

# *The (PLC) Technology*

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# Content

- *Basic Communication*

- *Modulation schemes*
- *FDM & OFDM*
- *Access schemes*

- *Wireless communication*

- *ISM*
- *ZigBee*
- *Z-Wave*

- *Wired communication*

- *M-BUS (Meter BUS)*
- *PLC - in practice*
  - *What is PLC?*
  - *The PLC Media*
  - *Narrowband and Broadband PLC*
  - *CENELEC*
  - *How does it work?*

- *Standardizing*

# Basic Communication

Why use modulation?

To be able to share the medium with several users

Low loss/energy requirements

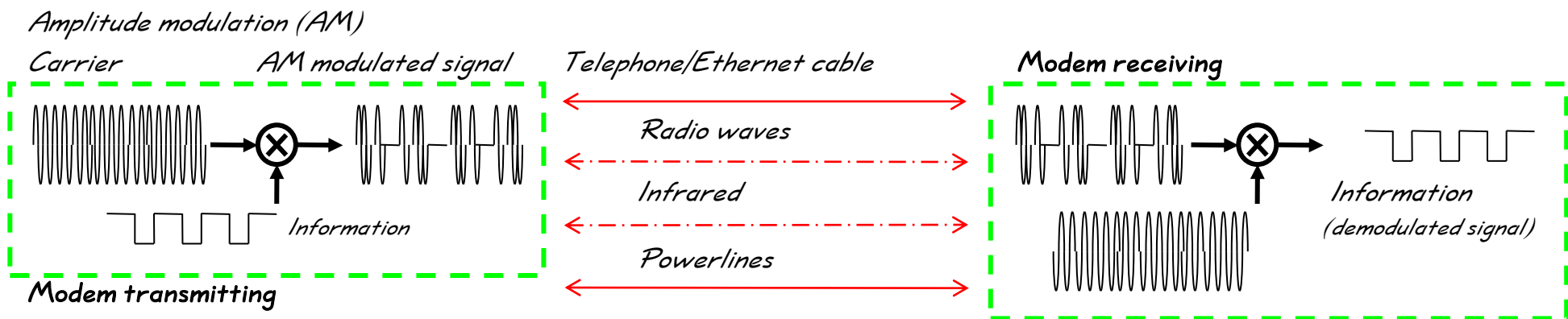
What is Modulation? – *"Morse Code"*

*Carrier* carrying information by changing (*modulating*) the carrier accordingly to the information (amplitude, frequency and/or phase)

*Bit rate* define the rate at which information is passed

*Baud rate* defines the number of symbols per second.

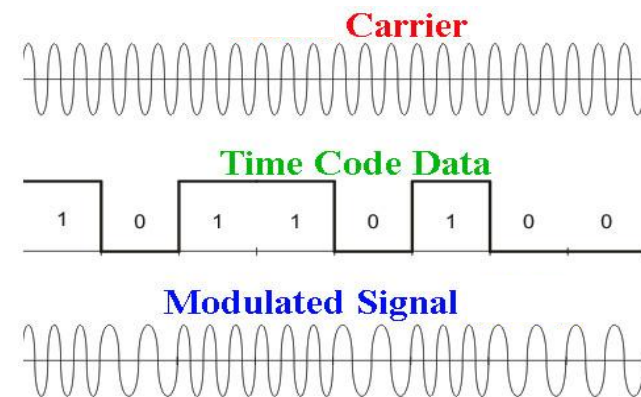
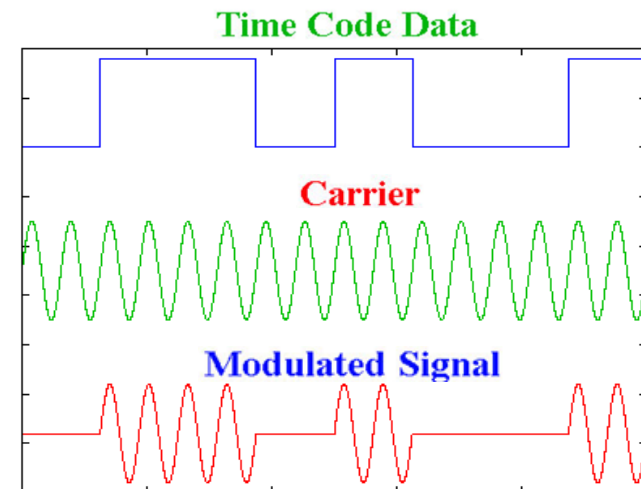
Each symbol represents  $n$  bits, and  $M$  signal states,  $M = 2^n$



# Modulation schemes

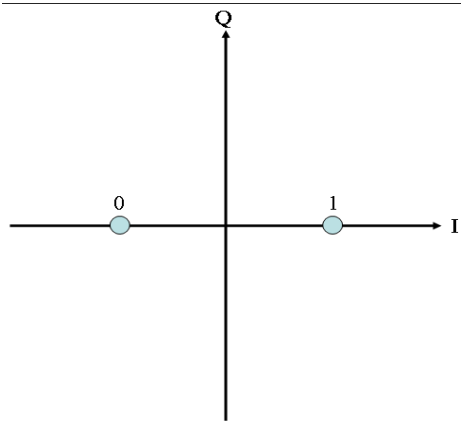
Typical modulation schemes:

- AM (Amplitude modulation)
- FM (Frequency modulation)
  - FSK (Frequency shift keying)

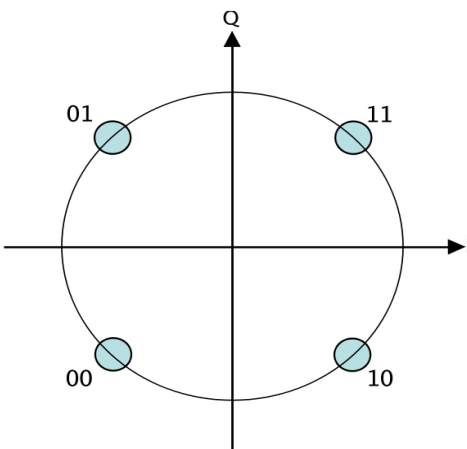


# Modulation schemes

Typical modulation schemes:



- PSK (Phase modulation)
- BPSK (Binary Phase Shift Keying)



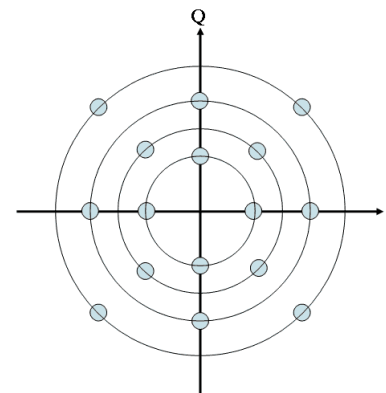
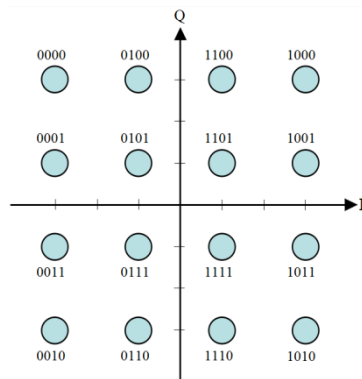
- QPSK (Quadrature Phase Shift Keying)

# Modulation schemes

Typical Modulation schemes:

QAM (Quadrature Amplitude Modulation)

Rectangular 16-QAM Circular 16-QAM



# Single carrier vs. multiple band

## Single carrier

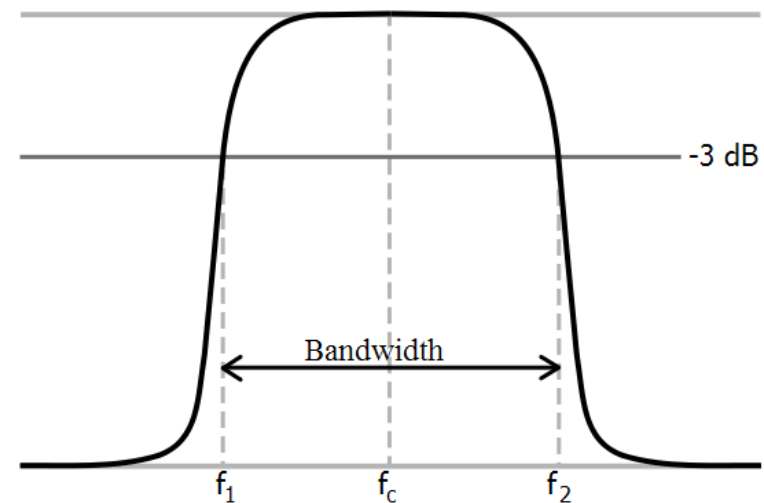
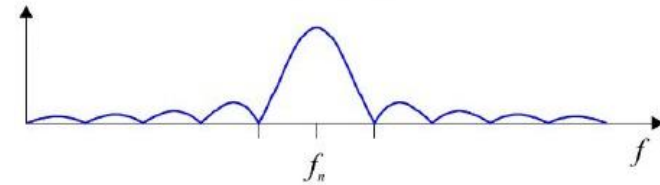
One channel

Low data rate

## Frequency band (Several carriers)

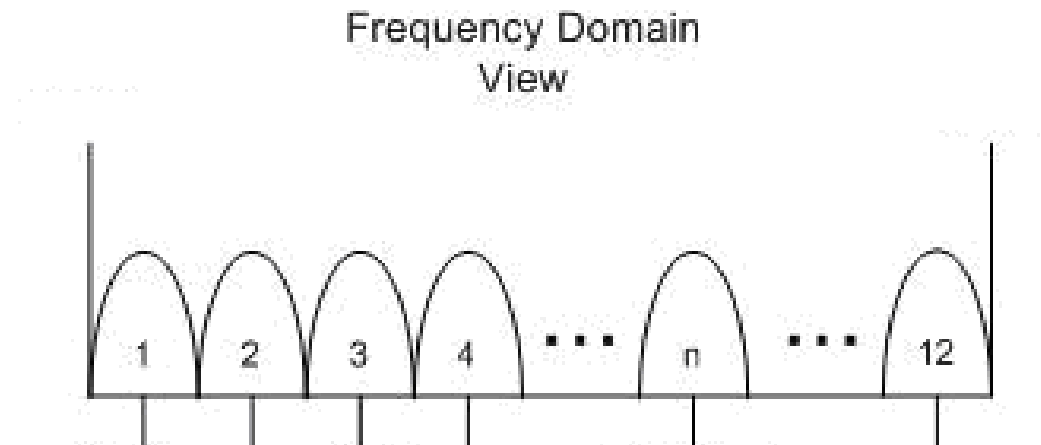
More channels

Higher data rate



# Frequency Division Multiplexing

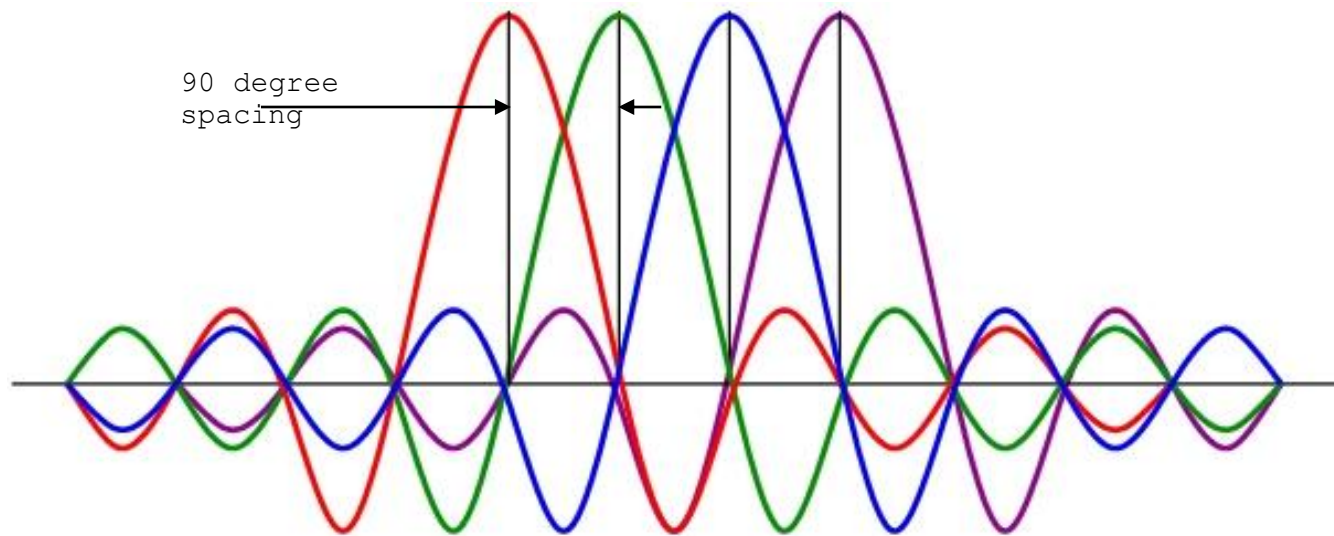
## FDM



*Divides the bandwidth into several "channels" (sub carriers) – with no other precautions the sidebands will interfere with adjacent channels*

# Orthogonal Frequency Division Multiplexing

## OFDM



## Orthogonal Frequency Division Multiplexing (Discrete Multi Tone)

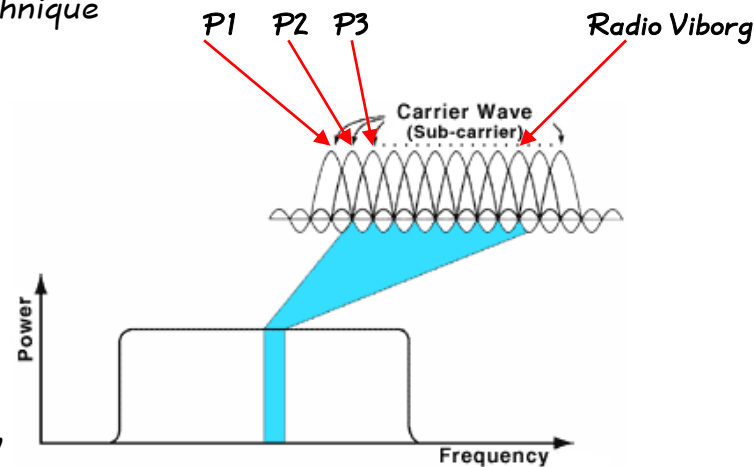
Introduces orthogonality between channels – minimizes Inter Symbol Interference and multipath reflection/fading

# Orthogonal Frequency Division Multiplexing

## OFDM

How to get a higher data rate in communication systems

OFDM → Orthogonal Frequency Division Multiplexing divides frequency spectrum in several channels, each with its own modulation technique



Also used in  
Powerline  
Communications!

- Large bandwidth
- Low speed on each channel → Long duration of each bit
- Great resistance to interference (e.g. multipath - wireless)
- Adaptive rate control
- Requires expensive and demanding circuitry

# Access Schemes

## *Multiple Access Schemes (for coexistence)*

*TDMA → Time Division Multiple Access*

*FDMA → Frequency Division Multiple Access*

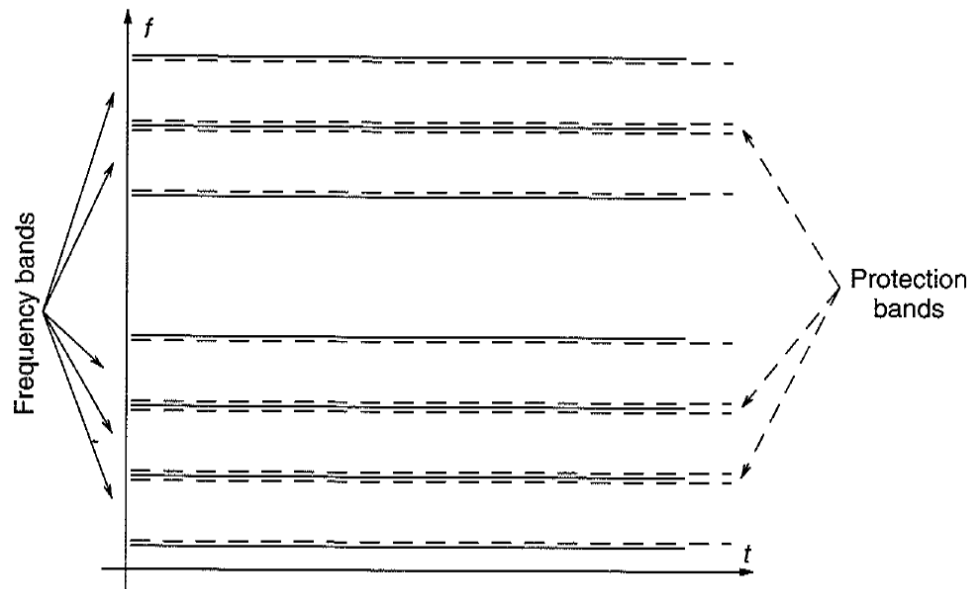
*CDMA → Code Division Multiple Access*

*CSMA → Carrier Sense Multiple Access*

# Frequency Division Multiple Access

*FDMA – Frequency Division Multiple Access*

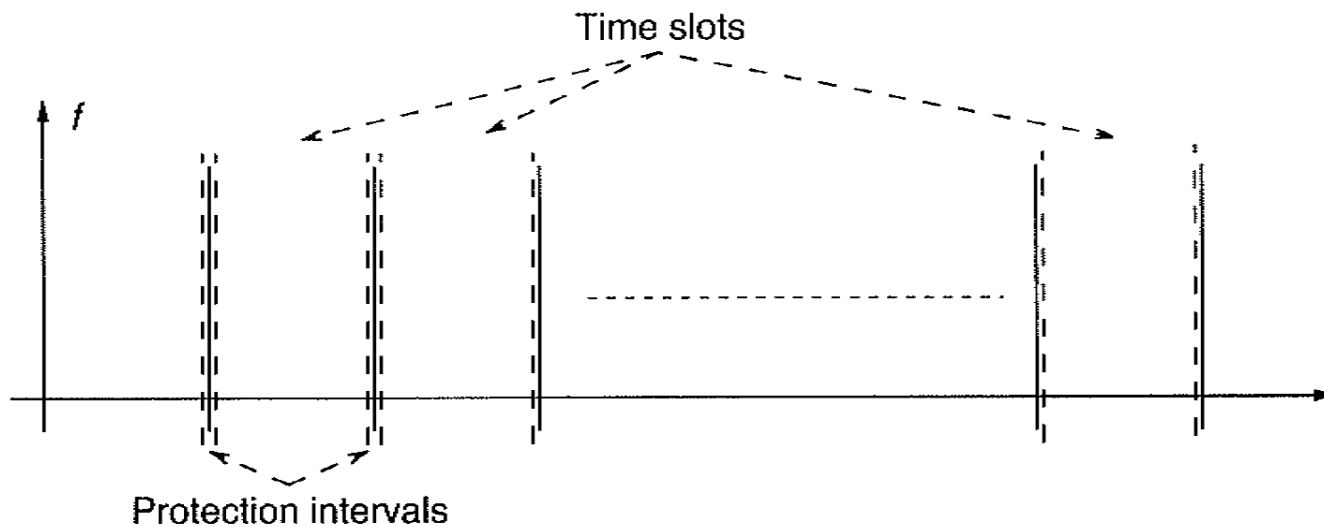
*Each "user" has it's own piece  
of the bandwidth continuously*



# Time Division Multiple Access

*TDMA – Time Division Multiple Access*

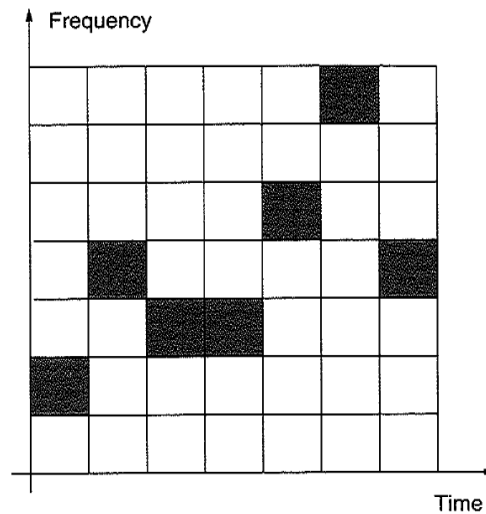
*Each “user” has a specific timeslot,  
using the entire bandwidth*



# Coded Division Multiple Access

*CDMA – Coded Division Multiple Access*

*Each "user" has a synchronized code-scheme to decode the received signal*



# Carrier Sence Multiple Access

## CSMA – Carrier Sense Multiple Access

*"Hello –  
Is there someone talking  
right now?"*

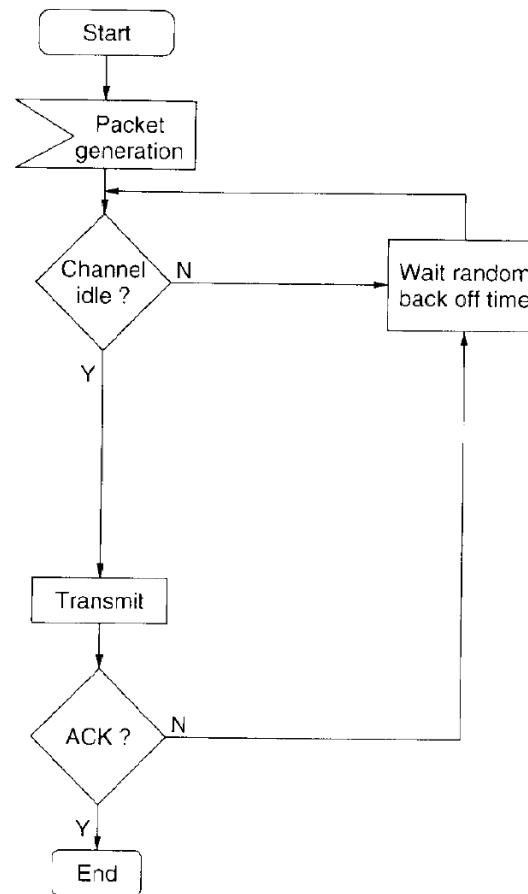
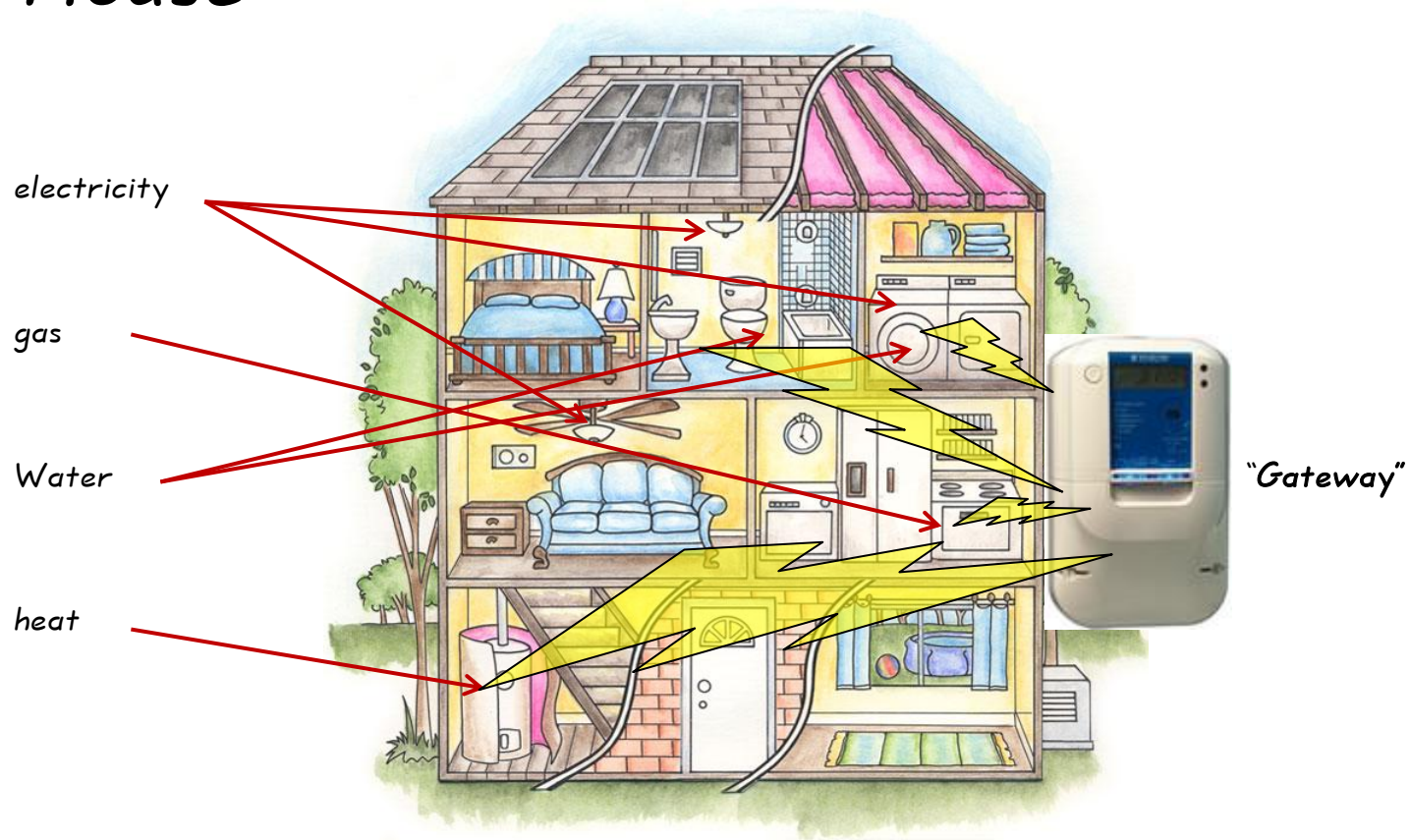


Figure 5.34 Flow diagram of nonpersistent CSMA

# The scene

## In-House



# *Wireless Communication*

# *Industrial Scientific and Medical*

*Wireless communication*

*ISM band*

*The ISM band are free frequency bands for communicating.*

*ISM frequencies are*

- 433 MHz (e.g. Baby alarms and doorbells, etc.)*
- 868 MHz (e.g. wireless headsets, etc.)*
- 2,4 GHz (e.g. Bluetooth, ZigBee, Z-wave and WiFi, etc.)*

# ZigBee

Wireless communication

*ZigBee (based on IEEE 802.15.4)*

- *868 MHz in EU, 915 MHz in USA & Australia and 2.4 GHz most places*
- *Defined by the ZigBee Alliance for*
  - *Home Automation*
  - *ZigBee Smart Energy*
  - *Telecommunication Applications*
  - *Personal Home*
  - *Hospital Care*

# ZigBee

## Wireless communication

### ZigBee (based on IEEE 802.15.4)

- *Self organizing and self healing mesh network*
  - *Supports Tree and Star network topologies*
- *Reliable and large range*
- *Three types*
  - *ZC: ZigBee Coordinator*
    - *Creates, manages and coordinates all traffic, cannot run any application*
  - *ZR: ZigBee Router*
    - *Is able to run applications along with retransmission*
  - *ZED: ZigBee End Device*
    - *Is able to run applications and can only communicate with either ZC or ZR,*
    - *Is not capable of retransmitting. Is however capable of using sleep mode.*

# Z-Wave

*Wireless communication*

*Z-Wave*

*Developed by Zensys (DK) and the Z-wave alliance*

*Very similar to the ZigBee standard*

# Z-wave vs. ZigBee

Wireless communication

## ZigBee Vs. Z-wave

	ZigBee	Z-wave
Standard	IEEE 802.15.4	Proprietary
Data rate	250kbps	40kbps
Frequency	900 MHz & most 2.4 GHz	900 MHz
Products on market	MANY!	+100
Developer	Freescale, TI	Zensys
Range (point-to-point)	10-75 m (~30m indoor)	30 m

# Pros and cons

## Wireless communication

- *Advantages*
  - *Easy to install*
  - *Easy maintenance*
  - *Suitable for all kinds of "meter'ed" supplies*
  - *Dedicated og license free communications frequencies*
- *Disadvantages*
  - *Some installations require an external antenna and repeaters*

# M-BUS

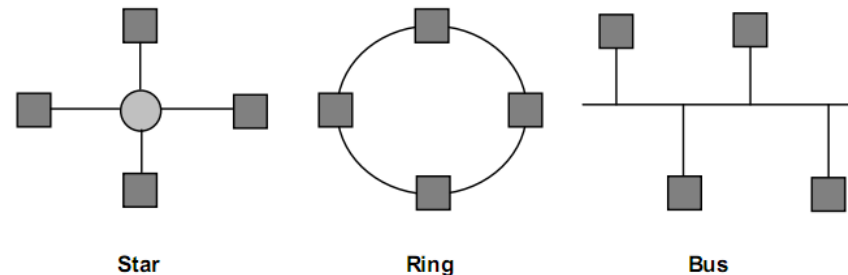
Wired communication

**M-BUS** (*NOT Modbus or Message Bus*)

Dedicated Meter Reading protocol (MBUS standard:  
EN13757-2 & EN13757-3)

Two pair wire communication from electric, gas, water  
and heat-meters.

Different network topologies



# M-BUS

*Wired communication*

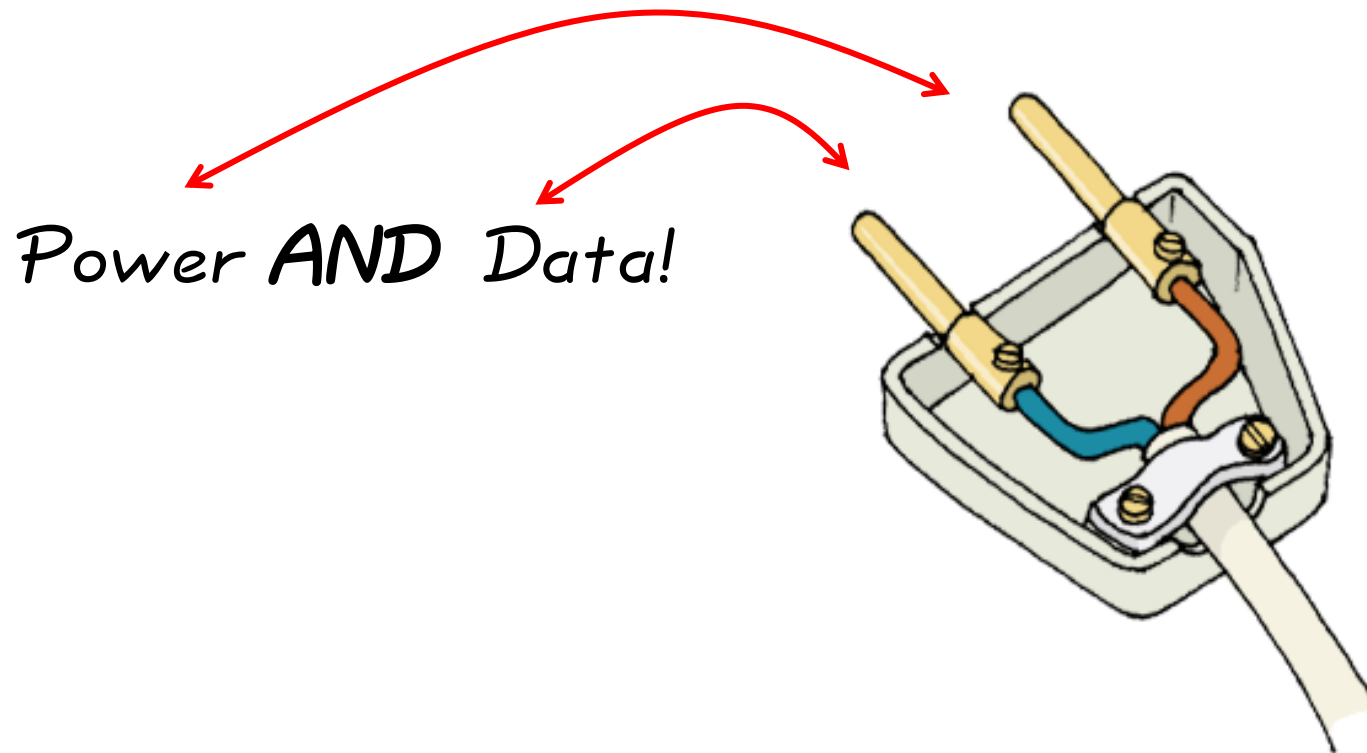
## M-BUS

- *Advantages*
  - *Easy to install*
  - *Easy to use*
  - *Easy to implement in other systems*
  - *Open communication protocol*
  - *Suitable for all kinds of distributed supplies*
  - *Competitive on price*
- *Disadvantages*
  - *Wired communication*
  - *Expensive to install (wires)*

# Powerline

Wired communication

## PLC – PowerLine Communication



# *PLC – in practice*

*What is PLC?*

*Communicating on the existing AC and DC power grid!  
No new wires!*

*Typical interfaces are RS232 or Ethernet*

# PLC – in practice

## The PLC Media

AC  $\leftrightarrow$  DC

$110\text{kV} \leq \text{High Voltage (HV)} \leq 380\text{kV}$  - (Access overhead)

$10\text{kV} \leq \text{Medium Voltage (MV)} \leq 30\text{kV}$  (Access overhead/In ground)

Low Voltage (LV)  $\leq 230/400\text{V}$  (In-House)

!! Powerless !!  
(twisted pair, dedicated wire, etc.)

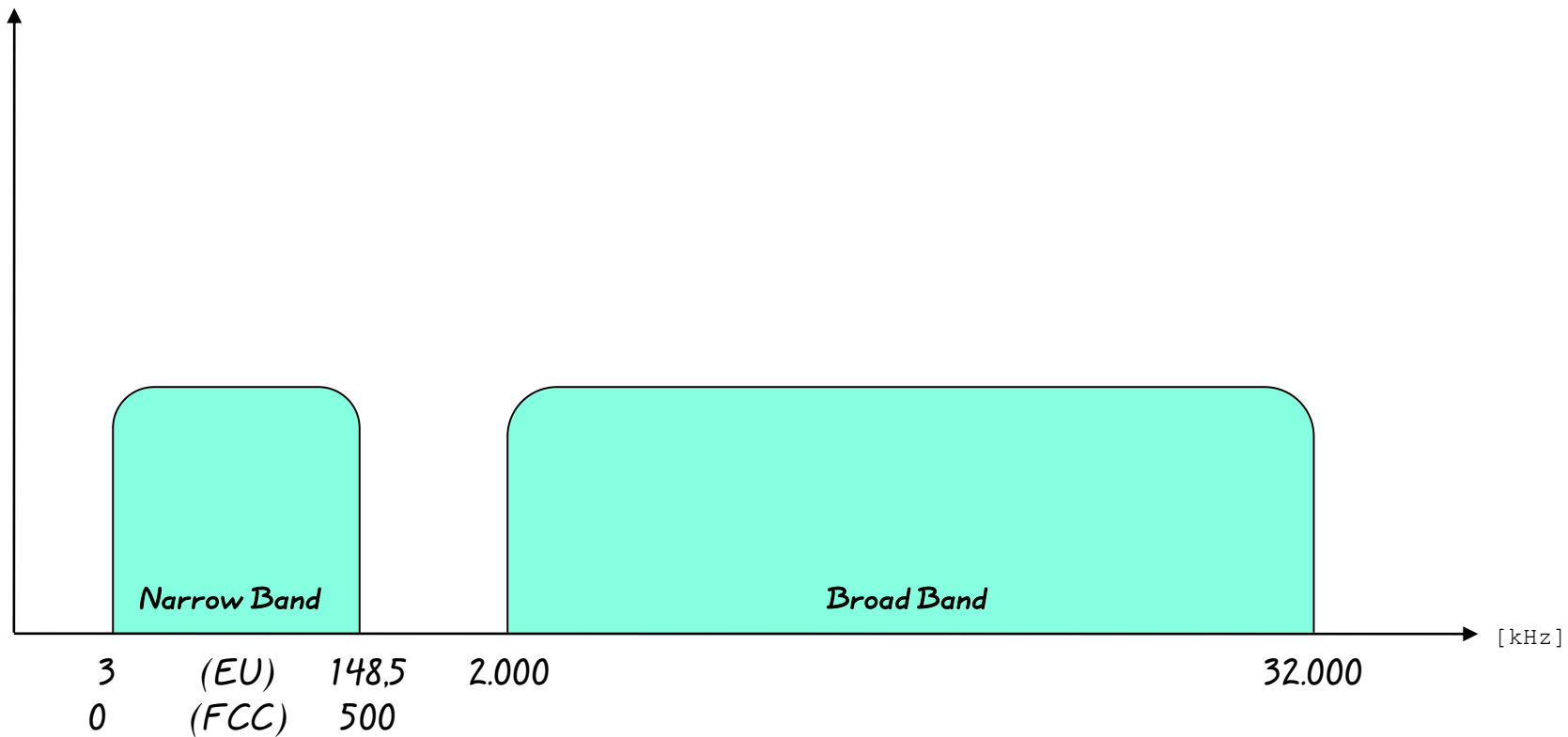
# PLC – in practice

**Narrowband**

*Typical data rate: 0.625kbps – 50kbps (<1Mbps)*

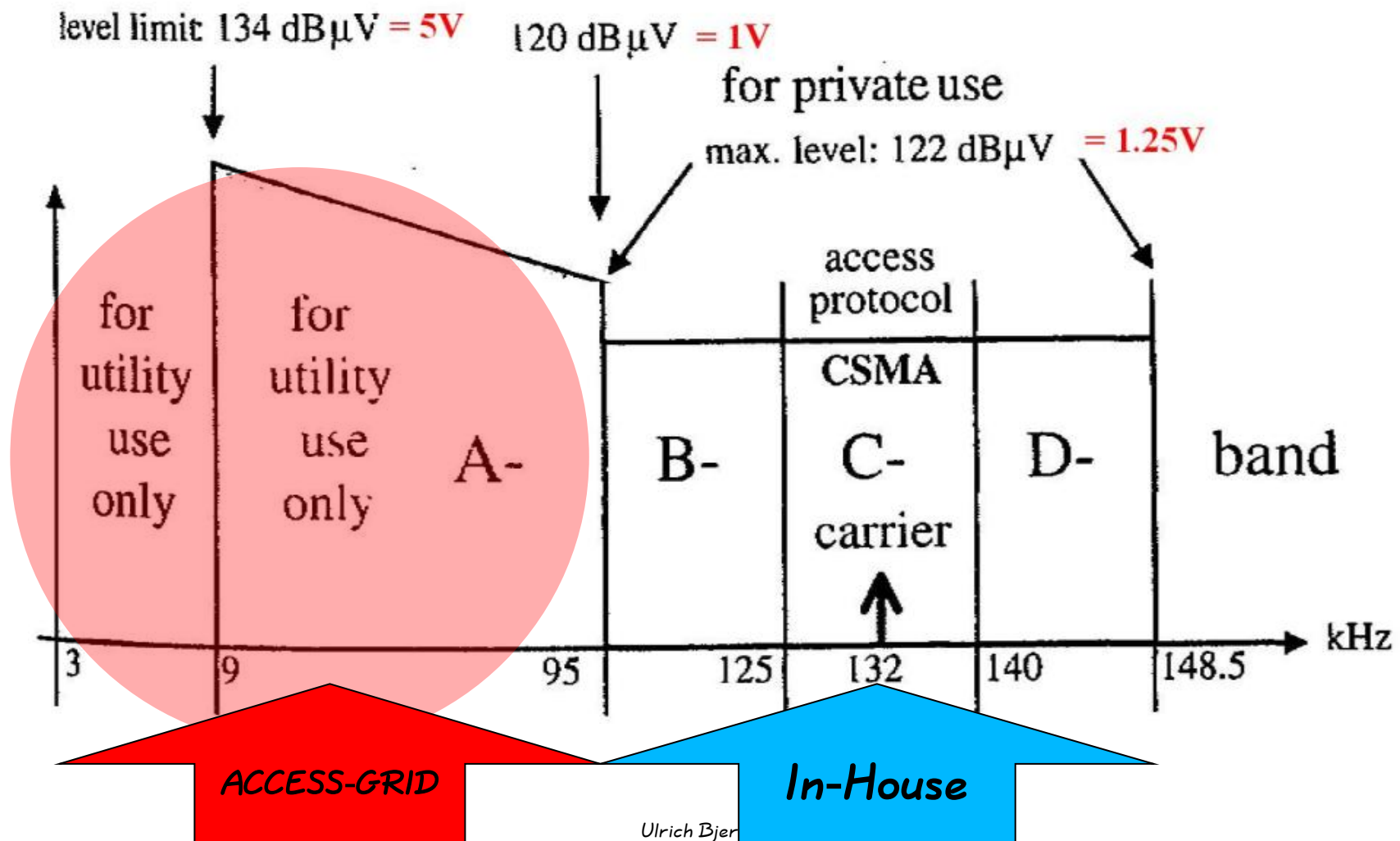
**Broadband**

*Typical data rate: > 1Mbps – ~200Mbps (phy)*



# PLC – in practice

## Narrowband

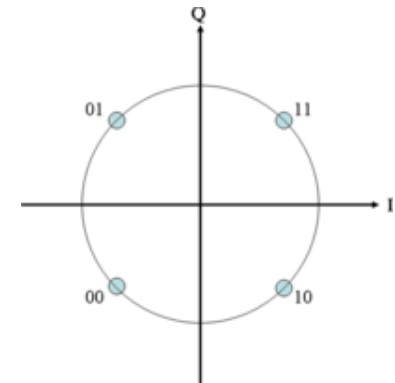


# PLC – in practice

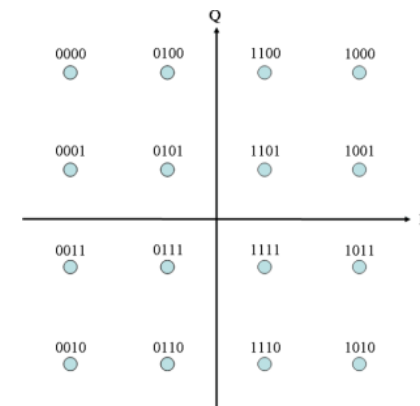
## Modulation (typical)

- **FSK** – Frequency Shift Keying
- **DCSK** – Differential Code Shift Keying (Yitran patent)
- **ACSK** – Adaptive Code Shift Keying (Yitran patent)
- **BPSK** – Binary Phase Shift Keying
- **QPSK** – Quadrature Phase Shift Keying
- **QAM** – Quadrature Amplitude Modulation
- **MSK** – Minimum Shift Keying
- **OFDM** – Orthogonal Frequency Division Multiplexing

QPSK

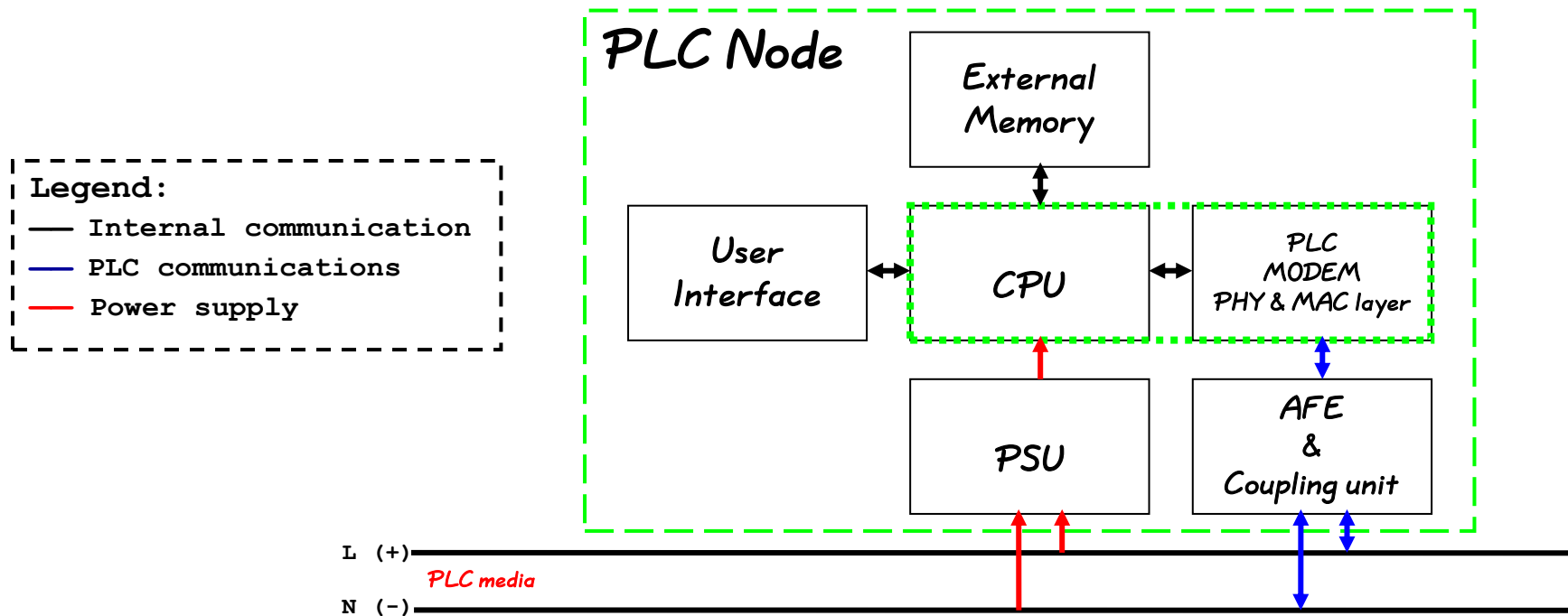


QAM



# PLC – in practice

## How does it work?

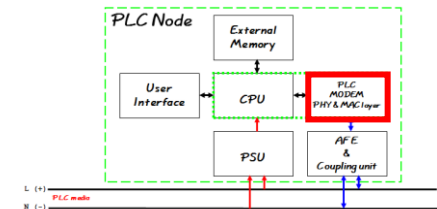


# PLC – in practice

## Physical layer & DLL layer

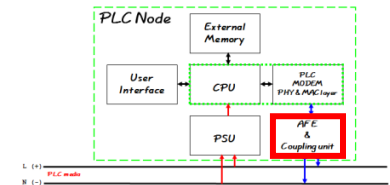
### Functionality and responsibility

- Communication to the PLC media
- Modulation
  - FSK – *Frequency Shift Keying*
  - DCSK – *Differential Code Shift Keying* (FSK Yitran patent)
  - BPSK – *Binary Phase Shift Keying* (Echelon)
  - OFDM – *Orthogonal Frequency Division Multiplexing*
  - ...
- Communication between external CPU  
(RS232, SPI, SCI, Parallel, Eth, etc.)



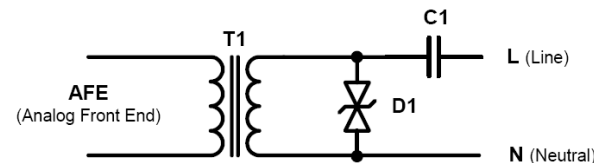
# PLC – in practice

## AFE – Analogue Front End



## Filtering, amplification and coupling to the power grid

- *Capacitive*



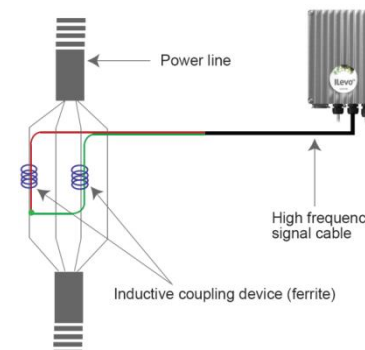
- *Direct connection*

- *Grid must be turned off*

- *Inductive*

- *Contact free connection*

- *Grid does not have to be turned off*



# Three phase capacitive coupling circuit

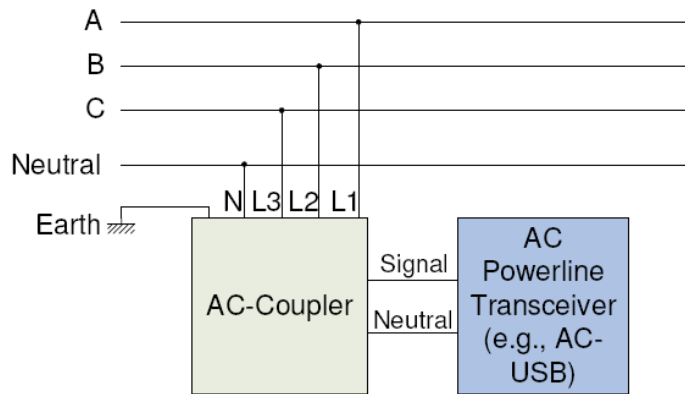


Fig.1 Three-phase coupling unit for AC transceivers

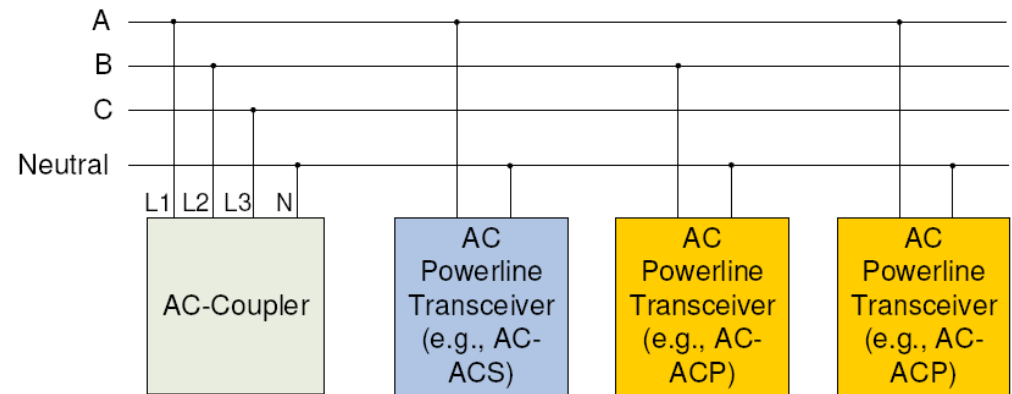
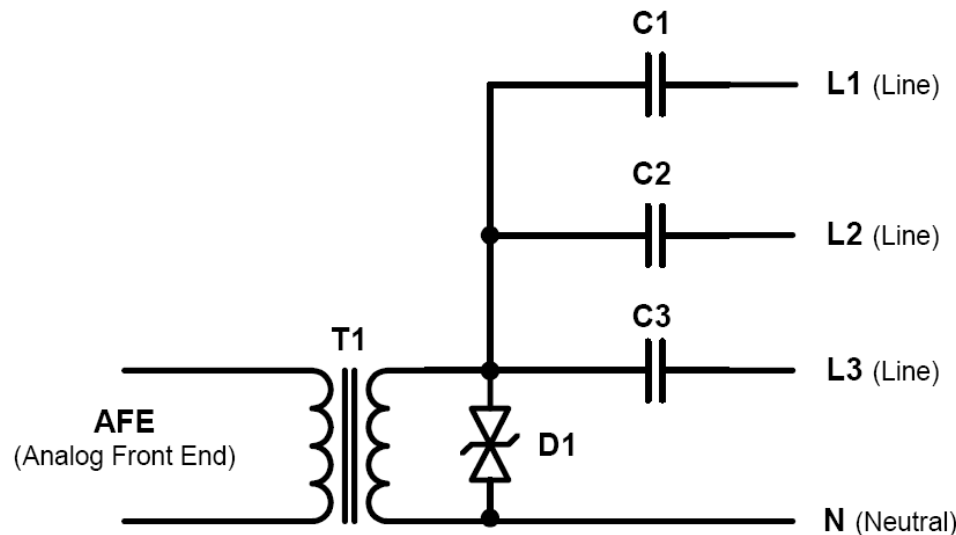


Fig.2 Passive phase coupler



# PLC – in practice

## PLC

- *Advantages*
  - *Easy to install – now new wires!*
  - *Easy to use*
  - *Easy to implement in other systems*
  - *Suitable for all kinds of distributed supplies*
  - *Replaces the RS232 or MBUS wires*
  - *CENELEC standard*
- *Disadvantages*
  - *Connectivity depends on the wired infrastructure*
    - *Phase coupling might be necessary*
  - *Platform dependent/proprietary communication protocol*
    - *It's typically possible to use standard communication and network protocols on top*

# Standardizing

- *Is there a common standard for choosing the right technology for the white goods?*

**NO!**

- *Elsparafonden recommends the Z-wave technology (since it's a Danish product??)*
- *The white-goods from e.g. China – will they have Z-Wave or ZigBee installed (most likely ZigBee)*
- *In Italy PLC is mandatory by legislation in the white-goods.*
- *What about PLC?*
  - *Easy to install "Serial/Ethernet to powerline bridge"*
  - *Nu issues communicating through walls and floors*
  - *Easy to install hybrid solutions e.g. "ZigBee to PLC bridge"*
  - *The white-goods need electric power from the grid – it's already there*
  - *The meters need electric power – most meters still need power from the electric grid*
    - *except e.g. water meter – it's typically battery powered – use a ZigBee to PLC bridge*

# Gateway

