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Broadband Communication over Power Lines: Issues, Challenges and Opportunities

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Abstract: Broadband over Power Line (BPL) Technology offers high speed affordable, robust and reliable voice and broadband communication services to all homes connected to the power lines. This makes use of the electrical lines for transmission of data up to the last mile and there is no need of separate copper cables, short haul satellite systems, optical fibre cable and Wi-Max, Wi-Fi etc. Hence, it is suitable for deployment in rural areas for smart grid communication. Now, in view of digital global economy, digital India Mission of Government of India and emerging business opportunities, particularly in rural areas have increased the thrust for research in power-line communication, worldwide.

The objective of this paper is to present a review of Broadband Power Line Communication in term of working, features, advantages, limitations, deployment, challenges and emerging opportunities.

Keywords: BPL, PLC, DSI, broadband, communication

I. INTRODUCTION

Broadband over Power Lines (BPL) uses Power Line Communications (PLC) technology provides broadband voice and data services over ordinary power lines. BPL is also sometimes called Power-line Communications (PLC). Many people use the terms PLC and BPL interchangeably. The FCC chose to use the term BPL for consumer applications.Every home connected to electrical power lines can be part of the BPL communication network and use broadband digital communication services just by plugging in the BPL modem connected to a computer or to any other suitable communication device to access high speed internet and enjoy voice and data communication. For this, the BPL user does not need copper cable, short haul satellite systems, optical fibre cable and wireless technologies such as Wi-Max, Wi-Fi etc. Hence, BPL technology presents a cost-effective option for broadband communication compared to other existing systems because it uses an existing infrastructure (power-line network) connecting every home.

On April 23, 2003, the FCC adopted a Notice of Inquiry (Inquiry)1, expressing enthusiasm aboutthe potential of the BPL technology to enable electric power lines to function as a third wire intothe home, and create competition with the copper telephone line and cable television coaxialcable line. The Commission subsequently issued a Notice of Proposed Rulemaking (NPRM)2 inFebruary 2004 based on the comments received in response to the Inquiry. Both the Inquiry andNPRM discusses two types of BPL: 1) Access BPL, and 2) In-house BPL.

II. BPL ARCHITECTURE

A. BPL Building Blocks

Access BPL equipment is comprised of three elements:

(1) Injectors: BPL injectors are connected to the Internet backbone via fibre-optic or digital signaling level 1 (DS1), or faster, phone lines. The injectors interface to the MV power lines feeding the BPL service area. MV power lines may be located overhead on utility poles or underground in buried conduit. Overhead wiring is attached to utility poles that are typically 10 meters above the ground.

Three-phase wiring typically comprises an MV distribution circuit running from a substation. These wires may be physically oriented on the utility pole in triangular, horizontal, or vertical configurations. This physical orientation may change from one pole to the next. One or more phase lines may branch out from the three-phase lines to serve a number of customers. A grounded neutral conductor is generally located below the phase conductors and runs between distribution transformers that provide LV electric power for customer use.

BPL signals may be injected onto MV power lines:
(a) between two phase conductors;
(b) between a phase conductor and the neutral conductor; or
(c) onto a single phase or neutral conductor.

(2) Repeaters: signal attenuation or distortion through the power line may require the BPL service provider to employ repeaters to maintain the required signal strength and fidelity. Figure 7 (shown below) illustrates the basic BPL configuration, which can be deployed in cell-like fashion over a large area served by existing MV power lines

(3) Extractors:Extractors (Fig. 1) provide the interface between the MV power lines carrying BPL signals and the customers within the service area.

BPL extractors (Fig. 2) are usually located at each LV distribution transformer feeding a group of homes. Some extractors boost BPL signal strength sufficiently to allow transmission through LV transformers and others relay the BPL signal around the transformers via couplers on the proximate MV and LV power lines. Other kinds of extractors interface with non-BPL devices such as WiFi™ that extend the BPL network to the customers' premises.

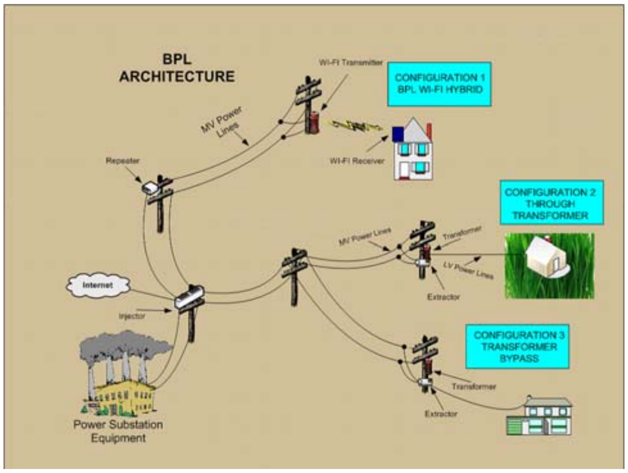

Fig. 1 access BPL building blocks

Fig. 2 BPL Extractor

For long runs of MV power lines, BPL modems use silicon chipsets specially designed to handle the workload of extracting data out of an electric current. These modems are capable of handling power noise on a wide spectrum. BPL modems are roughly the size of a common power adapter and plugs into a common wall socket and an Ethernet cable running to computer finishes the connection. There are various approaches available as far as last mile solution for BPL is concerned. While some carry the signal in with electricity on the power line, others use wireless links on the poles to send the data wirelessly into the homes. The BPL Modem simply plugs into the wall and then into subscribers' computer. These modems are capable of speeds comparable to DSL or cable modems.

B. Advantages of BPL over other connections

1) Wide, spread and extensive infrastructure that is already available in remote areas in terms of electrical cables, allow easy access to internet with relatively very little equipment investment, particularly in areas where limitations in terms of having a cable or DSL connections are experienced by service providers.
2) Maintenance costs of BPL are also extremely low.
3) In nutshell, cost effectiveness and large scale broadband penetration are two distinct and unique advantages of BPL.
4) In addition, installation time is less than 45 minutes and rural penetration is relatively easy.
5) BPL is a good solution for Home Networking than other available solutions as no other infrastructures is required.
6) Access BPL systems have the potential in increasing the availability of broadband services to homes and businesses.
7) BPL systems have been increasing the competitiveness of the broadband services market.
8) BPL systems have also been identified as a means of improving the quality and reliability of electric power delivery and creating a more intelligent power grid. BPL technology could allow utilities to more effectively manage power, perform automated metering and monitor the existing power grid for potential failures
9) Now in view of digital global economy and digital India Mission of GOI, business opportunities, which have increased the research in power-line, communications the last decade. The research has initially been focused on providing, services related to power distribution such as load control, meter reading, tariff control,remote control and smart homes. These value-added services would open up new marketsfor the power utilities and hence increase the profit. The moderate demands of theseapplications make it easier to obtain reliable communication. Firstly, the information bit, rate is low, secondly, they do not require real-time performance.
10) Power line channel surely is a cheap way to communicate, since it doesn't require any additional wiring. It can support the social needs for access to digital services from anywhere at any time. Despite these difficulties several communication techniques have been selected for applied on power line channel and there is a wide list of references in relevant conferences and journals. The market of PLC devices will continue to grow in the near future with the integration of PLC interfaces like Wi-Fi, Ethernet, cable T.V. and so on, to fulfil the aim of both network engineers and telecommunication engineers.
11) Every household would be connected at any time andservices being provided at real-time. Using the power-line as a communication mediumcould also be a cost-effective way compared to other systems because it uses an existinginfrastructure, wires exists to every household connected to the power-line network.
12) In BPL technology, by combining the technological principles of Radio, wireless networking, and modems, a mechanism has been created where one can plug in his computer into any electrical outlet in his home to have instantaneous access to high speed internet.
13) BPL uses the existing power grid infrastructure to provide high-speed, broadband Internet access to homes and businesses. It is a new innovation based upon existing Power-Line Communications (PLC) technology.

C. History of BPL

Earlier, BPL was limited to internal services related to power distribution such as load control, meter reading, tariff control, remote control and smart homes. Then, the information bit rate was low and there was no need for real-time performance.

Electric company linesmen have also used the transmission lines by tapping the wire with specialized radios for communicating with each other along through the line. On a smaller scale, in-home intercom systems have been available for many years that use the electric lines of the building to deliver audio data over the buildings electrical lines.

These historical uses of power-line communication typically operated at low frequencies, generally below 600 kHz. Modulation techniques vary for traditional PLC, from FM to Wideband.

The capability of using the electrical supply networks for telecommunications has been known since the 1800s. In the US, during the 1920s, AT&T was awarded several patents for these technologies. During the 1930s, ripple carrier signaling (RCS) began to operate on power lines. RCS used the frequency range 125 Hz - 3 KHz with amplitude shift keying (ASK) modulation. RCS provided data rates in the order of a few bits per second but this was sufficient for the load management and automatic reconfiguration of power distribution networks that were the most important tasks performed using RCS. In the 1950s, power utilities were using low frequencies (<1 kHz) to send control messages to equipment on the power grid. By the 1980s, bi-directional communications in the 5 – 500 kHz band were being used. Following these narrowband, low-data-rate BPL applications, broadband BPL started to develop and today commercialized products for LAN applications and Internet access are becoming more widely available.

BPL is an interdisciplinary topic that includes: antennas and propagation, power engineering, electromagnetic compatibility, telecommunications, and others. The FCC categorizes the new low-power unlicensed BPL systems into two general types: (1) Access BPL systems that couple RF energy onto medium and low voltage power lines, and (2) In-home BPL networks, which use electrical outlets available within a building or home to provision a LAN.

D. Current Trends

However, research and advancements have brought about lot of changes in BPL. BPL technology has evolved rapidly over the past few years. This has been possible due to worldwide technological developments and innovations on broadband over power lines. Still, there is a need of BPL technologies that can offer high speed voice data and internet access to communication starved rural homes through the commonly accessible electrical paths, thus eliminating the need of transmission of data over last mile through copper cable, short haul satellite systems, optical fibre cable and wireless technologies such as Wi-Max, Wi-Fi etc.

BPL is now being seen as an affordable alternative to various other communication technologies, particularly in rural populace of Asia, in view of growing demand of communication network after the global digital transform and Digital India mission launched by Government of India.

Electric companies have deployed technologies such as SCADA (Supervisory Control and Data Acquisition) over powerlines to perform simple command/control functions at remote locations, such as sub-stations, using the electric transmissions lines as the medium.

While the technology appears promising, there are a number of issues with respect to its operation as well as the possibility of it interfering into radio services in other frequencies range.

A number of foreign governments including USA, Australia, Austria, China, Finland, Hong Kong, Hungary, Ireland, Italy, Korea, Japan, Netherlands, Poland, and Switzerland are currently studying BPL technology or have permitted equipment trials. The outcomes have shown mixed results and have led some administrations to ban BPL systems while other administrations have allowed deployment under various conditions. A number of administrations have suspended BPL trials pending international developments.

According to the Institute for Electronic and Electrical Engineers (IEEE)iv and the International Telecommunications Union (ITU) the United States is lagging behind other countries in the deployment of broadband telecommunications networks. In December 2005, the ITU documented (see Figure 1) that among the top 20 worldwide economies, US broadband deployment ranks in the bottom 20%. In the US, broadband services to the home are largely provided by cable modems and digital subscriber loop (DSL) services. These broadband services operate mostly in the range of 1 - 6 megabits per second (Mb/s) downstream to the user, but only 750 kilobits per second (Kb/s) or less upstream. In most of South Korea, residents have access to 50 - 100 Mb/s, which in many cases is symmetrical. South Korea achieved this infrastructure through a government policy supporting deregulation, competition and Subscribers per 100 population investment.

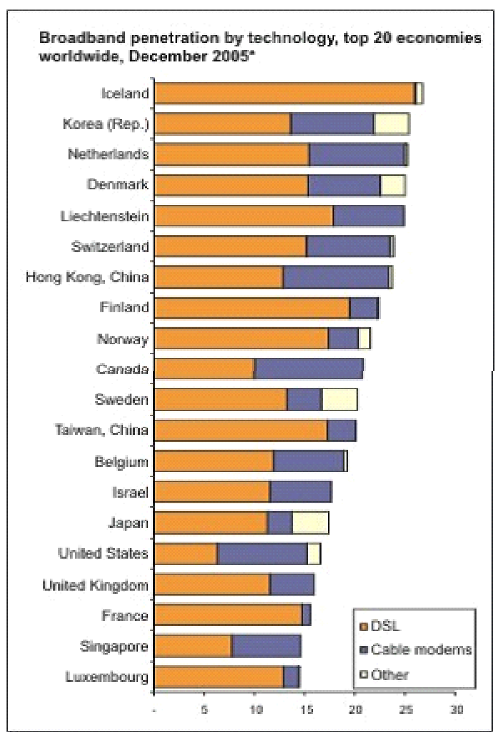

Fig. 3 ITU Broadband Adoption.

E. Electromagnetic Interference

The components of BPL interference include:
(1) Sky Wave (3-30 MHz);
(2) Space Wave (0.1-30 MHz); and
(3) Ground Wave (0.1-3MHz).

Ground waves and sky waves raise the possibility of interference being caused to radio services at distances of tens or even hundreds of kilometers due to the cumulative effect of a large number of BPL systems. International shortwave broadcasts (e.g., Voice of America, BBC World News) are also threatened by the potential for increase in the noise floor. The ability to achieve satisfactory communications depends on the ratio between the wanted signal and the noise. The noise consists of four components:
(1) internally generated receiver noise;
(2) atmospheric;
(3) man-made; and
(4) galactic or cosmic.

The usual ITU-R standard for non-safety-of-life radiocommunication data services is an Interference-to-Noise (I/N) ratio of –6 dB, which has the effect of raising the noise level no more than 1 dB.

The creation of electromagnetic interference is an obstacle that BPL needs to overcome in order to flourish as a successful technology. Around the world, BPL installations are being tested to verify that their radiation levels do not exceed authorized limits. In the United States, the National Telecommunications and Information Administration (NTIA) has completed, but not released, a study of the cumulative effects of BPL system deployments in major cities around the world on the users of HF spectrum.

F. Security Issues

Data transmitted over a BPL system needs to be encrypted if interception by other users on the same power network is to be avoided. BPL Access systems use a shared communication medium where multiple (e.g., 5 or more) homes are associated with a single-power transformer. BPL signal propagation operates in a LAN-like manner that makes detection and interception of neighboring transmissions simple. A BPL system can also suffer interruption or degradation of service by the operation of local HF-transmitting stations in a manner that produces results that are similar to a denial of service attack. Security requirements are currently being addressed by standards committees in the IEEE (See Section 4.5) and other standards organizations. Security specifications produced by the HomePlug Powerline Alliance (See Sections 4.2, 4.3) provide for the use of either 56-bit Data Encryption Standard (DES) or 128-bit Advanced Encryption Standard (AES).

Japan also adopted competitive policies leading to widespread 50- to 100-Mb/s symmetrical operations with low prices. Japan is rapidly deploying symmetric optical fibre networks connected directly to the home. Gigabit per second (Gb/s) availability to Japanese homes began in 2005.

In April of 2003 the FCC issued a Notice of Inquiry (NOI) titled: "Inquiry Regarding Carrier Current Systems, including Broadband over Power Line Systems."vi in the notice the FCC identified BPL as a new type of carrier current system that operates on an unlicensed basis under Part 15 of the FCC's rules.

BPL systems use the existing electrical power lines as a transmission medium to provide high-speed telecommunications capabilities by coupling Radio Frequency (RF) energy onto the power line. In the NOI, the FCC proposed that "because power lines reach virtually every community in the country, BPL could play an important role in providing additional competition in the offering of broadband infrastructure to the American home and consumers".

Additionally, the NOI offered that "BPL could bring internet and high-speed broadband access to rural and underserved areas, which often are difficult to serve due to the high costs associated with upgrading existing infrastructure and interconnecting communication nodes with new technologies." Thus, the FCC has identified that BPL has the potential to become an effective means for "last-mile delivery of broadband services and may offer a competitive alternative to digital subscriber line (DSL), cable modem services, satellite, Wireless Fidelity (WiFi™), fibre optic, and other high speed internet access technologies".

The FCC received approximately 5,000 comments from the NOI and subsequently on October 14, 2004 issued "Amendment of Part 15 Regarding New Requirements and Measurement Guidelines for Access Broadband Over Power Line Systems Carrier Current Systems, Including Broadband Over Power Line Systems.vii" This ruling placed the United States under the most liberal BPL regulatory environment found anywhere in order to encourage the rapid deployment of BPL systems.

III. BPL DEPLOYMENT IN INDIA

Many rural residents and rural entrepreneurs in India don't have access to DSL, FTTX, Wireless, cable or other telephone medium. But mostly rural users in India have the power lines. BPL technology is desirable option for those residents who want to get broadband service. On the urban side, BPL may be used as another cheaper technology for broadband services. BPL for broadband application may be considered an effective and less costly solution as access network. The Broad Band Over Power Line communication network technologies are new for Indian telecom network and will grow extensively in near future.

A. Challenges

Because of enormous variations in the physical characteristics of the electricity network and virtual absence of international standards make the provisioning of service far from being standard and a repeatable process.

Besides, the amount of bandwidth that a BPL system can provide compared to cable and wireless is in question. The issues being faced by BPL is that power lines are inherently very noisy due to high energy that they carry. Thus, turning on or off every time of any electrical device introduces a click into the line. And this becomes quite predominant in case of energy saving devices which introduce quite noisy harmonics into the line. The system has thus to be designed to effectively deal with these natural signaling disruptions.

Another major issue is signal strength and operating frequency. The system is expected to use frequencies of 10 to 30 MHZ. Since power lines are unshielded and act as antennas for the signals they carry, they have to interfere with short wave radio frequencies over which BPL operates. And this interference becomes quite perceptible in cases where the antennas are physically close to the power lines. However, this interference considerably diminishes and is barely perceptible where the antennas are moderately separated from the power network.

It is not yet clear completely that the deployment of operational BPL systems will not cause other problems like:

1) Compatibility problems with other users of the radio spectrum,
2) RFI related issues with other users of the spectrum,
3) Signal attenuation,
4) Signal boosting and repeater design,
5) Coordination among Telecom & Power service providers,
6) Security issues in adoption of Internet Services,
7) LV transformers act as a low-pass filter, allowing electricity through it with low losses at low frequencies but not higher frequencies etc.

B. Opportunities

Higher density of homes per transformer in overseas countries makes their power grids more efficient for BPL deployment. In the U.S., there are 5-6 houses per transformer, requiring more hardware to provision large communities. In Europe and Asia there are 200-300 houses per transformer, requiring much less hardware to service large communities. Europe has had commercial deployments for over two years. The prevailing trend in Europe is for utilities to deploy BPL as a “developer” with open access. The big differences are that utilities abroad tend to be less sensitive to capital investments in the telecom market and lower broadband penetration rates to date in Europe present a greater upside.

C. International Standardization

Interoperability that ensures that products from different vendors work welltogether to create healthy competition in the marketplace, accelerate technical innovation and ensure that customers get the best products at the best price has been one of the key issues confronting the power line industry.

Unfortunately, incompatible PHY/MAC standards led to the creation of multiple industry alliances. However, realizing that an altogether different approach was needed toaddress the issue of interoperability in a comprehensive manner, a number of companies started an effort inside ITU-T to create a unified G.hn networking standard that would bring three key advantages;

a) Would unify the power line networking industry and resolve the interoperability problem.

b) Would unify the power line, phone line and coaxial networking industries to create single market.

C) Would be “Next Generation Standard” that would bring performance levels significantly higher than what is available today.

In a landmark development, on Dec 12th 2008, ITU-T announced theadoption of draft G.hn standard (now officially called G.9960) as the international standard for networking over power lines, phone linesand co-axial cable.

The very factthat ITU-T G.hn’s single-PHY/MAarchitecture ensures full multi-vendor interoperability, and the factthat the same standard can operate over multiple wires (power lines,phone lines and coaxial cable) is expected to make G.hn as thedominant and acceptable standard for wired home- networking industry.

D. Conclusion, Recommendations and Future of BPL

In a Country like India where broad band penetration is extremely low and the costs of laying down copper cable or providing short haul satellite forproviding broad band for its final leg of journey is very high, providing broad band over power lines holds a great promise, provided issues relatingto interference etc. are sorted out. Even in advanced Countries like USA,Europe etc.the larger issues of interference remain unaddressed because of absence of stringent regulatory measures.Even in the absence of these regulatory measures, BPL is gaining ground in these Countries despite strong protestsfrom those agencies which are vulnerable to interference because of BPL.

In our Country where serious financial constraints exist in terms of heavy investments to be made for laying copper or installing satellite as a mode of final broad band transmission, giving serious consideration and priority to BPL would be worthwhile, while addressing other pertinentIssues.

Another great potential that BPL holds in future is that it can be used as a backhaul for wireless communications, for instance by hanging Wi-Fi access points or cell phone base stations on poles, thus allowing end users within acertain range to connect with the equipment they already have.

Besides, low maintenance costs and lesser installation time make BPL aworth technology for increasing broad band penetration.

The Broad Band over Power Line communication network technologies are new for Indian telecom network and will grow extensively in near future forhigher capacity applications e.g. Triple Play services (telephony, data andTV etc.).

Also, BPL is a better option with less cost for network operators.BPL is already on the scene with commercial products readily available.Green Energy technologies like Solar, Wind etc. may be used as Power Line solutions. Combination of BPL with FTTX, DSL, PON etc. may beeconomical solution for access networks in future.

Internet signals using a fibre are dropped at medium voltage using a device called “head end” Once the data is dropped onto the medium voltage lines, it cannot travel too far before it degrades. To overcome the problem of degradation of data before it reaches its final customer destination in a healthy condition, special devices which act as repeaters are installed on the medium voltage lines to amplify the data for further smooth transmission. Finally, internet is accessed by the end user using the plug-in BPL modem.

IV. POWER LINE COMMUNICATION (PLC) TECHNOLOGY

Many powerline devices use Orthogonal Frequency Division Multiplexing (OFDM) to extend Ethernet connections to other rooms in a home through its power wiring. Adaptive modulation used in OFDM helps it to cope up with such a noisy channel as electrical wiring.

Accepted international standard ITU-T G.hn for high speed local area networking over existing home wiring (power lines, phone lines and coaxial cables) uses OFDM with adaptive modulation and Low Density Parity Check (LDPC) FEC code.

Thus, PLC technology based on OFDM technique with adaptive modulation is quite consistent with envisaged ITU standards regulating BPL functioning. In order to achieve high bandwidth levels, BPL operates at higher frequencies than traditional power line communications, typically in the range between 2 and 80 MHz.

The modulation technique of choice for BPL is Orthogonal Frequency Division Multiplexing. OFDM is superior to Spread Spectrum or Narrowband for spectral efficiency, robustness against channel distortions, and the ability to adapt to channel changes.

BPL systems function by coupling radio frequency energy to the existing electrical power lines. For deliverance of high speed data communication to customers, technology is based on high density advanced modulation using Orthogonal Frequency Division Multiplexing (OFDM) modulation technique. To ensure that download and upload speeds are customer specific, data transmission is made configurable. The system is capable of working in the frequency band of 10-30 Mhz, amidst harmonics and distortions in the supply on line so that problems of noise and power quality do not arise. The strength of signal should not be less than 30 dB in any case throughout the network. This is achieved by optimizing the usage of repeaters.

PLC communication technology uses High Density Advanced Modulation at each sub carrier of the OFDM signal. It uses the highest number of sub carriers (1536) for any technology used in any wire communications at each of the possible operation modes (10, 20 and 30 MHz). In this technology, a modulation density of 2to 10 bits per sub carrier is added. This technology ensures highest quality communications even in the face of interference and this is particularly achieved by adapting number of bits for each and every carrier in real time to obtain high reliability and maximum performance. The number of bits to be adapted for each and every carrier depends upon the condition of the transmission medium and the signal received. As a consequence of using high density configurations, PLC delivers speeds of up to 200 Mbps throughout data journey for bandwidth hungry applications like BPL.

PLC is based on OFDM technique mainly because of immunity of OFDM towards interference which is an issue of serious nature encountered while transmitting data over mediums such as power lines. OFDM is not a new modulation technique and is being used in many other communication systems such as ADSL,VDSL,DAB,DVB etc. Besides implementation of OFDM modulation in PLC results in highest level of spectral efficiency and performance of any wireline communication technology in the market.

OFDM Modulation

Orthogonal frequency-division multiplexing (OFDM) is a frequency multiplexing scheme utilized as a digital multi carrier modulation method. In this technique, a large number of closely spaced orthogonal sub carriers are used to carry data. The data is further divided into several data cannels, one for each sub carrier. Each sub carrier is then modulated with a conventional modulation scheme. Low symbol rate helps in maintaining total data rates similar to conventional modulation schemes in the same range of bandwidth.

The orthogonality of sub carriers in OFDM scheme enables it to achieve distinct advantages over conventional modulation schemes in that it eliminates serious issues of cross talk and interference between sub channels. Besides, inter carrier guards are not required in OFDM scheme. OFDM technique has acquired added significance in broad band internet access because of its ability to deal with issues of attenuation of high frequencies, narrow band interference and frequency selective fading. The overriding feature of OFDM is that in this technique many slowly modulated narrow band signals rather than one rapidly modulated wide band signal is used and this helps in simplification of channel equalization.

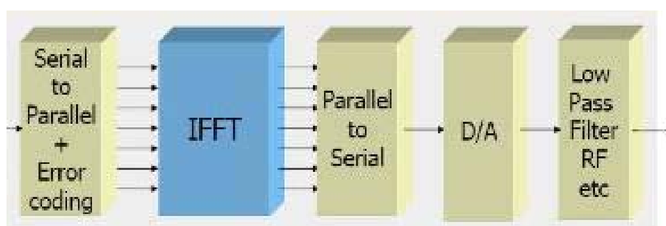

Fig. 4 OFDM Transmitter Block Diagram

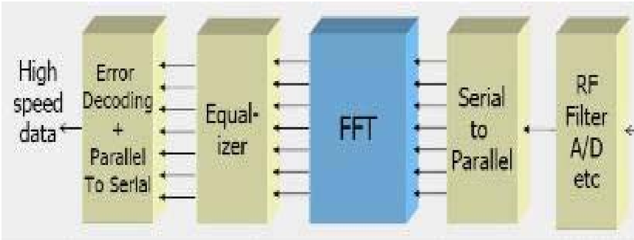

Fig. 5 OFDM Receiver Block Diagram

This project is about GRIDNET - Powerline Communication over the low-voltage grid, which has interested several researchers and utilities during the last decade, trying to achieve higher bit-rates and more reliable communication over the power lines. In the last decade, there was a large growth in small communication networks in the home & in the office places. Several computers & their peripherals interconnected together resulting the network to expand globally to the state of Internet.A number of networking technologies are invented which purely concentrates on home networks. But users are limited due to its nature of high cost. Some are over engineered or difficult to install in per-existing buildings. This report is based on one such communication medium, which has a very high potential growth. i.e., the power line, which give rise to power line carrier communication.

Power line carrier communication refers to the concept of transmitting information using the mains as a communications channel.Power Line Carrier communication systems consist of a high frequency signal injection over the electrical power lines. This kind of technology has been used since the 1950 decade in order to provide signaling and ripple control in high voltage lines, at transmission level. In the last years, the interest for this technology has suffered a revival because the impressing increase of the mobile telecommunications has brought a big development in transmission technologies for this kind of communications. In particular, new modulation technologies used for wireless communication are especially suitable for PLC communication and make massive data transmissions possible. Besides, the opening of the market, the need to integrate Distributed Energy Resources (DER) and the increase of the power supply demand create a new scenario in which the approach of the energy distribution system has to change.

In such a scenario, the distribution system needs to be automated in order to give a satisfactory response to the problems that will eventually appear. The actual automation ratio of the Spanish distribution system is of approximately a 2% or 3% and the prevision is that it should increase to more than a 50% in the following years. Currently PLC communications can be broadband as well as narrowband and both cases present successful transmissions. In the case of Narrowband PLC there are the CENELEC standards EN50065 and EN50065-1, for signals between 3 kHz and 148 kHz over low voltage public and/or private grids. For Broadband PLC, European Commission funded OPERA IST and Opera 2 projects are working towards the standard development currently. In this case the used signals range from 1MHz to 34MHz with a bandwidth between 10 and 30MHz and a bit rate of 200mbps. The results of the both above mentioned projects will feed the ETSI Broadband Power line Telecommunications standard. Thus, it would be possible to think of an automated distribution scenario with PLC used as a communication link used for multiple applications. Our project mainly aims at applicability of power line carrier communication techniques towards home networking. Communication over the power line will have the following advantages.

The modern electric grids are well maintained & far superior to any of the wired communication networks. No of electrical consumers are higher than telephone, cable or other wired communication customers. This will give a high potential market for the investors. The analog spread spectrum waves have much greater bandwidths or carrying capacity than the digital switched systems.

Block Diagram

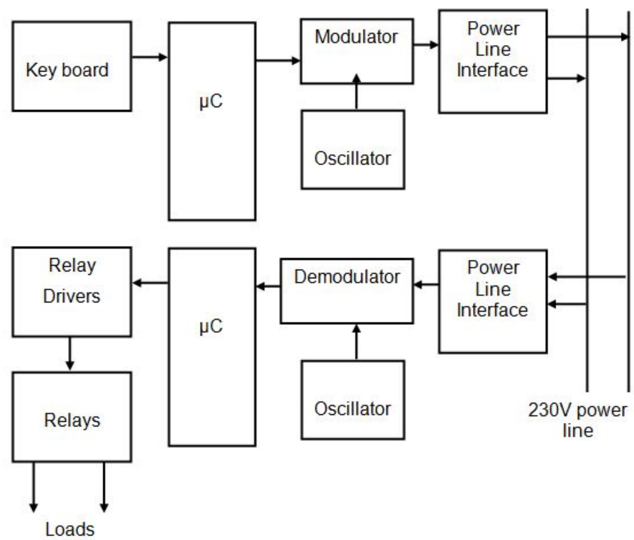

Fig .6 OFDM Receiver Block Diagram

A basic PLC transmitter consists of five main sub-stages: a data source, a serial to parallel converter, a carrier frequency oscillator, a digital modulator and an interfacing circuit. The transmitter function is to modulate the data signal using one of the digital modulation techniques and then to load it to the power-line network. A PLC receiver is connected to the power-line network via an interfacing circuit. A preamplifier is used to compensate for the losses in the power lines. The amplified signal is demodulated to recover the original data, and then passed to a data sink.

Key Board

This section is used to enter the code of the device to switch ON / OFF. This section consists of more than one push to on switches; each of them will be allotted with a unique number. The key board will be scanned and encoded with the help of a microcontroller.

Microcontroller

The microcontroller controls the entire actions of both transmitter unit and receiver unit. The microcontroller in the transmitter unit scans the key board in order to detect the closed key and encodes the key value. The key value will be a hexadecimal code in the parallel format. The µC in the transmitter also performs the parallel to serial conversion so that the code can be transmitted over a wireless channel. The microcontroller in the receiver unit will perform a serial to parallel conversion in order the retrieve the code of the closed key. Also, the microcontroller in the receiver unit analyzes the received code and switches ON/ OFF the load according to the received code.

Oscillator

This section generates the high frequency carrier wave which is used to modulate with the data. The frequency is set around.

Modulator

This section modulates the serial data out of the microcontroller with the carrier waver. The OOK modulation is usually used because it provides a reliable and yet a simple system. OOK modulation is a special case of ASK (Amplitude Shift Keying) modulation, where no carrier is present during the transmission of a zero.

Demodulator

This section demodulates the data from power line carrier signal. A phase locked loop will be the best choice.

Power Line Interface

An interfacing circuit is used to isolate the 220 V/50 Hz from the low voltage environment.

Relay and Relay Drivers

The relays are used to isolate both the controlling and controlled equipment. The relay is an electromagnetic device, which consumes comparatively large amount of power. Hence it is impossible for the interface IC to drive the relay satisfactorily. To enable this, a driver circuitry, which will act as a buffer circuit, is to be incorporated between of them. The Driver circuitry senses the presence of a “high” level at the input and drives the relay from another Voltage source. Here the relay is used to switch the electrical supply to the appliances.

Power Supply

The system requires a regulated voltage of +5V along with an unregulated 12V supply for relay. These low voltages are obtained from the domestic supply with the help of this block.

Background

Historically, power utilities have used alternating current (AC) power line distribution facilities to carry information by coupling radio frequency (RF) energy to AC electrical wiring in houses or buildings. In the past, these devices have operated on frequencies below 2 MHz with limited communications capabilitiesFootnote1. Due to power line characteristics, it has been difficult to achieve dependable high-speed communications. However, technological advancements have resulted in the development of new systemsFootnote2 which have overcome these technical obstacles. Trials have demonstrated thathigh-speed communication voice and data services can be achieved using the existing medium-voltage (MV) andlow-voltage (LV) power distribution grid.

BPL technology has evolved rapidly over the past two years. While the technology appears promising, there are a number of issues with respect to its operation as well as the possibility of it interfering into radio services in the 2-80 MHz range.

The Department has received numerous enquiries from power companies, manufacturers and other organizations regarding BPL technology. We are working with the industry to understand the compatibility of BPL technologies and applications with other radio services. There have been a limited number of BPL trials in Canada where the Department has performed preliminary analyses on BPL emissions.

Since power lines reach virtually every home in Canada, BPL may provide an additional option to delivering broadband services to rural and urban areas. Furthermore, the introduction of BPL fits within the Government of Canada's Federal Broadband project, which was developed to narrow the "digital divide" between Canadians living in urban, rural and remote communities.

Since BPL systems can transmit and receive intelligence by wire, they may be considered as transmission facilities under the Telecommunications Act. Therefore, BPL operators may ultimately be subject to the regulatory requirements of the Act and to the oversight of the Canadian Radio-television and Telecommunications Commission (CRTC).

In considering BPL under the Radiocommunication Act, the Department can give regard to the policies outlined in section 7 of the Telecommunications Act, which includes:

(a) to facilitate the orderly development throughout Canada of a telecommunications system that serves to safeguard, enrich and strengthen the social and economic fabric of Canada and its regions;

(f) to foster increased reliance on market forces for the provision of telecommunications services and to ensure that regulation, where required, is efficient and effective; and,

(g) to stimulate research and development in Canada in the field of telecommunications and to encourage innovation in the provision of telecommunications services.

The United States (U.S.) Federal Communications Commission (FCC) has carried out a consultation to implement BPL and recently established technical and operational rules for BPL systems.Footnote3 Considering the similarities between the U.S. and Canadian power distribution grids BPL manufacturers will view Canada and the U.S. as a common marketplace.

The Department is seeking comments on the technical and operational criteria which will facilitate the deployment of BPL systems in Canada with minimal impact on radiocommunication services.

V. GENERAL DESCRIPTION OF BPL SYSTEMS

BPL systems are comprised of different components which function together to deliver broadband services to customers. Briefly, data is carried by fibre optic or telephone lines to avoid high-voltage (HV - greater than 69 kV) transmission power lines. The data is injected onto the MV power distribution grid and special electronic devices, known as repeaters,re-amplify and re-package the signal because the signal loses strength as it travels along the MV power line. Other technologies are used to detour the signal around transformers. The signal is delivered directly into homes via their regular electric current.

The Power Distribution Grid

The power distribution grid is made up of a number of components aimed at delivering electricity to customers, and includes overhead and underground MV and LV power lines and associated transformers. MV power lines carry electricity in the range of 12.5-36 kV and the voltage is decreased by step-down transformers to provide LV power to houses and buildings. In general, the LV power lines carry electricity at 120/240 volts or 347/600 volts.

A. BPL Systems

Historically, power utilities have coupled RF energy to AC electrical wiring in houses or buildings to carry information. Although simple communication was possible, these systems were not capable of delivering dependable broadband services. Recent technological advancements have resulted in the development of new systems that promise to deliver broadband services over the existing power distribution grid. These systems are comprised of Access BPL, In-house BPL, or a combination of both technologies.

Access BPL systems utilize the power distribution network, owned, operated and controlled by an electricity service provider, as the means of broadband delivery to and from premises such as the home or office. Access BPL systems use injectors, repeaters, and extractors to deliver high-speed broadband services to the end-user.

Injectors provide the interface between the Internet backbone and the MV power lines. Once the signal has been injected onto the MV power line, it is extracted to deliver the information to the end-user. Extractors provide the interface between the MV power lines which carry the signals to the customers in the service area. Extractors are generally installed at LV distribution transformers that service groups of homes. Since the BPL signal loses strength as it passes through the LV transformer, extractors are required to retransmit the signal. In other cases, couplers on the MV and LV lines are used to bypass the LV transformers and relay the signal to the end-user. At least one company has designed a third type of extractor which transmits a wireless signal directly from the MV power line to end-users.

To transmit signals over long distances, repeaters are employed to overcome losses resulting from physical characteristics of the power line.

At this time, the Department is proposing to adopt the following definitionFootnote4 for Access BPL systems:

Access Broadband over Power Line (Access BPL): A carrier current system installed and operated on an electric utility service as an unintentional radiator that sends radio frequency energy on frequencies between 1.705 MHz and 80 MHz over medium-voltage lines or over low-voltage lines to provide broadband communications and is located on the supply side of the utility service's points of interconnection with customer premises.

The Department seeks comment on the above definition and its suitability for describing Access BPL.

B. Multiple Formats of Access BPL

The Department is aware of various implementation/deployment architectures of Access BPL systems. However, the Department believes that Access BPL systems can be generally classified as either: (1) an end-to-end system, or (2) a hybrid system.

C. End-to-End Access BPL

End-to-end Access BPL systems use either a combination of MV and LV power lines or LV power lines only. These systems represent the classical architectures for Access BPL. In this case the BPL signal is injected onto and carried by the MV power line. The BPL signal is then transferred to the LV power line via couplers or through the LV transformer and delivered directly to the end user.

In the case of LV only BPL systems, the BPL signal is injected onto the LV power line at the transformer or the utility meter.

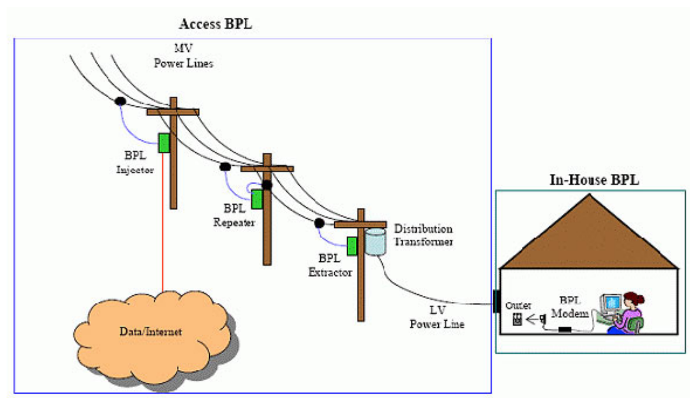

Fig. 7 Overview of End-to-End Access BPL System

D. Hybrid Access BPL

Hybrid systems use a combination of power lines and wireless transmission. For example, a hybrid system may inject a BPL signal onto an MV power line and use a special extractor to translate the signal into a wireless channel which is delivered to the end-user.

More recently, a second hybrid system has been developed. These systems capture wireless signals and inject them directly onto the LV power line. The signal is distributed using the LV power line and in-house wiring to the end-user.

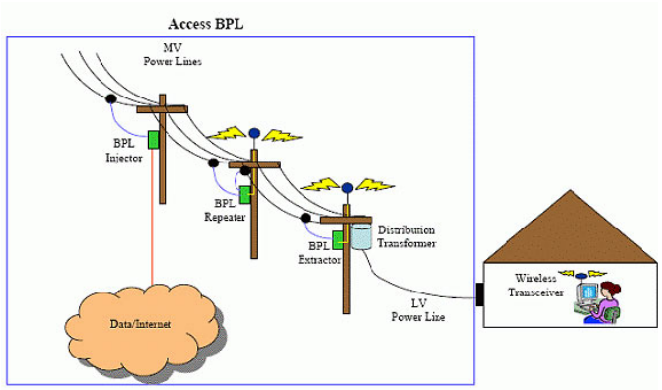

Fig. 8 Overview of Hybrid Access BPL System

As shown in Figure 2, the hybrid Access BPL system uses repeaters and extractors which are capable of transmitting and receiving wireless signals to and from end-users.

E. In-house BPL

In-house BPL systems utilize electric power lines not owned, operated or controlled by an electricity service provider, such as the electric wiring in a privately-owned building. Broadband devices are connected to the in-building wiring and use electrical sockets as access points (see Figure 1).

In-house BPL technologies are largely designed to provide short-distance communication solutions which compete with other in-home interconnection technologies. Product applications include networking and sharing common resources such as printers.

In Canada, In-house BPL equipment is regulated under Interference Causing Equipment Standard 006, AC Wire Carrier Current Devices (Unintentional Radiators) (ICES-006). Since there are established regulations for In-house BPL systems in Canada, the intention of this consultation paper is not to address these systems.

Although the main focus of this consultation is to address Access BPL systems, after reviewing the FCC's final rules in the context of the Canadian regulatory environment, the Department believes that separate definitions are required to differentiate between the two forms of BPL to prevent confusion. ICES-006 will be modified accordingly to reflect the adopted definitions for in-house systems.

At this time, the Department is proposing to adopt the following definitionFootnote5 for In-house BPL systems:

In-house broadband over power line (In-house BPL): A carrier current system, operating as an unintentional radiator, which sends radio frequency energy by conduction over electric power lines that are not owned, operated or controlled by an electric service provider. The electric power lines may be aerial (overhead), underground, or inside the walls, floors or ceilings of user premises. In-house BPL devices may establish closed networks within a user's premises or provide connections to Access BPL networks, or both.

The Department seeks comment on the above definition and its suitability for describing In-house BPL.

VI. BENEFITS AND DEPLOYMENT ISSUES OF ACCESS BPL

A. Benefits

Access BPL systems have the potential to offer a number of benefits including: (1) increasing the availability of broadband services to homes and businesses; (2) improving the competitiveness of the broadband services market; and, (3) improving the quality and reliability of electric power delivery.

With regard to increasing broadband services to Canadian homes and businesses, Access BPL systems can potentially provide high-speed data access and other broadband services to areas that do not currently have access to these services. Furthermore, Access BPL systems could potentially improve the competition for broadband services in Canada by providing another option for high-speed Internet access.

Access BPL systems have also been identified as a means of improving the quality and reliability of electric power delivery and creating a more intelligent power grid. BPL technology could allow utilities to more effectively manage power, perform automated metering and monitor the existing power grid for potential failures.Footnote6

B. Deployment Issues

International and Canadian activities have established that the deployment of Access BPL systems could potentially impact the current radiocommunication environment by creating interference to existing services. Moreover, some authorized radiocommunication service users have expressed concern about the potential interference to their respective services from Access BPL systems.

In Canada, there are a number of authorized radio services in the 2-80 MHz frequency range. These services include amateur radio, fixed mobile, maritime mobile, aeronautical mobile, fixed broadcasting, space research, radio astronomy and aeronautical radio navigation. They are used by public safety organizations, Federal government agencies, aeronautical navigation licensees, amateur radio operators, international broadcasting stations, and General Radio Service (i.e. citizens band or CB radio) operators (see Canadian Table of Frequency Allocations).

Access BPL systems are designed to send information within parts of the 2-80 MHz frequency range along unshielded power lines, which results in the unintended emission of RF energy. This unintentional radiation can create interference to the radiocommunication services mentioned above.

The Department continues to assess Access BPL systems to understand the technology and the interference mechanisms.

VII. CURRENT STATUS OF BPL

A. International Activities

A number of foreign governments including Australia, Austria, China, Finland, Hong Kong, Hungary, Ireland, Italy, Korea, Japan, Netherlands, Poland, and Switzerland are currently studying BPL technology or have permitted equipment trials. The outcomes have shown mixed results and have led some administrations to ban BPL systems while other administrations have allowed deployment under various conditions. A number of administrations have suspended BPL trials pending international developments.

B. United States Activities

The Department has closely followed the FCC's proceedings from the release of the Notice of InquiryFootnote7 to the final Report and OrderFootnote8, which established technical and operational rules for Access BPL systems. During the FCC's proceedings, many individuals and organizations expressed and documented concerns about the potential of Access BPL systems interfering with radiocommunication services.

In October 2004, the FCC published their final rules with regard to the deployment of Access BPL systems. The FCC's final rules outlined a number of technical and operational requirements for Access BPL systems and included: definitions of BPL systems; the frequency range of operation; emission limits; excluded frequency bands; exclusion zones and consultation areas; interference mitigation requirements; and equipment authorization procedures.

C. Industry Canada Activities

The Department is closely monitoring international activities relating to Access BPL systems and the potential interference to radiocommunication services. In particular, Industry Canada is monitoring the activities of: the International Telecommunication Union (ITU)Footnote9; the International Special Committee on Radio Interference (CISPR)Footnote10; the European Conference of Postal and Telecommunications Administrations (CEPT)Footnote11; the Institute of Electronics and Electronic Engineers (IEEE)Footnote12; the FCC; the U.S. National Telecommunications and Information Administration (NTIA)Footnote13; foreign regulators; the amateur radio relay league (ARRL) and other organizations.

In addition to monitoring international BPL developments and the results of engineering studies, Industry Canada has undertaken preliminary assessments of Access BPL technology in cooperation with utilities currently performing Access BPL trials. These assessments were performed to supplement the Department's current understanding of the technology; to understand the potential for interference; to characterize emissions generated by Access BPL systems; and, to develop a measurement method to characterize the emissions. Furthermore, the Communications Research Centre (CRC) has performed preliminary computational modeling studies for the Department.

VIII. DISCUSSION AND PROPOSALS

Although there are currently no specific standards in Canada to address the deployment of Access BPL systems, the current regulatory environment provides mechanisms to address interference complaints. In particular, theRadiocommunication Act provides the authority for the Minister to take steps to resolve cases of interference to authorized services.Footnote14

To address the needs of all stakeholders, the Department intends to develop technical standards and establish operational requirements in accordance with its powers under the Radiocommunication Act. The Department is of the opinion that this approach will allow Access BPL systems to operate in the current radiocommunication environment while minimizing the potential for interference to authorized radiocommunication services.

The following sections outline the Department's proposals with regard to regulating Access BPL. This consultation process represents the first step in developing specific requirements and standards for this technology. This process will allow the Department to identify pertinent issues and develop a regulatory framework. The next step will involve a consultation with stakeholdersFootnote15 to discuss and develop specific technical standards including a measurement procedure.

The following sections invite comment on specific standards and requirements for Access BPL systems. The Department also seeks comment on any other specific issue or concern relating to the Department's role in the deployment and regulation of BPL systems in general.

A. Equipment Standard and Approval Process

The Department is considering the development of a new Interference Causing Equipment Standard (ICES) for Access BPL equipment. With regard to demonstrating compliance with the technical standards, the Department has a number of options ranging from Declaration of Compliance to Certification.

Industry Canada believes that the potential for interference to existing radiocommunication services warrants an approach that will ensure equipment compliance with the technical standard. Therefore, the Department is proposing that the certification process be used for Access BPL equipment. The certification process will include the submission of a test report that will demonstrate compliance with the standards in the appropriate ICES.

The Department seeks comment on the proposed certification process and what, if any, alternative approaches could be used to authorize BPL equipment and systems.

B. Prospective Technical Requirements

The Department is cognizant of the similarities between the U.S. and Canadian power distribution environments. Therefore, IndustryCanada believes that technical harmonization with theU.S. is an important step towards facilitating the deployment of BPL technologies. As a starting point, the Department seeks comment on emission limits and is proposing that BPL equipment must conform to the standards outlined below.

In addition, components of Hybrid Access BPL that send and receive wireless signals will be required to comply with the applicable established standardFootnote16.

(a) Emission Limits

The International Special Committee on Radio Interference (CISPR) develops electromagnetic compatibility standards for electronic equipment. In particular, the CISPR 22 standard establishes limits and measurements techniques for radiated and conducted emissions from information technology equipment. The content of CISPR 22 is currently being revised to address BPL systems. Although this work was to be completed by August 2003, discussions on the potential interference to authorized radiocommunication services have slowed progress.

Several administrations and organizations have proposed or established rules for BPL deployments. A number of proposals have been presented on a regional basis for consideration to regulate emissions from cable and BPL equipment to minimize the potential for interference to authorized services. Since BPL manufacturers will view Canada and the U.S. as a similar marketplace, the Department is proposing technical harmonization with the U.S.

Access BPL systems operating below 30 MHz will be subject to following limits:

Frequency (MHz)	Field strength(microvolts/metre)	Measurement Distance (metres)
1.705-30.0	30	30

Access BPL systems operating above 30 MHz will be subject to the following limits:

Frequency (MHz)	Field strength (microvolts/metre)	Measurement Distance (metres)
30-80	90	3

(b) Interference Mitigation Requirements for Access BPL Systems

In addition to establishing appropriate emission limits, the Department is proposing that Access BPL equipment/systems incorporate adaptive interference mitigation techniques to minimize the potential for interference to radiocommunication users. These include:

- remote controllable shut-down features;
- remote power reduction; and,
- notch filtering and/or frequency avoidance.

The Department has proposed a number of technical requirements to address the use of Access BPL equipment and to minimize the potential for interference to authorized services from deployed Access BPL systems.

Operational Requirements

In addition to equipment standards, the Department is of the opinion that operational requirements should be established for deployed Access BPL systems to minimize the potential for interference to specific radiocommunication users. The proposed operational requirements are outlined below.

(a) Prohibited Frequency Bands

The Department is proposing to prohibit Access BPL systems from operating in specific frequency bands including bands used for anaeronautical services, public safety and national defense. The Department believes that this approach is necessary to ensure the protection of safety-related services.

(b) Geographical Frequency Restrictions and Coordination Requirements

The Department believes that there could be specific geographic areas where Access BPL systems should not be deployed and that coordination with specific authorized users may be necessary.

(c) Interference Resolution

The Department is considering requirements for BPL operators to address potential interference complaints. In particular, individuals and organizations with complaints would be asked to directly contact Access BPL operators to investigate and resolve problems. If a problem could not be resolved satisfactorily or in a timely manner, the Department would address the problem as an interference complaint under the Radiocommunication Act.

IX REFERENCES

[1] In the Matter of Amendment of Part 15 regarding new requirements and measurement guidelines for Access Broadband over Power Line Systems (ET Docket No. 04-37) and Carrier Current Systems, including Broadband over Power Line Systems (ET Docket No. 03-104). Report and Order. October 2004.

[2] National Association of Regulatory Utility Commissioners (NARUC). Report of the Broadband Over Power Lines Task Force. February 2005.

[3] FCC. In the Matter of Inquiry Regarding Carrier Current Systems, including Broadband over Power Line Systems (ET Docket No. 03-104). Notice of Inquiry. April 2003.

[4] FCC. In the Matter of Amendment of Part 15 regarding new requirements and measurement guidelines for Access Broadband over Power Line Systems (ET Docket No. 04-37) and Carrier Current Systems, including Broadband over Power Line Systems (ET Docket No. 03-104). Report and Order. October 2004.

[5] Stefano Galli, Senior Member IEEE, Anna Scaglione, Fellow IEEE, and Zhifang Wang, Member IEEE, For the Grid and Through the Grid: The Role of Power Line Communications in the Smart Grid, Proceedings of the IEEE |Vol. 99, No. 6, June 2011.

[6] T. Banwell and S. Galli, "A novel approach to accurate modelling of the indoor power line channel—Part I: Circuit analysis and companion model," IEEE Trans. Power Del., vol. 20, no. 2, pp. 655–663, Apr. 2005.

[7] M. Zimmermann and K. Dostert, "A multipath model for the power line channel," IEEE Trans. Communication., vol. 50, no. 4, pp. 553–559, Apr. 2002.

[8] ITU-T Recommendation K.60 Emission limits and test methods for telecommunication networks. Document1A/20, E Document 1C/20-E 28. October 2003.

[9] International Electrotechnical Commission (IEC). EMC of Information technology, multimedia equipment and receivers. Committee Draft - CISPR/I/89/CD. November 2003.

[10] Electronic Communications Committee (ECC) within the European Conference of Postal and Telecommunications Administrations (CEPT). PLT, DSL, Cable Communications (including Cable TV), LANs and their effect on Radio Services. Cavtat, May 2003.

[11] In July 2004, the IEEE created working group P1675: Standard for Broadband over Power Line Hardware.

[12] NTIA. Potential Interference from Broadband over Power Line (BPL) Systems to Federal Government Radiocommunications at 1.7 - 80 MHz Phase 1 Study. Report 04-413.

[13] A hybrid system that transmits signals using licence-exempt spectrum (e.g. 2.4 GHz) would be required to comply with Radio Standards Specification 210, Low power Licence-Exempt Radiocommunication Devices (All Frequency Bands) (RSS-210).