On Radio Interference Assessments of Access PLC System

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Abstract Access PLC system is considered as one of "last mile" solutions. However, HF PLCs using overhead distribution would be an interference source to radio communication services and scientific observations in this band. This paper describes assessment test results in Japan. One of them is carried out as a part of government's investigation. Bad LCL characteristics of mains results large amount of radio interference, and thus the deregulation in Japan is shelved.

1. Introduction

In Japan, almost all the distributions are of overhead wires. These wires are unshielded, unbalanced, unmatched to the high frequency signal source connected to the mains. The length of the line is comparable to or greater than the HF range wavelength. Therefore, access PLC systems will cause unwanted emission of wide band noise which interfere radio communication services in HF band[1]. The most difference of access PLC systems from other electrical equipment such as a refrigerator or a clear is that they always operate, *i.e.*, they radiate wideband noises 24 hours a day, 365 days a year.

Many amateurs as well as shortwave listners are worried about unwanted emission from the mains which connect HF PLC modems. In addition, The Japan Medical Association announced their fear for the impact to medical electronic equipment in common houses.

In this paper, we discuss assessment test results on radio interference due to access PLC system. At first, joint experiment results of *Japan Amateur Radio League* (JARL) and *Association of Radio Industries and Businesses* (ARIB) is described. We show that the access PLC system using HomePlug specifications is not enough to preserve amateur service and broadcasting listening. In the next section, we demonstrate S/N and SINAD measurement results under *The Power Line Communication Study Group*[2] (the Study Group) held by the Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT). It is also shown that the access PLC systems may cause harmful interference to radio communication services.

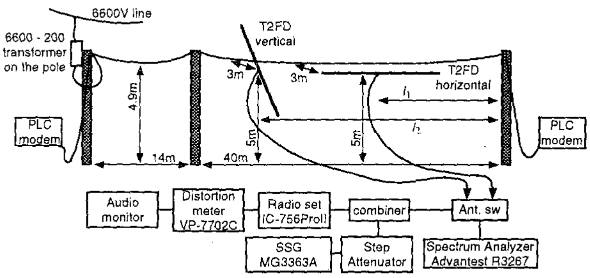

Fig.1 Configuration of Akagi joint experiments.

2. Joint Experiment Results

In late January 2002, JARL carried out joint experiments on PLC systems at Mt. Akagi, Gumma, Japan in cooperation with ARIB. We had measured noise floor level at receiver audio output in case of both modems are on and off, and radiation spectra from mains. Figure 1 shows configuration for the tests.

2.1. Noise floor measurements

RF noise floor degradations at the audio output of the radio set under test are measured by means of MOS evaluations (5 person, male, aged mid-20 to mid-60). The RF noise floor level when modems did not operate, *i.e.* external environmental noise, was little larger than the man-made noise level at the quiet rural area provided in ITU–R recommendation[3].

Although the degradations depend on frequency and modem type, we determine 5 to 25[dB] degradation at 600[Hz] receiver bandwidth in the frequency bands allocated for amateur service and standard time

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Table 1 Estimated field strength of actual amateur contacts. Receiver locations are in Japanese residential area.

Tx location	Rx location	Year	Month	SSN	UT	MHz	kW	Tx Ant.	dBμV/m
Hamburg	Matsuyama	1997	05	19	20	7	1.0	GP	10
Hamburg	Osaka	1997	07	10	08	14	0.2	3ele	−18
The Hague	Matsuyama	1997	07	10	14	14	0.1	GP	−22
Hamburg	Matsuyama	1997	08	24	13	18	0.3	3ele	−11
Los Angeles	Matsuyama	1997	06	13	09	7	0.1	GP	−5
Arlington Heights	Tokyo	2002	03	79	23	21	0.005	DP	−40

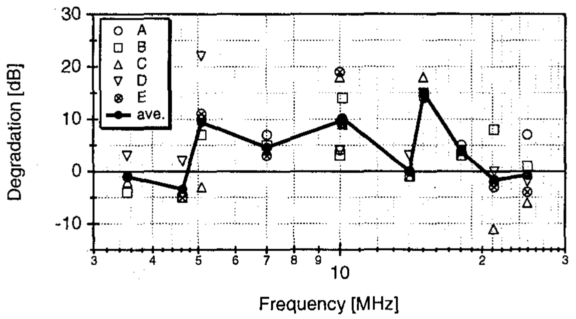

Fig.2 RF noise floor degradation results for OFDM modem, horizontal component. Receiver bandwidth: 600[Hz].

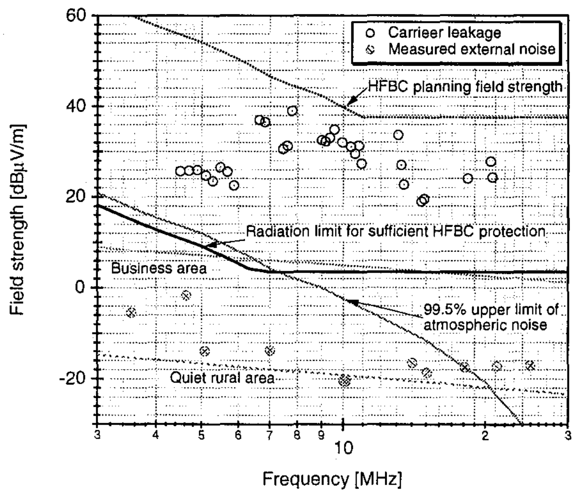

Fig.3 Measured field strength of radiated OFDM modem signals (vertical component) at 3[m] with man-made noise and HFBC requirements derived from ITU–R recommendations. Bandwidth: 3[kHz]

service. Figure 2 shows MOS evaluation results for OFDM modem with horizontal component reception. Note that these values are at least 10[dB] smaller than actual values, because current monitoring couplers are inserted into mains and their insertion losses are not taken into account. For the single-side band voice operation of 2.4[kHz] bandwidth, these degradations would be increased by 6[dB].

2.2. Radiated modem spectra from mains

We also measured field strength of radiated modem signals at the distance of 3[m] from mains with a wideband dipole antenna and a spectrum analyzer. Both horizontal and vertical components of received signals are evaluated.

Field strength of OFDM modem radiation, atmospheric and man-made noises[3], planning field strength for HF broadcasting and required limitation for HFBC protection[4] are shown in Fig.3. Note that the measured field strength of the modem radiation are at least 10[dB] higher because of transmission losses due to current monitoring couplers inserted into the mains. The modem noise is much larger than the current man-made noise level at business area recommended by ITU–R. It also far exceeds the limitation for HF broadcasting protection.

2.3. Field strength of amateur communications

Many amateur communications are made at field strength less than 10[dBμV/m]. Table 1 shows estimated filed strength of actual amateur contacts made by ionosphere propagation. Field strength calculations were performed by the means of ITU–R recommendation[5, 6] with average sun spot number at the contact date[7]. Surprisingly, very small signal communication was made between US and Japan. Such communications are the property of the amateur service.

We also calculate a short distance ground wave propagation model[8, 9] as shown in Fig.4. Currently, transmission signals from Tokyo are always readable with sufficient S/N at Akagi. However, when an access PLC system operates at the receiving location, no

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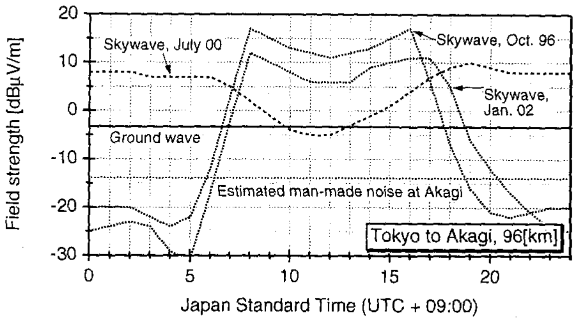

Fig.4 Estimated field strength of short range ground wave propagation at 7[MHz] under the conditions of 100[W] transmission power and $\lambda/4$ vertical antennas.

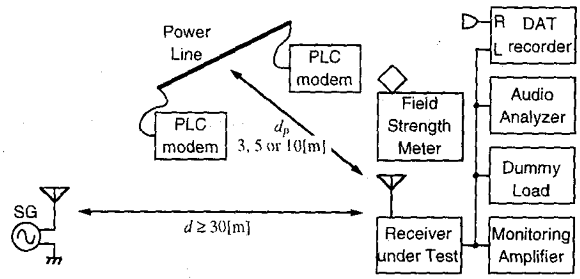

Fig.5 Measurement configuration of the Study Group assessment.

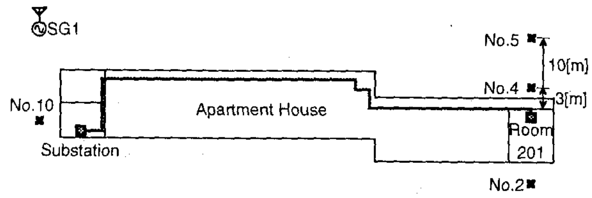

Fig.6 Site location map of the apartment house. Test receivers are located on No.2, 4, 5 and No.10 check points, 1[m] height above the ground.

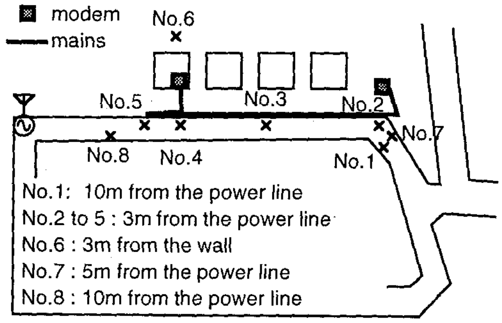

Fig.7 Site location map of the detached house. Modems are connected to the mains transformer on a pole and a receptacle in the house indicated in the figure. Test receivers are located on No.1 through No.8 check points, 1[m] height above the ground.

communications are available between these points.

These considerations result that the current PLC system, which have notches for amateur frequencies, are *not enough* at all for preservation of typical Japanese amateurs in residential and rural areas. Allowable emission level for amateur service protection should be under man-made noise level at the quiet rural area, *i.e.*, -15 to -23[dBμV/m] at 3[kHz] bandwidth.

3. The Study Group Assessment

The Power Line Communication Study Group organized by MPHPT had investigated the possibilities of joint use along with existing radio communications. One of the authors had been contributed to the Study Group as a member of field test working group, where we had carried out radio interference assessments under actual field environments.

3.1. Measurement configuration

Figure 5 shows the configuration for the assessment. Signal generator (SG) output is set that the field strength at the receiver be a certain value, 40[dBμV/m] for broadcasting and 20/15/10[dBμV/m] for general radio communication services. The test receiver is set to -10[dB] to the maximum audio output. Unweighted noise measurements provided in IEC 60315-1 and -3 are adopted[10] and S/N or SINAD degradations due to the modem operation are evaluated. Test receivers are Panasonic RF-B11 portable radio and ICOM IC-756ProII amateur transceiver.

In addition, received sounds of actual HF broadcastings together with modem noises are recorded digitally for the Study Group evaluations.

3.2. Measurement results

The above mentioned assessments are carried out at an apartment house in Fukuoka, a detached house in Matsuyama and a temporary accommodation in Mt. Akagi, respectively. Figures 6 through 8 show details of these sites.

3.2.1. S/N and SINAD degradation

Signal to noise ratio degradations for 40[dBμV/m] standard AM signal (1[kHz], 30[%] modulation) at the

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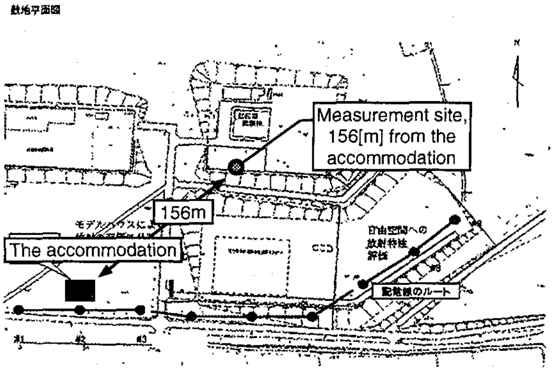


Fig.8 Site location map of the temporary accommodation. Distance between the accommodation and measurement equipment is 156[m].

Table 2 S/N degradation for standard AM signal (40[dBμV/m]) at the detached house. Receiver: RF–B11

Receiving Point	Freq. [MHz]	Modem type	S/N [dB]	
			OFF	ON
No.3	6.065	SS	21.4	3.6
No.3	6.065	OFDM	20.1	10.1
No.3	15.050	SS	26.7	−2.4
No.3	15.040	OFDM	15.8	−1.4

detached house in Matsuyama are summarized in Table 2. 10 to 16[dB] degradations are observed for OFDM modem, and 18 to 29[dB] for SS. Figure 9 shows a receiver output waveform for standard AM signal with operating OFDM modem situation, where the S/N at receiver output is negative. It is easily seen that the modem noise jams desired 1[kHz] tone.

ITU–R recommends that the minimum planning value of field strength for HF broadcasting should be greater than 37.5[dBμV/m][4]. The results demonstrate that this recommendation cannot be carried out any more.

For 20[dBμV/m] CW carriers, SINAD values over 24[dB] have degraded by approximately 20[dB]. Voice communications under such SINAD condition are very difficult to understand the contents of traffic. It is very severe for aeronautical and maritime radio operators who have "safety of life" mission.

3.2.2. Interference to actual HF broadcasting

Actual broadcasting signals of Nihon Shortwave Broadcasting, Co.Ltd (NSB) on both 6 and 9[MHz]

Table 3 SINAD degradation for CW carrier at the detached house. Receiver: IC–756ProII

Point	Freq [MHz]	Modem	Field [dBμV/m]	SINAD [dB]	
				OFF	ON
No.3	13.260	OFDM	20	26.5	7.6
No.3	13.260	SS	20	24.5	4

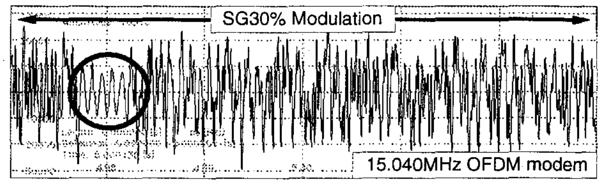
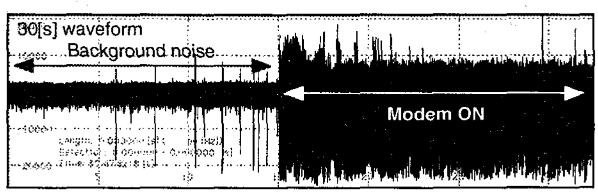
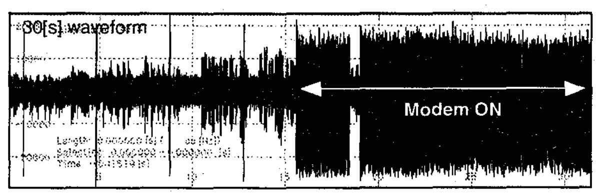


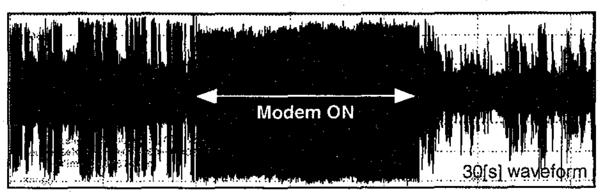
Fig.9 An example of the receiver output waveform. Desired signal: 15.040MHz, A3E, 1kHz, 30% modulation. The circle shows the desired 1kHz tone.



(a) 6[MHz] background and OFDM modem signal (17[dBμV/m]) at the apartment house.



(b) 6[MHz] NSB signal (36[dBμV/m]) and SS modem noise at the apartment house.



(c) 6[MHz] NSB signal (30[dBμV/m]) and SS modem noise at the detached house.

Fig.10 Receiver output waveforms of actual HF broadcasting signals and modem noises.

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bands are completely jammed by PLC signals at all the measurement sites. Figure 10 shows receiver output sound waveforms for background noise and NSB signal with modem interference, at 3[m] distance point from the power line. Note that the modem noise measurement results at the apartment house in Fukuoka include at least 10[dB] loss due to the current monitoring couplers. The results show that 40[dBμV/m] broadcasting signals are completely jammed by the modem operation.

3.2.3. Far field components

Modem noise has been radiated widely around the sites.

In Matsuyama, even at 340[m] off the site, modem signals can be received significantly by using a portable radio as shown in Fig.11. In Akagi, 6[MHz] NSB signals of 30[dBμV/m] are jammed by the modem signal emission even at 156[m] off the mains. Figure 12 shows vanishing point of modem signal reception in Akagi. Ranges of 200 to 400[m] are reported.

A reception of modem signal is reported at the Study Group meeting, where an amateur radio station of 600[m] off the measurement site has received an strange kind of noise in 9[MHz] BC band. He swept the whole HF band to obtain the frequency response of the noise and directed his beam antenna to the source successfully. On this reception date, indoor experiments are performed in an building where no outdoor modems are used.

These evaluations and reception report mean that a large amount of far field components is radiated from mains. We have not enough time to evaluate radiation characteristics in vertical plane, but most of those components must be radiated upward.

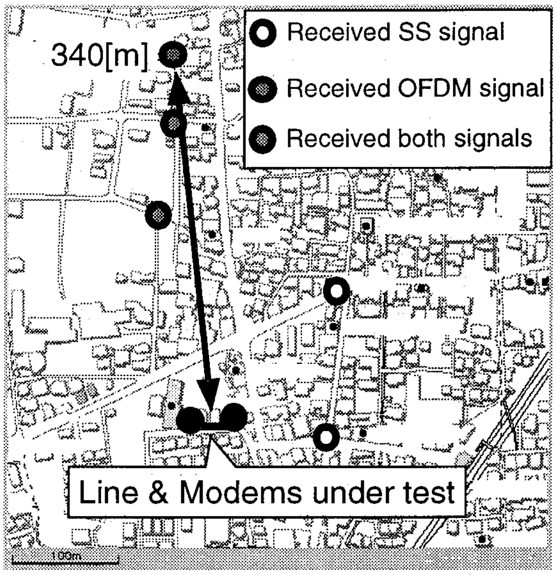

Fig.11 Modem signal received area in Matsuyama.

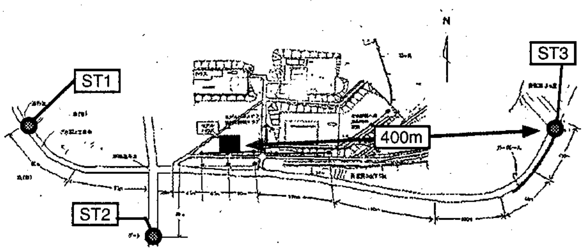

Fig.12 Modem signal received area in Akagi.

4. Relationship between LCL and emission

One of the authors had reported an examination result of radio wave emission from 20[m] length VVF cable[1]. Field strength analysis resulted that the cable was equivalent to −20[dBi] antenna.

The Study Group evaluated longitudinal conversion loss (LCL) at modem junction points, where 25 to 40[dB] are observed as mean LCL value. However, LCL only indicates the ratio of balanced and unbalanced components at the measurement points, not the unbalanced current distribution on the entire power line.

Morimoto *et al* recently reports that the power line acts as a folded dipole antenna[11]. Consider an ideal $\lambda/2$ dipole antenna fed by balanced open wires which characteristics impedance is equals to 73.13[Ω]. There is no unbalanced components on the feeder, *i.e.* infinite LCL on it, but a large amount of unbalanced current distribution on the antenna element which radiates radio wave. This concludes that the LCL is no significant measure to evaluate unwanted radiation from the mains.

5. Conclusion

In this paper, we discuss radio interference of access PLC system. It is proved that an access PLC system jams HF broadcasting and other radio communication services. Note that not only the near field, but also the far field component of the unwanted emission affects radio communications in surrounding area.

The study group has already announced its conclusion: "at this stage, increasing the frequency bandwidth that is used in power line communications would be difficult. "

We are only against unwanted PLC signal emissions

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from mains, not the system itself. We believe that technologies reducing such emissions are essential for PLCs to share the band with existing radio communications services.

Acknowledgement The authors would thank to all the members and secretary of the Power Line Communications Study Group at the Ministry of Public, Home Affairs, Posts and Telecommunications. We also express our special thanks to ICOM Inc., Kenwood Corp., Vertex–Standard Inc. and Daiichi Denpa Inc. for their kindful help in our measurements and Dr. Toshifumi Morimoto of Takuma National College of Technology, Japan, for his helpful discussions.

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