Broadband Over Power Lines (BPL) and Its Impact on Spectrum Allocation

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Introduction: For many years the electric utility companies have employed power lines to transmit signals in the tens of kHz range for the control of switches and relays on electric power transmission systems. The electric utility companies and internet providers have become interested in employing existing power lines for providing residential and commercial internet access, using frequencies from 1.6 to 30 MHz in order to attain data rates of 1 or more Mbits/s. Initially intended to provide high-speed internet service to consumers in rural areas, Broadband Over Power Lines (BPL) is of great interest to service providers as power lines reach virtually every home and community in the country. A major concern with BPL is that the data signals impressed upon power transmission lines can emit disruptive electromagnetic interference (EMI) to communications and high frequency (HF) radar receivers residing in the 2–30 MHz band. The NRL Radar Division and the Space and Naval Warfare Systems Center (SPAWAR) Charleston was tasked by the Naval Sea Systems Command to determine what changes in the ambient background noise levels might result from a BPL installation.

Description of a Typical BPL System: With the employment of digital signal processing (DSP) hardware and embedded software, BPL transmissions utilizing digitally modulated carriers in the frequency range of 2–30 MHz are a reality. As shown in Fig. 4,[1] the BPL concept relies on impressing computer data on medium voltage (MV) power lines carrying 1,000 V to 40,000 V and is supported by the following: (1) PC; (2) modem; (3) extractor, which is the transition from the residential/commercial low voltage (LV) power lines to one of the three phases supplying the residential or commercial establishment; (4) repeaters providing amplification and correction for phase distortion; and (5) injector supporting the transition from the power line phase to the fiber optic link.

Typically, BPL uses orthogonal frequency division multiplexing (OFDM). OFDM is a technique for transmitting data whereby parallel data streams digitally modulate multiple carrier frequencies with a frequency spacing equal to 1/T Hz where T is the duration of the data symbol in seconds. The digital modulation scheme to modulate these data streams can range from bipolar phase shift keying (BPSK) to quadrature amplitude modulation (QAM). The PC BPL modem thus converts a serial data stream into successive parallel streams that digitally modulate one of a group of orthogonal carriers. These modulated orthogonal carriers transition from the LV line to the MV overhead phase line either through an inductive coupler that bypasses the transformer, or through a Wi-Fi transponder and modem

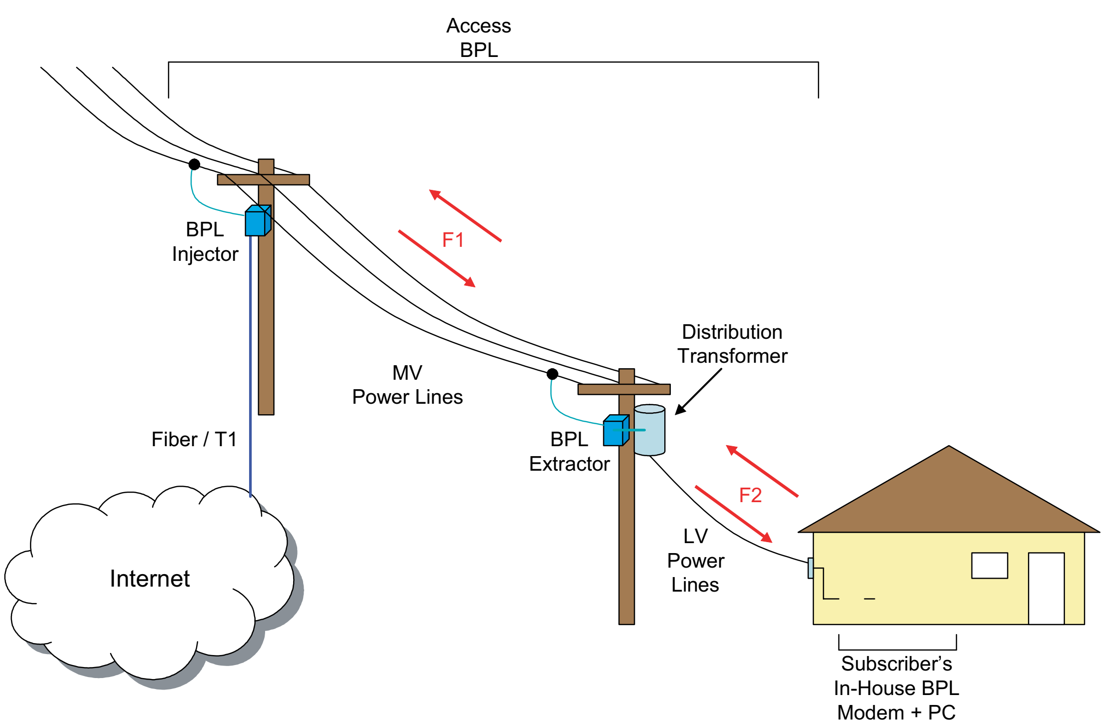

FIGURE 4
Basic BPL system.[1]

that resides adjacent to the PC and transmits the data signal to a transponder on the utility pole connected to the phase through an inductive coupler.

BPL Testing: A commercial BPL test site was chosen on the east coast of the United States. Measurements were conducted over a period of three days, October 26–28, 2004 (see Fig. 5). Measurements were taken using a spectrum analyzer with a 10.0 kHz resolution bandwidth and a calibrated loop antenna. The loop antenna was situated 1.8 meters above the ground and at a slant distance of 17.7 meters from the BPL energized power line phase. Table 1 provides a comparison of ambient noise levels that would occur in a rural environment (a natural setting to operate an HF radar or communications system) and the measured BPL emissions corrected for a 1.0 MHz bandwidth. BPL emissions can definitely degrade the operation of HF radar or communications receivers due to the significant rise in the noise floor. In fact, numerical modeling using a method of moments (MOM) electromagnetic simulation program indicates that the measured power line would be a source of EMI to a sensitive HF receiver beyond 183 meters.

Conclusions: Issues that need to be considered when performing BPL measurements are (1) the unsymmetrical radiation characteristics of power lines; (2) the changing load impedances resulting in different emissions characteristics; (3) the presence of structures such as buildings in the vicinity of the power lines; and (4) changes in BPL signal amplitude that maintain a given signal-to-noise ratio insuring reliable data transfer. Based upon measurements and modeling, it is our opinion that BPL in the 2–30 MHz band is a cause for concern when operating HF radar and communications receivers in close proximity to BPL excited power lines. The received power impinging on an HF radar antenna array is proportional to $1/R^4$, where R is the distance the electromagnetic wave traverses from the array to the target and back to the array, whereas the interference energy from BPL signals is only attenuated by space as $1/r^2$, where r is the separation between the power line and the radar antenna. Thus BPL signals that raise the noise floor of an HF receiver may greatly compromise performance.

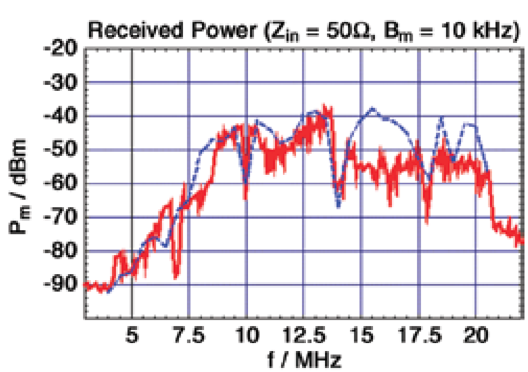

FIGURE 5
Corrected spectrum analyzer (red) and MOM (blue) data.

TABLE 1
Measured Versus Rural Ambient Noise Levels in a 1.0 MHz Receiver Passband

Frequency (MHz)	Rural (dBm/MHz)	Measured (dBm/MHz)
10	–86	–44
15	–89	–34
20	–92	–32

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References

[1] Potential Interference From Broadband over Power Line (BPL) Systems to Federal Government Radiocommunications at 1.7–80 MHz, National Telecommunications and Information Administration (NTIA) Report 04-413, April 2004.