Headroom for PLT: is it necessary?

Signal/Noise ratio considerations for PLT

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1) Introduction

It is commonplace to hear it stated that ***"Of course, PLT needs some headroom to operate, therefore the service must be allowed an interference level xxdB above that allowed for other products"***

This contribution examines this proposition from both practical and experimental viewpoints and concludes that useful PLT products could be designed within the limits already standardised in CISPR22 for mains ports. The headline data rate and working range would of course be lower – but still sufficient to be very useful.

2) An everyday view

The interference already found on the mains network is unpredictable in time and in frequency, although mandatory EMC standards should limit the amplitude. In the frequency dimension there are substantial bands of low amplitude interference as may be seen from any conducted emission test plot. **Figure 1** below is expanded into the time dimension to show that here too there are substantial gaps for PLT to operate. We have illustrated time-continuous interference at 7 and 10MHz, and isolated emissions at 22MHz.

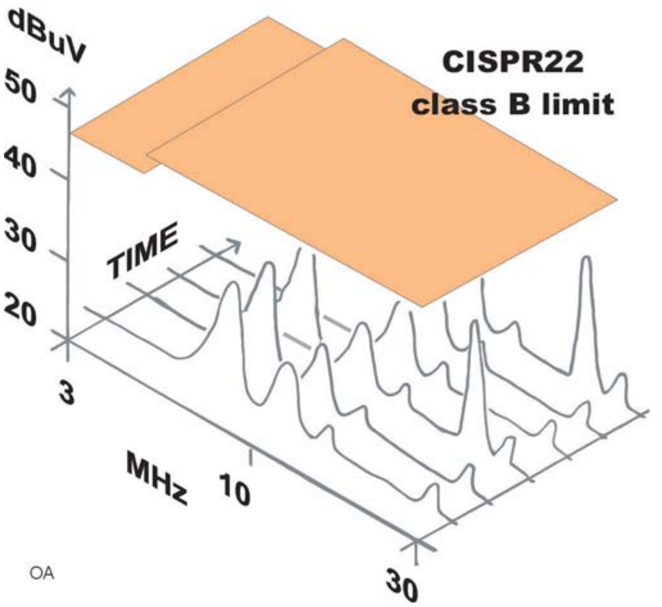

Figure 1. Conventional interference sources approach the limits only rarely across the range of frequency and time.

Data transmission coding algorithms are always designed to give maximum resilience with a specific data rate and interference profile. Those used by PLT must be chosen to exploit the gaps in frequency and time. These algorithms have been improved over the years and the benefit taken in increased data rate. Homeplug 1.0 claimed a physical layer data rate of 13.78 Mb/sec in 2001, and in 2005 Homeplug AV claimed 200Mb/s. **The designers could have chosen to take the benefit of an improved algorithm as improved conformance to CISPR22; but they chose instead to take all of the technology benefit as a higher headline data rate.**

3) Theoretical background

The Shannon-Hartley Theorem established the theoretical maximum data rate ***C*** for a signal of amplitude ***S*** in a communication channel of bandwidth ***B*** in the presence of white noise of amplitude ***N*** as;

$$C = B \times Log_2 (1+S/N)$$

This relationship is plotted with parameters appropriate to PLT by the solid curve in **Figure 2**.

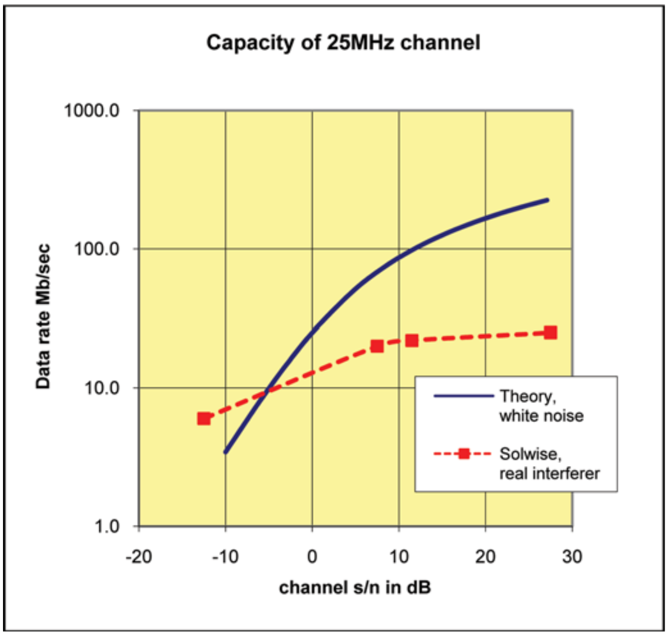

Figure 2. The capacity of a communication channel in the presence of interference.

This theory will *substantially understate* the available data rate for PLT since, as stated in Para. 2) above, the interference in a mains cable is not "white noise": It will have a much lower effective level than the "white" equivalent assumed in the Shannon-Hartley Theorem because of the substantial frequency and amplitude gaps between the peaks of emission from a continuous source, and the gaps in time between emissions of a discontinuous source.

This is emphasised by the dotted red plot of the throughput achieved by a pair of Solwise PL-85PE PLT modems in the presence of a "real interferer" adapted as necessary to give three different values of signal/noise ratio. Practical performance is considered further in the next section, but for comparison with theory note that for negative dB values of s/n the practical product out-performs simple theory because of the gaps discussed above. For positive values of s/n the practical performance is limited to well below the "sales specification" of 85Mb/s by protocol overheads and possibly by the inability of the associated computer hardware to handle very high data rates.

However the chart does illustrate that whilst higher data rates are available with higher signal power, **a significant data rate is available at zero or negative dB signal/noise ratio even with a "white noise" interferer.**

4) A practical demonstration

A number of "Grey Import" computer power supplies are being marketed in the UK which, although CE marked, have key EMC related components omitted. Trading Standards have been informed – but that is another story. These PSUs are very useful as sources to explore the capability of indoor PLT to tolerate interference, because they can be fitted with external filters crafted to produce any desired level of conducted emissions. By this means we can model the performance that would be achieved by a CISPR22-conforming PLT system by raising the interference environment to restore parity with the PLT modems.

External filters were used to establish the dotted red curve in **Figure 2**. For this test the sending and receiving modems and the interferer PSU were all plugged in to the same socket strip, which was powered via a CISPR16 LISN to provide a defined circuit impedance and isolation from any remote interferers.

The QP emission spectrum of the "Xpower" ATX-400TD PSU with external filter "C" is 20dB above that expected from a product compliant with the CISPR22 Class B limit within the PLT band of 3 to 30MHz, as may be seen in **Figure 3** below.

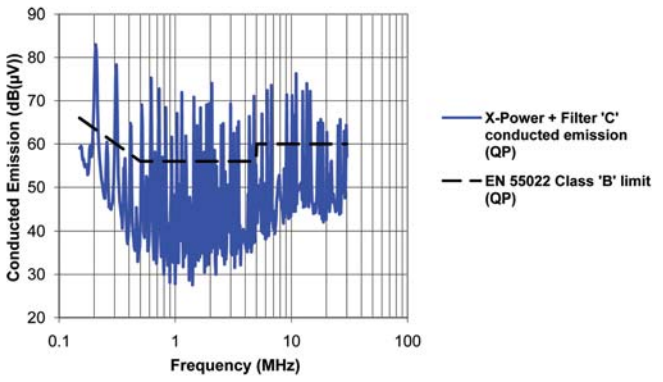

Figure 3. The mains conducted emission of a "20dB above CISPR22 class B" power supply feeding a 168 watt load.

A typical domestic PLT installation was set up to transmit a video file from a laptop via an adjacent PLT modem in an upstairs room to a desk-top computer with its adjacent modem in a ground-floor study. These two areas were served by different ring-mains connected to different mcbs in a single distribution board. The interferer was plugged into another socket in the same ground-floor study. When this was switched on the video throughput fell from 18 to 13 Mb/sec., as shown by the Netmeter plot in **Figure 4 below**.

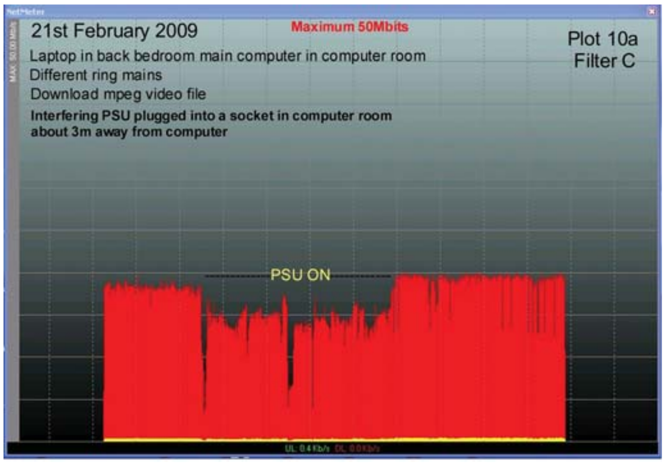

Figure 4. Turning on a local interferer reduced the throughput from 18Mb/sec to 13Mb/sec.

Under these conditions the PLT circuit is operating at a substantial negative signal/interference ratio, whilst producing an useful data rate for present-day applications. Moving the interferer to a third location elsewhere in the building increased the data rate to 16Mb/sec. Note that this quite-useful performance is achieved with a PLT data coding system that has not been optimised for low s/n ratio operation.

5) Conclusions

The development of power line telecommunications has been seriously handicapped by a tactic of leaving conformity to EMC standards to the last, rather than considering it at the earliest design stage.

This paper has presented theoretical and practical evidence that the technology could provide a useful function within the existing CISPR22 limits and without damage to radio services. It just needs properly-directed coding algorithm design within appropriate power limits and realistic headline data capacity.

6) Acknowledgements

The version of the Shannon-Hartley Theorem quoted here was given by K T Foster in the BT Technical Journal, 2008.

The QP figures and plot given above have been provided by Dr. D Lauder of the Department of Electronic Engineering, University of Hertfordshire.

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