EMC: The Impact of Power Line Communications, Part 1

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Although PLC may seem attractive on the surface, many technical and interference problems remain for the controversial broadband service.

Recent deregulation in the EU utility market has led to a new kind of competition with classical telecom providers. The new players are using utility-owned power lines in the low-voltage mains grid to provide broadband Internet access in areas that are mostly residential. Power line communications (PLC, sometimes called PLT for power line telecommunications) uses unshielded, 230 V/50 Hz, low-voltage distribution cables inside and outside of buildings as transmission media up to Mb/second data rates. This requires mains-injected radio-frequency (RF) levels (e.g., total power <1 W, spectral power 40d Bm/Hz, 1–30 MHz) that are EMC critical, with common-mode (CM) currents on wires (e.g., 20 dBμA at 1 MHz). Similar signals are normally injected at distribution transformers.

Many international standards have been developed to control radiated emissions below 30 MHz in the short-wave user spectrum. Most standards give field strength limitations only above 30 MHz. In Germany, for example, the applicable regulations are found in RegTP NB 30-07/01. Regulations and standards are supposed to protect, among others, sensitive monitoring and communications services in both military and government.

In contrast to PLC, other competing broadband services, such as digital symmetrical subscriber line (xDSL) and cable TV, use well-engineered, as well as symmetrical, telecom lines with less disturbance potential. Results from field trials of actual PLC systems throughout Europe are now available, and some conclusions can be drawn from these results. Some aspects of the EU mandate M313 regarding telecom networks are also discussed.

This article examines the latest PLC developments. Computer simulations are discussed and compared with EMC-critical measurement results. It also reviews the current state of PLC and related wire broadband technologies, with a focus on European activities.

PLC Background

In the past five years, PLC modem and system developments have increased throughout Europe. Field trials were started in the UK, Germany, Spain, Italy, and other EU countries.[1–10] Some utility companies want to use this new technology to provide value-added services, such as fast Internet access or relatively fast local bus systems, to clients in private homes or industry. The technology is designed to work simply by plugging into the 50 Hz, 230 V mains.

This is certainly an attractive idea. One should not confuse this technology with previously existing services that use slow data rates below 149 kHz. It should also not be confused with PLC that operates over medium-voltage distribution lines in the power grid. However, unlike xDSL, unshielded low-voltage distribution systems are not designed primarily for communication purposes.

In information technology (IT) equipment, TV and video equipment, and appliances, a number of obstacles prevent the even distribution of RF-energy for wire communications within buildings. Impedance changes, longitudinal signal attenuation, uncontrolled coupling, radiated emissions, light switches, and time-dependent loads all present difficulties. EMI filters designed to block high-frequency PLC signals also cause problems.

Early Field Trials. Early field trials in the UK, Germany, and Switzerland showed excessive radiated emissions (some up to 40 dB) above Germany's NB 30 RegTP limits, which were about 20 dB more relaxed than the earlier version of 4/2000 RA,UK MPT 1570 in the short-wave spectrum. The current not-yet-harmonized NB 30 is now viewed as a predominantly national approach. Germany initially followed a compromise with statistical EMI disturbance (i.e., not all German coffee mills are turned on simultaneously). The UK, however, worried mostly about the man-made noise increase in sensitive receivers, caused by the always-on phenomenon of this broadband service. Since 9/11, German agencies have increasingly dealt with sensitive radio communication issues in addition to medium-wave broadcast service coverage.

In Germany, broadcast, military, and commercial interests, as well as licensed amateur radio services, seriously objected to a nationwide implementation of PLC. Many theoretical studies by academic institutions were performed. The studies alluded to potential noise-floor issues. In parallel, EMC standards slowly but surely began to develop in consensus groups such as IEC, CENELEC, ETSI, and CEPT. Regulation authorities, therefore, had to quickly form technology-assessment advisory boards like ATRT RegTP PLC Working Group. ATRT addresses all related issues of wire and radio EMI in networks. The remaining participants in the PLC industry (after the withdrawal of big players like Norweb, Siemens, EON, and RWE) are fighting for rapid, widespread installation to fulfill business objectives and investors' expectations.

PLC Technology. Generally speaking, the PLC industry appears to be marketing driven. First-generation PLC modem technology uses mostly discrete frequencies in two bands (1–10 MHz outdoors and 10–30 MHz indoors).[11] Several independent measurement campaigns in Switzerland, the UK, Germany, and France indicate –40 dBm/Hz injected-signal levels result in radiated emissions of 20–40 dB above NB 30 limits (e.g., at 1 MHz results in 40 dBµV/m, 9 KHz BW, test distance d = 3 m and is equivalent to 20 dBµA CM current [wire to ground]) on lines in installations. Installation-specific parameters determine coupling factors and antenna gain in wide ranges.

Underground cables (1–10 MHz) are typically less critical than home installations (10–30 MHz). This was clearly observed in Swiss 200–300-m long cable systems buried in a residential area. Natural wiring resonance phenomena (stubs to light switches form /L length) in homes with indoor frequency bands may increase radiation easily by 10 dB or more. The higher the frequency the higher the radiation is from these systems.

Ongoing, large system measurements in Germany and elsewhere indicate additional measurement problems with present metrology of NB 30/MV05 (3 m distance, 60-cm BB magnetic loop) using a near-field test procedure.

Technicians have difficulty isolating PLC system signals from background or equipment noise at 3 m. Consequently, this argument is often used by PLC promoters to question the wisdom of setting current limits in standards. Man-made noise has increased over the past two decades (e.g., due to progress in microprocessor speeds). The 3-m test distance scenario originates from portable broadcast band receivers with built-in antennas used in apartments. At a 1-m test distance, however, it is less difficult to find the EMI source. Moreover, the instrument-noise floor in nonselective preamplifiers using the CISPR 16 loop antenna is also less difficult at 1 m.

Near-field measurements can be strongly affected by small location changes, frequencies, natural ambient noise, and emissions of other nearby electronic devices. Secondary radiators, such as water pipes, also affect measurements. RF current tests are more direct, but suffer from standing waves along the lines.

Far-field effects and underestimated PLC system antenna factors may also lead to short-wave signal mirroring at the ionosphere.[10] This effect is just beginning to be taken into account by the Ministry of Economy in Berlin, which supervises the RegTP agency. The EC has had some discussions on this matter in its EMC WP Group. These short-wave (sky-wave) propagation effects might lead to an increase in background noise even far outside Europe.[6, 7, 10]

Based on initial simulations, it appears that sensitive receiving sites in Germany may experience degradations of 10–40 dB at hundreds of kilometers away from the PLC-polluted area. This, of course, is unacceptable for security agencies, especially in light of the present unstable political scenario. Simple sky-wave experiments seem to confirm degradation shown in simulations. More R&D is needed to cope with aviation-radio band issues and with long-distance PLC network effects.

With digital technologies came the introduction of power reduction in broadcasting. Reducing transmit power lowered electromagnetic pollution and potential health hazards. Unfortunately, these improvements become useless if, at the same time, the signal-to-noise ratio (SNR) turns out to be degraded by PLC.

The automotive industry is also looking into PLC usage in cars. High-speed communication buses, however, produce excessive emissions.

These emissions leak into the environment, causing failed control limits in international CISPR standards.

In April, FCC issued a Notice of Inquiry seeking public comment on the use of power lines to provide Internet and broadband services (see the sidebar on page 57). Like the United States, Japan is densely populated and uses many overhead transmission lines in the low-voltage distribution system. Japan, however, decided in 2002 to prohibit PLC, except in limited R&D field trials.

Development of High-Frequency PLC

The transmission media mains (230 V/50 Hz) with Kb-per-second mains signaling (similar to EN 50065 3-148.5 kHz at several volts amplitude) dates back to around 1920. Using frequencies from 1 to 30 MHz (Mb/second) and injected-RF power levels, from megawatts to watts total spectrum power, started in the UK in 1996.

Indoor lines in homes exhibit bad symmetry, changing impedance, unfavorable coupling and resonances, and susceptibility to external EMI. So network internal emissions by CM currents are inevitable. Power levels of –40dBm/Hz lead to 20–40 dB above German NB 30 limits.

Modems have difficulty meeting current conducted disturbance limits of EN 55022 at the mains port. Moreover, it is extremely difficult to simulate real PLC traffic in a representative network EMC test-lab setup. Geometry, size, and, in particular, the ever-changing and adapting network data parameters make simulation difficult. For the purpose of broadband access to the Internet, for example, two bands are normally used: <10 MHz outdoors and >10 MHz indoors.

The industry now faces a major problem. Established radio-wireless technologies must peacefully coexist with new, unshielded PLC systems. If brute force on the transmit-level side is not an option, smart algorithms and system design from military spread-spectrum communications technologies might offer a solution.

Bandwidth, channel capacity, sophisticated modulations, SNR, and time-domain procedures, including signal processing and optimized multichannel path probing, are modern technical challenges. The old slow-speed applications and simple remote meter reading are far less critical. Automotive PLC applications are in the early R&D stages.

Present and Future PLC Technology

In Europe, there are basically two technologies (ASCOM [discrete frequencies] and main.net [spread spectrum]) in PLC over the mains. The current technology used by ASCOM (Switzerland) and by the former Norweb (UK) employs several RF carriers about 1–2 MHz wide (50%) on the mains. Main.net (Israel) uses a wideband spread-spectrum technology.

Conducted Limits:
Mains Port Class B, EN 55022 (1998)

- 0.15 to 0.5 MHz QP 66 to 56 (dBμV)
- 0.5 to 5 MHz QP 56
- 5 to 30 MHz QP 60
- (AV not given here, but needs to be met; 10 dB less)

Figure 6. Telecom port asymmetrical (tested with T-network) directly relevant to CM-current, EMI emission limits of EN 55022, 1998.

This technology tries to lower injected PLC levels, but potentially at the cost of the SNR. In later nets, there is sometimes a problem at night, when more people are home and the EMI of home appliances rises. The surge in use triggers serious signal-to-noise problems that cause data rates to drop below those of integrated services digital network (ISDN). To meet current EMC requirements, future PLC technologies need to decrease emissions by 40 dB. They could also apply smarter software channeling algorithms.

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Figure 5. Mains port (tested with V-network), conducted emission limits (EN 55022, 1998, for class B, QP-detector) combining both differential and common mode.

SNR (typically 15 dB) is EMI relevant. PLC signal levels, modulation, and existing line noise are important to bridge the distance without costly repeaters. The PLC community, therefore, is fighting for less-stringent regulations and is demanding new EMC standards. This is addressed in NB 30 in Germany (see Figure 1). It could also affect these standards: the EU EMC Directive, ITU-R SG1, CISPR/I/WG3 (TF xDSL), CEPT SE35, CENELEC SC205A, CENECEL/ETSI (Networks), German DKE UK 767.17.3, and RegTP ATRT UAGr.3.

Under PLC, problems include statistical limit model changes with always-on mode and questionable EMC metrology (near- and far-field, line impedance stabilization network [LISN], CM and differential mode (DM), longitudinal conversion loss [LCL]–transverse conversion loss [TCL]-coupling). PLC has become controversial concerning both EMC and general telecom issues.

Smarter PLC modulation, such as orthogonal frequency-division multiplexing (OFDM) and, in particular, spread-spectrum or time-domain options (similar to ultrawideband), are potentially more EMC suitable. Modulation is better than high-power individual multifrequency carriers, for which the only option is the hope that at least one out of three channels will successfully transmit the desired information to the end-user. MVV Mannheim (South Germany), which uses spread spectrum, sometimes has conducted EMI network problems with data-rate drops below ISDN speed.

Compensating for PLC in EMC and telecom standards will certainly affect all EMC standards developments. Many issues would need to be addressed, including:

- Limit and metrology issues (e.g., V-LISN CISPR versus T-Network).
- Mixed versus CM (radiation-critical) issues.
- EN 55022 multifunction port.
- Whether to allow PLC to use the mains port (presently at lower conducted EMI limits) like a telecom user (with symmetrical lines).
- Better-defined and better-suited test procedures. This includes LCL, network antenna factors (installation coupling), and updates of currently used, 20-year-old, man-made noise statistics.
- Mains port versus telecom port limits. This topic is so hot, it was discussed in CISPR 22 and put out for national committee comments worldwide. Equal rights and fair treatment for all parties involved is to be achieved.

There should be a safety margin between equipment and network emissions requirements. Equipment is easier to test compared with complete nets. Net status emission changes in time and location need consideration. This is typically a computer simulation effort. Tighter specs will most definitely affect the PLC industry. R&D is costly and risky. Time to market is essential. The other point of view, however, is whether it is reasonable to require earlier players in sensitive radio services to accept major disadvantages.

Relevant PLC Standards and Regulations

Because consensus is required from international technical experts, standards typically take 2–4 years to get established. Similar to existing technologies, PLC needs to be integrated into established harmonized standards. Fair and equal treatment is a must. Consequently, there should be no new PLC-only regulations with conflicting limits to those in EMC and telecom and wireless standards.

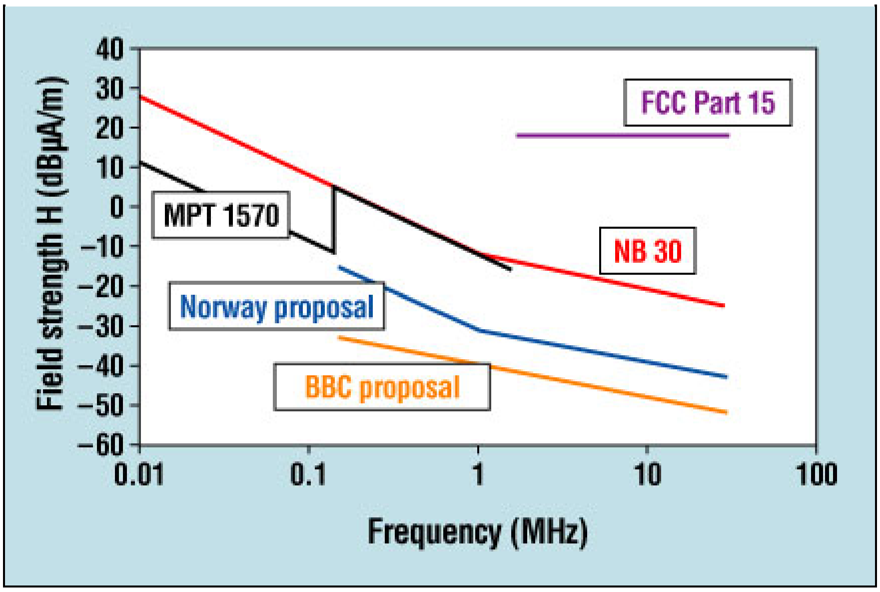

Figure 1. Field limits below 30 MHz (EdBμV/m = H+51.5 dB) FCC (>2 MHz still debated) NB 30 (1M Hz = 40 dBμVm), MPT UK, Norway, BBC.

There is no such thing as creating national standards anymore in the EU.[12] NB 30, with its MV05 test procedure, therefore, has triggered EU discussions about RegTP. NB 30 excludes several national-security frequency bands from PLC use. Even if NB 30 limits do not remain accepted in international norms as a compromise, peaceful coexistence in the spectrum with radio systems is mandatory. It was discovered recently that PLC signals interfere with some short-range devices (SRD) operating in the short-wave spectrum. Such SRDs include antishoplifting devices used in department stores.

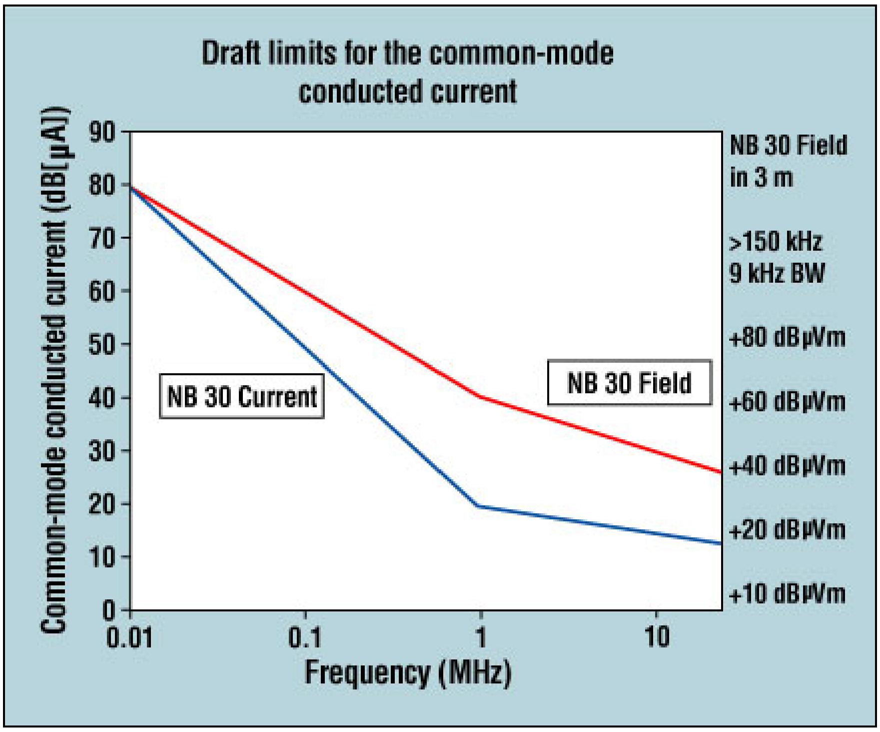

Figure 2. NB 30 E-field limits and corresponding common-mode current.

It is important to review the requirements of a standard such as ETSI EN 300 330-1 V1.3.1 (2001). The scope states, "The present document applies to SRD transmitters and receivers: a) transmitters operating in the range from 9 kHz to 25 MHz, and inductive loop TX operating from 9 kHz to 30 MHz; b) receivers operating from 9 kHz to 30 MHz. The present document applies to generic SRDs: inductive loop systems;

with an antenna connection and/or with an integral antenna; for alarms, identification systems, telecommand, telemetry, etc.; applications with or without speech."

According to EN 300 330-1, when selecting parameters for new SRDs that may have inherent human safety implications, manufacturers and users should pay particular attention to the potential for interference from other systems, such as PLC, operating in the same or adjacent bands.

The present document covers fixed stations, mobile stations, and portable stations. The issue here is emissions received, rather than transmitted (low-power, spurious emissions). To reach the limit set in NB 30, it takes 50–100 m in residential areas. There is no control of SRD interference from PLC installations, which worries groups such as the Low Power Radio Association (http://www.lpra.org).

For a 3-m receiving distance (and including secondary radiation effects of nearby conductors), CEPT has determined that a reasonable limit is 18 dBµVm for 8 MHz (QP-CISPR) and 15 dBµVm for 13.56 MHz. Consequently, this industry favors limits lower than those in NB 30. Reports from the UK have indicated that modern electronic fault, current-detection devices are being unintentionally tripped by PLC RF. This is a potential safety problem for the low-voltage grid.

Generally speaking, there are issues arising from requirements in both the EMC Directive and the R&TTE Directive. Unique national frequency allocations still exist and must be considered. For example, German regulations, as well as CISPR 11, define many safety- and security-critical frequencies in the short-wave ISM band. Among these are aeronautical and maritime distress channels. Moreover, ITU defines primary and secondary allocation status for user groups in general. It is estimated about one million SRD units, including electronic article surveillance, are installed throughout the EU.

The technical issues surrounding PLC are noise floor and SNR, especially when compared with existing technologies such as local-area networks (LANs) and xDSL and their interference potential. In the past, little attention had been paid to commercial system EMC; box testing was the dominant concern.

With the introduction of PLC, the commercial EMC community has now been forced into system thinking. Addressing system issues is also part of the new EU Mandate, M313. This mandate resulted from commercial interference. Leakage from worn-out coax cable caused cable TV systems to interfere with air-traffic-control systems over major German cities. For the military, aviation, and automotive industries, this system is mission critical. The box-test procedures must be made with system aspects in mind. In particular, procedures must address cables, which can propagate CM currents.

Figure 1 gives an overview of currently applicable and proposed magnetic-field strength limits below 30 MHz. Following conventions, the corresponding E field is calculated using 377 W (51.5 dB W), based on free space impedance (E/H = Z). Naturally, this calculation does not reflect physics, because at 10 MHz (L = 30 m) far field, using oversimplified L/6, the far field begins at roughly 5 m. A comparison of NB 30 field limits and CM currents in installations is shown in Figure

2. Depending on the equipment used, as defined in CISPR 16-1, these limits are already difficult to meet with 60-cm broadband loop antennas. The noise margin is below 6 dB in some areas (see Figure 3). Using 3-m limits below 10 MHz, the instrument noise introduces large measurement uncertainty SNR. Detector choice from peak-to-quasipeak or average may give about 10 dB better SNR. Tuned loop antennas can improve this further by 20 dB.

It is interesting to look at other limits as well. IT equipment under EN 55022 Class B is significant. At 30 MHz (30 dBµVm) at 10 m converted to 3 m (10 dB) distance (assuming far field) and converted from 120 to 9 kHz BW (11 dB, assuming PLC noise signals), the result is about 51 dBµVm results in H = 0 dBµA/m. This converted EMC limit is more than 20 dB higher than NB 30, which needs to take network-specific effects into account. To put the limits into the right perspective, one should compare limits found in other important industry standards below 30 MHz (see Figure 4).

CISPR 11 (industrial, scientific, and medical equipment), CISPR 15 (lighting), and EN 50121 (railways) all have limits above those in NB 30. Other standards are also based on fairly old interference statistics models. Modern telecom and wireless aspects are only partly accounted for in these standards. Moreover, before deregulation settled in during the last decade, the various public telephone services (formerly monopolistic) used their strength more easily to set spectrum usage rules. Certain industry groups now seem to dominate this process, and the focus is moving in nontelecom-oriented directions.
Another important consideration is the simple conducted- emissions limits (see Figures 5 and 6). Taking 60 dBµV (Class B, QP), 30 MHz across 50 W (34 dB W), gives a 26 dBµA mixed-mode signal (CM + DM). The CISPR 16 V-shaped LISN does not separate the components. The proposed draft value in NB 30—about 12 dBµA (30 MHz)—makes sense for residential areas and is consistent with the need to account for network effects.

It is also worth mentioning that actual mains impedance (P/N/PE) measurements in the Netherlands revealed, as expected, large variations from 9 to almost 500 W (1.8 to 29 MHz).[13] Such variations have been known in the EMC community for several decades. The statistical average value, 50 W, has been used for about 30 years. For the hotly debated PLC telecom port (see Figure 6), the limit is somewhat relaxed. This limit is 74 dBµV (Class B, QP), 30 MHz. The corresponding current is calculated using 150 W (44 dBW) line (CM) impedance. Consequently, the result is 30 dBµA.

The real interest of the PLC community is an interim clause that specifies a 10-dB relaxation in the CM case between 6 and 30 MHz (40 dBµA). PLC developers would like to use a multifunction port because mains is their telecom port. It would certainly be interesting to check for impedance variations as well. No data are currently available.

It is especially critical to note the technical noise-floor problem in measurements for real EMI environments in city locations such as a flat in Paris. In these locations, the appliance noise can easily mask network-related limits at 3 m (see Figure 7).

Looking at conducted effects as the origin of radiation, under normal

V-LISN conditions, it seems nearly impossible to operate PLC data transmission in a safe and reliable way.

FCC Docket 03-104: FCC Begins Inquiry Regarding Broadband Over Power Line

As part of its ongoing effort to promote spectrum flexibility and access to broadband services for all Americans, and to encourage multiple platforms for broadband, especially new facilities-based platforms, FCC issued a Notice of Inquiry seeking public comment on using existing electrical power lines to provide Internet and broadband services to homes and offices.

Broadband over power line (BPL) can provide consumers with the freedom to access broadband services from any room in the house, without adding or paying for additional connections, by simply plugging a BPL device into an existing electrical outlet. BPL may be able to provide an additional means for "last-mile" delivery of broadband services and may offer a competitive alternative to digital subscriber line (DSL) and cable modem services. This will also enable access to communications services in rural and remote areas of the country. In addition, BPL systems can be used by electric utility companies to more effectively manage their electric power networks.

The inquiry addresses the two types of BPL: access and in-house. Access BPL uses medium-voltage (1000 to 40,000 V) power lines to bring Internet and other broadband applications to homes and offices. In-house BPL uses existing electric utility wiring to network computers and printers, as well as smart appliances, within a building. The Commission noted that existing rules for unlicensed carrier current systems, which couple radio-frequency (RF) energy to the alternating current (ac) electrical wiring for the purpose of communications, have been successful. However, these carrier current systems have operated with relatively limited communications capability on frequencies below 2 MHz, over a narrow spectrum bandwidth. Now, the availability of faster chip sets and the development of sophisticated modulation techniques have produced new digital power line designs that use multiple carriers spread over a wide frequency range (e.g., 2–80 MHz) and are capable of high data rates. The Commission further noted that providers of broadband over power line equipment are free to continue to deploy their networks in conformance with existing Part 15 rules, and potential rule changes as a result of this proceeding will address prospective compliance.

The Commission, in this inquiry, seeks information, comment, and technical data on issues concerning broadband over power line, specifically:

- The current state of high-speed BPL technology.
- The potential interference effects, if any, on authorized spectrum users.
- Test results from BPL experimental sites.

- The appropriate measurement procedure for testing emission characteristics for all types of carrier current systems.
- Changes that may be needed in Part 15 technical rules and the equipment approval process to foster the development of BPL and to ensure that interference is not caused to other services as a result of this technology.

Action by the Commission April 23, 2003, by Notice of Inquiry (FCC 03-100). For more information, contact Anh T. Wride at 202-418-0577.

Following a recent proposal from the PLC industry to push the limits via CISPR/I/44/CD (September 2002), an interesting study was conducted as a response by the German administration. As shown in Figures 6 and 7, the question remains as to whether an approach of using the mains port for telecom PLC purposes is acceptable with respect to the overall consequences to spectrum users.

It is clear that there are problems testing PLC modems in transmission mode at the mains port using telecom networks and telecom limits. Simplifying this reduces the problem to trying to make use of some LCL, 36 dB with T-LISN, according to CISPR 22, in order to push the limits. LCL is a measure for the average RF symmetry of telecom network lines.
Experimental data presented at a recent CISPR/I/WG3 meeting left serious doubt about whether near-end LCL measurements can be used to predict a common network balance performance. Three effects were proposed for investigation. Each effect is suspected to cause better LCL measurement results if an additional cable is inserted in the test setup. For simulation, relevant common cable parameters were used. By this simple simulation, the following conclusions can be drawn:

- Near-end measurements of far-end balance conditions are not possible.
- The fault in exploring the network LCL rises with the length of the cable.
- The fault in exploring the network LCL rises when the LCL at the far end lowers.
- The serial inductance has the most dominating influence.
- The mutual inductance may cause problems referring to the LCL measurement method.

The desired injected symmetrical DM, PLC line signal (L to N) is partly transformed into unwanted, asymmetrical portions (L and/or N to ground), causing CM currents and, therefore, radiated EMI.

Conclusion

Consequently, implementing this CISPR/I/44/CD proposal—with the negative German administration response— (PLC chimney transmission bands about 2–5 MHz and 11–22 MHz) would lead to an EN 55022 B mains port limit increase by more than 50 dB. This strongly indicates unsolved technical problems with the present generation of PLC technology. Peaceful coexistence with established technologies is currently unlikely. The technical EMI problems are discussed in Part 2 of this article beginning on page 58.

References

01. http://www.PLCforum.com; http://www.ipcf.org; http://www.ascom.ch; http://www.hdl.de.

02. Power-Line Communications Literature Overview, University Essen, Germany, http://www.exp-math.uni-essen.de.

03. Diethard Hansen, "Megabits per Second on 50 Hz Power Lines," (*IEEE EMC Society Newsletter*, Practical Papers, Winter 2001) http://www.emcs.org.

04. German Amateur Radio Club, DARC, http://www.darc.de.

05. Measurements and Noise Considerations, RSGB UK EMC Committee, http://www.qsl.net/rsgb_emc/emcslides.html.

06. Minutes of ATRT UAGr.3 WG PLC –Advisory Board of RegTp protocols since 1998—Communications in German by e-mail to members, not classified: "Sky Wave PLC Simulation," Dr. Widmer, ASCOM CH (Estimates about 10dB noise increase for –40dBm/Hz nationwide PLC).

07. BND/FGAN-Benger Study: Auswirkungen PLC auf die Fernmeldeaufklärung 9/2001, "PLC Effects on Listening Posts, Including Sky Waves Result: Demanding 25 dB Decrease of NB 30 Limits 1.5–30 MHz."

08. First findings from tests and simulations, EMC Wroclaw 6/2000 Symposium, Poland-PLC WS with Dr. Vick -Dresden, Germany.

09. Manfred Stecher, "EMC Aspects of PLC," page 407 ff, (EMC Europe 2000 Brugge, Belgium, September, 2000).

10. DW Welsh, "Investigation of likely increase in established radio noise floor due to widespread deployment of PLT, ADSL and VDSL broadband access technologies," (EMC Zurich 2001 Symposium, March).

11. E Marthe et al., "Outdoor Radiated Emission Associated with PLC Systems," F.Issa et al. Session paper D3-A2-02; "Indoor Radiated Emission Associated with PLC Systems," session paper D3-A2-01.

12. EU-Workshop: "Compatibility between Radio-Communications Services and PLC Systems" WS EU DG Enterprise, Brussels, with Mark Bogers, March 5, 2001 (current state of technical work is not that high, including small product exhibition).

13. EMC Commissie Veron, Koos Fockens Dutch PLC Measurements, June 21, 2002, "The radio amateur and the effects of the use of the 230 Volt power line for broadband data communication (PLC)."

14. On August 7, 2001, the European Commission issued the standardization mandate M 313 addressed to CEN, CENELEC, and ETSI, asking them to produce EMC harmonized standards for all (not only PLC) telecommunication networks.

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