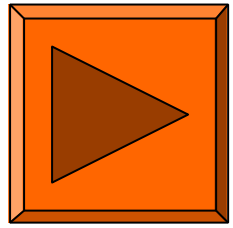
Tutorial II:
Power-line Communication, Technology and Japanese Activity

Shinji Tsuzuki
Ehime University, Japan
tsuzuki@ee.ehime-u.ac.jp
http://miyabi.ee.ehime-u.ac.jp/~tsuzuki/PLC/PLC.html

Third International Workshop on Networked Appliances, IWNA'2001, 01 March - 02 March, 2001
Time: 8:30AM -10:30PM
Date: Friday, 2nd March 2001
Venue: Empress Room, Level 2, Carlton Hotel, Singapore

Topics

- Overview of PLC and home-network
- Conventional PLC products
- Principle of PLC
- High-speed/reliable products
- Regulation and standardization activity
- Some Japanese activities



Overview of PLC and home-network

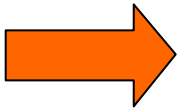
Home network (1)

Promising candidates

- Wire-less network
  - IEEE802.11, Bluetooth, HomeRF
- Wired network
  - Plastic Optical Fiber
  - twist-pair wire
    - IEEE802.3
      - cheapest, fastest & (most) reliable
      - But needs New Wires
    - IEEE1394 for AV applications
    - HomePNA
      - Relatively low-cost, fast, reliable, supports voice & streaming
      - But limited to existing phone jacks

Home network (2)

- Wired network
  - IEEE802.3, IEEE1394, (HomePNA)
  - ○ high speed, reliable
  - X new wire or re-wiring is needed

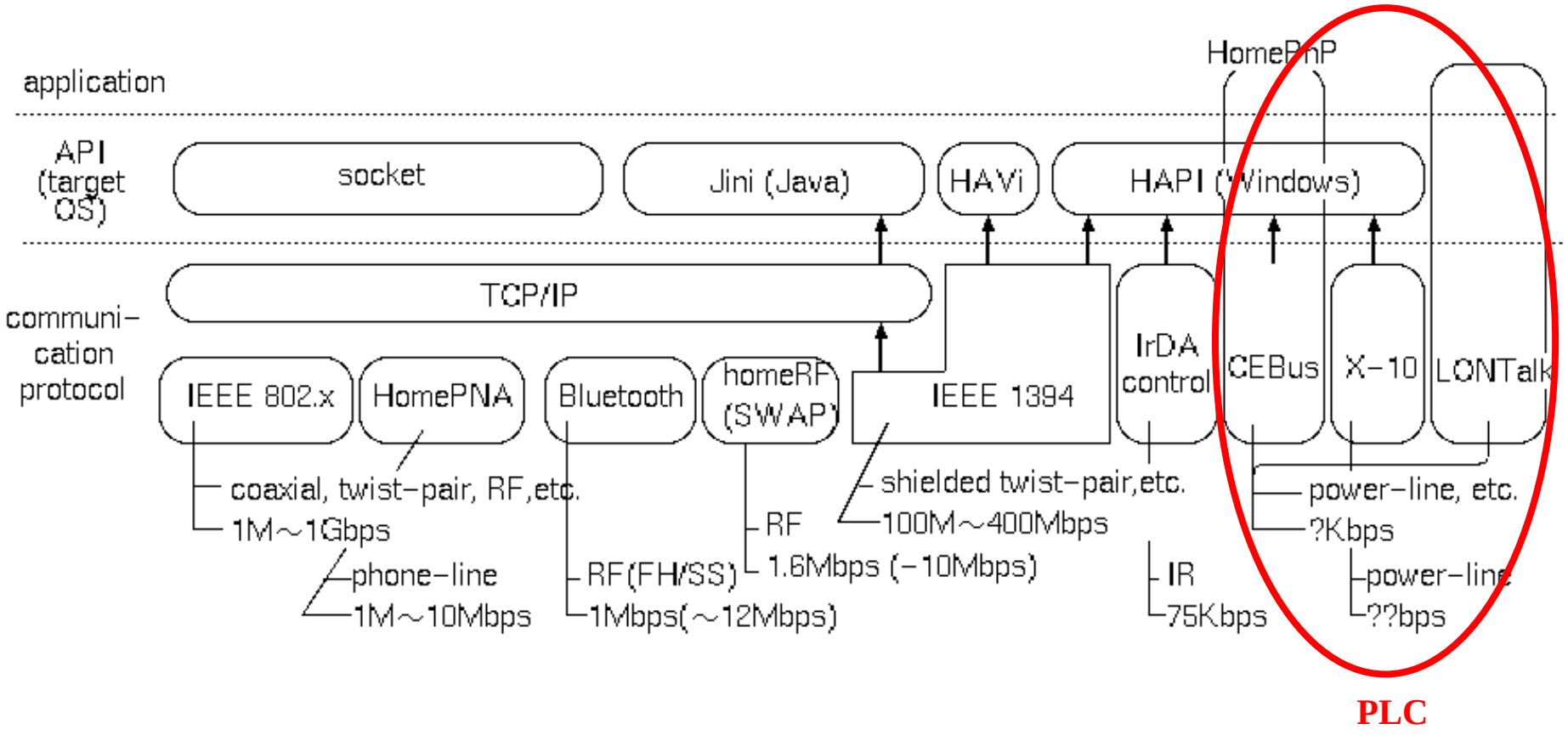


Power-Line Communication (PLC),
i.e.,

- No costly rewiring
- A ‘connection port’ (AC power outlet) in every room
- ecological method

Overview of PLC and home-network

Home network (2): related standards



High speed PLC: HomePlug (10Mbps)

Table 1. *Home Networking Technology Comparison*

	Phone line	Ethernet	Powerline	Wireless
Speed (1 Mbps = 1000 Kbps)	100 Kbps–10 Mbps	10 Mbps–100 Mbps	50 Kbps–350 Kbps	700 Kbps–11 Mbps
Estimated cost* **(in US dollars)**	$50–$130	$75–$200	$70–$150	$200–$300
Advantages	Convenient, simple (no new wires), secure	Fastest, most secure and reliable	Convenient, simple (no new wires)	Convenient, mobile, simple (no wires), secure
Requirements	Need computers and peripherals near phone jacks on the same phone-line	Requires special cabling; best in new home installations or remodels	Need computers and peripherals near power outlets on the same power circuit	Network components must be within a 250-foot range
Best use	Ideal for shared Internet access; good for home gaming	Ideal for shared Internet access, home offices, and home gaming	Good for low-bandwidth applications such as home security and control	Ideal for laptops, desktops, and handheld connected organizers; works inside and outside home or small office; great for shared Internet access; good for home gaming

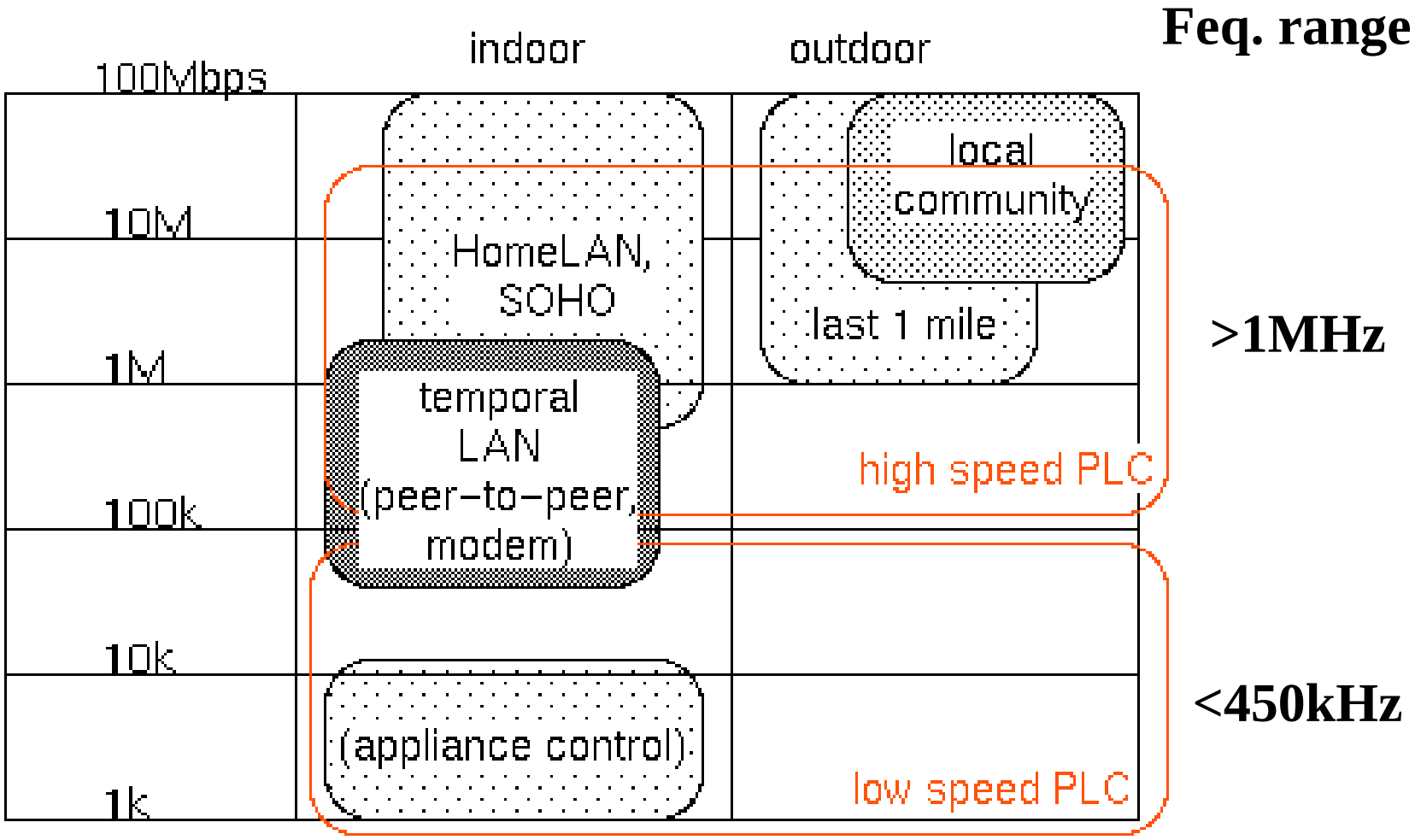
Split phase problem

http://www.3com.com/technology/tech_net/white_papers/503081c.html

*For comparison purposes, the prices include all the necessary software and hardware required to network two computers.

Overview of PLC and home-network

Home network by PLC (1)

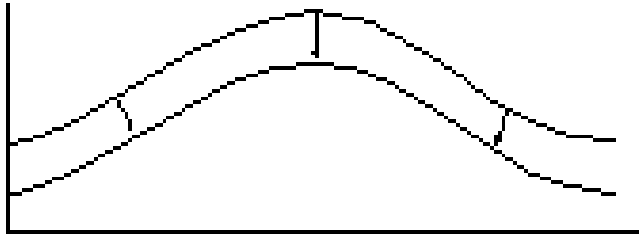


Good point of PLC (1)

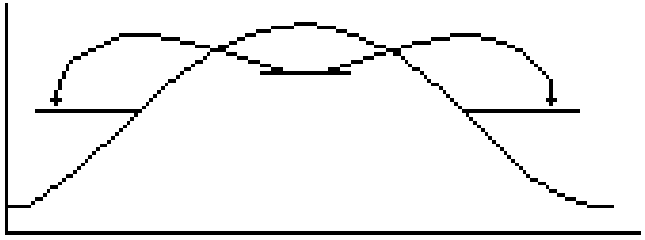
PLC can provide both solutions

- high-speed data communication
  (10Mbps, developing)
- appliance control (low-speed but cheap)
  ...(1)
  - for DSM (Demand-Side Management)
    - DSM is to smooth out the daily peaks and valleys in electric energy demand to make the most efficient use of energy resources and to defer the need to develop new power plants.

Lowers levels of energy consumption



Shifts the time of energy use.



http://www.state.hi.us/dbedt/ert/dsm_hi.html#anchor351481

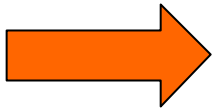
Good point of PLC (2)

- appliance control ...(2)
  - for home automation
    - can link lighting, entertainment, security, telecommunications, heating and air conditioning into one centrally controlled system.
      - http://www.homeautomation.org/welcome/welcomeMAIN_ie.html

Home network by PLC (3)

Epoch-making trial of "Internet Over Power-lines"

- Nortel (Northern Telecom) and NorWeb Communications: Nov., 1997
  - At Seymour Park Primary School in Manchester England
  - 12 PCs were connected to the Internet by power line. All 12 computers can operate concurrently from just one connection, from which they obtain permanent access to the Internet at speeds of up to 1 Mbps.



- Begin to develop higher speed PLCs
- Begin an activity of deregulation

http://www.iihe.ac.be/scimitar/J0398/IntOvPow.html

http://www.3com.com/technology/tech_net/white_papers/503081a.html#figure_3

Home network by PLC (4)

Home gateway (a)

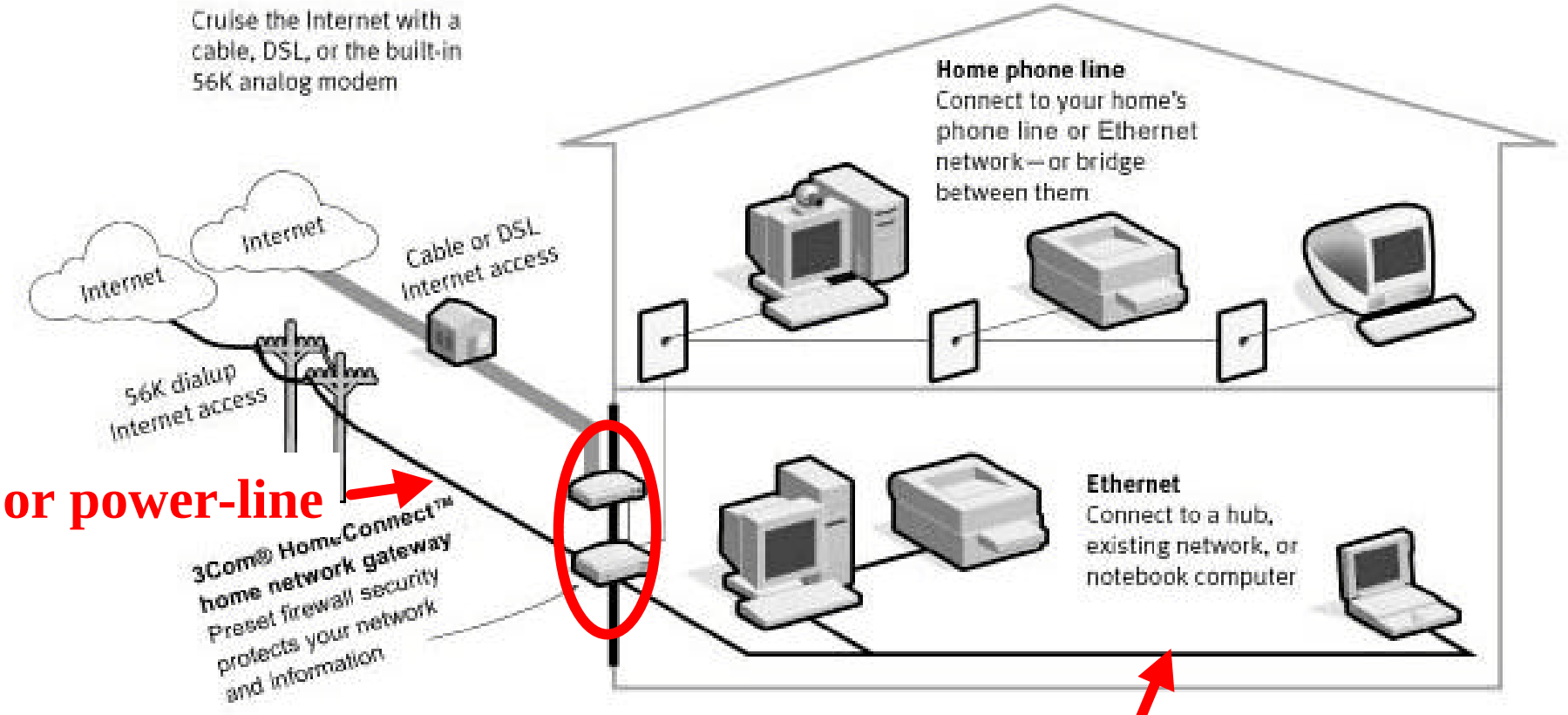
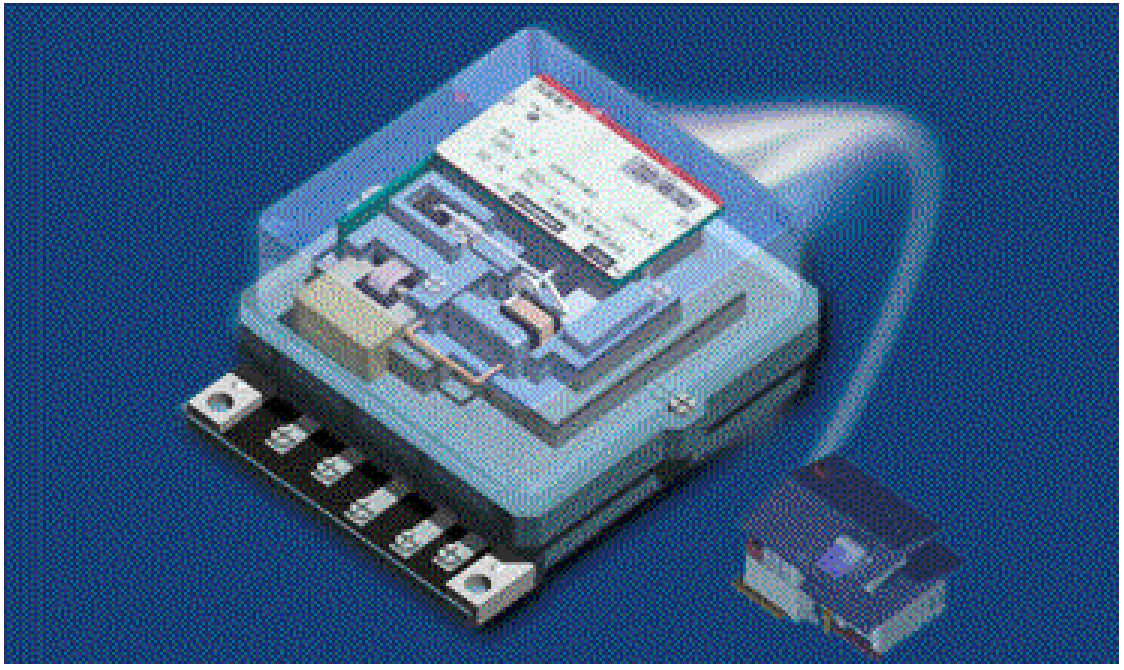


Figure 3. *Residential Gateway Product Connectivity*

Home network by PLC (5)

Home gateway using electric power meter

OpenPLANET server, developed by Shikoku Electric Power Company.



currently utilizes

- Residential network
  Echelon's LonWorks
- Global network
  PHS(Personal Handy-phone System)

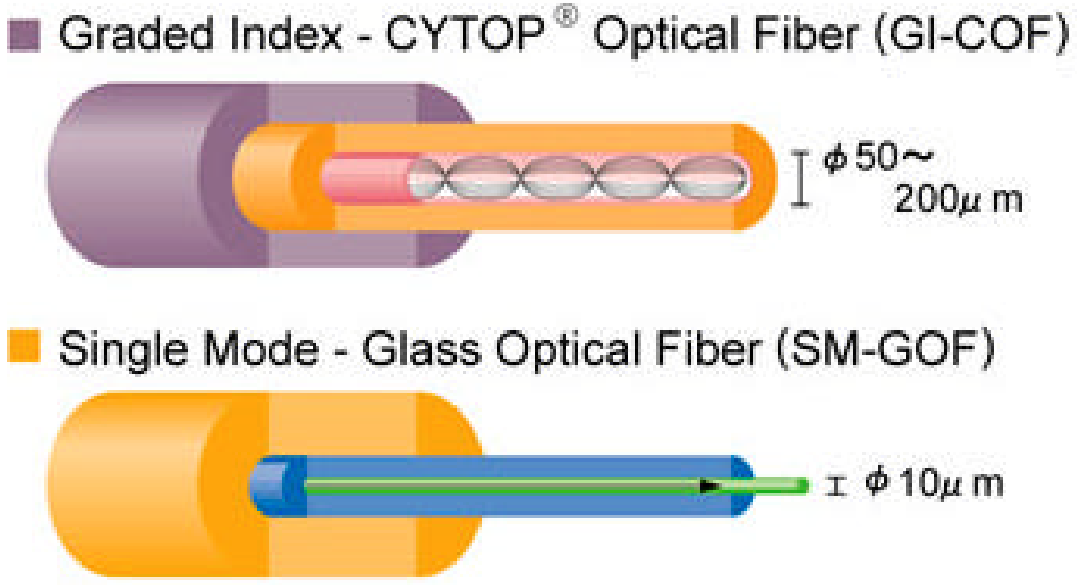
http://www.openplanet.co.jp/html-e/e-kosei.htm

Plastic Optical Fiber (POF) for Gigabit Communication

http://www.agc.co.jp/english/lucina/

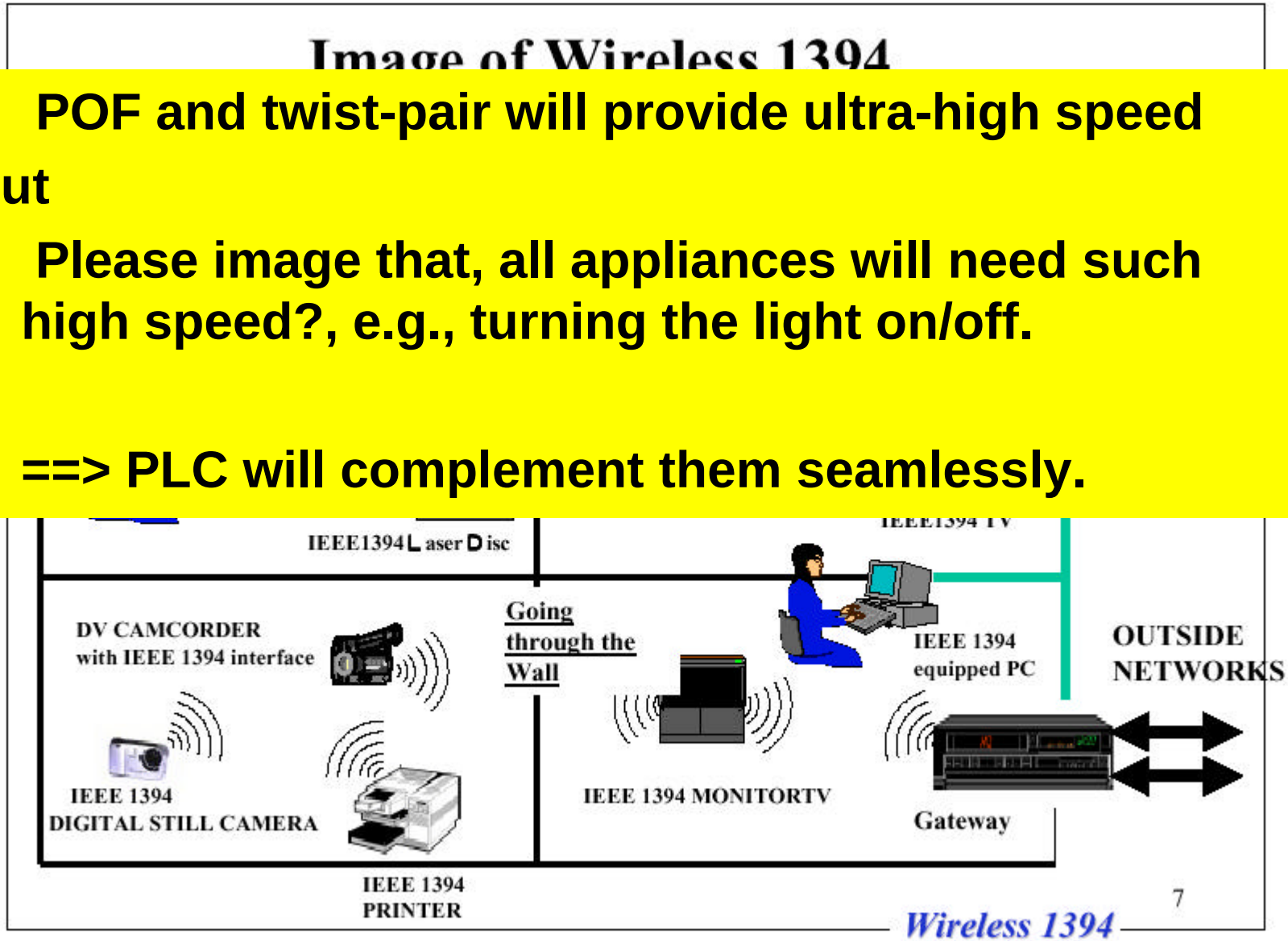
- High bandwidth (2.5Gbps over 200-500m)
  - a graded index (GI) profile
- large core fiber → Ease of handling and connection, Low installation costs

• Compatibility with commercially available transceivers of Multi Mode glass optical fiber(MMF), especially 850nm LED, 780nm LD, and 850nm VCSEL transceivers



http://www.arib.or.jp/mmac/download/m0003_3.pdf

An example of POF application to home-network



- **POF and twist-pair will provide ultra-high speed**

But

- **Please image that, all appliances will need such high speed?, e.g., turning the light on/off.**

- **==> PLC will complement them seamlessly.**

Conventional PLC products (1)

- for the traditional appliance-control, or home-automation
  - CEBus, LONtalk, X-10, SMART HOUSE, BatiBUS, European Home System, European Installation Bus, Japan's Home Bus System.
- for PC modem
  - some products around 100kbps

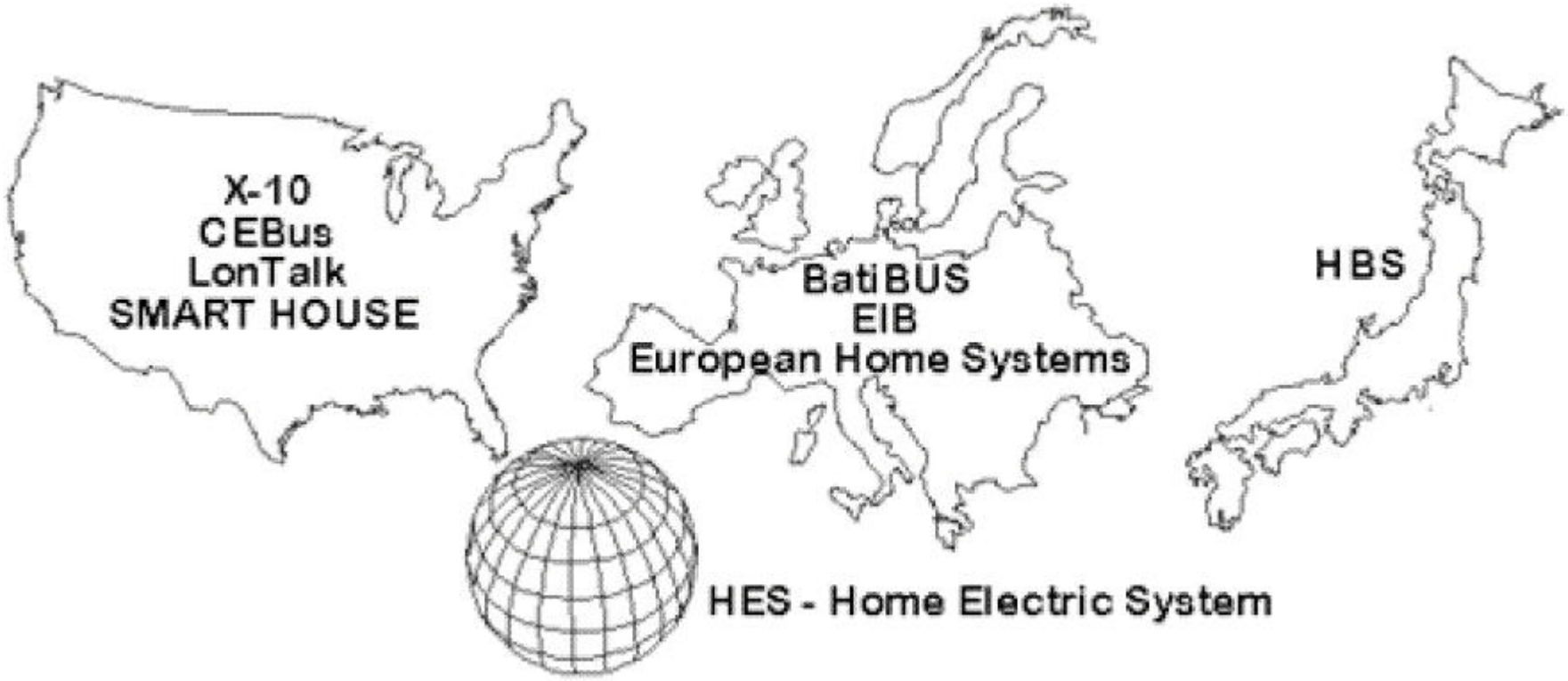
Conventional PLC products (2)

No.	modulation	data rate (bps)	transmission bandwidth	conformable standard
early PLC (around 1930)	RCS (ripple carrier signaling; a kind of ASK)	approx. 2/3		
1	AM	60		X-10 note1)
2 (INTELLON)	SS (chirp)	≅8.5k	100k – 400kHz	CEBus
3 (ALINCO)	DS/SS note2)	9.6k	10k – 450kHz	proprietary
4 (ECHELON)	DS/SS note2)	10k	100k – 450kHz	LonTalk
5 (CONLUX)	DS/SS note2)	19.2k	100k – 450kHz	proprietary
6 (ECHELON)	BPSK	5k	125k – 140kHz	LonTalk
7 (ITRON)	FSK	3.2k	9k – 95kHz	proprietary
8 (NS, LM1893)	FSK	4.8k	(FSK deviation: $\frac{f_2-f_1}{(f_2+f_1)/2} = 4.4\%$)	proprietary
9 (Adaptive Networks)	SS	100k	140k – 450kHz	proprietary
10 (Intelogis)	FSK	350k (1Mbps for the future version)		proprietary
11 (NorWeb)		1M	2MHz between 2.2MHz and 10MHz	proprietary

http://hometoys.com/htinews/aug97/articles/kwacks/kwacks.htm

Conventional PLC products (3)

Standards for home-automation



- X-10: registered trademark of X-10 (USA) Inc.
- LonTalk: technology of Echelon Corporation
- EIB: European Installation Bus
- HBS: Home Bus System (Japanese standard for home networks. Established in 1988 by the Electronic Industries Association of Japan.)
- HES: an international standard

Conventional PLC products (4)

CEBus (1)

- Consumer Electronics Bus (CEBus) : an open standard EIA-600, developed by the Electronics Industries Association (EIA)
  - since 1984
  - power-line (SS/chirp modulation), twist-pair, coaxial cable, IR, RF, optic fiber
  - Home Plug & Play (HomePnP)
    - The HomePnP Task Force was formed in late 1995 by Honeywell, Intel, Microsoft and Thomson Consumer Electronics
    - utilizes the Common Application Language (CAL, EIA-721) for a transport-independent application protocol.

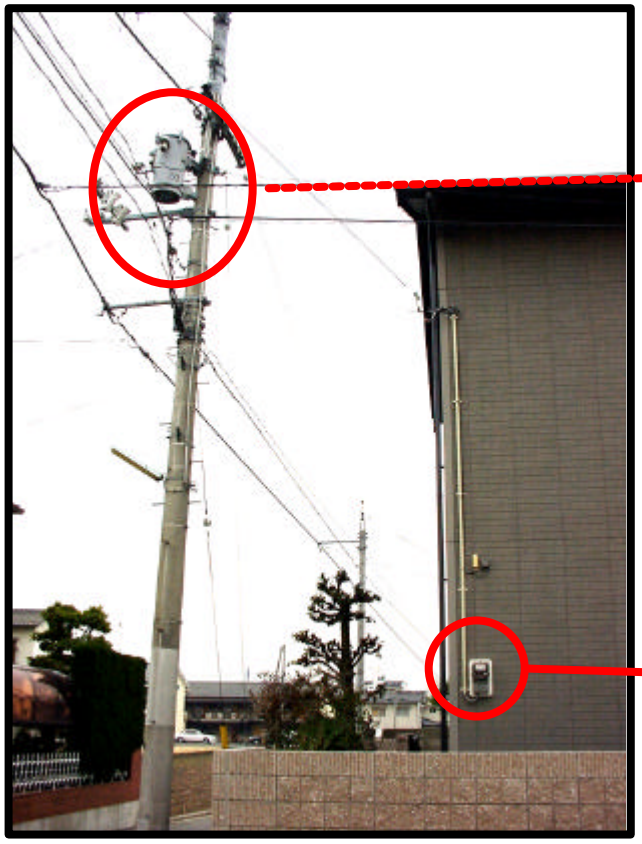
Conventional PLC products (5)

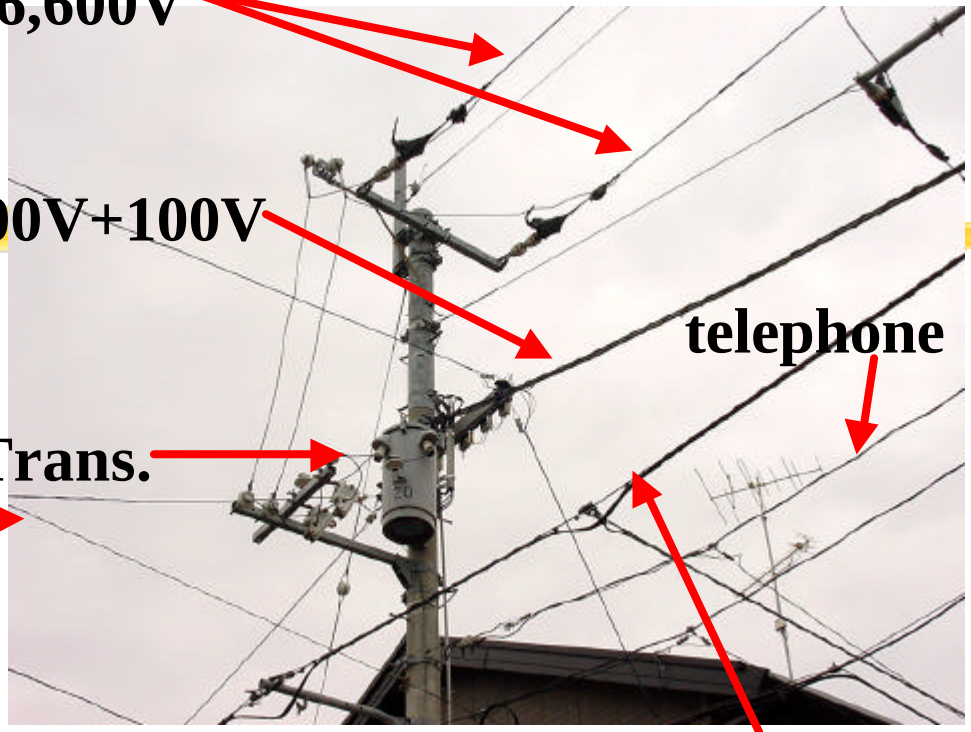
CEBus (2)

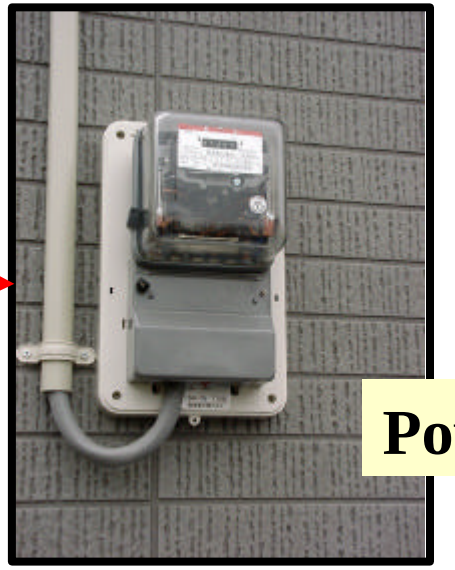
- SCP/CEBus ---- Microsoft
  - Microsoft has announced its Simple Control Protocol (SCP), that is a protocol based on CEBus lowest layer standard definition. SCP and CEBus devices can coexist on the same network. In the future, quite likely SCP will replace CEBus.
    - SCP: a lightweight, royalty free networking technology for devices such as smart appliances and home control products.

Principle of PLC

Electric (& telephone) pole, Japan







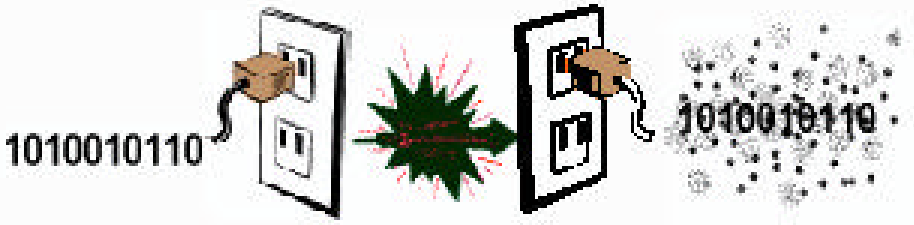
Power meter

Merit of PLC

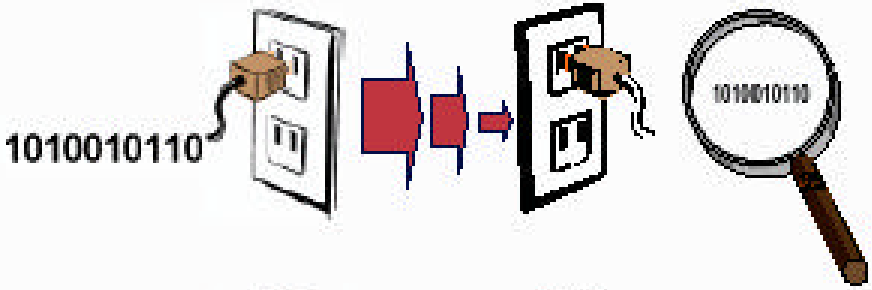
- No new wire
  - Appliances are already connected to power-line
- Available area is wider than radio waves, in indoor-communication(, in general)
  - no obstacle such as walls to propagate a signal
  - At Sakura elementary school in Ehime, we demonstrated that PLC of 100kbps was possible at all wall sockets, from 1st floor to 3rd floor, 18 classrooms.
    - IEEE802.11b LAN was limited to the visible area. Beyond a wall, its quality degrades so much.

Demerit in the conventional PLC using low frequency band

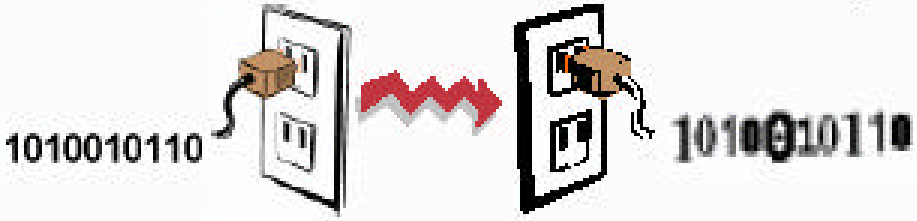
- Power lines are designed for delivering power not data
  - High noise



  - High attenuation



  - Signal distortion



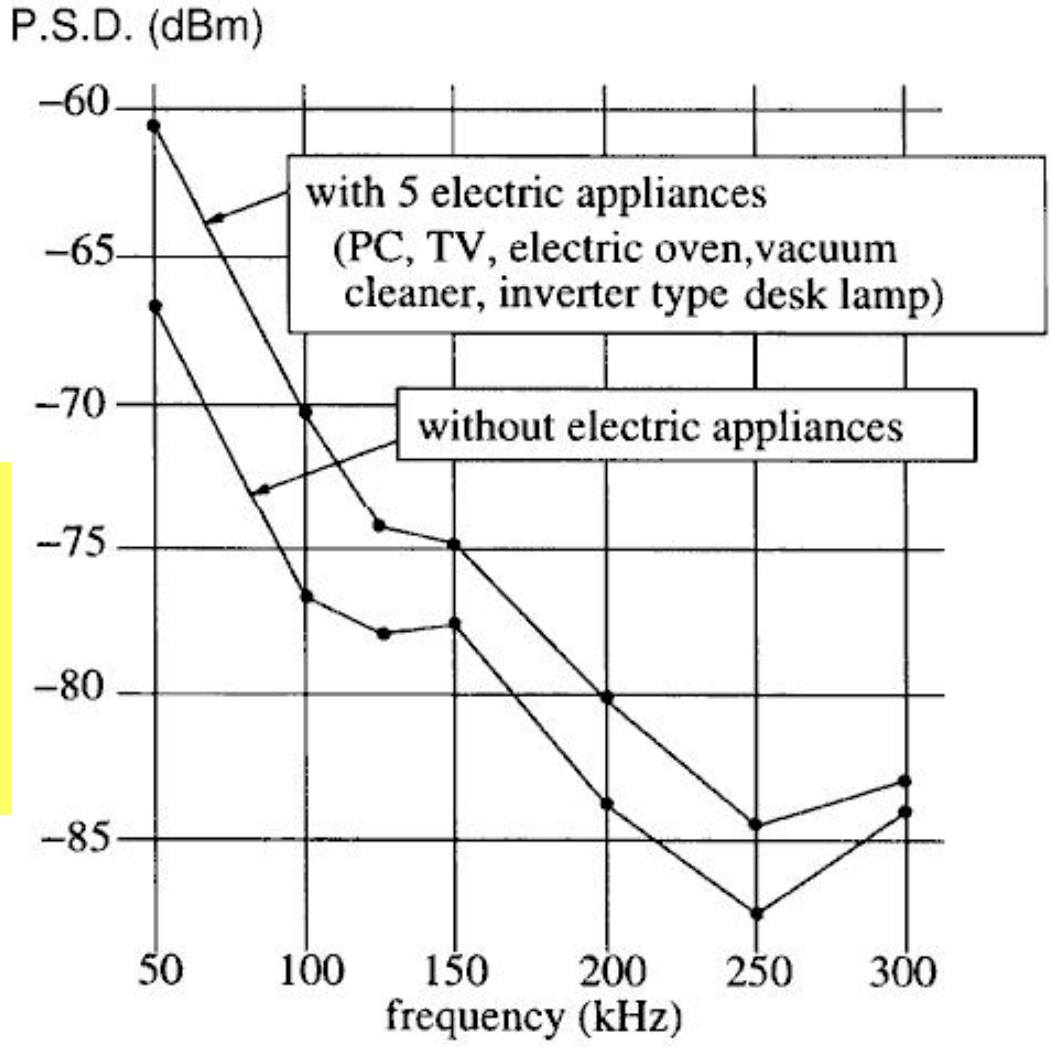
- It takes a sophisticated modem to communicate reliably

http://www.echelon.com/products/Transceivers/PLTPresentations/PLTechnology.pdf

High noise from appliances (1)

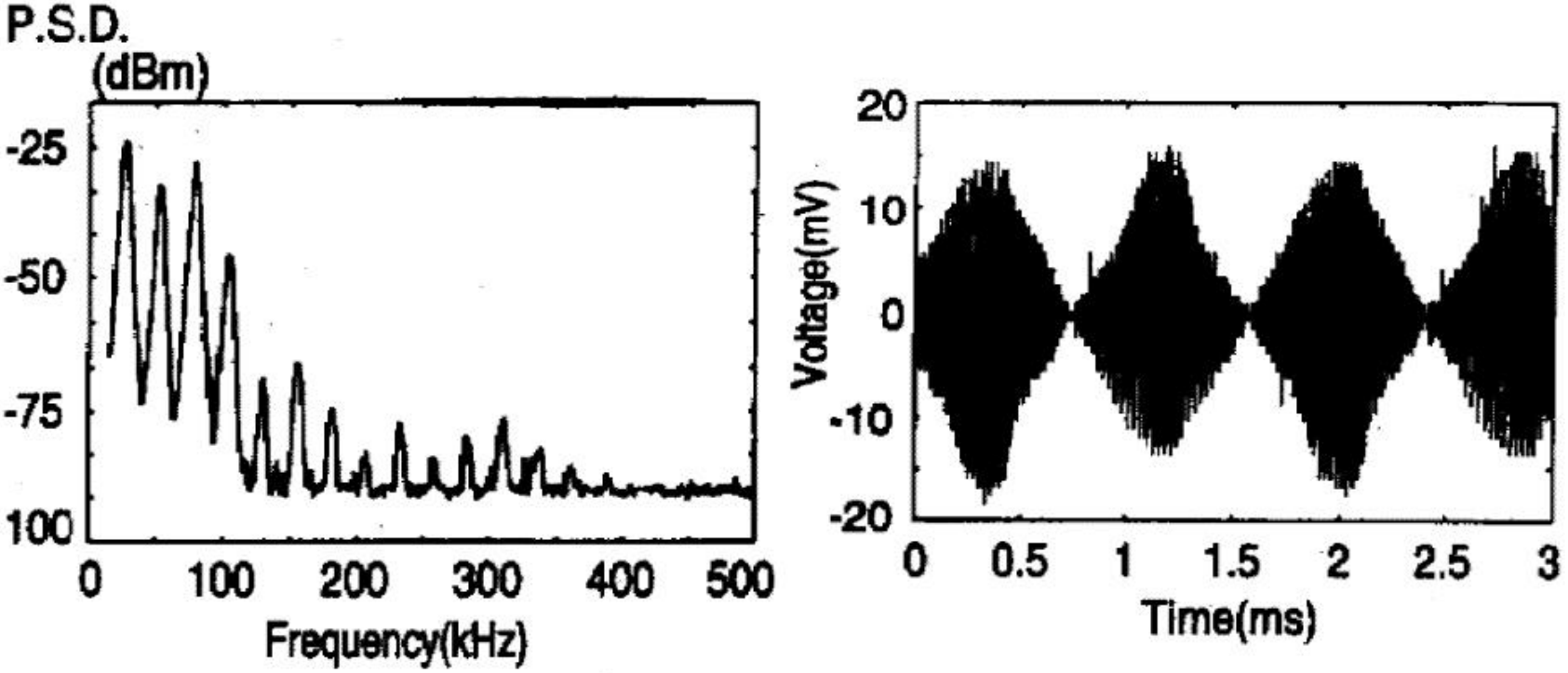
- Noise is additive.
- Dominant noise is colored, and modeled as a decreasing function of frequency

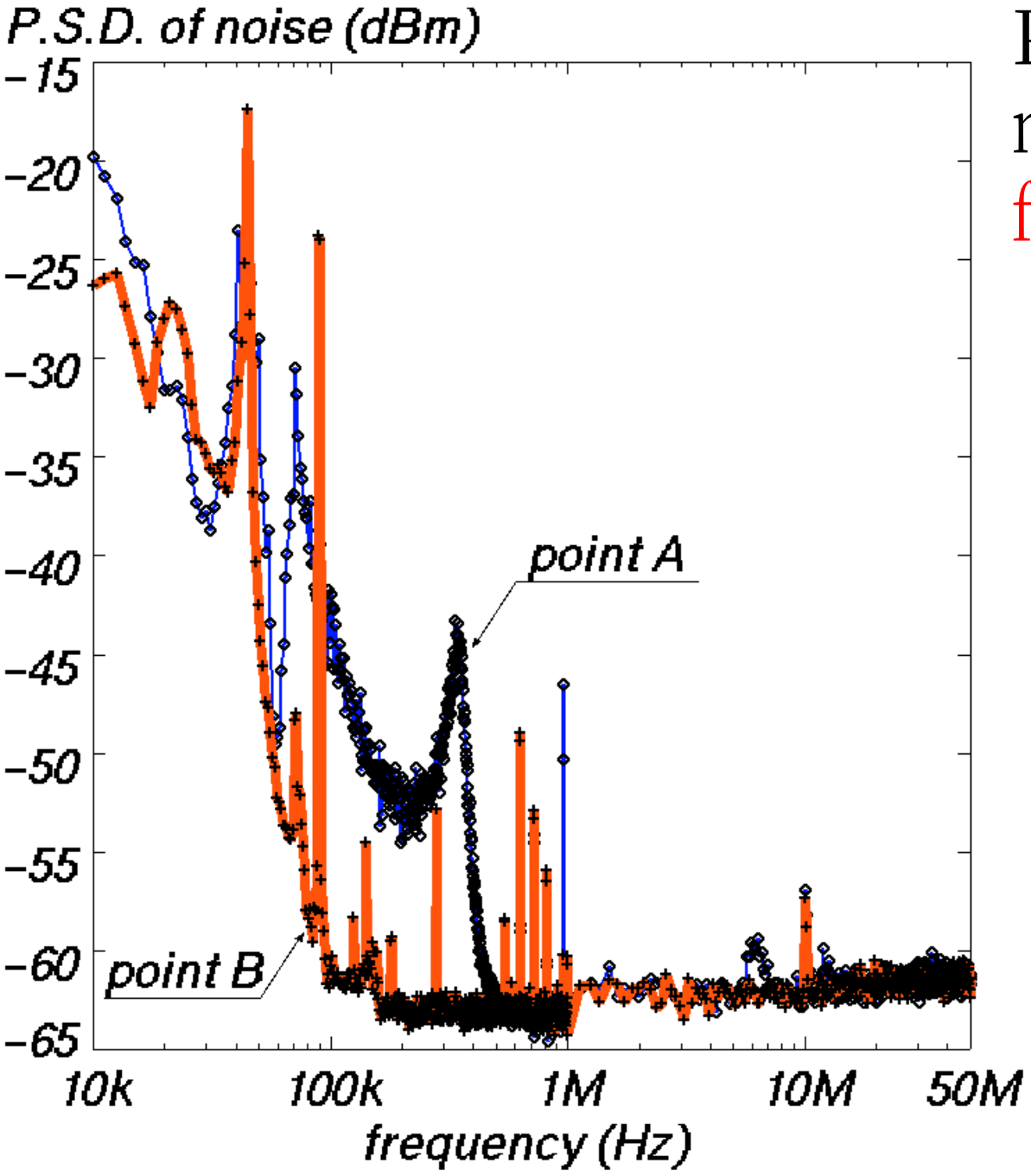
The lower frequency components of transmitting signals should be suppressed compared to the higher ones.



High noise from appliances (2)

IH cooking heater: periodic noise

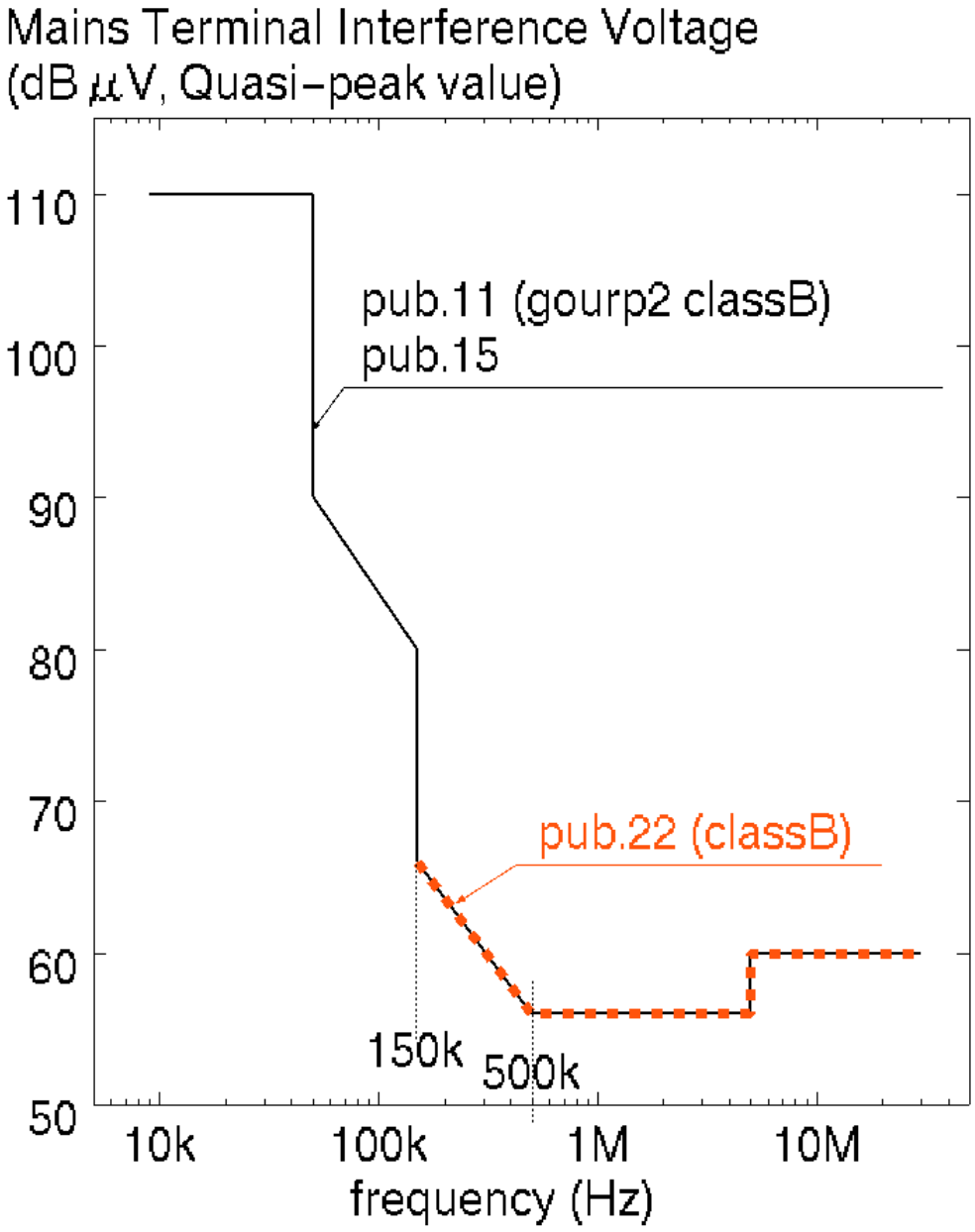




Power-line noise at high frequency band

- Low noise level

receives benefit of EMC regulation

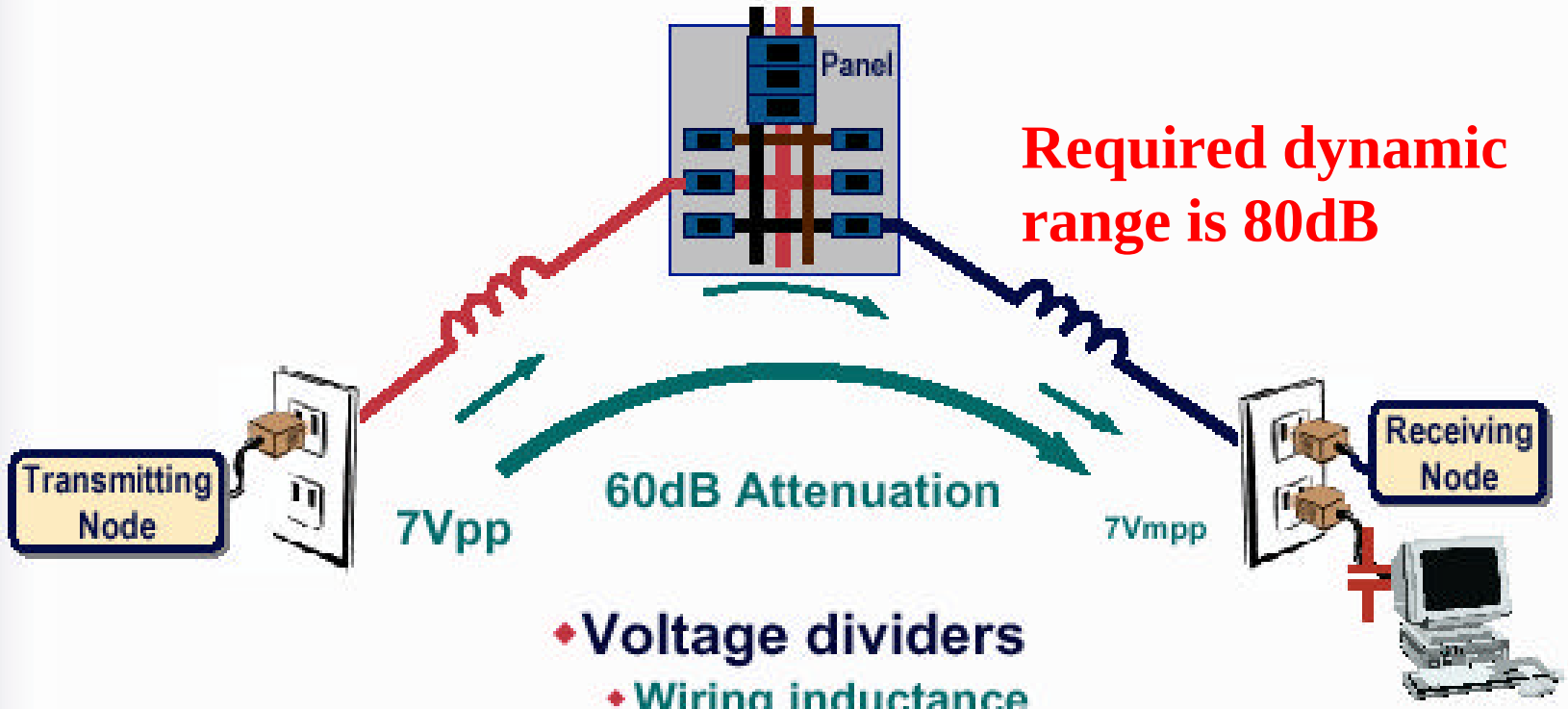


EMC regulation

Limits of CISPR (the International Special Committee on Radio Interference) Pub.11,15,22

- Pub.11 (Group2 Class B): ISM equipment, Microwaves
- Pub.15: Fluorescent Lamps, Luminary
- Pub.22: ITE (Information Technology Equipment; printer, PC, display, etc.).
  - Class B: The equipment which is used in residential area.

What Causes Attenuation ?



Required dynamic range is 80dB

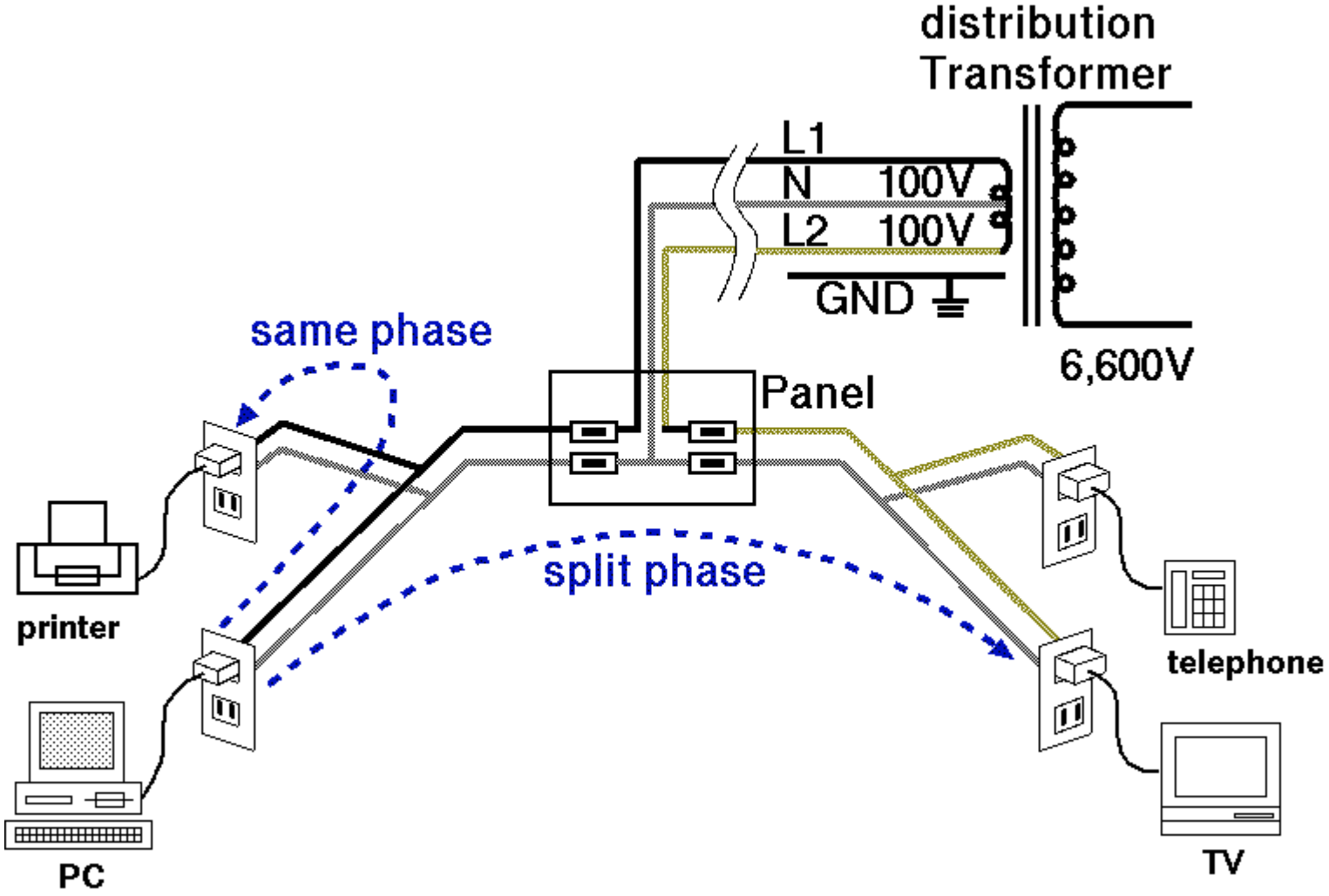
- **Voltage dividers**
  - Wiring inductance
  - Shunt loads → **Low impedance**
    - Panel loading
    - EMC capacitors
- **Phase coupling loss**

$$\text{Attenuation(dB)} = 20*\text{LOG}_{10}(V_{transmit}/V_{receive})$$

ECHELON
Bringing the Internet to Life

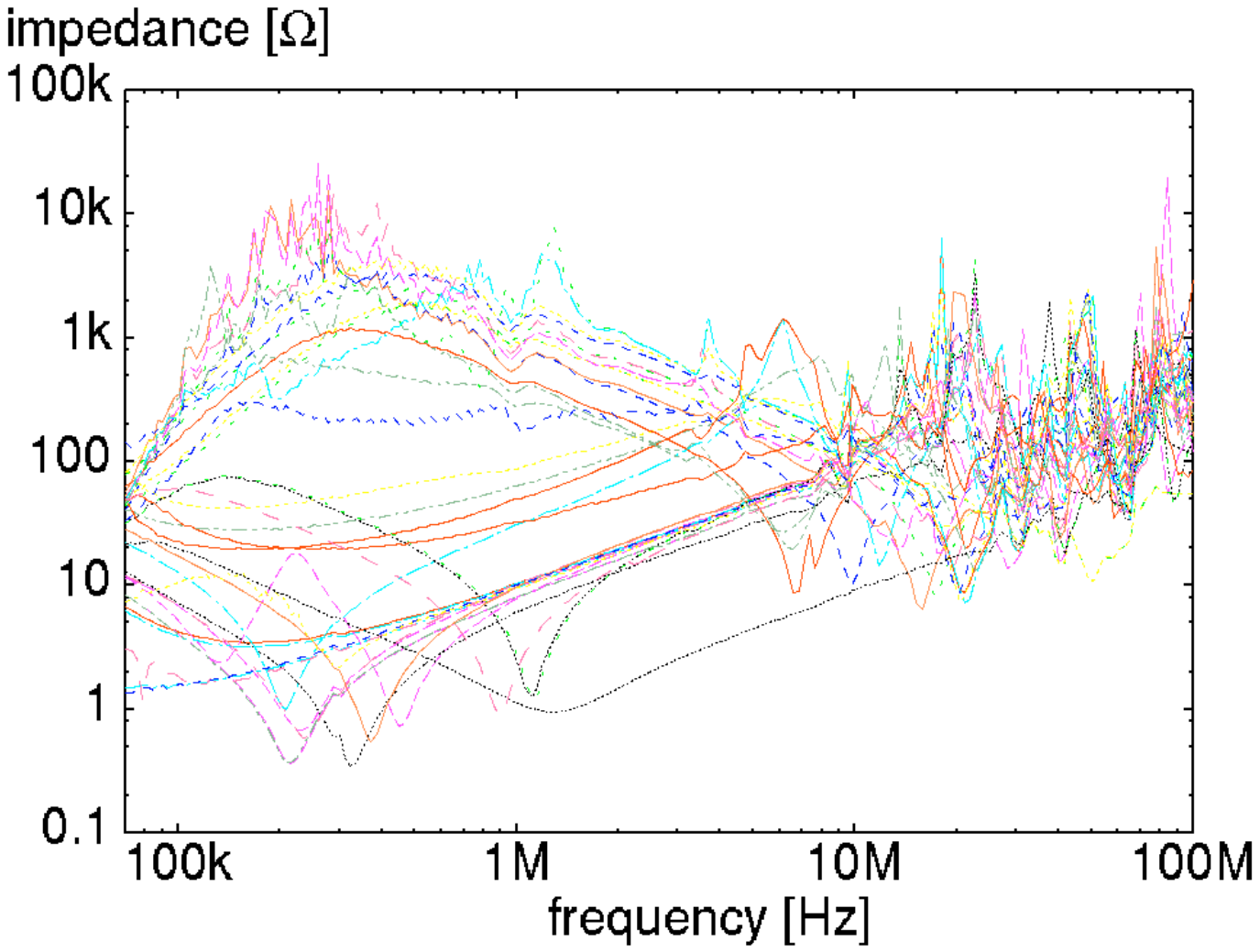
What causes attenuation? (2)

PLC channel model



What causes attenuation? (3)

Appliances' impedance (1)



In low freq.

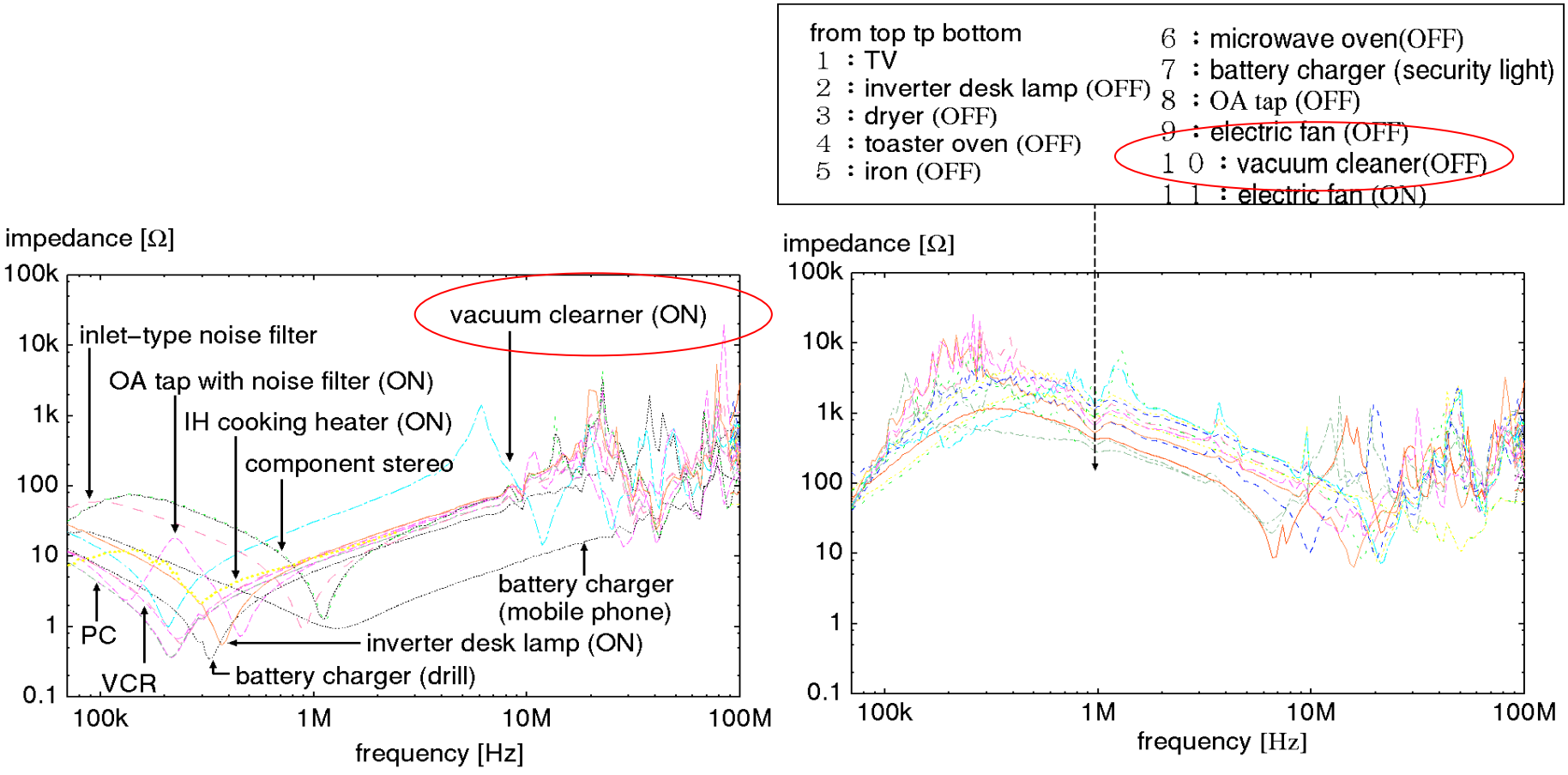
- 0.? Ω -- ?0Ω
  <-- EMC capacitors

In higher freq.

- Gradually increases <-- inductance (L)
- dispersion decreases

Appliances' impedance (2)

4 types' resonance (1)

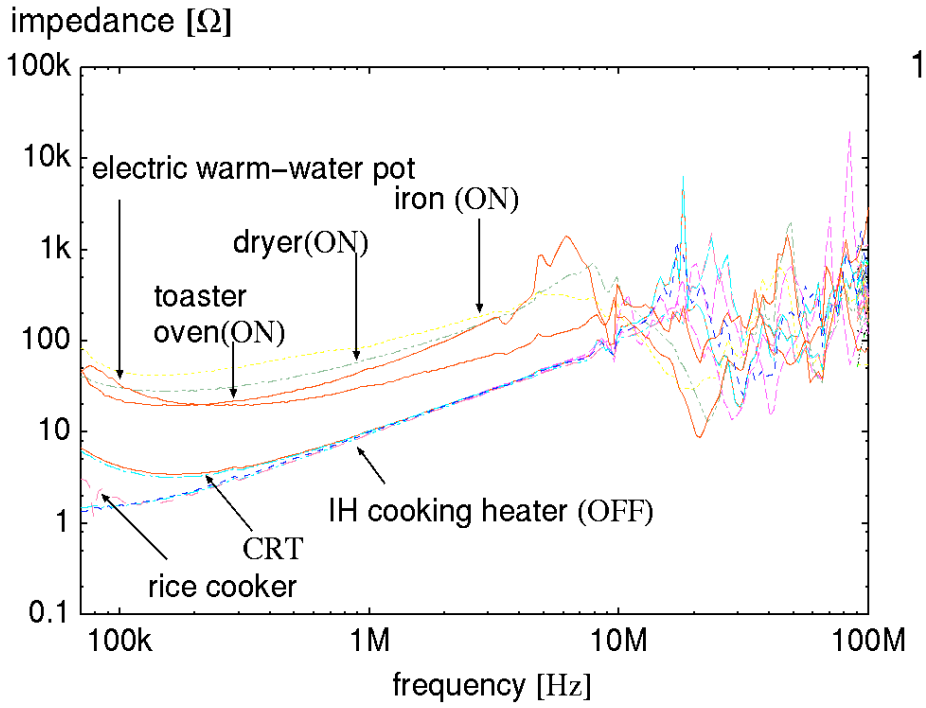


Dip type

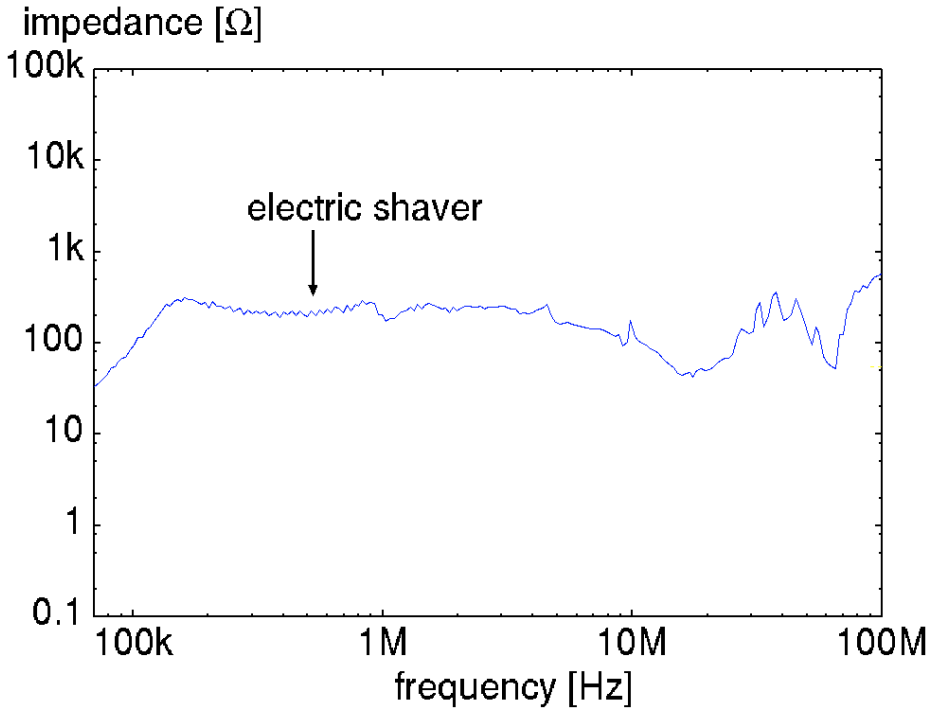
rise type

Appliances' impedance (3)

4 types' resonance (2)

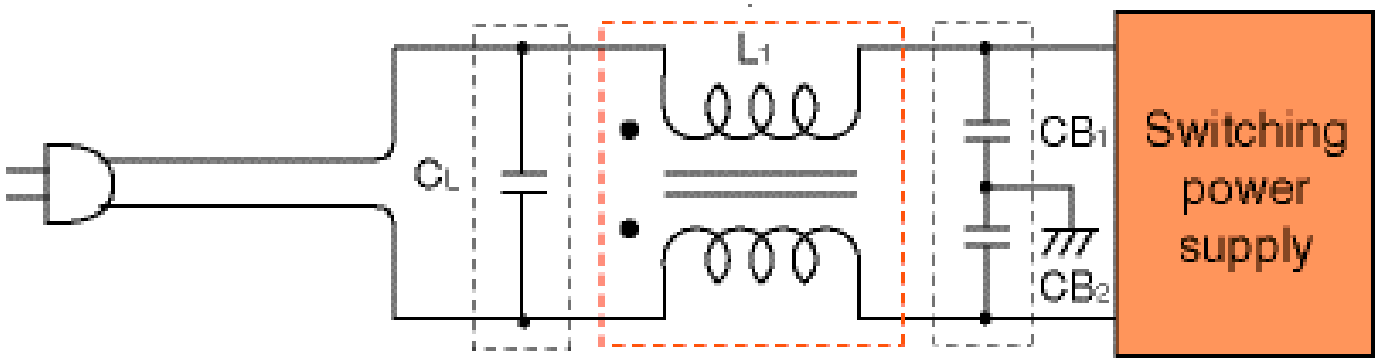


inductance type



flat type

Symbol	Name	Function
L1	Common mode choke coil	Suppresses common mode noise.
CL	Across the line capacitor (X-capacitor)	Suppresses differential mode noise.
CB1 CB2	Line bypass capacitor (Y-capacitor)	Suppresses common mode noise and differential mode noise.

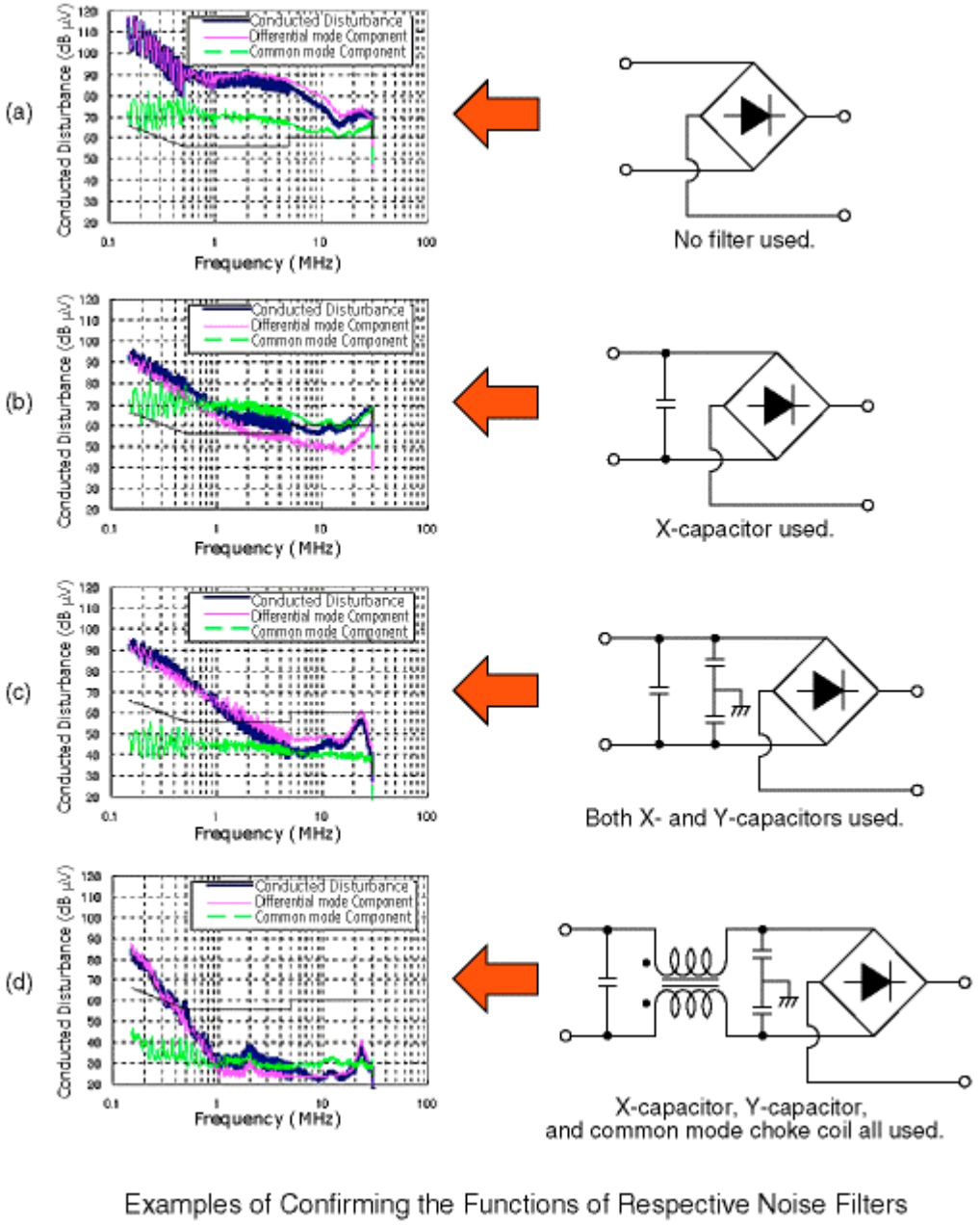


http://www.iijnet.or.jp/murata/products/english/catalog/emc/noise/k_3/acpwr_2.html

Appliances' impedance (5)

Why the resonance occurs? (2)

- Functions of Respective Noise Filters



Examples of Confirming the Functions of Respective Noise Filters

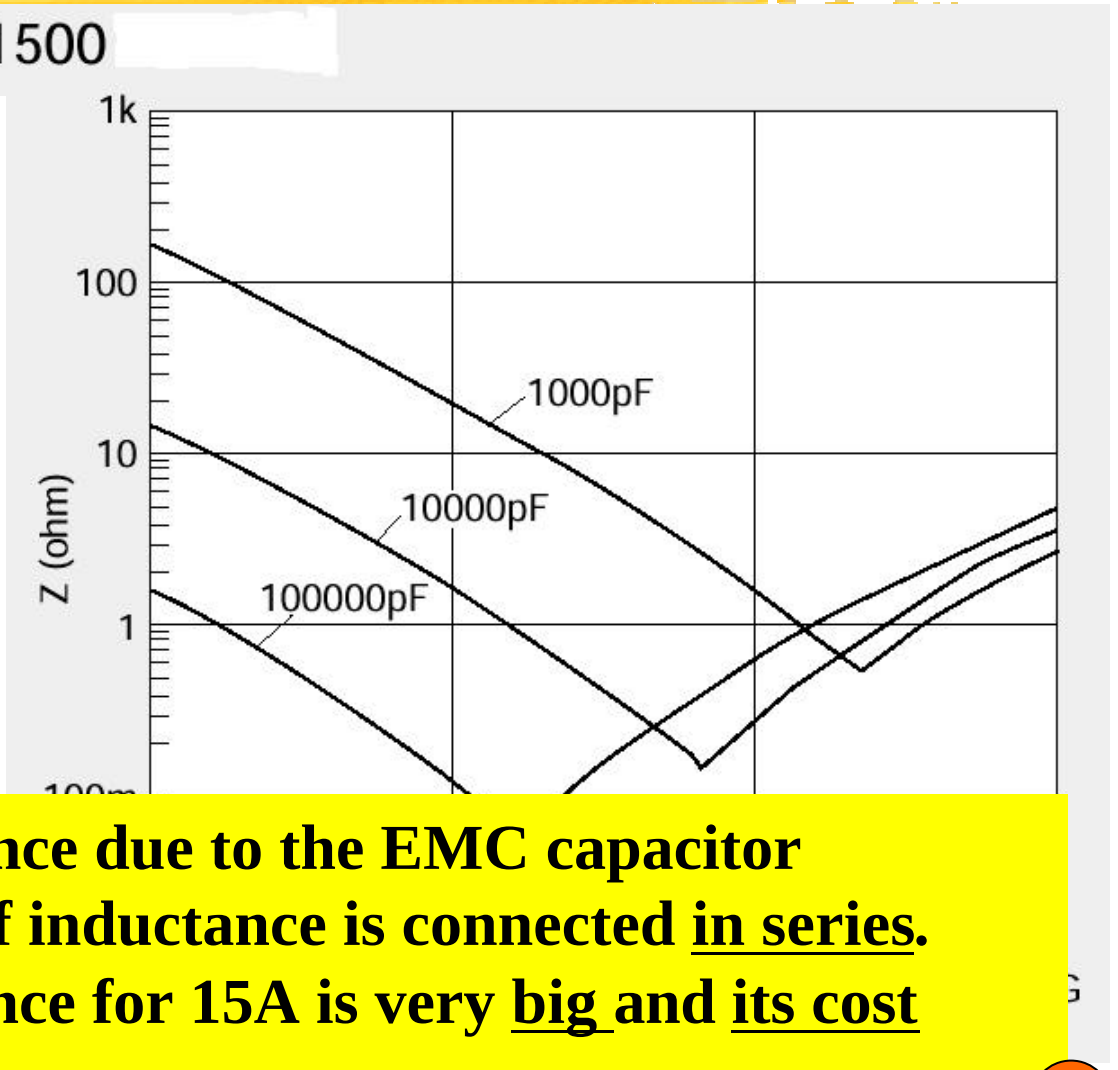
http://www.iijnet.or.jp/murata/products/english/catalog/emc/noise/k_3/acpwr_8.html

Appliances' impedance (6)

Why the resonance occurs? (3)

Example of impedance (Z) -frequency characteristic of a ceramic capacitor

- Z (min) < 1Ω
- Freq. of Z (min.) depends on used capacitors.

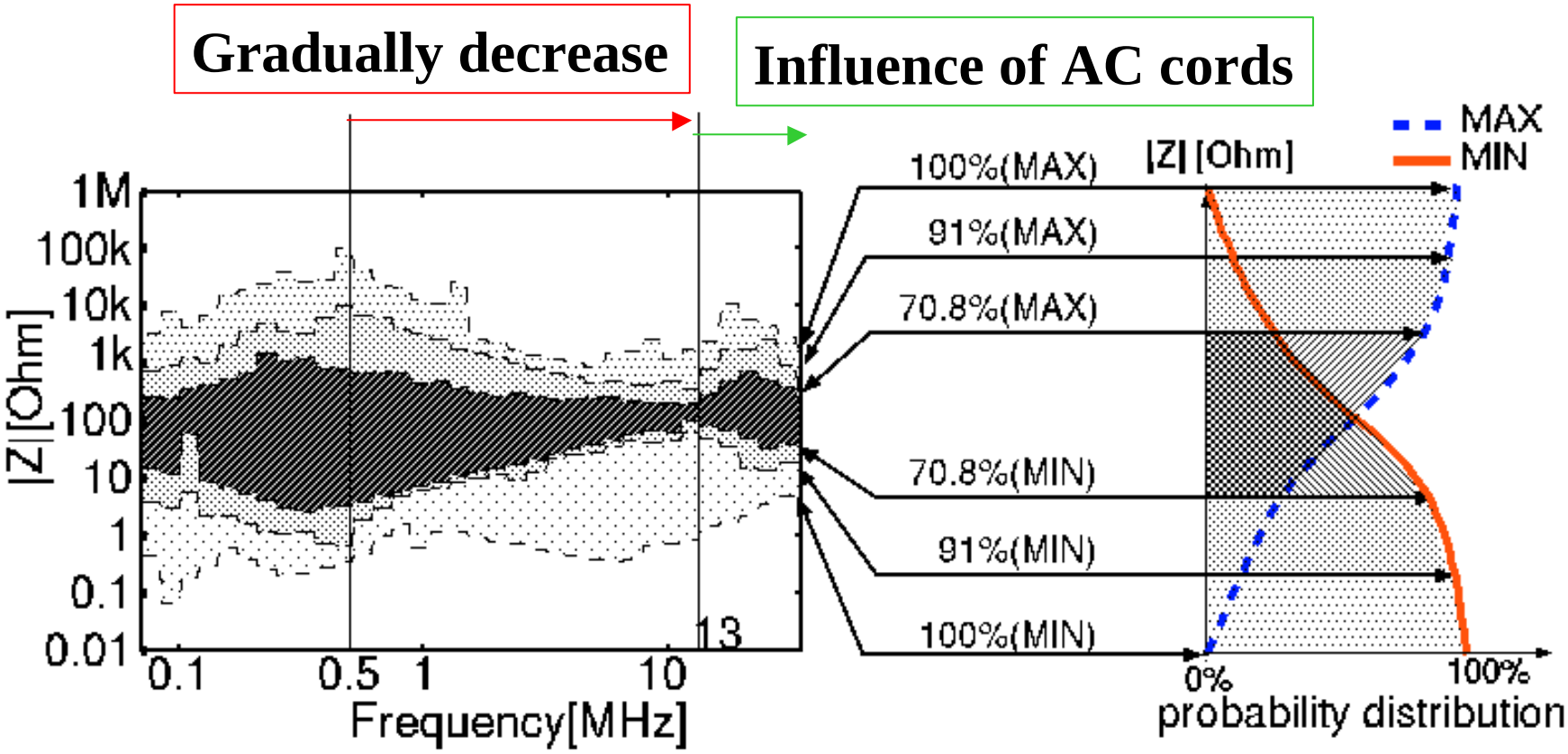


Solution of the low impedance due to the EMC capacitor

- **Impedance upper made of inductance is connected <u>in series</u>.**
  ---> The size of inductance for 15A is very <u>big</u> and <u>its cost reduction is difficult!!</u>

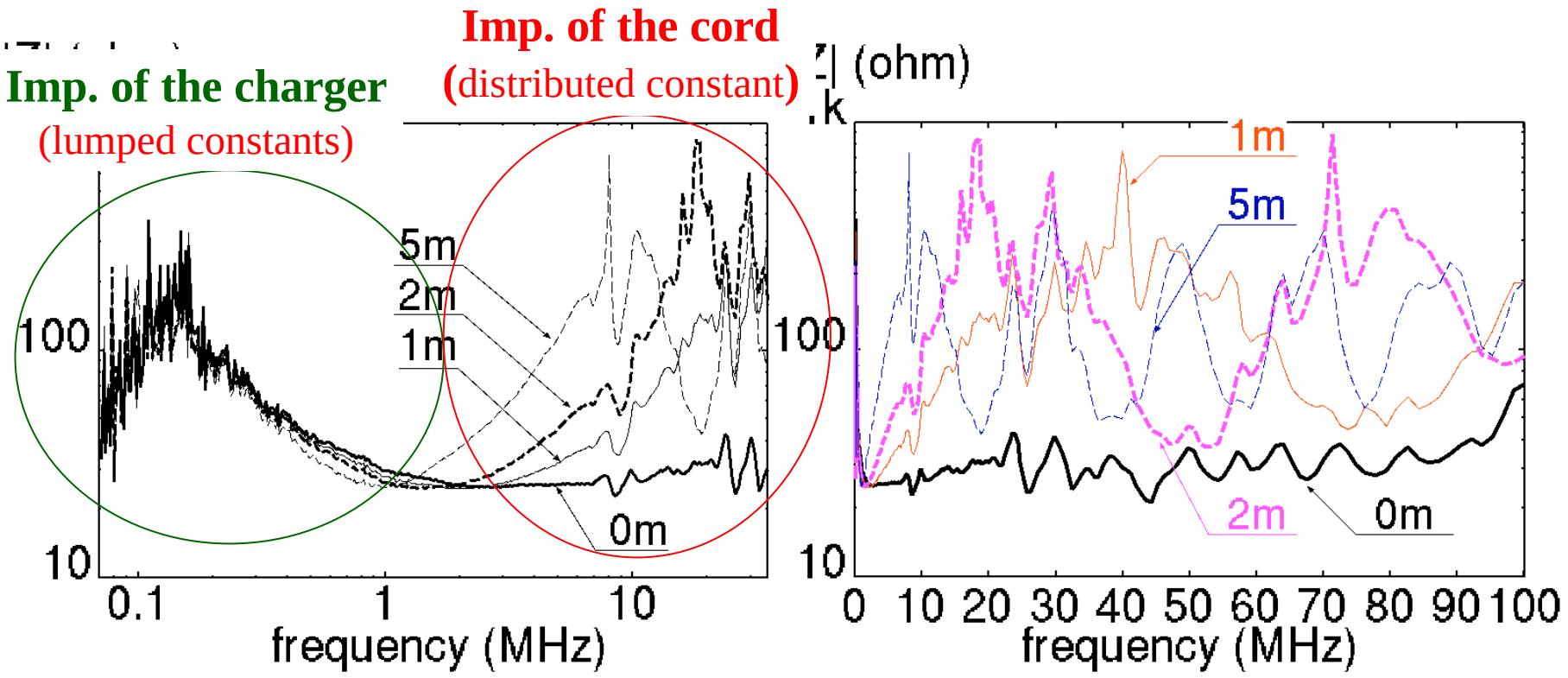
What causes attenuation? (3)

Appliances' impedance and its dispersion. (54 appliances, 89 on/off states)



What causes attenuation? (4)

Influence of the length of AC-power-supply cord on the appliance's impedance



(a) frequency axis in log scale **(b) frequency axis in liner scale**

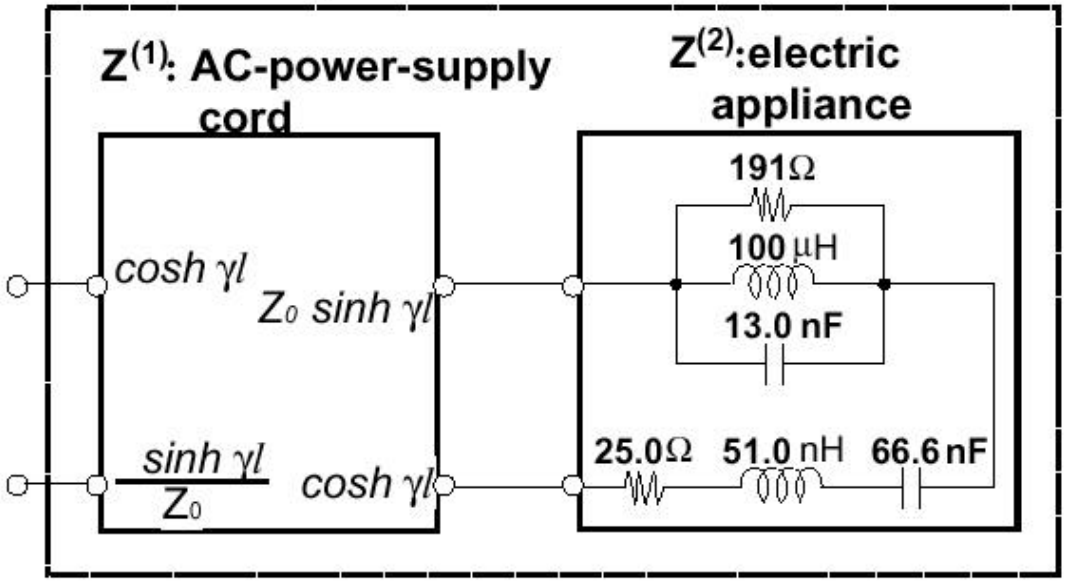
Impedance of a battery charger with a cord of length 0m,1m,2m,5m.

Influence of the length of AC-power-supply cord on the appliance's impedance (2)

Equivalent circuit of the battery charger

Z^(t) : is given as a cascade connection of Z^(1) and Z^(2).

$Z^{(t)}$: total impedance



$$Z^{(t)} = \frac{Z^{(2)} Z_0 \coth(\gamma l) + Z_0^2}{Z^{(2)} + Z_0 \coth(\gamma l)}$$

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} : \text{characteristic impedance}$$

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)} : \text{propagation constant}$$

l : AC-power-supply cord length
R : registance per unit length
L : indactance per unit length
G : condactance per unit length
C : capacitance per unit length

Z^(1) : four terminal network, composed of a distributed constant circuit

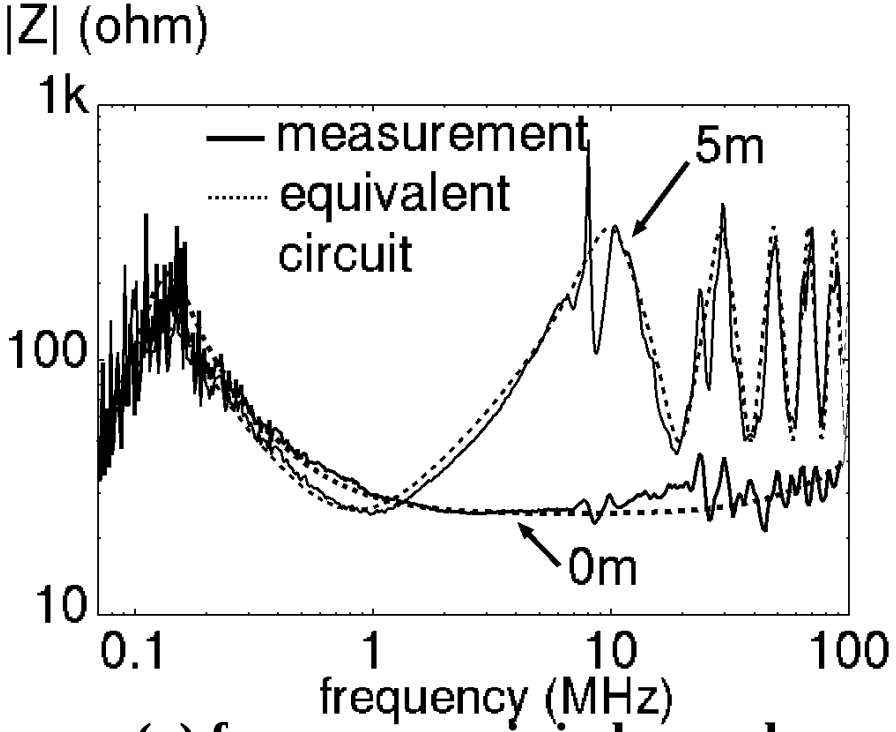
Z^(2) : two terminal network, composed of lumped constants

These values are similar to the distributed constants of a VVF cable

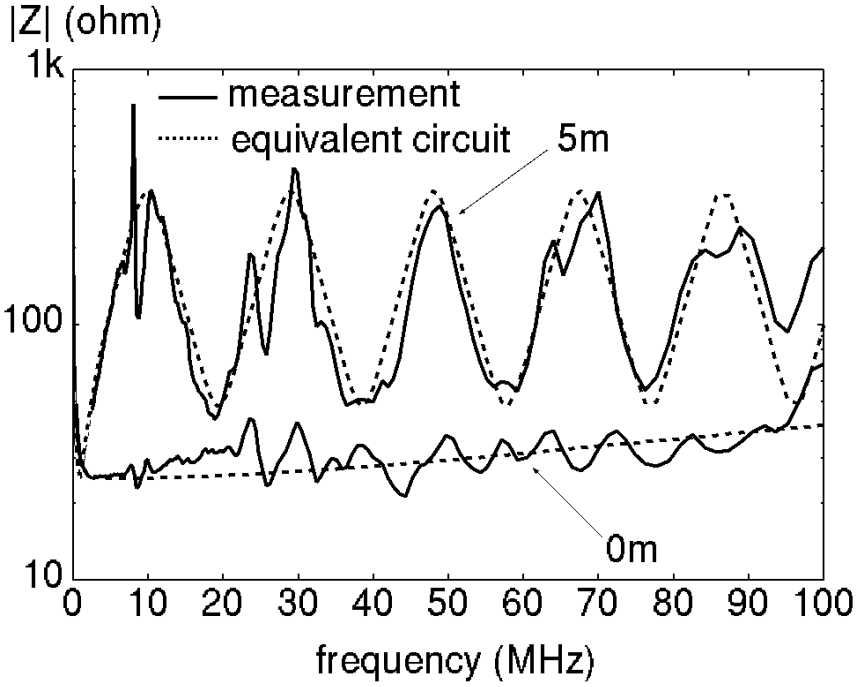
Influence of the length of AC-power-supply cord on the appliance's impedance (3)

Equivalent circuit of the battery charger (2)

- The distributed constants of Z^(1)
  - R=0.400[Ω /m], L=650[nH/m], G=0.600[m MHO /m], C=40.3[pF/m]



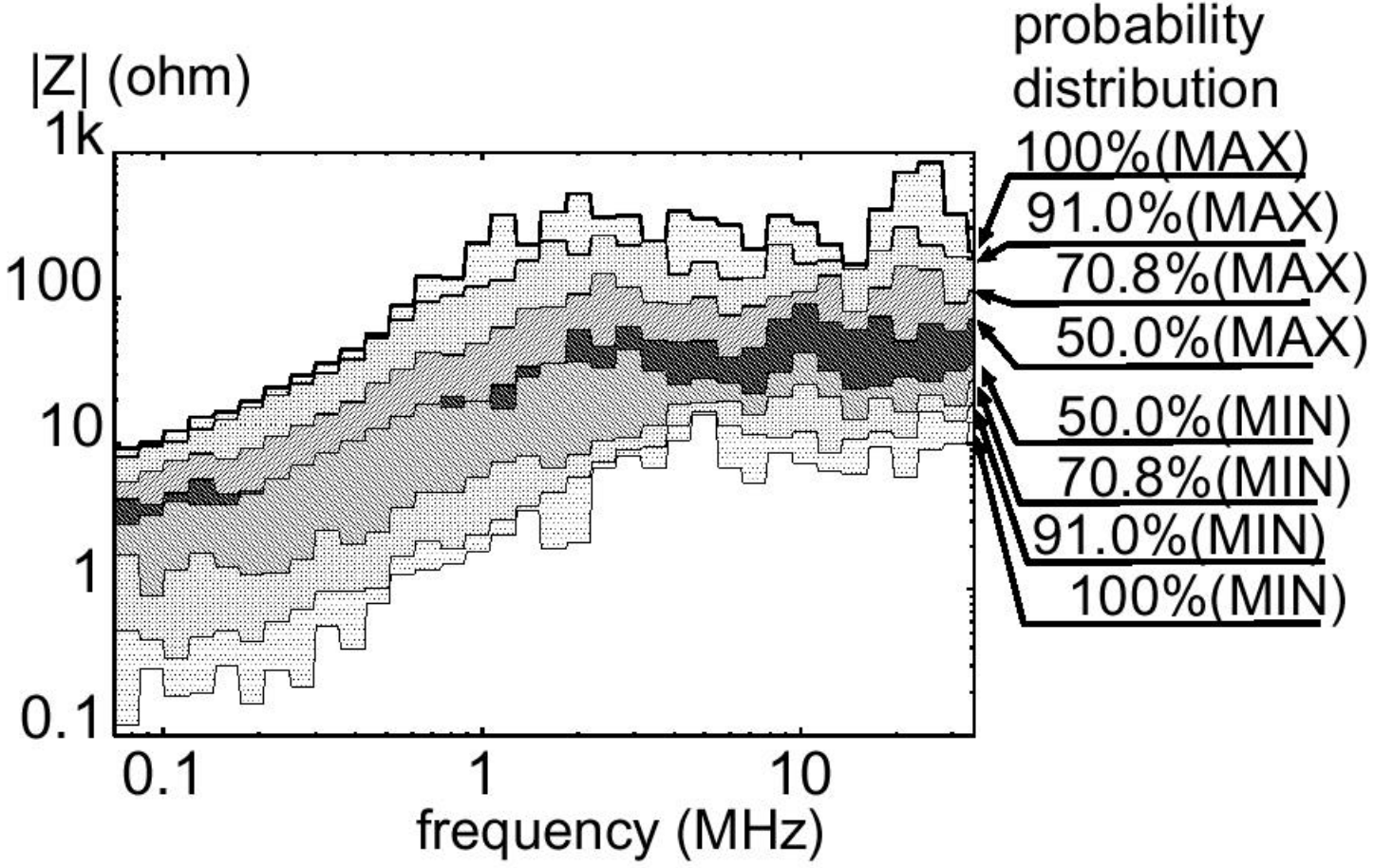
(a) frequency axis in log scale



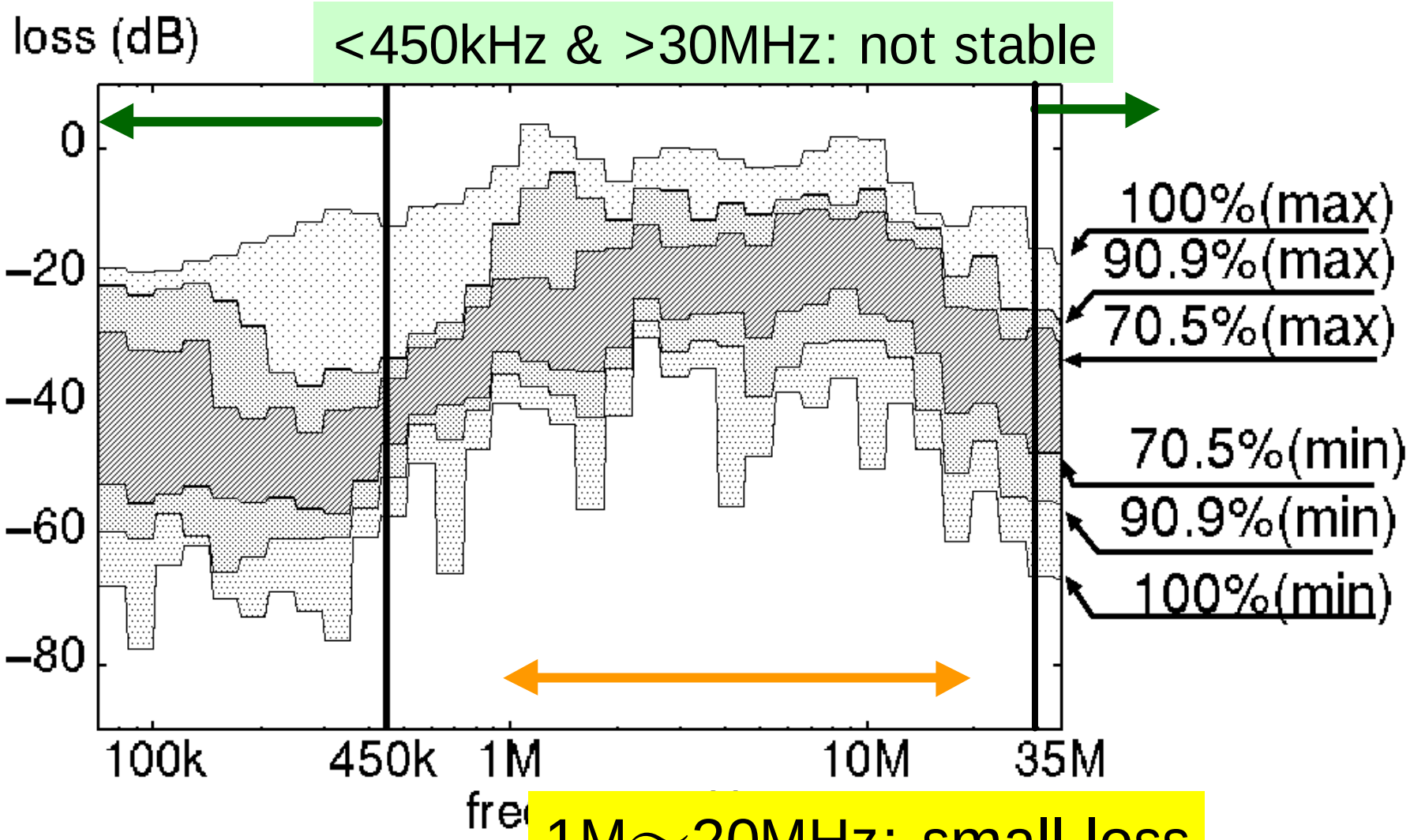
(b) frequency axis in liner scale

What causes attenuation? (4)

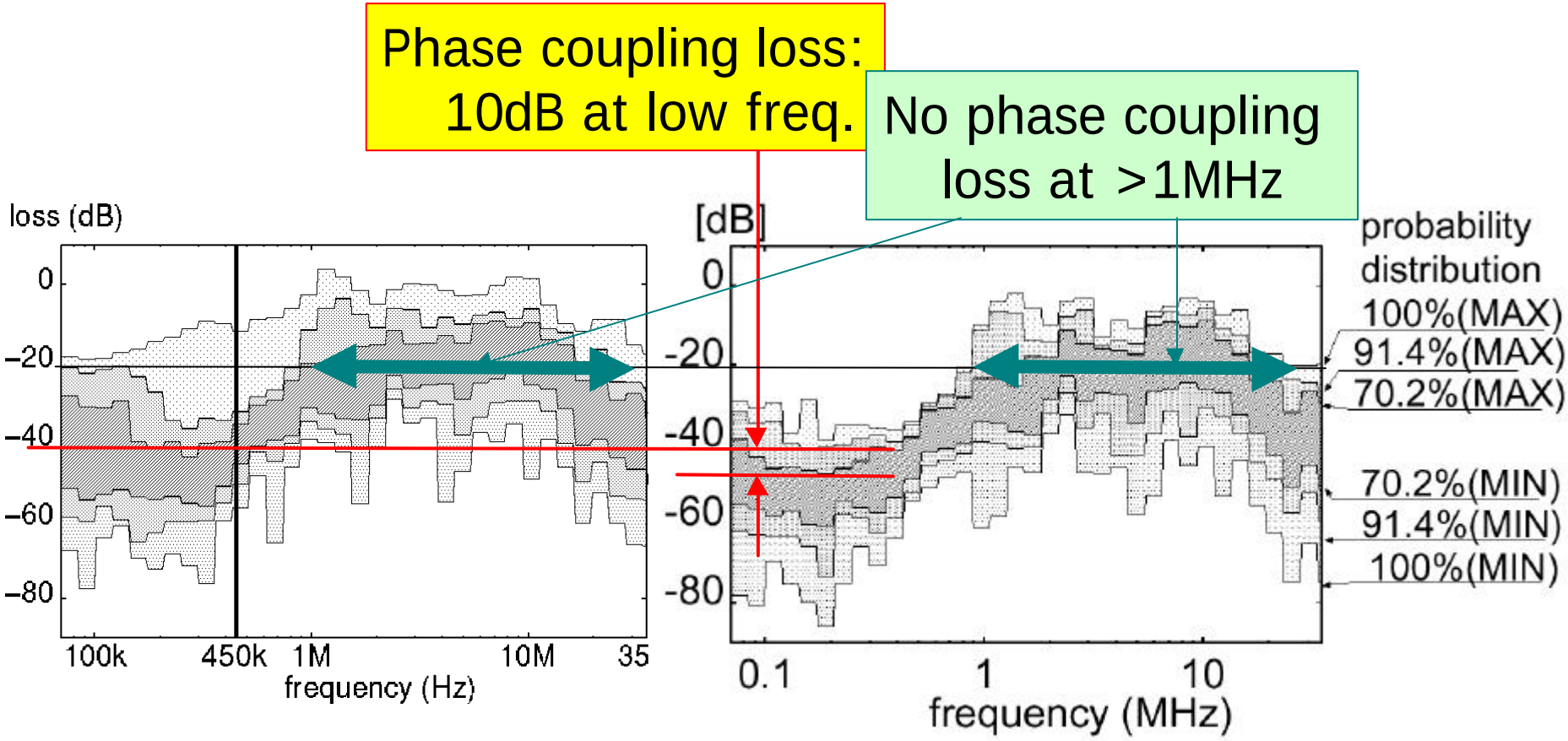
Power-lines' impedance and its dispersion. (24 outlets of Lab.)



Transfer function (loss property) between the same-phase outlets (in Lab., 44 cases)



Transfer function comparison between the same-phase and the split-phase



same-phase outlets

split-phase outlets (in the same Lab., 47 cases)

What causes attenuation? (2)

Phase Coupling loss

Same Phase Communication

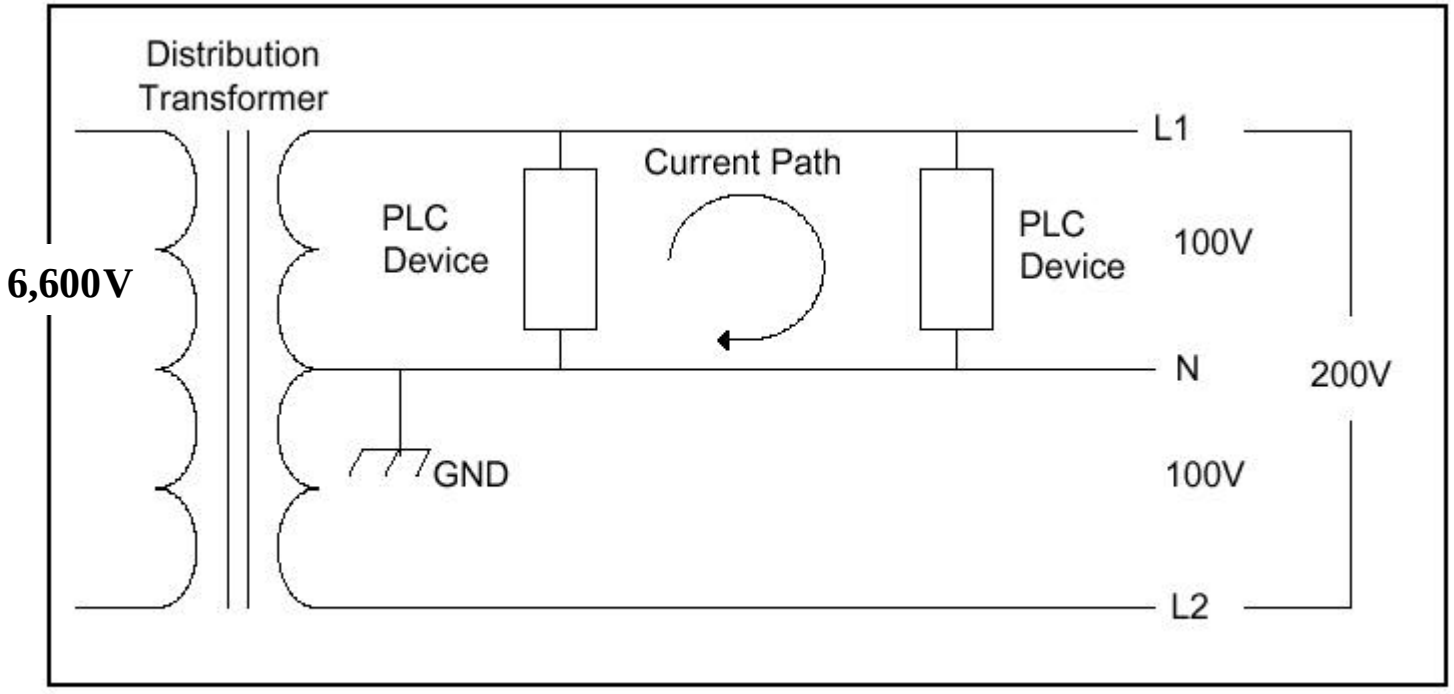


Figure 1 - Same Phase Communication

http://www.intellon.com/docs/appnotes/26001087.pdf

Phase Coupling loss (2)

“Split” Phase Communication

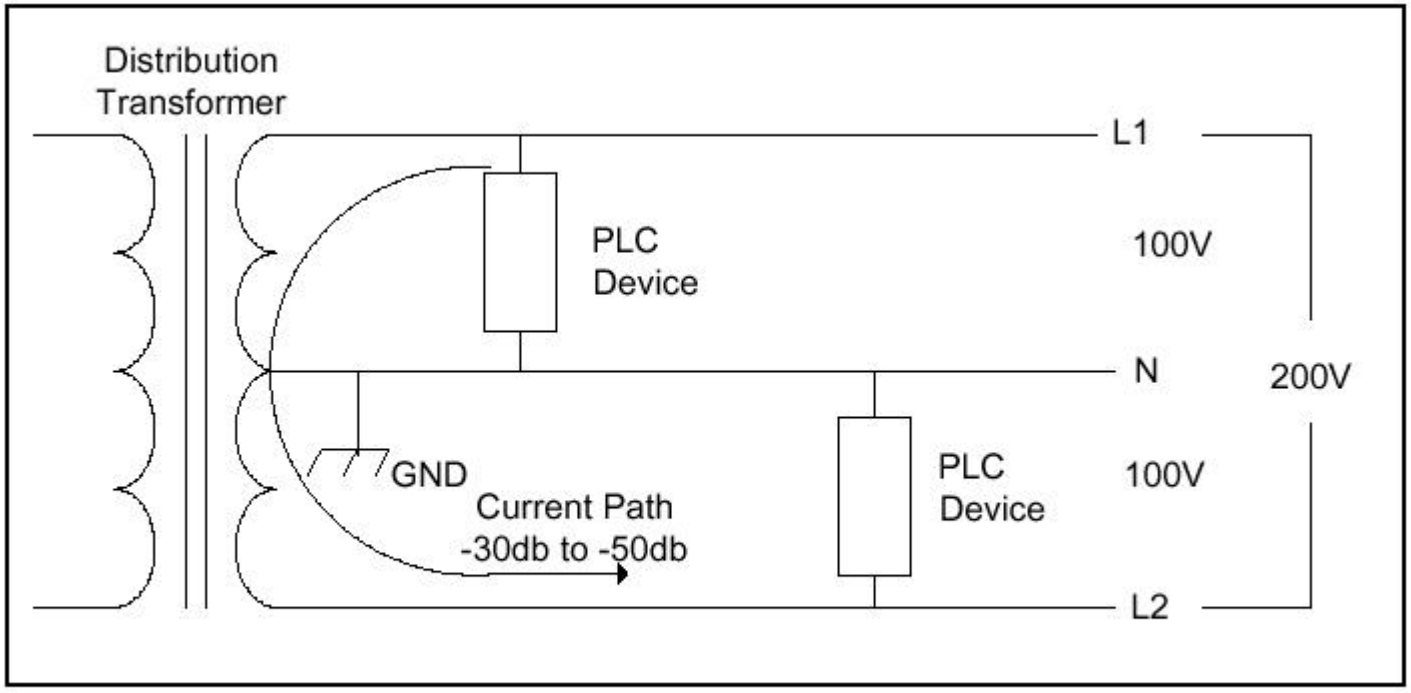


Figure 2 - “Split” Phase Communication Without Coupling

Phase Coupling loss (3)

Phase to Phase Communication Through a Coupling Device

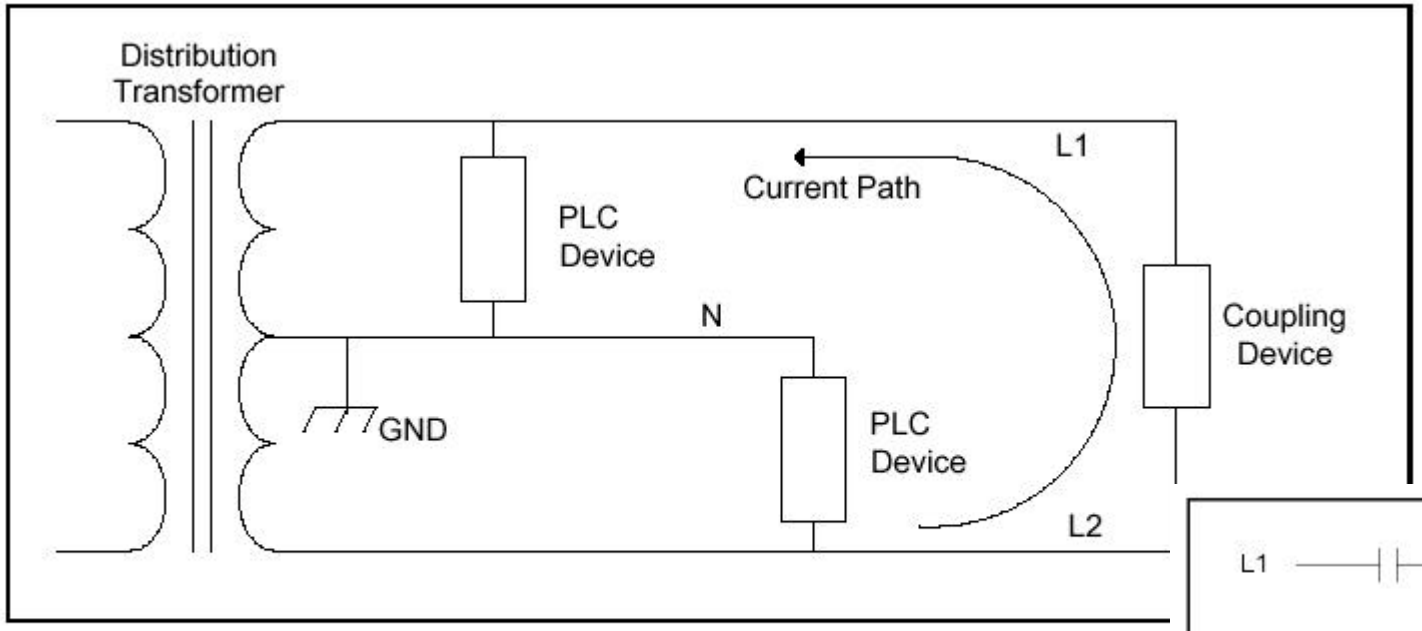


Figure 3 - Phase to Phase Communication Through a Simple Coup

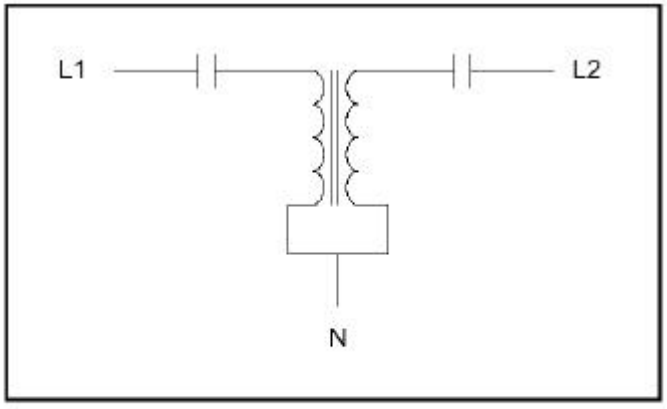


Figure 5 - Advanced Phase Coupler Example Schematic

Demerit in the conventional PLC using low frequency band

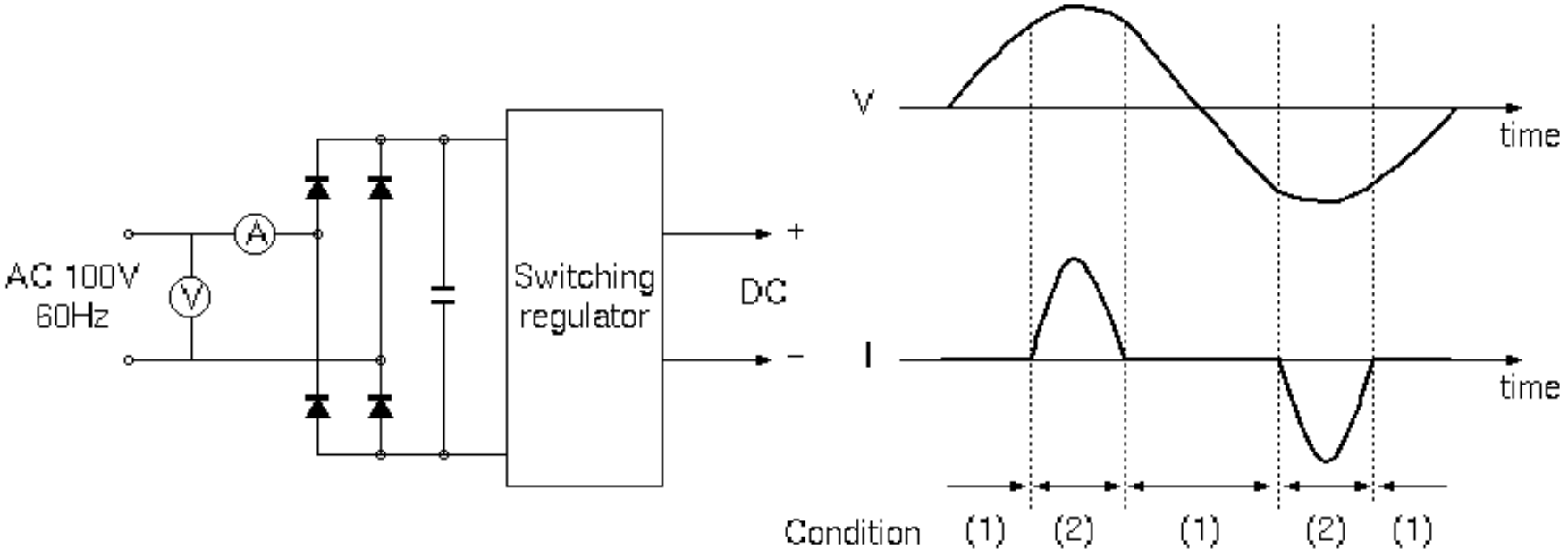
Signal distortion (1)

- If the impedance-frequency characteristic is static, the equalization is possible.
- If not (i.e., the characteristic changes dynamically), it is not easy!

Signal distortion (2)

Switching model of power-line channel (1)

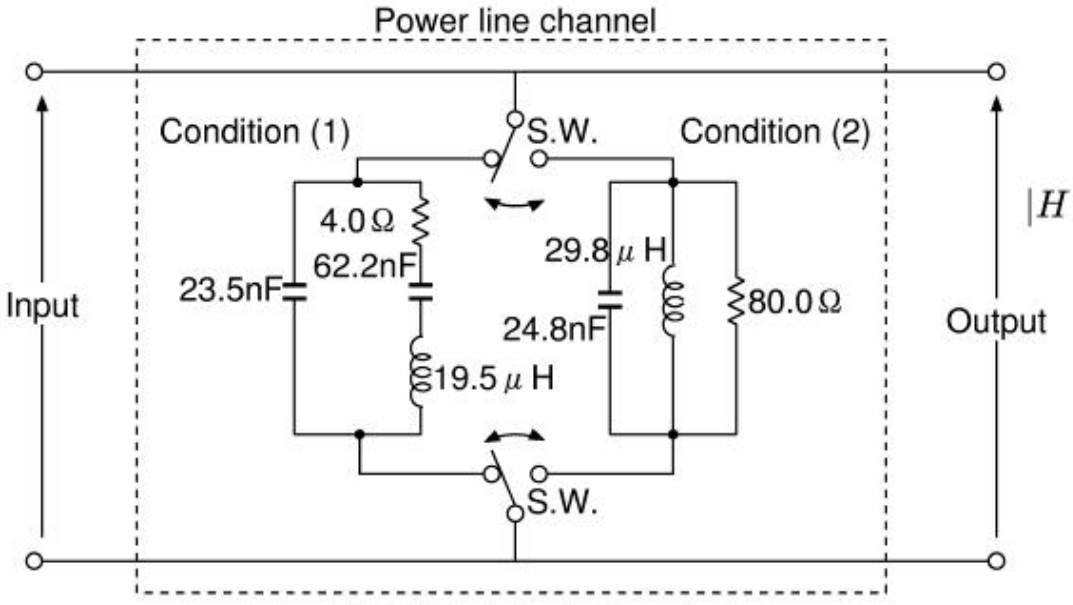
- Input AC voltage and current of a switchmode power supply



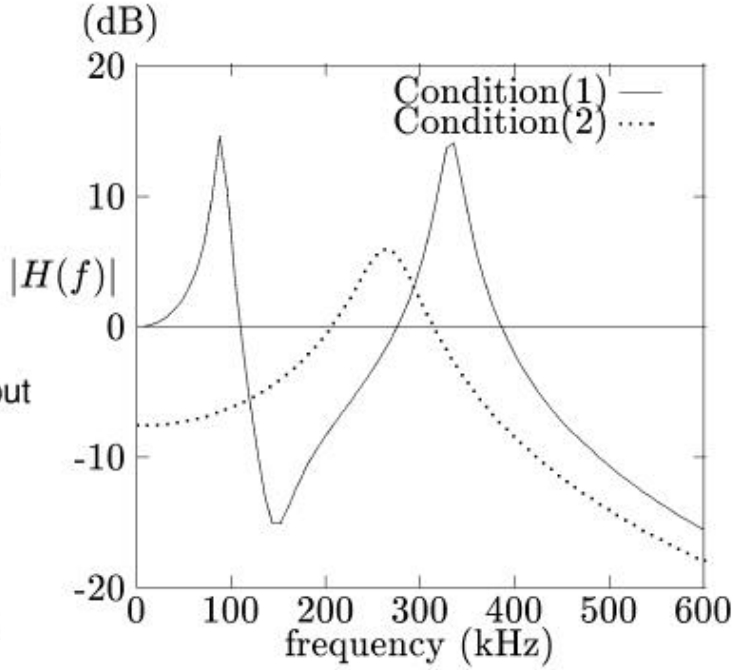
Switching model of power-line channel (2)

Transfer function model of a power-line to which a TV is connected

- Switching rate: 240 times/sec



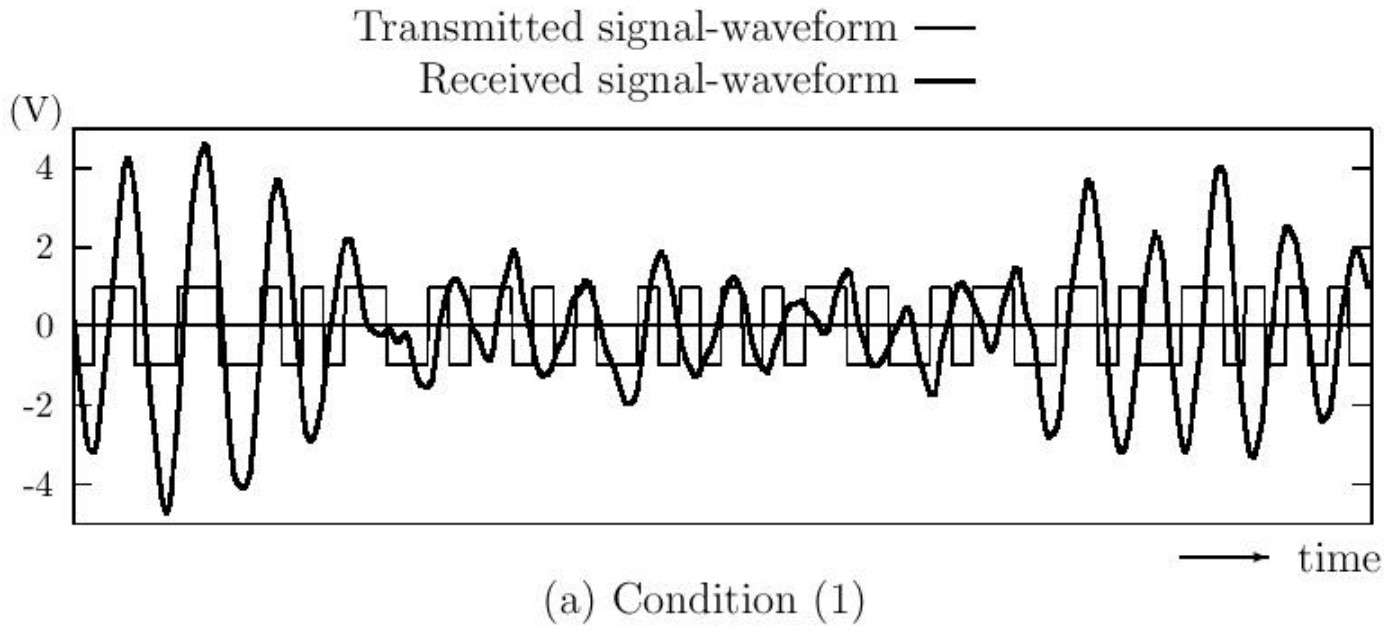
(a) Modeled circuit



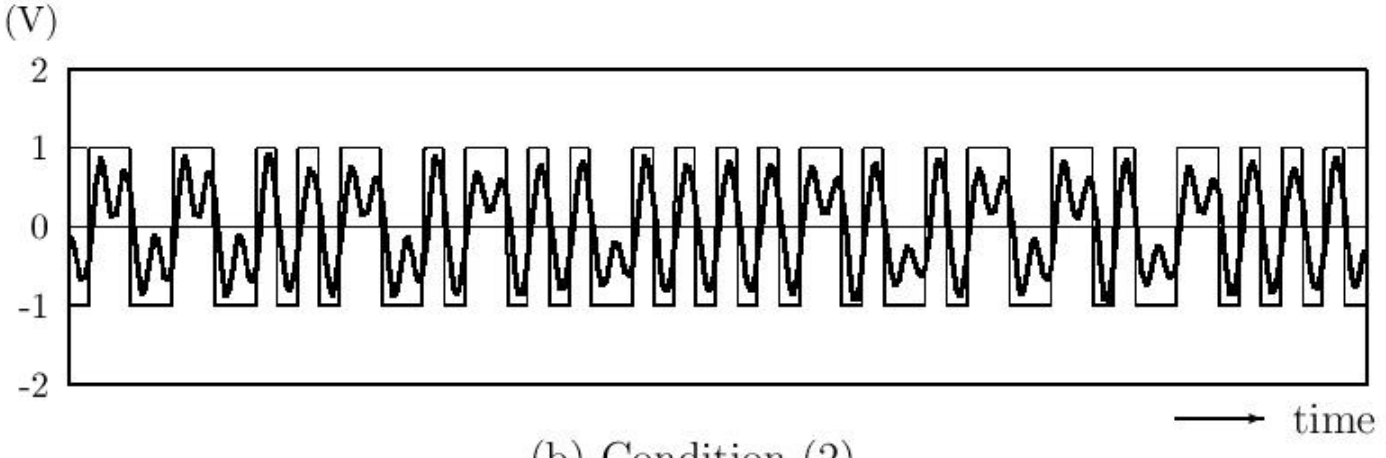
(b) Frequency response

Switching model of power-line channel (3)

Waveform distortion



(a) Condition (1)



(b) Condition (2)

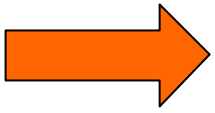
Summary

- Why the high frequency band is suitable for high speed PLC?

Frequency band	**Low (<450kHz)**	**High (>1MHz)**	**note**
Noise	High	Low	EMC regulation
Attenuation	High (a)	Low	(a) low impedance of appliances
	Phase coupling loss		
Signal distortion	Large	Smaller	(1) resonance of EMC capacitors (2) multipath
	Static (1), switching	Static (2)	

High-speed/reliable products (1)

- Modulation technique
  - multi-carrier, e.g., OFDM, or
  - spread-spectrum (SS).
- Protocol
  - Handshake base protocols for the robustness, and
  - QoS(Quality of Service) support
    - token passing
    - CSMA/CA



Nikkan-kougyou shinbun, 2001.1.18 (Japanese)

implemting it on the chip

High-speed/reliable products (2)

		BPS	NOTE
HomePlug	USA	10M	Based on Intellon's technology
Itran	Israel	1.5M--10M	partnership with Microsoft (SCP)
Adaptive Networks	USA	10M	Multi home token passing
Cogency	Canada	10M	Member of HomePlug
Inari (Intelogis)	USA	2M, 12M	business relationship with Thomson
Nsine	England	3M	Very low-cost ($3)
Mitsubishi	Japan	3M	10k-450kHz
Siemens	Germany	1M	Internet Access

Proto-type is available.

High-speed/reliable products (3)

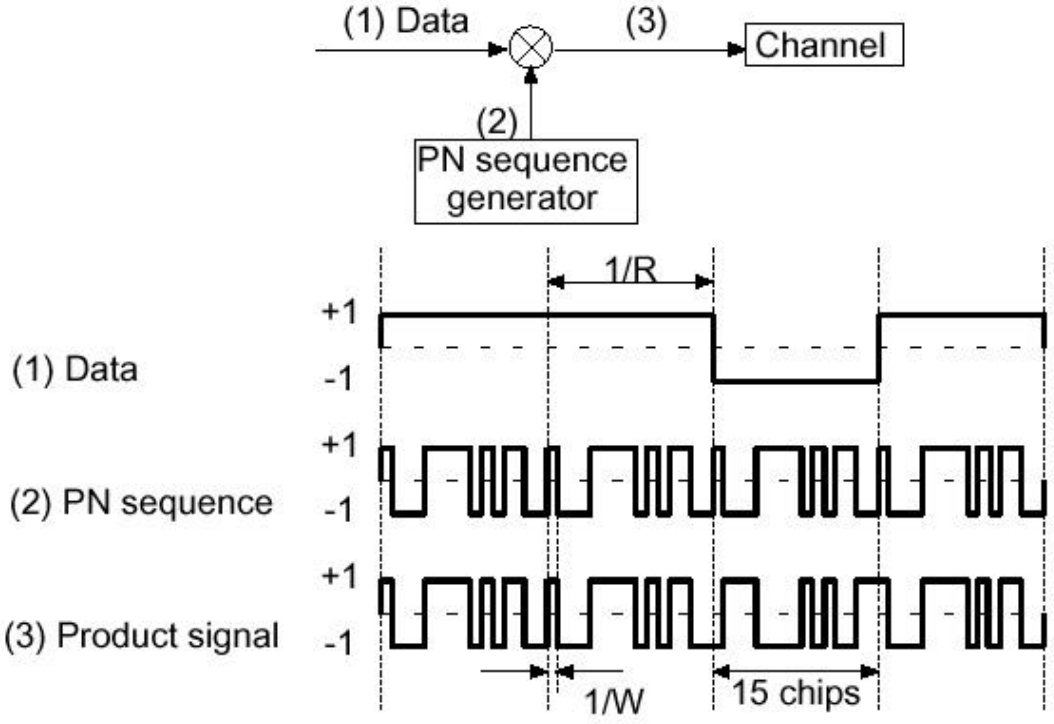
Protocol

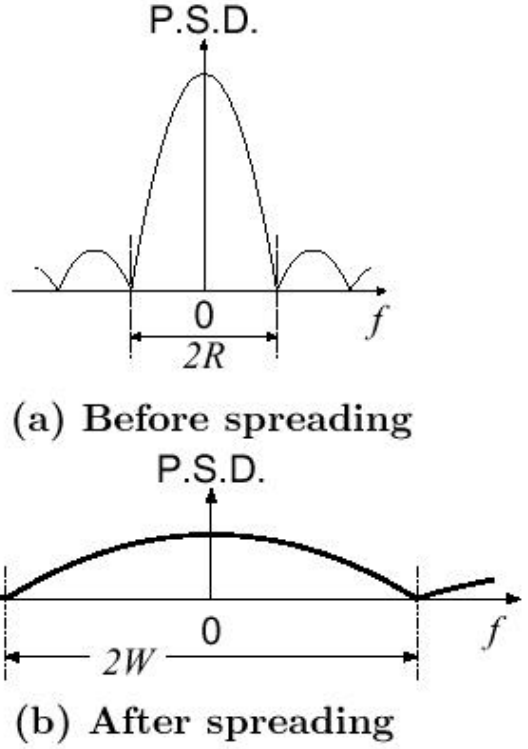
http://miyabi.ee.ehime-u.ac.jp/~tsuzuki/PLC/hiSpeed.html

developer (vender)	access method	modulation	trans. rate (bps)	carrier (trans. bandwidth)	trans. power, error correction, etc.
Adaptive Networks, Inc. (Busicom)	Token passing	DS/SS	∼100k	(140k – 450kHz)	∼100mW, AGC, BER<1e−9, FEC, ARQ, Raw rate: 268.8k bps
Intelogis, Inc	DSMA†, CTP‡		350k	5.5M Hz?	50mW(?), †: Datagram Sensing Multiple Access, ‡: Centralized Token Passing; Network Starter kit: USD59.99
ITRAN	CSMA/CD	DS/SS	2.5M (∼12M)		ITRAN and Microsoft have joined forces to co-develop a uniform PLC based platform for home networking and home automation
Intellon	CSMA/CA	OFDM	14M	(3.5∼16.5 MHz)	FEC; 84 carriers, 156 kHz spacing, Automatic channel adaptation; Carrier modulation methods supported: DQPSK, DBPSK, ROBO

developer (vender)	modulation	trans. rate (bps)	carrier (trans. bandwidth)	note
PowerTec	OFDM	100k	9∼140kHz (4.8∼38kHz)	
Nortel and Nor.web		1M	(2MHz between 2.2MHz and 10MHz)	Digital PowerLine was installed at the school in November 1997.
DS2	xDSL	1M?		
SIEMENS	OFDM	1.2M		
Ascom, Switzerland		1.3M (∼ 3M)		
PolyTrax (Power Net Com, Japan)	DMT with OFDM/QAM(?)	2M	(≤450kHz)	
Keyin Telecom		2∼ (10M)		Power-line Local LoopDistance : up to 6,000feet (1800m)
Enikia, Inc.		10M		Works with off-the-shelf Ethernet controllers (MACs) 10M speed over household powerlines
Ambient		∼25M		
Cogency Semiconduc-tor Inc.	HMT-SS†	25M (∼ 100M)	(CENELEC Bands + local access(1M-10M) + Home network(10M-(25M-50M?))); (Old name: Power Trunk); †: Harmonic Multi-Tone Spread Spectrum	
VideoCom, Inc	FM	∼100M	(15-30 MHz)	upto 25 miles(40km)
Media Fusion	Advanced Sub Carrier Modulation	2.5G		United States Patent: 5982276;

Direct Sequence/Spread Spectrum (DS/SS) modulation

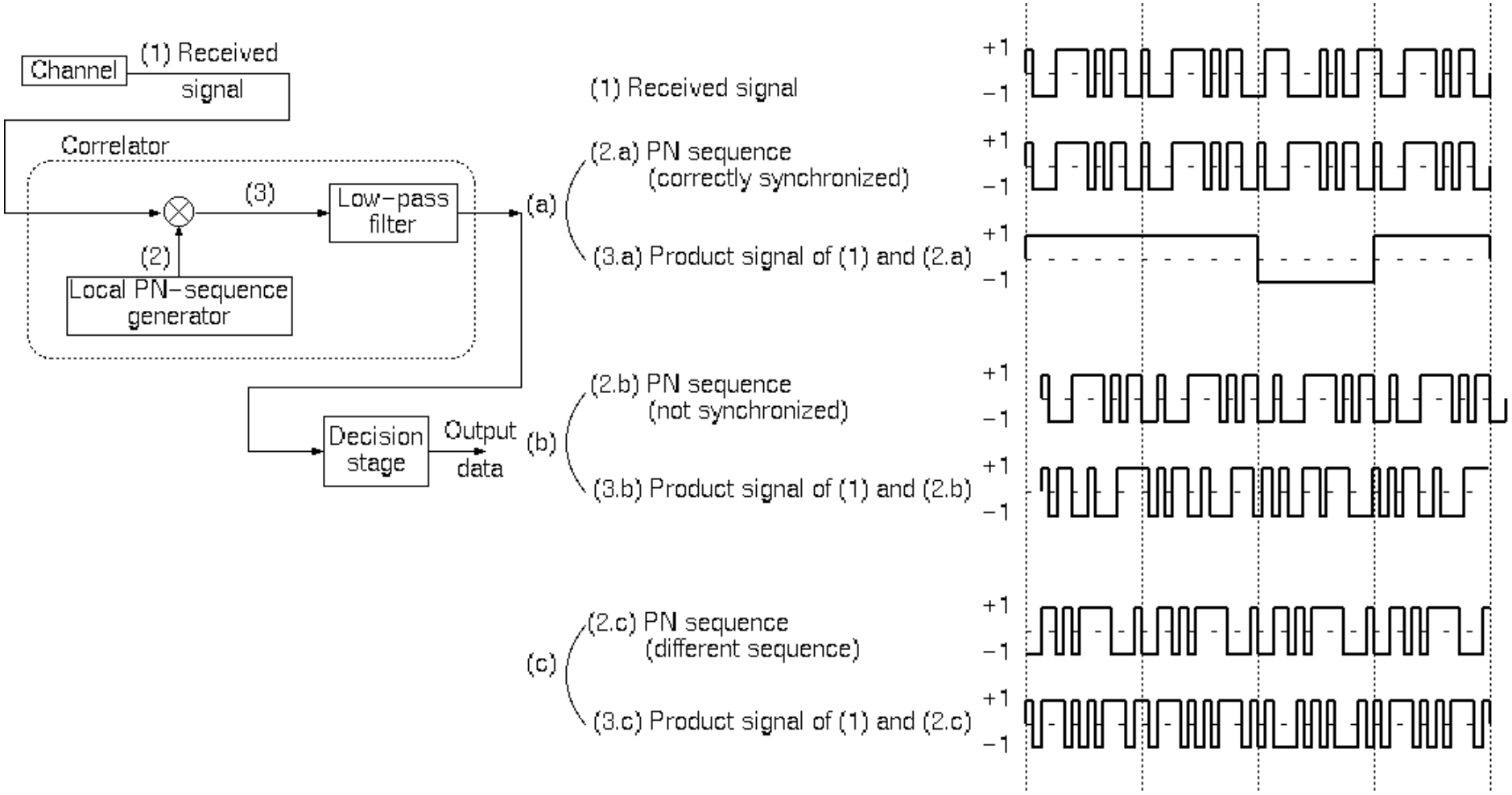




- PN sequence: pseudo-noise sequence
- **spreading factor: W/R=15=number of chips**
- P.S.D.: power spectral density (watts/Hz)

Spread Spectrum (SS)

demodulation (1)



Spread Spectrum (SS)

demodulation (2)

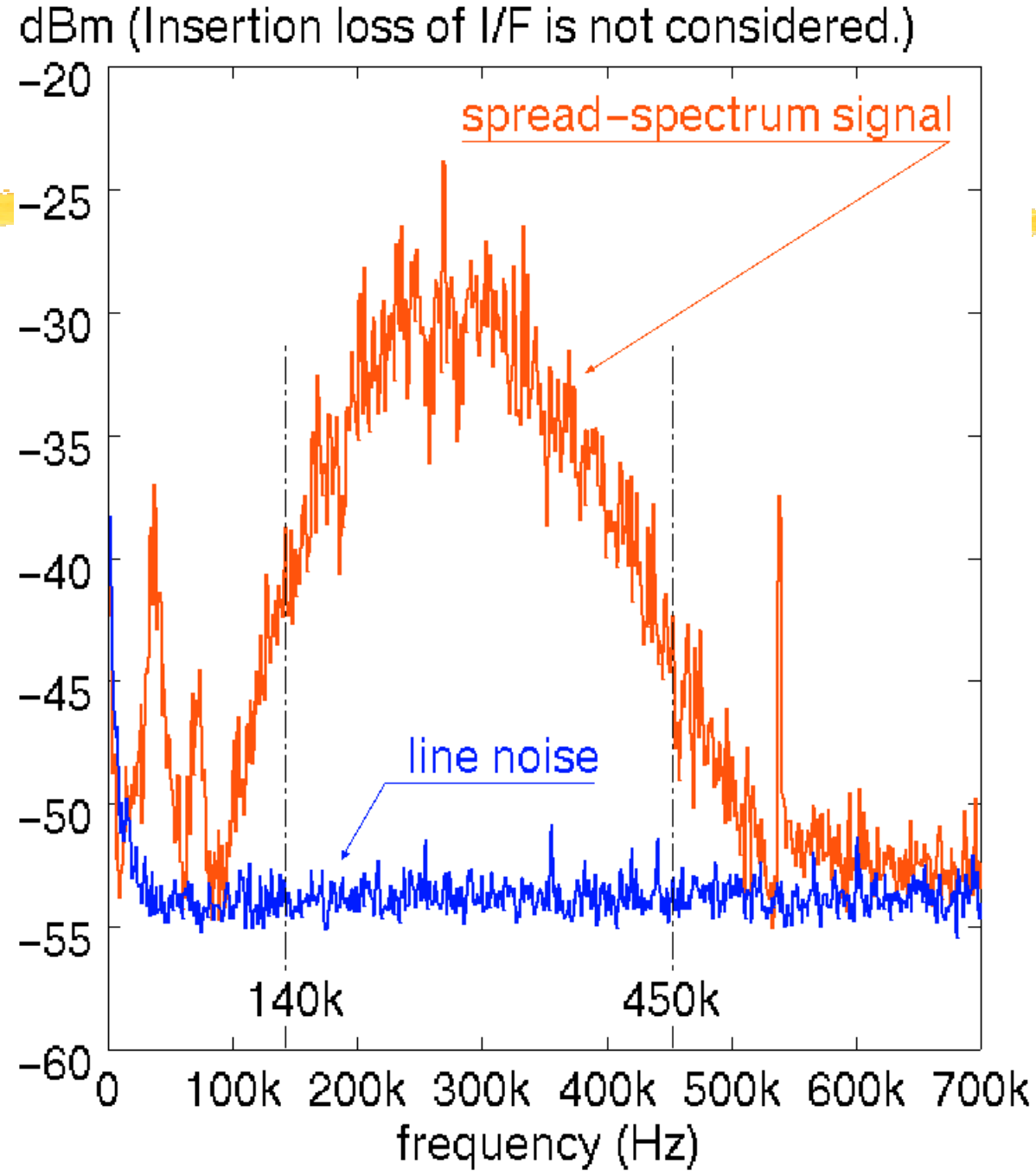
- In the demodulation,
  - the received spread-signal can be demodulated to be a narrow signal.
  - On the other hand, the noise is spread so that its P.S.D. becomes low.

○ Therefore, SS modulation is robust to the noise.

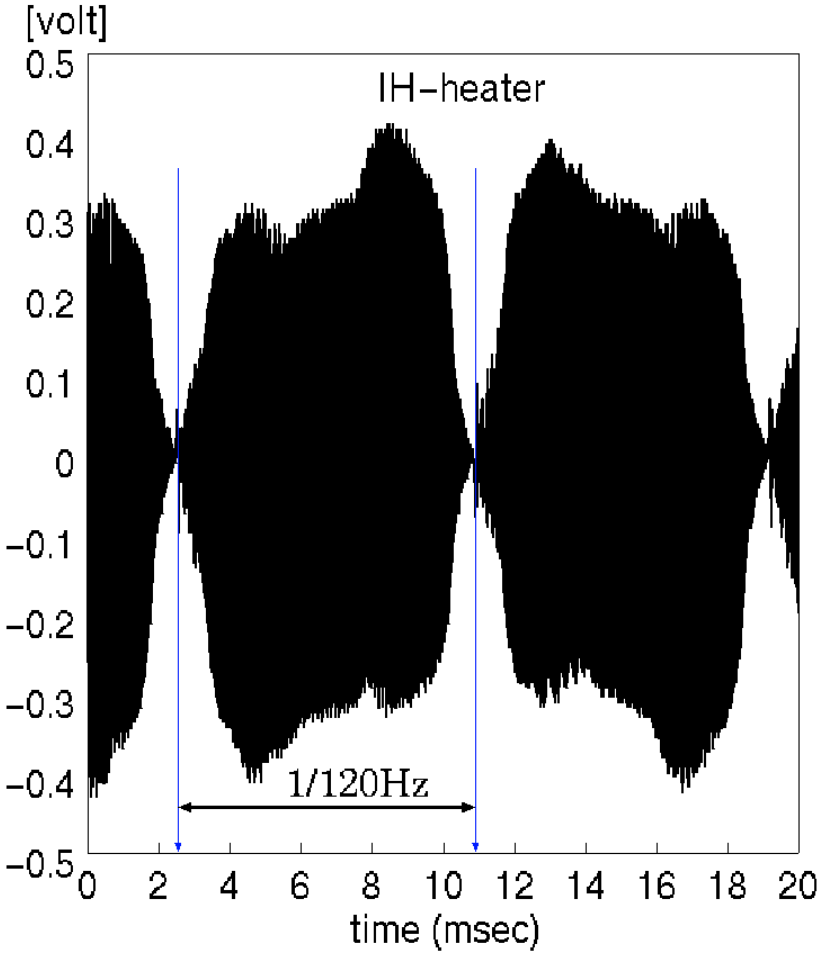
× Since the SS modulation consumes a broad frequency range, it is not easy to realize high speed PLCs. CDMA(Code Division Multiple Access) technique is needed additionally.

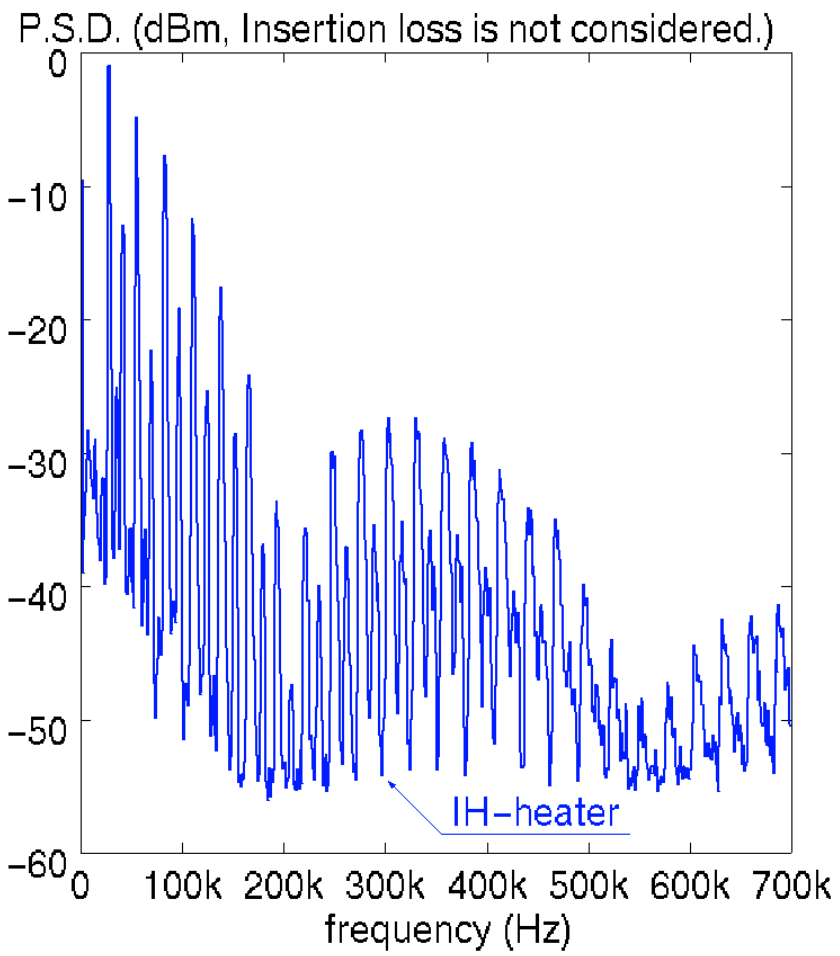
BPLM-100B
(Busicom, Japan)

- IC: Adaptive Networks
- 300bps - 100kbps
- DS/SS modulation
- token-passing

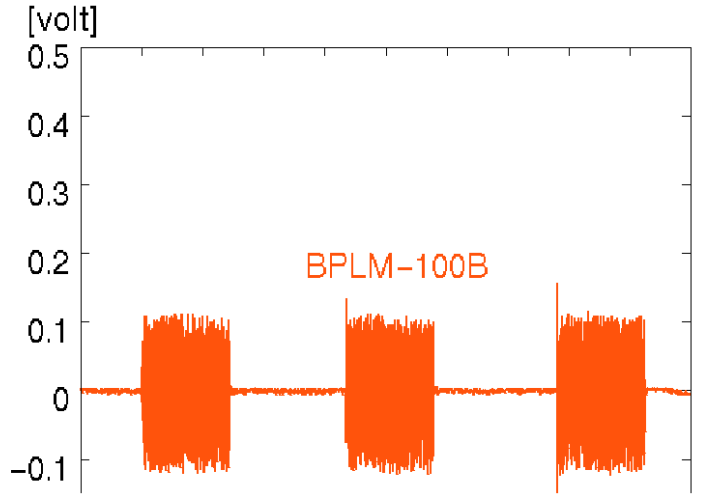


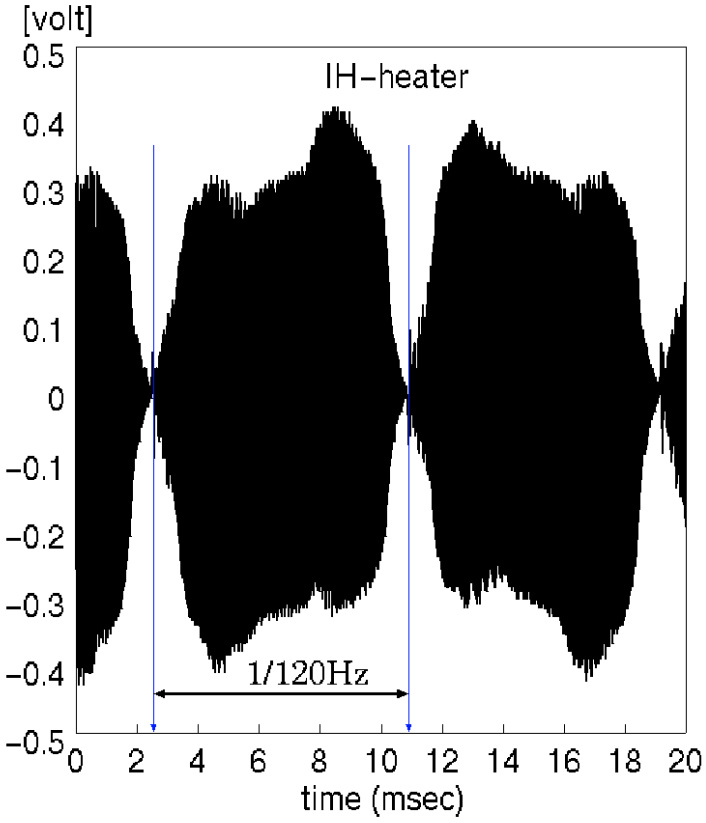
IH (Induction Heating / Induction Heater) cooking-heater

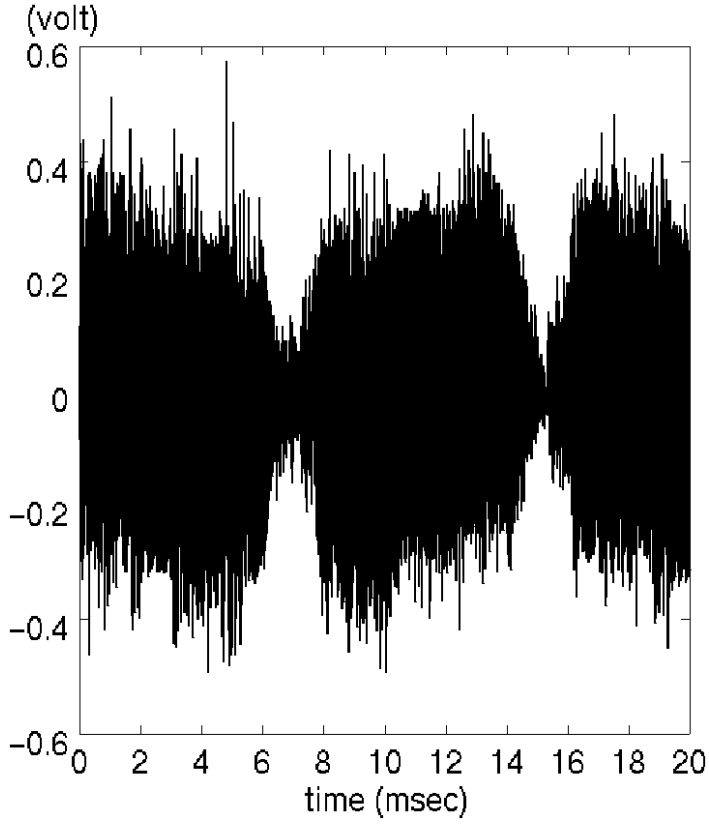




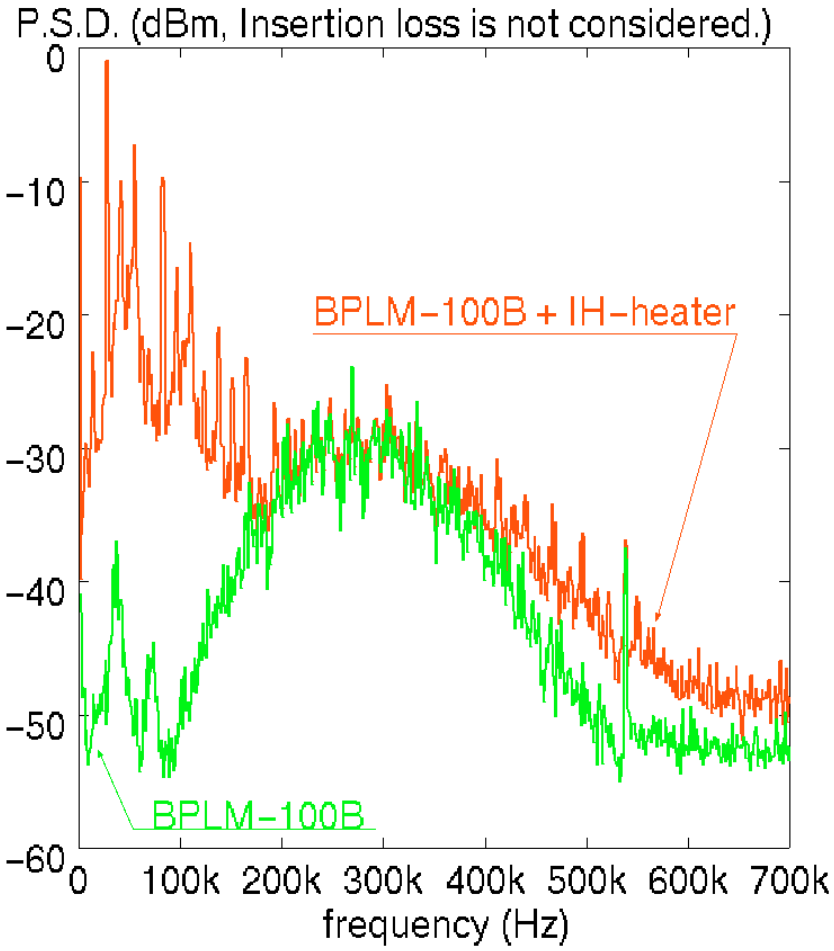
BPLM-100B + IH-heater

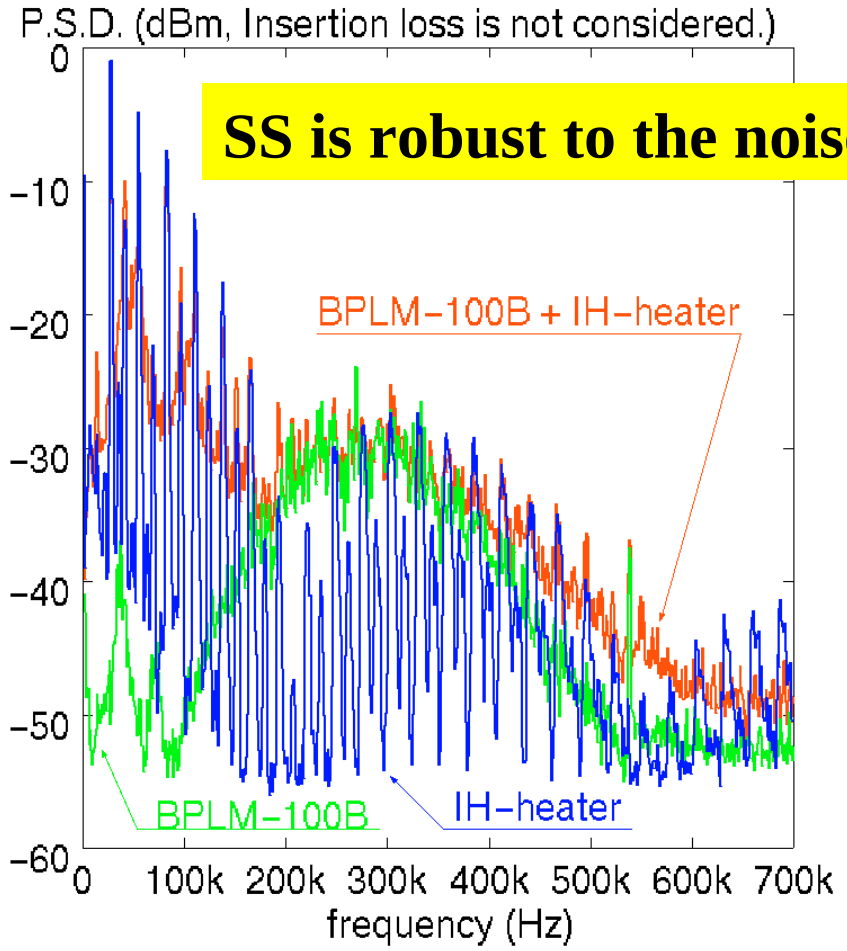






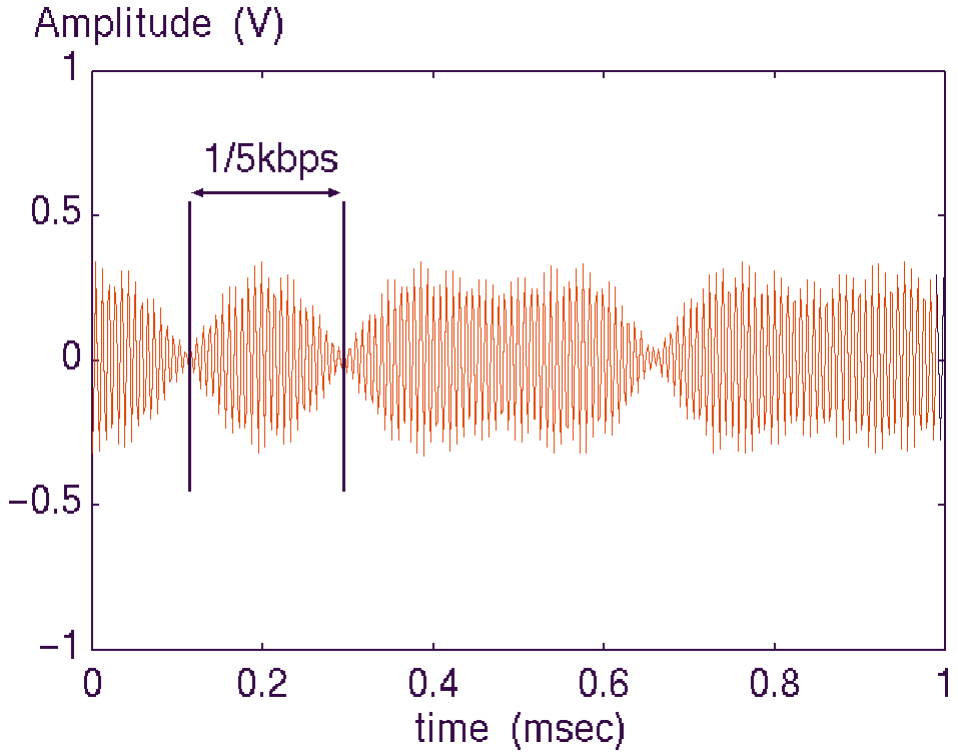
BPLM-100B + IH-heater





Multi-carrier modulation for the reliable communication

- 2 carriers' example: PLT-22 of Echelon Co.

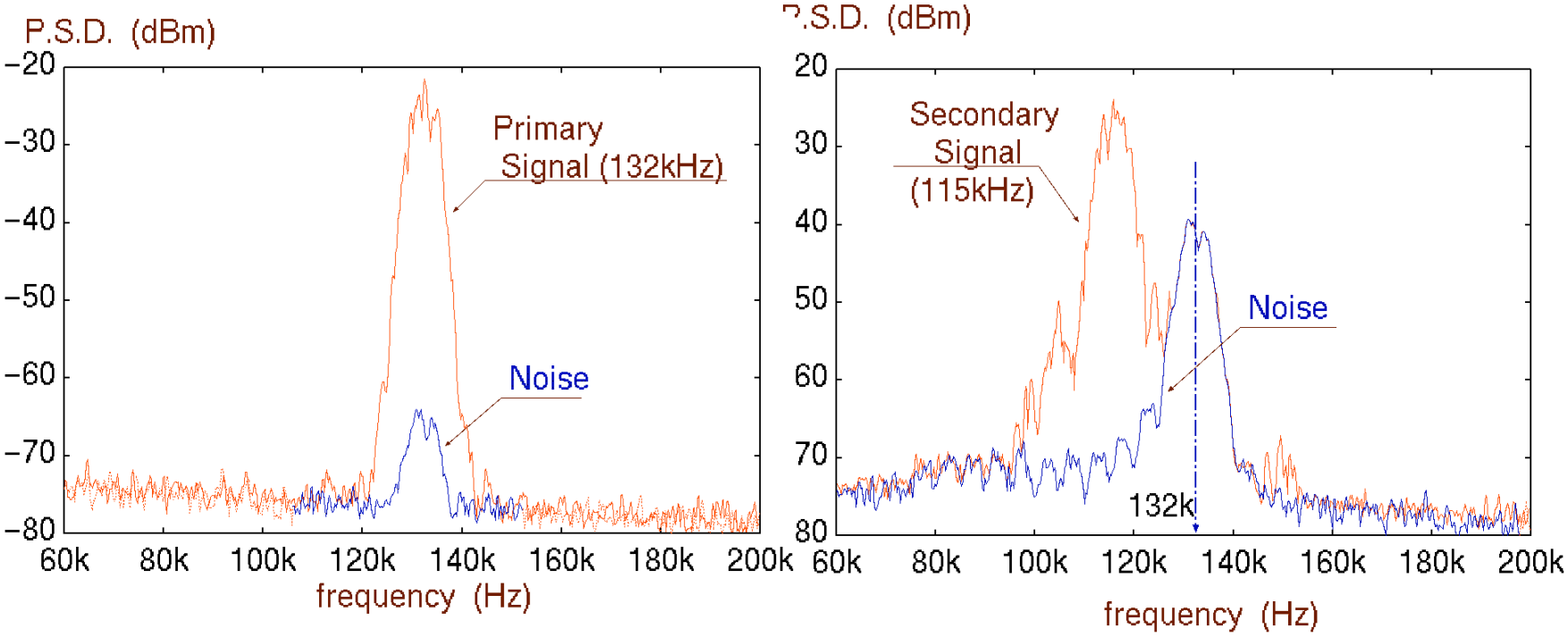


- **fixed 2 carriers** of 132kHz and 115kHz
- **5kbps**
- **BPSK (**Binary Phase Shift Keying

cf. Echonet (type B)

- **variable 3 carriers**

PLT22 (2)
Narrow band interference's case

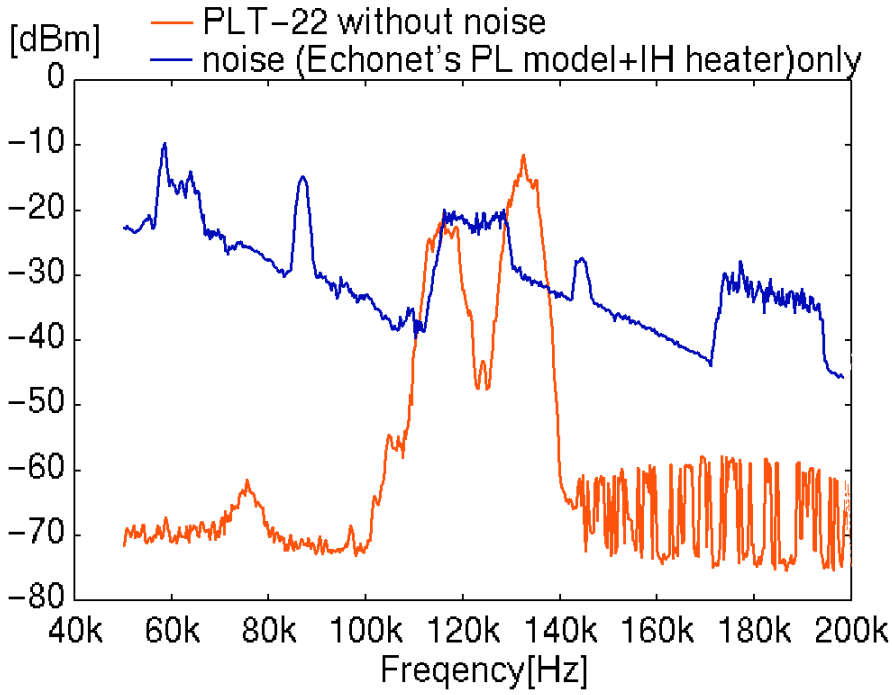


- When SNR>37dB,
  - uses only primary carrier

  (signal=14dBm, noise=-23dBm)
- When SNR<17dB,
  - uses only secondary carrier

  (signal=14dBm, noise=-2.7dBm)

PLT22 (3)
Residential power-line noise's case



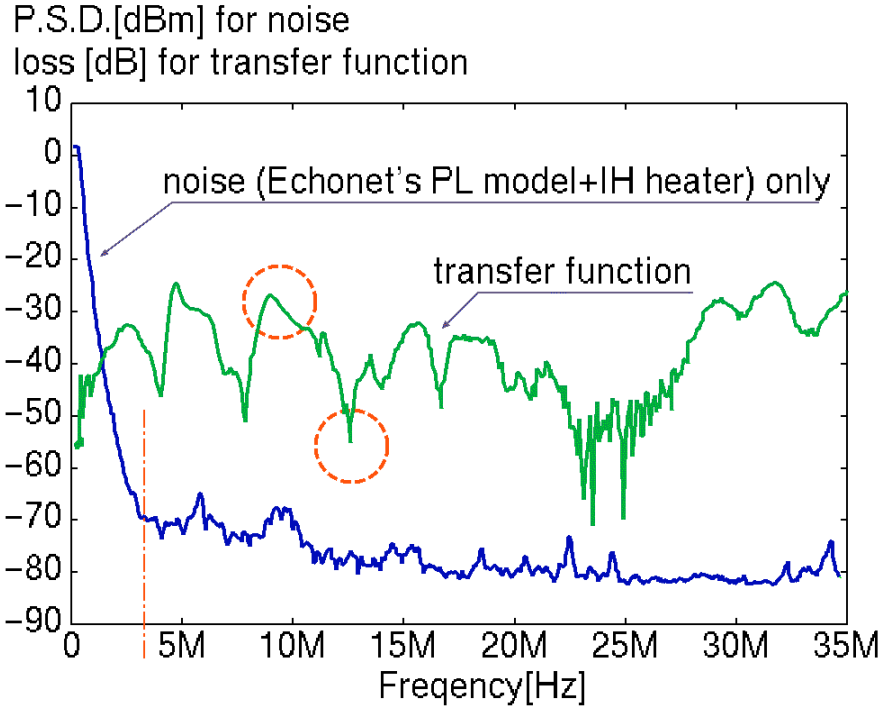
- Both carriers were used alternatively, but communication was impossible.

Cf. Echonet Power-Line model

- length: 21m
- branch:5
- inverter fluorescent- lamp: 24
- incandescent-lamp: 2

Residential power-line noise's case (2)

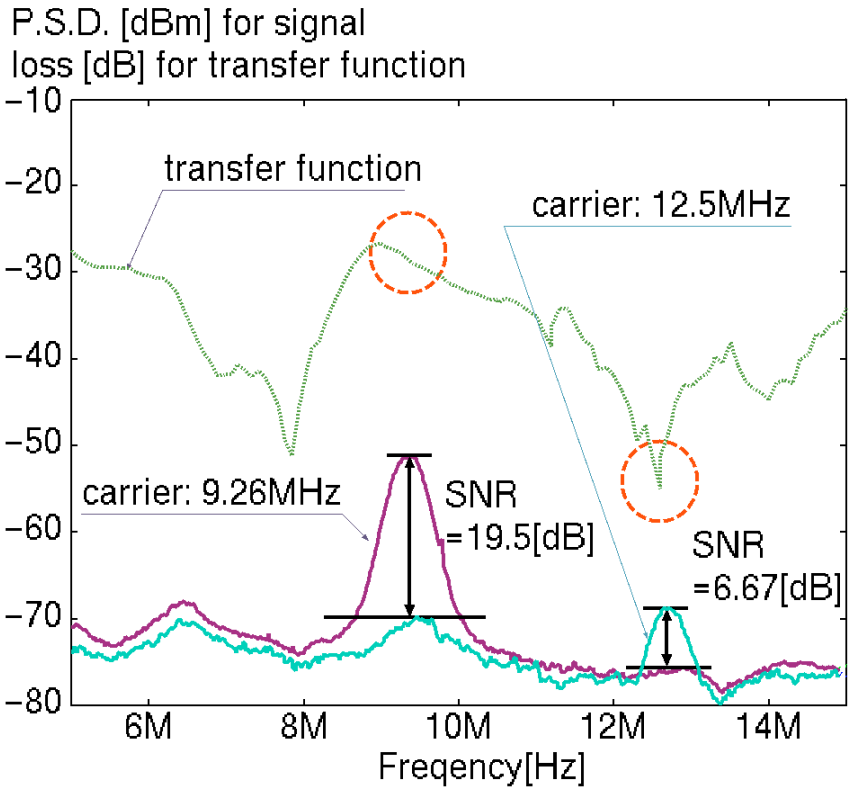
SNR in high frequency band (1)



- Noise is the decreasing function
  - >3MHz: good SNR can be expected

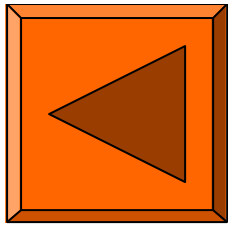
Residential power-line noise's case (3)

SNR in high frequency band (2)



- Spectrum of a handmade BPSK transmitter of 200kbps
  - carrier frequency is variable.
- In general, SNR in the high frequency is better.
- Adaptive selection of carrier frequency is needed to achieve the high-speed & reliable communication.

http://www.inari.com/2mbps/2mbps_spec.html



High-speed/reliable products (3)

Inari (formerly, Intelogis): IPL0201

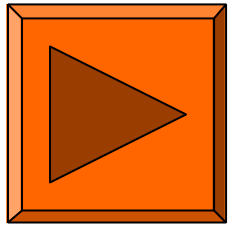
- Number of carrier: 4
- Trans. Bandwidth: 3M - 8MHz
- bit rate:
  - ～2.01Mbps for QPSK
  - ～1.01Mbps for BPSK
- Evaluation broad: available
- Access protocol:
  - DSMA (Datagram Sensing Multiple Access)
  - Centralized Token Passing
    - QoS control: possible (guaranteed bandwidth: ～460kbps)
- Security
  - 32-byte encryption array
  - 256-bit Diffie-Hellman public key exchange
  - Packet level authentication

Standardization activity (1)

Standardization activities
(cf.http://www.inari.com/tech/standards.html)

- CEA R-7.3 Committee
  - The R-7 Committee is part of the Consumer Electronics Association which is part of Electronic Industry Association
  - with the intention of deciding a standard sometime in 2001.
  - (Microsotf, ITRAN)

- HomePlug Powerline Alliance (HomePlug), U.S.A
  - for a high-speed PLC of 10Mbps



http://www.homeplug.org/docs/website_2.20.ppt

Standardization activity (2)

- Echonet Consortium, Japan
  - support home networks that are committed to energy conservation, boosting security, enhancing home health care, etc.
  - will use power lines, radio frequency and infra-red to provide a low-cost implementation of data transmission without requiring additional wiring.
  - The ECHONET Specifications V1.0 was disclosed to the public on July 26, 2000.

Note: The PLC forum is NOT involved in creating power-line specifications.

Regulation

- Standardization activities for a high-speed PLC, e.g., HomePlug)
- However, the Japanese regulation is too severe to introduce such standards.
  - Deregulation is required in order to activate research and development more.

American Regulation

(FCC CFR47 Part 15. Radio Frequency Devices)

TYPE	FREQUENCY RANGE	NOTE
(conventional) Power line-carrier system	9k- 490kHz [§90.63(g)]	used by an electric power utility entity [§15.113]
(for high speed PLC) Carrier current system Of an Unintentional-radiators [§15.109(e)]	e.g., 1.705M–30.0MHz	radiated emission limits : 30 μV/m at 30m distance [§15.209]
		conducted limits: none [§15.107]

The frequency band from 9kHz to 30MHz:

Unless the radiated emissions fall in the restricted bands, as defined in § 15.205(a), it is free to use, in principle.

conventional power line carrier system, defined in FCC

defined as: [47CFR15.3(t)]

- An unintentional radiator employed as a carrier current system[47CFR15.3(f)] used by an electric power utility entity on transmission lines for protective relaying, telemetry, etc. for general supervision of the power system.
  - The system operates by the transmission of radio frequency energy by conduction over the electric power transmission lines of the system. The system does not include those electric lines which connect the distribution substation to the customer or house wiring.

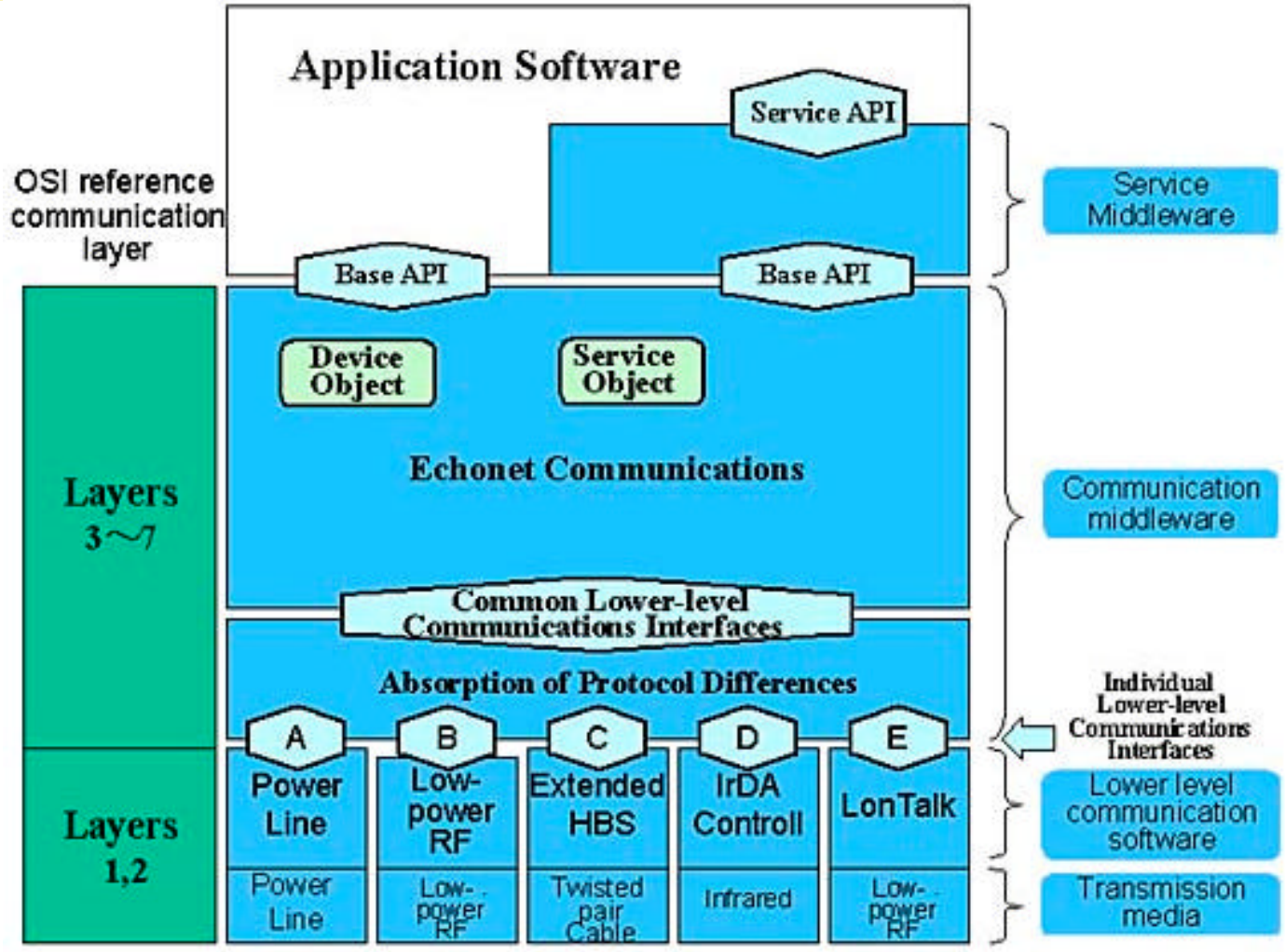
Comparison between Japanese and American(FCC) regulation

		FCC	Japan
Conventional PLC	Frequency range	9k-490kHz	10k-450kHz
	Tx power limit	minimum power possible [§15.113]	350mW for PSK
			Modulation scheme limit: PSK,ASK,SS Bit rate limit: 30kbps for PSK
Others	Frequency range	Free in principle, excluding a specific frequencies[15.205(a)]	none
	radiated emission limit	30 μV/m at 30m distance [§15.209]	

Japanese activities

- Echonet
- OpenPLANET
- Internet service

Echonet

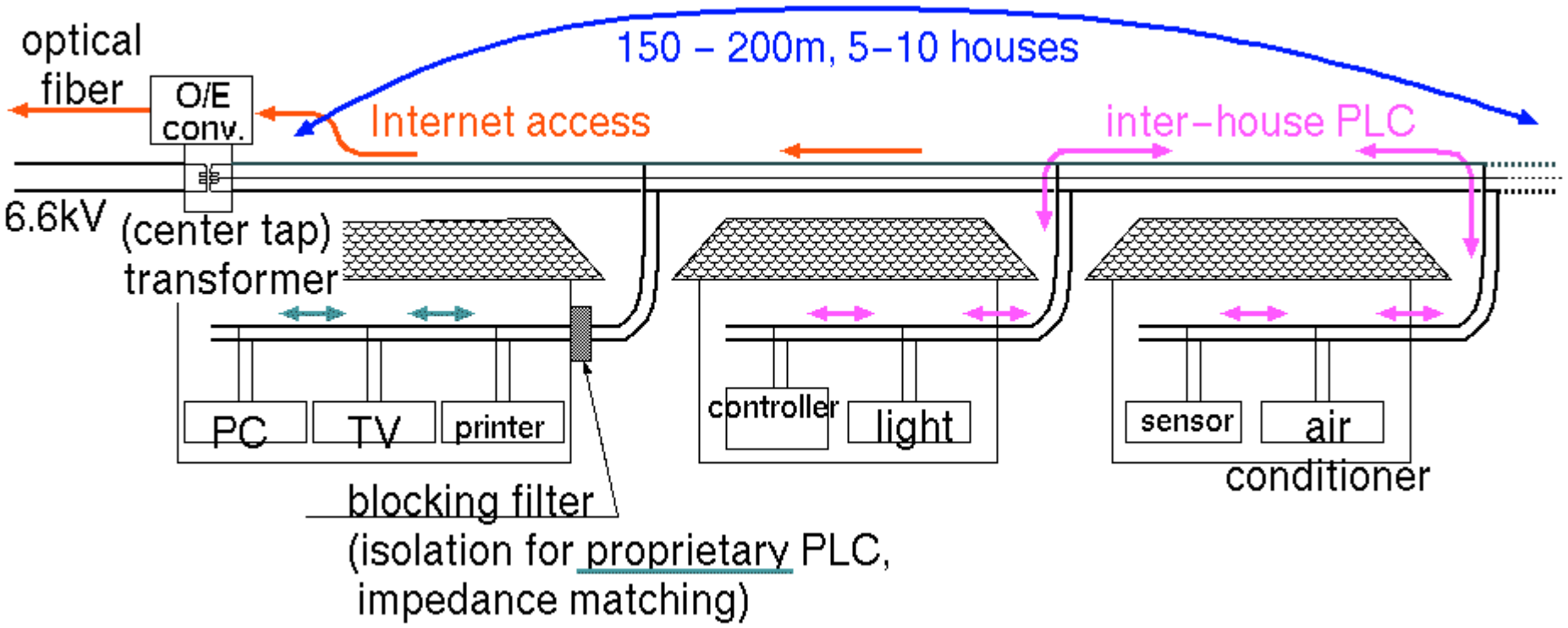

Application Software
Service API
OSI reference communication layer
Base API
Base API
Service Middleware
Device Object
Service Object
Echonet Communications
Layers 3~7
Communication middleware
Common Lower-level Communications Interfaces
Absorption of Protocol Differences
A
B
C
D
E
Individual Lower-level Communications Interfaces
Power Line
Low-power RF
Extended HBS
IrDA Controll
LonTalk
Layers 1,2
Lower level communication software
Power Line
Low-power RF
Twisted pair Cable
Infrared
Low-power RF
Transmission media

http://www.echonet.gr.jp/spec/spec_v10_e.htm

Echonet

- Type A (Matsushita, et.al.)
  - Spread Spectrum (No spreading code is specified. Differential coding. Sub-band Delay Detection.)
  - 9600bps
  - Available PHY-IC: SMK co.Ltd. (2000.10～)
- Type B (Mitsubishi, et.al.)
  - Multi-carrier (3 variable carriers, DQPSK/DBPSK/D8PSK)
  - variable rate (4.06k～36.5kbps)
  - IC will be available from 2001.2Q (?)

Japanese PLC network configuration (1)



Japanese PLC network configuration (2)

Note on Security issue

- **When the blocking filter exists**
  - **no problem**
- **When the blocking filter does not exist, the signal goes out; Intercept is possible.**
  - **Applications, like Internet access service, is not secure.**
  - **Presently, the standardized encryption, such as IEEE802.11's, does not exist.**
    - **Interoperability is the problem.**
    - **Complementing technology of higher layers, such as IPsec, VPN, etc., must be used.**

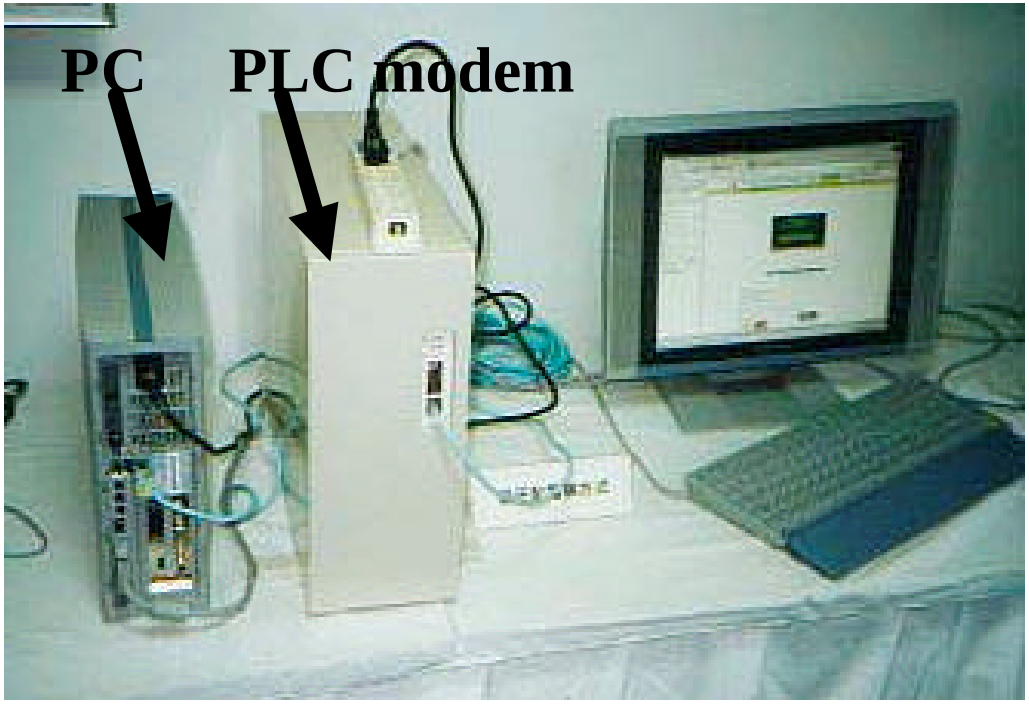

Welcome
Open Platform for Appliances Networking
©2000 Shikoku E
http://www.openplanet.co.jp/html-e/e-index.htm

Kyushu Electric Power Co.,Inc.,

Internet access service (1)

Field test

- 300 houses
- until Mar. 2001
- 10kHz - 450kHz
- max 3Mbps
- 5 slave stations@master station on a pole
- collaborates with Mitsubishi electric Co.



http://pcgaz.nikkeibp.co.jp/pg/pcgaz/minicol/2/col_45.shtml, (2001/02/13)

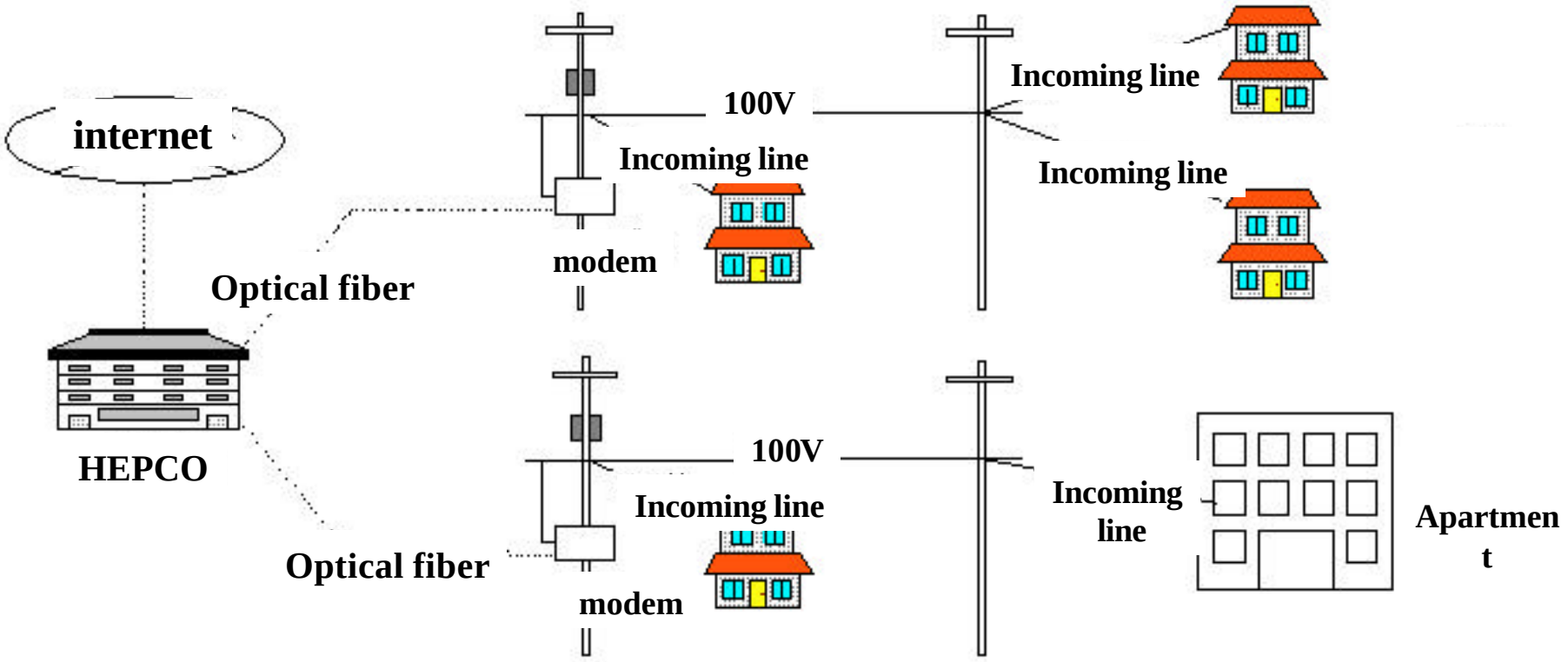
Internet-access-service experiment

Hokkaido Electric Power Company (HEPCO),

collaborates with Toshiba Co. and Power Net Com, Japan

- http://www.hepco.co.jp/press/h12/0126a.html
- Asahi newspaper, 2001.1.27

- Period: 2001.2～2002.3
- Place: company houses in Sapporo city
- 7,000km fiber-optic network, already installed in Hokkaido
- Target service speed: 1.5Mbps



Conclusion

- By introducing multi-carrier modulation technique,
  - about 1Mbps for low (conventional) frequency band (<450kHz)
  - more than 10Mbps for high frequency band (<30MHz)

  will be realized in this year.
- The reason why the high frequency band is promising was explained.
  - To use the band, de-regulation is needed in Japan.