‚Practical Experience Gained from Five Different Inhouse PLC Modems

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Introduction

Although many inhouse PLC modem measurements are available, the effect of interference on broadcast and ham radio reception is difficult to determine from them. In the test described here, the practical effect on a typical receiving installation in the frequency range from 1.8 MHz to 30 MHz is examined.

Some PLC modems comply with the HOMEPLUG standard, which, however, is not mandatory in Germany. This standard notches out the HF ham bands by approx. 30 dB in their transmit spectrum. The question is whether this attenuation is sufficient to protect the ham radio service adequately and whether the interference caused in the broadcast bands is low enough to ensure interference-free broadcast reception.

Test setup

The equipment consisted of an HF transceiver of type KENWOOD TS 850S followed by an antenna coupler of type MFJ-989C. The antenna was a 2 x 16.75 m dipole located 12 m above ground. The antenna crossed a house that had upper floor and a uninhabited loft. The distance between the upper floor containing the receiving equipment and the antenna was roughly 5 m. The PLC modems were connected to the AC mains in two different upper-floor rooms. The AC line between the two AC outlets that were used was kept as long as possible. One modem was set up in the "radio room" so that the transceiver and modem were close to the AC mains.

Measurements

The signal strength of the interfering PLC signal received by the tuned antenna at the frequencies shown in the following table was documented. The interfering signal was clearly detected at all frequencies except some ham bands between 4.3 MHz and 20.5 MHz.

MHz	Modem 1	Modem 2	Cable modem
6.5	140 µV	25 µV	6 µV
7.05	perceptible	not perceptible	not perceptible
8.8	100 µV	50 µV	0.75 µV
9.8	25 µV	6 µV	0.75 µV
10.12	perceptible	not perceptible	not perceptible
12.3	50 µV	25 µV	1.5 µV
13.3	3 µV	50 µV	0.75 µV
14.3	not perceptible	not perceptible	not perceptible
16.4	25 µV	6 µV	0.75 µV
18.1	not perceptible	not perceptible	not perceptible
20.1	6 µV	12 µV	0.75 µV
21.15	not perceptible	not perceptible	not perceptible

MHz	Modem 3	Modem 4 *)
6.5	100 µV	200 µV
7.05	1.5 µV	1.5 µV
8.8	100 µV	100 µV
9.8	50 µV	50 µV
10.12	perceptible	not perceptible
12.3	12 µV	6 µV
13.3	3 µV	6 µV
14.3	not perceptible	not perceptible
16.4	100 µV	6 µV
18.1	not perceptible	not perceptible
20.1	140 µV	100 µV
21.15	not perceptible	perceptible

Blue: ham bands

*) To the best of our knowledge, this modem did not pass the EMC test and thus is no longer on the market.

Observations

Due to the operation of a ham radio station in the "test house", some extension cords were provided with toroidal chokes to reduce radiated susceptibility. Doing so reduces common mode waves that appear due to unsymmetric operation of the modems. This mode is responsible for AC line radiation. When cables without chokes were used, modem operation resulted in an increase of approx. 6 dB in radiation.

Using a short AC mains connection between the modems resulted in a maximum data rate of 14 Mbit/s, whereas a connection between the upper floor and the ground floor provided 7 Mbit/s and, to the basement, only 1 Mbit/s. Furthermore, we observed a clearly higher potential for interference when operating at a higher data rate. For this reason, the test setup together with both modems was placed on the upper floor. All measurements and assessments are specific to this configuration.

Tests with modem 1

The objective here was to introduce an increased unbalance of the AC mains line by inserting an 8.8 nF capacitor between the neutral and protective earth wire. As it turned out, however, taking this step did not yield a change in the the radiation behavior. It is our interpretation that the original unbalance of the mains already exhibited a value that could not be further deteriorated toward common mode radiation by this capacitor.

Tests with modem 2
Taking one mains wire (e.g. neutral or phase; approx. 4 m) randomly through the room increased the interference in the upper frequency range considerably. At 13.1 MHz, an increase of approx. 33 dB was observed. This loose wire configuration represents an unbalance that occurs if (switched-off) loads that use only a single pole switch are connected to the mains. Floor lamps belong to this category of loads.

Tests with modem 3
A mobile receiving set was used to investigate the strength of the interfering signal at several distances from the house. A frequency of 13.1 MHz and a floor lamp, simulated by the 4 m wire (see above), were also used as the interference source for this test.
The signal strength measured on the inhouse receiver with the dipole antenna was 300 µV. In front of the garage (distance approx. 8 m), we measured 100 µV with the mobile set. Increasing the distance up to 50 m delivered a signal strength of 25 µV. The signal strength decreased to a value that was no longer detectable only after a distance of 120 m was exceeded.

Radiated susceptibility of modem 1
We examined how modem 1 could be influenced by transmissions in the ham bands using the equipment described above, operated at an RF output power of 100 W.

3.5 MHz	7 MHz	10 MHz	14 MHz	18 MHz	21 MHz
no influence	reduction to 8 Mbit/s	reduction to 10 Mbit/s	reduction to 9 Mbit/s	no influence	no influence

Transmissions in the ham bands appear to have little or no influence on the data rate. It is assumed that the HOMEPLUG standard has a positive effect on this result.

Concluding remarks

- Reception in the HF broadcast bands is impaired considerably by all AC mains PLC modems. In contrast, the TV cable modem causes only moderate interference.

  Weak broadcast signals in the 41 m band become inaudible. Even the reception of strong signals (3 mV) is impaired annoyingly: The broadcast station remains audible but is noisy and "scratchy".

- A pronounced effect on ham radio operations could not be observed. Except with modems 3 and 4, which produce a noise level of 2 µV in the 40 m band, noise is perceptible in some bands but does not cause strong interference.

  Addendum: A different test with modems that do not comply with the HOMEPLUG standard showed distinct radiated emissions and susceptibility of those modems in the ham bands.

- The cable modem produces much less interference, apparently due to its shielding.
- There is no evidence concerning the applicability of these observations to other home installations.
- Type designations of all tested modems are known but are not published here.