ELECTROMAGNETIC FIELD LEVEL IN THE IMMEDIATE VICINITY OF A LINKY METER

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ABSTRACT

Linky meters are going to be spread in France. These smart meters use G1 PLC and G3 PLC to communicate. These PLC signals create non-intentional electromagnetic fields in the frequency range 36-91 kHz around the meter. There are concerns related to these electromagnetic fields in the French population. This study defines an accurate measurement methodology in laboratory to assess the level of these electromagnetic fields of both the vicinity of the Linky meter and the low-voltage electric cable connected to the meter.

INTRODUCTION

In the next years, 35 million Linky meters are going to be spread in France. These smart meters contain a modem using the power line communication (PLC) to exchange information and be remotely raised through existing LV electric grid. The information is collected in the MV/LV substations by means of a data concentrator also equipped with a PLC modem. Two different protocols can be used: the G1 PLC and the G3 PLC. The G1 PLC uses two carriers, the first one at 63,3kHz and the second at 74 kHz (figure 1) [1]. The G3 PLC uses 36 carriers moved of 1,5kHz between 36 kHz and 91 kHz (figure 2) [2].
These smart meters constitute a new source of electromagnetic field and raised concerns about their potential health impact in France. In France, the electromagnetic fields have to be lower than the reference levels indicated by the European recommendation of 1999 [3] to guarantee the respect of basic restrictions. Previous electromagnetic field measurements close to Linky meters in laboratory and in different rooms of an apartment were previously presented by EDF [4]. The French Frequency Agency (ANFR) realized also electromagnetic field measurements close to smart meters in laboratory and in situ [5] [6] [7]. This study consists in the evaluation by measurement of the electromagnetic fields in the PLC frequency band close to a Linky meter in laboratory, upstream the meter, with small electromagnetic sensors in order to obtain accurately localized measurements.

TESTED CONFIGURATION

In order to avoid ambiant noise, the measurement of the electromagnetic fields is performed in a Faraday cage (height=245cm, proofness=185cm, width=308cm), in which the single-phase Linky meter and the horizontal wires connecting it to the LV network are mounted. A PLC filter is connected to the network and is followed by an isolation transformer and a line impedance stabilization network (LISN) which is connected to the Linky meter (figure 3). The PLC filter and the isolation transformer limit the transmission of signal in the PLC frequency band from the network to the Linky meter and reciprocally. The LISN fix the impedance which is seen by the Linky meter to a resistive value of 2 Ω commonly used to simulate impedance access of a real grid in PLC frequency band. A PC pilots a PLC emulator which is connected between the isolation transformer and the LISN and which communicates with the PLC modem contained in the Linky meter what causes the emission of the meter. The horizontal wires connecting the Linky meter to the network are flexible and LV isolated copper wires with 16 mm^2 section and a radius ρ=2mm (figures 4, 5 and 6). The distance a between the axis of the two wires is 15mm, corresponding to a worst case found at the customers in term of electromagnetic field. The two horizontal wires are rectilinear and have a length of 250cm.

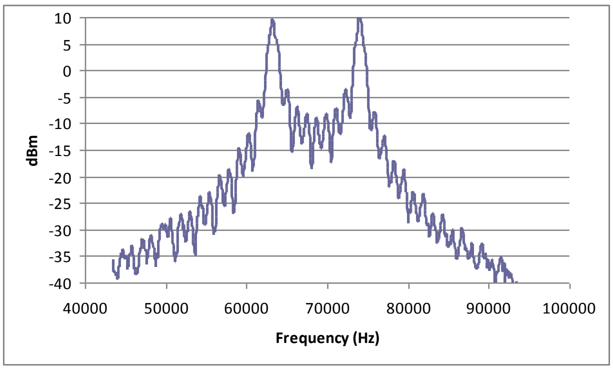

Figure 1: Spectrum of the G1 PLC signal (horizontal: 10kHz/div, vertical: dBm 50Ω, 10dB/div)

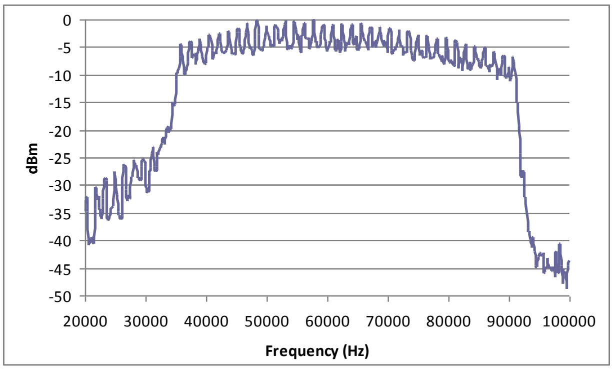

Figure 2: Spectrum of the G3 PLC signal (horizontal: 10kHz/div, vertical: dBm 50Ω, 10dB/div)

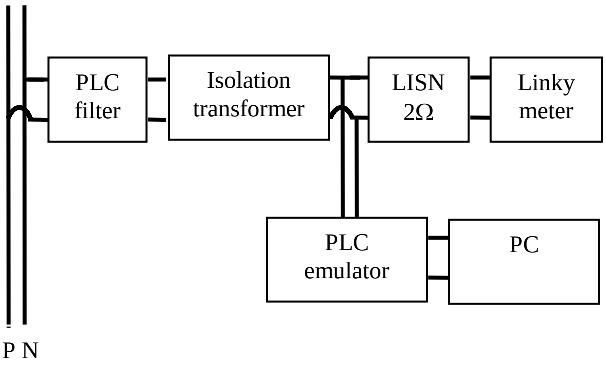

Figure 3: Overview of the studied configuration

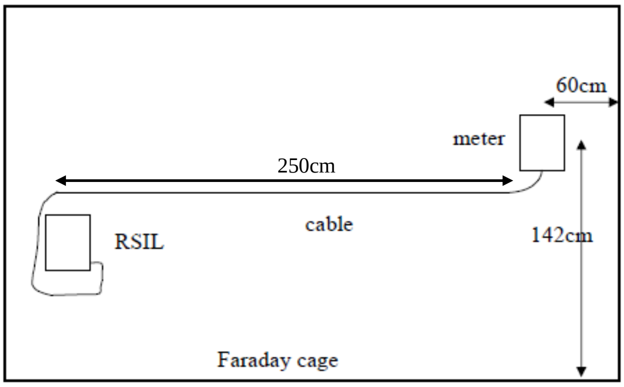

Figure 4: Experimental configuration

Figure 5: Meter and cable in the Faraday cage

ELECTROMAGNETIC FIELDS MEASUREMENT SYSTEM

As electromagnetic fields are known to vary quickly with distance close to localized source, the measurements must be local; consequently the sensor must have small dimensions. The magnetic and the electric field measurement systems were calibrated by means of a TEM cell. Measurements are performed with 'Max Hold' function of the spectrum analyzer during 1mn per measurement point, in a 5kHz frequency band around 63.3kHz and 74kHz for G1 PLC and a frequency band from 33kHz to 93kHz for G3 PLC. Each system measures only one cartesian component of the field and the measurement is repeated successively for the 3 components. The sensor is positioned by means of a synthetic foam support (Figure 7). The measurement accuracy is 10% for electric field and 9% for magnetic induction (Table 1).

Table 1: Accuracy of the electromagnetic fields measurement system

PLC	Electric field	Magnetic induction
Calibration	8%	7%
Spectrum analyzer	3.5%	3.5%
Max hold	4%	4%
Total	10%	9%

Figure 6: LISN and cable in the Faraday cage

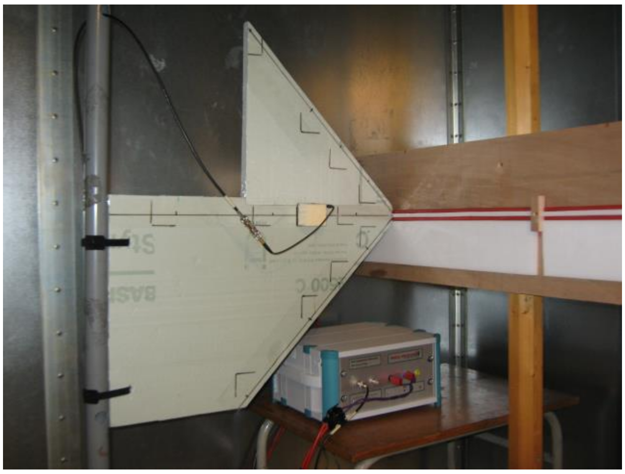

Figure 7: The synthetic foam support with the magnetic sensor

Electric field measurement system

The electric field is measured with an electro optic probe EFS-105 from Enprobe (figure 8). This probe includes a 6.6mm electric dipole followed by an amplifier which modulates the amplitude of the signal of a laser diode. The optical signal is led by an optical fiber until a system which converted the optical signal in electric signal. The link between the probe and its electronic part is dielectric what avoids electromagnetic perturbation. This device is followed by a low noise amplifier 11729-60014 from Hewlett-Packard. The output of this low noise amplifier is connected to the input of a spectrum analyzer EXA N9010A from Agilent through a bandpass filter (820Hz-4.6MHz). The electric field level equivalent to the noise is 40mV/m for G1 PLC and 90mV/m for G3 PLC.

Magnetic field measurement system

The magnetic field is measured by means of a small loop with 3cm diameter having 300 turns (figure 9). This loop is shielded for electric field. It is followed by a low noise amplifier 11729-60014 from Hewlett-Packard. . The output of this low noise amplifier is connected to the input of a spectrum analyzer EXA N9010A from Agilent through a bandpass filter (820Hz-4.6MHz). For the highest values of magnetic field, the low noise amplifier is suppressed to avoid measurement non linearity. The magnetic field level equivalent to the noise is 0.2nT for G1 PLC and 0.3nT for G3 PLC.

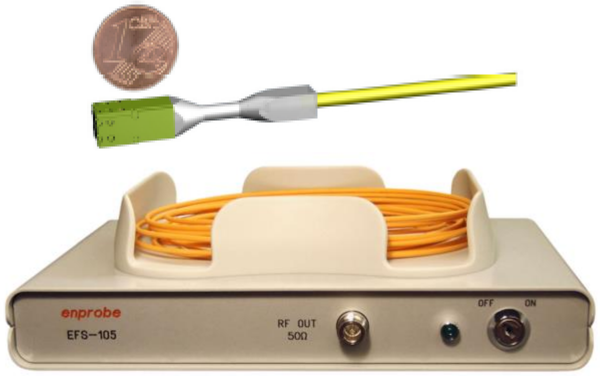

Figure 8: The electric measurement system Enprobe EFS105: the sensor and the base unit

Figure 9: The magnetic sensor

MEASUREMENTS

Location of the measurement points

The measurements take place in 5 vertical planes perpendicular to the wires (figure 10). The first plane is located in front of the meter and the other planes are regularly distributed along the cable, every 50cm (L), upstream of the meter. The measurements are performed on three different radii R centred on the cable in each vertical plane: one is horizontal and the two other are respectively oblique of -45° and 45° with regard to the horizontal. 5 different distances d with regard to the cable are chosen: 10cm, 20cm, 30cm, 50cm and 100cm, in order to characterize the spatial variations of the field.

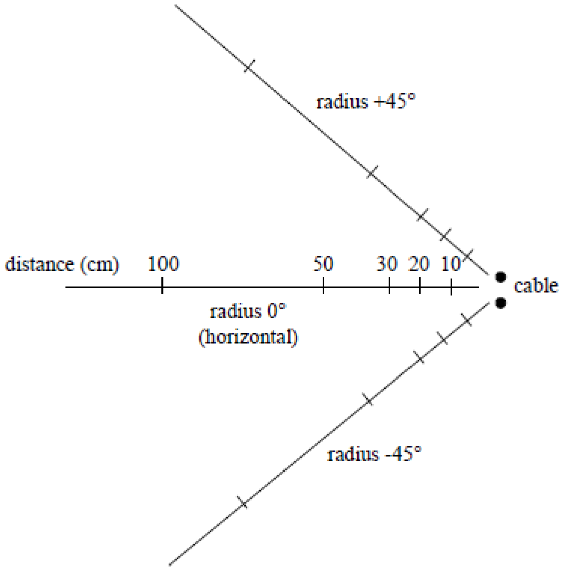

Figure 10: Location of the measurement points

Measurement results

Results

The measurement results are presented in tables 2 and 3 for electric field. The electric field is higher in front of the meter than along the cable: 3 times for G1 PLC and 8 times for G3 PLC. It is quite constant along the cable. It takes quite the same value along the cable for G1 PLC and G3 PLC. Its value decreases quite as the square of the inverse of the distance to the cable. Its maximum value at 10cm is 0.41V/m along the cable and 1.15V/m in front of the meter for G1 PLC, and 0,43V/m along the cable and 3.3V/m in front of the meter for G3 PLC.

The measurement results are presented in tables 4 and 5 for magnetic induction. The magnetic induction is lower in front of the meter than along the cable. It is quite constant along the cable. It takes quite the same value along the cable for G1 PLC and G3 PLC. Its value decreases quite as the square of the inverse of the distance to the cable. Its maximum value at 10cm is 99nT along the cable and 38nT in front of the meter for G1 PLC, and 70nT along the cable and 34nT in front of the meter for G3 PLC.

Comparison with a simple model

A simple model is proposed in [8] for the magnetic field around a bifilar line. For a distance d hardly larger than the wires diameter and the distance e between the two wires, the magnetic induction *B* and the electric field *E* are given by:

$$B(d) = \frac{\mu_0 I a}{2\pi d^2}$$

$$E(d) = \frac{aV}{2Log\left(\frac{a}{\rho}\right)d^2}$$

The PLC modem incorporated in the meter has a maximum available power of 1.5W during its communication time-slot and an impedance up to 50Ω. The cable is loaded with a resistance of 2 Ω. This leads to a voltage *V* of 0,67V and a current *I* of 0,33A on the line, for the PLC signal. This model predicts that both fields vary as the square of the inverse of the distance to the line for big enough distance in comparison with the transverse extension of the line (19mm).

Table 2: Electric field level (V/m) for G1 PLC Linky meter

L(cm)	d(cm) R(°)	10	20	30	50	100
0	-45	1.15	0.32	0.18	0.10	-
	0	0.93	0.32	0.16	0.099	-
	+45	1.04	0.34	0.18	0.10	-
50	-45	0.41	0.15	0.094	-	-
	0	0.38	0.12	0.075	-	-
	+45	0.31	0.11	0.067	-	-
100	-45	0.39	0.13	0.087	-	-
	0	0.34	0.12	0.069	-	-
	+45	0.34	0.10	0.083	-	-
150	-45	0.37	0.11	0.079	-	-
	0	0.34	0.11	0.074	-	-
	+45	0.39	0.14	0.078	-	-
200	-45	0.39	0.12	0.065	-	-
	0	0.32	0.11	0.077	-	-
	+45	0.38	0.12	0.086	-	-

Table 3: Electric field level (V/m) for G3 PLC Linky meter

L(cm)	d(cm) R(°)	10	20	30	50	100
0	-45	3.3	0.82	-	-	-
	0	2.5	0.71	-	-	-
	+45	2.9	0.66	-	-	-
50	-45	0.36	-	-	-	-
	0	0.33	-	-	-	-
	+45	0.36	-	-	-	-
100	-45	0.35	-	-	-	-
	0	0.35	-	-	-	-
	+45	0.39	-	-	-	-
150	-45	0.37	-	-	-	-
	0	0.33	-	-	-	-
	+45	0.41	-	-	-	-
200	-45	0.39	-	-	-	-
	0	0.38	-	-	-	-
	+45	0.43	-	-	-	-

Table 4: Magnetic induction level (nT) for G1 PLC Linky meter

L(cm)	d(cm) R(°)	10	20	30	50	100
0	-45	38	13.8	7.1	3.3	1.46
	0	16	4.8	3.7	2.0	0.79
	+45	10.2	2.8	1.9	1.5	0.80
50	-45	93	23	10.4	3.4	0.66
	0	87	23	10.3	3.3	0.56
	+45	99	23	10.1	3.7	0.86
100	-45	90	23	10.3	3.4	0.66
	0	82	22	9.6	2.9	0.52
	+45	80	23	10.2	3.7	0.93
150	-45	89	22	9.9	3.1	0.50
	0	81	21	8.5	2.4	0.52
	+45	94	23	10.4	3.8	1.07
200	-45	95	23	9.0	2.7	0.40
	0	83	19	7.5	2.9	0.44
	+45	95	24	10.9	4.5	1.27

Table 5: Magnetic induction level (nT) for G3 PLC Linky meter

L(cm)	d(cm) R(°)	10	20	30	50	100
0	-45	34	14	7.7	2.5	0.7
	0	18	6.2	3.2	1.3	0.6
	+45	19	4.8	2.4	1.1	0.6
50	-45	56	15	6.8	2.3	0.4
	0	56	15	6.5	2.1	0.4
	+45	61	15	6.7	2.4	0.6
100	-45	60	15	6.7	2.3	0.4
	0	60	14	6.4	2.0	0.4
	+45	58	15	6.9	2.4	0.6
150	-45	61	15	6.8	2.2	0.5
	0	56	15	5.8	1.7	0.4
	+45	63	15	7.0	2.6	0.7
200	-45	63	16	6.0	1.9	0.4
	0	54	13	5.3	2.0	0.4
	+45	70	16	7.7	3.2	0.9

Table 6: Predicted and measured values of the electric field (V/m) and the magnetic induction (nT) along the cable at a distance of 10cm

PLC	Measured		Predicted	
	Electric	Magnetic	Electric	Magnetic
G1	0.36	89	0.25	100
G3	0.37	60	0.25	100

The predicted and measured values of the electric field (V/m) and the magnetic induction (nT) along the cable at a distance of 10cm is presented in Table 6. The presented measured values are averaged on the 3 radii and the 4 distances. The difference between the measured and the predicted values is about some tenth of percent. The comparison with the canonical model allows to validate the experimental evaluation results.

Comparison with reference levels

The European recommendation reference levels are

87V/m for electric field and 6250nT for magnetic induction in the frequency band 30-90kHz (Table 7). The maximum measured electric field value is 3.3V/m, i.e. 28dB below the reference level of 87V/m. The maximum measured magnetic induction value is 99nT, i.e. 36dB below the reference level of 6250nT. At a distance of 50cm the maximum measured electric field value is 0.1V/m, i.e. 59dB below the reference level of 87V/m and the maximum measured magnetic induction value is 4.5nT, i.e. 63dB below the reference level of 6250nT.

Table 7: European recommendation reference levels [2] in the 30-90kHz frequency band

Electric field (V/m)	Magnetic induction (nT)
87	6250

CONCLUSION

We proposed a measurement methodology in laboratory allowing a proper evaluation of the related electric and magnetic field surrounding Linky meter during PLC communication and also in the immediate vicinity of the power cable connected to the meter. The sensors used in this study are very small what ensure a local measurement. The electromagnetic field levels are quite the same for G1 PLC and G3 PLC meters. They are quite constant for a given distance to the cable. They decrease as the square of the distance to the cable. The electric field is higher and the magnetic induction is lower in front of the meter than along the cable.

At 10cm, the maximum value of electric field is 3.3V/m and the maximum value of magnetic induction is 99nT, corresponding respectively to 3.8% and 1.6% of the reference levels of the European recommendation. At a distance of 50cm the maximum measured electric field value is 0.1V/m, i.e. 0.1% of the reference level and the maximum measured magnetic induction value is 4.5nT, i.e. 0.07% of the reference level. The values obtained in this study are similar to those obtained by ANFR [5] [6]: about 1V/m and 5nT in front of the meter at 20cm.

Based on our measurements with PLC communication enabled, we can conclude that the electric and magnetic field exposure in the immediate vicinity of a Linky meter and power cables is very significantly less than the guideline values for the general public.

The perspectives are to evaluate the level of the electromagnetic field downstream to the meter for several kinds of cabling and load, and to define a complete measurement protocol for Linky meter.

Acknowledgments

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