Research Paper Engineering

Simulation and Mitigation of Noise on Data Communication over Power Line Network

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ABSTRACT

Using the in-building power distribution system as a communications medium can be referred to as a "power line" network, and the advantage is that the wiring for the network is already in place and thus there is no requirement for dedicated network cable.

Power conductors have excellent coverage because every room in a building has power and thus the network is easy to access. However, it is difficult to communicate data effectively because the medium was not designed originally for data transmission. Attenuation, variable impedance, and noise are three factors which make this a harsh medium, making it difficult to achieve optimum signal transfer, low distortion, and high signal-to-noise ratios (SNR).

In order to characterize noise, observations of power distribution noise were made on several systems like Electric toothbrush charging stand, Powerline intercom, Vacuum cleaner, and Triac controlled light dimmers, and the spectral analysis results are displayed accordingly [1].

This paper aims at studying the various noises on powerline and also provide solution on how to mitigates it

Keywords : Communication, Simulink, Spectrum Analyser, Powerline network

1.0 INTRODUCTION

The communication flow of today is very high. Many applications are operating at high speed and a fixed connection is often preferred. If the power utilities could supply communication over the power-line to the consumers it could make a tremendous breakthrough in communications. Every household would be connected at any time and services being provided at real-time. Using the power-line as a communication medium could also be a cost-effective way compared to other systems because it uses an existing infrastructure, wires exists to every household connected to the power-line network [2].

The deregulated market has forced the power utilities to explore new markets to find new 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 markets for the power utilities and hence increase the profit. The moderate demands of these applications make it easier to obtain reliable communication. Firstly, the information bit rate is low, secondly, they do not require real-time performance. During the last years the use of Internet has increased. If it would be possible to supply this kind of network communication over the power-line, the utilities could also become communication providers, a rapidly growing market. On the contrary to power related applications, network communications require very high bit rates and in some cases real time responses are needed (such as video and TV). This complicates the design of a communication system but has been the focus of many researchers during the last years. Systems under trial exist today that claim a bit rate of 1Mb/s, but most commercially available systems use low bit rates, about 10-100 kb/s, and provides low-demanding services such as meter reading.

The power-line was initially designed to distribute power in an efficient way, hence it is not adapted for communication and advanced communication methods are needed.

This demand by companies is large, but the demand for data communication in the home is also becoming significant. Home users, who often have more than one computer, are looking to data communication networks to share information between computers. They are also looking to networks for the 'automation' of their home – including applications such as security systems, network gaming, and controlling heating, air conditioning and other household appliances.

This idea came from Hanson's work which observed that interference on the power line is synchronous and stationary in position with respect to the 50 or 60 Hz mains signal [3]. Noise appears only for short intervals, causing a high number of bit errors for a short period of time. These noisy intervals should be avoided. By detecting when noisy timeslots occur and avoiding them, bit error ratios can be dramatically reduced. Also, during periods of low noise, the transmission bit rate can be increased to further improve the throughput of the system.

2.0 NOISE MEASUREMENTS

The major obstacle to data transmission on the power conductors is the

noise which other researchers have shown extends from 50Hz to tt

several 100kHz. In order to characterize noise observations of power

distribution noise were made on several systems like Electric toothbrush charging stand, Powerline intercomm, Vacuum cleaner, and Triac controlled light dimmers, and the spectral analysis results are displayed accordingly. These results were made using the test setup as shown in figure 1. It shows that the majority of the line noise is synchronous with the 50 Hz.

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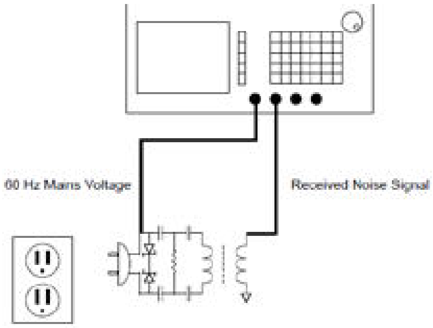
Figure 1: Noise Measurement Setup



2.1 Line Impedance Stabilization Network (LISN)

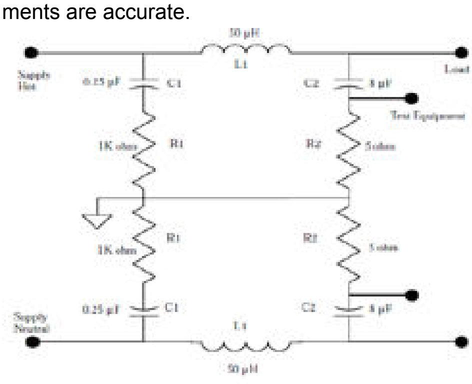
The line impedance stabilization network (LISN) is used for the

measurement of electromagnetic interference voltages originating from the electrical apparatus and conducting into the public power network. The purpose of the LISN is to provide a defined impedance over the specified frequency range 0.01 to 30 MHz between each of the power terminals and ground of the equipment under test and also to isolate the test circuit from unwanted radio frequency signals from the public power network. Figure 1 shows both the hot and neutral lines each connected through a LISN connected to a separate LISN. The LISN used conforms to the Canadian Standards Association CSA standard and will be used to observe synchronous noise generated by equipment under test.

Noise measurements were made using the set up shown in figure 1. The

line impedance stabilization network was connected to the filtered mains in

the communications lab to ensure that the noise measurements are accurate.



2.2 Results of Spectral Analysis of Noise

All noise is not created equal-nor is it perceived in the same way. There are many different types of noise, and depending on the circumstances and upon the person, some noises are far more annoying than others. This is important, because the typical method of measuring noise (i.e assessing the dBA) may not reflect all of the problematic components of the noise. In fact, it is widely acknowledged that noise measurements based on the A-weighted frequencies (dBA or Laeq) do not adequately characterize most noise environments and do not adequately assess the health impacts of noise on human –being[2].

Many electrical devices which are connected to the power mains inject significant noise back onto network. The characteristics of the noise from these devices varies widely. Examination and simulation of noise from a wide range of devices leads to the observation that the noise can be classified into just a few of categories:

- The presence of tones (tonal noise)
- The presence of low frequency noise
- Impulsive noise

2.3 Tonal Noise

Noise with distinct tones, for example, noise from fans, compressors, or saws, is generally far annoying than other types of noise. This annoyance factor is not taken into account in a broadband measurement. A spectral analysis was used to assess annoyance as shown in figure 3 and 4.

Most energy industry facilities typically exhibit a tonal or impulse/impact component. Examples of tonal components are transformer hum, sirens, and piping noise [4]. Tones are noises with a narrow sound frequency composition (e.g., the whine of an electrical motor). Annoying tones can be created in numerous ways: mahinery with rotating parts such as motors, gearboxes, fans and pumps often create tones. An imbalance, or repeated impacts may cause vibration that, when transmitted through surfaces into the air, can be heard as tones. Pulsating flows of liquids or gases can also create tones, which may be caused by combustion processes or flow restrictions. Tones can be identified subjectively by listening. Regulations, however, often require an objective measurement of tonal content as well. In such cases, frequency analysis, where a noise signal is electronically separated into various frequency bands (e.g octave bands or third-octave bands) was employed. The tonal audibility or annoyance factor is then calculated by comparing the tone level to the level of the surrounding spectral components.

The test for the presence of tonal components consists of two parts.

It is often useful to divide tonal noise into the two sub-categories of unintended and intended interference. The most common sources of the unintended tonal noise are switching power supplies. These supplies are present in numerous electronic devices such as personal computers and electronic fluorescent ballasts. The fundamental frequency of these supplies may be anywhere in the range from 15KHz to > 1MHz. The noise that these devices injet back onto the power mains is typically rich in harmonics of the switching frequency. Noise from the charging stand on an electronic toothbrush is shown in the spectrum analyze plot of figure 3

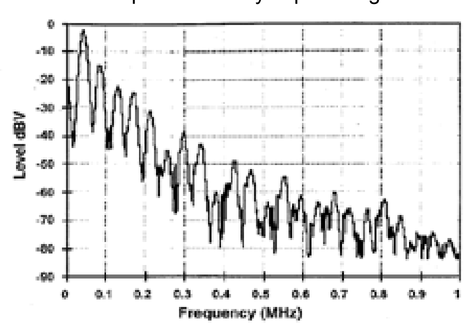


Figure 3: Noise from Electric Toothbrush Charging Stand

Intentional tonal noise can result from devices such as power line intercoms and baby monitors. In the United States and Japan these devices typically operate at frequencies between 150KHz to 400KHz, injecting signals of several volts peak to peak onto the power line. Figure 4 shows a spectral plot of a typical power line intercom (along side with a 50dB attenuated 131KHz communication signal which is shown for reference). A second source of intentional tonal noise results from pickup of commercial radio broadcasts. Power wiring acts an antenna to pick up signals from these multi-thousand watt transmitters. Interference on the order of a volt peak-to-peak at frequencies just above the communication band is not uncommon. Note that this interference has very specific implications for the filtering requirements of any power line transceiver [6].

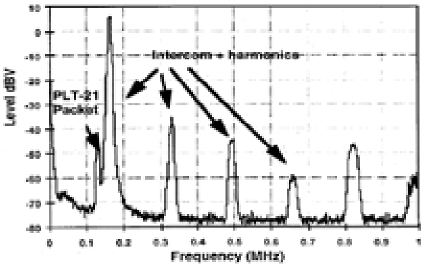


Figure 4: Powerline Intercom Spectrum

2.4 Low Frequency Noise

A large proportion of low-frequency components in noise may increase considerably the adverse effects on health. Low frequency noise can disturb rest and sleep even at low sound levels.

Low frequency noise does not have a consistent definition, but it is commonly defined as noise that has a frequency between 20 and 100-150Hz. Noise at levels below 20Hz is referred to as infrasound. Depending on the actual conditions, many types of noise can be regarded as low frequency noise:

- Low frequency noise and infrasound are produced by machinery, both rotational and reciprocating, and all forms of transport and turbulence. Typical sources include pumps, compressors, diesel engines, aircraft and fans.
- The firing rate of many diesel engines is usually belo 100Hz, so road traffic noise can be regarded as low frequency. Similar considerations can be made for engines or compressors in industries or co-production plants.
- Burners can emit broadband low frequency flame roar.
- Structure borne noise, originating in vibration, is also of low frequency, as is neighbor noise heard through a wall, since the wall blocks higher frequencies more than lower ones
- Low frequency noise can be noise or vibration from traffic or from industries, totally or partly transmited through the ground as vibration and reradiated from the floor or the walls in the dwelling[8]

Low frequency noise creates a large potential for community annoyance. It is most often experienced inside of homes and buildings where resonance amplifies the sound. It is a general observation that indoor noise is perceived as more 'low –frequency-like' than the same noise heard out of doors[8,10]

2.5 Impulse Noise

High frequency impulse noise finds its source in a variety of series-wound AC motors. This type of motor is found in devices such as found in vacuum cleaners, electric shavers and many common kitchen appliances. Commutator arcing from these motors produces impulses at repetition rates in the several kilohertz range. Figure is a spectrum analyser plot of noise from a household vacuum cleaner. Figure 6 is a frequency domain view of the noise from the same unit. Note that, of the various categories of power line noise, this motor noise is the only type which bears even a remote resemblance to white gausian noise used to analyze many communication systems [11].

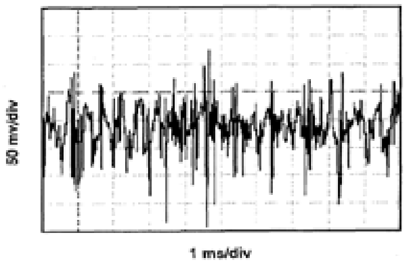


Figure 5: Vacuum Cleaner Noise

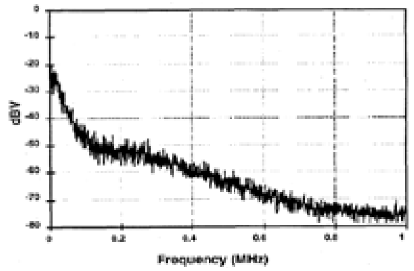


Figure 6: Vacuum Cleaner Noise Spectrum

Impulse noise is brief and abrupt, and its startling effect causes greater annoyance than would be expected from a simple measurement of sound pressure level.

Impulsive sounds, such as gun shots, hammer blows, explosions of fireworks or other blasts, are sounds that significantly exceed the background pressure level for a very short duration. Examples of impulse noise in the oil and gasindustry could include venting and flaring, pipe-on-pipe impacts due to unloading pipe at a well site, and pile driving.

The most common impulse noise sources are triac-controlled light dimmers. These devices introduce noise as they connect the lamp to the AC line part way through each AC cycle. When the lamp is set to medium brightness the inrush current is at maximum and impulses of several tens of volts are imposed on the power network. These impulses occur at twice the AC line frequency as this process is repeated in every ½ AC cycle. Figure 7 shows an example of this kind of noise after the high pass filter has removed the AC power distribution frequenc[12].

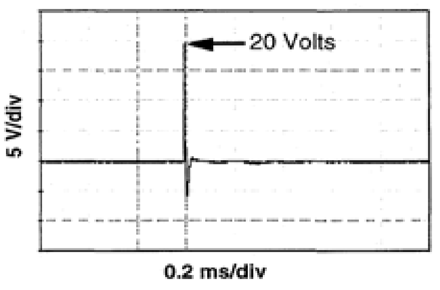


Figure 7: Lamp Dimmer Impulse Noise

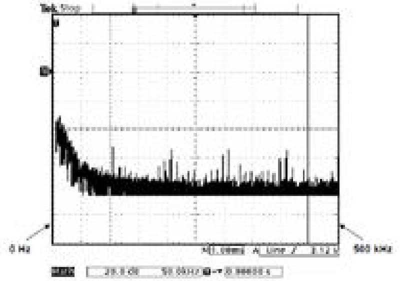


Figure 8: Noise Frequency Spectrum

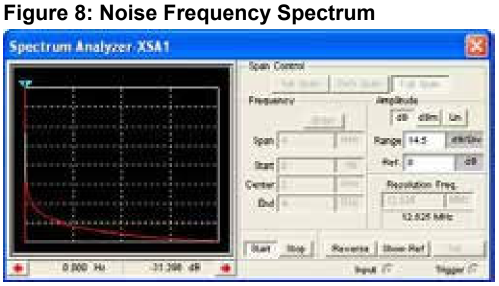


Figure 8: Noise Frequency Mitigation Display on Spectrum Analyzer

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3.0 Conclusion

A review of simulation and various experiments conducted on several systems like Electric toothbrush charging stand, Powerline intercom, Vacuum cleaner, and Triac controlled light dimmers, and the spectral analysis results displayed show that as the higher the Frequency the lower the Noise power spectral density. It was also observed that during periods of low noise, the transmission bit rate can be increased to further improve the throughput of the system. Hence inorder to reduce noise on the Powerline network drastically, it is advisable to apply a higher frequency spectrum between 3GHz- 4GHz.

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