HIGH DATA RATE PLC-VLC DESIGN
FOR 5G COMMUNICATION SYSTEM

Synopsis of the Thesis to be submitted in partial fulfillment of the requirements for the award of the degree of

Bachelor of Technology
in

Electronics and Communication Engineering

Thesis submitted by

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ABSTRACT

The hybrid Powerline Communication (PLC) and Visible Light Communication (VLC) systems can be effectively utilized for the efficient design of 5G communication setup. However, each of these integrated communication media is not primarily meant for the specific purpose of data communication, as PLC and VLC have historically served to transfer electrical energy transfer and light, respectively.

With the advent of high flickering rate Light Emitting Diodes (LEDs) and efficient multiplexing/modulation schemes, both technologies are observed as potential data communication carriers. Therefore, this paper presents a novel approach for modifying the modulation technique in accordance with the channel requirements of a hybrid PLC-VLC based 5G communication system.

We provide a thorough analysis of the research work done to co-use these two technologies for data communication, suggest some exciting applications of integrated PLC-VLC systems and propose of Orthogonal Frequency Division Multiplexing (OFDM) to tune the physical parameters as per the hybrid channel characteristics.The proposed hybrid system can be used to design smart buildings where indoor/intra-building connectivity is maintained by VLC whereas inter-building networking based on PLC communication.

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CHAPTER 1
INTRODUCTION

1.1 Introduction to the project:

The mentioned title itself tells us that the defined communication technology is for developing the fastest 5g communication system.this project is all about accessing the data at faster rate.the existed communication technologies uses various types of media as communication channels,those are:

1.wire
2.wireless-free space
3.light

among the above channels ,present project deals with wires and light to establish communication in secured manner and at faster rate.we are in the generation where everything is automated by avoiding complexity of dealing with wires and mobility,but yet to improve the speeds and latency.

The differences occurs at various factors and situations between wired and wireless communication,interms of hardware design ,security, range, cost,comfort etc.currently the security and speed became a challenge for us.to improve the speed of data accessing as a part of 5g communication system we came with a solution which is PLC-VLC communication system.PLC stands for Power Line Communication which uses power cables or co-axial cables as a communication channel or medium.

VLC stands for Visible Light Communication which uses light as a channel to transmit the data. integrating plc and vlc results in improved communication system in all aspects.The bandwidth constriction for high-speed LANs in applications where typical wireless communication systems are subject to severe interference and attenuation or may be blocked due to security concerns, the PLC-based LANs can be an effective alternative solution, augmented by Visible Light Communication (VLC) techniques.

1.1.1 PLC:

The hybrid power line communication is wired communication system uses general co-axial cables as a medium to make available the data accessing at higher rate for a user.power line Communication (PLC) technologies have been investigated by researchers in the recent past, and low data rate Narrowband PLC, and high data rate Broadband PLC, have been standardized for effective communication within home.as well as a potential access technique for the last mile technology such as IEEE P1901.1 and IEEE P1901.2.With the advancement in the digital modulation and coding techniques, the communication over the shared and noisy PLC channel is made reliable,secure and robust.

Thus, powerlines are considered an effective means of communication for in-home Local Area Networks (LANs) in addition to serving as a reliable medium of communication for the emerging applications of Internet of Things (IoT) and NB-PLC for smart grid communications.

PLC is designed with low cost,low complexity by using already available co-axial cables in houses as shown in Fig 1.1. Power-line communication (PLC) carries data on a conductor that is

also used simultaneously for AC electric power transmission or electric power distribution to consumers.
It is also known as power-line carrier, power-line digital subscriber line (PDSL), mains communication, power-line telecommunications, or power-line networking (PLN).

A wide range of power-line communication technologies are needed for different applications, ranging from home automation to Internet access which is often called broadband over power lines (BPL). Most PLC technologies limit themselves to one type of wires (such as premises wiring within a single building),but some can cross between two levels(for example, both the distribution network and premises wiring). Typically transformers prevent propagating the signal, which requires multiple technologies to form very large networks. Various data rates and frequencies are used in different situations.

A number of difficult technical problems are common between wireless and power-line communication, notably those of spread spectrum radio signals operating in a crowded environment.Power-line communications systems operate by adding a modulated carrier signal to the wiring system. Different types of power-line communications use different frequency bands.

Since the power distribution system was originally intended for transmission of AC power at typical frequencies of 50 or 60 Hz, power wire circuits have only a limited ability to carry higher frequencies. The propagation problem is a limiting factor for each type of power-line communications. 50 Hz signal is a more common frequency component that interfere with the data that we transmit through power cables in india where as 60 Hz componenet is generally available in US.this problem can be overcome through effective filtering system.The main issue determining the frequencies of power-line communication is laws to limit interference with radio services.

Many nations regulate unshielded wired emissions as if they were radio transmitters. These jurisdictions usually require unlicensed uses to be below 500 KHz or in unlicensed radio bands. Some jurisdictions (such as the EU), regulate wire-line transmissions further. The U.S. is a notable exception,permitting limited-power wide-band signals to be injected into unshielded wiring, as long as the wiring is not designed to propagate radio waves in free space.Data rates and distance limits vary widely over many power-line communication standards.

Low-frequency (about 100–200 kHz) carriers impressed on high-voltage transmission lines may carry one or two analog voice circuits, or telemetry and control circuits with an equivalent data rate of a few hundred bits per second.however, these circuits may be many miles long. Higher data rates generally imply shorter ranges. a local area network operating at millions of bits per second may only cover one floor of an office building, but eliminates the need for installation of dedicated network cabling.Historically,the PLC technology has very limited applications but now we are witnessing the possibility of it being acclaimed universally as a prime mode of long-haul data communication. with the inevitable arrival of broadband access,the demand for sending digital voice,video and Internet data within the home increases continuously.

While retrofitting the houses and neighborhoods with special wires is one option,it is expensive and time consuming. PLC Technology allows the use of the existing and widespread power distribution infrastructure to provide high speed networking capabilities along with many other benefits.

The primary use of power lines has been carrying electricity for domestic and industrial users.the frequency responce of the PLC is very poor (frequency selective) due to which it could not be used for data communication for ages.however,with the advent of efficient multiplexing techniques,the engineering got success in converting frequency selective nature into flat-faded channel responce.this breakthrough led the researchers to use PLC for data communication.till now,IEEE has standardized PLC for data communication.

As far as PLC channel is concerned,zimmerman and dostert modelled the low voltage distrinution grid and classify it as four different channel types classified based on the length of cable and the number of branches connected to the main cable.most of the works available on utilization of PLC-VLC channel have referred to this model of PLC channel that is mathematically described as

$$H(f) = \sum_{i=1}^{N} \{|g(f)|^{\phi_{g_i(f)}}\}\{e^{-\left(a_0+a_1 f^k\right)d_i}\}\{e^{-j2\pi f \tau_i}\},$$

where the first term is the frequency dependent weighting factor $g_i(f)$ for the ith path representing the reflection and transmission factors, the second term shows the attenuation factors a_0, a_1 for the path length d_i, while the last and third term expresses the i multipaths with corresponding τ_i delays.

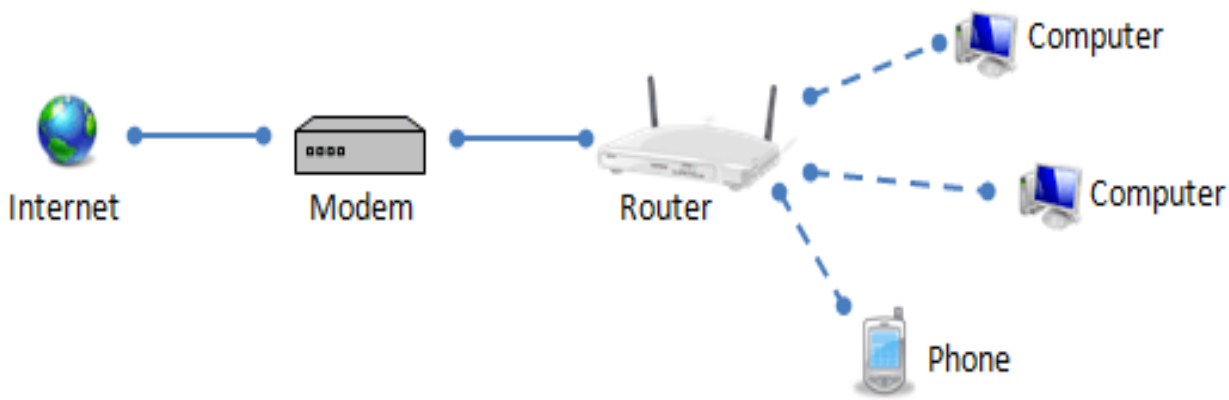


Fig 1.1. PLC System

1.1.2 VLC:

Visible light communication (VLC) system employe visible light for communication that occupy the spectrum from 380 nm to 750 nm corresponding to a frequency spectrum of 430 THz to 790 Thz as shon in Fig 1.2. the low bandwidth problem in RF communication is resolved in VLC because of the availability of the large bandwidth.

The vlc receiver only receives signals if they reside in the same room as the transmitter,therefore the receivers outside the room of the VLC source will not be able to receive the signals and thus, it has the immunity to security issues that occurs in the RF communication systems.As a visible light source can be used both for illumination and communication, therefore, it saves the extra power that is required in RF communication. Keeping in view the above advantages,VLC is one of the promising candidates because of its features of non-licensed channels,high bandwidth and low power consumption.

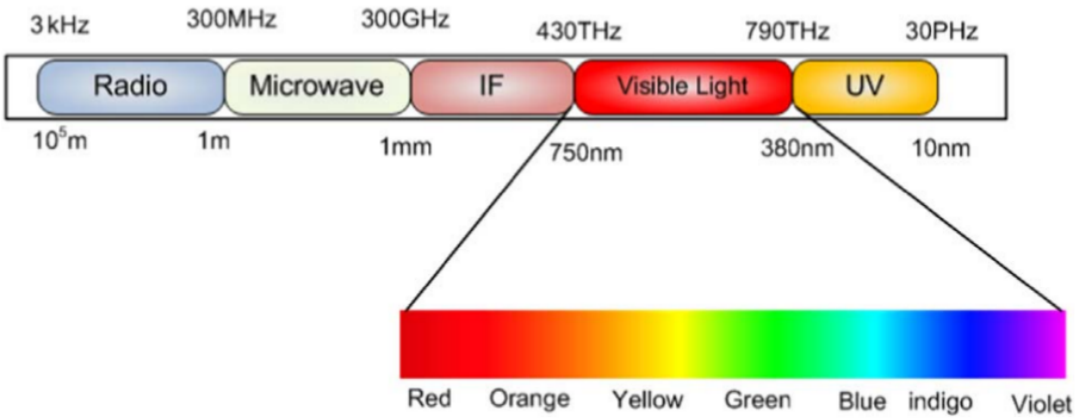


Fig. 1.2. VLC frequency spectrum.

VLC is a subset of optical wireless communication technologies.The technology uses floirescent lamps (ordinary lamps,not special communication devices) to transmit signals at 10 kbit/s,or LEDs for upto 500 Mbit/s over short distances as shown in Fig 1.3. Systems such as RONJA can transmit at full ethernet speed (10 Mbit/s) over distances of 1-2 kilometers.

Specially designed electronic devices generally containing a photodiode receive signals from light sources, although insome cases a cell phone camera or a digital camera will be sufficient.The image sensor used in these devices is in fact an array of photodiodes (pixels) and in some applications its use may be preferred over a single photodiode. Such a sensor may provide either multi-channel (down to 1 pixel = 1 channel) or a spatial awareness of multiple light sources.

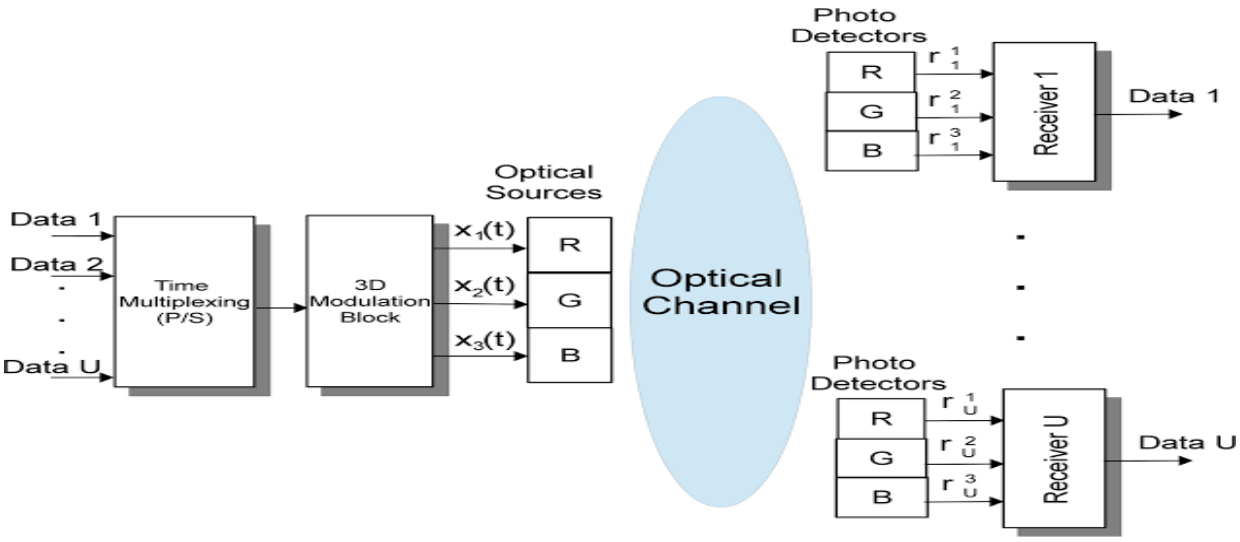


Fig 1.3. VLC System

VLC can be used as a communications medium for ubiquitous computing and IoT ecosystems because light-producing devices (such as indoor/outdoor lamps,TVs, traffic signs, commercial displays and car headlights/taillights) are usedeverywhere. Using visible light is also less dangerous for high-power applications because humans can perceive it and act to protect their eyes from damage.

Fifth generation (5G) wireless systems represent the next wave in mobile telecommunications beyond the current 4G standards. Compared to the existing 4G systems, 5G systems should achieve a much higher capacity, data rate, spectral efficiency, energy efficiency, and user experience. At the same time, lower battery consumption and lower implementation costs are also deemed to be a must. Small cell has emerged as one of the most promising 5G technologies due to its ability to significantly increase the network capacity/coverage, prolong the battery life of mobile devices, and achieve high network energy efficiency. Millimeter wave (mmWave) spectrum, with a small coverage area and abundant available bandwidth, has also become a promising technology for 5G networks to enable gigabit-per-second data transmission.

The mmWave band normally refers to the frequency range from 3 GHz to 300 GHz with wavelengths ranging from 1mm to 100mm. It has already been standardized as a physical layer (PHY) alternative for wireless personal area networks (WPAN) in IEEE 802.15 Task Group 3c (TG3c) at the 57-64 GHz band, and IEEE802.11ad (WiGig) at 60 GHz for short-range applications.

Researchers have shown that when the considered cell size is in the order of 200 m, rain attenuation and atmospheric absorption impose a relatively small impact on the propagation of the mmWave band For future communication, many studies have shown that wireless users will spend approximately 80 percent of their time indoors and 20 percent of their time outdoors.

Therefore, high-data-rate services in indoor and hotspot areas will contribute to the majority of the ever increasing traffic. Although the mmWave spectrum aims for high-speed short-range communications in both indoor and outdoor areas, wireless networks will eventually face a skyrocketing capacity explosion that could even overstretch the mmWave spectrum. This motivates us to continue exploring new spectrum, new technologies, and new architectures to cater to the ever-increasing demands of capacity and high data rates.

Visible light communication (VLC), also known as optical wireless communication (OWC), has become another potential candidate technology for 5G networks. First proposed in 1999, VLC already has several standards released, i.e. VLCC-STD-001, JEITA CP-1221, JEITA CP-1222, and the IEEE 802.15.7 standard.

It has been attractive for both indoor and outdoor communications, e.g. high-date-rate (LiFi) communication; indoor localization; device-to-device (D2D) communication with LCD screens or camera sensors; traffic control between traffic lights and vehicles or traffic signals between vehicles; and special applications in electromag-netic-sensitive environments such as hospitals, airplanes, and the underground mining industry.

In this article we mainly consider its indoor application in 5G network. Compared to mmWave, VLC has similar advantages such as abundant spectrum, the ability to support gigabit-per-second data rates, high security, high spatial reuse, low co-channel interference, interference-free communications between indoor and outdoor users, etc. On the other hand, VLC also shares similar disadvantages such as the susceptibility to blockage and the requirement of line-of-sight (LOS) alignment, etc. There are crucial factors that empower VLC to be more suitable for indoor applications and to be a desirable complement of mmWave communication in 5G networks. Table 1 captures the major differences between VLC and mmWave.

First, the VLC band has a richer spectrum than the mmWave band. Spectrum in the VLC band has a wavelength range from 380nm to 780nm and a frequency range in the vicinity of 385 THz to 790 THz. The VLC spectrum is completely license-free and safe for the eyes and human body.

Second, VLC is based on the luminaire infrastructure realized by white light emitting diodes (LEDs), which is expected to serve nearly 55 percent of indoor illuminations by the year 2020, and nearly 100 percent by 2030.

VLC needs no additional costs and no additional power since white LED light is equipped in almost every indoor environment. On the contrary, mmWave communication needs to be equipped with advanced CMOS chips and high-gain and steerable antennas at both the mobile terminal and the base station sides, which mandates nontrivial hardware costs and implementation complexity.Finally, although mmWave supports a larger communication distance than VLC, both are subject to very strong penetration loss, which makes them rather comparable to each other in indoor deployments. Therefore, mmWave has no evident propagation advantages over VLC in the indoor scenario, where the practical communication distance is normally limited to several meters based on the typical room size.

It is important to note that the Line-Of-Sight (LOS) is an essential requirement in VLC transceiver due to which it finds ready applications in the field of localization.

Similarly, VLC technology can also be readily employed for underwater communication where WiFi signals normally get weaker after certain depth. The VLC channel is considered to be composed of a LOS and a Diffused Non-Line of Sight (NLOS) component.

Due to the standardized illumination of 400 lux, the LOS component of the VLC channel presents high Signal-to-Noise Ratio (SNR) channel conditions, while the diffused NLOS component suffers from multipath propagation and attenuation, thus provides lower SNR channel conditions.
Mathematically, the VLC channel takes the form

$$H_{VLC}(f) = \sum_{i=1}^{N} \eta_{LOS_i} e^{j2\pi f \Delta\tau_{LOS_i}} + \frac{\eta_{DIFF}}{1 + jf/f_0} e^{-j2\pi f \Delta\tau_{DIFF}}$$

where η LOS i and η DIF F are the channel gains due to LOS and diffused NLOS components of VLC channel. Δτ LOSi and Δτ DIF F represent the corresponding components signal delays and f0 is the 3 − dB cut off frequency. The NLOS and LOS components can be defined as,

$$\eta_{LOS} = \frac{A_R (r+1) \cos^r \varphi \cos\theta}{2\pi d^2},$$

$$\eta_{DIFF} = \frac{A_R \rho}{A_{Room} (1-\rho)},$$

where AR and ARoom are effective receiver area and room area respectively, ρ is the average reflectivity from the walls, d is the distance between LED lamp and the receiver and φ and θ denote angle of irradiance and incidence respectively.

$$r = \frac{-1}{\log_2 \theta/2}$$

is the Lambert index that depends on half intensity beam angle θ/2.

1.1.3. PLC-VLC:

Visible Light Communications (VLC) and Powerline Communications (PLC) are two independent wireless and wired technologies, respectively. Both have great potential and attraction for future generation communication systems. Over the past decade or so, with the advent of OFDM, the PLC has emerged a good alternative to Ethernet for data communication. However, the advantage of PLC over Ethernet communication is quite obvious, i.e., no new cables need be installed for data communication.

With the newly established standards for both PLC and VLC there is a strong motivation to explore the integration of the VLC and PLC technologies. The resulting PLC-VLC system is an efficient and economical way to fulfill the need of broadband access for indoor users. The LED lighting system then functions as a wireless broadcaster for data fed from power line communication and enables the deployment of a broadband distribution downlink with very little extra cost.

The authors have provided introduction about the hybrid channels, however, no practical work has been carried out. Similarly, it is proposed to use the existing power lines as a wiring system for optical communication, however, no modulation/ demodulation is carried out.

A very low complexity PLC-VLC interface was proposed. With a very simple modulation scheme, i.e., OOK,the performance of a Spread Orthogonal Continuous Phase Binary Frequency Shift Keying (SOCPBFSK) receiver was analyzed over physical PLC-VLC link and the system was demonstrated reliable at least for low data rate applications. It is worth-noting that the proposed system is also costefficient compared to WiFi-Ethernet integration.

Extending the notion of cost-effective PLC-VLC system, the authors proposed a cost-effective PLC-VLC System for ubiquitous broadband access. The novelty lies in the du-plex Decode-and Forward (DF) which could in turn support multi-user broadband access. The modulation adopted in the physical implementation was NRZ-OOK. The achieved data rate was of the order of 5Mbps over a distance of 3 meters with BER approaching 10^{-5} .

It is significant to note that PLC-VLC is meant for providing high speed communication system. With the rapid spread of the LED, VLC is becoming an emerging wireless communication technology. VLC offers advantageous properties such as safety, environmental protection, worldwide availability and high capacity. It can be used as an effective supplement of the existing wireless communication.

Conversely, PLC using the omnipresent power line cables in driving LED also can be used as a communication medium between the LEDs and other network. It only requires little modification of the existing infrastructure to achieve the purpose of illumination and communication simultaneously.In this paper, we propose an efficient and low-cost indoor broadband broadcasting system based on the integration of PLC and VLC technologies.

The proposed system take full advantages of existing cabling infrastructure, providing high-speed communications while achieving better signal coverage.

1.1.4. Cascaded PLC-VLC Channel Model:

The overall cascaded PLC-VLC channel can be described by the transfer function

$$H_{Cas}(f) = \sum_{i=1}^{N_{LED}} H_{i,PLC}(f) H_{i,VLC}(f),$$

where HCas (f) is the cascaded PLC-VLC channel, Hi,P LC (f) is the PLC channel as described earlier, while Hi,V LC (f) represents the VLC channel for the channel path between the ith LED and the optical receiver for total number of NLED lamps.

Contrary to the classical VLC based broadcasting scheme that allows LEDs to act as data Access Points (APs), and requires the more costly solution of adding modems in addition to LED drivers to these points, the PLC-VLC broadcasting scheme relies on the data carrying power lines as the backbone. This scheme utilizes the PLC modem to couple the data from the Ethernet source to the powerline. In the perspective of a PLC-VLC communication system for data communication within a Small Office-Home Office (SOHO) using VLC technology, with PLC as the back-bone, it is imperative to consider the integrated PLC-VLC communication channel so as to ensure reliable communication at appropriate data rates. In recently published research, authors have referred to a cascaded PLC and VLC communication channel for the hybrid PLC-VLC communication system.

While considering communication within a SOHO, the main concept is to utilize existing powerline infrastructure as the major data carrying medium of communication, thus linking the SOHO with the data APs from the access network.

In a SOHO, every power socket is a node which can further distribute the digital data after signal processing through a coupling device. However, VLC in conjunction with PLC allows the light emitting devices connected with power sockets to act as data transmitters, as shown in Fig. 5. Each intelligent device connected in the PLC-VLC SOHO is able to receive the data through optical receivers .

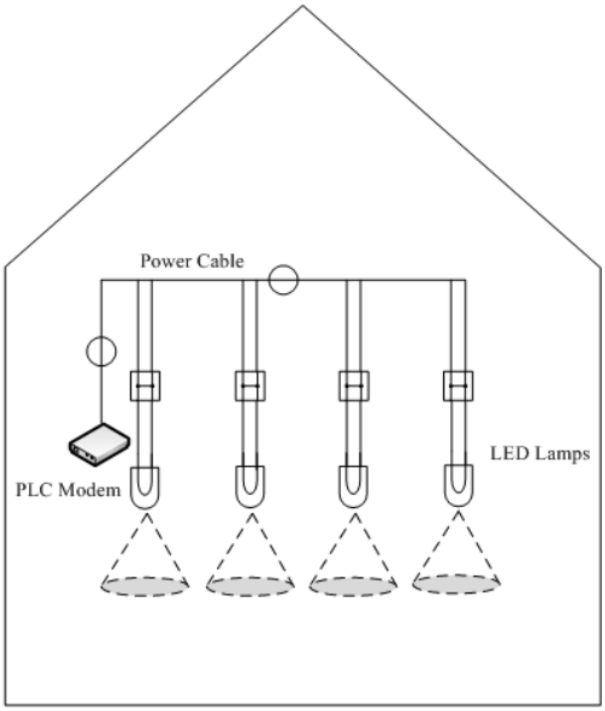


Fig. 1.4. PLC-VLC based SOHO communication system.

The integrated PLC-VLC transmission process is shown in 6. The purpose of the PLC-VLC transmitter is to direct the data carrying powerline signal in each socket towards light emitting diodes, which allows the signal to be broadcast towards a single receiver or multiple receivers in a room in addition to providing illumination. Consequently, the communication signal is subjected to a cascade of a PLC and VLC channel.

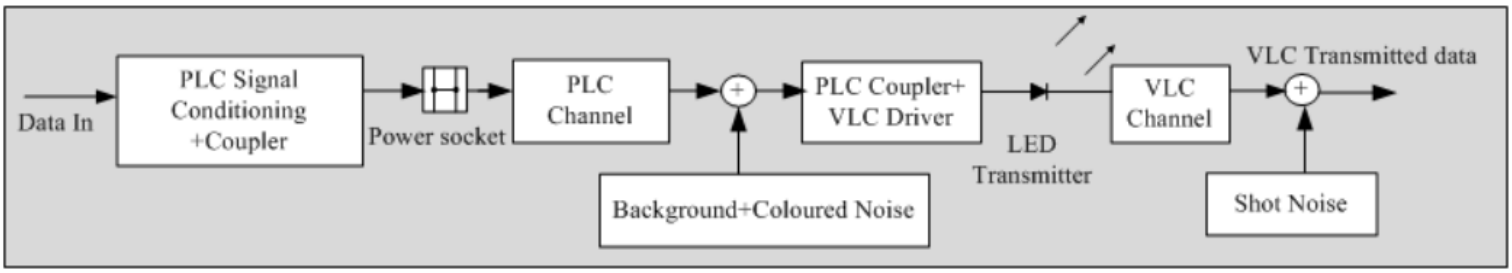


Fig.1.5. Functional block diagram of PLC-VLC transmitter.

As shown in Fig. 1.5, the data is conditioned for the PLC socket, including the process of Forward Error Correction (FEC), modulation, data framing and finally converted to an analog form that is suitable for communication over the power lines. The modulated analog signal is transmitted through a coupling device over the power lines. PLC channel noise that mainly comprises of background and coloured noise is added to the signal during propagation through the powerline channel. The PLC to VLC conversion module in the LED fixture is used to receive data from power lines through a coupling device.

This module performs precompensation on the received signal, amplifies it and adds this signal to the DC bias of LED, thus formulating the LED driving signal. LED lamps, therefore operate as optical transmitters in this integrated PLC-VLC system.

1.2 A Bit of History:

History of PLC:

Initially,the first application involving data transmissions over power lines were primarily done only to protect sections of the power distribution system in case of faults.(In fact,powerline protection remains one of the primary functions of powerline communications). In such an event,the fast exchange of information is necessary between power plants, substations and distribution centers so as to minimize their detrimental effects. The robustness of the powerlines and their ready connectivity and availability make this technique an optimal solution.

Narrowband power line communications started soon after the beginning of wide-spread electrical power supply. Around the year 1922 the first carrier frequency systems began to operate over high-tension lines in the frequency range 15 to 500 kHz for telemetry purposes, and this continues to the present time. Consumer products such as baby alarms have been available at least since 1940.

Historically, also, a primary motivation for power line communications has been to do load management in future. The currently employed ripple control systems have the disadvantage of requiring several megawatts for information transmission. A second important motivation has been to facilitate meter reading from a distance An English study has shown that a meter reader achieves an average information rate of only about 1 bit/s.

The Tokyo Electric Power Co was running experiments in the 1970's which reported successful bi-directional operation with several hundred units.Considering that data transmission over power lines has been around for quite some time, one might wonder why it is receiving such renewed attention recently especially considering the data rate for protection and telemetering purposes is at most a few kb/sec and is not comparable to the Mb/sec data that needs to be supported for multimedia applications? The answer is a combination of effects that took place during the mid thru late 1990s, namely, the explosive growth of the Internet and the gigantic leaps in VLSI (Very Large Integrated Circuits) and DSP (Digital Signal Processing) technology.

Then was the telecommunications market deregulation, first in the US and then in Europe and Asia. All these events have made power line communications a viable technology for numerous other applications.

History of VLC:

In ancient times, light was used to convey messages using methods such as fire and smoke signals. The Roman used polished metallic plates for sunlight reflection to carry out long distance signaling. Semaphore lines based Optical Communication (OC) systems were developed in the 1790 s. The first visual telegraphy system was developed by the Claude Chappe in 1792 in France.

A series of towers (shown in Fig. 1.6) equipped with semaphores were used for information transfer between the cities. Heliograph, a wireless solar telegraph developed by the US military in the early 1800s was based on Morse code flashes of reflected sunlight by a mirror. The flashes were established by either interruption of the beam with a shutter or momentary mirror pivot. In 1880, Graham Bell introduced his photo-phone that was based on transmitting voice signal on a light beam.

Fig. 4. Semaphore towers in Nalbach, Germany

The voice signal is projected toward a mirror which causes vibrations on the mirror. The mirror was then bounced by sunlight and thus, the vibrations are caught by the sunlight. At the receiver side the sunlight was received and converted back to a voice signal. The major drawback of this device is that it does not work well in cloudy weather.

Optical communication did not gain much popularity till the development of Light Amplification by Stimulated Emission of Radiation (LASER). In 1970, Corning Incorporated successfully developed optical fibers for commercial purposes with low attenuation. The GaAs semiconductor laser was also developed at that time for use in optical fiber cables for long distance communication. The invention of the in-fiber Bragg grating (1990) and Optical Fiber (OF) amplifier (1980) was the basis of the revolution in the field of telecommunication in the late 20th century. VLC is a type of optical communication that uses the range of frequencies from 430THz to 790 THz. In 2003 at the Nakagawa Laboratory at Keio University, Japan, transmission of data was carried out using LEDs.

TECHNOLOGIES USED:

Technologies used in building the current project are, OFDM,different modulation schemes.the main purpose of using OFDM is to transmit the data at faster rate.OFDM is a multi-carrier modulation obtained by using orthogonal sub-carriers in a frequency division multiplexing (FDM) system. It divides the total data rate to be transmitted into the number of subcarriers.

Cyclic prefixes (CP) are used in OFDM to combat multipath by converting an ISI channel into a fix number of ISI-free parallel sub-channels. Each of those sub-channels is affected by an additive white Gaussian noise(AWGN) of zero mean and variance equal to the number of sub-channels divided by 2.

the dictionary meaning of modultion is variation,variation in the signal parameters is to be carried out to provide a kind of strength to the signal to travel to far distances.
Modulation schemes used are

under plc:ASK,FSK,PSK
under vlc:OOK.

CHAPTER-2

OFDM ITRODUCTION

2.1.OFDM DESCRIPTION:

2.1.1 Frequency Division Multiplexing (FDM):

Frequency Division Multiplexing (FDM) has been used for a long time to carry more than one signal over a telephone line. FDM divides the channel bandwidth into subchannels and transmits multiple relatively low rate signals by carrying each signal on a separate carrier frequency. To ensure that the signal of one subchannel did not overlap with the signal from an adjacent one, some guardband was left between the different subchannels. Obviously, this guardband led to inefficiencies.

To achieve a VLC-PLC integrated multi-service system compatible with the function of positioning, a well-designed frame structure is necessary. As the figure Fig 2.1a. illustrates, frequency band in the range of 500 kHz to 2 MHz is used for transmission of positioning while the frequency above 2 MHz is for data transmission. Frequency band below 500 kHz is reserved for automatic meter reading (AMR) or other low data rate service applied in the PLC system. Both PLC and VLC schemes make use of the spectrum in the same way, so that the direct re-transmission concept can be conducted.

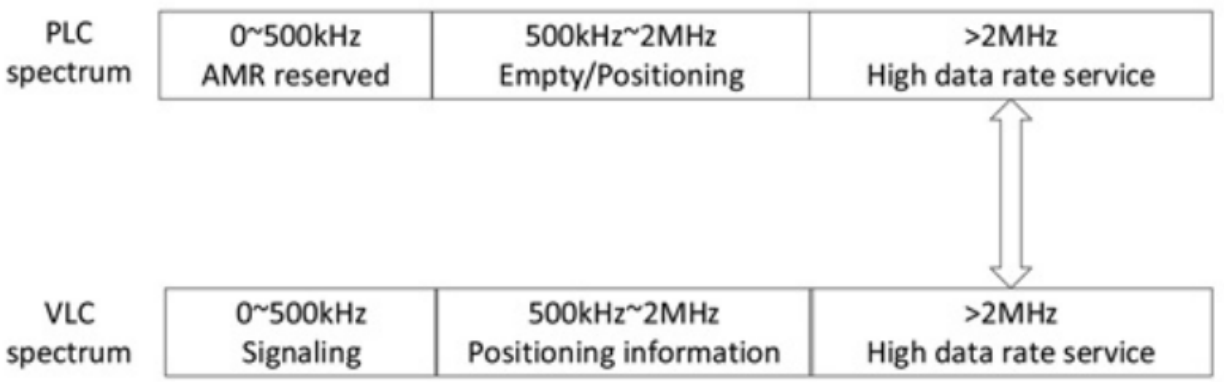


Fig 2.1 a. Structure of the proposed frequency-domain frame

Since the function of positioning needs only a relatively low data rate while a quite high data rate is required for the application of data transmission above 2 MHz frequency, different modulation schemes can be implemented for the two different functions.

For positioning with low data rate, a low spectrum-efficiency but simple modulation scheme can be adopted such as OOK, FSK, PSK and so on.Regarding high rate data transmission where an insurance of spectral efficiency improvement is essential.

OFDM is an excellent choice where a zero prefix-OFDM (ZP-OFDM), cyclic prefix-OFDM (CP-OFDM) or time domain synchronous-OFDM (TDS-OFDM) scheme can be chosen as candidates. The modulation schemes for data transmission of both PLC and VLC are always the same in a specific frequency band. Therefore, it is not a conflict to the concept of direct re-transmission.We are imagining a prospect that every LED lamps have the ability to broadcast its position information as well as transmission data.

On this purpose, there are two alternative sources of the positioning information available: one from the data source such as Ethernet, the other from the LED lamp itself. For the former, the positioning information is modulated when the signal from the data source is coupled to the power line. For the latter one, the positioning information is originally set into the AF module and the information varies for each LED lamp.

The first method authorise the input signal the right of a unified control for all of the positioning information and is flexible to make a modification, however, much overhead is needed, thus leading to a spectral efficiency decrease. On the other side, the second method is effective in spectrum, but need a more complex AF module for the sake of adding positioning information when PLC signal is transformed to the VLC form. The two methods have their own strengths and can be implemented in different cases.

2.1.2 Time domain multiplexing scheme(TDM):

Apart from the frequency domain scheme, a time domain scheme is proposed in this section. Various service as well as the positioning information are arranged at different time blocks. The structure of the proposed time-domain frame is shown in Fig. 14b, where PN is short for pseudo-noise sequence.

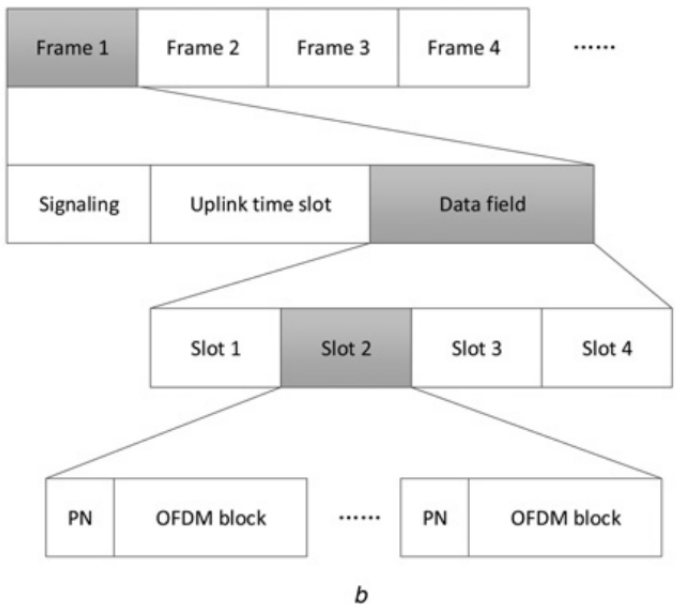


Fig 2.2 b. time-domain frame

As we can see, the signal transmitted in the power line or wireless optical channel is a sequence of consecutive frames, each of which is composed of the signalling, uplink time slot, and the data field. All of the three components are multiplexed in the time domain. The data field undertakes the main task of data transmission and it is divided into blocks to support multi-service.

A four-service example is shown in Fig. 2.2 b. The signalling transmits the instruction of the whole frame such as the frame length, size of other components, number of the service and so on. Moreover, the positioning information is included in the signalling. The uplink time slot is used to support the uplink transmission in order for users to make feedbacks or demand service.

Some details about the time domain frame is noted in themfollowing:

(i) Adding positioning information:

Similar to the frequency domain scheme, the modulation of positioning information takes place either from the data source or in the AF module. The multi-carrier modulation principle of OFDM makes sure that different service are able to be modulated in various sub-carriers. At the receiving end, the receiver can first acquire positioning information by demodulation signal in the specific time slot, while obtaining data loads in the time slots of data field.

(ii) Uplink time slots:

In order for user feedbacks, an uplink time slot is designed in the proposed frame. For the transmitter sides of both PLC and VLC, the uplink slot is vacant to avoid interference for the uplink transmission from user devices of the receiving end. The receiving end can conduct the uplink transmission by means of visible light uplink scheme, Wi-Fi scheme, 3G/4G scheme and so on. All schemes are strictly performed in accordance with the time slot, therefore an isolation between downlink and uplink is achieved to reduce interference of each other.

(iii) Data field:

The data field which carries data loads is divided into parts of service. Each part makes up to a time-domain sub-channel. For one of the sub-channels, a fixed modulation scheme of OFDM is adopted, which consists of ZP-OFDM, CP-OFDM, TDS-OFDM as described above. In Fig. 3b, a TDS-OFDM scheme is adopted.

The application of OFDM can effectively improve the spectral efficiency while the sub-channels offer great help to realise multi-service. Therefore, a VLC-PLC integrated system supporting multi-service with high data rate is introduced.

2.1.3 Orthogonal Frequency Division Multiplexing (OFDM):

In order to solve the bandwidth efficiency problem, orthogonal frequency division multiplexing was proposed, where the different carriers are orthogonal to each other. With OFDM, it is possible to have overlapping subchannels in the frequency domain, thus increasing the transmission rate. This carrier spacing provides optimal spectral efficiency.

Today, OFDM has grown to be the most popular communication system in highspeed communications. OFDM is becoming the chosen modulation technique for wireless communications.OFDM can provide large data rates with sufficient robustness to radio channel impairments.

Modulation : A mapping of the information on changes in the carrier phase, frequency, amplitude or combination .
Multiplexing : Method of sharing a bandwidth with other independent data channels.

OFDM is a combination of modulation and multiplexing. Multiplexing generally refers to independent signals, those produced by different sources. In OFDM the question of multiplexing is applied to independent signals but these independent signals are a subset of the one main signal. In OFDM the signal itself is first split into independent channels,modulated by data and then re-multiplexed to create the OFDM carrier.

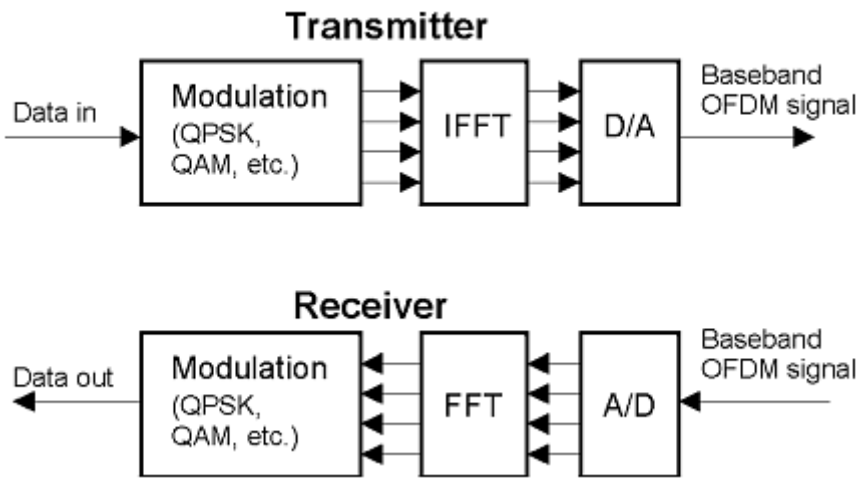


Fig.2.3. Multi-carrier FDM and Multi-code division multiplex Tx and Rx.

2.2 ROLE OF OFDM :

2.2.1. ORTHOGONALITY:

The main concept in OFDM is orthogonality of the sub-carriers.The "orthogonal" part of the OFDM name indicates that there is a precise mathematical relationship between the frequencies of the carriers in the system. It is possible to arrange the carriers in an OFDM Signal so that the sidebands of the individual carriers overlap and the signals can still be received without adjacent carriers interference. In order to do this the carriers must be mathematically orthogonal.

The Carriers are linearly independent (i.e. orthogonal) if the carrier spacing is a multiple of 1/Ts . Where, Ts is the symbol duration. The orthogonality among the carriers can be maintained if the OFDM signal is defined by using Fourier transform procedures.

The OFDM system transmits a large number of narrowband carriers, which are closely spaced. Note that at the central frequency of the each sub channel there is no crosstalk from other sub channels.

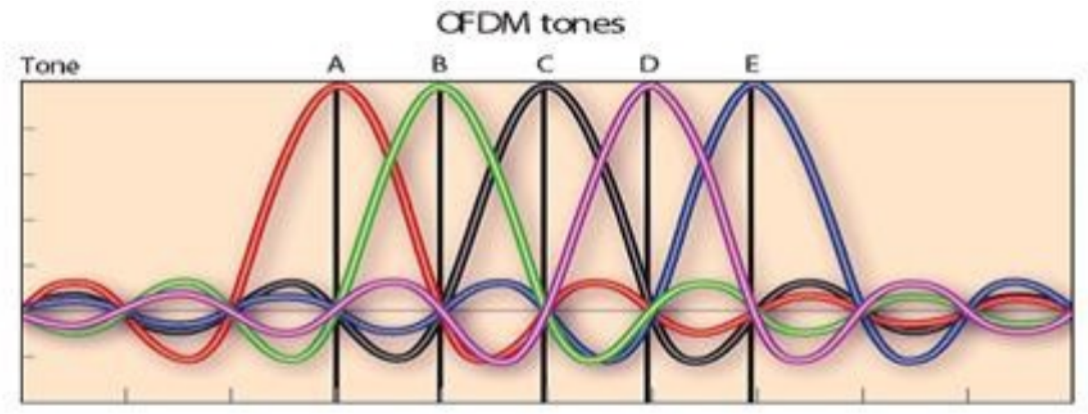


Fig. 2.4 . Example of OFDM spectrum for 5 orthogonal carriers

Since the carriers are all sine/cosine wave, we know that area under one period of a sine or a cosine wave is zero. This is easily shown.

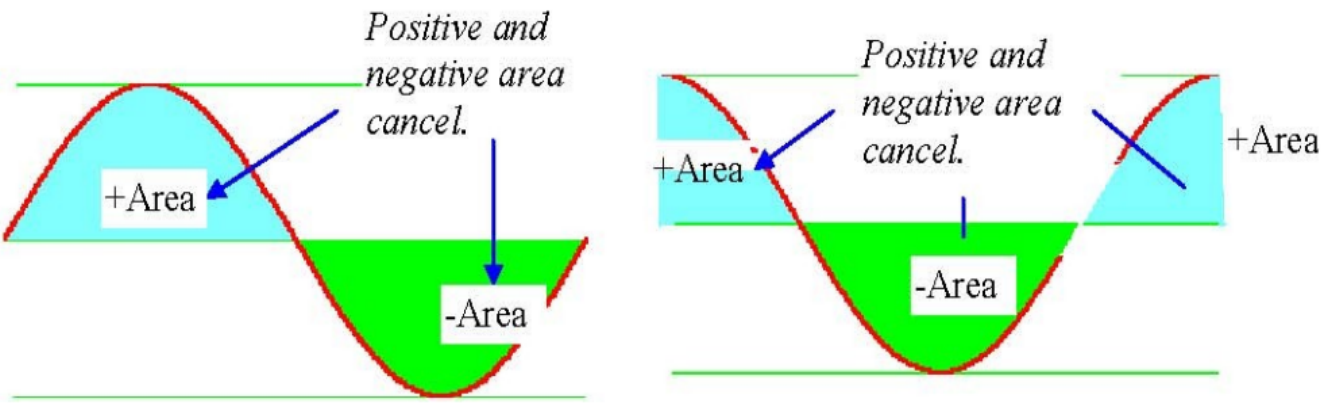


Fig. 2.5 . The area under a sine and a cosine wave over one period is always zero.

If a sine wave of frequency m multiplied by a sinusoid (sine or cosine) of a frequency n,

$$f(t) = \sin mwt \times \sin nwt$$

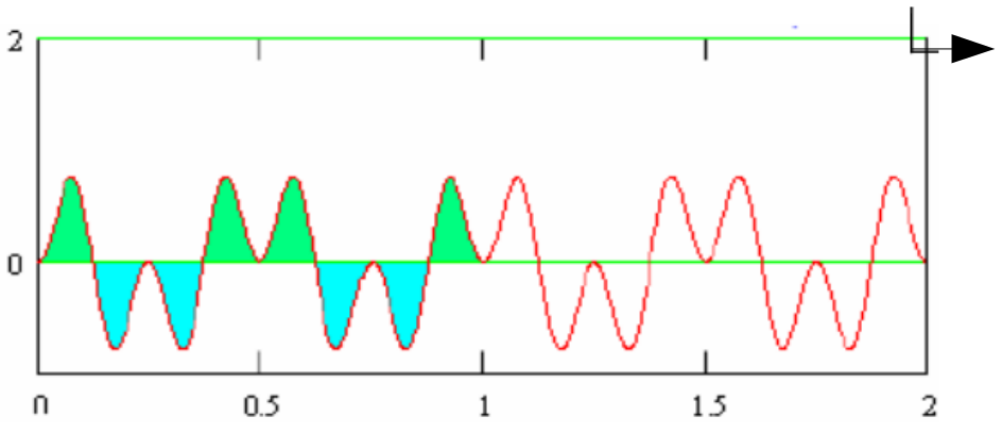
Where both m and n are integers, since these two components are each a sinusoid, the integral is equal to zero over one period. The integral or area under this product is given by

$$f(t) = \int_0^{2\pi} \frac{1}{2} \cos(m-n)wt - \int_0^{2\pi} \frac{1}{2} \cos(m+n)wt$$

$$= 0-0$$

So when a sinusoid of frequency n multiplied by a sinusoid of frequency m/n, the area under the product is zero. In general for all integers n and m, sin mx, cos mx,
cos nx, sin nx are all orthogonal to each other. These frequencies are called harmonics.

f (t) = sin wt *sin nwt



Sine wave multiplied by another different Harmonic.

Fig. 2.6 . the area under a sine wave multiplied by its own harmonic is always zero.

The orthogonality allows simultaneous transmission on a lot of subcarriers in a tight frequency space without interference from each other. In essence this is similar to CDMA, where codes are used to make data sequences independent (also orthogonal) which allows many independent users to transmit in same space successfully.

2.2.2. FDM to OFDM:

Frequency Division Multiplexing FDM is a special case of FDM. If we have a bandwidth that goes from frequency say a to b, we can subdivide this into a frequency of equal spaces. In frequency space the modulated carriers would look like this.

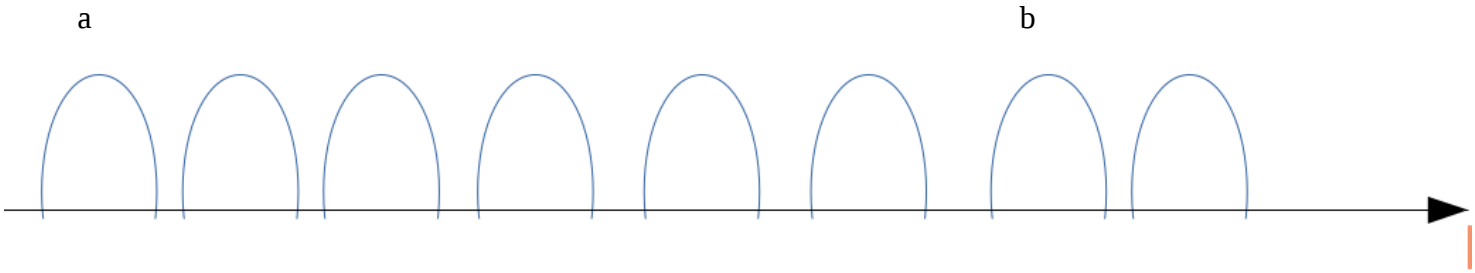


Fig. 2.7. bandwidth utilization of FDM

The frequencies a and b can be anything, integer or non-integer since no relationship is implied between a and b. same is true of the carrier center frequencies which are based on frequencies that do not have any special relationship to each other. If frequency C 1 and C n were such that for any n, an integer, the following holds.

$$C_n = n \times C_1$$

So that

$$C_2 = 2C_1$$
$$C_3 = 3C_1$$
$$C_4 = 4C_1$$

All three of these frequencies are harmonic to C 1 .

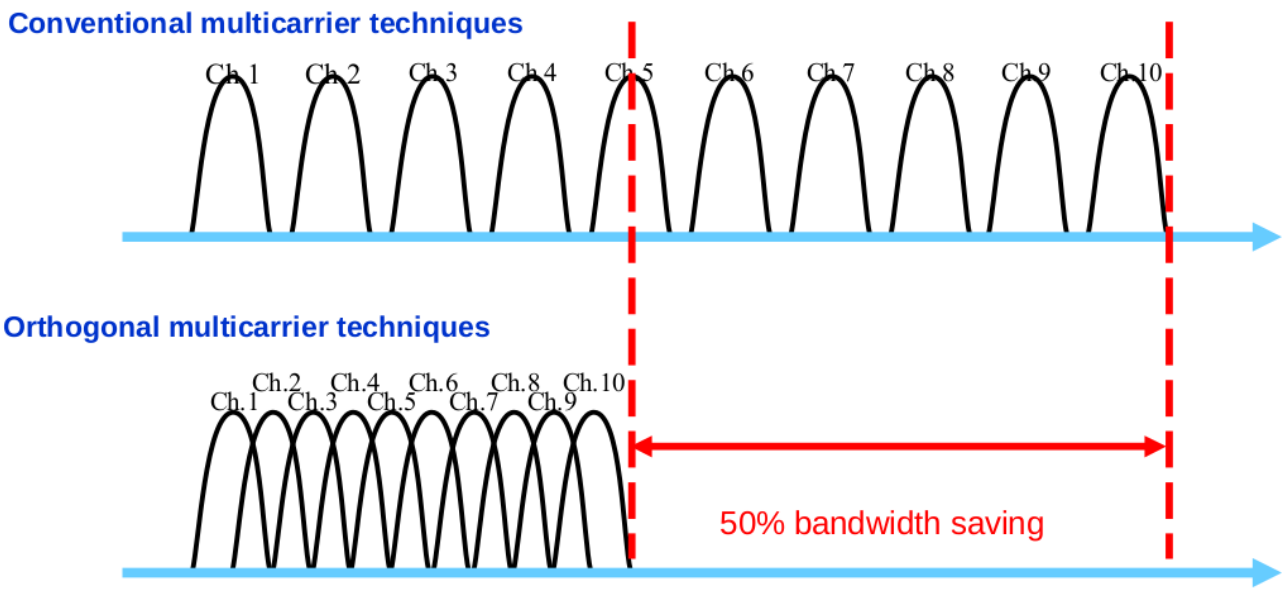


Fig. 2.8. bandwidth utilization of OFDM

In this case, since these carriers are orthogonal to each other, when added together, they do not interfere with each other. In FDM, since we do not generally have frequencies that follow the above relationship, we get interference from neighbor carriers. To provide adjacent channel interference protection, signals are moved further apart. Each carrier may be placed apart allowing for a 10% guard band. The frequencies would not be orthogonal but in FDM we don't care about this. It's the guard band that helps keep interference under control.

Fading:

The attraction of OFDM is mainly because of its way of handling the multipath interference at the receiver. Multipath phenomenon generates two effects (a) Frequency selective fading and (b) Intersymbol interference (ISI). The "flatness" perceived by a narrowband channel overcomes the frequency selective fading. On the other hand, modulating symbols at a very low rate makes the symbols much longer than channel impulse response and hence reduces the ISI. Use of suitable error correcting codes provides more robustness against frequency selective fading. The insertion of an extra guard interval between consecutive OFDM symbols can reduce the effects of ISI even more.

Defining fading :

If the path from the transmitter to the receiver either has reflections or obstructions, we can get fading effects. In this case, the signal reaches the receiver from many different routes, each a copy of the original. Each of these rays has a slightly different delay and slightly different gain. The time delays result in phase shifts which added to main signal component (assuming there is one.) causes the signal to be degraded. See fig.2.9.

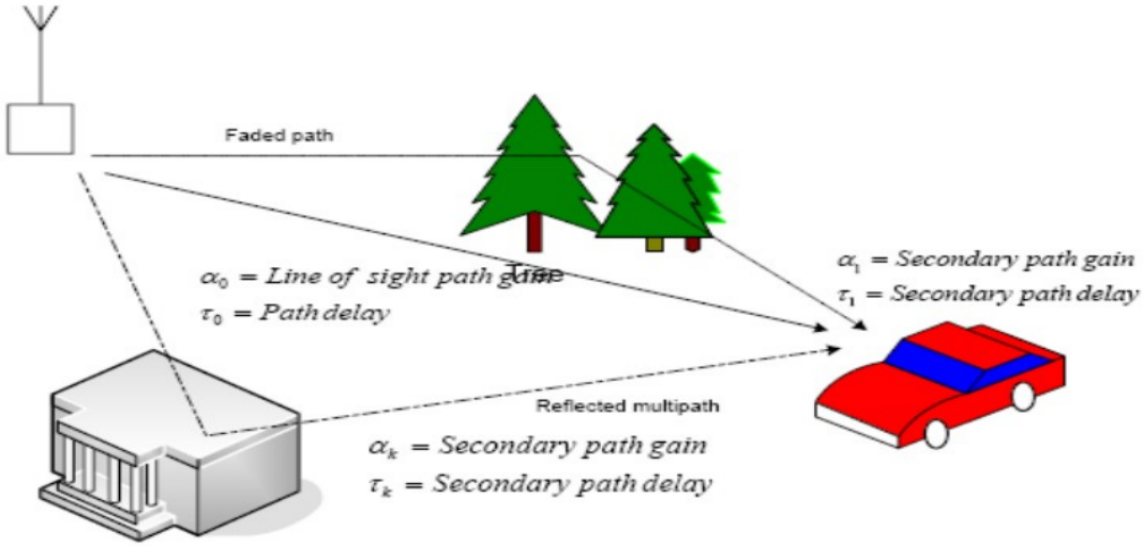
Fading is big problem for signals.The signal is lost and demodulation must have a way of dealing with it. In fading, the reflected signals that are delayed add to the main signal and cause either gains in the signal strength or deep fades. And by deep fades, we mean that the signal is nearly wiped out. The signal level is so small that the receiver can not decide what was there.

The maximum time delay that occurs is called the delay spread of the signal in that environment. This delay spread can be short so that it is less than symbol time or larger. Both cases, cause different types of degradations to the signal.The delay spread of a signal changes as the environment is changing.

Fig. 2.10 shows the spectrum of the signal, the dark line shows the response we wish the channel to have. It is large enough that it allows the signal to go through without bending or distortion. A fading response of the channels is something like shown in fig.2.9, we note that at some frequencies in the band, the channel does not allow any information to go through, so called deep fades frequencies. This form of channel frequency response is called frequency selective fading.

Because it does not occur uniformly across the band. It occurs at selected frequencies. If the environment is changing, then this response is also changing. In general when the delay Spread is less than one symbol, we get what is called flat fading. When delay spread is much larger than one symbol that it is called frequency-selective fading.

Rayleigh fading is a term used when there is no direct component and all signals reaching the receiver are reflected. This type of environment is called Rayleigh fading.



$$h_c(t) = \sum_{k=0}^{K-1} \alpha_k \delta(t - \tau_k)$$

α k = Complex path gain
τ 0 = Normalized path delay relative to LOS
Δ k = τ k -τ 0 difference in path time

Fig. 2.9. Fading is particular problem when the link path is changing, such as for a moving car or inside a building or in a populated urban area with tall building.

If we draw the interferences as impulses, they look like this

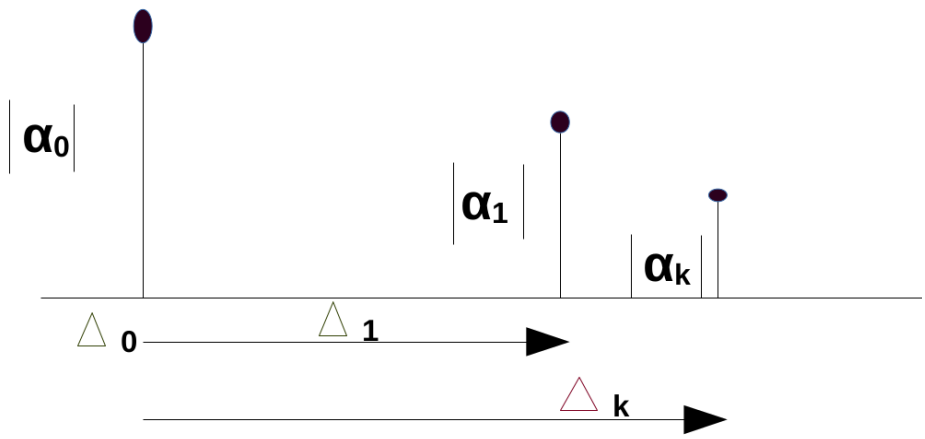


Fig. 2.10. Reflected signals arrive at a delayed time period and interfere with the main line of sight signal, if there is one. In pure Raleigh fading, we have no main signal, all components are reflected.

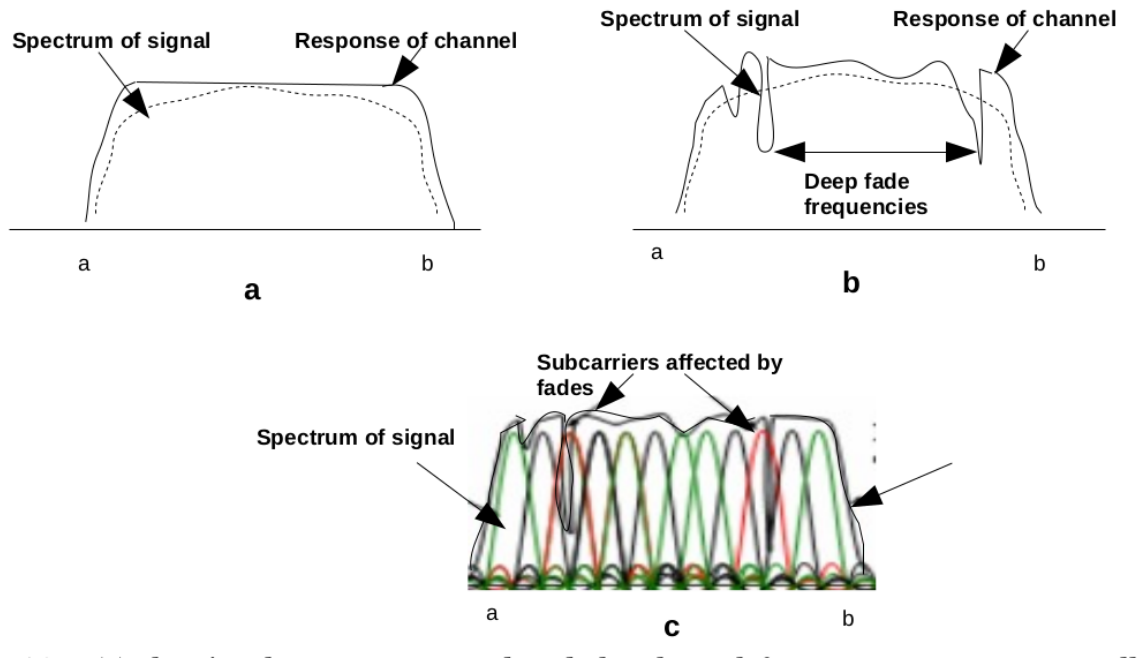


Fig. 2.11. (a) the signal we want to send and the channel frequency response are well matched. (b) A fading channel has frequencies that do not allow anything to pass. Data is lost sporadically. (c) With OFDM, where we have many little subcarriers, only a small subset of the data is lost due to fading.

An OFDM signal offers an advantage in a channel that has a frequency selective fading response. As we can see, because of the fading response of the channel, only two subcarriers are affected, all the others are perfectly OK.Instead of the whole symbol being knocked out, we lose just a small subset of the (l/N) bits. With proper coding, this can be recovered.

The BER performance of an OFDM signal in a fading channel is much better than the performance of QPSK/FDM which is a single carrier wideband signal. The BER of the OFDM signal is same as the BER of 8PSK signal in Gaussian channel. But in channels that are fading, the OFDM offers far better BER than a wide band signal of exactly the same modulation. The advantage here is coming from the diversity of the multicarrier such that the fading applies only to a small subset. In FDM carriers, often the signal is shaped with a Root Raised Cosine shape to reduce its bandwidth, in OFDM since the spacing of the carriers is optimal, there is a natural bandwidth advantage and use of RRC does not buy us as much.

Use of cyclic prefix to mitigate delay spread:

You are driving in rain, and the car in front splashes a bunch of water on you. What do you do? You move further back, you put a little distance between you and the front car, far enough so that the splash won't reach you. If we equate the reach of splash to delay spread of a splashed signal then we have a better picture of the phenomena and how to avoid it.

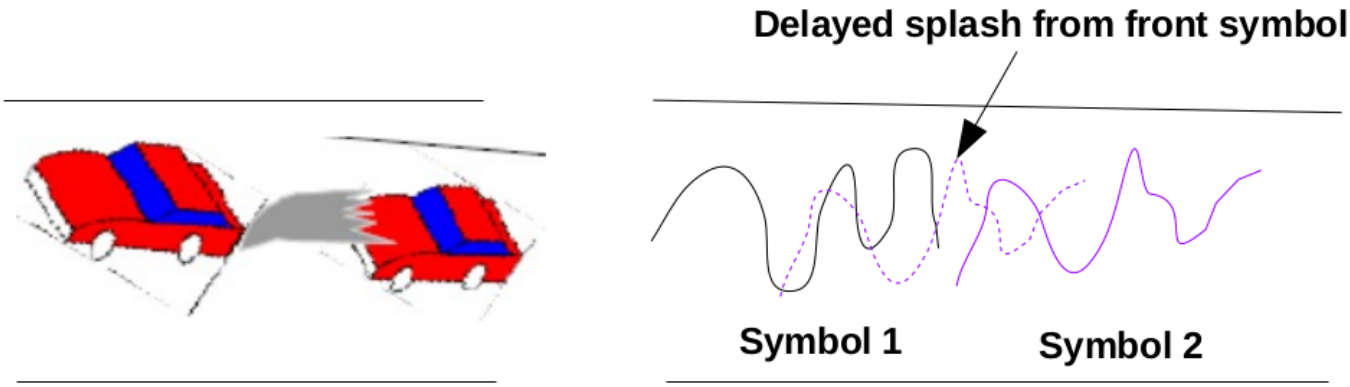


Fig. 2.12. Delay spread is like the undesired splash you might get from the car ahead of you.In fading, the front symbol similarly throws a splash backwards which we wish to avoid.

Increase distance from car in front to avoid splash. The reach of splash is same as the delay spread of a signal. Fig. 4.10 shows the symbol and its splash. In composite, these splashes become noise and affect the beginning of the next symbol as shown in fig. below.

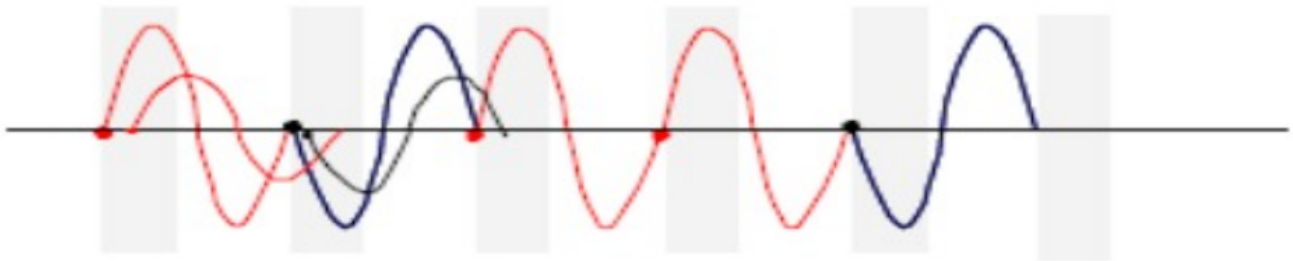


Fig.2.13. (Composite interference) The PSK symbol and its delayed version.

To mitigate this noise at the front of the symbol, we will move our symbol further away from the region of delay spread as shown below. A little bit of blank space has been added between symbols to catch the delay spread.

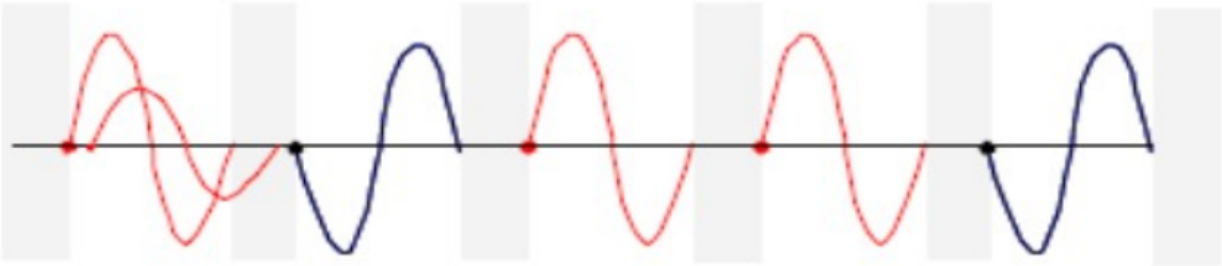


Fig.2.14 Move the symbol back so the arriving delayed signal peters out in the gray region.No interference to the next symbol.

But we can not have blank spaces in signals. This is won't work for the hardware which likes to crank out signals continuously. So it's clear it need to have something there. So, just let the symbol run longer as a first choice.

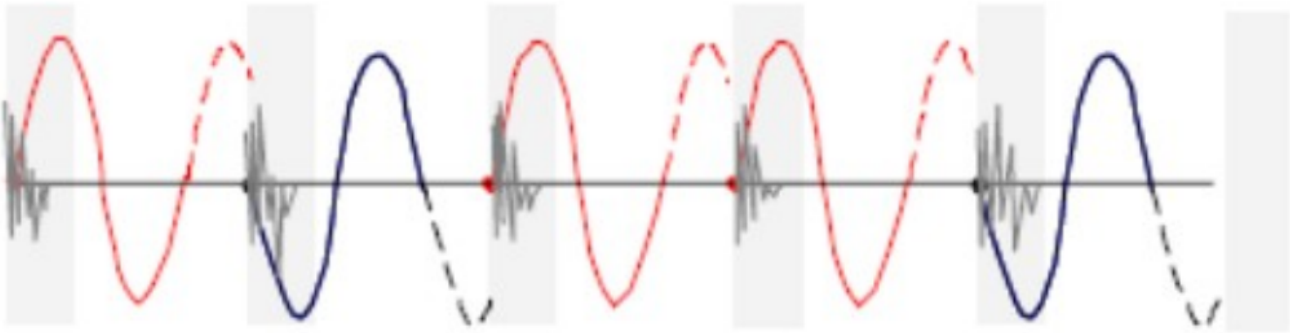


Fig.2.15 If we just extend the symbol, then the front of the symbol which is important to us since it allows figuring out what the phase of this symbol is now corrupted by the "splash".

We extend the symbol into the empty space, so the actual symbol is more than one cycle. But now the start of the symbol is still in the danger zone, and this start is the most important thing about our symbol since the slicer needs it in order to make a decision about the bit. We do not want the start of the symbol to fall in this region, so lets just slide the symbol backwards, so that the start of the original symbol lands at the outside of this zone. And then fill this area with something.

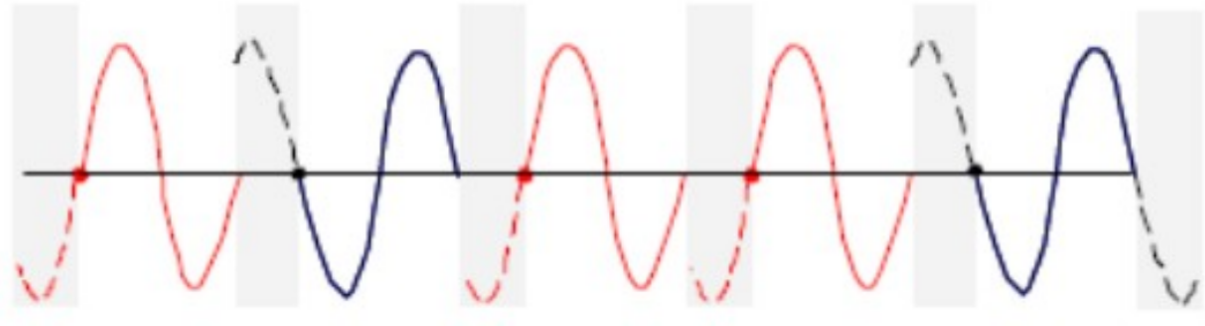


Fig:2.16 If we move the symbol back and just put in convenient filler in this area, then not only we have a continuous signal but one that can get corrupted and we don't care since we will just cut it out anyway before demodulating.

1. We want the start of the symbol to be out of the delay spread zone so it is not corrupted.
2. We start the signal at the new boundary such that the actual symbol edge falls out side this zone.

So, Slide the symbol to start at the edge of the delay spread time and then fill the guard space with a copy of what turns out to be tail end of the symbol. We will be extending the symbol so it is 1.25 times as long, to do this, copy the back of the symbol and glue it in the front. In reality, the symbol source is continuous, so all we are doing is adjusting the starting phase and making the symbol period longer.

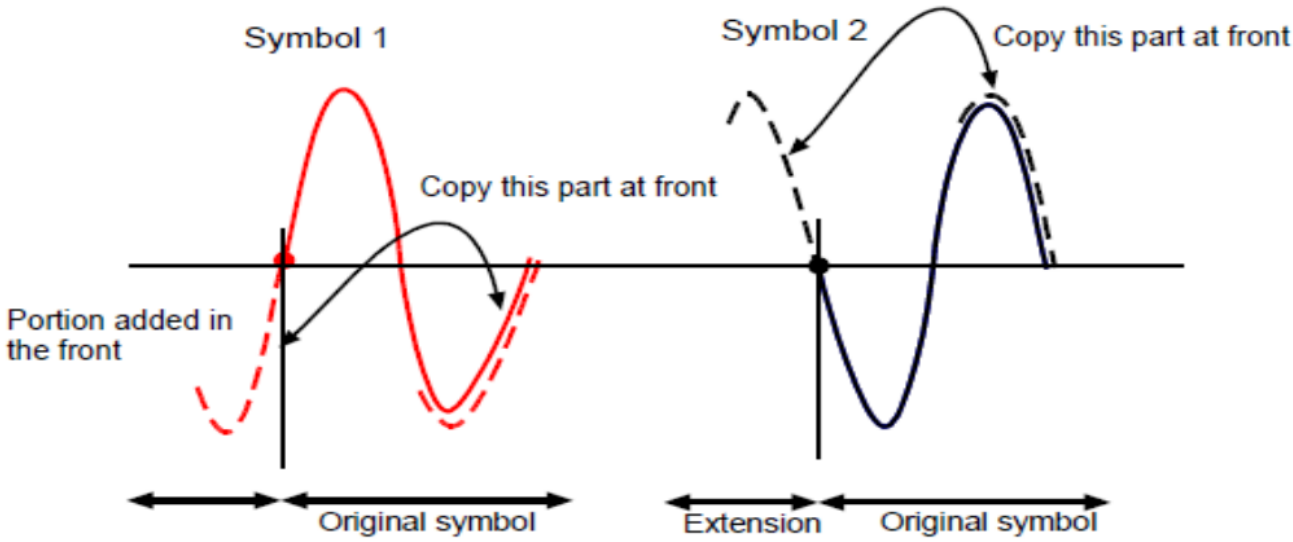


Fig:2.17 Cyclic prefix is copy of back of the symbol we add to the front of the symbol.

This procedure is called adding a cyclic prefix. Since OFDM, has a lot of carriers, we would do this to each and every carrier. But that's only in theory.

Since the OFDM signal is a linear combination, the whole process can be done only once to the OFDM signal, rather than doing it to each and every subcarrier. We can add cyclic prefix just once to the composite OFDM signal.

The prefix is any where from 10% to 25% of the symbol time. We add the prefix after doing the IFFT just once to the composite signal. After the signal has arrived at the receiver, first remove this prefix, to get back the perfectly periodic signal so it can be FFT'd to get back the symbols on each carrier. However, the addition of cyclic prefix which mitigates the effects of link fading and inter symbol interference, increases the bandwidth.

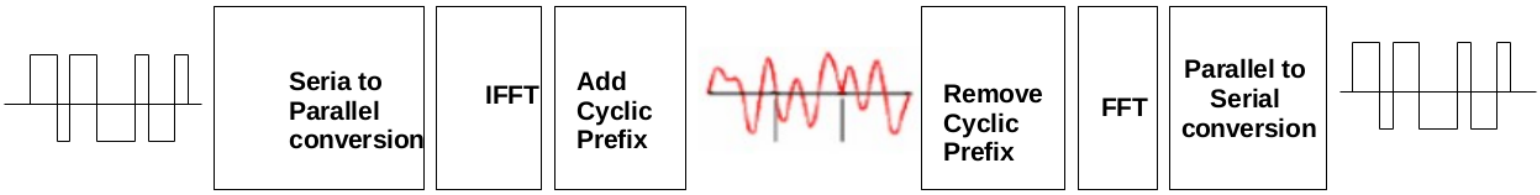


Fig: 2.18 Addition of Cyclic prefix to the OFDM signal further improves its ability to deal with fading and interference.

Here is an OFDM signal with period equal to 32 samples. We want to add a 25% cyclic shift to this signal.
1. First we cut pieces that are 32 samples long.
2. Then we take the last .25 (32) = 8 samples, copy and append them to the front as shown.

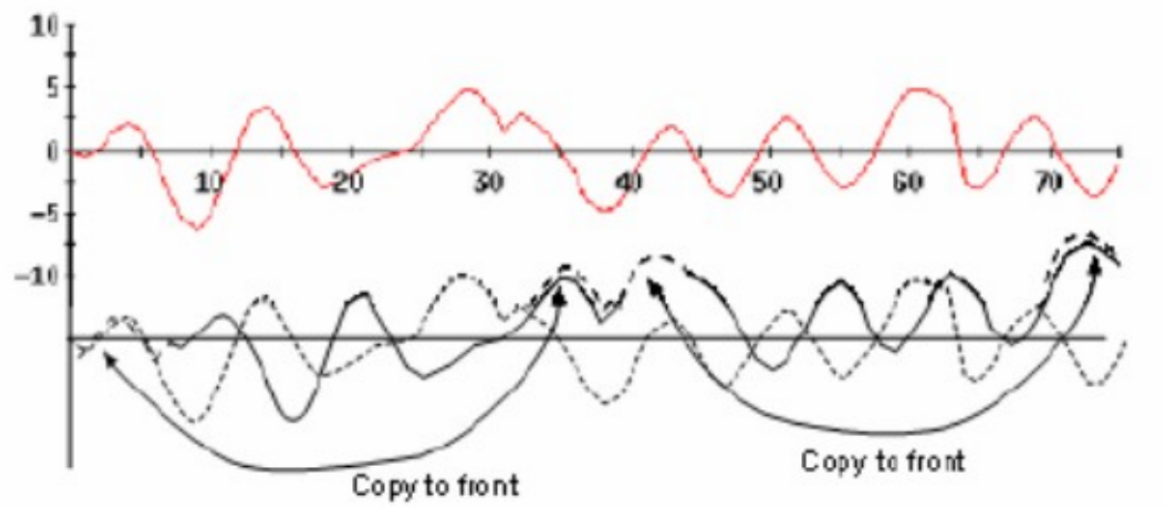


Fig:2.19 The whole process can be done only once to the OFDM signal, rather than doing it to each and every sub-carrier.

CHAPTER-3

DIGITAL MODULATION TECHNIQUES

3.1 INTRODUCTION:

Modulation is the process of facilitating the transfer of information over a medium. Sound transmission in air has limited range for the amount of power your lungs can generate. To extend the range your voice can reach, we need to transmit it through a medium other than air, such as a phone line or radio.

The process of converting information (voice in this case) so that it can be successfully sent through a medium (wire or radio waves) is called modulation.

There are three basic types of digital modulation techniques. These are
1. Amplitude-Shift Keying (ASK)
2. Frequency-Shift Keying (FSK)
3. Phase-Shift Keying (PSK)
4.On-Off Keying
5.PPM,PWM.

All of these techniques vary as a parameter of a sinusoid to represent the information , which we wish to send. A general carrier wave may be written:

$$C(t) = A \sin (2*\pi*ft+\varphi)$$

A sinusoid has three different parameters than can be varied. Those are its amplitude, phase and frequency. Modulation is a process of mapping such that it takes your voice (as an example of a signal) converts it into some aspect of a sine wave and then transmits the sine wave, leaving the actual voice behind. The sine wave on the other side is remapped back to a near copy of your sound.

The medium is the thing through which the sine wave travels. So wire is a medium and so are air, water and space. The sine wave is called the carrier. The information to be sent, which can be voice or data is called the information signal. Once the carrier is mapped with the information to be sent, it is no longer a sine wave and we call it the signal.

3.1.1 ASK:

In ASK, the amplitude of the carrier is changed in response to information and all else is kept fixed. In Binary ASK Bit 1 is transmitted by a carrier of one particular amplitude. To transmit 0, we change the amplitude keeping the frequency constant. On-Off Keying (OOK) is a special form of ASK.

3.1.2 FSK :

In FSK, we change the frequency in response to information, In Binary FSK one particular frequency for a 1 and another frequency for a 0 is used as shown in fig 3.3 for the same bit sequence as above. In the example below, frequency f1 for bit 1 is higher than f2 used for the 0 bit.

Binary FSK(t) = $\sin(2\ \pi\ f\ 1\ t)$ for bit 1
Binary FSK(t) = $\sin(2\ \pi\ f\ 2\ t)$ for bit 0

3.1.3 PSK:

In PSK, we change the phase of the sinusoidal carrier to indicate information. Phase in this context is the starting angle at which the sinusoid starts. The transmitted signal is a sinusoid of fixed amplitude. Phase shift keying is a modulation process where by the input signal, a binary PCM waveform, shifts the output waveform to one of a fixed number of states. For Binary PSK It has one fixed phase usually 0° when the data is 1. To transmit 0, we shift the phase of the sinusoid by 180°.

Phase shift represents the change in the state of the information in this case. ASK techniques are most susceptible to the effects of non-linear devices which compress and distort signal amplitude. To avoid such distortion, the system must be operated in the linear range, away from the point of maximum power where most of the non-linear behavior occurs. The use of phase shift keying produces a constant amplitude signal and was chosen for its simplicity and to reduce problems with amplitude fluctuations due to fading.

Binary PSK(t) = $\sin(2*\pi*ft)$ for bit 1
Binary PSK(t) = $\sin(2*\pi*ft+\pi)$ for bit 0

3.1.4 On-Off Keying (OOK) :

In OOK, the data bits 1 and 0 are represented by LED on- off respectively. In off state, the intensity of light decreased not completely turned off. The main feature of OOK is its simplicity and easy implemen tation. It is mostly adopted by the wireline communication. In early work, the majority of the researchers have used OOK modulation for VLC using white LED.

It produces the blue emitter with a yellow phosphor. The significant limitation of white LED is its restricted transfer speed (few megahertz) because of the slow response time of yellow phosphor. It is proposed by to utilize NRZ (Non-Return-to-Zero) OOK with the white LED and VLC link was demonstrated with the data rate of 10 Mbps. The blue filter is used to remove the slow response rate of the yellow component resulting in a data rate of 40 Mbps.

Proposed to consolidate the blue filtering with simple equalization at receiver to confine and achieve data rates of 100 Mbps and 125Mbps respectively. The performance can be enhanced through suitable photodiode selection.
The authors in demonstrated that the avalanche photodiode works well rather than the P-I-N photodiode at the receiver side.

Through avalanche photodiode, the data rate was achieved up to 230 Mbps.The white light is produced by the combination of RGB frequencies. The main factor of the white LEDs is that they have not the slow response time. RGB white LEDs needs three separate driving circuits to escape the white light. In this paper a distinctive approach is used and it has been observed that the RGB white LED was utilized but only the red LED is modulated by the data transmission while remaining provide illumination.

The authors have used P-I-N photodiode and achieved a data rate of 477 Mbps but could not provide the range of distance. The two methods were proposed in IEEE Standards in [5] as IEEE 802.15.7 which offers dimming support OOK is used as a modulation scheme.

1) Redefine ON and OFF levels:

To accomplish the desired level of dimming, the different levels of light intensity are allocated to the ON and OFF levels. The benefit of this technique is that desired level of dimming can be acquired without adding an overhead bit. It retains the data rate which is same as NRZ-OOK modulation, similarly, the communication range reduces at low dimming levels. The noticeable drawback is utilizing lower intensities of light for ON/OFF makes the LEDs be worked at low power driving circuits which is, in turn, has shown to acquire changes in rendering (radiated shade of LED changes) .

2) Compensation periods:

The solution of the problem is the additional compensation periods are added with the same ON and OFF level of modulation when the LED fully turned on is known as ON periods or off (OFF periods). The term duration of compensation periods is determined

based on the desired level of dimming. In particular, if the required dimming level should be more than 50% the ON periods are added otherwise the OFF periods are added. In [6] authors have presented a
calculating method of dimming level based on the percentage time of active data transmission within the (γ) transmission interval T to obtain a dimming level of D as

$$\gamma = \begin{cases} (2-2D)\times 100 & : D > 0.5 \\ 2D\times 100 & : D \le 0.5 \end{cases}$$

When the desired dimming level is D with OOK, the maximum communication efficiency E D can be calculated using information theoretic entropy as

$$ED = -D \log_2 D - (1 - D) \log_2 (1 - D)$$

It implies that communication system efficiency is a triangular function of the dimming level with maximum proficiency at dimming level of 50%. The efficiency drops linearly when the dimming level decrease in between 0% to 100%. The data rate is reduced due to compensation periods used in dimming.

The ON/OFF modulations have unchanged intensity property and also the range of communication is unchanged using inverse source coding to preserve high data rate while achieving the desired level of dimming.

Pulse Modulation Methods:

Pulse Modulation Methods: OOK offers different features such as simple and feasible implementation; the main restriction is its lower data rates particularly when maintaining various dimming levels. It is the motivation for design alternative modulation schemes based on pulse width and position which are expressed as follows:

3.1.5 Pulse Width Modulation (PWM):

A proficient method of accomplishing modulation and dimming through the use of PWM. In this scheme, the width of pulses is balanced based on the required dimming level while the pulses themselves take modulation signal in the form of a digital pulse.

The data is transmitting when the brightness of the LED light is full. Based on dimming requirement data rate can be accommodated and adjusted. authors observed that the higher data rates can be achieved through any dimming level 0% to 100% with the modulation technique of PWM frequency.

One of the most important advantages of PWM is that it achieves the dimming without changing light intensity. therefore it does not require any color shift like redefine on and off levels in the LED. PWM has a limited data rates up to 4.8kbps . To cater this restriction, it is intended to consolidate PWM with Discrete multitone for jointing dimming control and communication. On transmitter-side communication based on DMT disjointed with dimming based on PWM. The Quadrature Amplitude Modulation (QAM) is bit-streamed and mapped to symbols as shown in Fig.

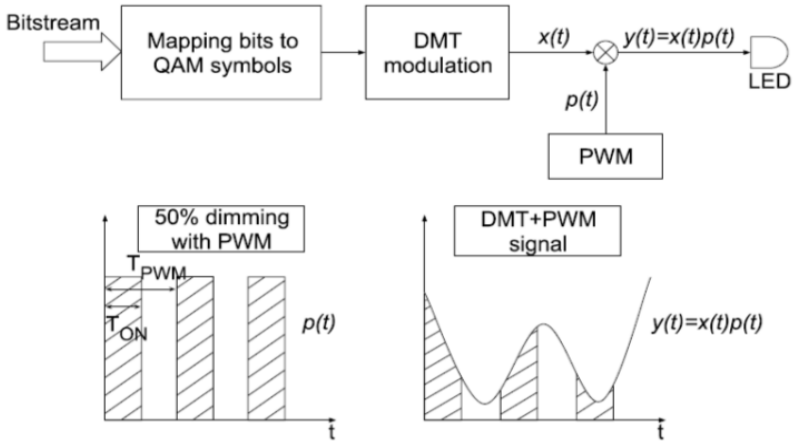


Fig 3.1 :Transmitter block diagram of DMT transmitter with dimming control (top). An example of how 50% PWM-controlled dimming signal can be combined with a DMT signal.

3.1.6 Pulse Position Modulation (PPM):

In visible light communication another modulation depends upon the pulse position. The symbol duration is segmented into t time slots of equal duration in PPM technique. In one time slot, the pulse is transmitted. The transmitted pulse is recognized through the position of the pulse due to its simplicity and numerous early designs, of optical wireless communication adopt the PPM as a modulation.

PPM is used for infrared communication in earlier work, in this work has recommended the use of rate adaptive transmission schemes where redundancy coding is used to elegantly reduce data throughput in presence of poor channel condition. Researchers have proposed in a rate variable penetrated convolution coded PPM applied in infrared communication systems and it adopts modulation order with the channel conditions through Convolution codes.

For higher data rates both rate adaptive techniques were used. One is the repeated and another one is punctured convolution coded PPM. Because of the restrictions of lower spectral efficiency and data rate of PPM (only one pulse per symbol duration), a different variation of pulse position based modulation has been suggested over time.

The overlap PPM (OPPM) which enables the more symbols duration transmitted through one pulse and the different symbols can be seen in Fig 3.2. Demonstrated that OPPM not only acquired higher spectral efficiency but also a wide range of dimming levels can be achieved along with higher data rates. The other type of PPM was proposed by, which is known as Multi-pulse PPM (MPPM). OPPM, it enables numerous pulses to be transmitted amid the single symbol duration, however, the pulses within symbol duration do not need to be consistent as shown in Fig. 3.2. It has been observed and shown in that MPPM can acquire a higher spectral efficiency contrasted to OPPM.

Authors have suggested with introducing variation in PPM through a combination of OPPM and MPPM schemes is known as Overlapping MPPM (OMPPM). In this technique, more than one pulse position represents a single optical signal. It was observed that the OMPPM can improve the spectral efficiency of MPPM without the extension of data transfer capacity in noiseless photon tallying channel.

In presence of background noise, the effectiveness in terms of direct detection addressed in Trellis-coded OMPPM including other modulation schemes for VLC is differential PPM (DPPM) was proposed which is similar to PPM but the OFF symbol was removed and next symbol starts right after the pulse of the previous symbol. The DPPM requires low power than PPM for given bandwidth in the optical communication channel.

Differential overlapping PPM (DOPPM), where differential cancellation of OFF symbols is used to OPPM and presents that it accomplish better spectral and cutoff performance than PPM, DPPM, and OPPM.EPPM (Expurgated PPM) where the symbol of MPPM are purged to maximize the inter- symbol distance. The number of pulses per symbol and length of symbols is changed to support dimming support through EPPM rather than PPM.

The flickering can be mitigated by EPPM as with the PPM modulation technique. Multi level EPPM (MEPPM) broadens the EPPM design with support to multiple amplitude levels in order to increase the constellation size and spectral efficiency. IEEE 802.15.7 standard proposed a pulse modulation scheme call it a variable PPM (VPPM) which is the consolidation of PPM and PWM. In this, different position of pulses is encoding with bits.

The width depends on the requirement. VPPM holds that simplicity and heftiness of PPM while permitting distinctive dimming levels by change the pulse width.

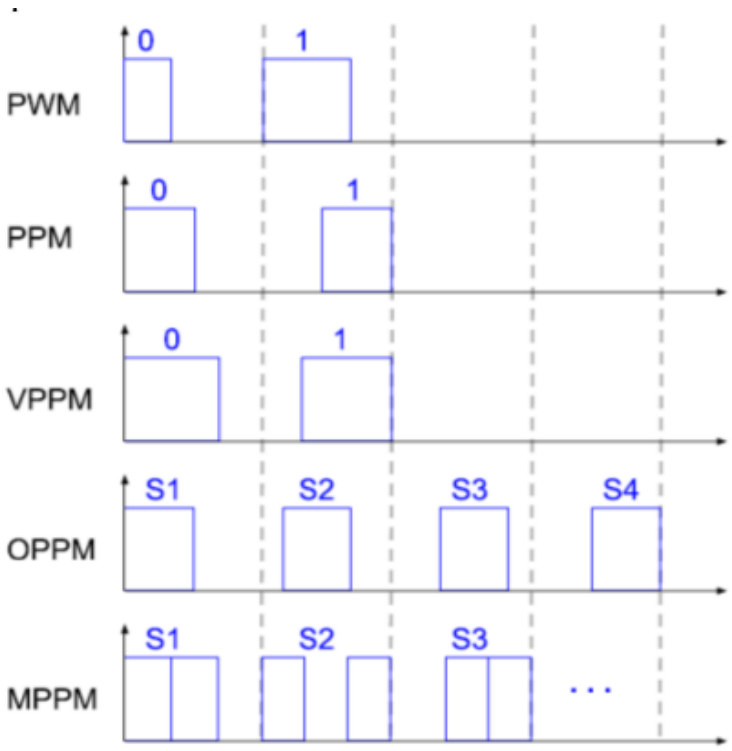


Fig 3.2 : Schematic diagram showing the difference between Pulse Width Modulation (PWM), Pulse Position Modulation (PPM), Variable Pulse Position Modulation (VPPM), Overlapping Pulse Position Modulation (VPPM) and Multi-pulse Pulse Position Modulation (MPPM); Sn refers to the nth symbol.

CHAPTER-4

DESIGN OF PLC-VLC

4.1 Block Diagram:

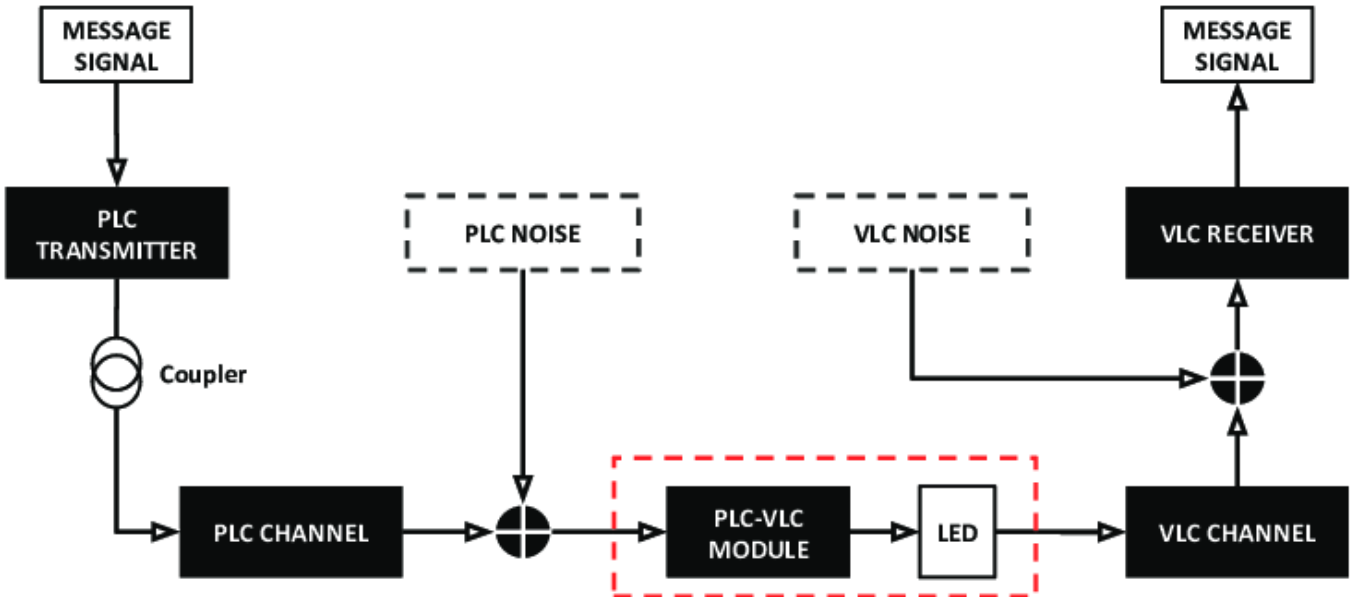


Fig 4.1: Block diagram of PLC-VLC System.

4.1.1. Block by Block Description:

Message signal:

It is the data that which we desire to transmit through the channel.generally the data is encoded and converted in the form of 1s and 0s.any how we cannot transmit the data directly as 1s and 0s,a kind of unique signal is generated for each bit and transmitted as a signal with particular amplitude.

PLC Transmitter:

It mainly consists of modulator and the ofdm block.the data generated is given to the block of mosulator where a carrier is added as a support for the message to travel to the longer distances,where we can use either of the method among ask,psk,fsk.after modulating the data,that modulated data bits are converted from serial to parallel,the parallel data bits are given to the block of ofdm modulator (ifft).

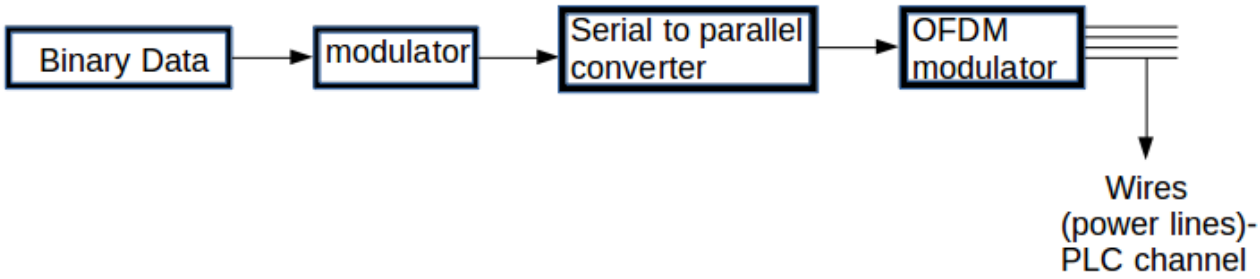


Fig4.2 : PLC Transmitter Block diagram

PLC Coupler:

The effectiveness of coupling between the power line and PLC transceivers has become a very important issue. Coupling devices used to inject or extract data communication signals into or from power lines are very important components of a PLC system.

In the case of power lines used to transmit AC power, the coupling circuit has also to filter out the AC mains signal. On the other hand, the coupling circuit simply has to block the DC mains voltage of the DC electric power grids.

The design of a PLC coupler considering impedance matching, flat frequency response to minimize distortions, efficient electrical protection against transients and low cost have been the major challenges in recent years. To carry out such design, several issues must be addressed in order to come up with a PLC coupler which may be useful for the target application.

In general, PLC couplers can be grouped according to different criteria. In this sense, this work outlines a classification based on the type of physical couplings, voltage levels,frequency bandwidths, propagation modes and numbers of connections.

PLC Channel:

As far as PLC channel is concerned, Zimmermann and Dostert modelled the low voltage distribution grid and classify it as four different channel types classified based on the length of cable and the number of branches connected to the main cable. Most of the works available on utilization of PLC-VLC channel have referred to this model of PLC channel that is mathematically descried as,

$$H(f) = \sum_{i=1}^{N} \{|g(f)|^{\phi_{g_i(f)}}\}\{e^{-\left(a_0+a_1 f^k\right)d_i}\}\{e^{-j2\pi f\tau_i}\}$$

where the first term is the frequency dependent weighting factor *gi(f)* for the *ith* path representing the reflection and transmission factors, the second term shows the attenuation factors *a0,a1* for the path length *di,* while the last and third term expresses the *i* multipaths with corresponding *Ti* delays.

PLC NOISE:

Power line channel presents a harsh environment for data transmission owing to the challenges of impulsive noise, high attenuation, selective fading and etc. Impulsive noise poses a severe challenge as its Power Spectral Density (PSD) is between 10–15dB above background noise. For good performance of the PLC system, this noise must be mitigated.

The mitigation of impulsive noise in PLC which is classified into four categories, namely time domain, time/frequency domain, error correction code and other techniques. Time domain technique is a memoryless nonlinear technique where the signal's amplitude only changes according to a specified threshold without changing the phase. Mitigation of impulsive noise is carried out on the received time domain signal before the demodulation FFT operation of the OFDM.

Time/Frequency technique is a method of mitigating impulsive noise on the received signal at both before FFT demodulation and after FFT demodulation of the OFDM system. Error correction code technique is the application of forward error correction code by adding redundancy bits to the useful data bits for detection and possibly correction of error occurring during transmission.

Identifying the best performing technique will enhance the deployment of the technique while exploring the PLC channel capacity enhancement in the future. The best performing scheme in each of the category were selected and their BER vs SNR curves were compared with respect to the impulsive noise + awgn curve. Amongst all of these techniques, the error correction code technique had a performance that presents almost an outright elimination of impulsive noise in power line channel.

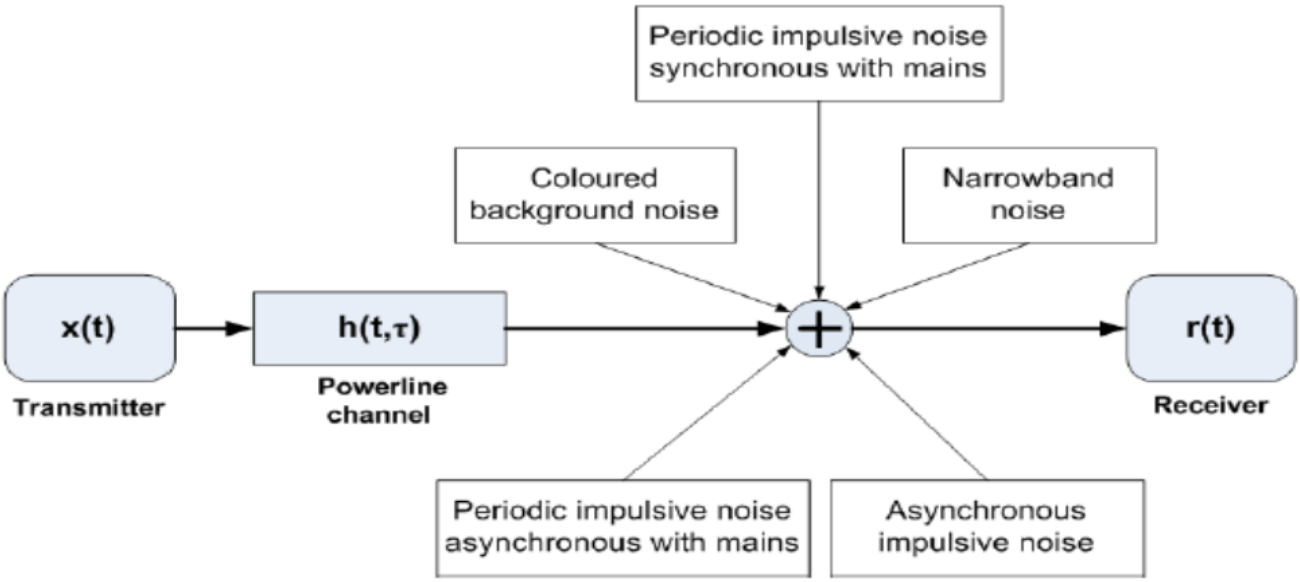


Fig.4.3 Power line channel noise scenario

PLC-VLC MODULE:

It consists of demodulator and ofdm demodulator.the modulated data first converted from parallel to serial,then it is passed through the block which removes the cyclic prefix in case if it is added at the time of modulation.then the data is applied to the block of ofdm demodulation and finally gets demodulated with the corresponding demodulation scheme.this binary data is applied to the series of LEDs as input,correspondingly the LEDs switches ON and OFF.through Llight amplitude variation data is transmitted via free space.

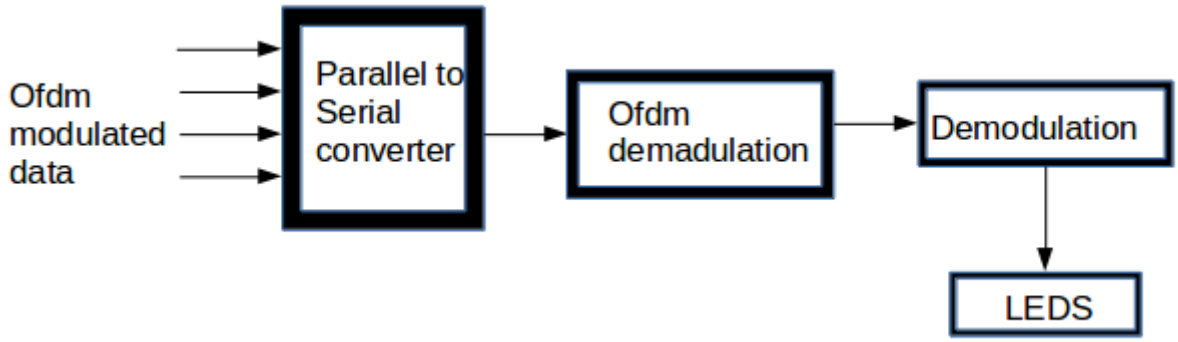


Fig.4.4. PLC-VLC block diagram

VLC CHANNEL:

The VLC channel is considered to be composed of a LOS and a Diffused Non-Line of Sight (NLOS) component. Due to the standardized illumination of 400 lux, the LOS component of the VLC channel presents high Signal-to-Noise Ratio (SNR) channel conditions, while the diffused NLOS component suffers from multipath propagation and attenuation, thus provides lower SNR channel conditions.Mathematically, the VLC channel takes the form

$$H_{VLC}(f) = \sum_{i=1}^{N} \eta_{LOS_i} e^{j2\pi f \Delta\tau_{LOS_i}} + \frac{\eta_{DIFF}}{1 + jf/f_0} e^{-j2\pi f \Delta\tau_{DIFF}}$$

where η LOS i and η DIF F are the channel gains due to LOS and diffused NLOS components of VLC channel. Δτ LOSi and Δτ DIF F represent the corresponding components signal delays and f 0 is the 3 − dB cut off frequency. The NLOS and LOS components can be defined as,

$$\eta_{LOS} = \frac{A_R\,(r+1)\cos^r\varphi\cos\theta}{2\pi d^2},$$

$$\eta_{DIFF} = \frac{A_R\rho}{A_{Room}\,(1-\rho)},$$

where AR and ARoom are effective receiver area and room area respectively, ρ is the average reflectivity from the walls, d is the distance between LED lamp and the receiver and φ and θ denote angle of irradiance and incidence respectively. Where

$$r = \frac{-1}{\log_2 \theta/2}$$

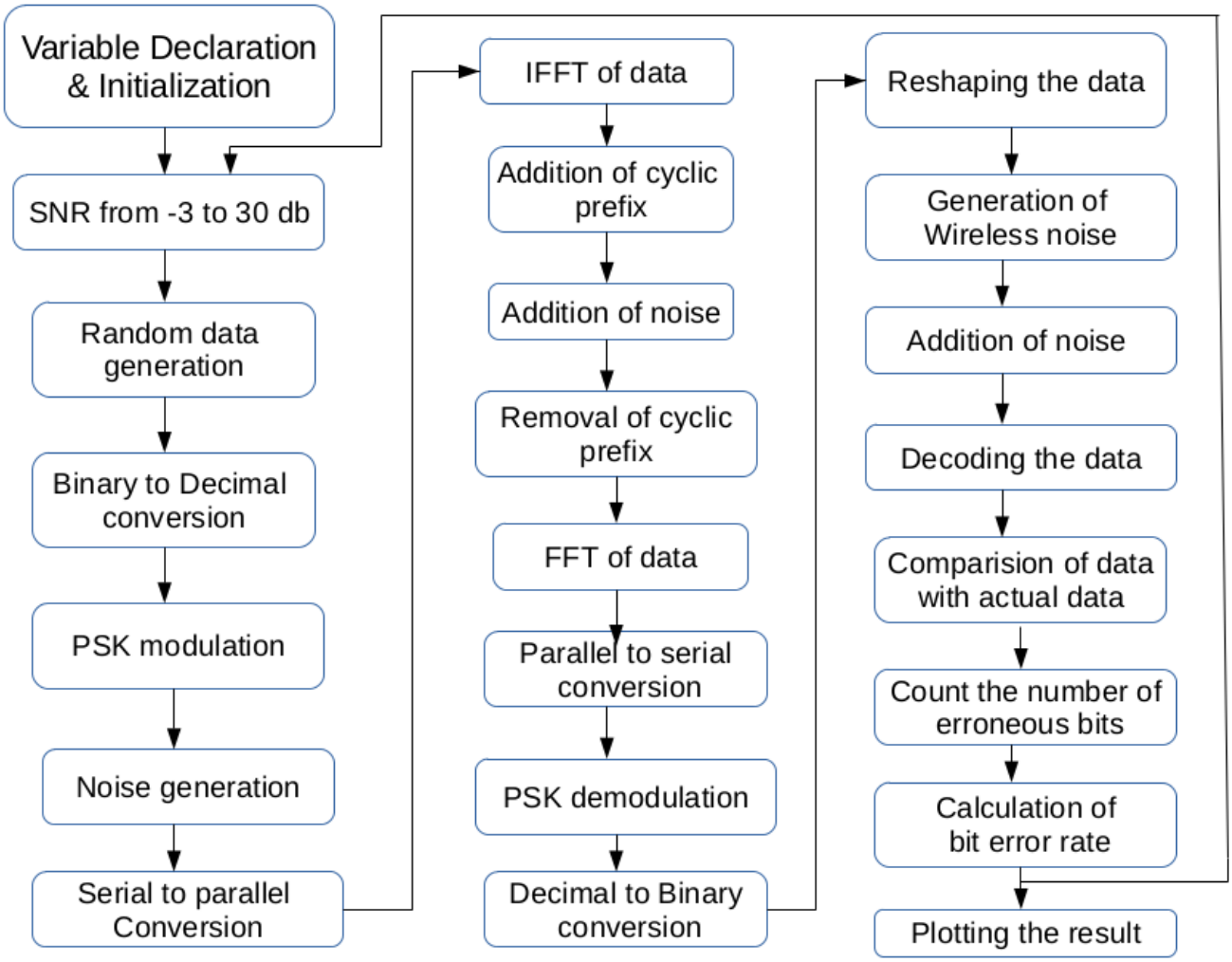
is the Lambert index that depends on half intensity beam angle θ/2.

VLC RECEIVER:

Series of photo diodes are used as reciver .these photo diodes converts the light into electrical signal.A photodiode is a semi-conductor device that converts light into an electrical current.the current is generated when photons are absorbed in the photodiode. Photodiodes may contain optical-fibers,built-in lenses,and may have large or small surface areas.

Photodiodes usually have a slower response time as their surface area increases.the common,traditional solar cell used to generate electric solar power is a large area photodiode.

FLOW CHART :

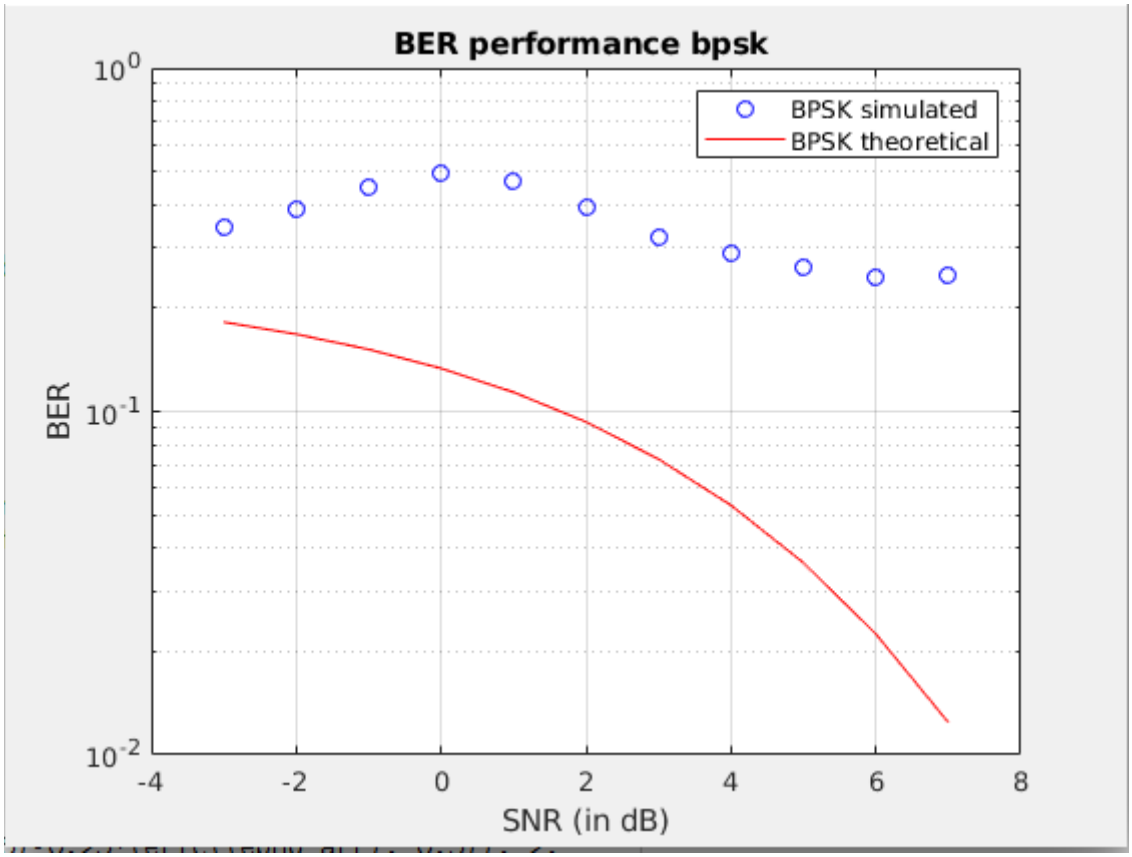


ALGORITHM :

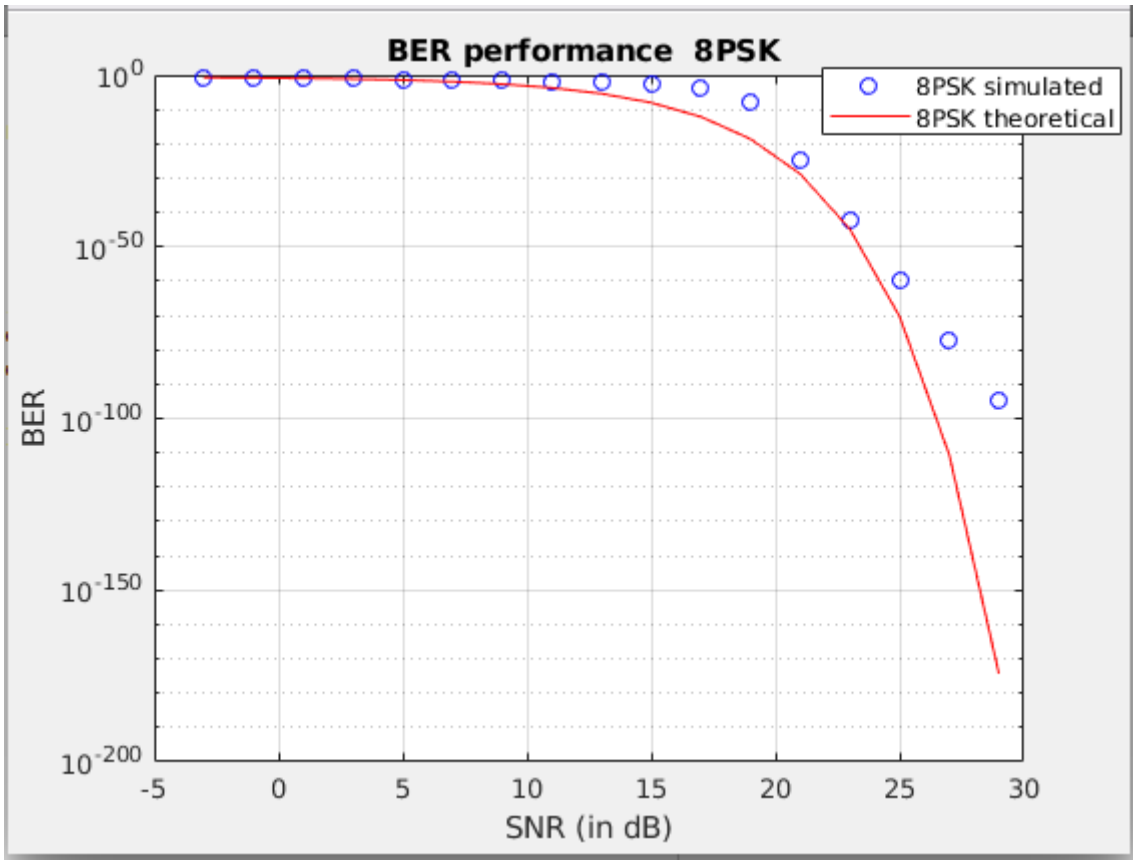
01. Declare and initialize the variables. SNR from -3 to 30.
02. Generate random data. Modulate the data using PSK modulation.
03. Generate wired channel noise.
04. Apply IFFT for the data. Add noise to it. Apply FFT for this data.
05. Demodulate the using PSK Demodulation.
06. Reshape the data (convert the bits in to serial).
07. Generate wireless channel noise.
08. Add this noise to the bits and send through wireless channel.
09. Decode the data and compre this data with initially generated data.
10. Count the number of error bits and calculate bit error rate (BER).
11. Plot the result as SNR vs BER.
12. Go to step 2 and do it for all the vales os SNR.

4.2 Simulation results :

Modulation scheme : BPSK



Modulation scheme : 8psk



CHAPTER-5

APPLICATIONS

1.HEALTHCARE

Electromagnetic Radiations (EMR) of WiFi are not suitable for sensitive environments such as hospitals and primary schools, where these can seriously affect the patients and children's health. These radiations can also effect the functionality of medical equipments, e.g., MRI, CT scanner in the hospitals. Increasing the number of Service Access Points in this type of environment will further increase the Electromag-netic Interference (EMI).

In May 2011, the World Health Organization (WHO) formally stated that EMR (Electromagnetic radiation) associated with RF wireless devices increases the risk of brain cancer (WHO press release No.208, May, 2011).

The challenge in this is to introduce cost effective solutions harmonized with existing regulations that attract users and technology suppliers. In these environments, a radiation free PLC-VLC communication system using LED lighting offers a new technology that can provide a safer and high speed communication. PLC system can use the ubiquitous power line network to power the LED lights while serving as the backbone network for the indoor VLC systems naturally.

2.UNDERGROUND MINING COMMUNICATIONS :

With the rapid advancement in data and voice communication in last two decades, various possible technologies such as Bluetooth, WiFi, ZigBee, IrDA etc. have been introduced for communication of alarm signals between miners working underground and workstation on ground and also to send the location of miners to control room. Each of these tech-
nologies has some challenges and limitations. WiFi signal is effected by electromagnetic field and requires a high power signal transmitter. Infrared (IrDA) transmission is dangerous for miner's skin and eyes. Bluetooth and ZigBee are suitable but still have signal path interference and fading issues. The two in one characteristics of VLC to transmit high speed data
and light from same LED bulb make this suitable to deploy PLC-VLC system for communications between miners and people working on ground in-spite of harsh underground environment. In the underground mining environment, the system mainly consists of LEDs and miner head lamps. When the miner is within the coverage area of LED lamp, he/she can communicate alarm signal and send location information to the people on ground station using that head lamp and LED fixture within mine.

3.CRITICAL INFRASTRUCTURE

In critical infrastructures installations (Defence, nuclear installations, power plants,etc.), EMI can severely effect the performance of the infrastructure and also due to high security requirements, WiFi networks are not recommended in such places. Due to secure confined coverage, PLC-VLC integrated system can be considered as a possible solution in such environments.

D. RELAY NETWORK

Relay networks are gaining importance these day to increase the range and data rate of communication networks if there is no direct link possible between source and destination.

A VLCPLC system can be considered as a relay-assisted communication for such co-operative network environments . Application of such environment can be visualized in train communications where signal is relayed from carriage to carriage using PLC-VLC network.

E. AIRCRAFT CABINS

Radio frequency is not suitable for communication within aircraft cabins. LEDs are safer and faster data transmission sources for in-flight entertainment. PLC-VLC system provides a secure, safer and EMI free data transmission than traditional WiFi technology and it is appropriate for in-flight entertainment.

CHAPTER-6
CONCLUSION

6.1 Summary:

In this paper, we have provided a detailed analysis on hybrid PLC-VLC 5G communication system based on two leading communication technologies namely VLC and PLC. It has been demonstrated how their integration can alleviate the flux on existing data communication technology such as WiFi. Not only has their integration been discussed and analyzed but their readily applications have also been delineated. It has been proposed that PLC-VLC system can be used for smart health, smart building, critical infrastructure system, and aircraft infotainment system.

6.2 Future Scope:

In the present paper we have proposed the communication Technology with FFT based OFDM,there is a scope for us to improve the snr vs ber curves by replacing the FFT-OFDM with DWT-OFDM. Where DWT stands for Discrete Wavelet Transform.and it might prove that the DWT-OFDM outperforms an OFDM based PLC-VLC system.

Discrete Wavelet Transform (DWT) can be implemented through a dyadic filter bank structure, that serve to decompose a signal into its constituent high and low frequency bands using analysis filter banks and can facilitate perfect reconstruction of the signal employing synthesis filter banks.

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