A ROADMAP FOR CHARACTERIZING BPL MODEMS WITH RESPECT TO EMC: Part B: Power Mains Parameters

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Abstract
By the introduction of BPL in order create a network for datacommunication, the problem raises about the interference with the established radio services in the frequency range from 1.6 upto 30 MHz.
In a first part A of this paper, general considerations about the roadmap to characterise BPL modems with respect to EMC have been discussed. In this part B, specific measuring methodologies to characterize the appropriate parameters of an average Power Mains Network (PMN) will be discussed.

1. Characterization of the Power Mains Network(PMN)

The characterisation of the power mains network regarding the use of PLT/BPL is dealing with the possible conversion effect of DM signal transmission into a CM interference signal.

1.1. Measurement of Longitudinal Coupling Loss or LCL

Referring to some proposals within different CISPR task forces, the so called MacFarlane probe is used for these measurements. The probe is shown in figure 1.

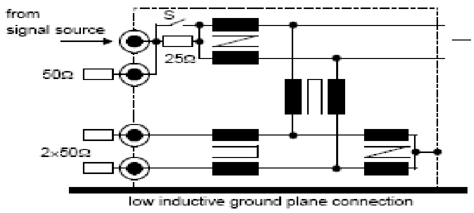


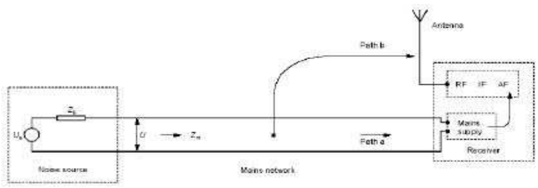
Figure 1a. Schematics of the MacFarlane probe [6]

Figure 1b. Picture of the MacFarlane probe, as realised by the team of Open University, UK [9]

In principle, a DM signal is generated to be transmitted over a PMN section, using the generator V1 and the coupling transformer T1. Resulting CM mode voltages are measured as V2 over the impedances Z2 and/or Z3. The probe itself should have high level LCL values, and may be checked and calibrated by using known unbalanced loads at the terminal N. The advantage of this probe is that it may be connected, by a short (and high quality power cord) to any wall outlet, without any need of other auxiliary connections.

1.2. Measurement of Mains Decoupling Factor or MDF

As an alternative, different configurations for measuring the MDF have been proposed, based on research work by Seifried, Dunker and Battermann. Originally, the setup has been defined to measure the possible interference due to CM coupling into radio receivers. A signal is injected in the mains network and is characterised using a CISPR-AMN or LISN at a socket of the mains. A radio receiver is plugged at another socket. At the input connector of the measuring receiver, a rod antenna is fixed. In this way, the radiated emission from the PMN is monitored, providing a very special CM path over the power cord and chassis of the receiver in combination with a conducted CM coupling inside the receiver. During a lot of research measurements, it has been found that the receiver should be battery-operated, in order to be independent from the connection of the receiver to the PE of the PMN.



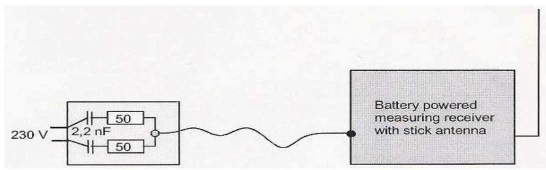


Figure 2. MDF measuring setup, as given in CISPR 16-4-4 [7] (left)and proposed by Dunker & Seifried [8] (right)

During some Short Term Scientific Missions (STSM) of the COST 286 action [9], researchers from the technical universities of Hannover, KHBO Oostende and UTC Barcelona, exchanged a lot of experience on this method. A typical set of results is presented in figure 13. The large
spread on the results is mainly due unknown CM paths between the chassis of the receiver and the electonic circuitry (mainly the input amplifier of the receiver).

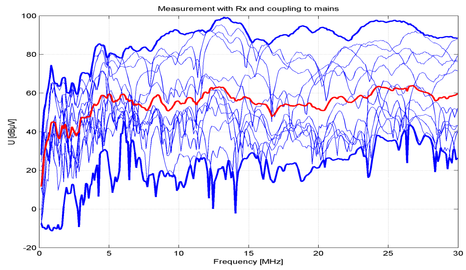


Figure 3. Example of MDF measurements by Dunker & Seifried [8]

As a first conclusion, it can be seen that there is a very wide spread in the parameter values, when performing measurements under real conditions. So, it will not be easy to determine an “average” PMN with respect to the BPL applications. Part of the uncertainty is also due to unknown CM current paths in the measuring setup, which is not well conditioned within the purpose of this type of measurements.

<u>1.3. Measurement of Coupling Loss Mains or CLM</u>

Consequently, Battermann and Dunker proposed an alternative method, overcoming the problem of unknown CM path effects in the receiver used. They introduced the idea of a dummy receiver. The setup is shown in figure 4 and has been presented in some papers by Battermann and Dunker/Battermann [10]. Detailed measuring results are presented in the documents mentioned above.

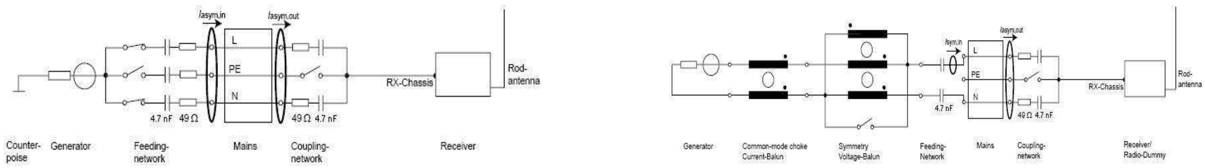


Figure 4. CLM measurement setup, using current clamps and dummy receiver and both CM and DM signal injection

The main differences with respect to the earlier MDF measuring method are the use of a dummy receiver and the fact that currents are measured instead of voltages. Using appropriate current clamps, no more contact is made with the PMN under test. The use of a dummy receiver ensures that the unknown CM path between chassis and electronic circuitry is no more an issue of measuring uncertainty. Taken from the work of Battermann and Dunker, a comparison is shown between the ”old” voltage measurements using a receiver and the ”new proposed” current measurements using a dummy receiver.

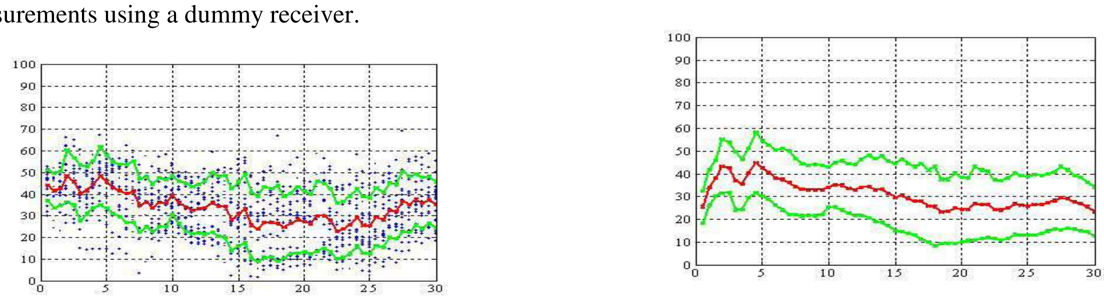


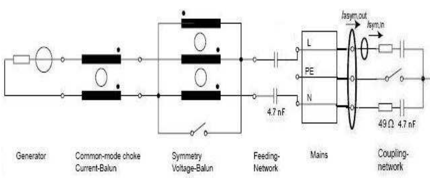
Figure 5. Comparison of MDF - voltage (upper) and CLF - current (lower) measurements
by Battermann and Dunker

It is clear that a correct and unambiguous definition of the measuring setup is excluding a lot of measurement uncertainties. However, some comments may be formulated on this method, although it is a very interesting one, because of a well-defined CM path in the dummy receiver itself, and the fact that is it is a non-contacting method.

The first remark is dealing with safety of the setup. The proposed setup used a CDN with 22nF capacitors, which may be connected between the power wires and the PE. For safety reasons, this capacitor should be restricted to 4.7 nF as a maximum. The second remark is dealing with a question about the need of a rod antenna. This is a residue from the older methods, looking for the coupling partly by radiation. As there is only a dummy termination of the PMN, and the measurements performed are based on conducted methods, there seems no more need to include a rod like antenna at the dummy termination. Also because it has been found that the interference voltage induced at the antenna input is directly proportional with the measured CM current in the setup. In more, it should be noted that by injecting both CM and DM signals, the effect of the type of load might be cancelled out. By applying both current clamps at the same position, the local level of the DM/CM conversion is characterised.

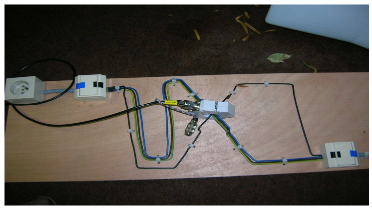
1.4. Measurement of Mode Conversion Factor or MCF

The proposed setup by the KHBO-team [1] is shown in the next figure 6 and is overcoming both problems as mentioned above.



(a) Schematic

(b) Picture of the CM termination



(c) Picture of combined setup for measuring DM and CM currents using one fixed current clamp

Figure 6: Alternative MCF measuring setup, as proposed by KHBO

The modifications are the CDN coupling network, with a coupling capacitor of 4.7 nF and a metal box or plate as termination of the extending wiring, used as AW as described in previous sections.
Measuring results are shown for 2 configurations of PMN, and the difference between the results obtained from the LCL (voltage probe as from MacFarlane) and the new proposed MCF/KHBO are shown in figure 7. A difference of 25-30 dB is observed between both methods. As the LCL is based on voltage and the MDF is based on current measurement. The difference between MCF and LCL is due to the fact that DM and CM impedances are not identical, and may vary independently in function of the frequency. Which means that a careful analysis of both measuring methods and of the impedances concerned is still needed. It is also referred to Annex E of CISPR 22, where an expression is given to calculate CM current from LCL values and appropriate impedances of the system.

As a first conclusion, it may be stated that cable length and the size or dimensions of the metal termination box have only a minor effect on the measuring results bu will need to be defined for repeatability. The CM impedance of the AW used as an extended wiring has a larger effect, and need to be well defined

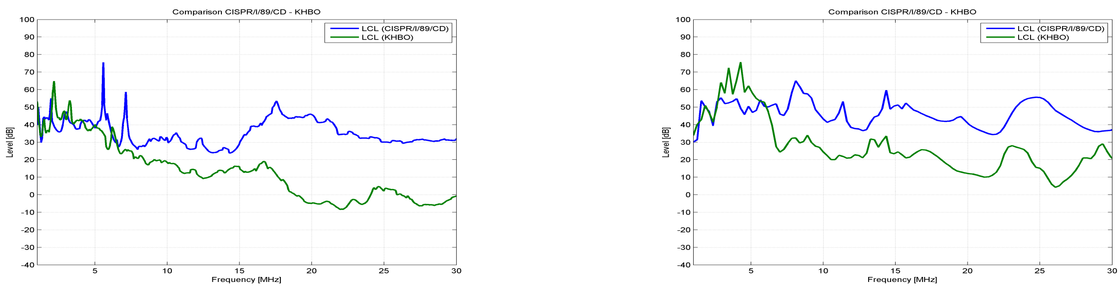


Figure 7. Comparison of LCL and MCF results at two different locations

1.5. Measurement of related K-factor

By injecting a known DM signal level into the Power Mains Network, the related H-field strength is measured at a given distance from the cabling. The ratio between the received signal level and the injected signal level is defined as the K-factor of the system under test. A typical measuring setup is shown in figure 8.

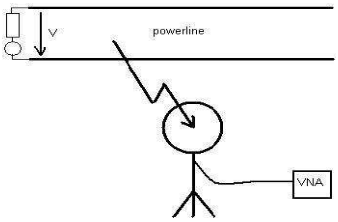


Figure 8. Principle of K-factor measurement

Figure 9 . Picture of the setup with loop antenna

A picture of the practical setup is shown in figure 9. One of the power cords had a built-in EMI filter, which could be switched on/off. A set of 3 power cords has been used as a wiring, without being connected to the power mains of the building. In this case, the K-factor represents a type of antenna factor of a 13m long wire antenna. This situation is called ”passive”. Afterwards, the set of powercords was connected to a power socket, and the AW was becoming part of the power mains network of the building. This is called ”active”. The measured K-factors for both conditions are given in figure 10.

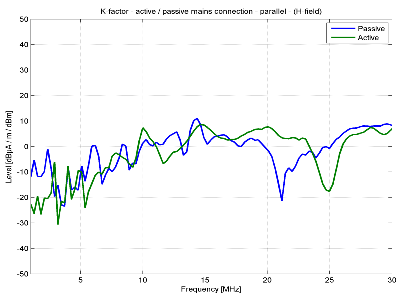


Figure 10. K-factor measurements for H-field

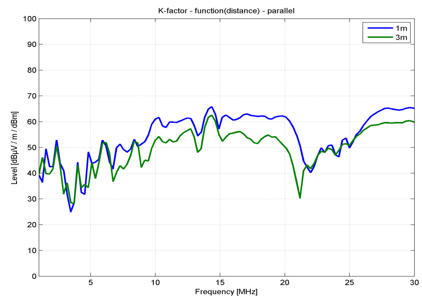


Figure 11. Variation of K-factor in function of the measuring distance

Looking to the difference between the “passive” and “active” state, it may be stated that the main effects are due to the ”local” wiring. This has already been observed by Battermann. [11, 12, 13]. Changing the measuring distance results in a shift of the K-factor, as expected. A 10 dB shift is observed for a variation in measuring distance from 1m to 3m, as can be seen in figure 11. When the EMI filter is switched on, a larger coupling path for CM currents is locally created, and a higher value of the K-factor (6 dB as an average value) was observed.

Conclusion

In this paper, different measurement methodologies to characterise the appropriate parameters with respect to BPL of a PWN have been discussed.

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