



Technical EMI Problems in PLC Systems, Part 2

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Analyzing the results of PLC data reveals excessive emissions and incompatibility with existing technologies.

As discussed in Part 1, power line communications (PLC) presents significant interference issues and technical problems. These problems became evident in various studies throughout Europe. Individual radiated-emissions measurement campaigns in 2000 and 2001 showed numerous inconsistencies, which are as follows:

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- University of Dortmund/Siemens, Germany. Tests using -2 dBm at 10 MHz result in just meeting NB 30 limits.
- Sevilla, Spain. Tests show -40 to -50 dBm/Hz (0 to -10 dBm in 9 kHz BW) at $d = 10$ m ($5-10$ MHz) results in more than 20 dB above NB 30. These PLC systems require a minimum signal-to-noise ratio (SNR) of 15 dB.
- Cologne, Germany. Measurements show $+17$ dBm total injected RF power, at 2–3 MHz, results in more than 13 dB above NB 30.
- Suhr/AG, Switzerland. With -16 dBm, around 20 MHz results in 14 dB above NB 30. Outdoor cables are not so critical; 200–300 m in the street with one party at the end of the street being ASCOM connected.
- Fulpmes/Stubai, Austria. Running an ASCOM system with typical specs: outdoor frequencies of 2.4, 4.8, and 8.4 MHz; indoor frequencies of 19.8 and 22.8 MHz; and PLC power levels of 17 dBm (50 mW, 124 dB μ V, 90 dB μ A) to -17 dBm (20 μ W, 90 dB μ V, 56 dB μ A).

The result was complete blocking of HAM short-wave receivers at $+17$ dBm, and the final result was this: no PLC signal was detected at -17 dBm (system bit rate unknown). At only 5W RF power from mobile TX at 21 MHz, the PLC system crashes.

Some reasons for problems are strong variations in cable coupling factors ranging from 5 to 30 (and even 60) dB within homes, depending on national electrical wiring codes and other national installation specifics.

More statistics about real signal-to-noise environment and LCL asymmetrical measurements in mains low-voltage distribution systems are needed. Generally speaking, telecom lines have about 20–30 dB better symmetry than low-voltage systems. Telecom lines, therefore, create less EMI common-mode (CM) current over electricity cables. Power lines transform symmetrically injected signals into asymmetrical, interfering currents (CM), causing network radiation problems.

PLC System Measurement Data

The first field trials with a few clients connected to UK Norweb showed dramatic emissions problems. The UK RadioCommunications Agency and the Radio Society of Great Britain (UK-licensed radio amateurs) documented these cases. Norweb finally left the UK market and started PLC activities in Germany, where it pulled out later as well. In Germany, RegTP ATRT protocols documented emissions up to 40 dB above NB 30 limits for most of the field trial.

Austria revealed serious radiated emissions and immunity problems with ASCOM systems. RWE pulled out in 2002 for technical reasons. Norway showed excessive emissions, about 30 dB over NB 30 limits (13 locations, up to 10 V pp = 140 dB μ V injected; P-PE, 2–3 MHz). Consequently, no government license was granted to PLC providers.

Evaluation Table of Amateur Radio Reception, Interfered by Power Line Communication		
	German quad: a square loop of 20 20 m, 10 m high.	Duo bander, 2 4

Receive antenna:		The smallest distance to the house is 12 m. Connected via balun trafo and matching circuit. Full matching only on 3.5 and 14 MHz band. []: inverted L receive only antenna, 30 m horizontal, 10 m height, 40 m distance to house. Connected via broadband trafo.				elements beam. Positioned at mast 2 m from house, 21 m above ground.		
Experiment:	Frequency:	1.84	3.575	7.03	14.09	21.1	28.4	MHz
1. E = E ₀	Injected power:	0	0	0	0	0	0	dBm
	E@3 m:	79.9	78.9	74.4	68.4	59.9	64.9	dBµV/m
	V _{antenna} :	49 [39]	62 [43]	55 [55]	49 [35]	56	56	dBµV
	Experience of interference: (on rx: NRD525)	Very strong [very strong]	Very strong [very strong]	Very strong [very strong]	Very strong [very strong]	Very strong	Very strong	—
2. E = E _{NB30}	Injected power:	-42.2	-43.8	-41.9	-38.5	-31.6	-37.7	dBm
	E@3 m:	37.7	35.1	32.5	29.9	28.3	27.2	dBµV
	V _{antenna} :	8 [0]	19 [0]	14 [14]	10 [-4]	23	19	dBµV
	Interference:	Reasonable [weak]	Rather strong [reasonable]	Well [well]	Reasonable [very weak]	Rather strong	Rather strong	—
3. E = E _{CISPR22}	Injected power:	-48.2	-48.5	-43.2	-48.6	-52.0	-46.8	dBm
	E@3 m:	31.7	30.4	31.2	19.8	7.9	18.1	dBµV/m
	V _{antenna} :	1 [-6]	13 [-]	12 [12]	1 [-14]	3	9	dBµV
	Interference:	Weak [very weak]	Reasonably well [hardly perceptible]	Well [well]	Hardly perceptible [no]	Reasonable	Rather strong	—
4. E = E _{Norway}	Injected power:	-61.9	-63.2	-60.9	-57.2	-50.1	-56.1	dBm
	E@3 m@	18.0	15.7	13.5	11.2	9.8	8.8	dBµV/m
	V _{antenna} :	-13 [-]	-1 [-]	- [-]	-7 [-]	6	0	dBµV
	Interference:	Hardly perceptible [no]	Hardly perceptible [no]	No	No	Reasonable	Weak	—
5. E = E _{BBC}	Injected power:	-70.6	-72.0	-69.8	-66.3	-59.2	-65.3	dBm
	E@3 m:	9.3	6.9	4.6	2.1	0.7	-0.4	dBµV/m
	V _{antenna} :	- [-]	- [-]	- [-]	- [-]	-3	-7	dBµV
	Interference:	No	No	No	No	Very weak	Very weak	—
6. Ambient noise	B = 500 Hz:	-12 [-6]	3 [-4]	3 [1]	-4 [-9]	-20	-21	dBµV
	B = 2.7 kHz:	-3 [1]	10 [3]	10 [8]	3 [-2]	-13	-14	dBµV
	Antenna factor:	Unknown	Unknown	Unknown	Unknown	-11.2	-8.7	dBm
	Noise field strength	—	—	—	—	-24.2	-22.7	dBµV/m

Table I. Amateur radio reception interference by PLC (Veron NL 2002). Power-injection level, frequency versus proposed PLC regulations limit.

All over the EU, modem and system emissions, including conducted EMI, were mostly way too high,

according to EN 55022 Class B. In Switzerland, a 200–300-m street area with one single home connected to the ASCOM PLC system demonstrated excessive indoor emissions around that home.

PLC interference has been identified as other background ambient in bands <30 MHz, receiver jamming (desensitization), and time-variant EMI. It takes wireless experts to confirm that the cause is PLC and not other EMI. Normally at continuous wave (CW), amplitude modulation (AM), and single sideband (SSB), the whole receive spectrum is experiencing a massive noise-floor increase (which sounds like an old steam locomotive sometimes), resulting in total blocking. Sensitivity is wiped out. Figures 1 and 2 illustrate actual PLC signals.

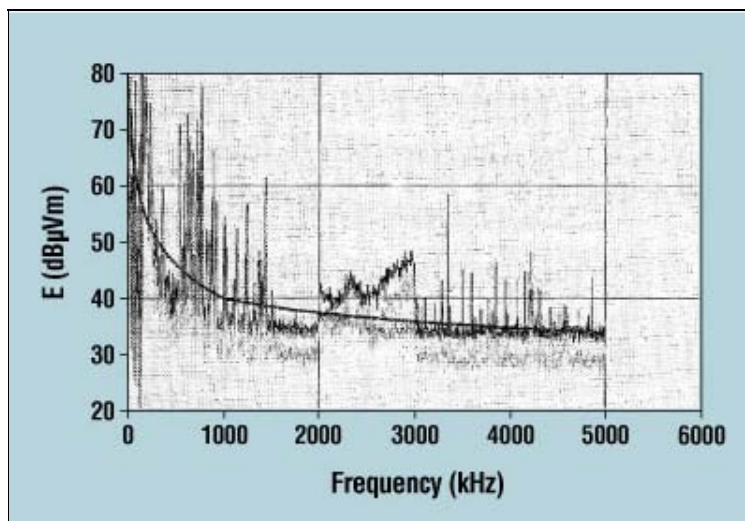


Figure 1. Siemens/RegTP 2001 (Cologne) PLC field trials, +17 dBm, PLC Carrier 2–3 MHz, radiated emission (13 dB over NB 30 with high background noise).

The conducted PLC mains signal shown in Figure 2 is already 60 dB above the informative CM current limit of NB 30. Converting with 50 W mains port impedance gives a 112 dBµV (+5 dBm~3 mW) CM signal, which is way too high for EN 55022 Class B. For spread-spectrum PLC signals, the practical situation does not look any better (see Figure 3). These results further demonstrate where the current PLC technology stands. Lowering the transmit signal results in reduced data rates, and further reductions stop proper operations completely. Figure 4 and Table I indicate the amount of reduction needed from a spectrum user's point of view. This reduction is almost 50 dB below present levels in the field. A range of 30–50 dB was confirmed by researchers of France Telecom R&D at the Sorrento EMC Symposium 2002. The PLC industry must, therefore, search for new transmission techniques to peacefully coexist with other, earlier spectrum users.

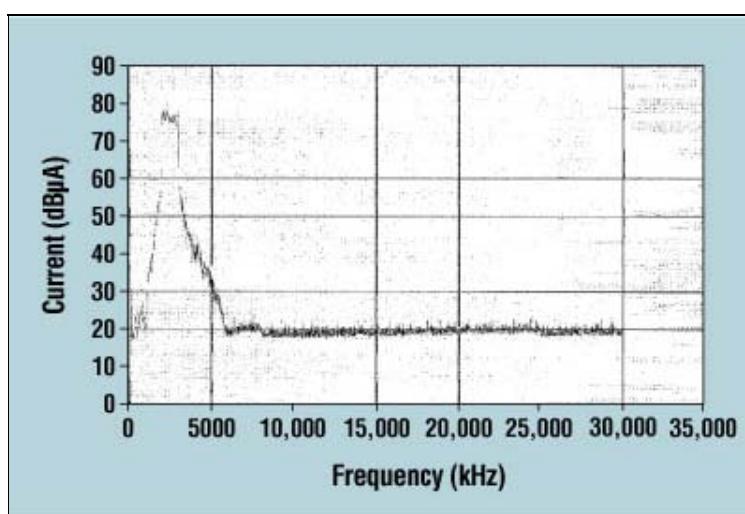


Figure 2. To Figure 1, corresponding PLC E-signal + 17 dBm, 2–3 MHz carrier, CM current 78 dBµA peak.

Further confirmation of these results can be found in the RegTP/Dresden study. This study suggested that about 44 dBµV symmetrically injected PLC signal was needed to stay below NB 30 limits. For signals up to 10 MHz, $V_{(CM)} = 0.5 V$, then $V = V - TCL$ (dB). This means transverse

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and longitudinal cable coupling are about 6 dB apart. In symmetrical telecom cables, the result could be much better.¹

Comparing PLC to Other Cable Technologies

Table II lists important features of cable TV networks, subscriber lines, and PLC. Looking at radiated emissions results ($d = 1\text{ m}$) from field trials in France, Germany, and the UK and reviewing some U.S. standards work on local-area networks (LANs) provides perspective on the complexity of present equipment (hardly system) EMC approaches. Of these technologies, ADSL and VDSL are typically less than NB 30 limits and higher than BBC limits (see Figure 4). The same applies to 100BaseT Ethernet LANs. Excessive radiation, however, is produced by lighting equipment (low-voltage halogen lamps). All networks must be correctly installed and maintained, with due consideration of EMC aspects such as shielding integrity and proper connectors.

Many leaking cables have been found in old German cable TV installations (e.g., Berlin and Hannover). This leakage caused problems with very-high frequency signal interference to air-traffic control. EN 50083 defines 27 dBpW at 5 MHz. From 30–1000 MHz, this limit is 20 dBpW. An E-field estimate at 3 m (9 kHz) and point source radiator assumption in free space indicates 34–27 dBµVm. Such emissions fall within the NB 30 limit range. Several thousand homes have been tested statistically. Some places, however, showed initial leakage to be orders of magnitude too high.

PLC Impact on Sensitive Radio Services

Listening posts, the military, and embassies—just to name a few—use short-wave communication. So does the worldwide experimental, licensed amateur-radio service, including technical education and emergency services. A detailed investigation from EMC professionals and the Dutch Amateur Radio Club came up with an interesting summary from a typical residential home where they injected different RF power into the mains home installation (see Table I).² Using typical HAM antennas, the receiver voltage +SNR was checked to determine the level of interference at that frequency.

Table II clearly shows the critical effect of PLC injected signals on the nearby environment. Real ambient noise-floor figures are also given. Most importantly, an assessment is made regarding the level of communication degradation. Even NB 30 and CISPR 22 (EN 55022) induce rather strong interference in some bands.

Technology Feature	Coaxial Cable	DSL	PLC
BB transmission media suitability	very good	medium	poor
RF characteristics of transmission line	screened	balanced	unclear
Available BW for expansion	very good	fair	poor
EMI mitigation	good	medium	very poor

Table II. Comparison of cable technologies.

Sky-wave PLC effects have not been tested in this effort. Various research-oriented studies have been performed in recent years. Some simulations indicate problems. For example, noise-floor increases—up to 5 ionosphere hops to 3500 km distance—reduce the signal by only about 15 dB (1 W/m² EIRP results in 40 dBµVm); overseas aircraft will receive PLC EMI in flight almost independent of altitude, depending on the choice of simulation parameter (–40 to –70 dBm/Hz PLC source, modem area coverage, antenna factors, assuming broadband incoherent PLC, network emission geometry-configuration effects neglected).

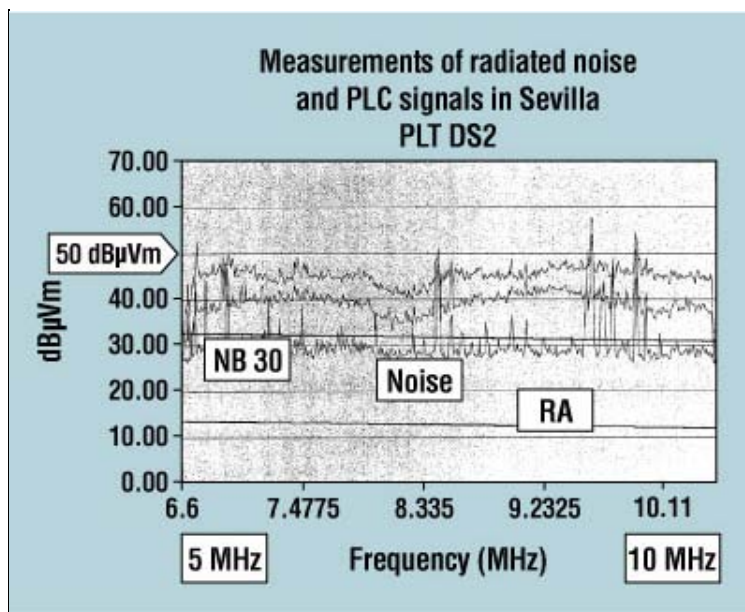


Figure 3. PLC radiated emissions about 20 dB over NB 30 RA UK MPT 1570 old limits, -20dB below NB 30 (Source: PLC Forum WS 2001 Brussels).

It is difficult to know what statistics apply. Large-scale experiments are needed to finally prove these complex assumptions. Ionosphere propagations (1–30 MHz) have been investigated for many years. There are critical input parameters to be evaluated statistically, e.g., the effective system (network) antenna factor. Other questions surround how efficiently the complex net radiates in the far field and the appropriate noise figure to use at the receiving location, possibly thousands of kilometers away. Propagations may easily change by as much as 60 dB depending on temporary conditions. Maximum usable frequency (MUF) depends strongly on the time of the day. Solar flux is important. It is well known that worldwide short-wave connections can be established (at low SNR) with only milliwatts of effective radiated power.

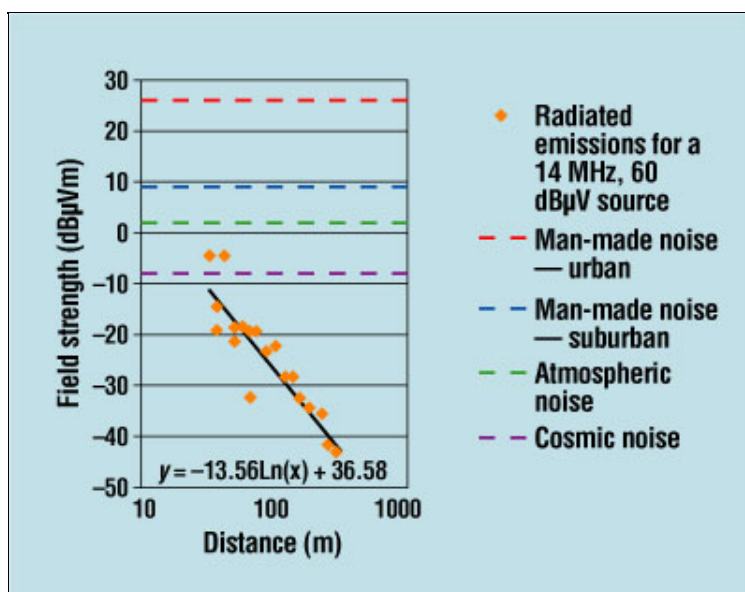


Figure 4. As distance increases from the PLC radiation source, field strength decreases. To attain a "no problem limit" of PLC, radiated emission requires "only" -87 dBm/Hz PLC signal (Source: UK) PLC sign, 14 MHz (free space)

Minimum Field Strength in Broadcasting. According to ITU Recommendation 703, the noise floor to calculate the minimum field strength is determined as the largest one among the values of atmospheric noise, man-made noise, and intrinsic receiver noise. The resulting value for noise (whatever the cause), E_n , usually lies between 3.5 to 7 dBµV/m in the frequency bands under consideration (1–10 MHz, PLC access). The RF signal-to-noise ratio, SNR_{RF} , is taken to be 34 dB for the high-frequency band and 40 dB for the low- and medium-frequency bands. Therefore, the

minimum usable field strength, F_{\min} , is calculated as shown in Table III.

At $41 \mu\text{V/m}$ ($32 \text{ dB}\mu\text{V/m}$), in the short-wave band (10 MHz), this barely matches NB 30 limits. Less signal-to-noise demands increased transmit power. Increased power, however, is economically difficult, and from an environmental, health hazard point of view, is rather limited. New digital modulations live off SNR as well. A coverage study of radio Netherlands 500-kW, 9.7-MHz, 110° beam indicates a service reduction (based on NB 30 limits) from international (East Bloc) to basically national (Dutch and German) dimensions.

The Business Case for PLC

Utility companies in the EU, Asia, and South America are doing pilot PLC projects. Some claim to have as many as 1500 connected clients. In the West German area of RWE Essen (modems from ASCOM) and the southern area of MVV Mannheim, these companies had hoped for more than 3000 new subscribers each year, but RWE stopped PLC completely in 2002. Comparing this conservative growth to the more than 600,000 T-DSL clients already using 700 kb/second ADSL via phone lines makes PLC look much less viable.

Noise Floor	LF	MF	HF
E_n ($\mu\text{V/m}$)	20	20	3.5–7
SNR_{RF} (dB)	40	40	34
F_{\min} ($\mu\text{mV/m}$)	60	60	37.5–41

Table III. Broadcast (AM) minimum usable field strength.

Moreover, PLC proponents have focused much of their efforts on marketing rather than on solving technicalities such as radiated emissions problems. PLC faces strong competition from LAN, radio-LAN, cable TV, xDSL, and satellite. Important opposition groups of concerned spectrum users are now speaking up. RWE and ASCOM also face legal EMC trouble (modems measured with conducted emissions are still excessive according to EN 55022 Class B) by official RegTP market inspections in Germany. It is unlikely that this technology can become profitable in one or two years.

Public Relations, Public Opinion, and German Politics

The mighty PLC PR engine has been described in other articles.³ The stronger the technical problems became, the more money that went into promoting PLC, mainly at CEBIT in Hannover, Germany. Norweb, Siemens, EON, and RWE, meanwhile, all left the PLC scene because of the technology's unclear future. Restructuring is taking place at Swiss ASCOM. Generally speaking, there is very little willingness in the PLC industry to address technical aspects and problems even today. And, in spite of all of the PR efforts, client acceptance is relatively low. PLC technology is still premature, at least with respect to disturbance control.

However, it is important to note that 100 serious, technical, professional objections to NB 30 (some demanding even lower limits) were filed with RegTP and were politically ignored by the Ministry of Economic Affairs when NB 30 was released. It reflects how little top-ranking officials in Berlin and Brussels act on the advice of technical experts. Many decisions are marketing driven with unfulfilled promises.

Conclusion

PLC technology, in principle, is potentially attractive, if it were to become compatible with existing telecom technologies. PLC technology is still premature in terms of EMI prevention. PLC has little to offer over the competitors and certainly does not justify more EMI. Standards will evolve relatively slowly. The requirement of the EMC Directive with harmonized norms (to conducted EN 55022) are not met by most PLC systems, regardless of the stricter limits of regulations such as NB 30.

It is unlikely that PLC will experience widespread application under its currently implemented status. With delays in implementation and lackluster client acceptance, even the business case is becoming less attractive.

References

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