ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 8, August 2015

Noise Study in the Integrated System of Power Line Communication and Visible Light Communication

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ABSTRACT: Visible light communication based on LEDs is an eco-friendly IT green technology. Light-emitting diode (LED) is the main part of visible light communication. The optical wireless communication provides many advantages, such as being license-free, high directional channel, and electromagnetic interference (EMI) free. Meanwhile, in power line communication we are using the power lines as a medium for communications, that is here power lines are carrying the data. PLC technology could provide the consumer with a spectrum of services such as Internet, home entertainment and home automation. Dealing with very high voltages and its isolation is a problem of PLC. Also power line communication is affected by a number of noises, it make the communication system a worst one A solution to this problem is proposed by combining Power Line Communication and Visible Light Communication.. The motivation of this work was to offer a better understanding of the noise effect on the integrated system of PLC and VLC can help mitigate it and improve the communication performances.

KEYWORDS: Generalized Background Noise, Impulsive noise, Power Line Communication, Visible Light Communication, White LED

I. INTRODUCTION

Visible Light Communication (VLC) system based on white LEDs has emerged as an eco-friendly IT green technology using THz visible light spectrum in provision of both lighting and wireless access. Installation of new communication cables between other fixed network (PC, Set-Top Box, fiber networks, etc.) and LED lights is expensive, disruptive and time consuming process. Meanwhile, the power line communications (PLC) can make it possible to use the power lines as the medium of communications. The utilities of home networking over power lines can take advantage of the existing wiring infrastructure for provision of illumination cum communication. The integrated system of VLC and PLC is a smart way of fulfilling the premise of broadband access for home networking, while providing efficient and low-cost lighting. To achieve the higher data rates (MHz), PLC channel is simulated using DMT-QAM modulation scheme. The idea of integration of these two systems for indoor networking which was based on single carriermodulation then to improve their old system to overcome the effects of power-line noises they used multicarrier modulation (OFDM) method. A simple on–off keying (OOK) modulation scheme is employed for IM/DD VLC channel.

On analyzing the noises in power line communication, the power line channel does not represent an AWGN, but it includes a superposition of five noise types: coloredbackground noise, narrowband noise, periodic impulsive noise asynchronous to the main frequency, periodic impulsive noise synchronous to the main frequency, asynchronous impulsive noise. Thus, all these three can be summarized in one noise class that is seen as colored PLC background noise class and is called “Generalized Background Noise (GBN). In visible light communication AWGN noise is independent of the optical power. When little or no ambient light is present, the dominant noise source is receiver preamplifier noise, which is also signal-independent and Gaussian (though often non-white). Thus we usually model the noise as Gaussian and signalindependent. Multipath fading in VLC can be ignored because an information carrier is in the order of 10^{14} Hz. Detector dimensions are in the order of hundreds of wavelengths, which leads to efficient spectral diversity that minimizes the effects of multi-path fading[3]

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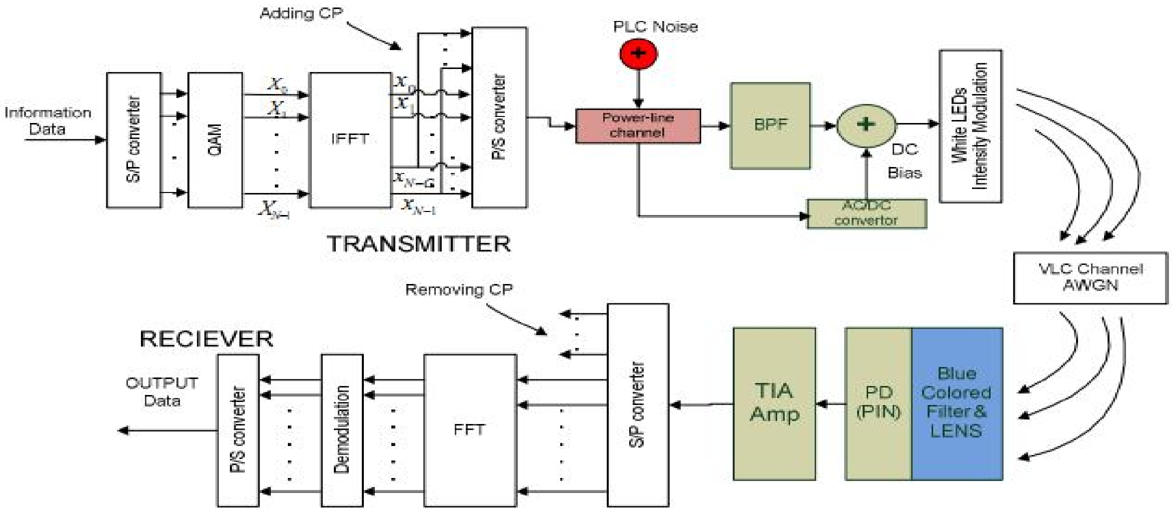

Fig 1: integrated system of power line communication and visible light communication [7]

The integrated system of VLC and PLC is a smart way of fulfilling the premise of broadband access forhome networking, while providing efficient and low-cost lighting. To achieve the higher data rates (MHz), PLC channel is simulated using DMT-QAM modulation scheme. The discrete multi-tone (DMT) modulation using 16-QAM is applied for PLC and VLC channel with presence of noises. A simple on–off keying (OOK) modulation scheme is employed for IM/DD VLC channel.

II. POWER LINE COMMUNICATION

Power line communication (PLC), as the name suggests, provides connectivity using existing power lines as the communications medium. There are many different types of systems (and terminologies) associated with PLC, and nearly as many standards. Furthermore, there are technologies aimed at in-building or in-home use, those aimed at external electrical plant use, and those that support both.Power line communication systems operate by adding a modulator carrier signal to the wiring system. Different types of powerline communications use different frequency bands. Broadband powerline communications systems, also known as powerline telecommunications (PLT) systems or broadband powerline (BPL) systems, are a new type of powerline communications (PLC)system capable of providing significantly higher data rates than previous PLC systems. They have the potential to provide simplified in-house interconnection of computers and peripherals, and cost effective last-mile delivery of broadband data services. PLC systems consist of terminal devices that are plugged into or attached to the electrical power supply network and allow data to be transmitted via the network to other terminal devices plugged into or attached to the network. The use of the existing electrical power supply network wiring reduces costs and provides convenient access to broadband interconnection between devices. Historically, powerline communications systems had been limited to relatively low data rates - typically less than 500 kbit/s. These low data rate systems are still in use and are used in such applications as the remote control of switches in domestic installations and by power supply authorities.

The wiring in place to supply electrical power to, and within, homes and offices was not designed to carry high-speed data at high frequencies. It was designed to carry large currents at high voltages alternating at 50 or 60 Hertz so that significant amounts of energy could be delivered conveniently to consumers, at one primary very low frequency. Powerline communications systems can “piggyback” on this wiring – subject to various limitations – to provide connections between their terminals. As this wiring is not shielded, radiofrequency signals passing along it are in part, and unavoidably, radiated from it. One issue then is whether these radiated signals might interfere with radiocommunications. Impedance mismatching of devices connected to the network can result in significant signal loss (nulls) at particular frequencies, which will inhibit the use of those frequencies for communications. Many electrical devices which are connected to the power mains inject significant noise back onto network. The

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characteristics of the noise from these devices vary widely. Examination of the noise from a wide range of devices leads to the observation that the noise can be classified into just a few categories: Impulse noise (at twice the AC line frequency),Tonal noise,High frequency impulse noise. It is often useful to divide tonal noise into the two sub-categories of unintended and intended interference. The most common sources of unintended tonal noise are switching power supplies. These supplies are present in numerous electronic devices such as personal computers and electronic fluorescent ballasts.

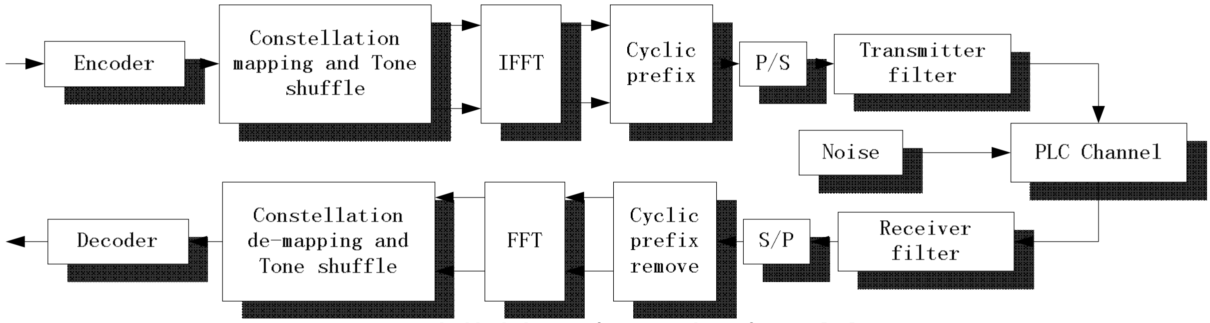

Fig 2 : The block diagram for DMT scheme for PLC [11]

$$H(f)=\sum_{i=1}^{N} g_i \; e^{-(a_0+a_1 f^k) l_i} e^{-j2\pi f \tau_i} \text{eq. (1)}$$

Where, $g_i$is a weighting factor representing the product of the reflection and transmission factors along the path. a_0,a_1, $_k$are constants. The variable, representing the delay introduced by the path which is calculated by dividing the path length $l_i$by the phase velocity v_p=150*10^6m/ sec and N is the total number of reflection paths.

III. VISIBLE LIGHT COMMUNICATION

Recently, there has been increased interest in visible light communication systems. The research is motivated by an increasing need of indoor communication systems and the improvements of light emitting diode technologies (LEDs). High brightness LEDs are already used for several applications and it is foreseen that they will also replace conventional lighting sources in the next decade. Furthermore, the bandwidth of optical free space communication systems using LED technology is high in comparison to radio frequency based solutions. This widespread use provides the necessary infrastructure and hence removes one of the major hurdles faced by new communication schemes; thus making the technology particularly appealing. A typical application scenariomight be to additionally use the reading lights in planes for high speed wireless transmission.

IV. INTEGRATED SYSTEM OF PLC AND VLC

It consists of a transmitter including power-line channel, optical interface (white LED), the VLC channel which to one point at the receiving surface includes a number of lines-of sight (LOS) as well as a contribution of reflections off the walls or objects in the room and finally receiver consists of a blue filter, a concentration lens, a photo-detector (PIN type) and low noise trans-impedance amplifier (TIA) following by demodulation section. In this system, in order to bias the LED and achieve the required illumination intensity, the LED is driven by a DC current (generated by AC to DC converter). The output signal (including AC current 50Hz and information data signal) from PLC channel is passed through band pass filter to pick up data signal. The power of LED is varied according to the waveform of data signal (Intensity Modulation). A DC current level is chosen such that, ensures the device operates in a linear regime, and one which is typical of operating conditions when the device is used for illumination. In the receiver side the practical down-conversion technique is direct detection (DD), in which a photo-detector produces a current proportional to the received instantaneous power, i.e., proportional to the square of the received electric field[5].

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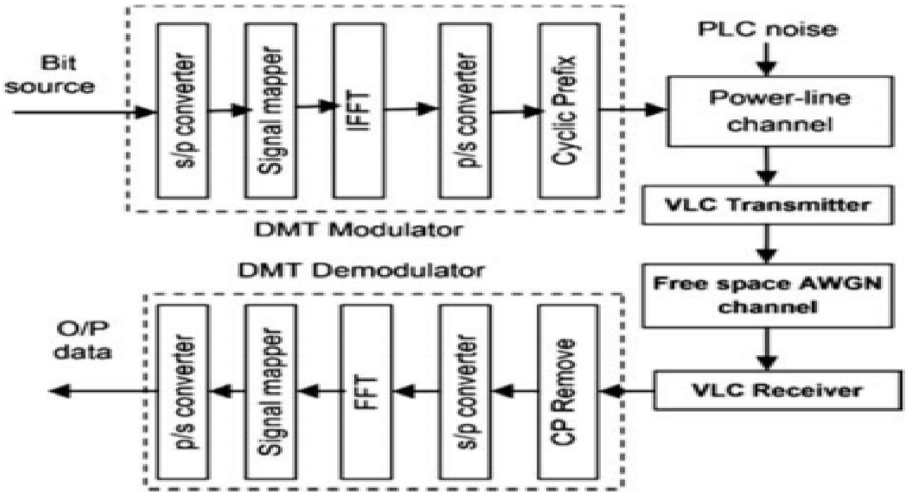

Fig 3: Block diagram for integrated system of PLC and VLC [3]

V. NOISES AFFECTING THE INTEGRATED SYSTEM OF PLC AND VLC

The noise affecting the integrated system of power-line communication and visible light communication are

- colored background noise
- narrow band noise
- periodic impulsive noise asynchronous to the mains frequency
- periodic impulsive noise synchronous to the mains frequency
- asynchronous impulsive noise
- Shot noise
- Thermal noise

The first five types of noises are power-line channel noises and rest two are visible light communication noises.

The first three types of noise generally stay over long periods of time. Colored background noise and narrow band noises can be summarized as background noise. The next two types are time varying and can be summarized as impulsive noise.Impulsive noise has a random occurrence and its duration varies from a few microseconds to milliseconds. This periodic impulsive noise interfered with the transmitted OFDM signals affect the system performance. So these impulsive noises must be removed to improve the performance of the PLC system. The power line noises are the summation of background noise and impulsive noises.

- Coloured background noise-It is caused by summation of multiple sources of noises with low power and intensity. Its power spectral density decreases with increasing frequencies. Parameters of noise vary over time in terms of minute or hours
- Narrow band noise-consists of amplitude modulated sinusoidal signals which is caused by broadcasters, radio stations etc. This type occupies several sub-bands which are relatively small and continuous over the frequency spectrum. Amplitude generally varies over the day time and becoming higher at night when reflection properties of atmosphere becomes stronger.
- Periodic impulsive noise asynchronous to mains frequency-It is a kind of impulsive noise which is caused by switched-mode power supplies. Usually have repetition rate between 50 and 200KHz and which results in the spectrum with discrete lines with frequency spacing according to the repetition rate. Because of higher repetition rate this noise occupies frequency that are close to each other.
- Periodic impulsive noise synchronous to mains frequency: which is mainly caused by switching actions of rectifier diodes found in many electrical appliances. Repetition rate 50 or 100KHz. These

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noises are of short duration in the order of micro seconds. Power spectral density decreases with frequency. Generally caused by power supply operating synchronously with the mains frequency.

- Asynchronous impulsive noise: which caused by switching transients in the power network. Have duration from of some micro seconds upto a few milliseconds. Power spectral density can reach values of more than 50dB above the background noise, makingthem the principle cause of error occurrence in digital communication over PLC networks.

The noise affecting the VLC channel (N_{Total}) contains a shot noise component and a thermal noise component,

$$N_{Total} = \sqrt{N_{Shot}^2 + N_{thermal}^2} \quad \text{eq. (2)}$$

The shot noise is proportional to the total optical noise power incident on the receiver. The effect of the shot noise can be minimized by using optical filters, but still this remains a perturbing noise source, limiting the communication's performances. In day-time outdoor communications, shot noise is the dominant noise component.

$$N_{Shot} = 2qIB \quad \text{eq. (3)}$$

Where q is the electronic charge (q=1.602*10^(-19)coulombs), B is the detector bandwidth and I is the produced photocurrent.

The thermal noise is represented by the preamplifier noise, and is the predominant noise source in the absence of background light.

$$N_{thermal} = \frac{4KTBN_{circuit}}{R} \quad \text{eq. (4)}$$

Where K is Boltzmann ' s constant (k=1.381*10^(-23)) , T is the temperature, $N_{circuit}$ is the circuit noise, and R is the load resistance.

Both the shot noise and the thermal noise are signal-independent and Gaussian. Under these conditions, the total noise affecting the VLC channel can be modeled as signal-independent Gaussian noise.

Background optical noises can afect the performance of VLC significantly. Scenarios may happen when the LED lamps and conventional flurescent lamps or AC-LED lamps consist in the same place. The background noise mitigated by using white LED OFDM VLC. 64 OFDM subcarriers were used (each subcarrier was in 4-QAM). The transmission data rate was12Mbps and the B.W was 6.25MHz. The OFDM carrier spacing was 97.66KHz. A flurescent lamp was used to produce different optical interference noise powers. The gas discharge lamps, like the flurescent lamps needed a ballast to operate. The ballast convert the main supply 60Hz frequency to higher frequencies for efficient lightning. The flurescent lamp had a dominant frequency tone at 90KHz, and harmonic tones at 180, 270KHz.

VI. CONCLUSION

The noises affecting the integrated system of power line communication and visible light communication is analysed here. The impulsive noise is affecting powerline communication system severly, since it is varying over seconds or micro seconds and its amplitude is really high.. The visible light communication is mainly affected by shot noise. Shot noiseis proportional to the total optical noise power incident on the receiver. The effect of the shot noise can be minimized by using optical filters, but still this remains a perturbing noise source, limiting the communication's performances.Better understanding of the noise effectcan help mitigate it and improve the communication performances.

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