High speed transmission of signal level for white light emitting diode (LED) as a transmitter device by using modified phase equalization

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Article Info	ABSTRACT
	Visible light communication (VLC) also known as "Li-Fi", uses standard LEDs to transmit data such as information, images, music, and videos. The first LED was developed in 1927 by Oleg Vladimírovich Lósev (1903-1942), however it was not used in the industry until the 1960s. In this paper, will describe the implementation of Modified Phase Equalization (MPH) on visible white LED lamps signal because it's has slow transition time that severely limits in the communication system data speeds with phase equalization that increases the bandwidth of the LED modulation. Employ two filters with Modified Phase Equalization: first, Complementary (C) filter to combine between all kinds moving signals and second, finite impulse response (FIR) filter to obtain all coefficients that respective. Implementation in two phases: first, frequency 150KHz with number of signals 15000 signals and second, doubling frequency 300KHz with number of signals 30000 signals of LEDs without losing their main functionality as illumination sources.

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1. INTRODUCTION

Since the end of the 20th century, a society has changed. Data are becoming increasingly important and symbolic of the digital revolution [1]. Data transmission is one of the cornerstones of development, without the ability to send information back and forth between technical devices, the digital revolution would be unthinkable [2]. The latter has meanwhile covered all areas of life for communication between individuals as well as in entrepreneurial processes [3]. Nowadays, a lot of researchers are working on the development of light-emitting diode (LED) lighting system [4]. The lighting of a home, office or public space can't be used only to generate sensations and have a correct visibility of the space, but also for the transmission of data. This is possible thanks to the technology called Visible Light Communication (VLC), which uses light emitted by an LED to exchange thousands of data to computers, cell phones or tablets. Meanwhile, we encounter LEDs everywhere, no matter if traffic lights, television or lighting in private and business areas. Due to their long life, their small size and the variety of shapes and color spectrums, LEDs have prevailed in a short time compared to light bulbs, halogen and energy-saving lamps [5].

White LEDs are considered as a major candidate for future illumination [6]. Due to the potential for simultaneous use of these light sources for lighting and communication, visible-light communications have been a subject of increasing research and development activities [7]. Light-emitting diodes (LEDs) consist of semiconductor crystal layers depending on the material which is used, the wavelengths of light emitted when a current flow through in one direction, called the forward direction (electroluminescence) [8]. The light up of an individual diode either red, green or blue. White light can be obtained from this, by a various way [9].

In the past, light-emitting diodes have mainly served as colorful but dimly lit signal lamps [10]. After decades of research and development, the digitally controllable, energy-saving light bulbs are revolutionizing lighting by replacing obsolete, inefficient light bulbs [11].

The existing problems in implementing any VLC system and it's necessary to take the consider the following limitations: The LED signal as transmitter has a slow switching speed, which limits the transmission speed of the system [12]. The light information which transmitted from the LED will be weakened (fading) while transmitted on the free space channel, it means the farther the distance of the receiver, the weaker the signal received, and the information may not be received at all [13]. The receiver is illuminated by energy sources such as ambient light, natural sunlight, fluorescent lamp light and incandescent lamp light, these sources cause variation in the received photocurrent that is not related to the transmitted signal, which results in an additive noise component in the receiver [14]. The distance of the maximum link is limited by the power of the light source.

In this paper, implemented Phase Equalization with modified which it's used between the transmitter such as white LEDs and the receiver such as computers, cell phones or tablets etc., because it's allowed to increase the bandwidth of modulation of the LED, that achieves the recovery of the sent signal that attenuates from the passage to the transmission channel, using equations of two filters they are Complementary filter and Finite Impulse Response filter with the equalization, makes it easy to adjust to changes between the transmitter and the receiver by modifying the coefficients of this filters.

The rest of the paper is organized as follows: In Section 2, describe System Model. Section 3, Modified Phase Equalization and Results. Performance Evaluation is discussed in Section 4. Conclusions is presented in Section 5.

2.   SYTEM MODULE

VLC is considered a futuristic technology applied to both data communication and illumination [15], VLC broadcasting is limited to the application to the Internet services, where there are various applications and all receivers can communicate within the area of illumination sources [16]. VLC has several implementation challenges, one of the biggest challenges is improving the transmission speed of data with high spectral efficiency [17]. An optical links is a telecommunications links, intensity modulation techniques (IM) are used with direct detection (DD) is popular techniques in optical communication, being a viable transmission technique in indoor links [18]. A waveform with the information to be transmitted on VLC links by directly modulates of the instantaneous optical power emitted by an LED through the propagation channel and this information is retrieved by the receiver in end by direct detection on a photodiode [19] as shown in the Figure 1 [20].
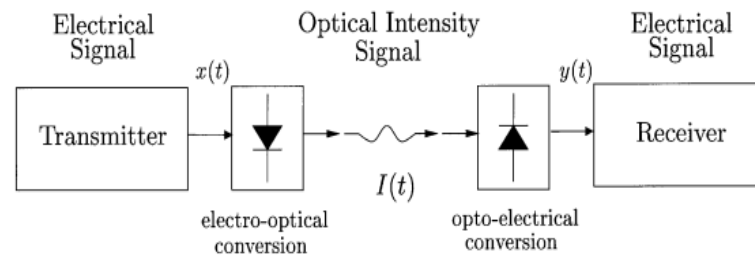

Figure 1. A simplified block diagram of an optical intensity direct detection communications system

An Optical wireless communication system (OWCS) can be generated by an equivalent baseband system is a signal that has a near-zero frequency range [21] as shown in Figure 2 [22], where X (t) is the time signal that the transmitted signal suffers, as a consequence of the propagation channel, is modelled by an impulse response Rh (t), where R is a coefficient which symbolized the photodiode response and h (t) is the impulse response function (IRF) of the linear time-invariant (LTI) [23]. The noises that generates of the ambient light is looks like as white noise, Additive Color, Gaussian noise and independent of the signal be transmitted [24]. This additive residue has been represented as N (t) [25].
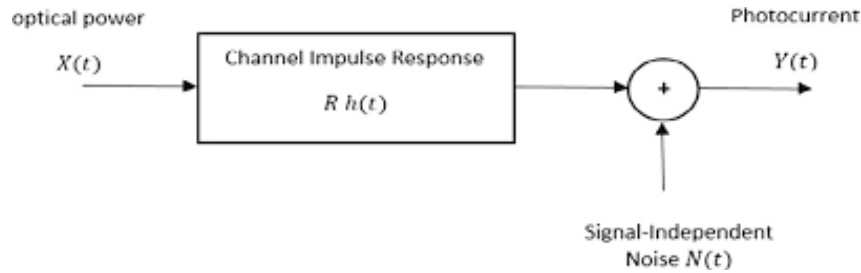
Figure 2. Effects of selecting different switching under dynamic condition

This allows characterizing a VLC link by the equation [26]:

$$Y(t) = X(t) \otimes Rh(t) + N(t) \tag{1}$$

where $\otimes$ denotes convolution

3. MODIFIED PHASE EQUALIZATION AND RESULT

Equalization generally processes the overall frequency response of the electrical signal with a frequency filter. In this work, it's has been applied to a number of signals N between 15000 and 30000 signal from LEDs at a frequency $fs = 150$KHz with time $T = 1/fs$ with values determined of coefficients Cof for the frequency response of desired $G_{(z)}$ with N and also only one coefficient A for $hled_{(z)}$ with N where z is values of coefficients, number of signals and frequency as shown below:

$$hled_{(z)} = (A, 1, N, fs) \tag{2}$$

$$G_{(z)} = (Cof, 1, N, fs) \tag{3}$$

Creates *module functions for Hled, $G_{(z)}$, dB* from the following equations:

$$moduleHled = abs(hled(z)) \tag{4}$$

$$moduledB = 10 * log_{10}(moduleHled) \tag{5}$$

where dB is a decibel is a unit used to measure the intensity of sound and also used in other specialties in acoustics, electricity and telecommunications.

$$moduleG_{(z)} = abs\left(G_{(z)}\right) \tag{6}$$

$$moduleG_{(z)}dB = 20 * log_{10}\left(moduleG_{(z)}\right) * T \tag{7}$$

The implementation as shown in Figure 3 when used $N = 15000$ signals at $fs = 150$KHz where the results of desired frequency response $G_{(z)}$, which are in red color in the one direction at value of 0 dB, while frequency response of $Hled_{(z)}$, which are in blue color also in one direction at a value of 9 dB. The another implementation as shown in Figure 4 when used $N = 30000$ signals at $fs = 300$KHz it is affected by the change in the number of signals or frequency, hat it is required to changing frequency response from LEDs and desired frequency response $G_{(z)}$ thus leading to an increase the bandwidth of LED and both of them $Hled_{(z)}$ and $G_{(z)}$ have different moving signals where desired frequency response $G_{(z)}$ is slow moving signals while frequency response from LEDs are fast moving signals.
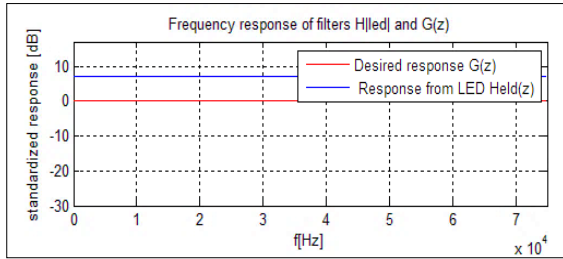
Figure 3. Desired frequency response of $G_{(z)}$ in red color and frequency response of $Hled_{(z)}$ in blue color with N =15000 signals at $fs = 150$KHz
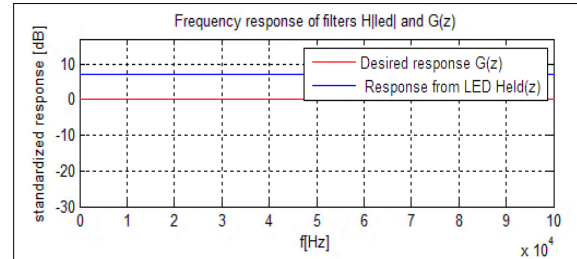

Figure 4. Desired frequency response of $G_{(z)}$ in red color and frequency response of $Hled_{(z)}$ in blue color with N =30000 signals at $fs = 300$KHz and different x-axis

To achieve a compensation of LED response $Hled_{(z)}$ by employing zero forcing equalizer (ZFE) which are applied to the inverse of the frequency response of LED, the LED transfer function that must be multiplied by its inverse by ZFE according to the following (7).

$$C_{(z)=} \frac{1}{Hled_{(z)}} \tag{7}$$

The filter resulting from the inverse of the LED transfer function is an ideal filter, which requiring a great digital processing. Due to the indicated a frequency response is analyzed to increase the modulation bandwidth of the LED $moduleHled$ and it's feasible to implement, then to design the complementary filter $C_{(z)}$ the desired frequency response $G_{(z)}$ divided over the frequency response of $Hled_{(z)}$, that can be expressed mathematically by the (8).

$$moduleC_{(z)} = \frac{moduleG_{(z)}}{moduleHled_{(z)}} \tag{8}$$

Complementary filter that is used to combine between slow moving signals $G_{(z)}$ and fast moving signals $Hled_{(z)}$. The result of the division of equation $moduleC_{(z)}$ combine between all signals with different moving as shown in Figure 5 with N =15000 signals at $fs = 150$KHz and also in Figure 6 with N =30000 signals at $fs = 300$KHz by using a two-dimensional stem plot in Matlab to displays all signals as lines extending from a baseline along the x-axis while a circle whose y-position represents the data value of all signals terminates for each stem. The difference between each figures are x-axis where Figures 6 when doubling the number of signals N and frequency fs increased the bandwidth of LEDs speed transmission.
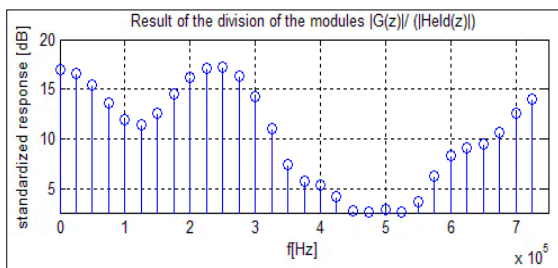

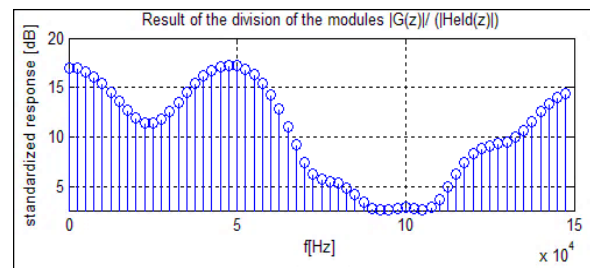Figure 5. The result of the division of equation $moduleC_{(z)}$ with N =15000 signals at $fs = 150$KHz

Figure 6. The result of the division of equation $moduleC_{(z)}$ with N =30000 signals at $fs = 300$KHz and different x-axis

Implementing a finite impulse response (FIR) filter in Matlab with the result of an equation the complementary filter to obtain all coefficients that respective in red color which is a star-shape as shown in Figure 6 it can be analyzed then $C_{(z)}$ is a high pass filter that a compensation value of 17 dB with N =15000

at a frequency fs of 150 KHz, in Figure 7 and Figure 8 show the result FIR filter when doubling the number of signals and frequency and therefore doubling all coefficients and increasing the modulation bandwidth at the same value in Figure 6 which is 17 dB, in both figures there are no changing in value of complementary filter $C_{(z)}$ no matter how much coefficients values.
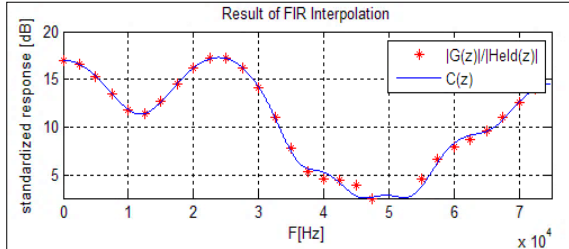

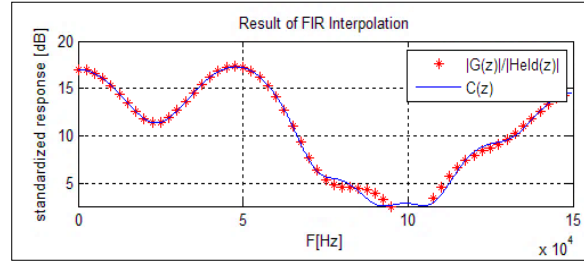Figure 7. The result of FIR interpolation with N =15000 signals at $fs = 150$KHz

Figure 8. The result of FIR interpolation with N =30000 signals at $fs = 300$KHz and different x-axis

Creates *module functions for* FIR interpolation from the following equation:

$$h1 = (A, 1, N, fs) \tag{9}$$

$$h2 = (B, 1, N, fs) \tag{10}$$

$$modHt = 20 * log10(abs(h1 * h2)) \tag{11}$$

where $h1$ is module $Hled$ while $h2$ is module FIR interpolation, modHt is the result of module $Hled$ multiply by module FIR interpolation, N is number of signals, fs is frequency and A, B are coefficients of $h1$ and $h2$. Figure 9 and Figure 10 shows the difference between all values for $Hled_{(z)}$, $C_{(z)}$ and the result of module $Hled$ multiply by module FIR interpolation, where the value of the $Hled_{(z)}$ in green color remained at value of 0 dB, the signal of $C_{(z)}$ in blue color stay constant at value of 17 dB while the signal of $modHt$ in red color at value of 3 dB that is required the signal of LEDs remains constant at a certain value without losing their main functionality as illumination sources.
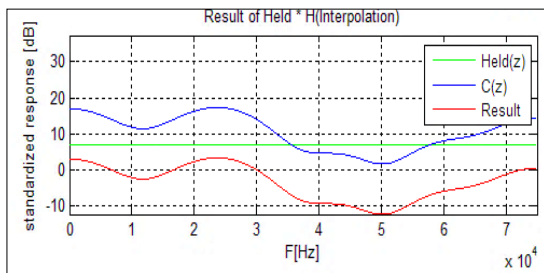

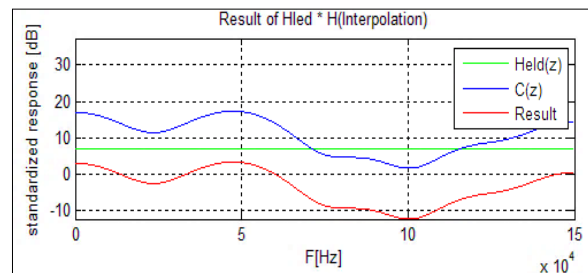Figure 9. The result of $modHt$ with N =15000 signals at $fs = 150$KHz

Figure 10. The result of $modHt$ with N =30000 signals at $fs = 300$KHz and different x-axis

4. PERFORMANCE EVALUTION

The modulation of modified phase equalization (MPH) is created by the Matlab software in this section, a comparison the result bandwidth white LED transmission was made with pre-equalization. From the Figure 11 shows the frequency response of the LED with N =15000 signals at $fs = 150$KHz at a value of 4 dB, which is the result of the modulation of modified phase equalization (MPH) after applying two filters they are finite impulse response (FIR) filter and complementary filter, while Figure 12 shows the frequency response of the LED with N =1200 signals at $fs = 30$KHz at a value of 1 dB, which is the result of the pre-equalization with different coefficients value.
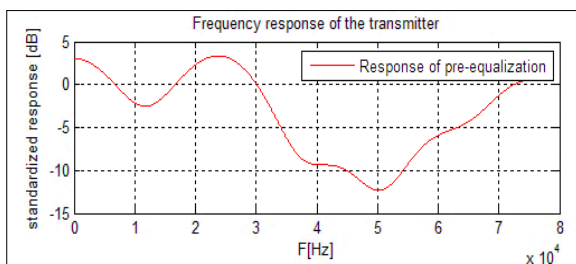
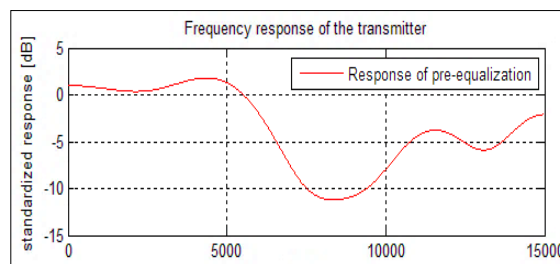Figure 11. The result of the modulation of modified phase equalization (MPH) with N =15000 signals at $fs = 150$KHz

Figure 12. The result of the pre-equalization with N =1200 signals at $fs = 30$KHz

As for the distance of bandwidth of pre-equalization, it's less than from modified phase equalization because they have different number of signals, different frequency and also different coefficient values are explained in both earlier figures with keeping the power of white LEDs unchanged as illumination sources.

5.   CONCLUSION

Light is a form of energy that has great impact on life on earth no matter if it comes from natural sources such as the sun or artificial sources such as a lamp. Designing the modified phase equalization (MPH) is allowed to improve the modulation of bandwidth white LED between 150KHz and increasing by 50% at 300KHz without introducing any kind of radio whilst the pre-equalization only achieved improved the bandwidth white LED between 15KHz and also increasing by 50% at 30KHz. A new coefficients values have proven to be correct values to increase the signal level in high speed data transmission. Complementary filter is combined between slow and fast moving signals and most this signals are fast moving.

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