A paper on the difficulty of measuring broadband interference emissions from cables and the problem of assessing the results with respect to interference to radio reception. Tests and experiences from an installed PLT system

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1. Introduction

For about a year now there have been discussions on the appropriate limits for emissions from telecommunication cable systems. Measurement and monitoring has been conducted at the site of a PLT installation in the area of a German city to get first-hand information on this matter. The scope of this preliminary short study was mainly to assess the effect of the newly redefined "broadband-emissions" from data-communication systems using new broadband- or spread-spectrum transmissions.

Previously the term "broadband-emissions" described unwanted, short and steep single pulses or bursts in the radio-frequency-domain, generated mainly from mains switching. Their harmful effects on broadcast radio systems were then measured with a quasi-peak-detector which assessed the acoustic and psychological effect of repetition rates. In the following paragraphs, the measurements conducted in these new tests are set out. These measurements were made using a Schwarzbeck FMZB 1517 loop antenna, R&S, ESH 2-Z3 voltage probe and Advantest R3131 spectrum analyser. Listening experiences, including sound recordings are also included.

2. Interference characteristics: first acoustic impressions of the interference

When the PLT system was in stand-by-mode or when only a few data packets are being transmitted, one noticed short crackling/spark-like noises every 1 to 3 seconds, generated by the data packets from the PLT system. Their start seemed to be controlled by a random generator. To the untrained ear, the interference was difficult to distinguish from other sporadically generated switching noises. The interference from the PLT system (other than true switching sparks with limited spectrum coverage), seemed to be similar on all channels in the whole frequency-range up to about 18 MHz, with the possible exception of some small notched frequency bands.

Transmission of web-cam-data (with 5 to 100kBit) generated somewhat more frequent spark-like bursts in one minute intervals, which corresponded to the refresh-time of these pictures. With an increased data-packet-rate, or if there were more active service-subscribers on the lines, the crackling/spark-rate increased, such that during radio broadcast transmissions even speech readability was lost. Future digital radio-broadcast-transmissions like DRM (Digital Radio Mondiale) under these conditions suffered total interference. Listening tests were performed with several broadcast shortwave channels between 6 and 20 MHz under good reception conditions with a field strength of at least 55 to 65dBμV/m. The interference with medium data rates was reminiscent of the hard sparking noise coming from an old tramway pantograph on an infrequently used overhead-wire. With higher data-rates the interference noise became a continuous sharp crackling-sparking noise.

On driving through several streets of a built-up area in the evening, quasi- continuous noise could be heard at a distance of 10 –30 m around electric distribution cabinets along the streets, in empty as well as in occupied broadcast-channels, all over the above noted frequency range. In addition, on some channels between 1 and 18 MHz, there was a continuous grained rustling noise, similar to qpsk-data. As the area under review included some military sites, it could not be discounted that some signals came from there.

3. Magnetic Field-measurements with various weightings

Measurements were performed with a magnetic loop 1m above ground on the street, at least 10m from an electric distribution cabinet. Other measurements were performed in the middle of a room, at least 3m from the PLT modem. The position of the mains lines in the wall could not be determined. The radiated PLT interference fields measured within the room or on the street had about the same characteristics with respect to their frequency coverage and their directivity. Turning the loop-antenna over a wide range of angles brought only small amplitude variations, other than with radio-reception, where a discrete minimum was detectable. Without better knowledge of the working principles a distinction between data-up- or download was not possible.

3.1 Measurements with PLT-stand-by and various weightings

Figure1: PLT: Stand-by, only occasional data-transmission; spec-analyser: sampling-mode. Indication with statistic averaging over 10 sec.

The diagram from 1 to 20 MHz shows after statistic averaging only constantly present carriers like radio signals or possibly continuous PLT signals around some carriers. Spasmodic single events like switching or single, short PLT-data-bursts are not represented. The stronger carriers appear at about 65 dB(μV/m).

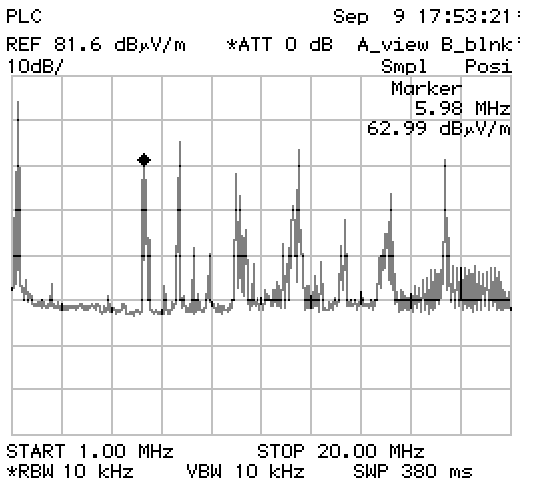

Fig.1: PLT: Stand-by, only occasional data-transmission; spec-analyser: sampling-mode. Indication with statistic averaging over 10 sec

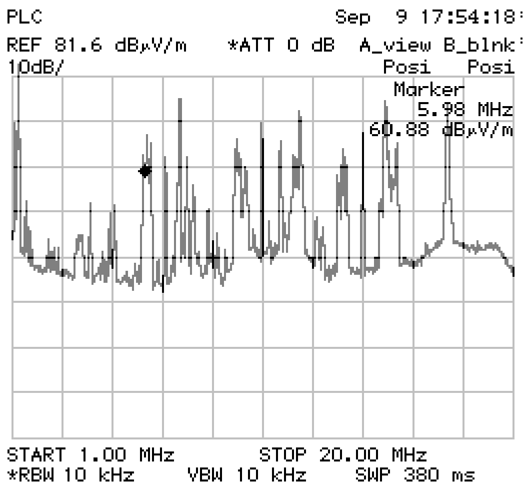

Fig 2: PLT system obvious stand-by; Spec-analyser: Peak detect max-hold 10 sec

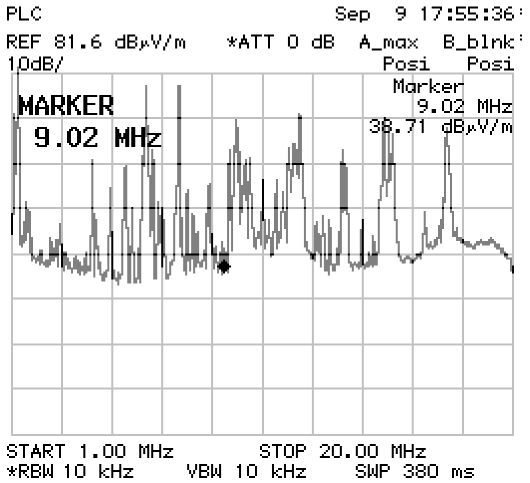

Fig3: Stand-by, peak detect, max-hold 1 min

Figure 2: The PLT system is obviously in stand-by mode; Spec-analyser: Peak detect max-hold 10 s; some more lines with peak values of 75 dBµV/m.

Figure 3: Stand-by, peak detect, max-hold 1 min; similar to fig. 2, no big differences.

Conclusion. In the stand-by mode or with low data packet rates harmful interference may present over the whole spectrum, but it is obviously not possible to capture or present these emissions with standard spectrum analyser settings.

3.2 Denser data packet transmissions

With denser data traffic, the effect of the interference becomes visible on the spectrum analyser. With peak hold mode, the width of spectrum covered seems to increase with data rate.

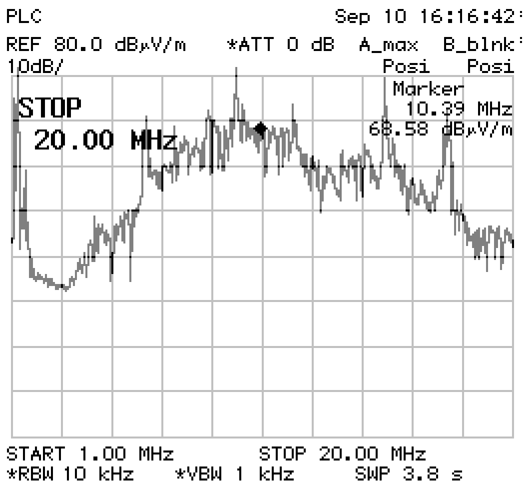

Fig 4: Peak hold 1 min,
Dense data traffic, probably more subscribers are on line

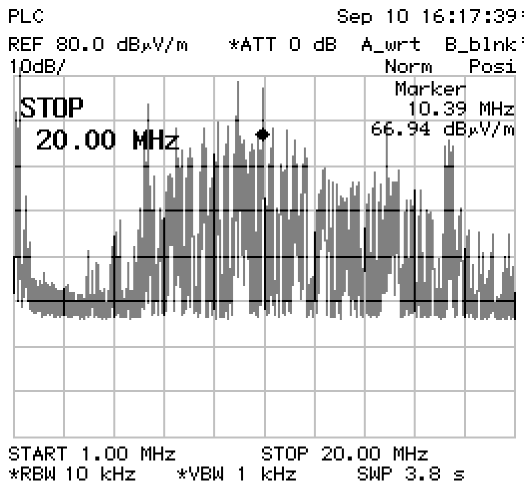

Fig 5: Peak detect
Dense data traffic, probably more subscribers are on line

Figure 4: Peak hold 1 min, with dense data traffic; probably more subscribers are on line: large parts of the measured spectrum field strength are over 60dBµV/m.

Figure 5: Peak detect, shows already after one 3.8 sec sweep that the whole spectrum up to 18 MHz is affected.

4. The PLT signal in the quasi-receiving channel

The following figures are taken in a building with a magnetic loop and spectrum analyser with zero-span-mode, that means it remained on one centre frequency (e.g. a radio-channel at 6005kHz) and with a resolution bandwidth of 9 or 10 kHz it worked as quasi-receiver.

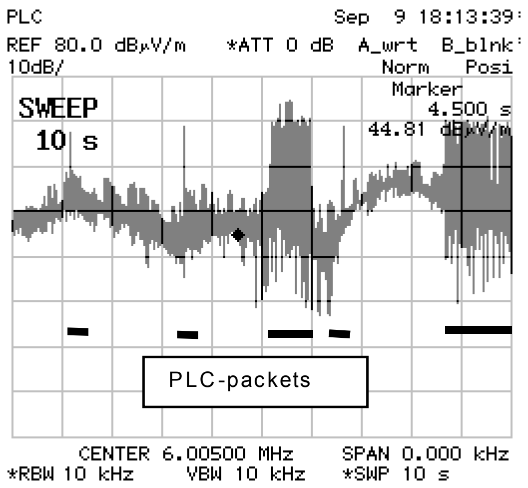

Fig 6: Spec-analyser Zero-Span, at 6005 kHz, sweep over 10 seconds, radiobroadcast-modulation, superimposed by PLT data transfer wanted signal level approx 50 dBµV/m

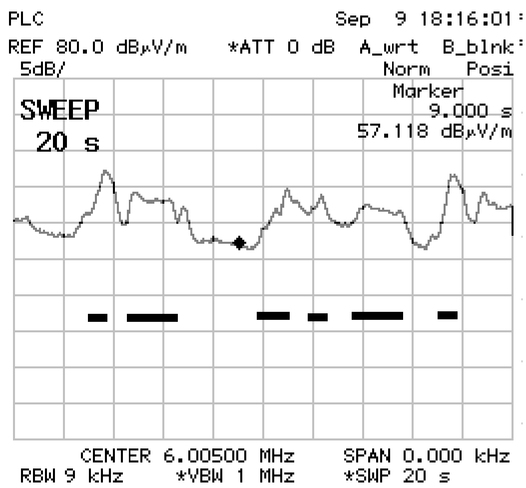

Fig 7: Zero-Span at 6005 kHz sweep over 20 s, QP –mode, radiobroadcast-modulation, superimposed by PLT data transfer, wanted signal level approx. 50 dBµV/m

Figure 6: Spec-analyser zero-span at 6005 kHz, and sweep over 10 seconds of radiobroadcast-modulation, superimposed with PLT-data-transfer. The vertical axis represents the actual received field strength. The mean value was about 50 dBµV/m, the field strength for minimum radio coverage, according to ITU-R is 40dBµV/m, and thus is well exceeded. The horizontal axis gives the signal-strength over a 10 second period. The broken lines in the figure show some of the audible PLT interference noises, heard during reception. There are some shorter bursts to the left, two of about 1,0 and 1,6 sec to the right.

Fig 7: Shows zero-Span, at 6005 kHz, sweep over 20 seconds, with simulated QP-mode as understood from classic EMC-measurements. The line represents radio broadcast modulation, superimposed with PLT-data-transfer. The wanted signal level is approximately 50 dBµV/m. In this case it seemed as if the QP-method, used over the whole band of unwanted emissions, was the appropriate method, which allows comparison to field strength values of the radio system.

Measurements with other parameters and reception frequencies are given below. For easy comparison, the four diagrams are set out on one page:

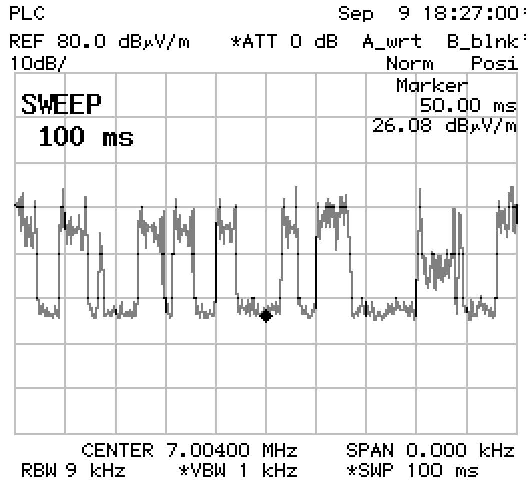

Fig 8 PLT pulses at 7 MHz reception channel, empty channel, but PLT packets audible
The 28dBuV/m pulse base line is the noise floor of measuring system - not the environmental radio noise.

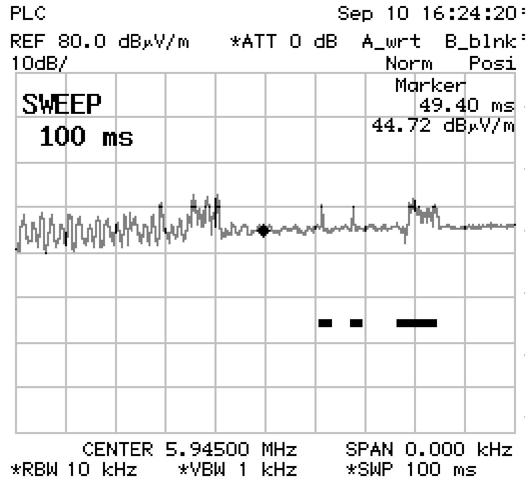

Fig 9: reception at 5945 kHz
modulation and interfering packets, (dashed lines below) mean wanted signal level 48 dBμV/m

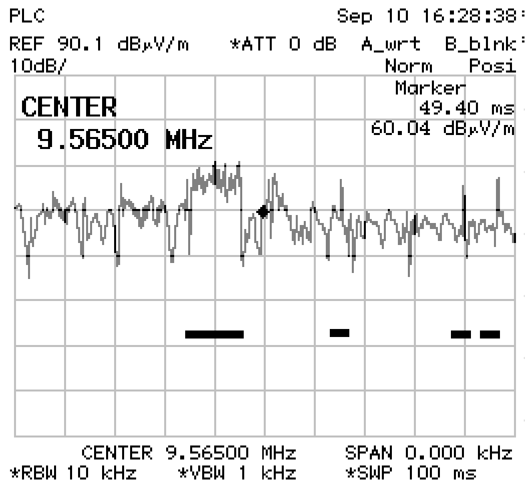

Fig 10: reception at 9565 kHz
radio-modulation with PLT interference superimposed, mean wanted signal level 57 dBμV/m

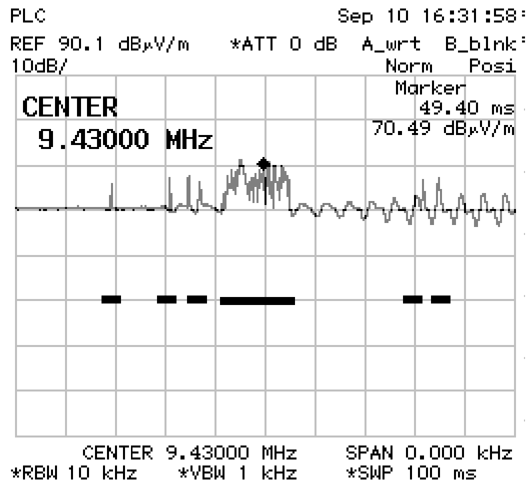

Fig. 11 Reception at 9430 kHz
radio-modulation with PLT interference superimposed on mean wanted signal level 60 dBμV/m

Fig 8: Reception of audible PLT packet pulses in an empty channel, i.e. without wanted signal, at 7.004 MHz. The data pulse train can be seen in the diagram. The electrical environmental noise is far below the measuring system sensitivity limit (noise floor) of about 28 dBμV/m - at the base-line of the pulses

In figure 9 pulses appear within a modulation pause, as indicated by a broken line.

Figure 10 shows the appearance of PLT-pulse-packets during modulation at 9565 kHz

Figure 11 shows packets at the end of a modulation-pause and during the beginning of a broadcast tuning signal (musical tones).

5. Interference-voltage measurements

Because of lack of time, only two interference voltage measurements could be performed on a mains socket. (Asymmetric voltage, voltage probe R&S, ESH2-Z3). Therefore it was not possible to get information about the details of the mains cabling in that house. By listening to the radio it was found that only low data-rates (stand-by) of the PLT occurred during these measurements.

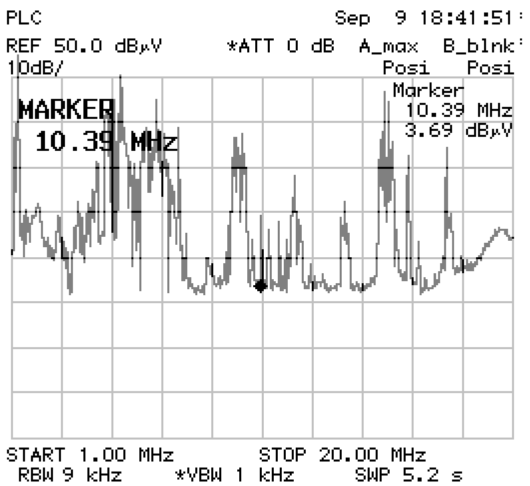

Fig 12:Mains-interference-voltage with voltage-probe (add +30 dB to reading), low PLT data-rate, Phase

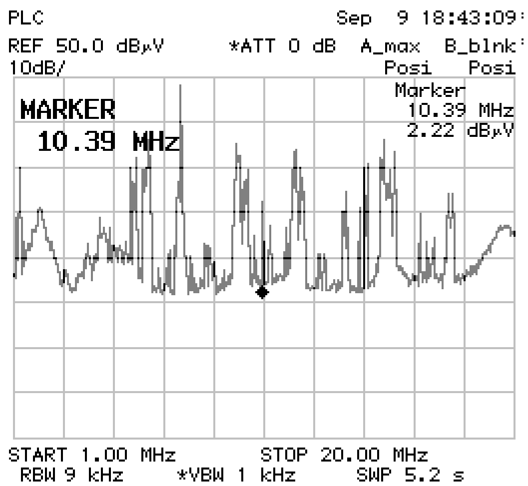

Fig 13: Mains-interference-voltage with voltage-probe (add +30 dB to reading), neutral

Figures 12 and 13 represent the asymmetric voltage of Phase and neutral conductors to the best available ground. Comparisons between figures 12 and 13 with similar data-rate conditions should only be done with reservation, as the analyser settings were not fully comparable. Additional information: the signal strength of radio DLR Berlin at 6005kHz at that point was 55 dBµV.

6. Sound-samples of the interference

Sound-samples were taken with a Sony ICF-SW 100 receiver, a rod antenna for frequencies above 1,6 MHz and recorded with MD-Recorder. For easier data transfer through mail they were compressed as MP3-data. Some notes are included in the Appendix below. As these samples were taken in the street, far-field conditions are valid and the recorded magnetic field strength values can be used. Because of lack of time for preparation, some slight interference from the MD-recorder located near the receiver entered into the recordings.

7. Results and conclusions

As already reported elsewhere, it is difficult or almost impossible to capture and present the emissions from new broadband-communication systems using spread-spectrum-technologies at low or unknown data-rates (stand-by) by simple use of a spectrum analyser. Nevertheless even at these very low data rates, the harmful effect of these emissions on radio systems all over the spectrum used for radio communication is at once evident, as soon as emissions exceed the conventional limits. Measurement and assessment is therefore only possible with conventional measuring receivers tuned sequentially over the whole spectrum in use.

One finds from the preceding field strength diagrams taken at 3 to 15m distance from the wiring of an actual PLT installation, that there is often interference to signals that are at the 50 to 65 dBμV/m wanted signal level.

From the diagrams presented, before taking into account the given wanted signal field strengths, it becomes clear, the unwanted interference emissions (independent of data-rate) have to be kept below the well known interference limits, given through simple signal-to-noise-ratio-relations. The parameters are given from the ITU-R defined minimum coverage field strength and the minimum required S/N-ratio of at least 20 to30 dB.

Appendix: Commentary on sound-samples

Reception was done with a Sony ICF-SW100 (rod-antenna) and MD-Recorder, later MP3 coded to reduce file size and ease mailing. This results in slightly higher background-noise, but the effect of the interference is unfortunately also reduced.
MP3-Data: 40 kBit/sec 22010kHz, mono, linear

For playback a MP3-player program like Win-media-player should be installed on your computer. For objective judging, one should have quality loudspeakers on the computer.

Click here to Play (41sec)

First impressions from medium PLT-data rate, at 7 MHz, then after 8th to 20th second switching to several other, pre-programmed frequencies at 6, 9 and 15 MHz. Between switching short blanking of the receiver gives the impression that the interference noise over the spectrum is about the same everywhere. After 20th sec 6005kHz News-speaker; Interference comes up above wanted signal level >55 dBμV/m

Click here to Play (14 sec)

News, but from 12th second additional higher rates, or further PLT transmissions from other 2nd user

Click here to Play (12 sec)

6085 kHz, Bayer. Rundfunk, News, wanted signal level >60 dBμV/m, sample contains both types of interference, first some grainy noise, over several second periods, then second type

Click here to Play (17 sec)

9 MHz, strong interference over weak radiosignal