Broadband PLC for Smart Communication Infrastructure

Kyushu Institute of Technology

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1. Introduction

PLC is used for Home-Network

- **Nature of Power Line Communication**

  # No new wiring=Power Line is ubiquitous

  # Connect to Power Supply Network

  # Over 100Mbps capability available

- **PLC application & required rate**

  # Router to PC →100Mbps required

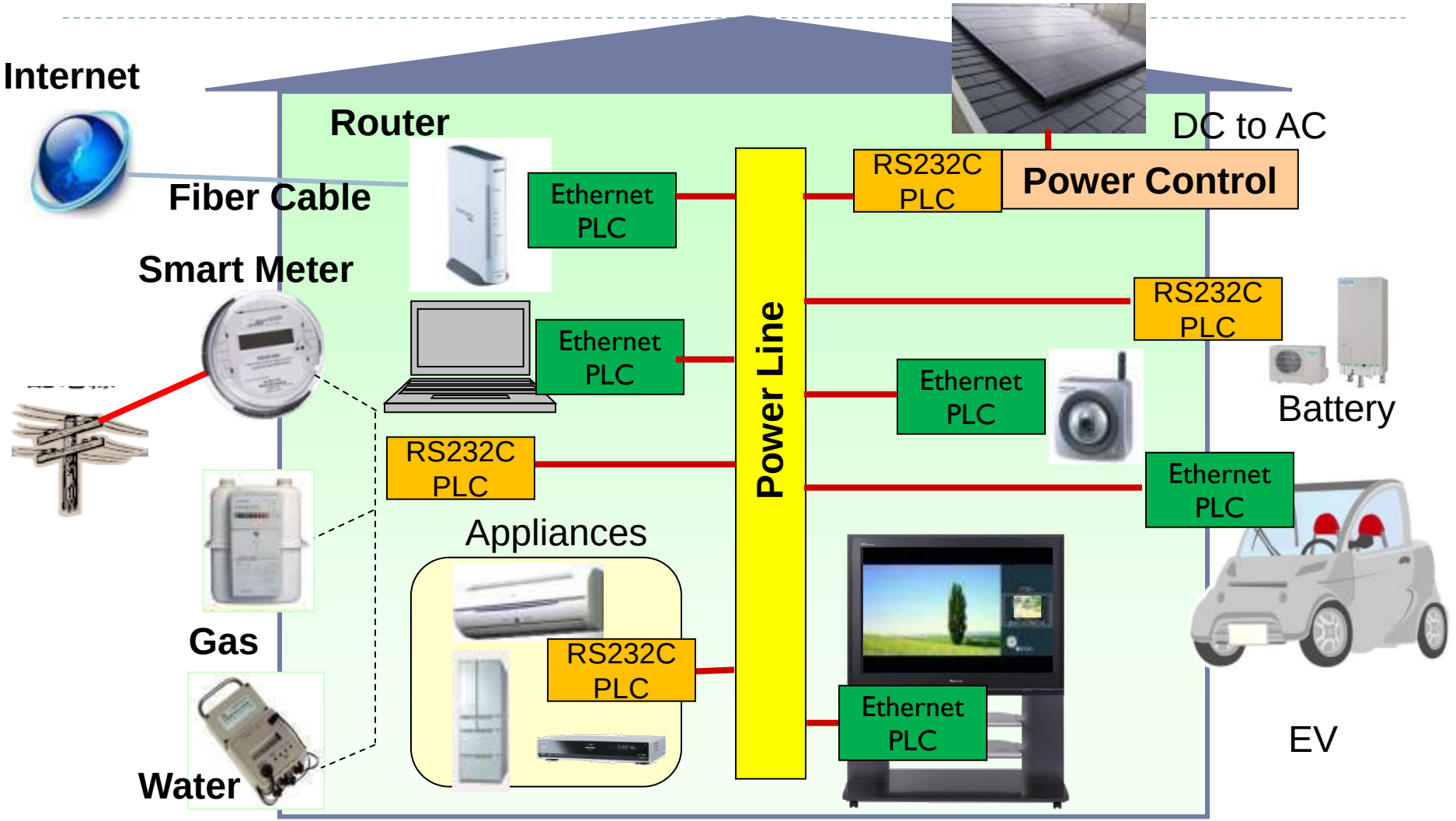
  # Router to TV (Broadcast) → 24Mbps necessary

  # Router to Telephone → less than 100mS delay

  # Smart Meter to HEMS-GW →1kbytes/minute

  # Auto-Meter-Reading →100bytes/month

PLC applications

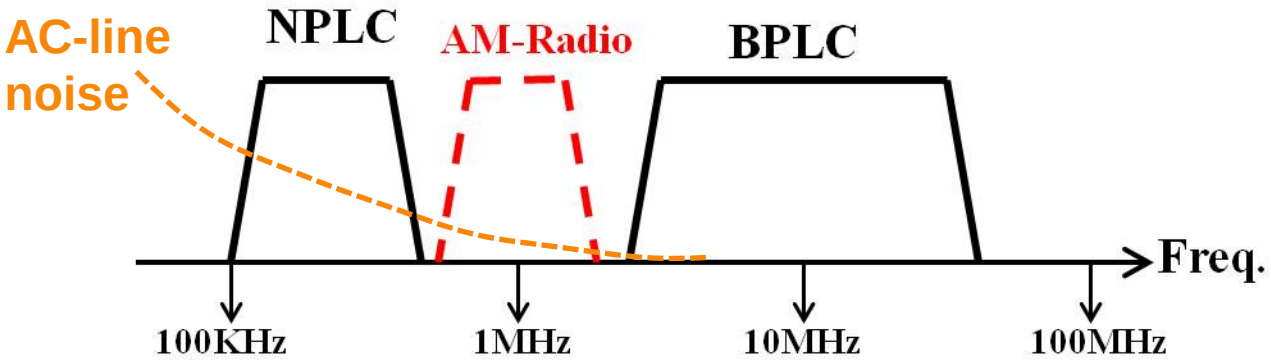


2．Physical layer of PLC & Noise/Attenuation

Doctoral dissertations of Mikio Mizutani ;Kyushu Institute of Technology 2014
‘Studies on Reinforcement of Power Line Communications on Home Networks’

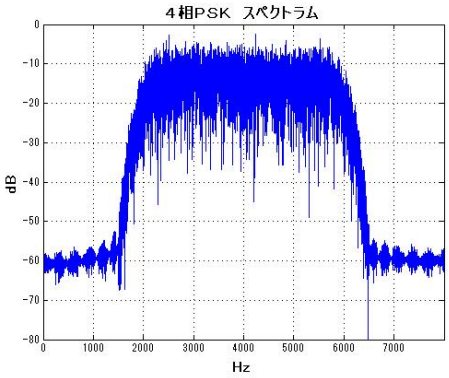
PLC-standards in Japan

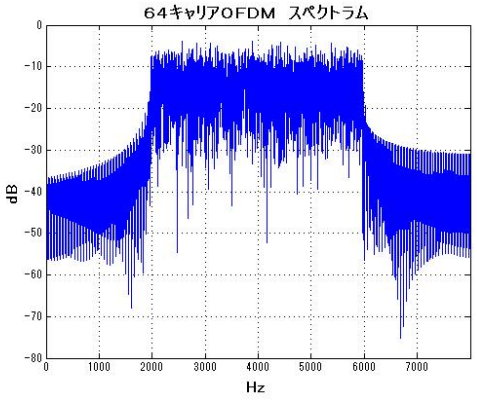
- Broad-band PLC:BPLC≒120Mbps
  Narrow-band PLC:NPLC≒30kbps



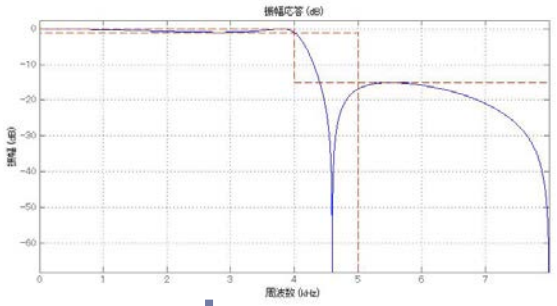
- **BPLC-standard IEEE1901,ITU-T G.9972 (2011)**
  Application in Japan is limited to use only in-house
- **NPLC-standard IEEE1901.2,ITU-T G.9903-ARIB(2014)**
  TEPCO start to use for Smart-Meter from 2015 Spring

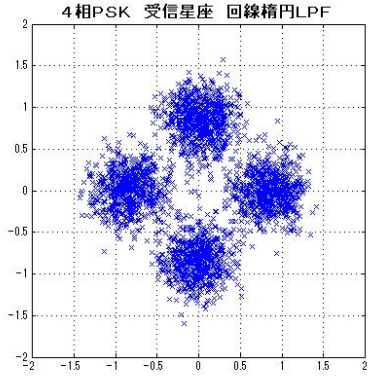
OFDM Modulation is better for wideband

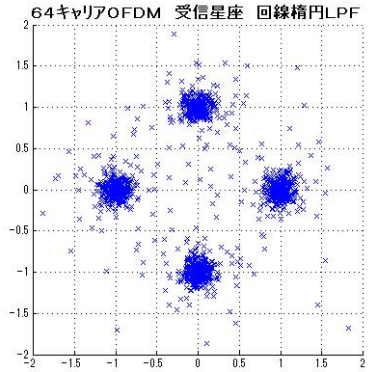




Line spectrum







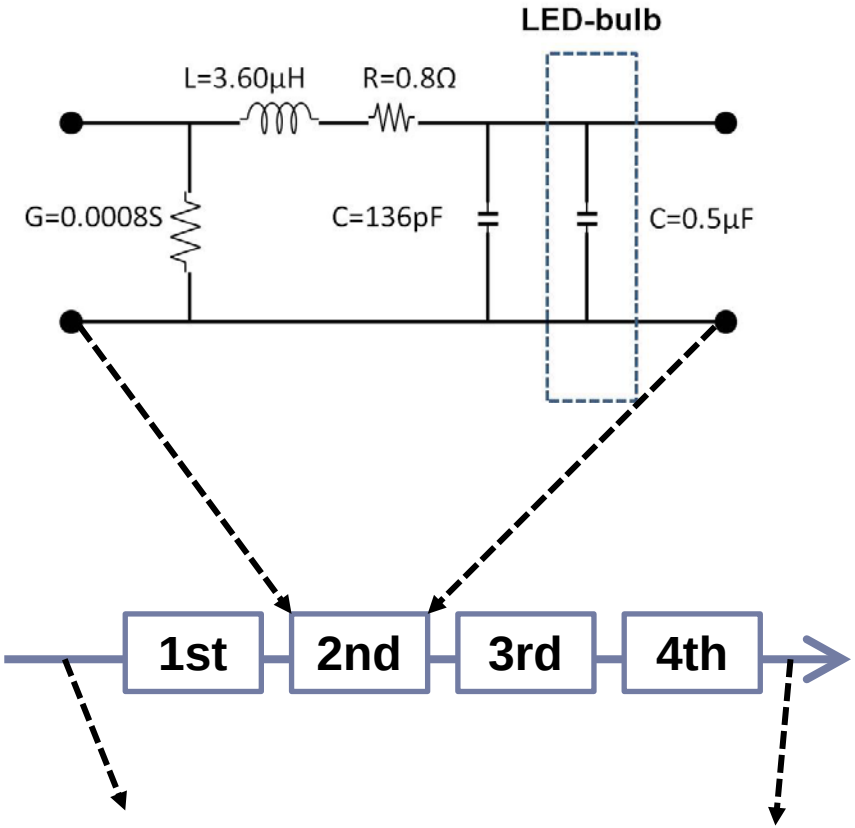
Single-Carrier-PSK

OFDM

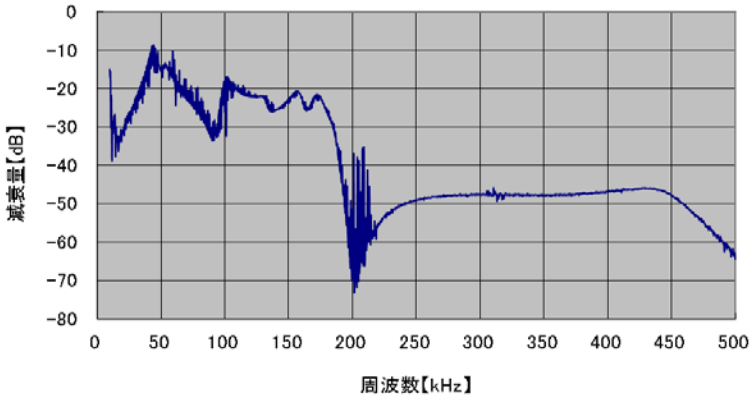
- **In deeply-notched-spectrum-line, OFDM is less damaged than Single-Carrier system.**

Typical Line-Attenuation is Low-Pass in high rise housing vertical cable.

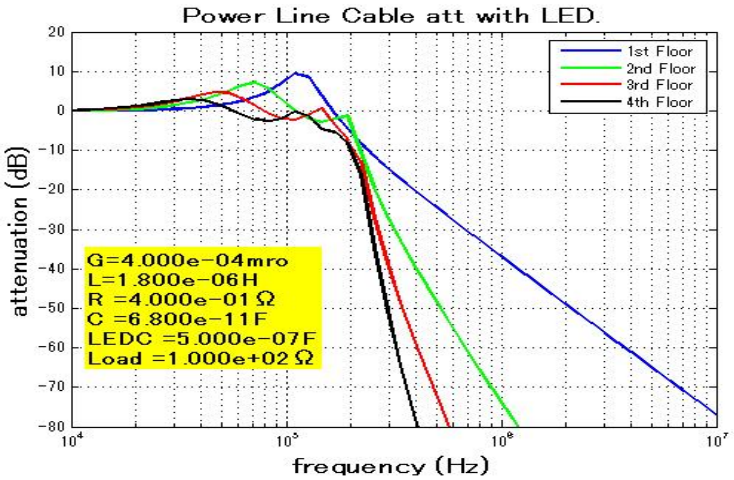
25mm2 cable model + LED-bulb



Total line attenuation 1st to 4th

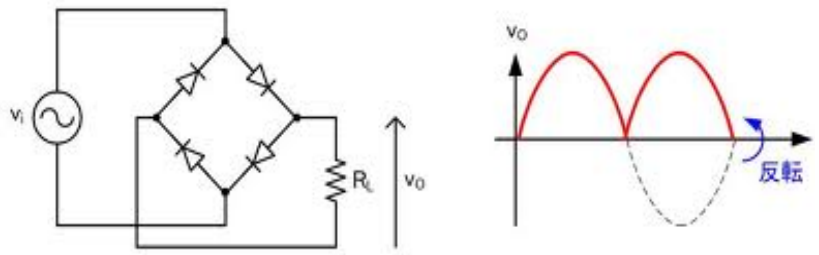


Observed line attenuation 1st to 4th

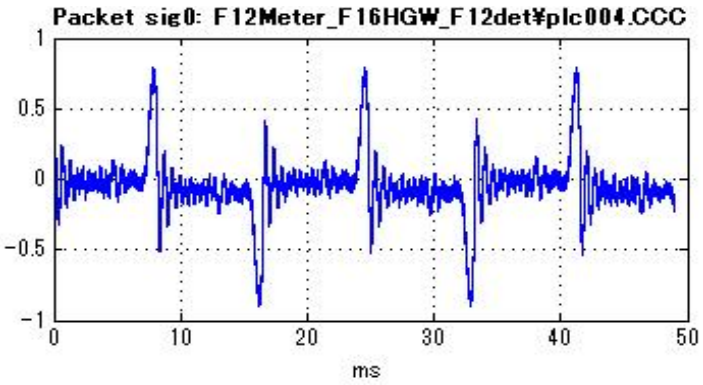


Simulated line attenuation

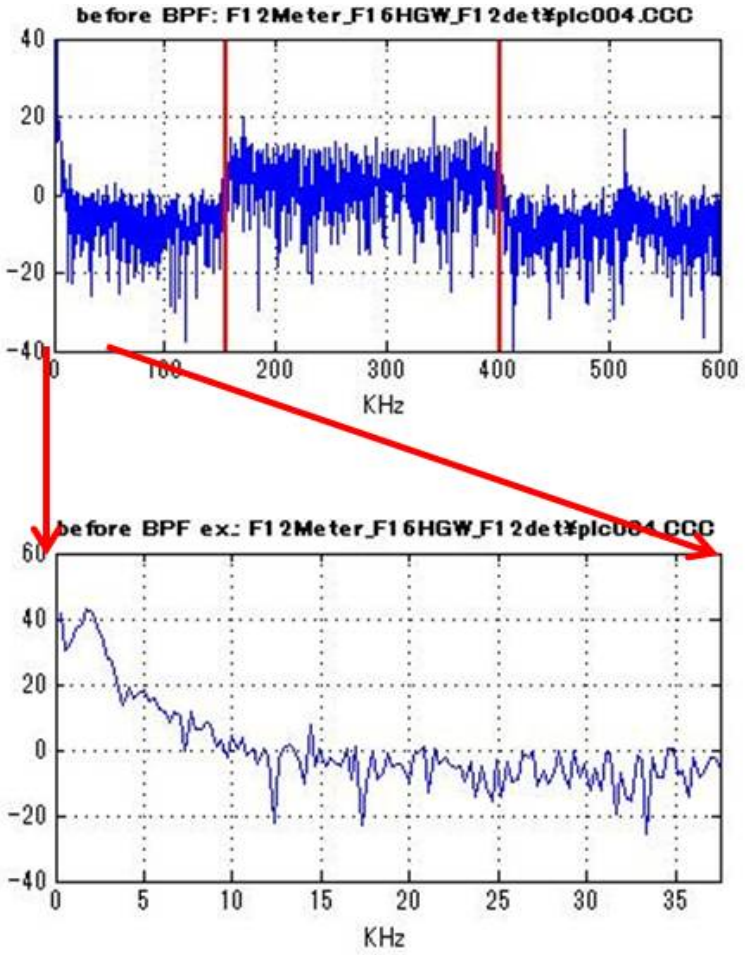
Diode bridge noise is limit under 10kHz.



Diode bridge in power-supply

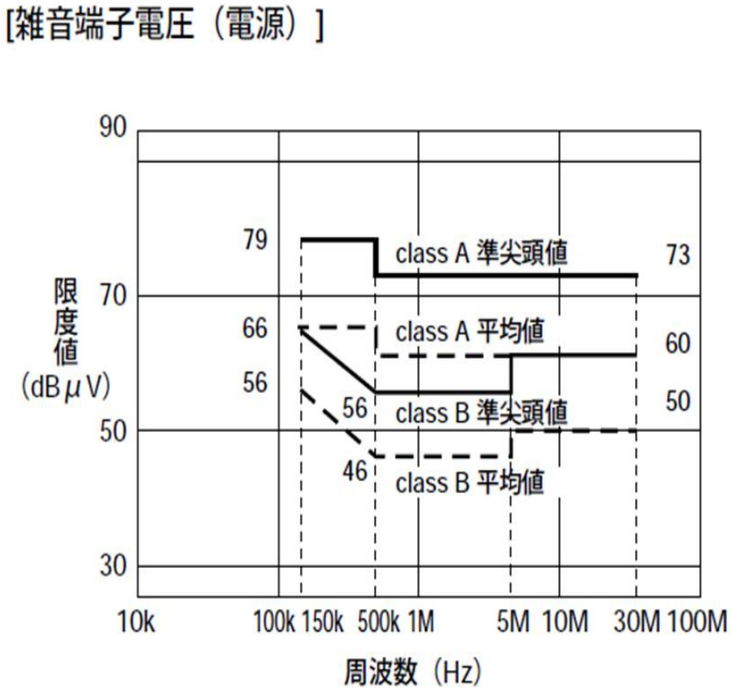


■ **Noise wave of Diode bridge**

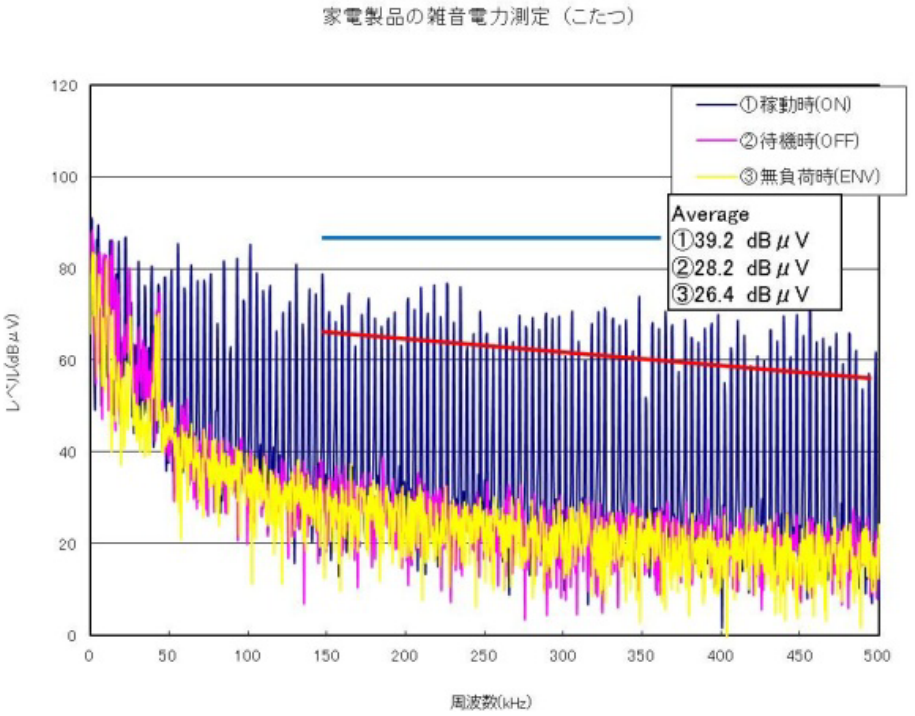


■ **Diode bridge has no damage for NPLC**

Equipment with dimmer has over 150kHz noise.



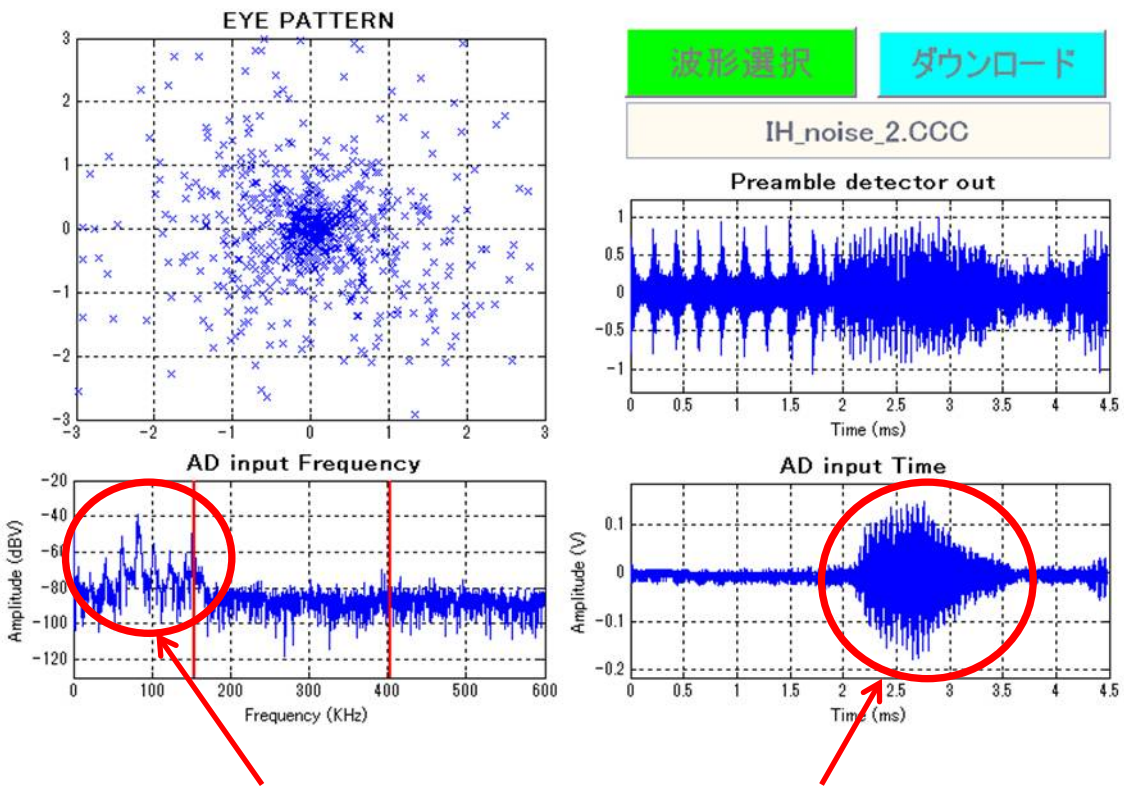
■Japan regulation of AC-noise



■Noise of KOTATSU with dimmer

■ **Over 150kHz noise has damages for NPLC**

IH-cooking-heater power-supply-burst-noise exceed 150kHz.

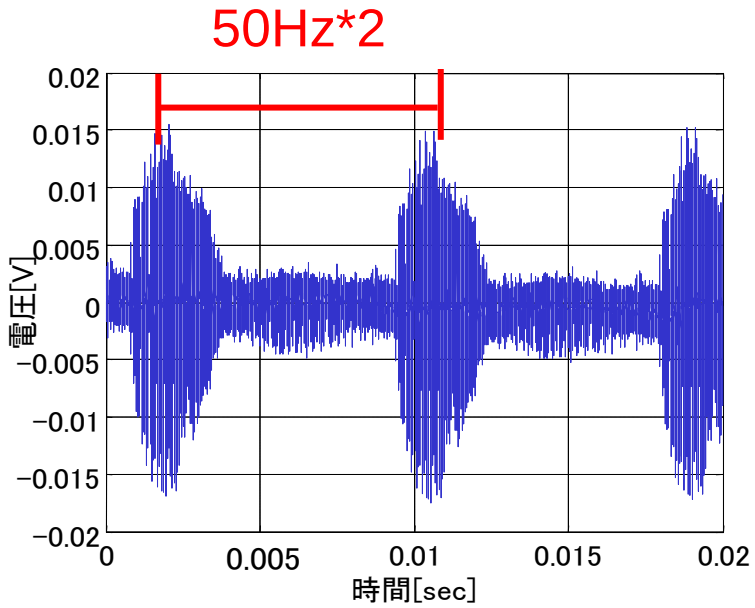


Display of G3plc_monitor By Egretcom

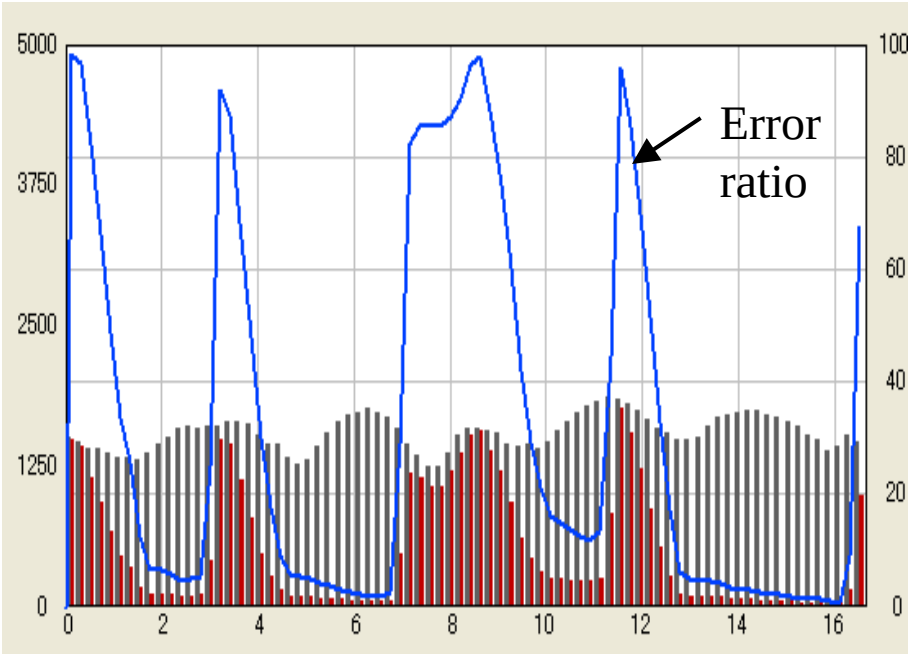
■IH-cooking-heater-Noise

■ **IH-noise is burst in every 20mS cause error in NPLC.**

Impedance up/down by 50Hz



■Wave of Impedance up/down

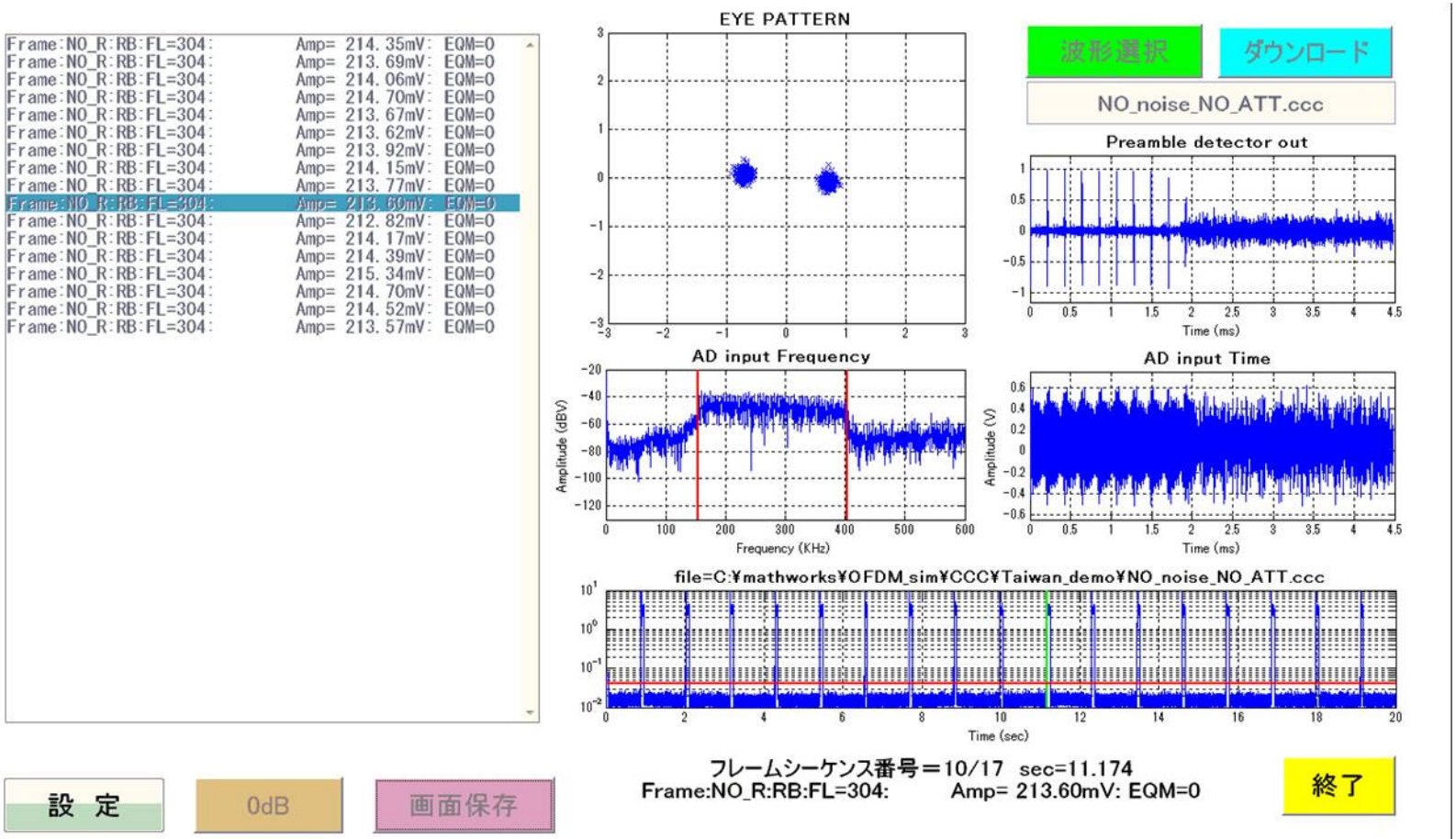


■Packet-error-ratio vs. 0-cross of 50Hz

■ **Packet-error-ratio varies from 0% to 100% depend on AC-wave zero-cross timing.**

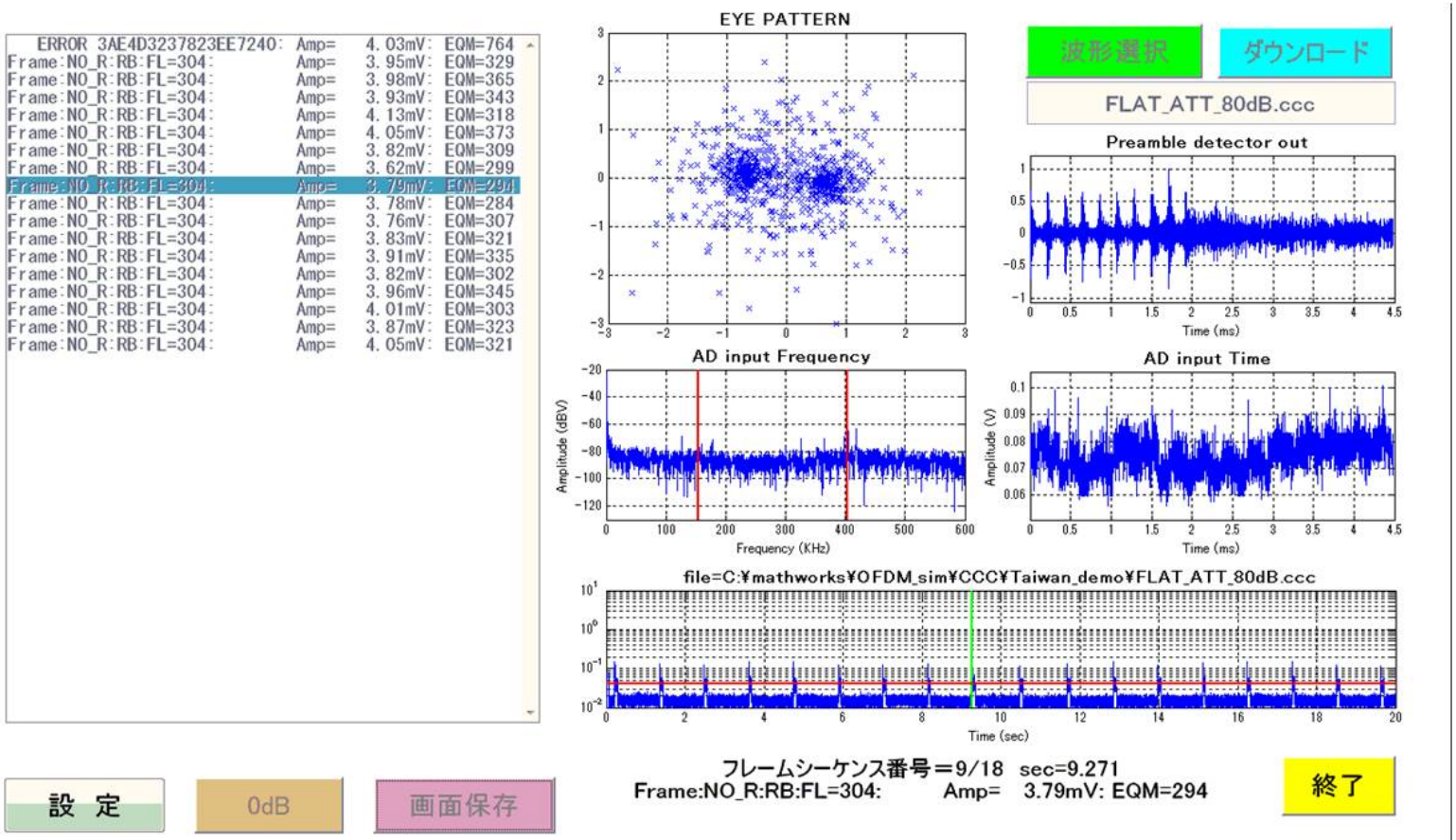
3. G3PLC & real environment

G3PLC-ARIB frame in real environment-1. no-ATT & no-noise



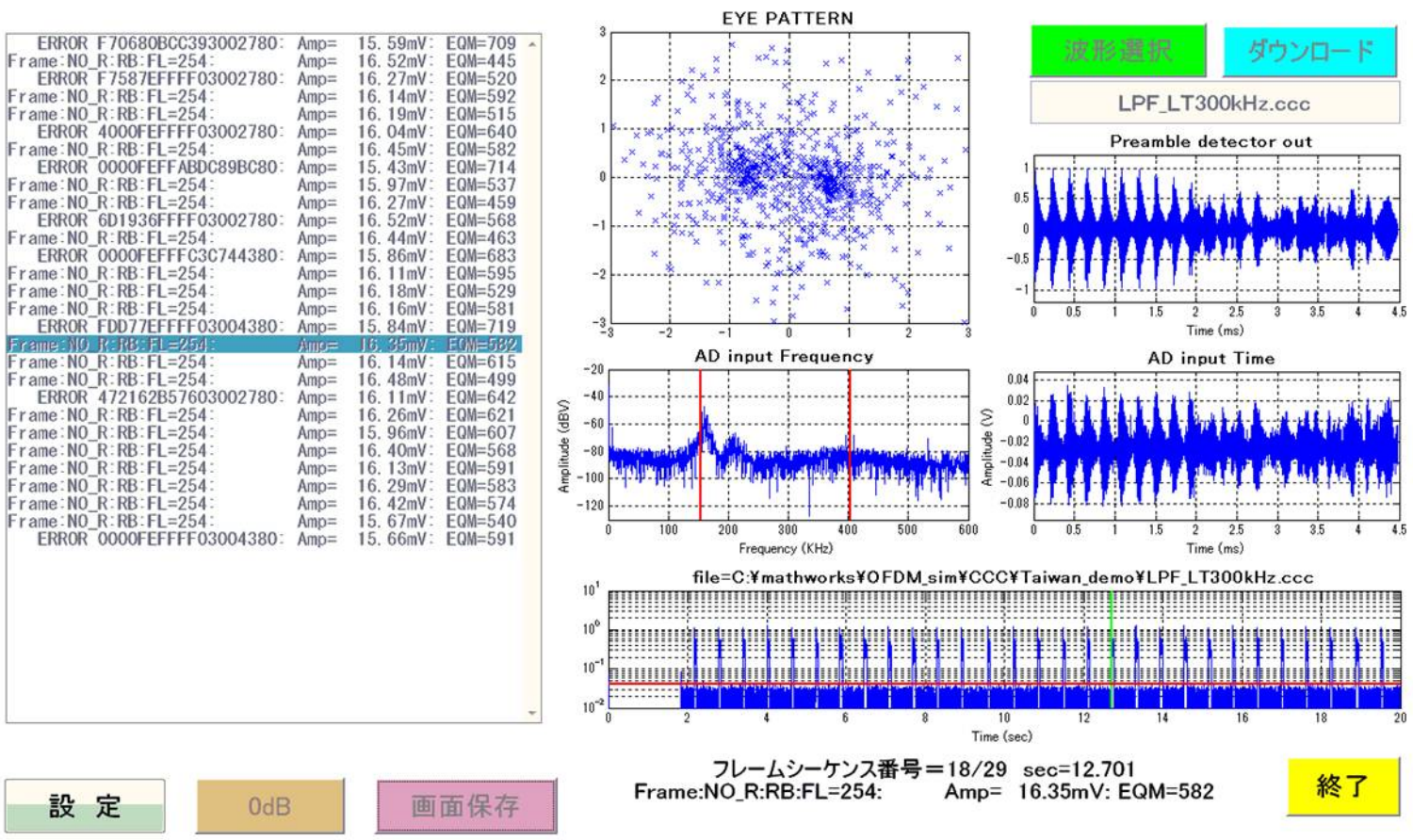
■ **FCH-no-error EQM=0**

G3PLC-ARIB frame in real environment-2. Flat-ATT 55dB=SN 0dB



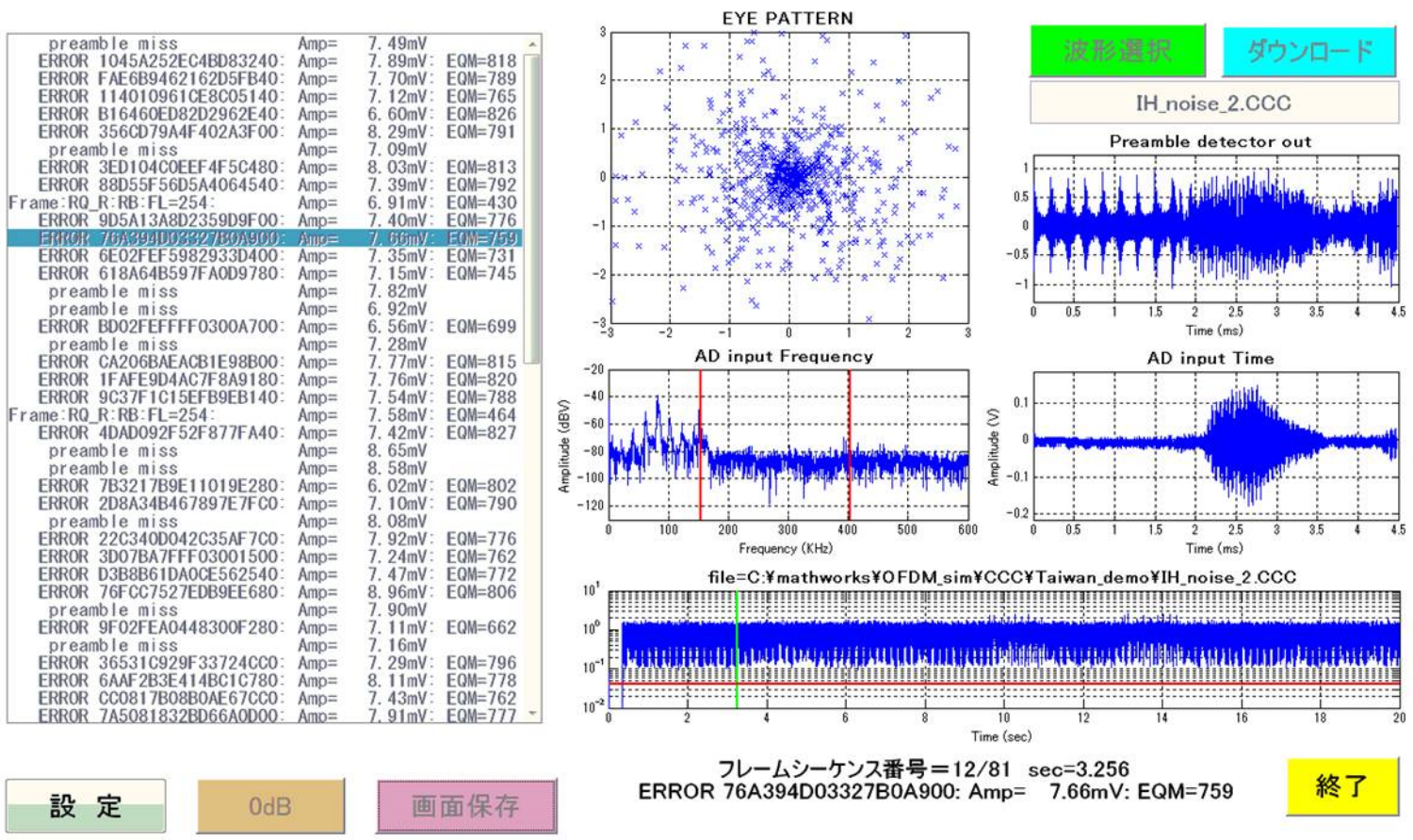
■ **FCH-no-error EQM=294**

G3PLC-ARIB frame in real environment-3. Line=180kHz low-pass



■ **FCH-no-error EQM=582**

G3PLC-ARIB frame in real environment-4. IH-cooking-heater-burst-noise

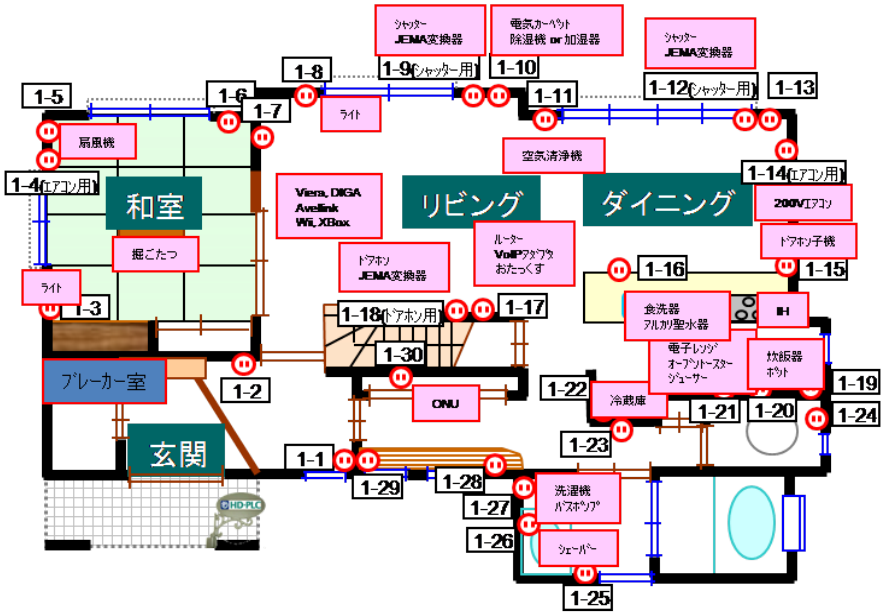


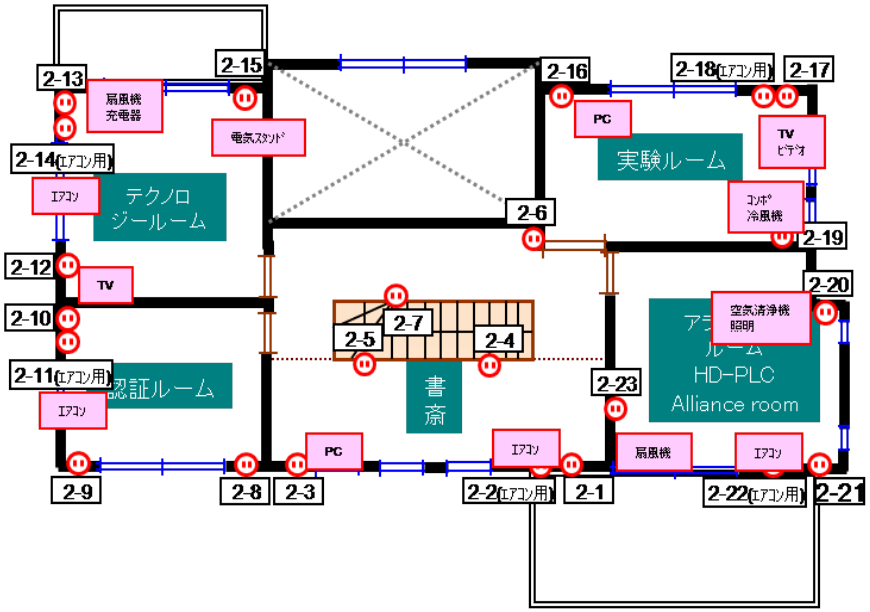
■ **FCH-FCS-error EQM=759.**

4. HD-PLC performance issue

Mikio Mizutani, Masato Tsuru, Yuji Oie, “New Performance Estimation Scheme and Applications for Broadband Communications Over Power Lines in the Home,” Proc. 2011 IEEE Pacific Rim Conference on Communications, Computers and Signal Processing (PACRIM2011), pp. 578-583, August 2011.

Panasonic PLC house in Minoshima



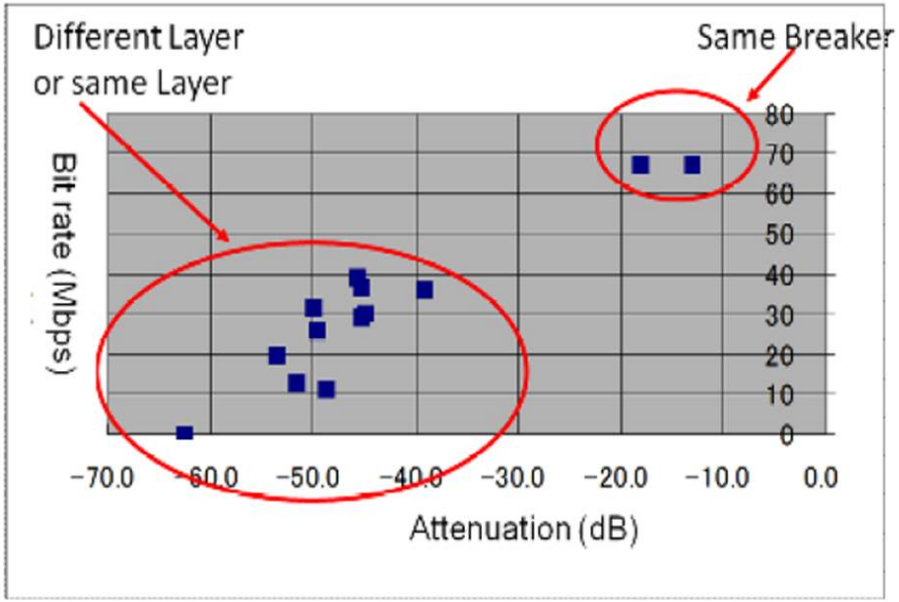


■ **Number of outlets is 84**

Observed UDP-rate in PLC house

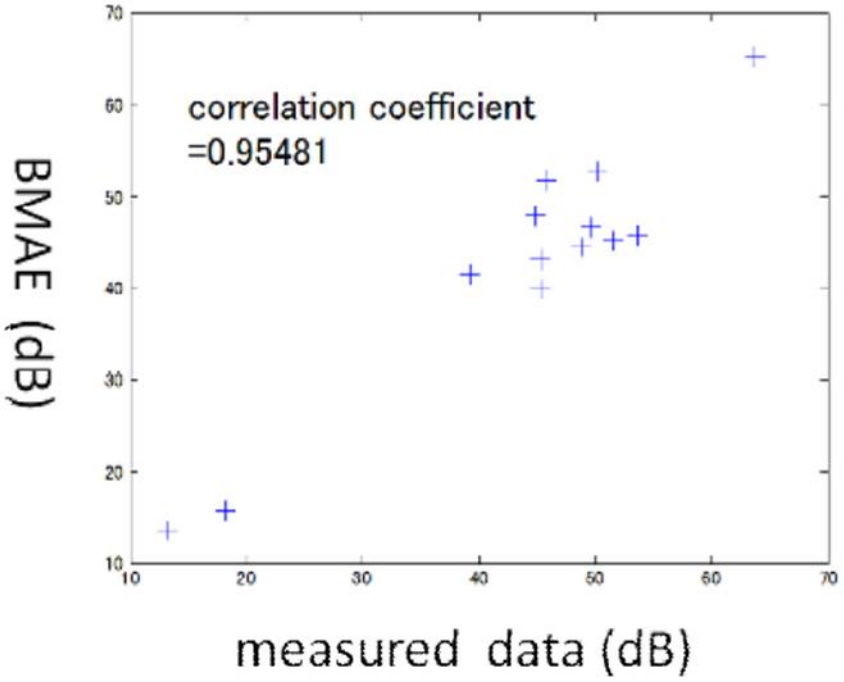
TX outlet	RX outlet	Bit rate [Mbps]	Att. [dB]	Layer
1-17 (2)	1-7 (2)	67.7	−13.2	same B
	1-20 (10)	36.9	−45.3	diff. L
	1-26 (4)	36.2	−39.3	same L
	2-1 (7)	30.2	−44.9	diff. L
	2-10 (5)	25.6	−49.6	diff. L
	2-17 (6)	19.7	−53.6	same L
2-1 (7)	1-5 (3)	12.9	−51.6	same L
	1-7 (2)	29.4	−45.3	diff. L
	2-5 (7)	67.8	−18.2	same B
	2-17 (6)	31.7	−50.1	diff. L
2-10 (5)	2-17(6)	39.1	−45.7	diff. L
	1-15 (1)	11.3	−48.8	same L
1-12 (2)	2-13 (5)	0.0	−63.7	diff. L

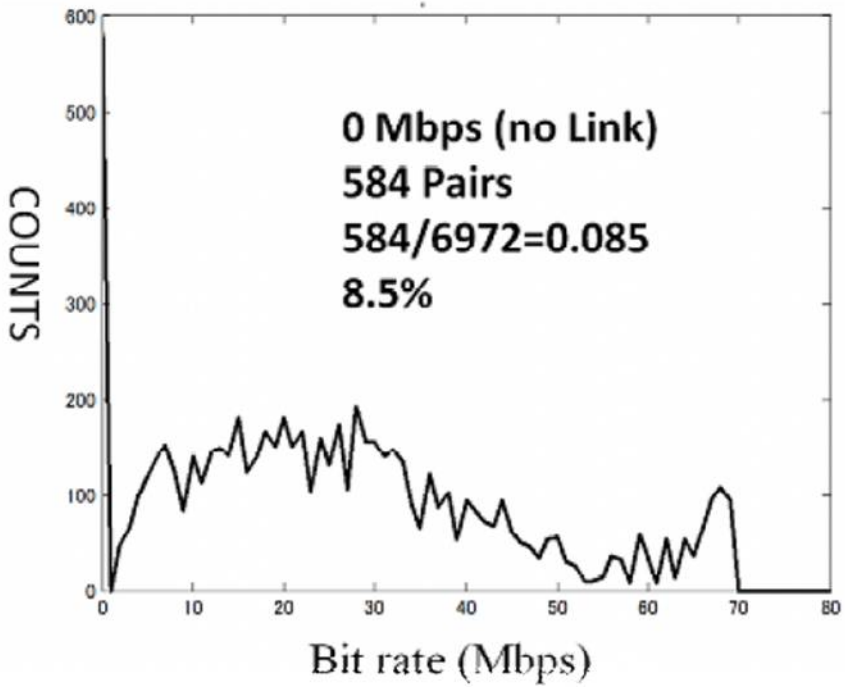
Table 1. Attenuation (dB) and bit rate (Mbps)



- **UDP-rate vs. Attenuation in each 13 pairs of outlet**

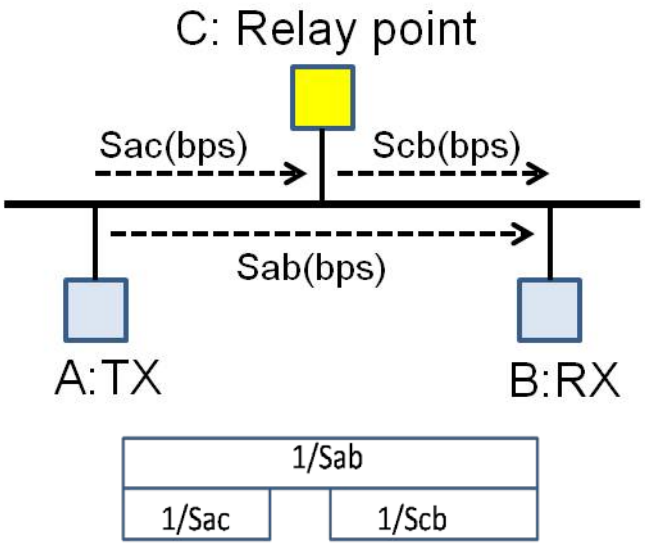
UDP rate Estimation of every outlet pairs



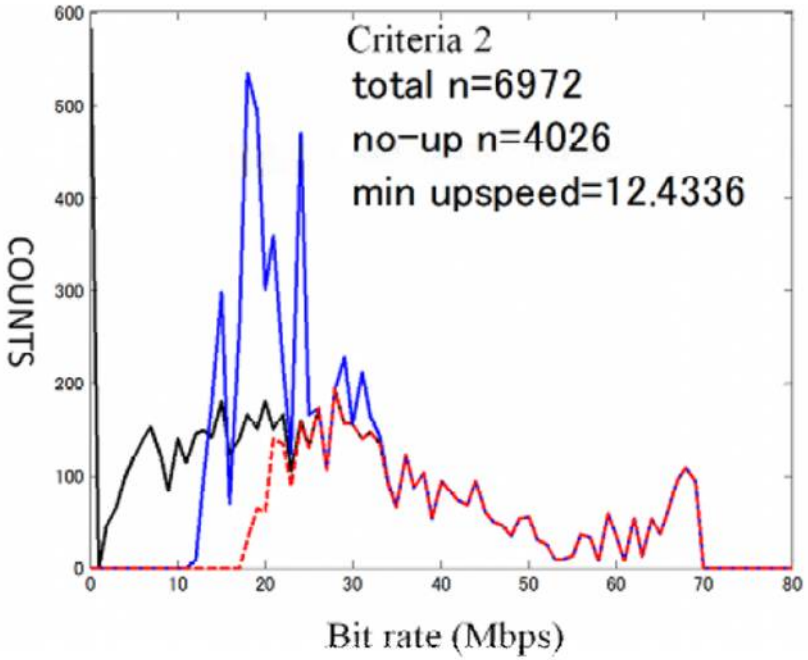


- Attenuation estimation by BMAE
- Estimated UDP rate of every outlet pairs

UDP rate up by relay transmission



■ Rate up criteria
Sac>Sab*2 &
Scb>Sab*2



■ UDP rate up by relay transmission
RED: no improve Blue: Rate up

■**Relay transmission improve UDP rate.**
100% up-12Mbps :95% up-20Mbps : 90% up-24Mbps

Thanks your corporation