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**Power Line Communication Channel Modelling: Investigation of Multipath  
PLC Channel Model for Households**

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**A thesis submitted in partial fulfillment for the degree of Bachelor of Science in the  
Department of Electrical and Electronics Engineering, BRAC University**

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## DECLARATION

We, hereby, declare that the thesis titled “POWER LINE COMMUNICATION CHANNEL MODELLING : INVESTIGATION OF MULTIPATH PLC CHANNEL MODEL IN HOUSEHOLDS” is submitted to the Department of Electrical and Electronics Engineering of BRAC University in partial fulfilment of the Bachelor of the Bachelor of Science degree. This is our original and was not submitted elsewhere for the award of any other degree or any other publication.

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## **Abstract**

Power line communication () has as of late increased across the board enthusiasm, from both industry and mainstream researchers, as a suitable option innovation for broadband interchanges particularly in the time of building up Smart framework systems. With a specific end goal to create PLC frameworks for Internet, voice, and data services requires estimation based models of the exchange qualities of the mains arrange appropriate for execution examination by recreation. This thesis aims at establishing an analytic model describing complex transfer functions of typical power line networks using a set of parameters playing vital role in the power line channel. The channel model will be based on physical signal propagation effects in mains networks including numerous branches. Besides multipath propagation accompanied by frequency- selective fading, signal attenuation of typical power cables increasing with length and frequency will be considered. The verification of the performance of the proposed model incorporates carrying out experimental investigations into the electrical influence factors of network components on PLC operation & presentation of the results in a suitable graphical and written form.

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## Abbreviation

PLC	Power Line Communication
PSK	Phase Shift Keying
CPFSK	Continuous Phase Frequency Shift Keying
16-QAM	16- Quadrature amplitude modulation
OFDM	Orthogonal frequency-division multiplexing
BER	Bit Error Rate
SNR	Signal to Noise Ratio
MV	Medium Voltage
LV	Low Voltage
HV	High Voltage
BPL	Broadband Power Line
WAN	Wireless Area Network
WLAN	Wireless Local Area Network
IFFT	Inverse Fast Fourier Transform
FFT	Fast Fourier Transform
MIMO	Multiple Input Multiple Output
CP	Cyclic Prefix



# Chapter 1

## Introduction

### 1.1 Background of power line communication

The concept of communication in terms of a power line network starts back in 1920s. The energy providers introduce this idea, to establish communication between their plants. The main target is to use the existing networks for communication such as narrow band tele-remote relay applications, public lighting and home automation rather than to establish a new one. The beginning of research on use of electrical power lines to support data transmission between the 5 – 500 KHz bands in mid 1980s. The first bidirectional data transmission over the power line network is tested and companies like Ascom (Switzerland) and Norweb (UK) begins their researches on this field in 1997. The first tests are carried out by France and North America. It is observed that PLC systems have some limitations on data transmission [13].

For maintaining the function of HV transmission systems, it is necessary to develop the communication over PLC channel. Companies for tasks such as monitoring, operations management, and fault finding required to create a new fast bidirectional flow of information between power plants, switching gears, transformer stations and coupling points. The requirement of all communications points due to the unavailability of telephone lines and also unreliability of the telephone lines (often caused serious interruptions during necessary communications), it is necessary to use the HV lines to fulfil the communication tasks. [20] [22]. General structure of a PLC system for energy related services channel models are useful for design and modelling of communication systems. There are several power line channels are available for PLC systems as the Philipps model, Zimmermann, Dostert model and the Anatory model[5].

The data transmission through power line system facing number of challenges. Power line topology i.e geometry and transmission voltage levels vary from region to region and country to country. For example in Tanzania the MV, LV and Indoor-Voltage (IV) systems have a potential to supply a broadband services through power line network to end users whereas in UK the potential of these has not been confirmed yet. The Committee International Special des Perturbations Radio electriques (CISPR) (the special international committee on radio interference) takes five years of study is unable to produce any conclusion which would guarantee reliable transmission of data through PLC [4] indicates that the maximum distance for a lossless data transmission through power grid is about 300 m. Later on it is found that researches are still necessary to better understand and improve the performance of power lines for higher bit rate transmission [21]. Some investigations are made regarding the variation in time/frequency responses due to the influence of load impedance, branches and line length. But

no one of them mention the exact contribution of each parameter to the stochastic behavior of channel responses. The test and simulation is done in Tanzania for a MV/LV line in which it is observed that as the line length increases there are rapid changes in the signal phase response. This would perhaps limit the available transmission bandwidth of the MV channel [8]. Later on in [11] the influence of load impedance, branch line length, and effect of number of branches and direct line length of transmitter to the receiver point on the performance of a LV power line network system is presented. Model based on the transmission line is determined in this work for PLC systems. The main focus for this research is to signal degradations caused by the time variant connections of electrical devices on the power line grids. It establishes the channel condition that changes when customers switch on/off their electrical devices to power line socket. It is helpful in suitable design for the BPL systems for reliable high-rate data transfer [11] [9].

For evaluating the performance of OFDM modulation for high data rate transmission over PLC channels. An investigation made in many research studies .It indicates that OFDM modulation is a better solution for transferring data over PLC system to evaluate better performance. The number of data transmitted with sub carriers within the usable spectrum thereby increasing the data rate transmission in a multipath environment in OFDM modulation. Besides, it is convenient to avoid any interference in terms of frequencies/sub carriers susceptible to interference can be turned off. Coding increases the performance in terms of Bit Error Rate in other communication system. Block code, convolutional code hamming code, turbo code can be repeatedly used to improve the PLC performance.

## **1.2. Power line distribution system**

A power plant produces the electric power, at that point transports it through High Voltage (HV) links to Medium Voltage (MV) substations. The substations change the Medium Voltage into Lower Voltage (LV) and after that disperses it to countless networks. Ordinary voltage esteems for HV, MV and LV transmission lines individually, are 425 KV, 33 KV and 11 KV. Each LV lattice contains one substation. This substation conveys the voltage, which is changed into 400V line voltage, to every one of the families that are associated through LV lines. PLC works through electrical signs. These 5 signals convey data over the electrical cable. A correspondence channel can be clarified as a physical way that exists between two imparting hubs. The sort of correspondence that happens through the electrical cable stations decides the nature of the channel. The channel quality is for the most part a factor of the level of the commotion at the beneficiary and the weakening of the electrical motion at various frequencies. It is harder to recognize the gotten flag when the clamor level is high because of conceivable interfered with signals. On the off chance that the signs get constricted on their approaches to the beneficiary, the nature of the channel disintegrates promote because of the way that the flag gets more covered up by the current commotion. The clamor on the electrical cable is created by each heap (electrical gadgets), which is connected to the framework. PLC frameworks involve distinctive

segments which work together to give web network administrations to shoppers in their homes, workplaces or structures. The information is conveyed by either fiber optic or phone lines to dodge HV transmission electrical cables. The information is infused onto the MV control circulation framework and uncommon electronic gadgets, known as repeaters, re-open up and re-transmit the flag in light of the fact that the flag loses quality as it goes along the MV control line. Different advancements are utilized to reroute the flag around transformers.

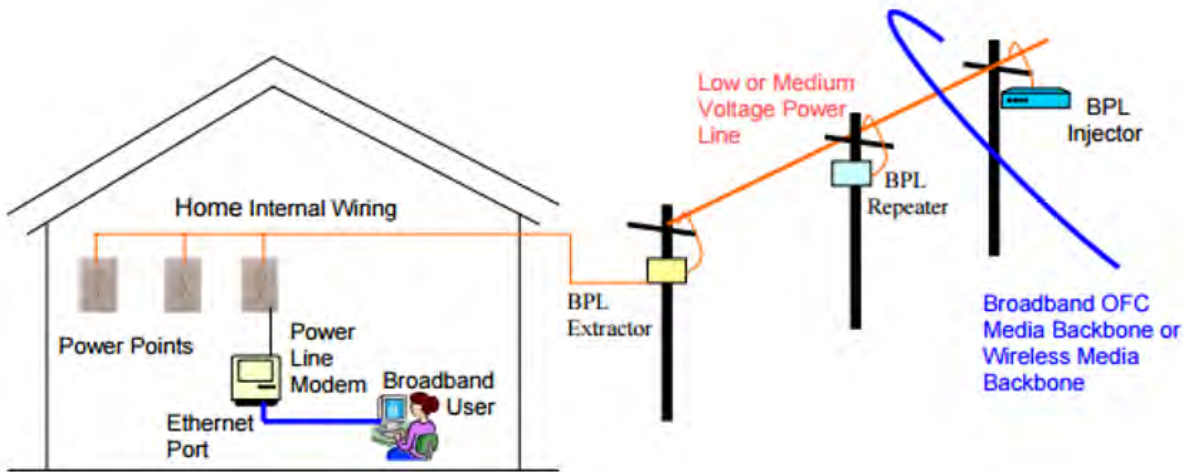


FIGURE: Overview of End-to-End Access PLC System [12]

An Access PLC framework utilizes either a blend of LV and MV electrical cables or LV electrical cables as it were. It likewise utilizes repeaters, injectors and extractors to convey network access to clients. For this situation the Broadband Power Line (BPL) (another name for PLC which is regularly utilized as a part of Europe) information is infused onto furthermore, conveyed by the MV control line. The BPL flag is then exchanged to the LV control line by means of couplers or through the LV transformer and conveyed specifically to the end-client. On account of LV just BPL frameworks, the BPL flag is infused onto the LV control line at the transformer or the utility meter [12].

### 1.3. Outline of Thesis

This proposal includes five chapters. The main section fills in as an introduction to the exploration ponder though the second part introduces a speedy writing review of the PLC and related subjects. The paper is sorted out as take after:

# Chapter 2

## Literature Review

A Literature study on PLC frameworks is made in section two. Initially electrical cables were not intended for fast information correspondence purposes, consequently the section starts by delineating the fundamental structures and physical properties of control line systems and a brisk foundation of interchanges over power lines. The utilization of OFDM tweak in PLC applications is likewise clarified. Applying diverse channel coding to upgrade the information transmission is likewise given. The part wraps up by introducing a portion of the regular security approaches for more dependable PLC innovation and in addition the plausibility of such a system. After doing the application of PLC we have discussed the home PLC networks.

# Chapter 3

## Power Line Of communication system model

This chapter is all about OFDM. Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequency. The essential preferred standpoint of OFDM over single-bearer plans is its capacity to adapt to extreme channel conditions (for instance, weakening of high frequencies in a long copper wire, narrowband obstruction and recurrence specific blurring due to multipath) without complex adjustment channels. Channel evening out is rearranged on the grounds that OFDM might be seen as utilizing many gradually regulated narrowband flags instead of one quickly tweaked wideband signal. In this chapter we've also used Zimmermann channel and the proposed model is CPFSK, because phase shift is continuous, that's why band with will be efficient.

# Chapter 4

## Result and Evaluation

Firstly we compared four path Zimmermann model (PVC) versus Teflon and air. We got different phases and magnitudes. Then we took CPFSK instead of 16 QAM and QPSK for better performance because of flat fading and continuous shifting with given values. For different insulating materials we came up with different curves of CPFSK.

In OFDM, there had been used 16 QAM modulation and the graph gave the BER vs SNR curve but we tried to use CPFSK modulation instead of 16 QAM modulation, but it did not give the desired BER vs SNR curves.

# Chapter 5

## Conclusion and further works

This part compresses the principle finishes of this paper and displays conceivable future heading. This exploration consider work is about electrical cable correspondence stations which has intrigued a few specialists and utilities amid the most recent decade, attempting to accomplish more dependable correspondence over the electrical cables with higher piece rates.

### 1.4 Summery

This thesis goes for building up an investigative model depicting complex exchange elements of run of the mill control line systems utilizing an arrangement of parameters assuming indispensable part in the electrical cable station. The channel model will be founded on physical flag engendering impacts in mains systems including various branches. Other than multipath engendering joined by recurrence specific blurring, flag constriction of commonplace power links expanding with length and recurrence will be considered.

# Chapter 2

## Literature Review

### 2.1. Introduction to PLC

The most extraordinary change in our lives since the previous couple of years is the entrance and huge advance of the Information innovation. These exceptional changes that data innovation has presented in our lives have totally changed our lives and maybe our ways of life. Life has turned out to be considerably less manual and a great deal bother free for individuals all around the world that have dynamic access to the developments of data innovation [32]. Wired internet network, (for example, XDSL and link systems) and remote internet network, (for example, a remote neighborhood) are promptly accessible urban territories as opposed to country regions for business reasons. A PLC framework subsequently turns into an appealing alternative for fast information exchange for correspondence. Broadband over electrical cable can give web access over the electrical cable framework. A portable workstation or some other gadgets can be connected to any electrical plug (by utilization of PLC modem) in working to access fast web. [13] To use the existing infrastructure of power line grid resulting in providing internet to the customers and economizing the infrastructure in rural areas who do not have access to cable modems. Power line links are not intended for exchange of information; therefore there are constraining elements, for example, electromagnetic obstruction, debasing the framework from commotion loads and different gadgets associated with the electrical cable lattice. Power line cables are not intended for exchange of information; in this way there are constraining components, for example, electromagnetic impedence, corrupting the framework, for example, from clamor loads and different gadgets associated with the electrical cable matrix. Undoubtedly designing in any PLC model, properties of the power line channel and adequate knowledge are required [5] Although there are strong wireless communication competitors, it is believed that power line communications (PLCs) will fulfill various communication tasks in upcoming as PLC provides the natural upgrade from simple electricity conductors to hybrid and bidirectional electricity and data communication solutions.

### 2.2. Advantages of Power Line Communication

The benefits of utilizing the power line as the transmission medium for in-home systems administration. Omnipresence of electrical outlets: The primary favorable position of utilizing the power line framework for home systems administration is the accessibility of different electrical plugs in each room. Hence, the, no new wiring' idea takes out the need to do extra wiring (or rewiring) inside the home.

Circulation of interactive media Power line organizing is equipped for disseminating sound, video, and other continuous administrations nearby information, all through the home.

With the mechanical headways, power line organizing is fit for circulating information at 40Mbps to 80 Mbps speed and future information transmission rates incorporate 300 Mbps,

making it a propelling innovation with a future. Phones, PCs, video gadgets, printers and different sorts of electrical gadgets can likewise be associated with the PLC frameworks introduced inside a house. This could spare a considerable measure of cash in light of the fact that new correspondence links would not need to be introduced. Robotization administrations are in effect progressively utilized as a part of the mechanical and business segments and vast structures. They are additionally being utilized as a part of the places of normal everyday citizens and computerization administrations, for example, programmed light control, warming control and security perception are being utilized. Electro-engines, sensors, cameras, lights and different sorts of electrical gadgets are interconnected to build up these programmed frameworks. The family units and structures which don't have a satisfactory correspondence framework can make utilized of the PLC innovation to make mechanized systems.

The PLC get to frameworks in light of low voltage systems are a remarkable same as the PLC systems introduced inside. These frameworks have a base station which interfaces the framework to the range outside. The meter unit, or some other suitable place in the indoor PLC framework, can be the site for the area of the base station and PLC modems, similar to the PLC get to arrange supporters, are utilized to interconnect the diverse gadgets in the PLC organize introduced inside the family as it is appeared in

The power supply attachments in the divider are utilized to give electrical energy to the modems and the different specialized gadgets can be connected to the PLC organize introduced in the house through the electrical plugs in the dividers. The autonomous PLC systems are implied just for a solitary house or a building and the PLC benefits inside the structure can't be utilized from far away, yet the remote controlled PLC frameworks inside the family units can give successful computerization capacities like security and vitality administration. A WAN correspondence framework can be utilized to empower the clients of an indoor PLC system to profit by numerous media transmission administrations from the electrical plugs in the house. The PLC get to frameworks can undoubtedly be connected to the PLC systems introduced inside the house and different sorts of correspondence frameworks can likewise be gotten to by the PLC systems. A power utility controlled access system can give extra metering administrations by utilizing the PLC systems. The remote electrical meter perusing gadgets spare cost and vitality and a great tax structure can be presented.

The advancement of the broadcast communications market can profit the indoor PLC arrange clients and the broadband indoor frameworks can likewise be actualized.

## 2.3. Scheme of Power Line Communication

### 2.3.1. Power Line Channel Model

#### 2.3.1.1. Channel Coding:

The convolutional coding procedure is utilized to encode and disentangle a consistent stream of bits. The fundamental idea driving the convolution is the covering of two signs to shape the other one. Due to the idea of convolution coding method the double piece stream source is convolved by applying some paired operations on them. It is a memory based framework, which implies the yield bit is reliant of the present piece being encoded and additionally the past piece stream put away in the memory. Convolution encoder in the punctured framework gives encoding and deciphering of high information rate. The fundamental uses of convolution coding is in the profound space applications and in remote correspondence frameworks.

Decoding is the opposite process -the transformation of an encoded arrange over into the first succession of characters. Encoding and deciphering are utilized as a part of information interchanges, systems administration, and capacity. The term is particularly material to Electrical cable interchanges frameworks.

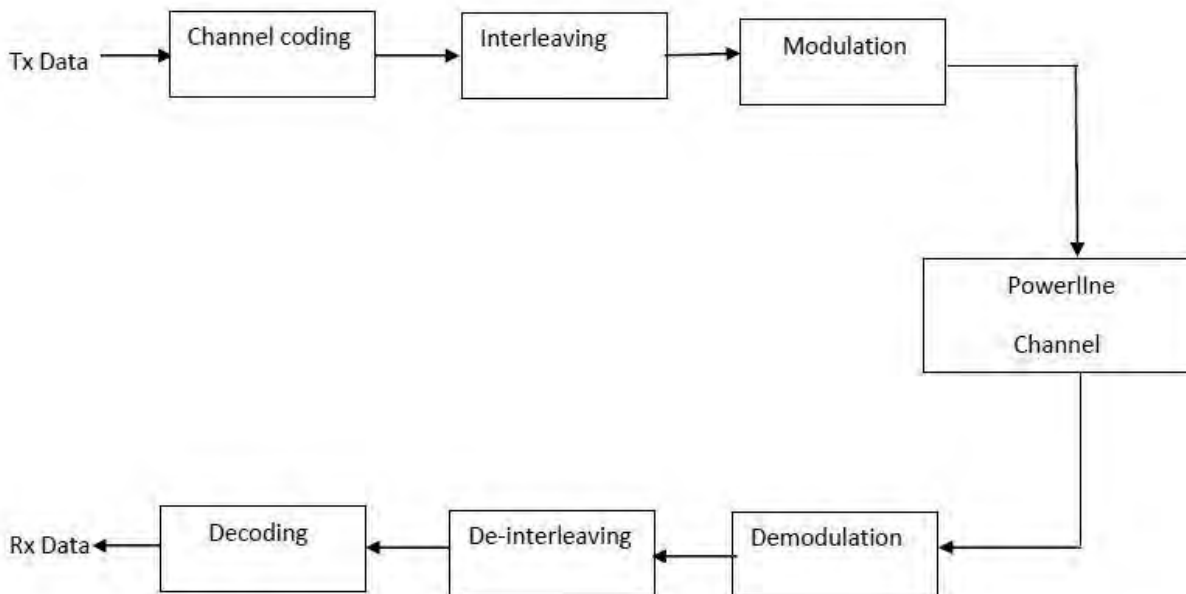


FIGURE: Power Line Channel Model

#### 2.3.1.2. Interleaving

This is the standard notion of labeled transition system calculi without value passing is straightforward. Interleaving is a common process in channels which is applied with memory because it can handle the burst errors [27]. In PLC bit interleave is employed before the output bits of the convolutional encoder are modulated. In PLC, interleaving is performed such that an



OFDM symbol is spread over several other OFDM symbol and at the same time each individual OFDM symbol is also interleaved [27]. Interleaving is very much connected with OFDM system. There are different process of interleaving one is conventional interleaving, here The conventional block interleaving is mainly time interleaving, trying at mitigation of TIN. Time-domain burst errors could be dispersed into several FEC code words to reduce the probability of decoding errors by block interleaving. It is crucial to choose an appropriate block size for the conventional block interleaved to achieve better anti-TIN capability for a certain system [28]

There are also some Interleaved OFDM models for MIMO system [29].

Firstly the conventional MIMO-OFDM means that it does not apply subcarrier interleaving within or between MIMO systems. Hence, if every radar transmitter has 128 subcarrier, and it is assumed that the MIMO configuration consists of 4 transmitters and 4 receivers [29].

Secondly, Yoke interleaved model differ with the conventional one, where there is an interleaving between two successive subcarriers of MIMO radar with two subcarriers of the other radar system

Lastly, Random Subcarrier interleaving. Each MIMO transmitter consist of 128 subcarriers, and the subcarrier allocation for each MIMO transmitter is done in random way [29]

One the other hand, de interleaving step incorporates accepting interleaved information to various transmission channels. The recipient then de interleaves the bundles into their unique organization dispensing burst blunders between all parcels in the parcel square. In the event that an information thing is embedded at the gap of the arrangement before the succession is appropriately DE interleaved, an erroneous situated information thing is resolved and repositioned.

### **2.3.1.3. Modulation & De Modulation**

Modulation is the addition of information to an electronic or optical carrier signal. A bearer flag is unified with a consistent waveform - steady tallness (adequacy) and recurrence. Data can be added to the bearer by changing its abundance, recurrence, stage, polarization (for optical flags), and even quantum-level marvels like turn. Tweak is generally connected to electromagnetic signs - radio, lasers/optics and PC systems. Regulation can even be connected to coordinate current (which can be dealt with as a deteriorate transporter wave with abundance 0 and recurrence 0) for the most part by turning it on and off (as in Morse code telecommunication), or connected to rotating present (as with control line organizing). For our coding purpose, we have used CPFSK Modulation Technique.

On the contrary, Demodulation is extracting the original information-bearing signal from a carrier wave. A demodulator is an electronic circuit (or PC program in a product characterized radio) that is utilized to recuperate the data content from the adjusted transporter wave.[1] There are many kinds of balance so there are many sorts of demodulators. The flag yield from a demodulator may speak to sound (a simple sound flag), pictures (a simple video flag) or twofold information (a computerized flag).

These terms are generally utilized as a part of association with radio beneficiaries, yet numerous different frameworks utilize numerous sorts of demodulators. For instance, in a modem, which is a withdrawal of the terms modulator/demodulator, a demodulator is utilized to separate a serial advanced information stream from a bearer flag which is utilized to bring it through a phone line, coaxial link, or optical fiber.

### 2.3.2. The multipath model

Power line channel system structure and topology is not same as the other telecommunication system. In power line system, the connection between a substation and the consumers at their places is not presented by a point-to-point connection as it is structured in the telecommunication systems. The power line network differs in topology, structure, and physical properties from available media such as twisted pair, coaxial, or fiber-optic cables. The propagation of data signal in power line system work as a multipath channel like any wireless network signal in cellular transmission system [5]

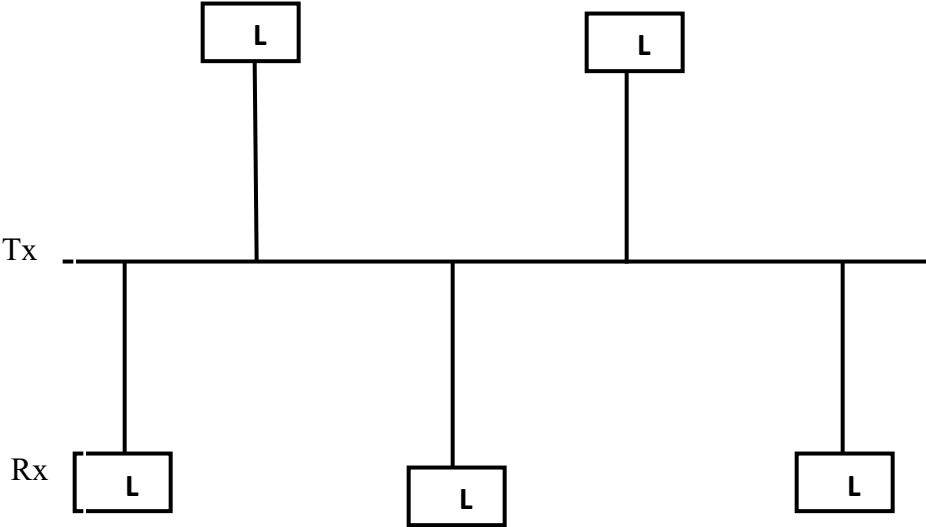


FIGURE: Typical topology of power line transmission line [2]

From the figure 2.1 we can see that the connection from Power line transformer is a single line distribution then branching with many house connection and Length/Loads (Tx is the transmitted point and Rx is the receiving point). Impedance mismatching and many branching causes a lot of reflection in this system which leads to a multipath propagation with frequency selectivity, however coupling and line losses needs to be considered as well in modeling the power line channel [2] Because of the reason that there are different electrical devices with constantly being switched on and off which cause changes in the transfer function, for that the channel transfer function is time-varying and depends on the location of the receiver [10]

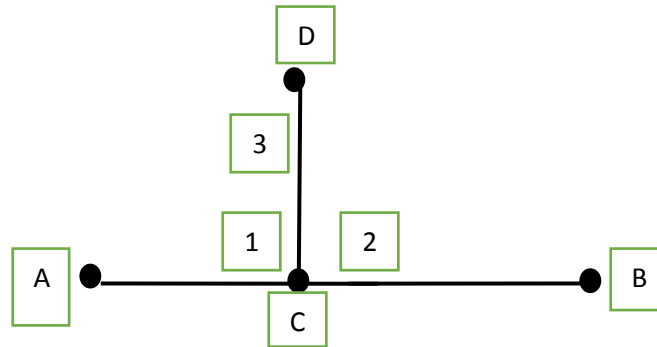


FIGURE: A multipath propagation data from A-C [5]

In this figure.2.2. assume C is the receiver end, the signal that generated in point A can take any path to send the signal to C point, such as:

The bit error rate and the signal power of received signal at point C depend to the path selected and also the length of it. Multipath propagation is also responsible for delay ( $\tau_i$ ) in PLC system, which is given by:

Here  $C_0$  is the speed of the light,  $d_i$  the path length and  $\epsilon$  is the dielectric constant of insulating material [5]

The losses of cables cause an attenuation increasing with length and frequency. The signal components of the individual paths have to be combined by superposition.

There in given equation below ( $f$ ) is the frequency of operation,  $g_i$  is weight factor which is directly proportional to number of reflections and the selected path. An experimental data A ( $f, d_i$ ) can be mathematically approximated by the formula for attenuation factor ( $\alpha$ ); Where  $a_0$  and  $a_1$  are attenuation parameters [6]

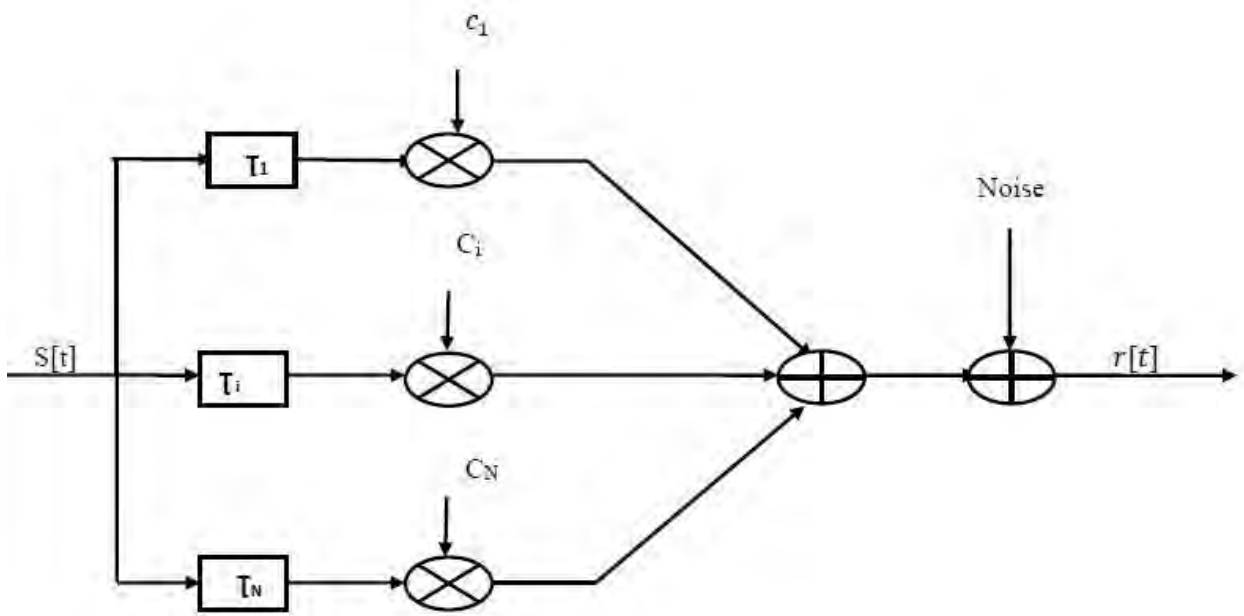


FIGURE: Multipath Channel Model

By working with all the above given mathematic expression and Using  $A(f, d_i)$  in  $H(f)$  the mathematic multipath model, as it is shown in the above Figure for PLC can be written as [32] [11].

Where:

$g_i$  Is the weighting factor

$e^{-(a_0+a_1f^k)d_i}$  Is an attenuation portion and [write the equation in word]

$e^{-j2\pi f d_i/v_p}$  Delay portion.

### 2.3.3. Narrowband over PLC

Narrowband power line communication (PLC) has been used for making an impact in frequencies under 500 kHz [27] the narrowband PLC are widely used in automation systems. The automation systems based on PLC technology are implemented without any further addition of communication networks, which reduces the costs for the installation and realization of the new network within the existing buildings. The automation system can be used in as follows[33]:

- i) To establishing a central control of various home system such as controlling doors, windows etc.

ii) Controlling connected devices to change their condition and to instruct them according to the users use like turning on/off lights, Air conditions etc.

iii) The Security function, sensor control

Smart metering is another application for narrowband PLC system. The smart meter system includes meters at the user site, communication medium between a service provider and the user, such as a gas, an electric, or water, and data management systems in a service provider site that make the information more easier to find, calculate and available for the provider to know the amount of data or other services that has been given to the users. The smart meter collected data by the PLC to a Meter Data Management System for data analysis and billing [25] If someone insert a smart meter in his house he will get a lot of benefits such as:

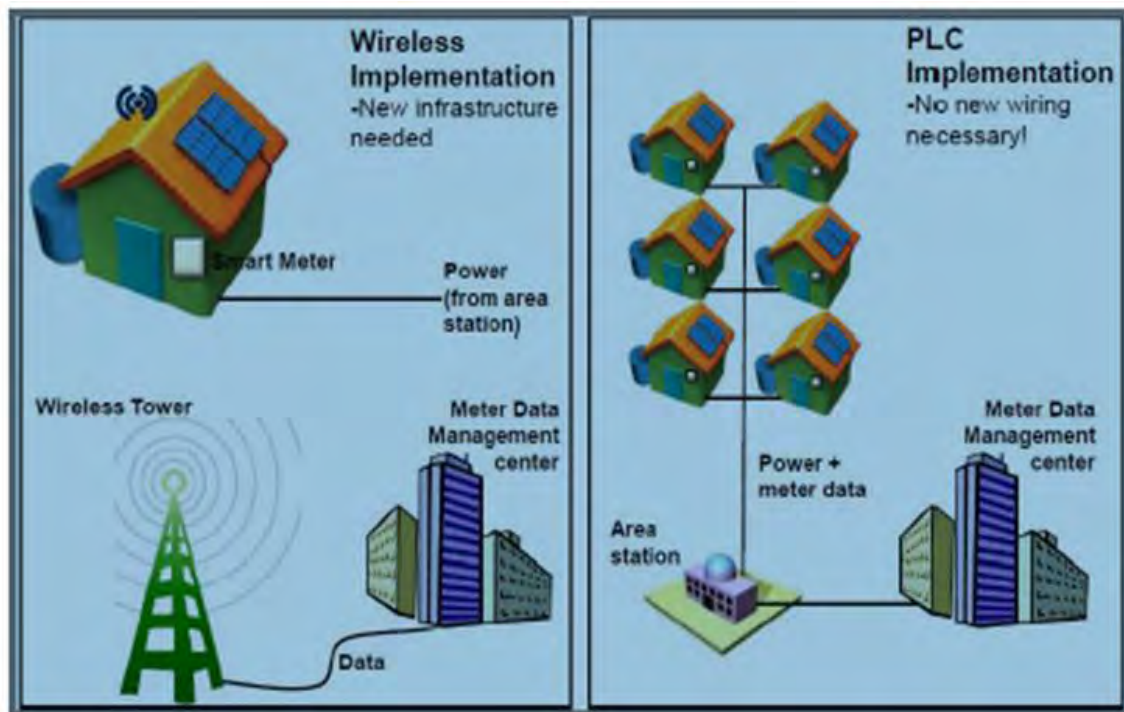


Figure: Smart Metering System [33]

a) Easily finding out the accurate bills; the smart meter sends information to your energy provider on how much energy you have exactly used, so no more estimated bills.

b) Saving money; by knowing what you're using, and having an idea of which appliances use the most energy, we may be able to reduce your energy usage and save money.

c) A standard in-home energy display; a smart meter has a small screen which shows your energy usage at any one time with no any additional cost and that will help you to know the energy amount .

d) Reduced theft of energy; the energy theft detection is more easily detected by this device, therefore it can be easily prevented, meaning you won't have to pay for stolen energy [25]

### **2.3.4 Broadband over PLC**

Now a day's internet technology has become an important element in every sector of life starting from business field to daily communication system. Wired internet network and wireless internet networks are readily available urban areas rather than rural areas for commercial reasons.

A PLC network therefore becomes an attractive option for high-bit-rate data transmission [33] one method of establishing broadband network by PLC as a section of last mile access network. The main advantages of using PLC system in Broadband network is to use existing power line infrastructure, eliminating the need to install new infrastructure thus reducing deployment costs[26] A PLC system is now considering as an alternative to the broadband access network. Broadband power line can provide internet access over an ordinary power line. A laptop or any other end devices can be connected into any power outlet (by use of PLC modem) in building to get access to high-speed internet. The main advantage is to use the existing infrastructure of power line networks resulting in economizing the infrastructure cost and providing internet to customers in rural areas, who do not have access to cable modems. Around twenty four million homes in the UK will be required to have a smart meter for gas and electricity by 2020. To reduce the cost of establishing this connection system installing PLC system will also take place at the same time [33] In the past, the idea of using PLC as a last mile solution was primarily in theory since PLC technology that time could support data rates of only a few megabits per second but now PLC technology is significantly developed and today's PLC adapters support data rates of 500 Mbps on physical layer and distances up to 1200m [26].

Today's broadband over power line grids has three primary parts [23]

- 1) Internet access as the substation connected via backhaul, which can be fixed wireless, fiber optic or any other communication systems.
- 2) Use repeater/extractor on the MV line enable digitized data to be conveyed through the distribution power line.

- 3) Use devices such as Modem, couplers or extractor to move the data around or through the transformers to connect to the consumer premises.

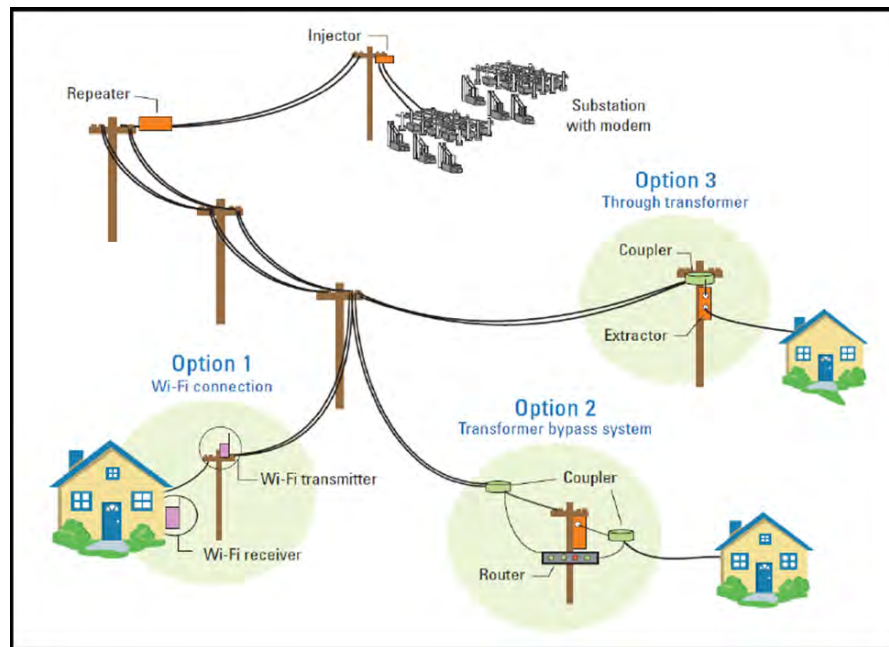


FIGURE: PLC with different system architecture [23]

## 2.4. Power Line Communication access networks

### 2.4.1. Structure of PLC access network

The access networks are very important for network providers because of the following reasons:

- Investment is necessary for the access area about 50%.
- The telecommunication market in a large number of countries the access networks are still the property of former monopolistic companies. Therefore, new providers try to find a solution to realize their own access network to the subscriber.
- The telecom sector has made a revolutionized improvement which increase the demand for more transmission capacity and WAN networks as well as in the access area.

The expansion of the access networks are: building of new networks and usage of existing infrastructure. Techniques of building of new networks can be:

- Wireless access network [DECT, WLAN]

- Satellite system.
- New cable / fiber optic networks.

First two techniques are expensive and low transmission rates. Another problem is higher cost for building of new cable or optical network. So, the favorable solution is the existing infrastructure because of the usage. There are following three possibilities:

- Development of new transmission method [XDSL]
- Usage of TV cable networks [CATV]
- Power line communication [PLC]

There is a disadvantage of first two solutions. Because of that PLC access network seems to be a reasonable solution shown in. The subscribers are belong in a low voltage electrical power supply network which have to share the transmission capacity of the PLC access network. So there is a need for higher capacity in PLC network which can't be realized in frequency spectrum specified by CENELEC. The frequency spectrum should be up to 20MHz even higher for PLC system. A PLC system [working at higher frequency] causing electro- magnetic radiation. Because of that, other communication service faces disturbance. For the existing problem signal power of the PLC has to be defined to ensure a mutual existence of PLC another communication. Regulation bodies and other organizations are working on this but there is still no standardization for the PLC and CENELEC standard. It is expected that the signal power used in PLC has to be very low.

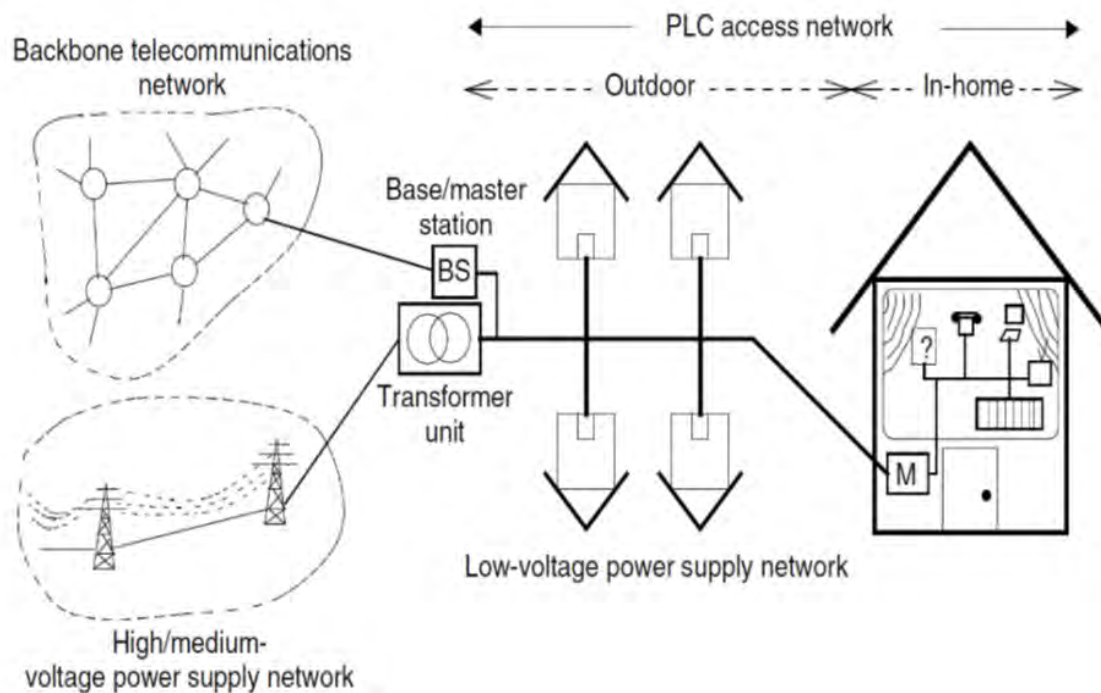


FIGURE: Typical PLC access network [34]



## 2.4.2. In-home PLC network

Electrical system is used as a transmission medium for the purpose of transmitting signals in-home PLC system. Such as telephone, computer, video device, printers etc are connected to the PLC system installed within the house. It helps us to reduce the cost of new communication cable installation. In recent times, automation service is becoming more popular in industrial and commercial areas as well. They are using automatic light, heating control, security service etc. electric-motors, lights, cameras are interconnected to establish these automatic system.

The PLC system works on low voltage network as same as PLC network which installed in the home. It has a base station [BS] which links the system to the area outdoor. The meter is used as the site for location of the base station and PLC modem like PLC access network subscribers are interconnected to the different device in the PLC network installed in the house. There is a power supply sockets in the wall are used to provide electrical power to the modem. The various communication device are interconnected to the PLC network installed in the home through the power outlet in the wall. It is only for the single house or building. Smart security service and energy management can be done by the remote controlled PLC system within the house. PLC network in the house helps to link with the other communication device by PLC system. It also provide additional metering service by using PLC network which save our money and energy. [34]

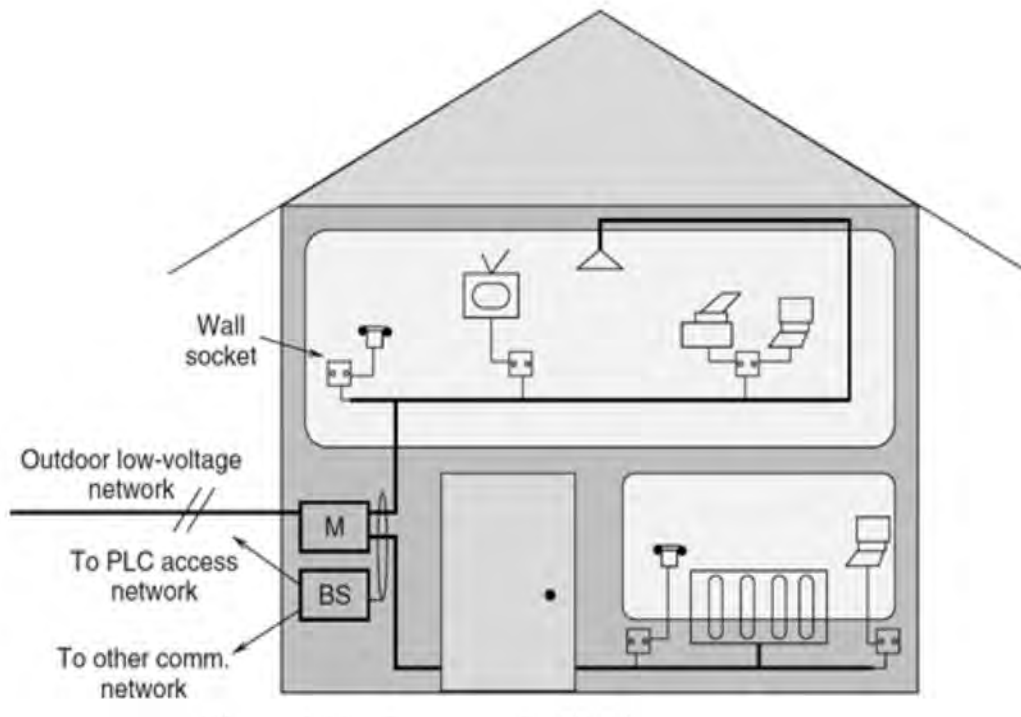


FIGURE: Structure of PLC in-home network [34]

## 2.4.3. PLC network elements

### 2.4.3.1. Repeater

On the off chance that the separation between the base station and the individual endorsers, or the separations between the distinctive PLC supporters in a low voltage supply arrange, are too long, the PLC get to framework won't have the capacity to work and a repeater could be utilized for the operation of long range systems. The PLC get to organize is isolated into various system sections by the repeaters and these systems are separated into different vacancies or groups of recurrence. Transmission is conceivable inside the main fragment by utilizing an availability and the second section can be used by picking an alternate schedule opening as it is appeared in Figure.

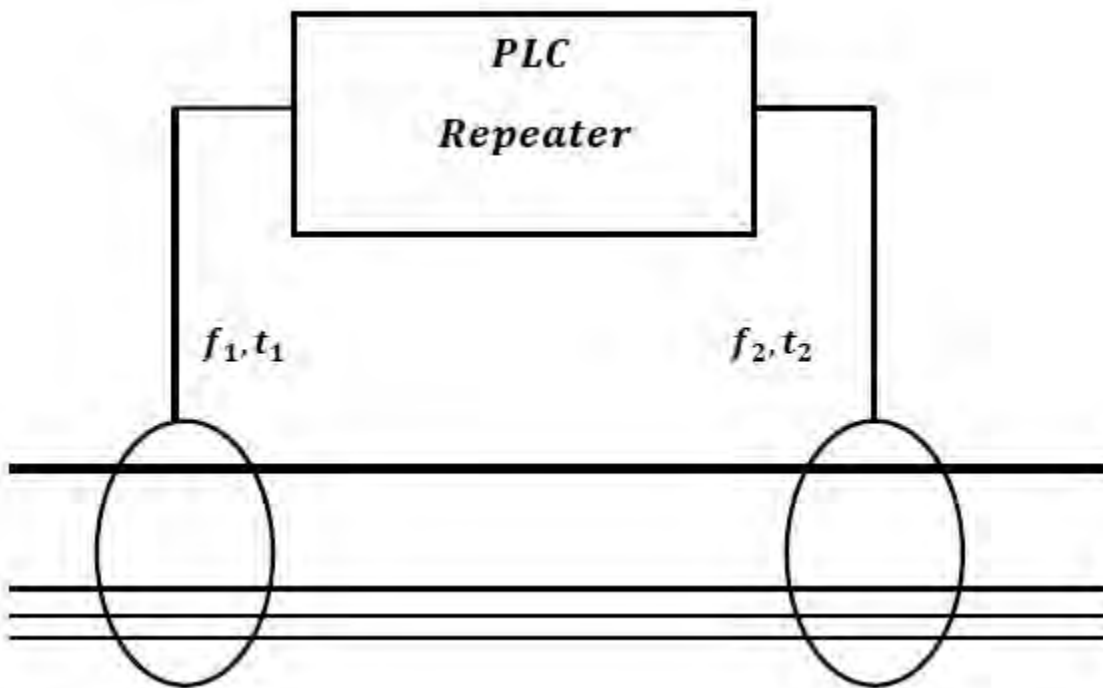


FIGURE: Repeater

### 2.4.3.2. PLC gateway

The PLC supporters can associate with the PLC get to organize through the divider attachments in two distinctive ways:

- Coordinate association
- Circuitous association over a portal.

The main case comprises of PLC modems which guide associations with the PLC base stations and the entire low voltage arrange. The indoor and open air regions are not isolated and the power meter unit fills in as a medium for the transmission of the correspondence flag. There are sure issues identified with the electromagnetic similarity and the properties of the PLC transmission channel. These issues happen because of the distinction in the indoor and open air control systems. The indoor PLC system can be isolated by the PLC get to organize by utilizing an entryway which changes over the frequencies utilized for the transmission of the signs between the indoor regions and the entrance ranges. The portals are regularly set alongside the house meter unit as it is appeared in Figure.2.16. The consistent system division of the indoor and access ranges should likewise be possible by utilizing a PLC door.

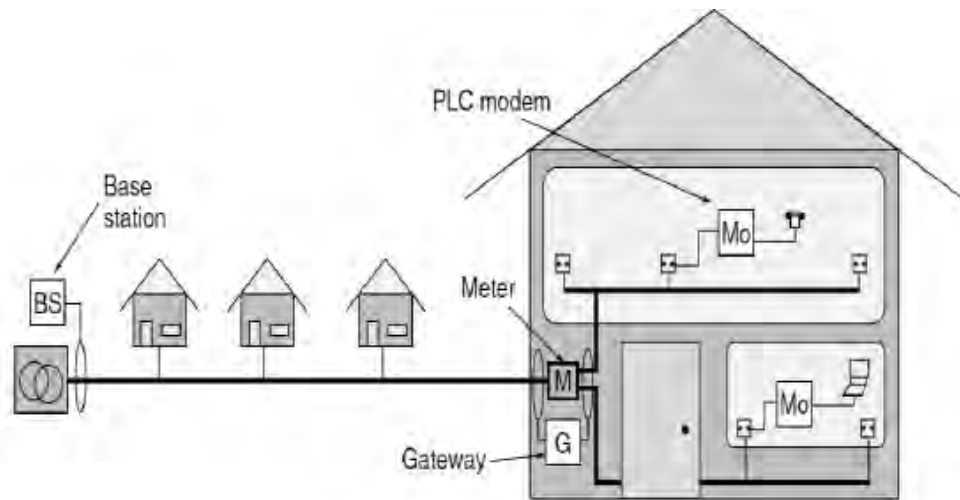


FIGURE: PLC Gateway

The information contribution to the entrance region isn't required for the interior correspondence between the PLC modems connected in an indoor. On the off chance that the separation between the base station and the individual endorsers, or the separations between the distinctive PLC supporters in a low voltage supply arrange, are too long, the PLC get to framework won't have the capacity to work and a repeater could be utilized for the operation of long range systems. The PLC get to organize is isolated into various system sections by the repeaters and these systems are separated into different vacancies or groups of recurrence. Transmission is conceivable inside the main fragment by utilizing an availability and the second section can be used by picking an alternate schedule opening as it is appeared in above figure.

### 2.4.3.3 Plugs and Sockets

In-home or in-office, the PLC network modems are connected directly to the wall socket .Power line network that installation power cables are connected with the power socket. It is important to understand the effects of used sockets and plugs and also the performance of the power line network as high frequency transmission media. In this work the 3D model for a power plug and a socket with PE connection is built using CST microwave studio software [13]. The structure which are modeled of plugs are simulated by software shown in fig:[number]. The insulation materials have effects on the transmission properties of connected plug and socket affected by the dielectric parameter values. These parameter values are further discussed in table 1.

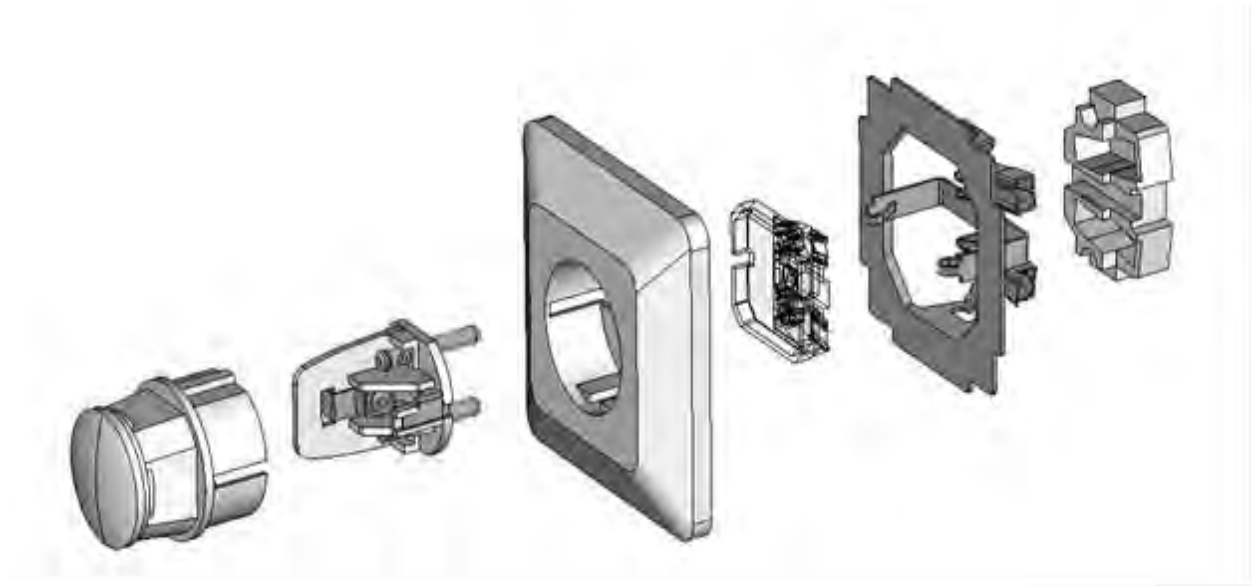


FIGURE: Structure of a plug and a socket [34]

**TABLE 1. THE PARAMETERS OF INSULATION MATERIALS [34]**

Name of the material	Permittivity	Loss tangent
Plug cover	3.33	2.21.10 <sup>-4</sup>
Socket cover	3.67	5.66.10 <sup>-3</sup>
Plastic inside Socket	4.32	6.14.10 <sup>-3</sup>
Insulation material	6.85	5.28.10 <sup>-2</sup>
Plastic outside install. cable	3.24	1.65.10 <sup>-2</sup>
Plastic outside of underground cable	3.37	1.42.10 <sup>-2</sup>

#### 2.4.3.4. Coupler

In the power line network a wideband coupler is needed to provide wideband interface to connect a data terminal. It is hard to find out 220V AC signal which doesn't cause damage to users and telecommunication measurement of equipment. There is an isolation between the measurement equipment and the power line network. The loss of coupling of RF power should be at a high level and the frequency response should be flat within the investigated frequency band. It is challenging to design of wideband RF coupler. Therefore, it should be designed and manufactured a wideband coupler to the frequency range between .1-1 GHz. The structure of the coupler follows mainly the same principle presented in. It is important to find out a good impedance matching for improving overall performance. The RF coupler is built on a Rogers PCB R04350 [thickness .33] using a wideband transformer and two 100PF safety high voltage capacitors. It is important to find out high voltage 50V AC main signal and uses in 500V voltage environment effectively. The designed coupler with small loss is used and provides impedance matching between 50 ohms and 75 ohms.

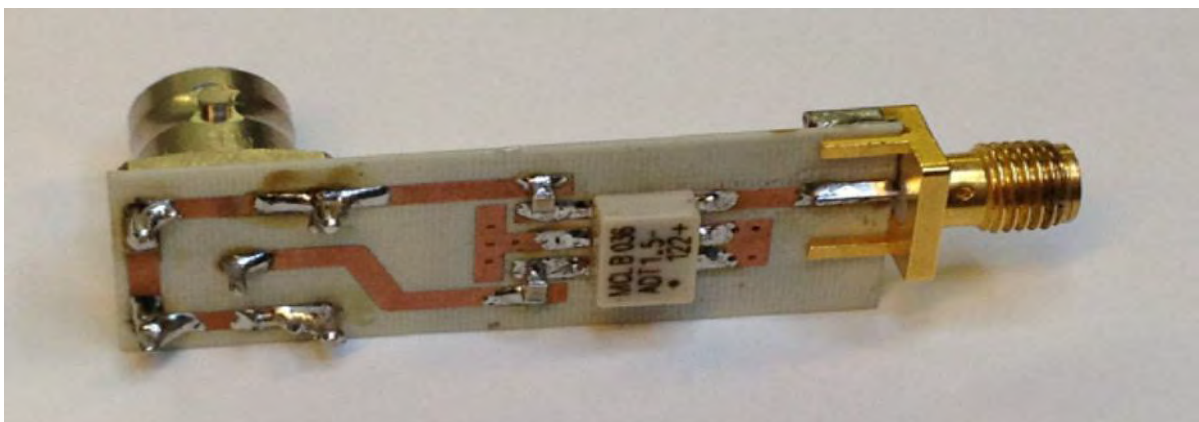


Figure: RF coupler used in measurement [34]

# Chapter 3

## Power line communication system model

Power line communication system model that is used in this paper is configured with the elements such that channel coding, interleave, modulation, OFDM transmitter, power line channel, OFDM receiver structure, demodulation, DE interleaving, decoding. The Power line communication system model is given below:

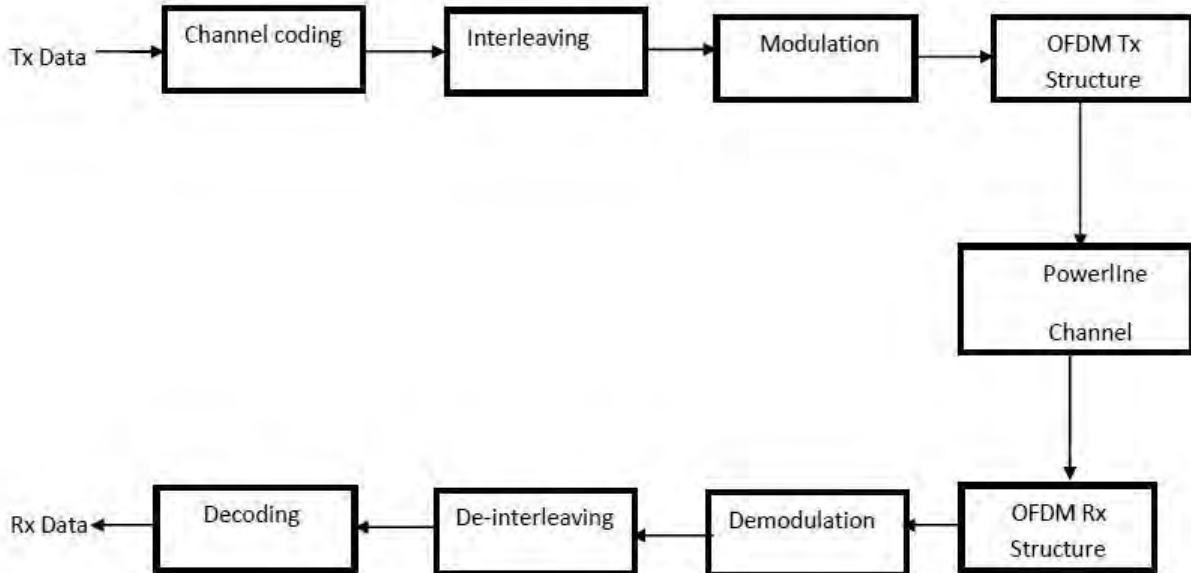


FIGURE: Power Line communication System Model

### 3.1. OFDM structure

#### 3.1.1. OFDM transmitter configuration:

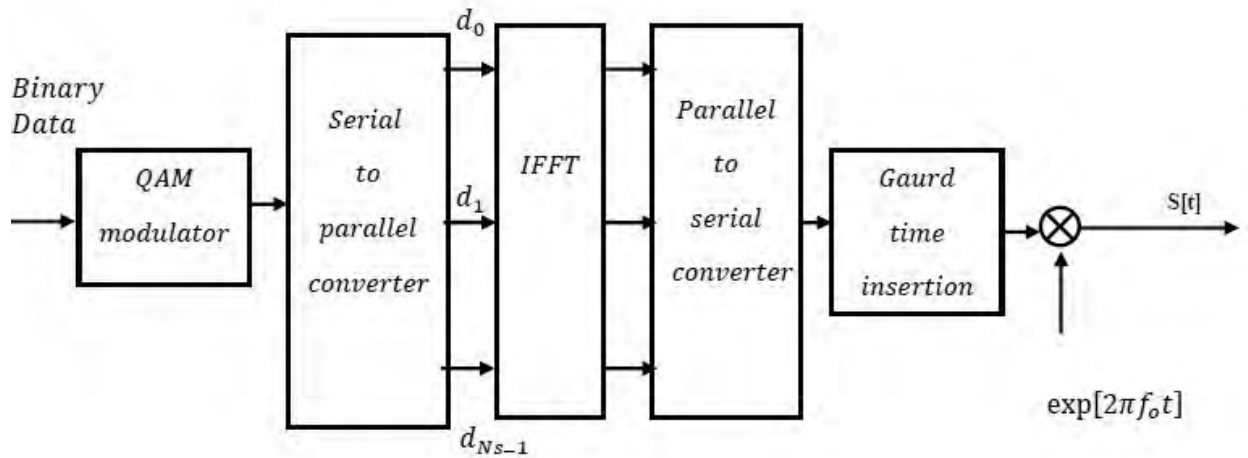


FIGURE: OFDM transmitter configuration [3]

In Figure 3.1.7 an OFDM transmitter configuration is shown, here at the beginning in the transmitter side, the transmitted data converted to parallel data of some (N) sub channels, after that this parallel sub channels goes through the PSK modulation process. Let's just consider some data sequence of the N channels ( $d_0, d_1, d_2, \dots, d_{N_s-1}$ ) and  $d_I$  and  $d_Q$  (I and Q axis) are  $\{1, -1\}$  in QPSK and  $\{\pm 1, \pm 3\}$  in 16-QAM. Now as an input these modulated data is served to the inverse fast Fourier transform circuit, by doing this an OFDM signal is generated. The advantage of using OFDM is that it can transmit many low rate streams in parallel and there is less inter-symbol interference which happens for the multipath. A interval is introduced in between the OFDM symbols to overcome the inter symbol interference problem. There are a lot of benefits of the guard interval, It helps to overcome the time synchronization problems with that, the cyclic prefix is also transmitted during this interval. Because of the multipath fading this is obvious that the sub-channels spread their power into the adjacent channels. Separating the sub channels and the orthogonally of the sub channels in the absence of ISI and inter-carrier interference (ICI) is maintained by using an FFT circuit at the receiver side. The signal can suffer interference if the delay time of the signal is greater than the delay time of the symbols, to solve this problem either increasing the number of carriers or the symbol duration should be done. Considering the carrier stability this problem has some drawbacks to FFT size and Doppler frequency. Inserting cyclically extended guard interval can be an alternative to this problem [3]. As we already know that the symbol consists of two parts, we can write the total symbol duration as  $T_{tot} = T_g + T_n$ , here  $T_g$  is the guard time interval. Insertion of the guard interval on the symbol reduces the data throughput. By keeping the guard interval longer than the channel impulse response or multipath delay the ISI can easily be removed. On the other hand the ICI still remains and the ratio of guard interval and symbol duration depends upon the applications [3].

### 3.1.2. OFDM receiver configuration

The configuration of OFDM receiver has shown in figure 3.1.8. Band pass filter is used in the receiver side for filtering the received  $r(t)$  signal. Besides that the band pass filter has to have a wide pass band so that it can prevent any distortion of the signal. Then the signal is again converted to FFT band by an orthogonal detector. This is done by the FFT circuit to get the Fourier coefficients in the time of the observation. The sub channels modulation schemes decides the BER performance and the orthogonally is maintained in the OFDM transmission. BER can be varied the noise of the receiver [3]

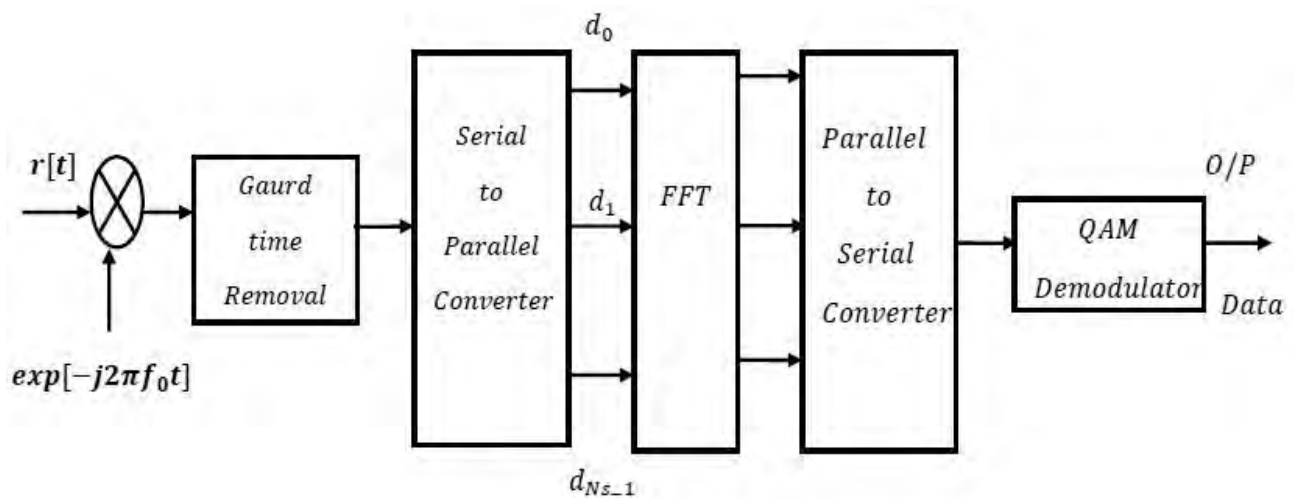


FIGURE: OFDM receiver configuration [3]

### 3.1.3. Mapping & Demapping

At the transmitter, the bits at the output of the encoder and interleave are mapped to modulation symbols, which will constitute the input to the IFFT. The transmitter also uses the no differential or differential encoding to map bits to modulation symbols. At the receiver, the modulation symbols at the output of the FFT are DE mapped to bits or “soft” bits, which will constitute the input to the DE interleave and the decoder. The receiver uses coherent or differential detection to DE map modulation symbols to bits/soft bits, depending on the mapping scheme used at the transmitter [30]



### 3.1.4. Cyclic Prefix

Cyclic prefix is used mainly for reducing inter symbol interference. Typically including cyclic prefix (CP) has two purposes that is dispense with the ISI and ICI. It duplicates the back piece of the OFDM image and put it in front of the image. Image period will increment from  $T$  to  $T' = T + \Delta\tau$  is secure space. The length of cyclic prefix must be more prominent than the channel most extreme defer spread max. This permits the past image multipath duplicates fall into the cyclic prefix of the following image. In this way killing the obstruction between the two images. As including of the cyclic prefix, makes the coordination interim of the OFDM flag images has the repetitive nature, so that an OFDM image with the multi-way between various sub-transporters are as yet ready to look after orthogonally. This will keep the between channel impedance (ICI). [10.11.....49]. We consider an OFDM framework with [17]  $M$  sub channels , and a CP of length  $\mu = N - M$  tests, where  $N$  is the standardized sub-channel image period (OFDM image span in tests) accepting that the inspecting time frame  $T$  is equivalent to the time unit in the framework. The standardized subcarrier frequencies are characterized as  $f_k = k/M$ , for  $k = 0, M - 1$ .

The OFDM flag is transmitted over a channel that has a comparable discrete time complex motivation reaction,

$$g_{ch}(n) = \sum_{p=0}^{v-1} a_p \delta_z(n - p)$$

Where  $a_p$  signify the mind boggling channel coefficients, and the discrete time delta motivation is characterized as  $\delta(n) = 1$  for  $n = 0$ , and zero generally. Additionally, we accept  $v \leq M$  with the goal that the channel is shorter than the valuable OFDM image term. The channel span can be longer than the CP. Therefore, at the collector side, after synchronization, CP disposing of, and discrete Fourier change calculation, the flag for sub channel  $k$  can be composed as

$$z^{(k)}(lN) = G_{CH}^{(k)} a^{(k)}(lN) + I^{(k)}(lN) + W^{(k)}(lN)$$

where  $a^{(k)}(lN)$  is the information image transmitted on that tone at time moment  $lN$ ,  $G_{CH}^{(k)}$  is the channel transfer function,  $I^{(k)}(lN)$  is the between image (ISI) in addition to inter carrier (ICI) impedance term that emerges in light of the loss of orthogonally due to an inadequate CP, and  $W^{(k)}(lN)$  is the added substance commotion commitment. The achievable rate of OFDM frameworks isn't really amplified while sending a cyclic prefix (CP) as long as the channel drive reaction. Despite the fact that for shorter CP lengths both between image and between bearer obstruction do happen, the rate pick up offered by an abbreviated CP may surpass the misfortunes because of impedance [17] In CP-OFDM, after the converse Fourier change, the keep going NG tests of each OFDM square are duplicated and embedded toward the start of the piece. The output of the transmitter can be written as

$$s(k) = [F_{cp}, F]^H y(k)$$

Where  $F$  is the  $N_C$  point FFT matrix with entries

$$F_{v,\mu} = \left\{ \exp\left(-\frac{j2\pi v\mu}{N_C}\right) \right\} / \sqrt{N_C}$$

Each piece  $s(k)$  is separated with the drive reaction  $h \triangleq [h_0 \dots h_{N_C}]$  and AWGN  $\tilde{n}(k)$  is included.

At the recipient side, after expulsion of the CP, the got piece is Fourier changed to yield the flag  $z(k)$ . It is outstanding, that this operation diagonalizes the channel bringing about the  $k_{th}$  received block

$$Z(k) = \text{diag}(\tilde{h}_0, \dots, \tilde{h}_{N_C-1}) \tilde{y}(k) + [0, F] \tilde{n}(k). \quad [16]$$

### 3.1.5. Coded OFDM

Coded OFDM is the process in which the forward error coding system and OFDM modulation technique combined together. The main work of that process is to interleave and code the bits prior to IFFT. For spreading the adjacent bits in the source data or information across multiple subcarriers is another work of that process. The interleaving part of the transmitter spreads out the contiguous bits such a way that the bits errors spaced apart in time as a result it gets easier for the receiver decoder section to correct the errors [1]

## 3.2. CPFSK Model

CPFSK is a continuous phase regulation technique. It is furnished with the benefit of high band usage rate and low out-of-band power. Also, CPFSK balance flag is a consistent envelope flag which is anything but difficult to open up and transmit in the nonlinear channel. In the meantime, the age of CPFSK additionally advances the improvement of remote correspondence framework [36]. Contingent upon the pre-adjusting channel utilized we consider the following classes of CPFSK tweaked signals:

- Integral response CPFSK modulated signals Defined by modulating impulses extending over one symbol period:

$$g(t) = \begin{cases} \neq 0; t \in (0, t_s) \\ 0, \text{ otherwise} \end{cases}$$

- Partial-response CPFSK modulated signals defined by modulating impulses extending over more symbol periods:

$$g(t) = \begin{cases} \neq 0; t \in (0, Lt_s) \\ =0, \text{ otherwise} \end{cases}$$

The most much of the time utilized pre-modulating filters by the CPFSK modulations are

LRC (Raised cosine in time), LSCR (raised cosine in frequency) and LREC (rectangular impulse)[36].

CPFSK is produced on the premise of Minimum Shift Keying (MSK). We examined the issue that how to elevate CPFSK. MSK signal is considered as a CPFSK signal whose balance file is 0.5. [35]. Assume a code grouping of M-framework advanced flag  $I=I_1, I_2, \dots, I_n, L$ , where  $I_n \in \{1, 2, \dots, (M-1)\}$ . Its recurrence is  $f_c$ , the underlying stage is 0, the time-fluctuating of bearer stage is  $\phi(t, I)$ . Present that,

$$D(t) = \sum I_n g(t-nT)$$

Where  $g(t) = \begin{cases} 0, & t \leq 0 \text{ or } t \geq T \\ 1/2T, & 0 < t < T \end{cases}$  is a rectangular pulse.

CPFSK signal can be expressed as,

$$S(t) = A \cos [2\pi f_c t + \phi(t, I) + \phi_0]$$

From this equation,  $\phi(t, I)$  includes many transmission information. [35].

The advanced information to the modulator is a succession of paired digits of bits, say a n-bit grouping  $a = (a_1, a_2, \dots, a_n)$  where  $a_i$  ( $1 \leq i \leq n$ ) is the  $i_{th}$  bit information taking esteem from the set  $(+1, -1)$  with break even with likelihood. besides it is expected that information bits are autonomous. keeping in mind the end goal to transmit flag data over band pass channel it is important to balance information on to a high recurrence transporter, more often than not a sinusoidal  $c(t) = a_c \cos \theta(t)$  at the point when the advanced data is inserted in the recurrence of the transporter, we acquire computerized recurrence adjusted flag. The connection deliver between recurrence balance and stage adjustment is given through,

$$F(t) = 1/2\pi d/dt \theta(t) \quad [35]$$

CPFSK is a generally utilized variety of FSK, which is itself an uncommon instance of simple recurrence tweak. FSK is a strategy for adjusting advanced information onto a sinusoidal transporter wave, encoding the data display in the information to varieties in the bearer's prompt recurrence between one of two frequencies (alluded to as the space recurrence and check recurrence). By and large, a standard FSK signal does not have consistent stage, as the tweaked waveform switches immediately between two sinusoidal with various frequencies.

Since our proposed channel model was supposed to be done by CPFSK Model constructing in OFDM, we firstly used the equation and then had come up with a continuous phase shifting curve which had been approved our supervisor. Although, 16 QAM and QPFSK are used generally and available, we tried to distinguish by doing CPFSK modulation.

CPFSK Modulation is not only bandwidth efficient but also it is a continuous phase shifting modulation which is better to get any desired result.

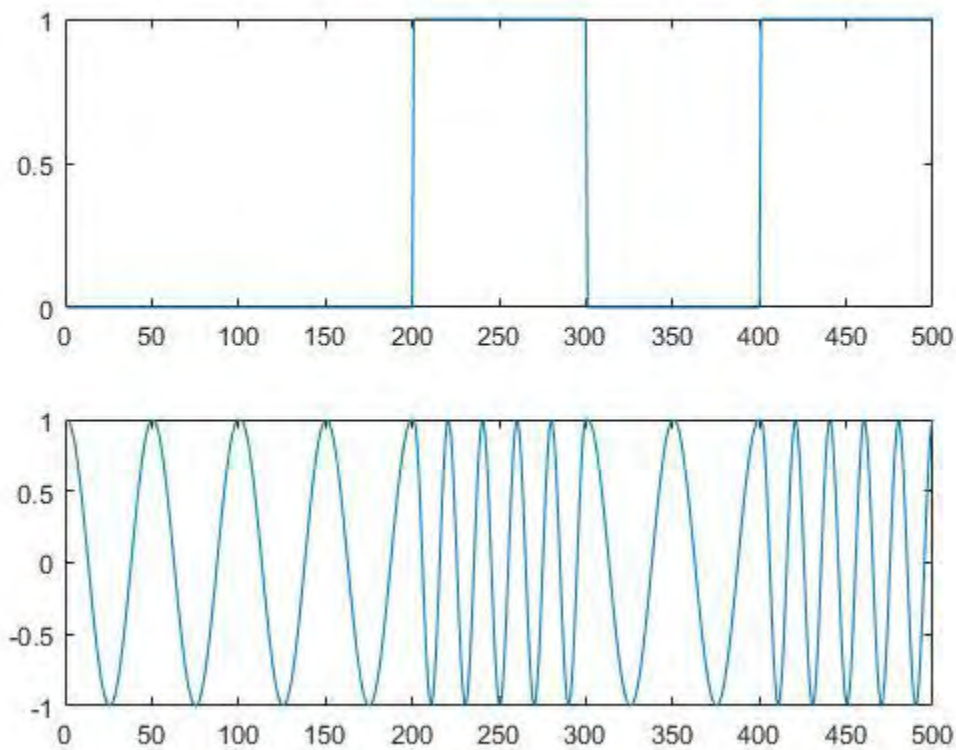


FIGURE: A CPFSK Modulation

### 3.2.1 Multipath

#### A Multipath Show for Power line Channels

The power line medium is a non-stationary transmission channel attributable to the change of impedance caused by assortment of apparatuses that could be associated with the electrical plugs. The

Power line channel displays negative channel attributes with significant commotion and high lessening for information transmission. Since it is dependably time differing, the power line can be considered a multipath station that is caused by reflections created at the link branches on account of impedance discontinuities coming about because of different electrical burdens. The impedance of power line directs is profoundly differing in a range between exactly couple of ohms up to a couple of kilo-ohms. The impedance is chiefly affected by the trademark impedance of the links, the topology of that bit of the system under thought and the idea of the associated electrical hubs. The power line medium as a correspondence channel brings weakening and stage move into the transmitted signs. A power line channel display is depicted to talk about the command highlights that influence the signs that are transmitted over it, in particular, the weakening and deferral. A power line medium is portrayed by impedance discontinuities. The transmitted signs are along these lines mirrored a few times bringing about a multipath transmission. The power line channel can by and large be considered as a multipath channel. The multipath idea of power line channels emerges from the nearness of a few branches and impedance bungles that reason many flag reflections. The proliferation of signs over power line presents a lessening, which increments with the length of the line and the recurrence. Notwithstanding the recurrence subordinate blurring that describes the power line channel, profound narrow band indents happen in the exchange work, which might be spread over the entire recurrence run. These indents are caused by different reflections at areas of link gear impedance discontinuities. The length of the drive reaction and the quantity of the reflected vitality tops that happen can differ significantly contingent upon the specific power line organize condition. This recurrence subordinate lessening conduct can be portrayed utilizing a 'reverberate show' for the channel conduct. Multipath proliferation approaches, which are appropriate for depicting the transmission conduct of control line channels, have been proposed by Philips and Zimmermann. Philipp's reverberate demonstrate portrays the channel motivation reaction as a superposition of  $N$  Dirac beats speaking to the superposition of signs from  $N$  distinctive ways. Each of these driving forces is duplicated by a complex factor.

### 3.2.2 Zimmerman Channel & Corresponding Result

Expanded estimation battles uncovered that it is conceivable to additionally rearrange the particular of the weighting factors to being intricate, yet not recurrence subordinate. As a rule of down to earth intrigue, can even be expected as genuine esteemed. In heterogeneous systems, frequently a few ways with practically equivalent postpones exist, with the goal that it isn't remunerating to follow the elements back to their physical inceptions. From a multipath perspective, just portrays the heaviness of way. In this way, utilizing the last form of the recurrence reaction is given by weighting factor weakening divide, delay divide an outcome which has been generally demonstrated practically speaking. Table I clarifies the parameters. A parametric model, portraying the complex recurrence reaction of commonplace power line

channels, covering every single generous impact of the move attributes in the recurrence extend from 500 kHz to 20 MHz by a little arrangement of parameters, which can be gotten from measured recurrence reactions, as appeared . Besides, the quantity of ways, permits a control of the accuracy of the model, which is particularly vital for characterizing reference channels for PLC-framework execution investigation. Since Zimmerman has shown four path and fifteen path model in the paper, both are given here.

Here is the Zimmerman Channel equation:

$$H(f) = \sum_{i=1}^N |g_i[f]| e^{g_i[f]}. e^{-[a_0+a_1f^k]d_i}. e^{-j2\pi f\tau_i}$$

Weighting	<i>attenuation</i>	<i>delay</i>
<i>factor</i>	<i>portion</i>	<i>portion</i>

### Parameter Estimation Methodology

Estimation of the parameters requires a refined system. The methodology connected to determine the parameters recorded in this paper includes a three-advance approach. In the initial step, the lessening coefficients are resolved from the lessening profile utilizing a solitary way show with a slightest squares estimator. In the following step, the number, position, and sufficiency of the huge ways is gotten from the drive reaction by a basic pinnacle identification approach. In less confused cases, this progression regularly conveys as of now adequate exactness. Be that as it may, if a higher number of ways is required, the parameters must be additionally advanced by a developmental technique with either drive reaction or abundance also, stage reaction as quality measures. A model of the unpredictable recurrence reaction of PLC joins for the recurrence run from 500 kHz to 20 MHz has been gotten from physical impacts, to be specific multipath flag

Proliferation and regular link misfortunes. Estimations at a test connect with surely understood parameters demonstrate great assertion between reproduction and estimation comes about. Besides, the relevance of the model to true systems has been illustrated. The introduced demonstrate offers the likelihood to do examinations for various system topologies and to think about their effect on PLC-framework execution by methods for reenactments. Other than lessening profiles, itemized models for singular connections can be set up. Moreover, reference models of run of the mill channels can be characterized for institutionalized PLC-framework assessment and execution correlation. This is a part of most extreme significance, e.g., for up and coming PLC-specialist organizations, with a specific end goal to have the capacity to choose the best frameworks for their applications out of different contenders.

### Parameters of 15 paths model description

Segment and model charts, this may seem disadvantageous. In any case, seeing applications, for example, reproduction based PLC-framework execution assessment, it is more imperative that the model spreads basic impacts just, i.e., utilizing all around characterized reference channels.

All things considered reference channels cover the general impedances of power line connections and cover up insignificant subtle elements, they may speak to helpful and powerful devices by and by.

In Zimmerman’s Paper, the materials were changed such as PVC, AIR and TEFLON due to their relative permittivity ( $\epsilon_r$ ) differences. The delay of a path can be calculated from the dielectric constant of the insulating material, the speed of light, and the lengths of the cables. Due to the different values of insulating material we got different  $V_p$ . Thus, we have got the different graphs. The delay of a path equation is given below:

$$\tau = \frac{d_i \sqrt{\epsilon_r}}{C_0} = \frac{d_i}{V_p}$$

**TABLE 2: PARAMETERS OF THE MODEL OF THE TRANSFER FUNCTION [5]**

$i$	Number of paths .Where the path with the shortest delay has the index $i=1$
$a_0, a_1$	Attenuation Parameters.
$k$	Exponent of the attenuation factor.
$g_i$	Weighting Factor for path $i$
$d_i$	Length of path $i$
$\tau_i$	Delay of path $i$

**Parameter of the 15 path model**

---

**Attenuation parameters**

$k = 1$

$a_0 = 0$

$a_1 = 7.8 \cdot 10^{-10} \text{m/s}$

**TABLE 3: Path-parameters**

$i$	$g_i$	$d_i/m$	$i$	$g_i$	$d_i/m$
<b>1</b>	0.029	90	<b>9</b>	0.071	411
<b>2</b>	0.043	102	<b>10</b>	-0.035	490
<b>3</b>	0.0103	113	<b>11</b>	0.065	567
<b>4</b>	-0.058	143	<b>12</b>	-0.055	740
<b>5</b>	-0.045	148	<b>13</b>	0.042	960
<b>6</b>	-0.040	200	<b>14</b>	-0.059	1130
<b>7</b>	0.038	260	<b>15</b>	0.049	1250
<b>8</b>	-0.038	322			

The above speaks to a parametric model, depicting the complex recurrence reaction of average electrical cable stations, covering every single considerable impact of the move attributes in the recurrence run from 500 kHz to 20 MHz by a little arrangement of parameters. The quantity of ways  $N$ , permits a control of the accuracy of the model, which is particularly vital for characterizing reference channels for PLC framework execution analysis. The control line multipath flag proliferation is displayed by considering  $N = 15$ . The prevailing ways of the drive reaction are adequately secured by the basic four-way show.

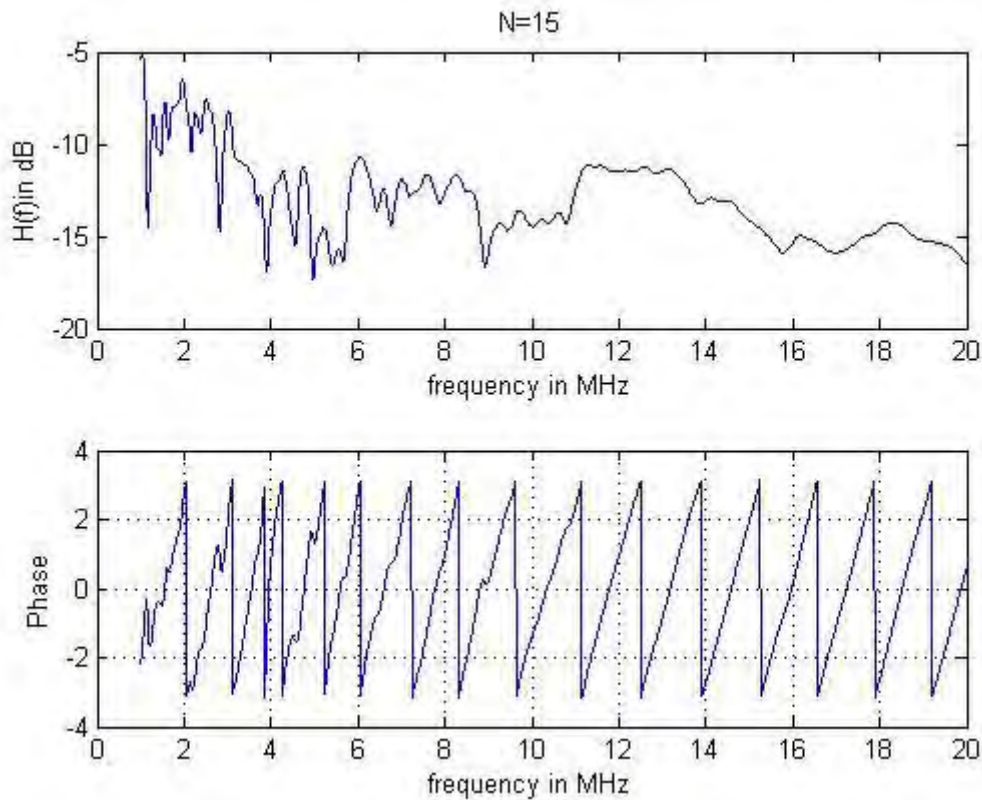


FIGURE: 15 Path Model with Amplitude Response and Phase

#### Four Path Zimmerman's Model:

The above addresses a parametric model, delineating the mind boggling repeat response of normal electrical link stations, covering each and every extensive effect of the move characteristics in the repeat keep running from 500 kHz to 20 MHz by a little plan of parameters.



The amount of ways  $N$ , allows a control of the precision of the model, which is especially key for portraying reference channels for PLC structure execution examination. The control line multipath signal expansion is shown by considering  $N = 4$ . The common methods for the drive response are enough secured by the essential four-way appear. The used parameter set which is gotten from repeat response estimations is recorded in the from the multipath show it can be watched that the debilitating keeps an eye on increase as the detachment and repeat increases.

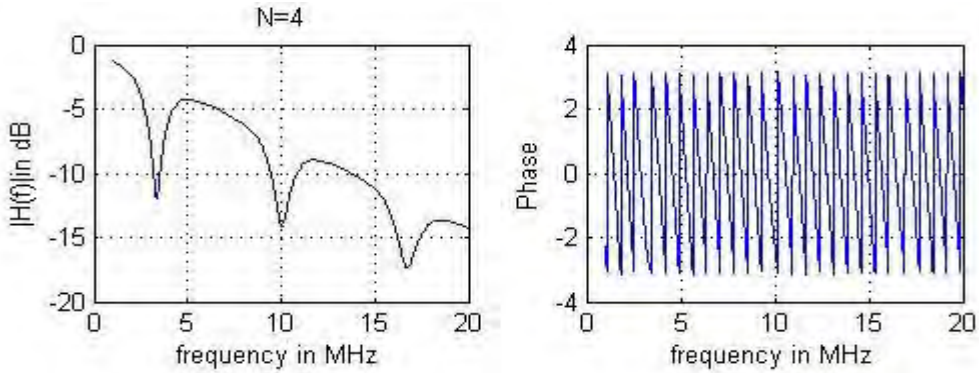


FIGURE: 4 path Model ( PVC)

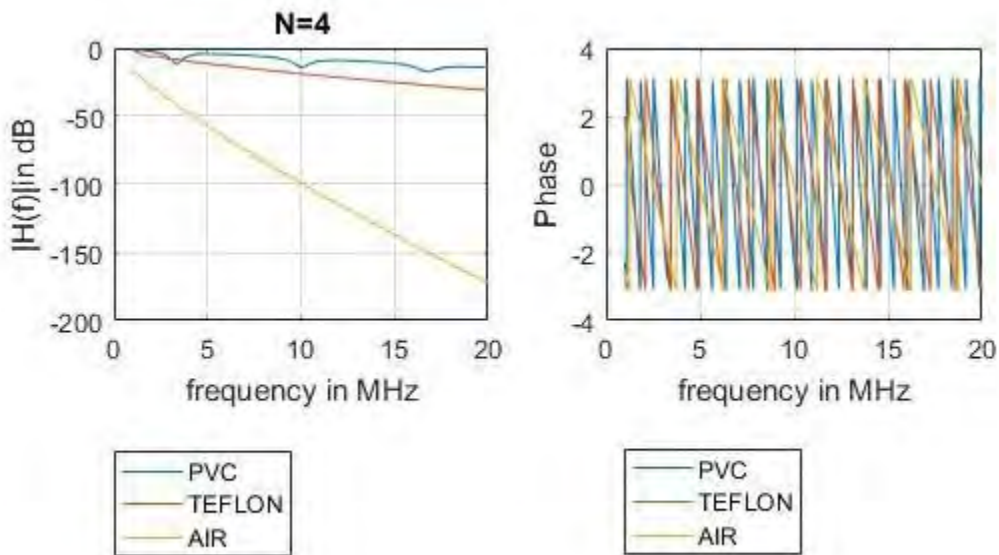


FIGURE: 4 path Model

Parameters of the 4 Path model

TABLE 4: Attenuation parameter

K=1		$a_0 = 0$		$a_1 = 7.8 * 10^{-10} m/s$	
$i$	$g_i$	$d_i/m$	$i$	$g_i$	$d_i/m$
1	.64	200	3	-0.15	244.8
2	.38	22.4	4	0.05	267.5

From The Zimmerman Equation and his paper we come up with a model of the perplexing recurrence reaction of PLC while joins for the recurrence extend from 500 kHz to 20 MHz has been gotten from physical impacts, to be specific multipath flag

Engendering and run of the mill link misfortunes. Estimations at a test connect with understood parameters demonstrate great understanding between reenactment and estimation comes about. Moreover, the materialness of the model to true systems has been illustrated. The introduced display offers the likelihood to complete examinations.

For various system topologies and to think about their effect on PLC-framework execution by methods for reenactments. Other than constriction profiles, point by point models for singular connections can be set up. Besides, reference models of common channels can be characterized for institutionalized PLC-framework assessment and execution examination. This is a part of most extreme significance for up and coming PLC-specialist co-ops, so as to have the capacity to choose the best frameworks for their applications out of different contenders.

# Chapter 4

## Result and Evaluation

### 4.1. Channel H (f):

The different electrical power line channel models accessible are the Zimmermann and Dosteret display show and the Anatory et al. show [8] The multipath display proposed by Philpps and Zimmermann is a broadly utilized model for examining the information transmission over electrical cables. Where H (f) is the recurrence reaction of the channel and the different parameters utilized as a part of condition (3.6) are given in Table.3.1. The weighting factor  $g_i$  and the length of the information transmission way  $d_i$  for different way numbers where N is the aggregate number of ways.

$$H(f) = \sum_{i=1}^N |g_i[f]| e^{g_i[f]} \cdot e^{-[a_0+a_1f^k]d_i} \cdot e^{-j2\pi f\tau_i}$$

Weighting	<i>attenuation</i>	<i>delay</i>
<i>factor</i>	<i>portion</i>	<i>portion</i>

Equation describes the signal propagation along a way by the delay partition and the low-pass trademark, i.e., the constriction expanding with length and recurrence, by the lessening segment. The weighting factor  $g_i$  abridges the reflection and transmission factors along a spread way. Because of the way that reflection focuses may show complex and recurrence subordinate esteems, is when all is said in done complex and  $g_i$  recurrence dependent. Extended estimation battles uncovered that it is conceivable to additionally rearrange the determination of the weighting factors  $g_i$  to being mind boggling, yet not recurrence subordinate. Much of the time of commonsense intrigue,  $g_i$  can even be accepted as genuine esteemed. In heterogeneous systems, frequently a few ways with practically measure up to defer exist, so it isn't remunerating to follow  $g_i$  the variables back to their physical starting points. From a multipath perspective  $g_i$  essentially depicts the heaviness of way , If we consider the long distance link, Common long-distance connections 300 m with PVC-protected underground links show considerably higher weakening, principally caused by higher misfortunes because of length and many branches (up to 15). In addition, constriction is frequently increased by profound indents caused by multipath fading. Attenuation regularly begins in a range from 10 to 30 dB at 500 kHz and may achieve estimations of more than 80 dB at frequencies of 5– 8 MHz (which is near the commotion floor of the utilized measuring gear). Fig. 4 demonstrates the estimation aftereffects of a connection in a urban local location with 12 branches providing for the most part little pieces of pads. Other than the adequacy response, the clamor floor of the connection is appeared. Clearly, the lessened flag is falling beneath the commotion floor at frequencies over 7 MHz.

## 4.2. BER VS SNR:

SNR stands for signal to noise ratio, The ratio of specific analog or digital data signals amplitude with the amplitude of noise in a transmission channel at a particular point of time. SNR is expressed logarithmically in decibels (dB). SNR is needed to measure the quality of a Transmission channel over a PLC channel. If the SNR ratio is Zero, that means the desired signal is virtually can't be changed from the unwanted noise. So the greater value of ratio is needed to isolate and eliminate the source of noise. Bit error rate (BER) means the percentage of bits with errors divided by the total number of bits that have been transmitted or received in given time period over a transmission channel. The rate is expressed as 10 to the negative power. Now by observing the SNR vs. BER (with OFDM) curve, it is seen that as the number of iterations increases the BER performance is also going to increase. Besides that if we look at the BER vs. SNR curve, it shows the system have achieved the bit error performance of .01 for SNR just for 5.7 dB for six iterations. On the other hand, the BER vs. SNR curve (without OFDM) is found that the same bit error.01, The SNR is 12.1dB. By comparing, we have come to a decision that using OFDM in PLC system gives better BER vs. SNR

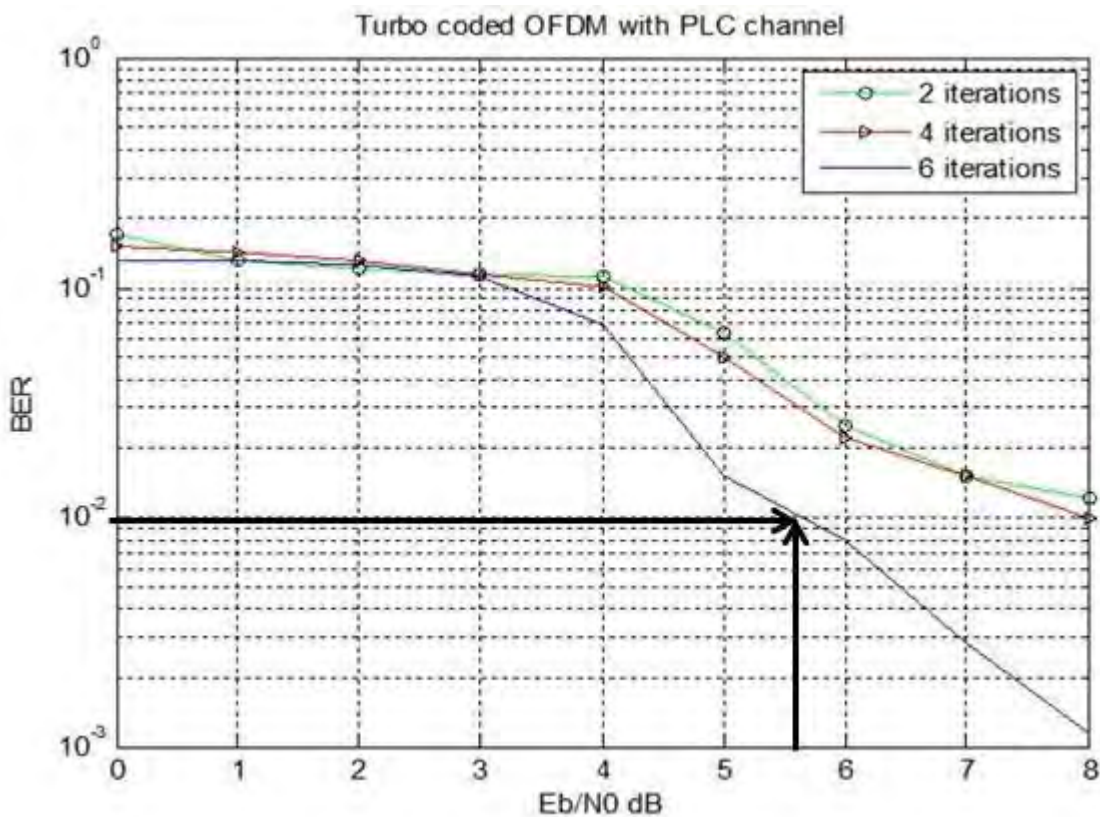


FIGURE: BER vs. SNR with OFDM

[http://shodhganga.inflibnet.ac.in/bitstream/10603/160551/16/16\\_chapter%207.pdf](http://shodhganga.inflibnet.ac.in/bitstream/10603/160551/16/16_chapter%207.pdf) Access on 21/12/2017

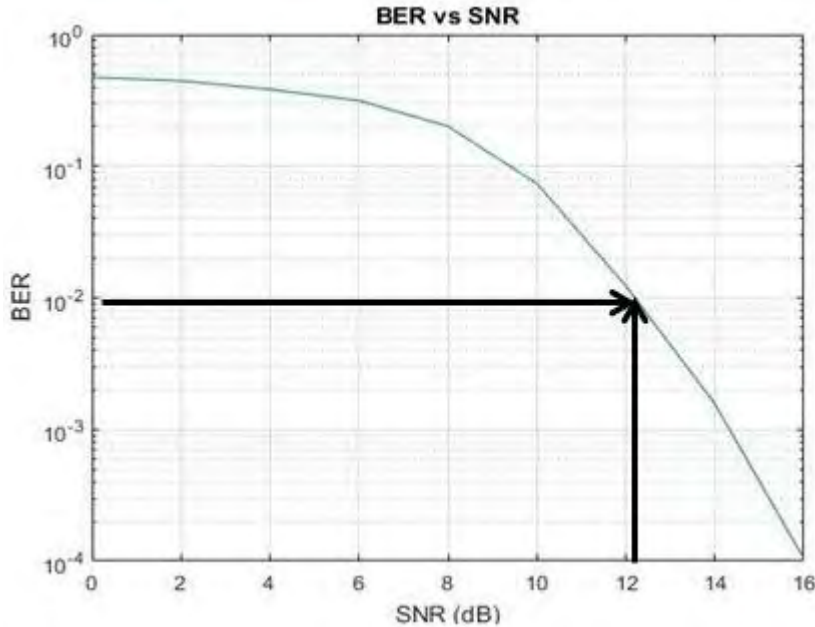


FIG: BER vs. SNR without OFDM

Since we have the waterfall curve without OFDM, we used a reference paper to see the better result which had been attached here. It was our deserved curve but we did not get it.

### 4.3. Comparison:

Continuous Phase Frequency Shift Keying (CPFSK) is a memory based modulation scheme in which phase is contained to be continuous. This is a power/bandwidth efficient signaling technique for data transmission. This process also offers some advantages in error rate performance as well as signal spectrum containment. CPFSK modulation scheme break down a large frequency into several small or low frequency packets and transmit them, that is why that is known as frequency bandwidth efficient scheme. In channel modeling system there are many impairments and effects including short-term and long-term fading in the channel but by using the CPFSK process of modulation the frequencies breaks down into several low frequency parts, as a result the fading effect gets reduced.

16-QAM, is called the 16-state quadrature amplitude modulation. The major benefit of QAM modulation variants is efficient usage of bandwidth. This is due to the fact that QAM represent more number of bits per carrier such as 16-QAM maps 4 bits per carrier. QAM system have some disadvantages like QAM modulation is more susceptible to the noise. Due to this QAM receiver is more complex compare to receivers of other modulation types in addition with that QAM uses amplitude component of signal to represent binary data so that, linearity need to be maintained and hence linear amplifier is needed which consumes more power.

PSK (Phase-shift keying) is a modulation process which transmit data by changing the phase of the reference signal. PSK system is less power consuming and also not susceptible to noise. But

this process is discontinuous and other main drawback of this system is it produce more incorrect demodulations because the error can integrate with time as the reference signal for demodulation is not fixed.

By comparing all the modulation and demodulation schemes we get to know that CPFSK gives the best performance as it is more immune to noise and continuous .

#### **4.3.1. OFDM with PLC:**

In PLC, the primary advantage of OFDM is, over single carrier schemes is ability to cope with severe channel conditions.

- 1) Attenuation of high frequencies in a long copper wire.
- 2) Narrowband interference
- 3) Frequency selective fading due to multipath.

Fading can cause poor performance in communication system because it can result in a loss of signal power without reducing the power of noise. The signal loss can be same or all of the signal bandwidth. Fading is also a problem as it changes over time. Communication systems are often designed to adapt to such impairments, but the fading can change faster than the adaptations can be made. In such cases, the probability of experiencing a fade (and associated bit errors as the signal to noise ratio drops) on the channel becomes the limiting factor in the link's performance. The effects of fading can be combated by using diversity to transmit the signal over multiple channels that experience independent fading and combining these at the receiver.

The probability of experiencing on this composite channel is then proportional to the probability that all the component channels simultaneously experience a fade, a much more unlikely event. Diversity can be achieved in time, space and frequency. There are some common techniques need to overcome signal fading include:

1. Diversity reception & transmission.
2. MIMO
3. OFDM
4. Receiver
5. Space time codes

Multipath causes multipath interference including constructive and destructive interference and phase shifting of the signal. Destructive interference causes fading where the magnitude of the signals arriving by the various paths have a distribution known as the Rayleigh distribution, this is known as Rayleigh fading. PLC uses OFDM with a CP to avoid ISI.

Frequency selective fading is a radio propagation anomaly caused by partial cancellation of a radio signal by itself, as example multipath, selective fading manifests as a slow, cyclic disturbance, the cancellation effect or "null" is deepest at one particular frequency which changes constantly and sweeping through the received audio. The coherence bandwidth

measures the separation in frequency after which two signals will experience fading. In fact fading the coherence bandwidth is larger than the bandwidth of the signal. Therefore all frequency components of the signal will experience the same magnitude of fading.

#### **4.3.2. OFDM without PLC:**

An AWGN does not give a complete description of the noise on a power line channel. The channel suffers from different forms of narrow-band interferences and impulse noise. To study impulsive noise a few of the models available were presented in the research work. The impulsive noise can significantly degrade the performance of PLC systems. Hence, to provide the impairments in the hostile channel, channel coding becomes important. To improve the effects of fading and the impulsive noise on the signal, the OFDM modulation technique was used. According to the simulation results, noise depended on time and frequency which caused deterioration in system BER and the degradation was significant at higher bandwidth and bit rates. In an incautious commotion as one of the significant difficulties which can cause major issues in OFDM-based PLC framework.

# Chapter 5

## Conclusion and suggestion for further works

The examination gives a definite review of the advance and progressions in PLC and the significant parameters of the field. Information transmission has not yet been conceivable in electric power matrices on account of various issues. In any case, with headways in innovation, it has begun to wind up noticeably a probability. Electrical cables are considered as an opposition to transmission lines and modems to give web access to the shoppers whether private or business, LV and MV of the fundamental preferred standpoint of PLC is that it doesn't require any new wiring for the usage of the framework, in this way it is practical. There has been a developing enthusiasm for the likelihood of misusing the power framework to give broadband web access to private clients. The alluring element of this thought is the nearness of a tremendous foundation in the place for control dissemination, and the infiltration of the administration could be substantially higher than some other wired option. Access to the web is getting to be as essential as access to electrical power. Since gadgets that entrance the web are ordinarily connected to an electric outlet, the unification of these two systems appears a convincing choice. Other broadband choices, for example, advanced supporter line and link modems have just 10 percent of U.S. families, despite the fact that 60 percent of family units are associated with the web. There is a gigantic open door for power line interchanges to connect this hole. There is likewise developing enthusiasm for the possibilities of reusing in-building power line links to give a broadband LAN inside the home or office. The significant favorable position offered by power line based home systems is the accessibility of a current foundation of wires and divider outlets, so new link establishment can be avoided. As a rule we can't know the topology of the circulation arrange, on the grounds that the topology is changing because of apparatuses association or detachment and in this manner we were computed exchange elements of electrical cable demonstrating for various topologies. From the specified aftereffects of impact of associated taps on the exchange work the impact of individual branches on the subsequent exchange work is obvious.

In this research work we worked with the impulsive noise effect on the PLC system, in future further analysis of few other types of noise and mixed noise can be done. CPFSK has been used in this study work, more features and advantages of using CPFSK in PLC system can be researched in future. Using of various types of filters which can reduce the effect of noise and increase the data transmission in PLC system can be observed. Different types of wireless and wired channel can be made and observe their effect in PLC system. Investigation of more than one channel with different frequency and data transferring through PLC.



# Chapter 6

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