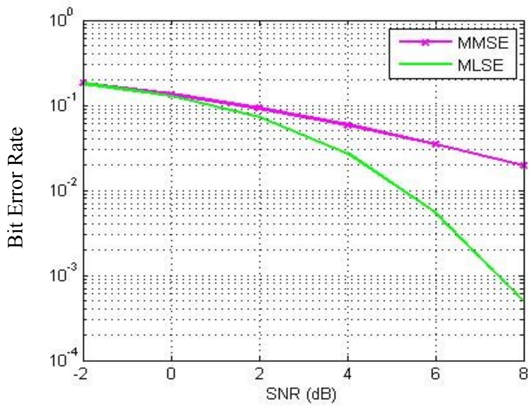

Fig. 6. Comparison of BER performance of MMSE equalizer and MLSE equalizer for BPSK signal, NLOS environment, Ld=1000.

When the outcome in Fig. 6 is analyzed, it is seen that increase in SNR value changes the BER performances extremely. In higher SNR values, MLSE equalizer has quite better performance than MMSE equalizer. When this simulation was done for Ld=300 and Ld=500, similar results were found.

This result shows that MMSE equalizer can be a useful solution for 60 GHz communication applications. Using VA has better performance, but it has very computational complexity.

4. Conclusions

To sum up, BER performance of MMSE equalizer in 60 GHz communication channel is investigated in this study. When the results obtained by the simulations are examined, it is possible to say that MMSE equalizer can be used in 60 GHz indoor LOS and NLOS environments.

It is obvious that Viterbi Algorithm for the MLSE solution has better results. On the other hand, computational complexity of VA is such a high that it is not efficient to use in practical applications of 60 GHz channel. Whereas MMSE equalizer does not have this computational complexity and gives applicable BER performance for 60 GHz communication channel.

5. References

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