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Post-Equalization Techniques for Visible Light Communication Technology

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A B S T R A C T

The Visible Light Communication (VLC) is the emerging technology that uses light as source for transmission of data through free space. In indoor environment, the data transmitted through light got disturbed due to reflectivity of walls and ceiling, such noise affected data is recovered by several techniques. In this proposed work, the post-equalization techniques for Visible Light Communication Technology is analyzed by using various equalizers at receiver side namely, Feed Forward Equalizer (FFE), Decision Feedback Equalizer (DFE), Combination of FFE and DFE, Maximum Likelihood Sequence Estimation (MLSE) Equalizer and Adaptive Equalizer. This system setup is implemented in *Optisystem V.15* Software, which allows 1 Gbps of data upto 5 meters. The performance of this system is analyzed by Q-factor and output sequence obtained.

Keywords: Visible Light Communication, Post-equalization, Optisystem, Free space Communication, White Light Source.

Introduction

The Visible Light has high frequency range which lies between 400 THz and 800 THZ, whose wavelength range is between 780 nm to 375 nm. So, it allows high speed transmission of data and deliver high datarates. For VLC, generally white light is used as source, as it is used for both lighting and data transmission. Even in indoor applications there is certain attenuation in free space, due to light reflections from walls, ceilings, furniture etc. So, the transmitted data got affected by noise when received at receiver. Inorder to overcome this problem techniques such as pre-emphasis, pre-equalization, post-equalization, combination of pre and post equalization are used [1,2,3].

The data to be transmitted is intensity modulated, due to its simple implementation rather than other modulation techniques. The modulation of data is necessary because the data is to be imperceptible to human eyes while transmitting via free space. Then the light carrying signal travelled through free space is detected at receiver side by means of photodetector, which converts optical signal to electrical signal. This method is called direct detection [4].

In this proposed paper, post-equalization technique is chosen and the performance of the VLC system is analyzed. The practically measured values from earlier research work [5] for 5X5X3 m^3 is used for simulation in *Optisystem V.15* software. Various equalizers including Feed Forward Equalizer (FFE), Decision Feedback Equalizer (DFE), Combination of FFE and DFE, Maximum Likelihood Sequence Estimation (MLSE) Equalizer and Adaptive Equalizer are placed at receiver side and the system characteristics are analyzed. The performance of system is determined using Q-factor and output sequence obtained at receiving end.

This paper is organized as follows. In section 2, the experimental setup of system is described. Section 3 discusses the results and the conclusion is given in section 4.

Experimental Setup

The experimental setup of Post-equalized VLC system is shown in Fig. 1, which is implemented in *Optisystem V.15* simulation software. The input sequence is generated by Pseudo Random Bit Sequence, which is modulated with Non-Return to Zero (NRZ) pulse generator as it needs less bandwidth. Then the white light carries modulated sequence to photodetector via free space channel. The white light source parameters and Free Space Optics (FSO) channel parameters are given in Table 1 & 2. The PIN (Positive-Intrinsic-Negative) photodetector used is of silicon type, which converts optical signal to electrical signal. The electrical signal obtained at Oscilloscope Visualizer is the given input sequence. Due to noise it may be degraded. To get rid of this problem an equalizer is placed after the low pass Bessel filter. The equalizer, equalizes the signal by means of training sequence which is either electrical null or any modulated signal. The Q-factor of the signal is determined by BER analyzer. For the good system the Q-factor value must be greater than 6. This system arrangement is analyzed by using different kind of equalizers that are aforementioned.

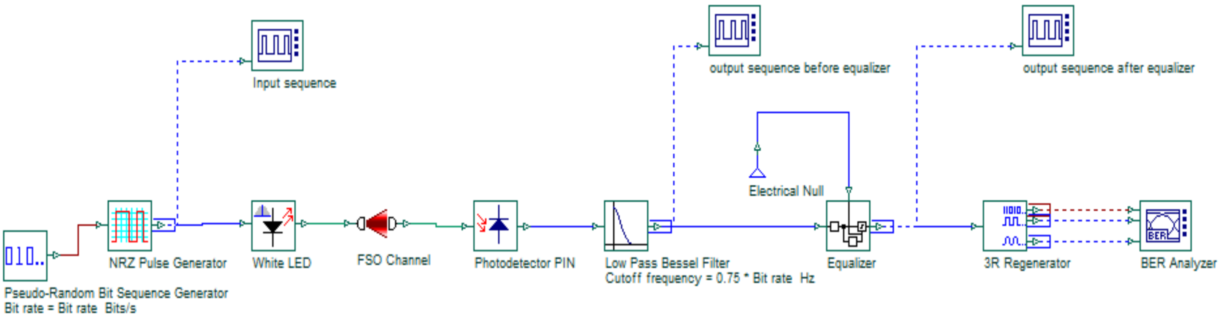


Fig. 1 : Post-Equalized VLC system

Table 1 – White light source parameters for 5X5X3 m^3 room

Wavelength	550nm
Electron life time	100ps
RC constant	100ps
Quantum efficiency	0.65
Bandwidth	300 nm

Table 2 – FSO channel parameters for 5X5X3 m^3 room

Attenuation (for free space)	8dB/m
Transmitter aperture diameter	7 cm
Receiver aperture diameter	1.5 cm
Beam divergence	1108.284mrad

3. Results and discussions

Table 3 shows results of all equalizer in VLC system, the blue signal is input given and green signal is noise.

3.1 Feed Forward Equalizer (FFE)

- This equalizer is used to reduce distortions due to channel loss. In reference to Table 3, it removes noise in the signal, but it is not amplified and still susceptible to error propagation.
- By Q-factor analysis, this equalizer in VLC system Supports 100 Mb/s bitrate; transmits 1 Gb/s bitrate upto 1 or 2 meters only.

3.2 Decision Feedback Equalizer (DFE)

- This equalizer uses feedback network to update tap coefficients and to make decision regarding error signal in equalizer. In reference to Table 3 the signal is amplified to desired amplitude unit and noise is also removed. But the signal is slightly distorted.
- By Q-factor analysis, this equalizer in VLC system Supports 100 Mb/s; transmits 1 Gb/s bitrate upto 2 or 3 meters only.

3.3 Combination of FFE and DFE

- FFE is linear equalizer and DFE is Non-linear equalizer. The combination of these two equalizers in VLC system is much improved than individual performance of DFE and FFE.

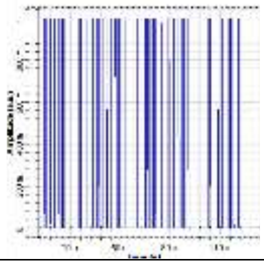
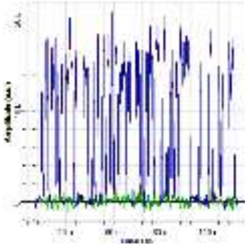
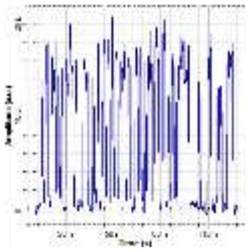
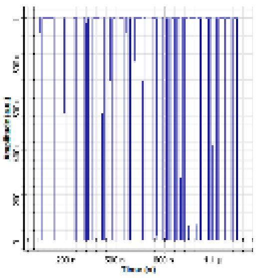
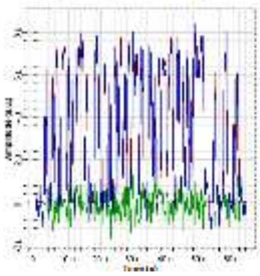
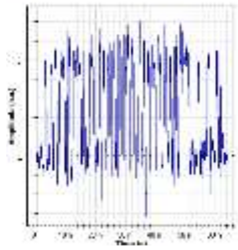
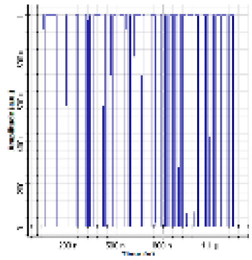
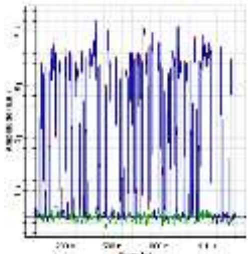
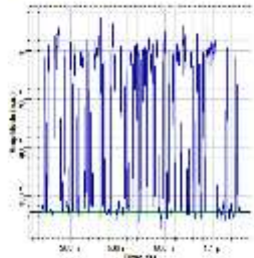
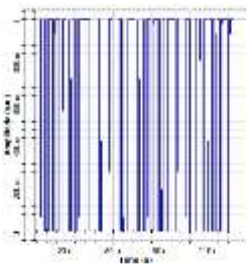
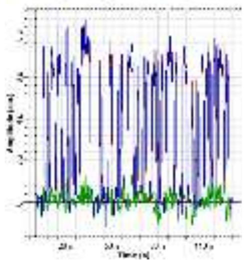
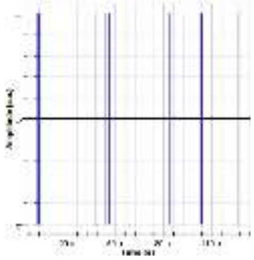
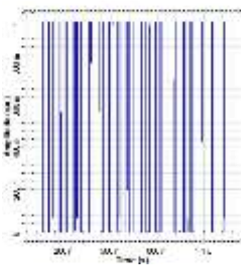
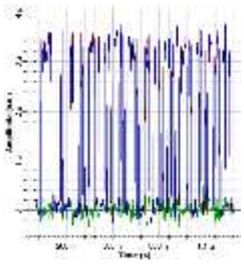
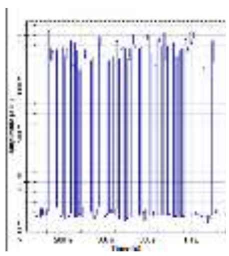
3.4 MLSE equalizer

- It is Post equalization algorithm based on viterbi algorithm, which needs FIR coefficient to be calculated for every sequence.
- They are computationally intense. The likelihood equations needs to be specifically worked out for a given distribution and estiation problem.

3.5 Adaptive equalizer

- This equalizer adapts to time varying characteristics of a channel. It removes signal noise and distortion to a great extent than other equalizers.
- By Q-factor analysis, this equalizer in VLC system Supports 100 Mb/s; transmits 1 Gb/s bitrate upto 5 meters and 2 Gb/s upto 3 meters.

Table 3 – Results of various equalizers on VLC system

Type of equalizer	**Input sequence**	**Output sequence before equalization**	**Output sequence after equalization**
FFE			
DFE			
Combination of FFE and DFE			
MLSE			
Adaptive Equalizer			

Conclusion

In this paper, the performance of VLC system with various equalizers is performed, by practically measured parameter values. The system is modeled in *Optisystem v.15* software. By analyzing different types of equalizers adaptive equalizer works well in noise and distortion removal from obtained output signal. The VLC system with adaptive equalizer supports 1 Gbps effectively upto 5m with a Q-factor of 13.52, it also supports 2 Gbps upto 3m with a Q-factor of 11.56. The simulation analysis reported here is very promising for future VLC systems. This system can be further improved by pre-equalization technique as it utilizes the white light spectrum fully and helps to achieve higher data rates.

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