Qualified Partner Programme QPP

Electro Magnetic Compatibility EMC

Felice Guarna

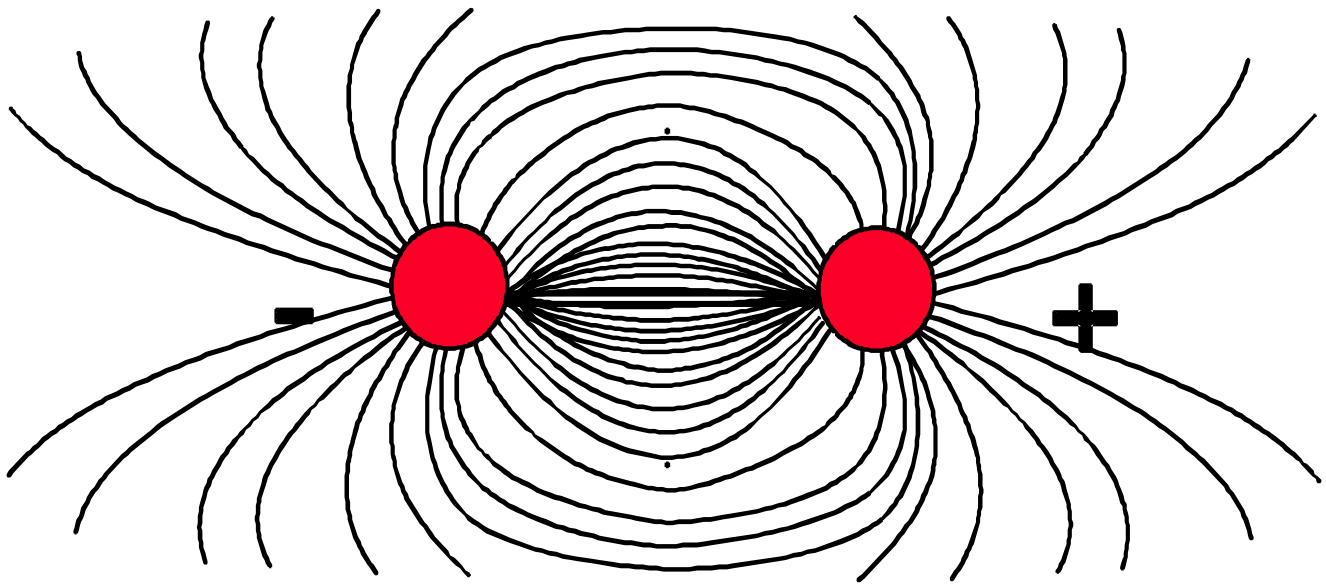
R&M
Convincing cabling solutions

EMC

Part 1: Basics of EMC

Part 2: EMC requirements for passive components

Part 3: Practical comparison tests with UTP and FTP cables

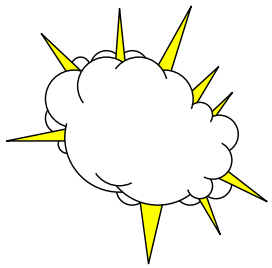


What is EMC?

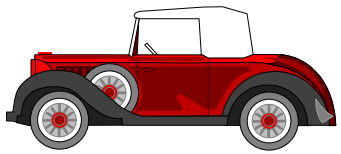
- Electro Magnetic Compatibility is the ability of a device to function without errors in its intended electromagnetic environment
- Devices can be active or passive but both can become victims or source or conductive path for unwanted electrical signals

What can causes EM noises?

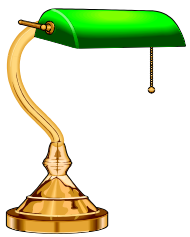
Electrical generators, motors



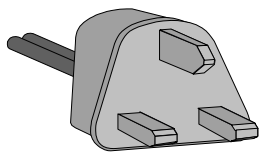
Lightning
cosmic radiation



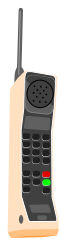
Car
engines



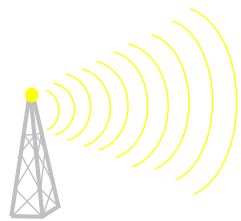
Fluorescent lights



A/C mains/power cables

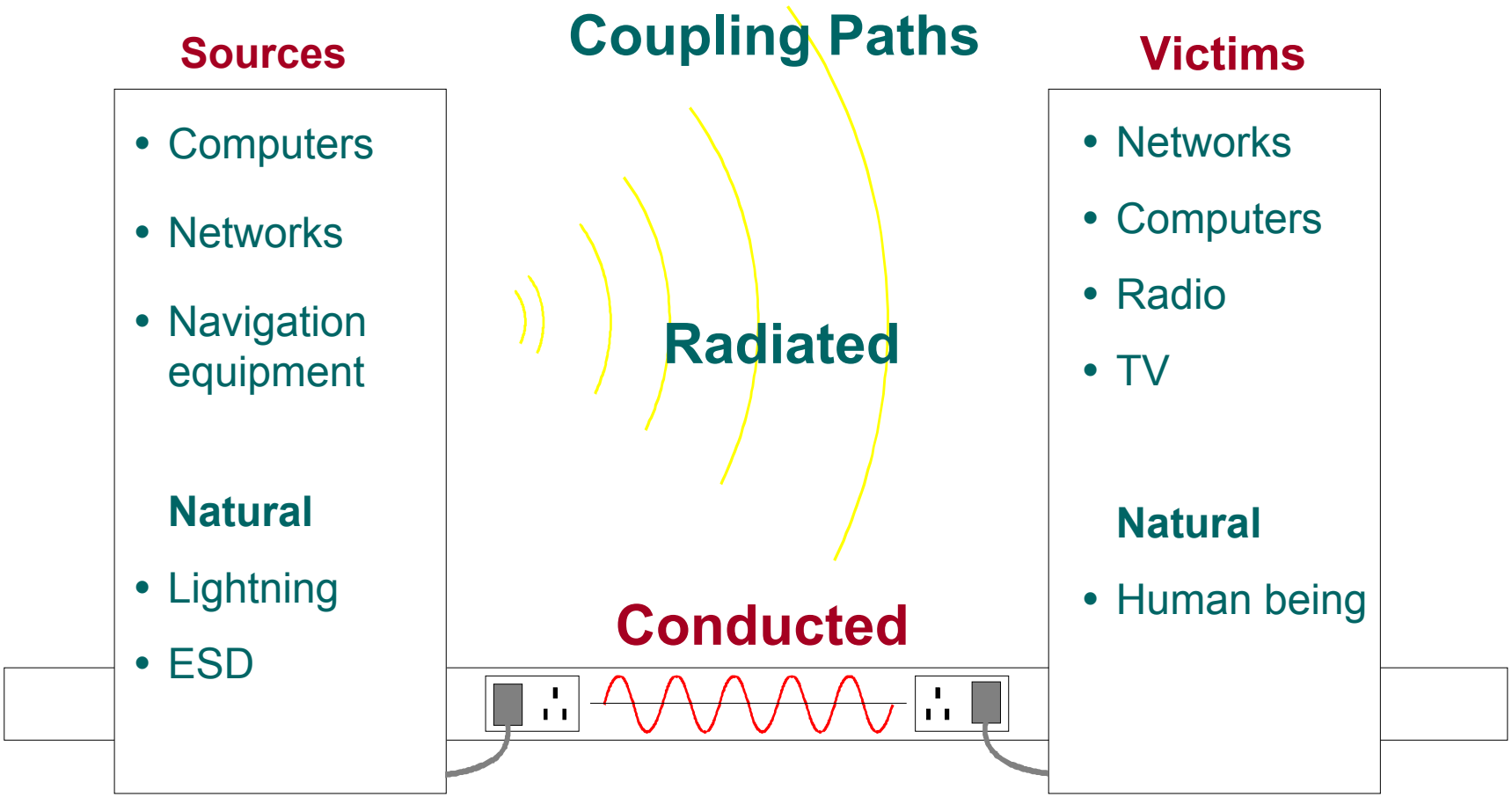


Mobile phones

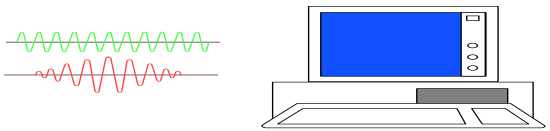


Radar/microwave
transmissions

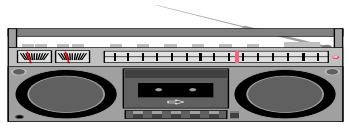
Coupling model



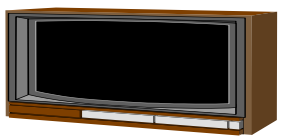
Symptoms



High bit error rate



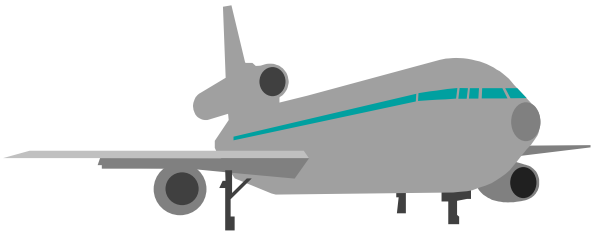
Tape deck hum



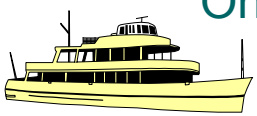
TV flicker

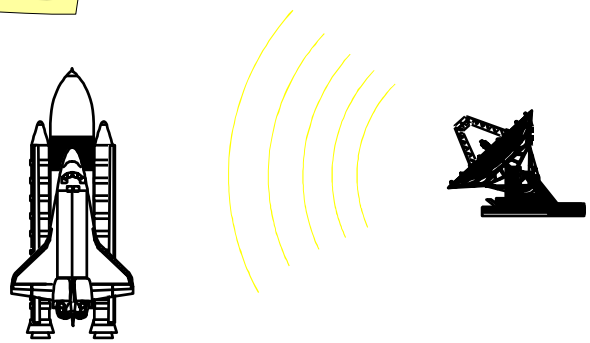
Hiss on AM radios

More serious problems

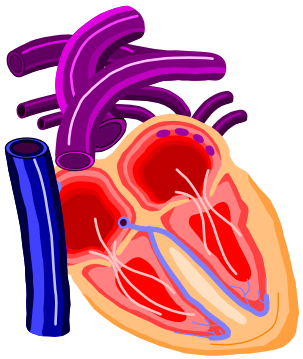


Onboard computers

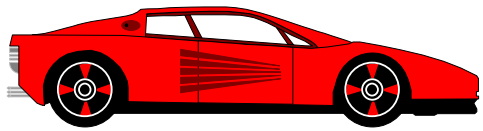




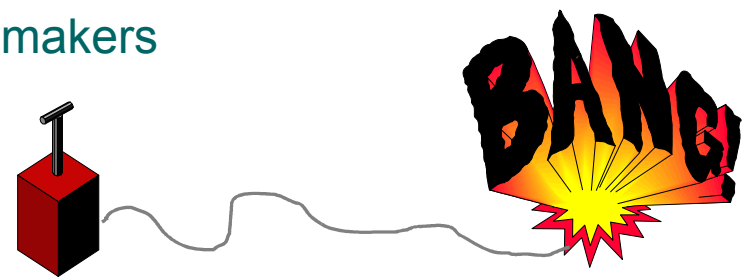
Navigation & tracking



Pacemakers



ABS braking



Remote detonation

EMC directives and norms

EC guidelines

- 89.336.EC guideline for assimilation of statutory requirement of member countries, concerning electromagnetic compatibility (1/96)
- EN55022 limits and methods for radio interference of information transmission equipment
- EN50081-1 EMC generic emission standard
- EN50082-1 EMC generic immunity standard
- prEN55024-4 limiting value of interference voltage on data transmission cables
- Others under discussions since long time but not yet agreed!

EMC standards for passive devices

- Only EMC standards for active devices today
- **NO** EMC standards for passive devices (cables and connectors)
- EN 50174-2 giving some direction for cabling installation
- EN 50310 giving directions on grounding and bonding
- Draft for measurement and classification of passive devices in discussion

EMC compliance for passive components?

Measurements require perfectly defined environment and:

Test Setup:

Emission: Location of antenna

Immunity: Location interference source

Both: Not interfering environment

Routing of the connection media

- Transmission protocols/applications

=> Overcome these problems by performing comparison tests (UTP versus FTP)

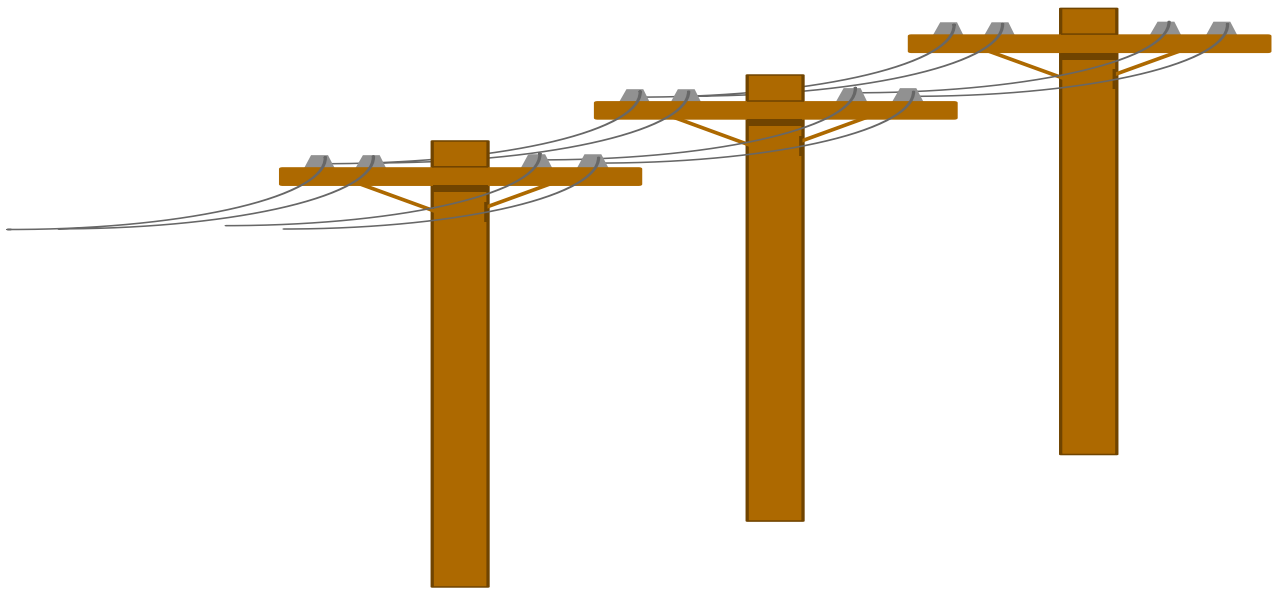
What is important in a cabling system?

Being in control ...

- Cables and connectors
- Equipment
- Operations
- Environment/Installation

EMC and cabling

Cables are important because they are the longest parts of a system and therefore act as antennas that pick up radiated noise along the route.



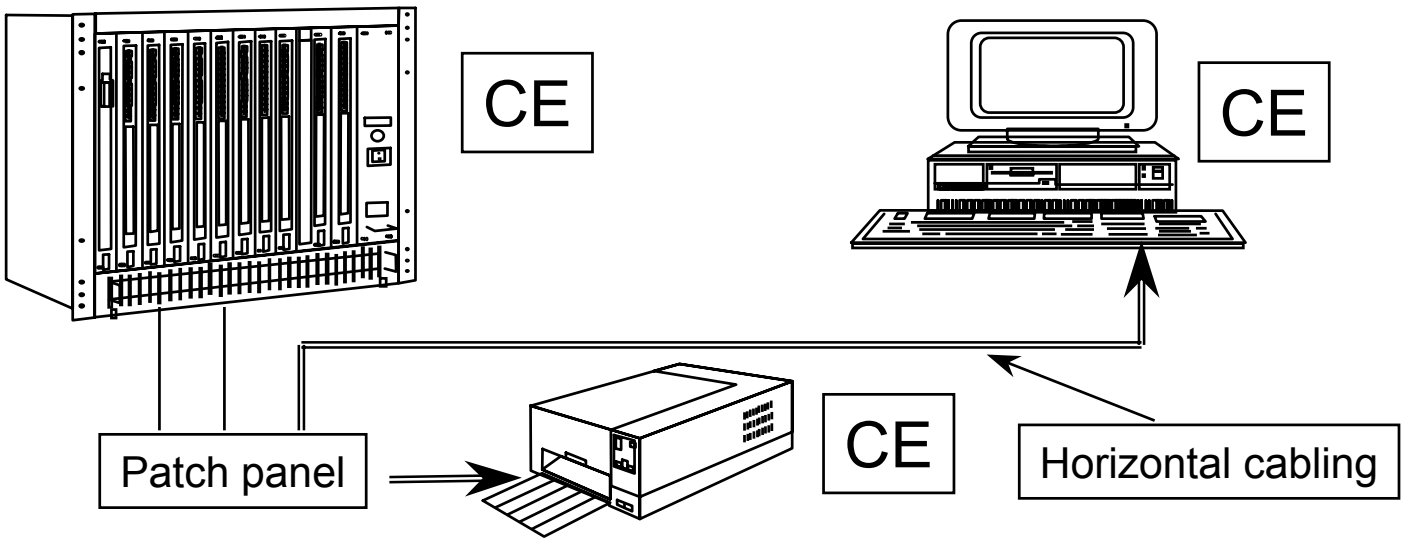
EMC and environment

Do we have control over the environment?

- Density
- Type (rural, residential, industrial…..)
- Development and infrastructure (high energy consumption)

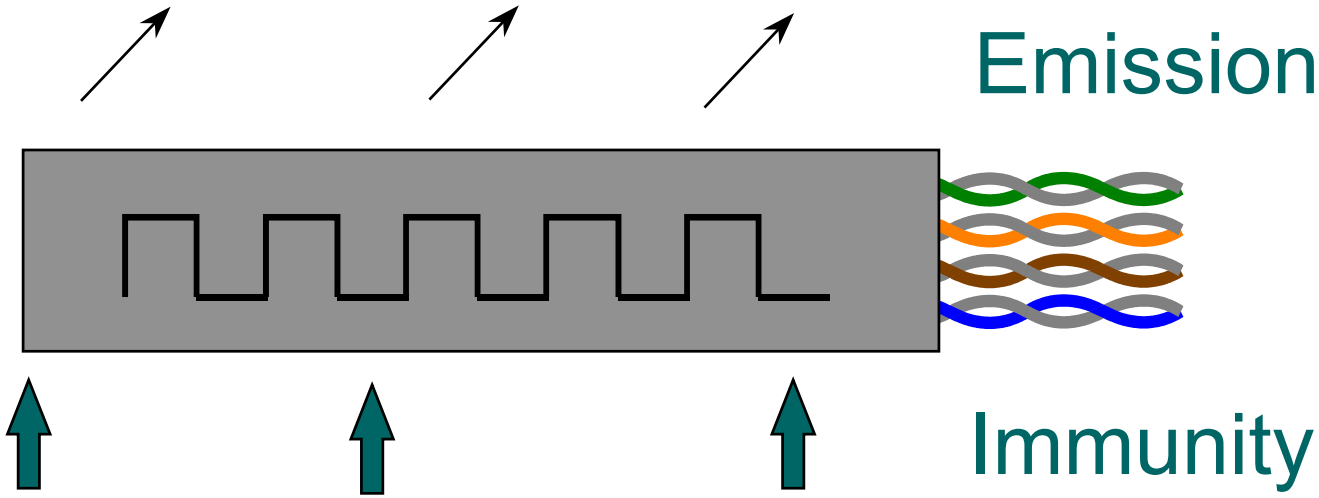
- Static or developing ….
- Today and tomorrow

EMC and equipment



Target:
Minimum emission
Maximum immunity

EMC: emission and immunity

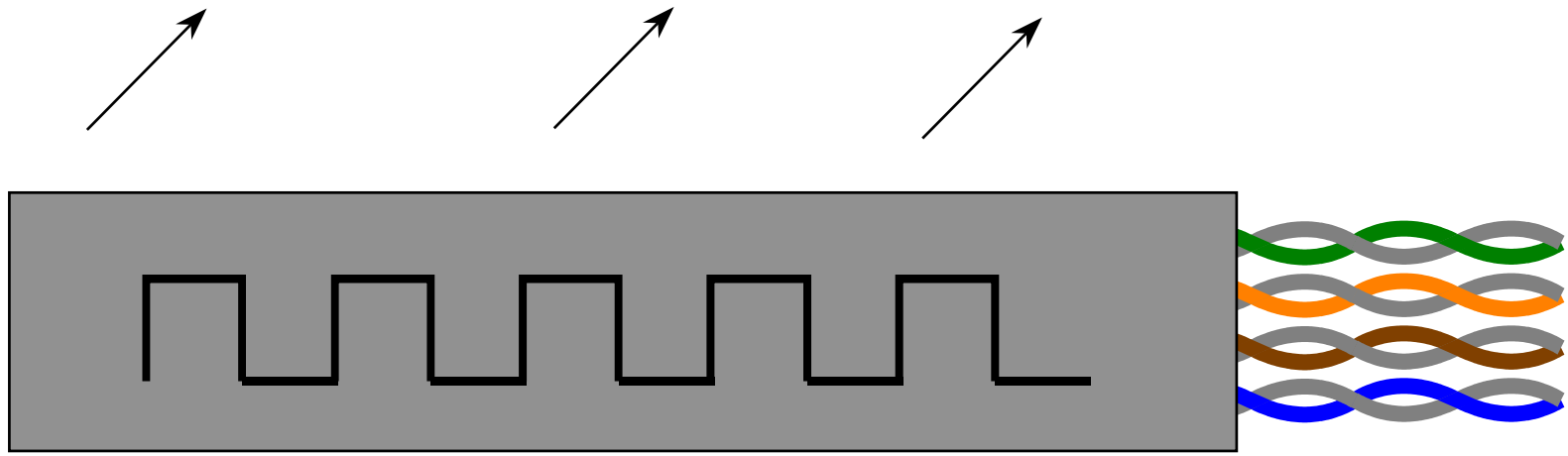


- Immunity > affecting my system performance
- Emission > affecting other system performance > legal requirement

- EMC target: Low emission and high immunity

Radiated emission

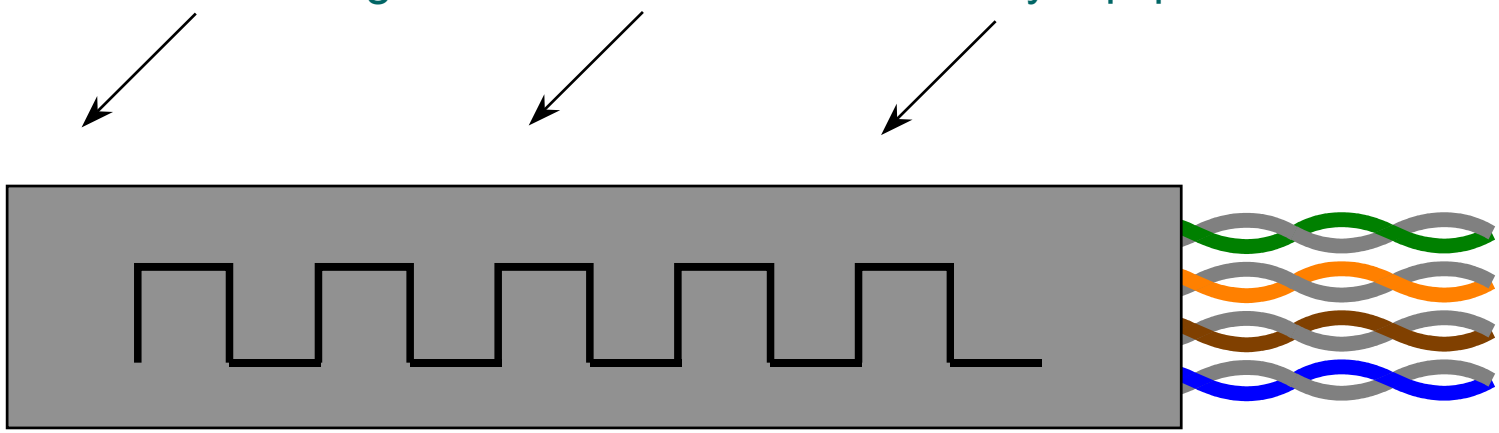
- Digital data **signal** are fast with wide spectral response (Fourier transformation), but small amplitude.
- Controlled through line **balancing** and using twisted pair or coax cables.
- However for twisted pairs becomes more of a problem as frequencies increase, typically above 30 MHz.



Immunity against radiated emission

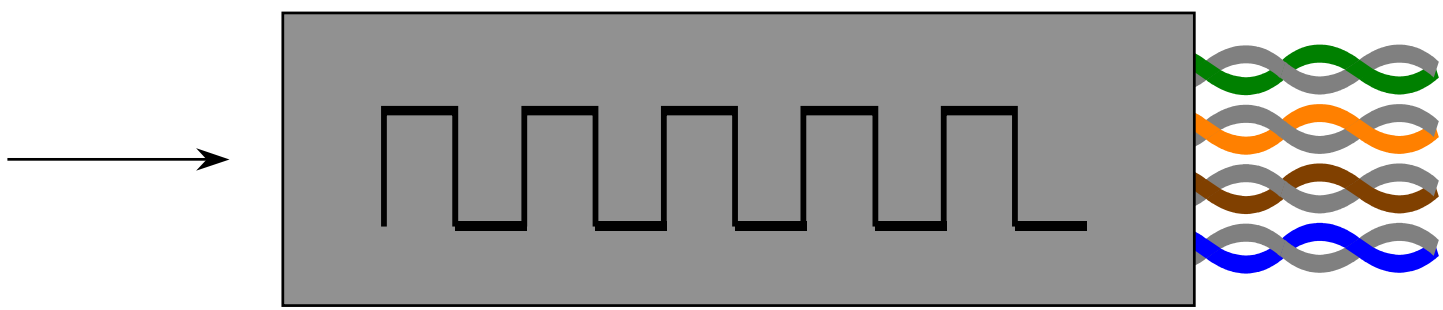
- Little or no control of radiating source.
- Level of disturbance/disruption unpredictable.
- Results in data corruption, loss, machine retries at the best.
- **Controlled by:**

  - Shielding
  - Line Balancing
  - Twisted pair/Coax
  - Error Correction by equipment

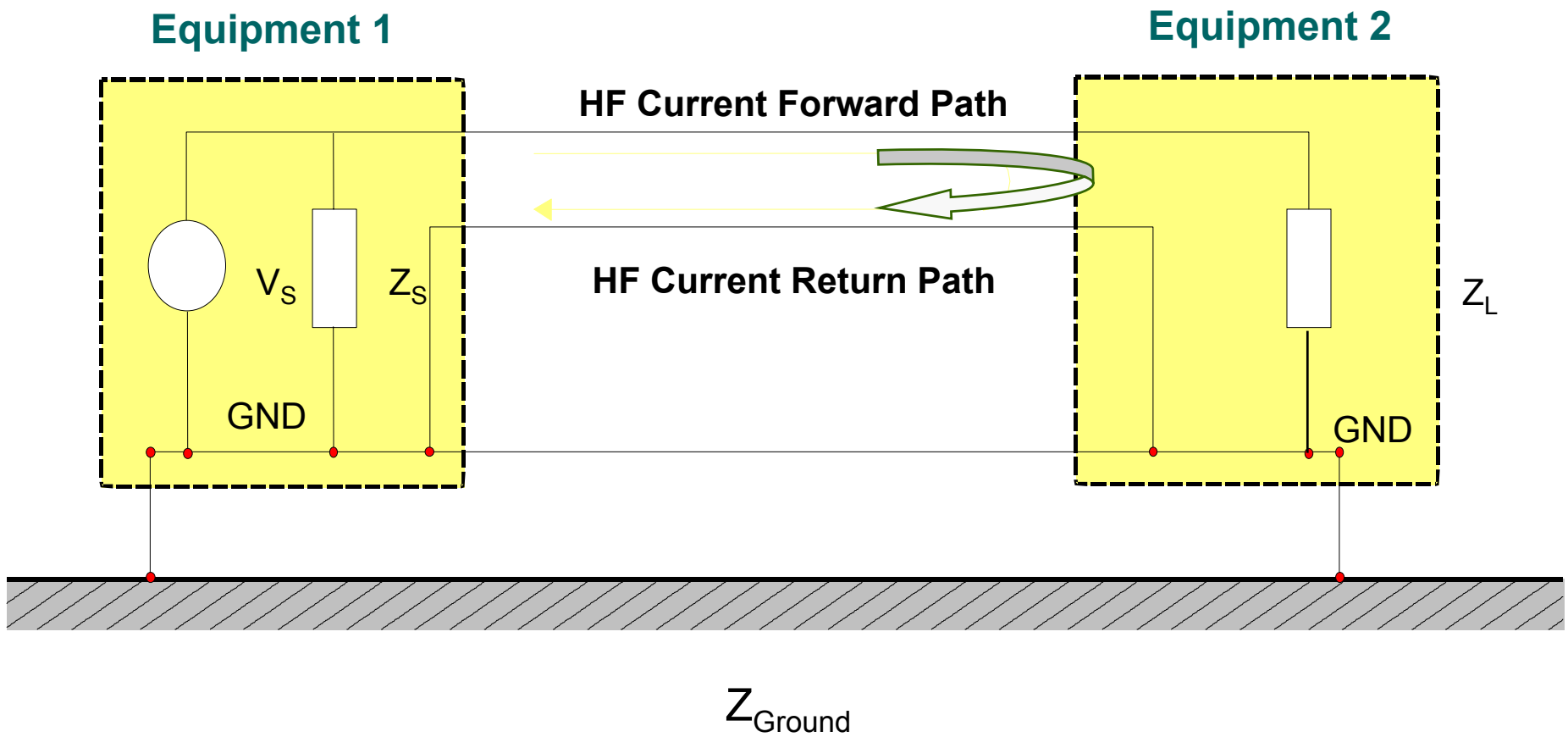


Conducted emission & immunity

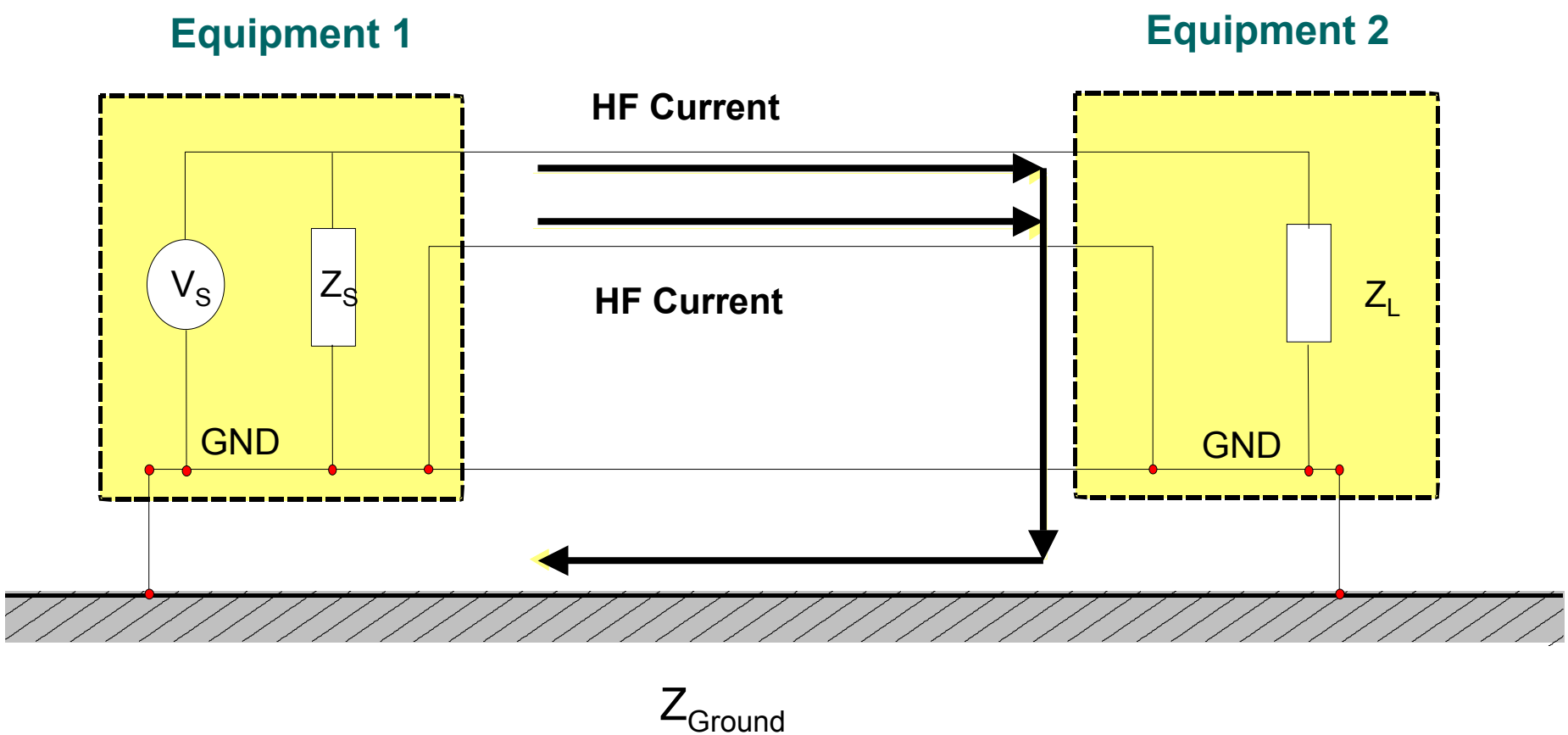
- Caused by inductive coupling from power lines.
- Noise voltage normally coupled into system through power cords of active devices.
- Cabling affected only by proximity effect.
- Controlled at equipment by filtering, and use of suppression devices.



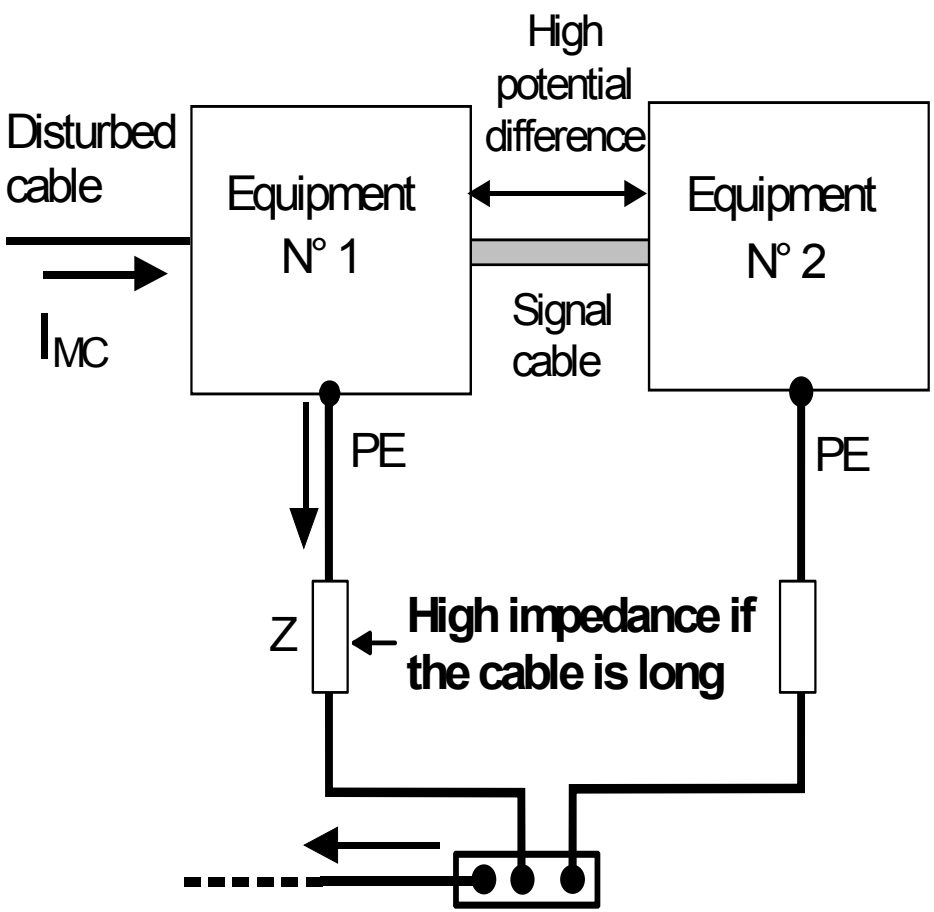
Differential mode noise

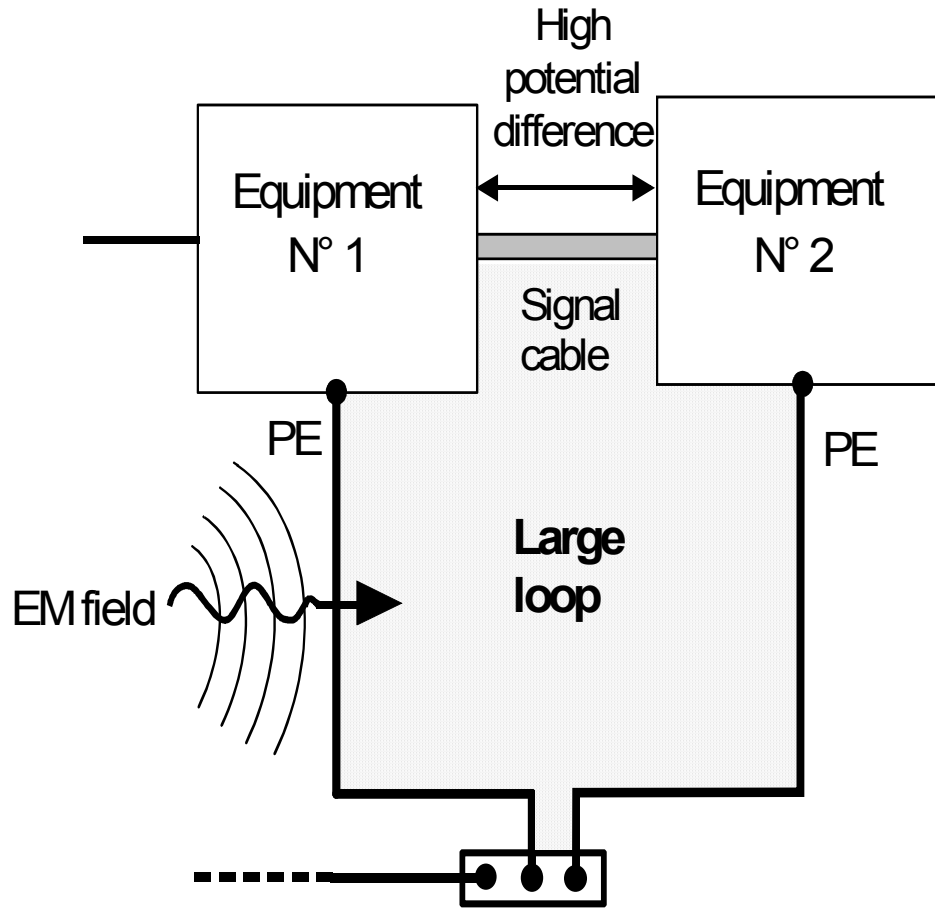


Common mode noise

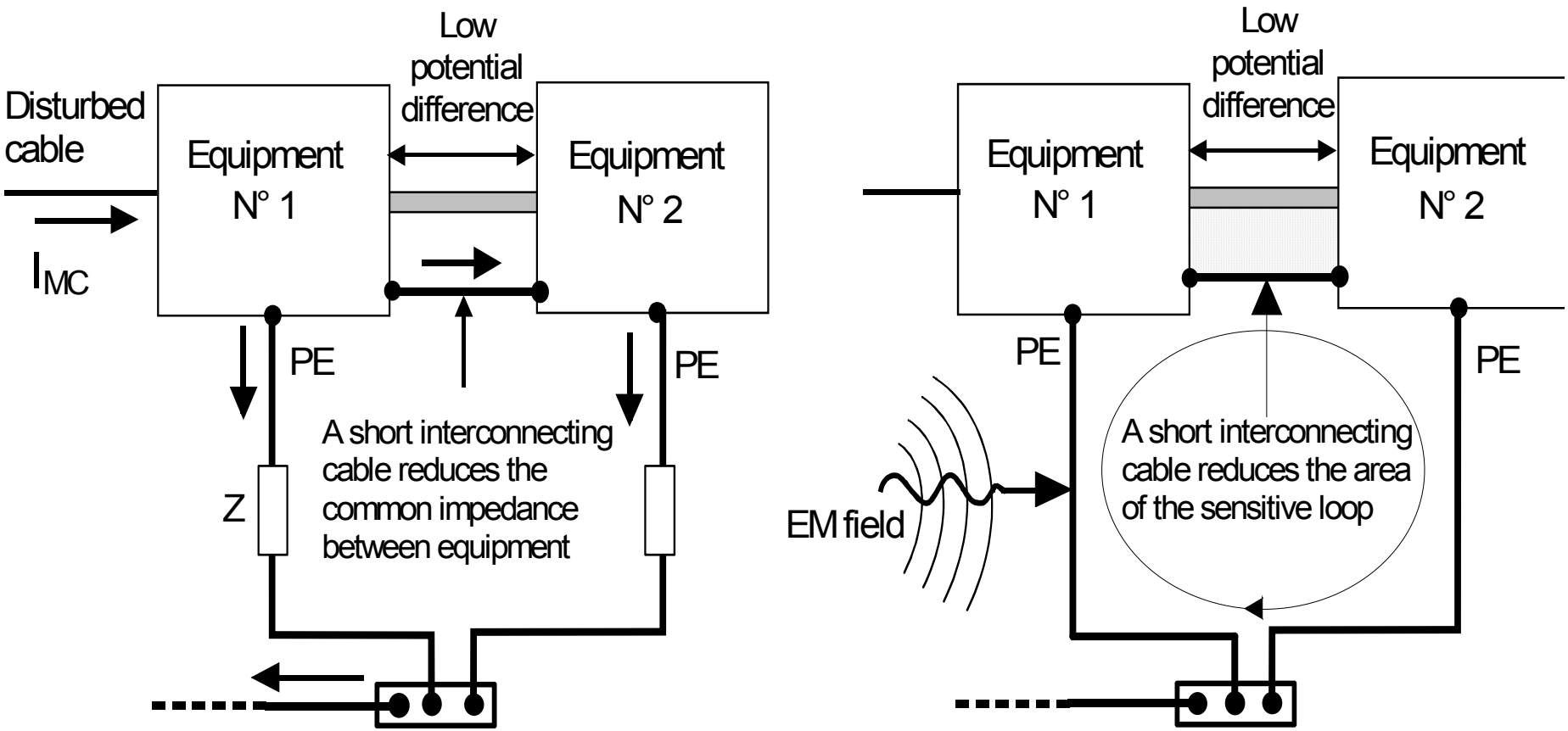


Ground loop


Disturbed cable
Equipment N° 1
High potential difference
Equipment N° 2
Signal cable
I_{MC}
PE
PE
Z
High impedance if the cable is long


Equipment N° 1
High potential difference
Equipment N° 2
Signal cable
PE
PE
EM field
Large loop

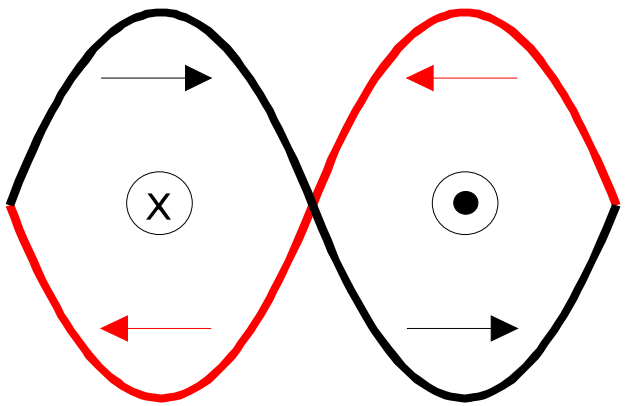
Ground loop-countermeasure



Field cancellation

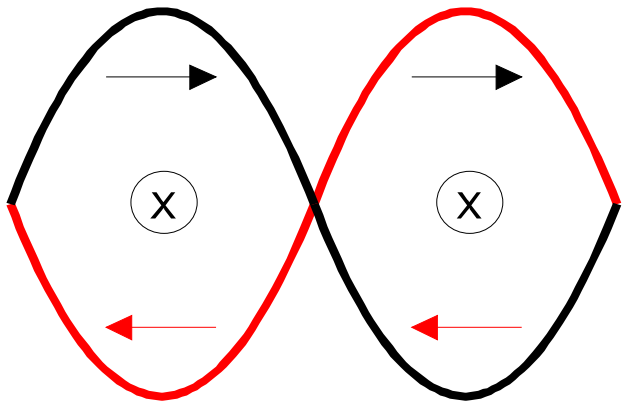
Twisted pair (below 30 MHz)

Conducted radiation
Differential mode
H-Field cancellation



Improve emission

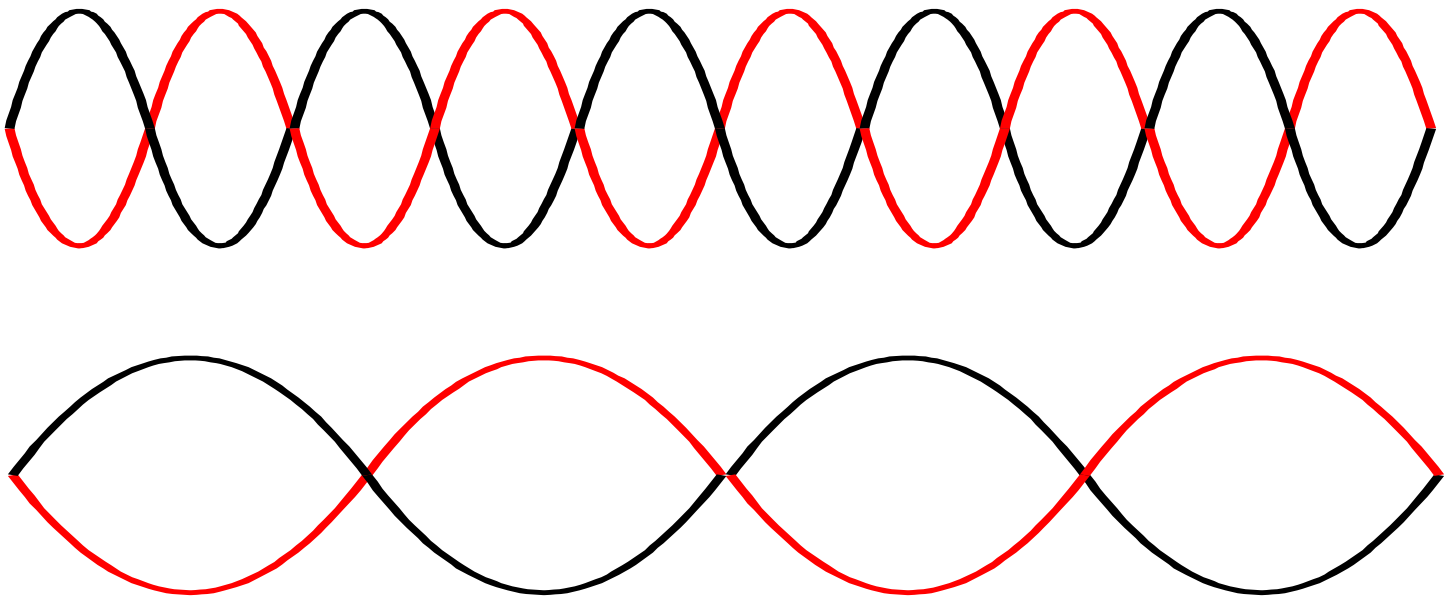
Immunity against
H-Fields



Improve immunity

Twisted pairs (< 30 MHz)

Short lay length imply more points of H-Field Cancellation:
=> Lower emissions/Higher immunity



Summary: Field cancellation

Twisted pairs can protect against H-Fields below 30 MHz.

Above 30 MHz twisted pairs lose field cancellation effectiveness and begin to radiate due to:

- Increased reflections from twists.
- Antenna effects from increased inductive impedance ($Z_L = 2\pi f Lc$)
- Decrease impedance (capacitive) pair to ground

Twisted pairs are not effective against common mode noise.

Ref. study: E.B. Joffe/A. Axelrod

0-7803-1398-4/94/0000-0087 1994 IEEE

So where are the limits of UTP?

Impossibility of too much twisting

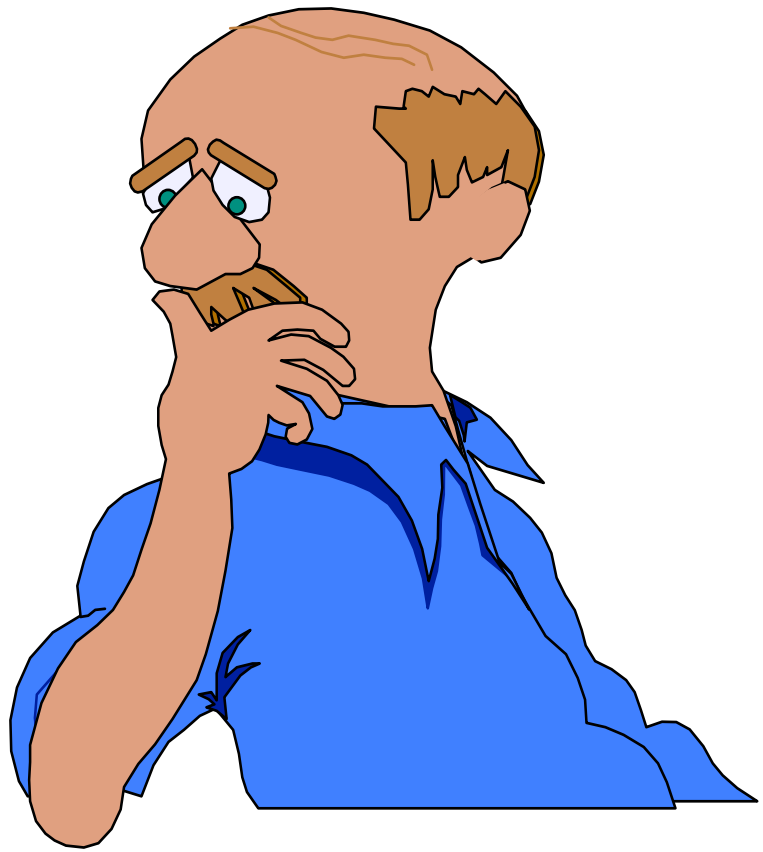
Impossibility of making all twist the same

With today data cable construction:

limit at 30 MHz

Cables bandwidth:

- Cat. 5 <-> 100 MHz
- Cat. 6 <-> 250 MHz
- Cat. 7 <-> 750 MHz (only shielded)



Cables protection

The best protection against E-and H-Field:

- Use balanced lines (twisted pairs)
- Aluminium foil shield only grounded at one end to communication earth. (At patch panel side)
- Use a coupled earth on other end of aluminium shield (active equipment and or N.I.C.)
- Additional tinned-copper braid

Summary (EMC basics)

- EMI causes data corruption that generates machine recovery procedures and consequently degradation of system performance
- UTP cables can be used when data signal **and/or** the interference signal has a frequency 30 MHz.
- Above 30 MHz additional EMI protection is required. Being this in the form of properly grounded shielded cabling or metallic grounded conduits.

Which system to use?

- Security
  - Level of security required
  - Bit rates - high speed
- Frequency
  - Is signal frequency above 30 MHz?
  - Are frequencies of disturbance sources above 30 MHz?
- Separation
  - Distances (parallel power cables, active equipment's) can be maintained?
- Installation
  - Are cable ducts metallic and bonded to earth?
- Environment
  - Level of disturbance sources. Type and frequency.
- Applications
  - Are application well defined? Will be changed in the future?

End Part 1

EMC protection

- Twisted pair cables
  -> 30 MHz limitation
- Screening the cables and connecting hardware
- Separation between power and data cables
- Grounding and earth bonding

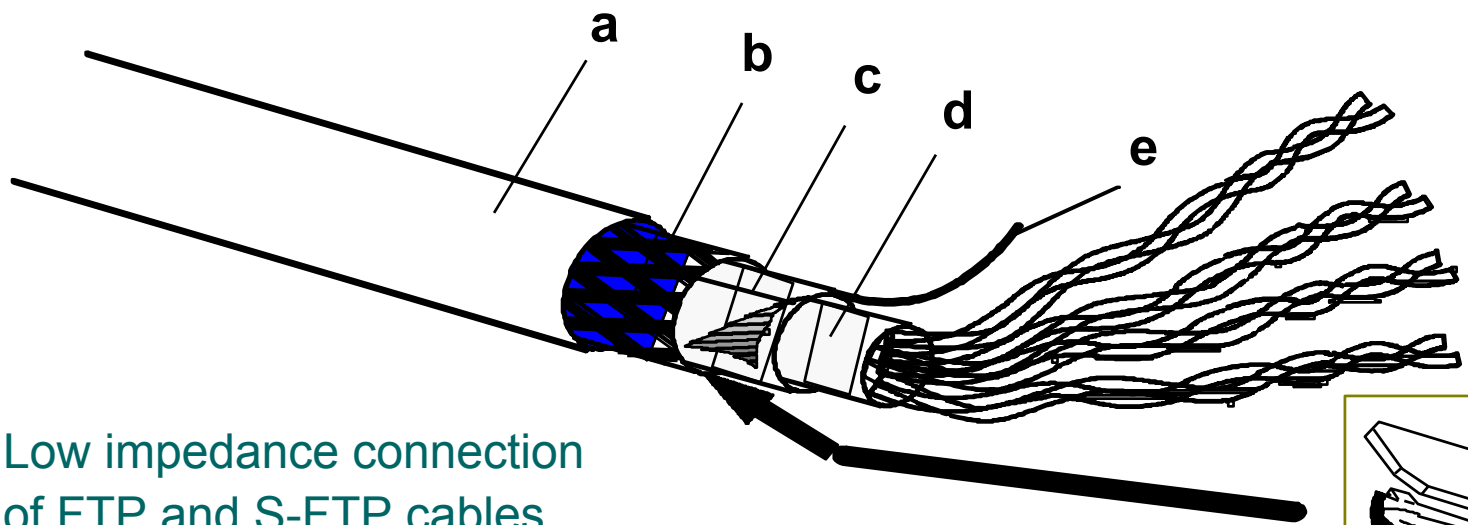
Screening

Screening offers the best EMC protection for a cabling system.

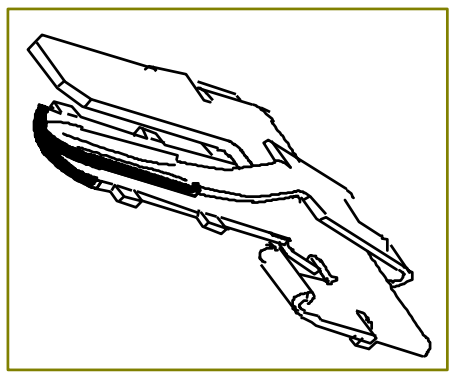
What are the requirements on the

- Cable
- Connecting hardware

Connection of horizontal cables



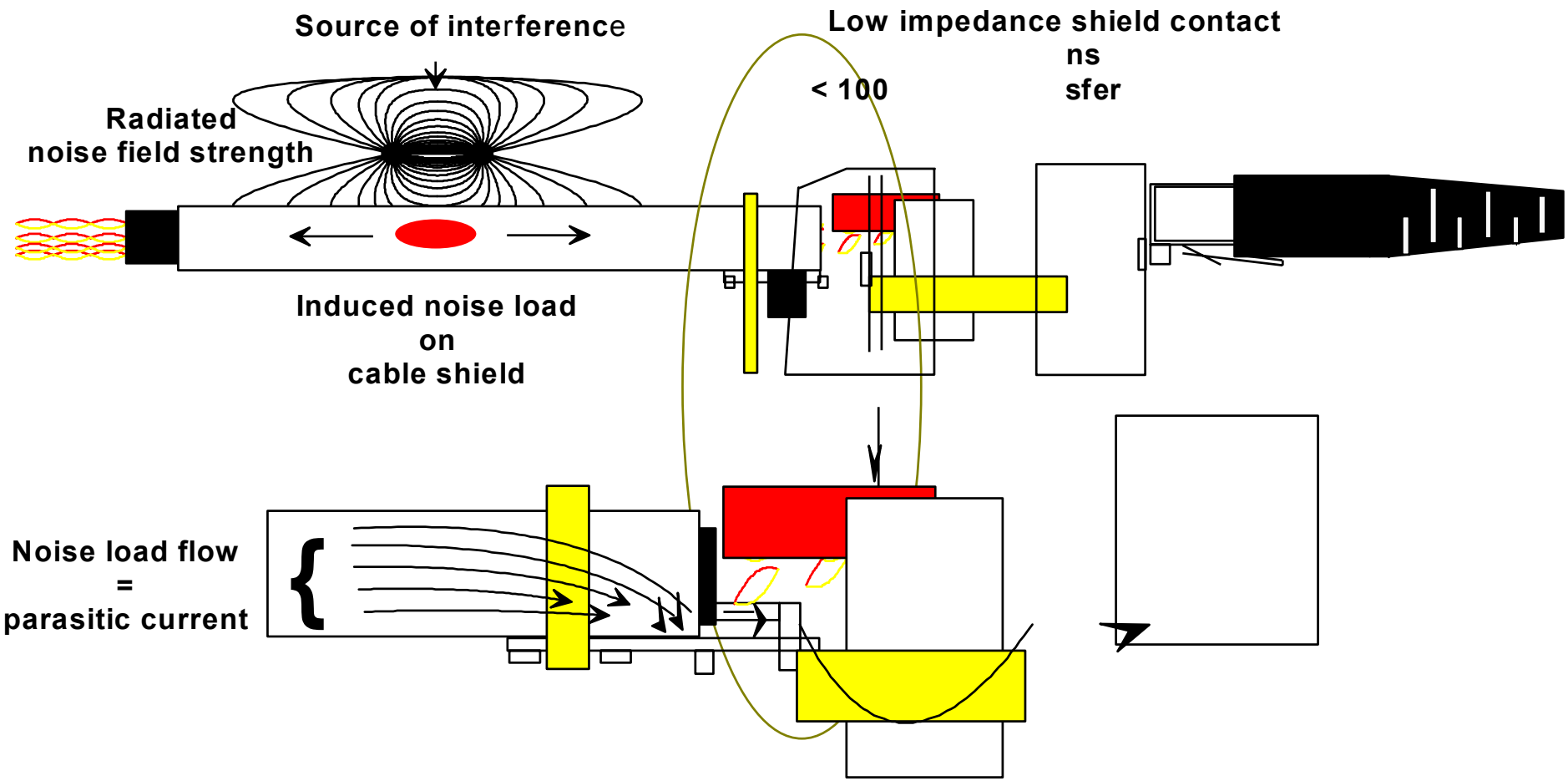
Low impedance connection
of FTP and S-FTP cables



Connection module
shield tongue

Efficient strain relief
and large contact
surface guaranteed

Shield continuity through the link



360 degree protection

Screen coverage:

- The screen coverage has to be 360 degree over the whole link.

Screen connection:

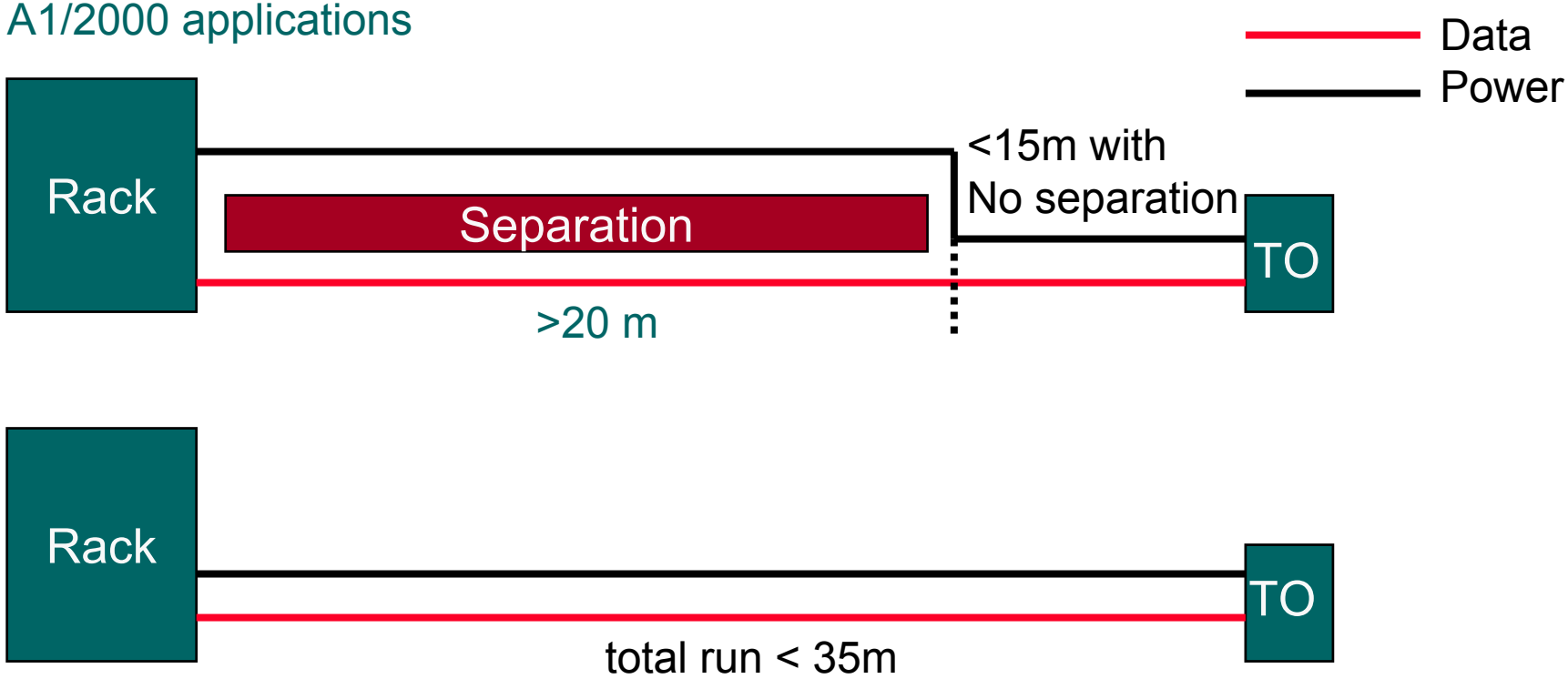
- The connection between the cable shield and the connecting hardware has to be over a large surface area to assure low impedance. 360 degree connection is not required

- Drain wire must be connected (EN 50174 new requirement!)

  Drain wire if present must be in contact (with **R&Mfreenet** bayonet)

Power and data cable separation

Assuming: EN 50081/82 apply to environment. Data cabling supporting EN50173 A1/2000 applications



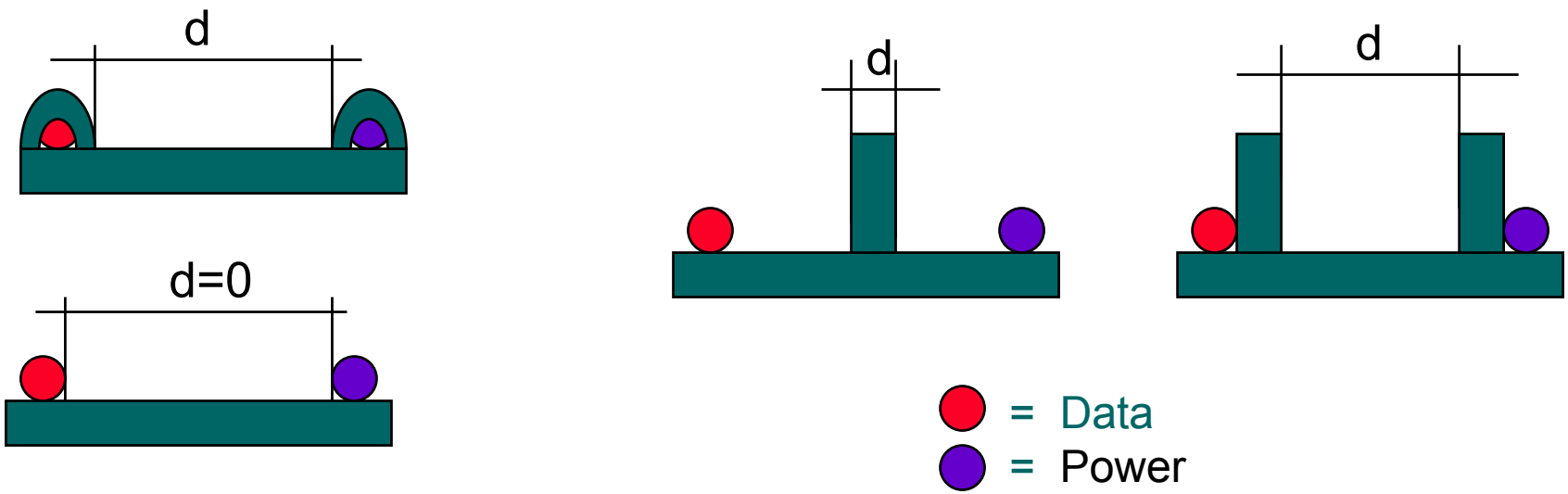
Power and data cable separation

Assuming: environment exceeding limits of EN 50081/2

distance = distance between cable fixing points if present

distance = divider thickness if cable fixing point not present

distance = distance between dividers if cable runs in non adjacent conduit or compartments



Power and data cable separation table

Installation		Distance d	
	Without divider or Metallic divider	Aluminium divider	Steel divider
Both cables unscreened	**200 mm**	**100 mm**	**50 mm**
Unscreened power Screend data	**50 mm**	**20 mm**	**5 mm**
Screened power Unscreened data	**30 mm**	**10 mm**	**2 mm**
Both cables Screened	**0 mm**	**0 mm**	**0 mm**

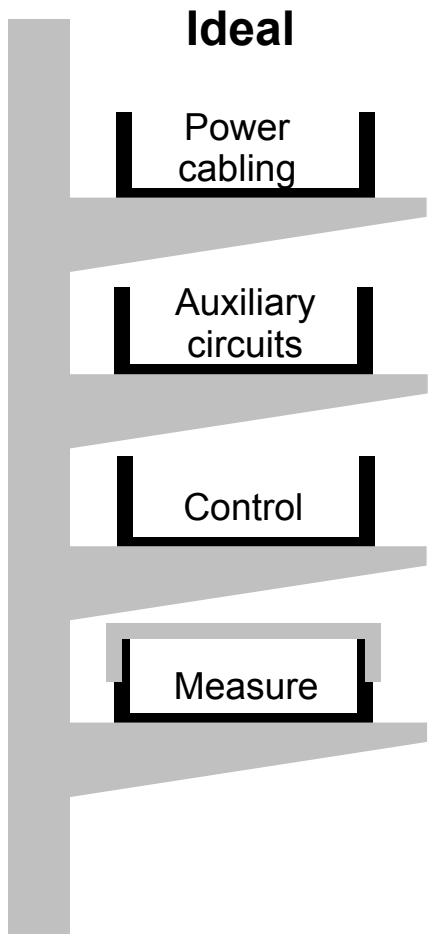
Cable separation

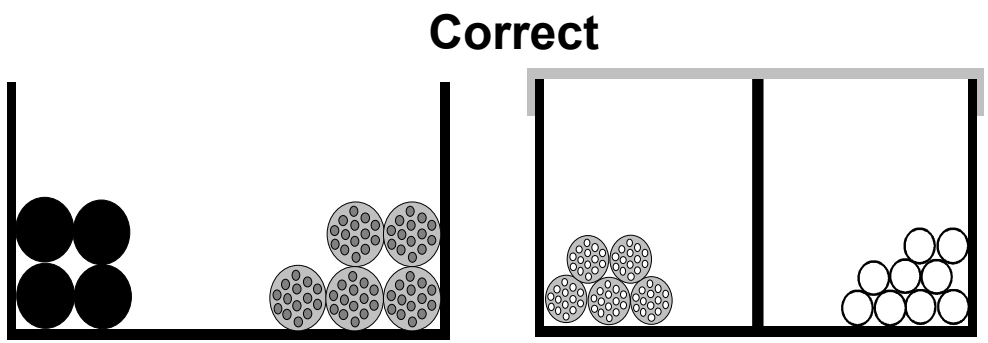
Power cabling

Auxiliary circuits

Control

Measure

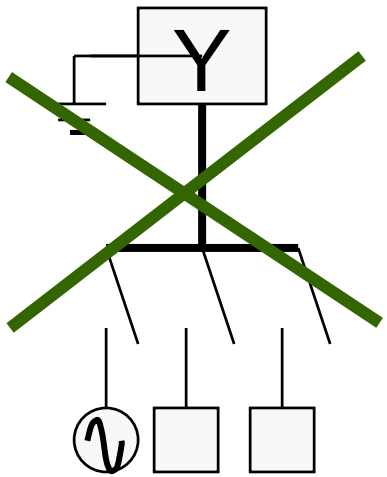


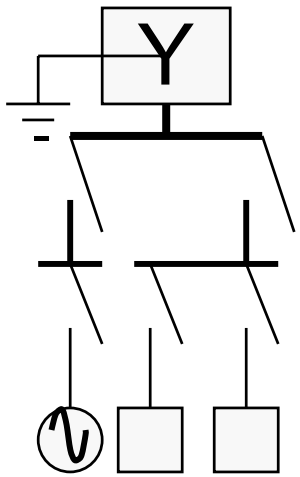


Metallic cable trays

Picture from EN 50174

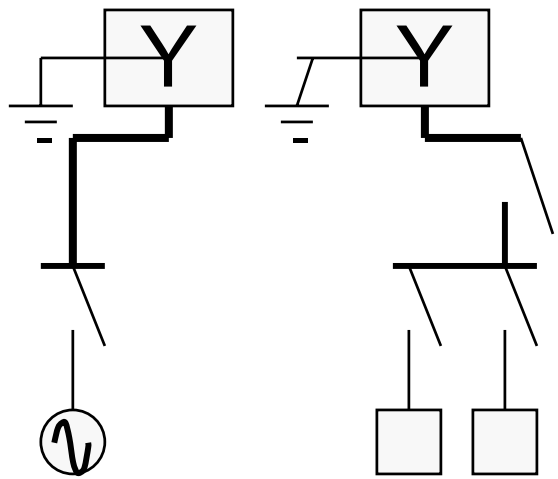
Power and data separation





Acceptable

- Keep equipment supply as much as possible separated
- Segregate supply of disturbing equipment from victims supply



Ideal

Earth bonding and grounding

Communication earth:

- The communication earth is bonded to a central building earth together with the power/safety earth.

- The communication earth is connected to the earth kit of the patch panel at the other end.

System ground:

The system ground is the ground potential of the active equipment/PCB board.

Power/Safety earth:

The power/safety earth is used to connect the frame of a rack, any metallic part (if not double insulated) and equipment power supplies.

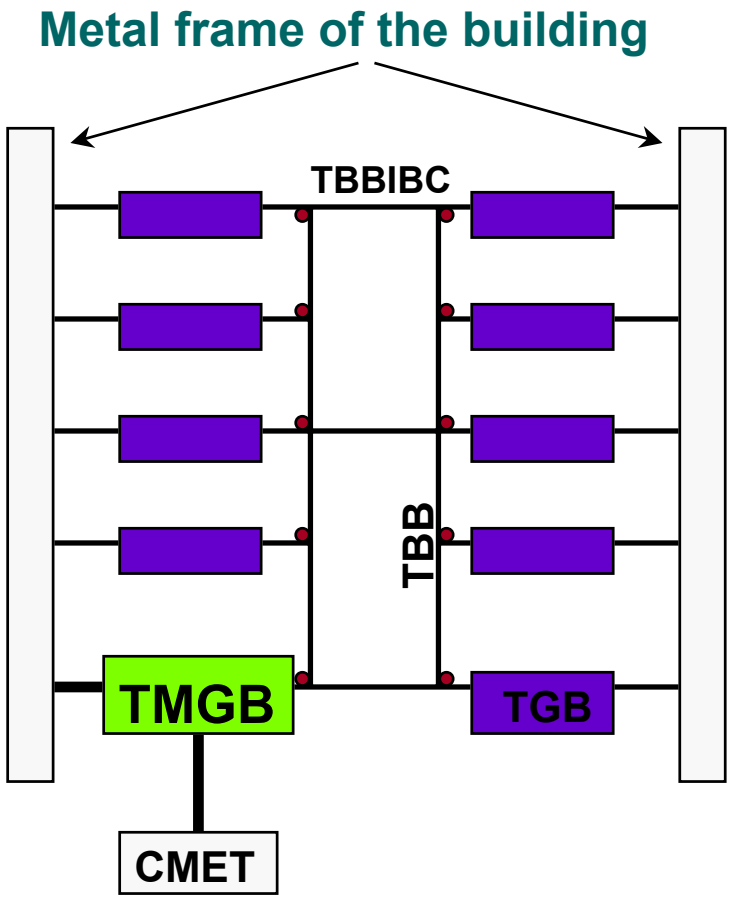
Earth bonding and grounding

Standards regulating earth bonding and grounding

- EIA/TIA 56
- EN 50310 Draft 11/1999 "Application of equipotential bonding and earthing in buildings with information technology equipment"

- EN 50174-2 "Installation planning and practice inside buildings"
- HD 384 series "Electrical installations of buildings"

Telecommunication grounding



- TMGB telecommunication main ground busbar- One per building, in the building distributor
- TGB telecommunication ground bus-bar One or more per floor distributor
- TBB telecommunication ground backbone **Cable shield is not TBB**
- TBB to be green/yellow insulated cable of min. 3 AWG, depending on carrying current could be 0
- TMGB and TGB to be connected to panelboard

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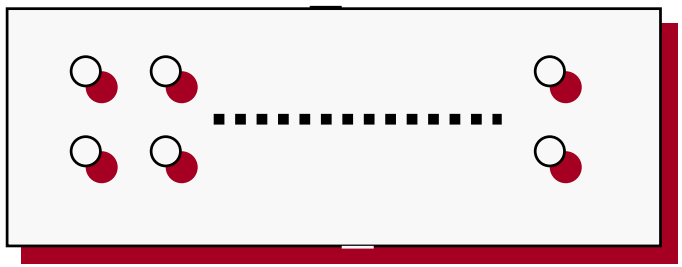
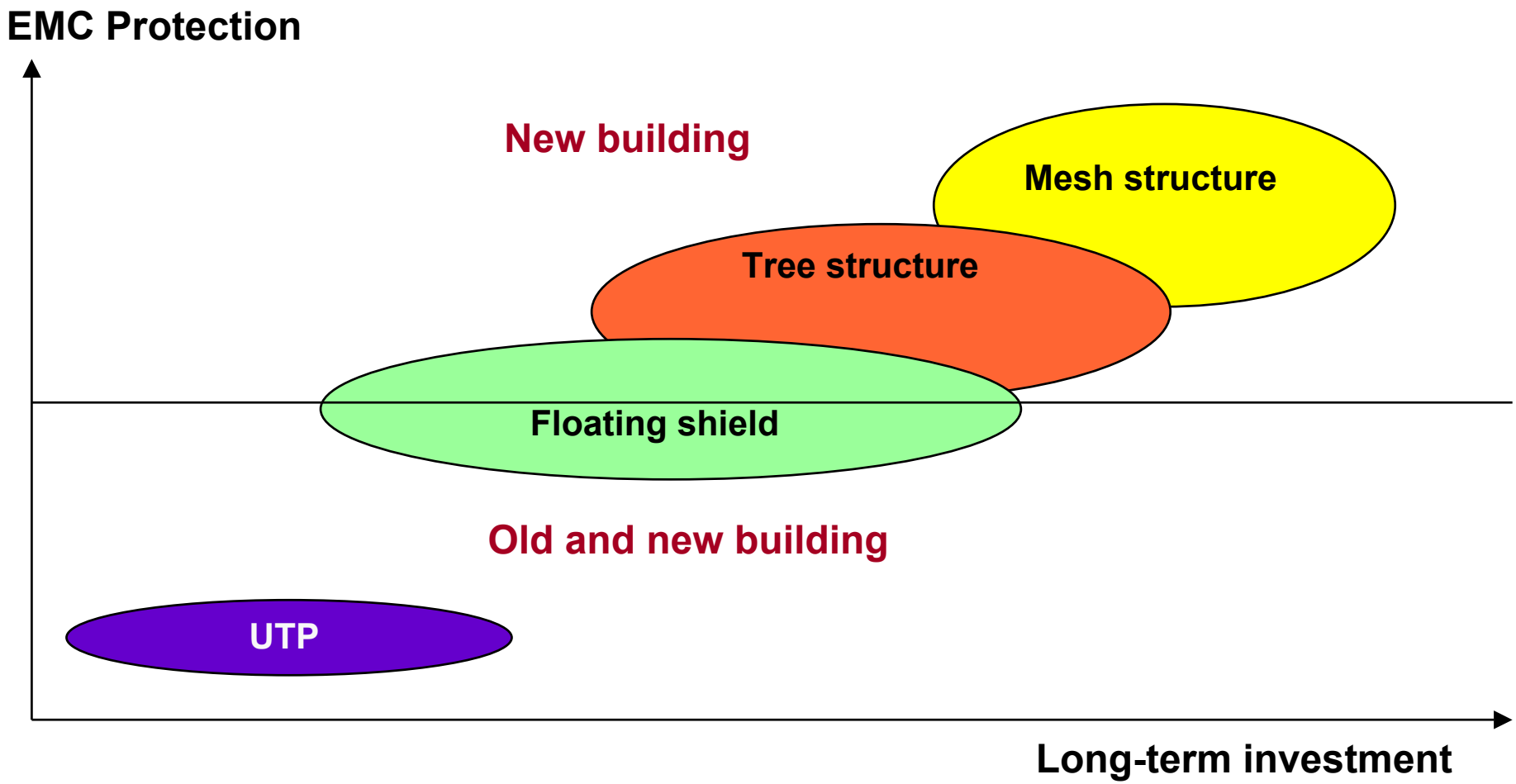
Convincing cabling solutions

TMGB and TGB characteristics

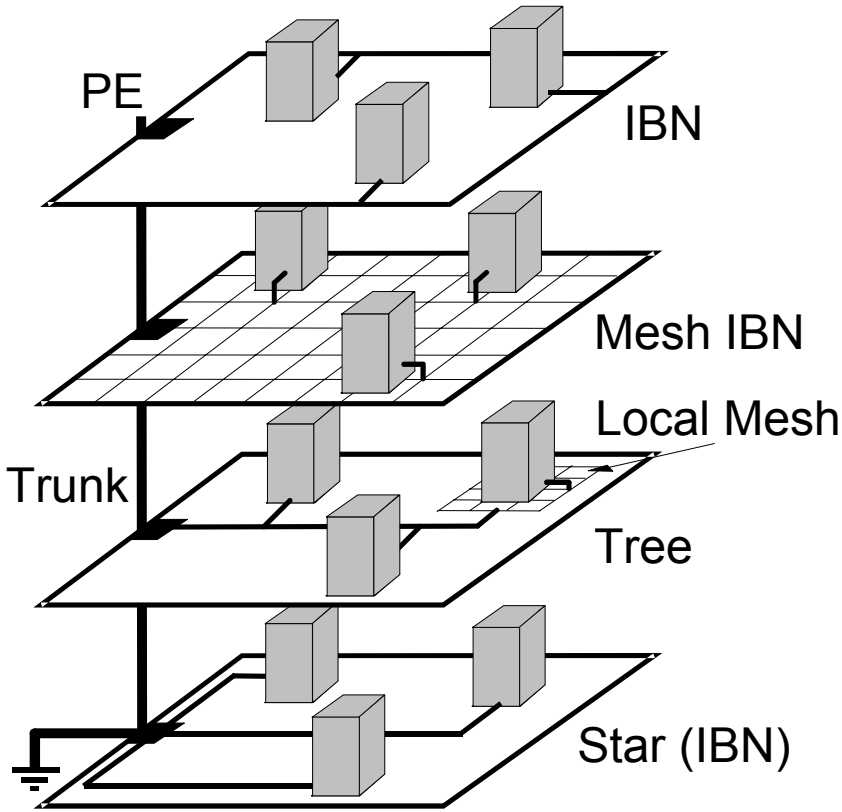


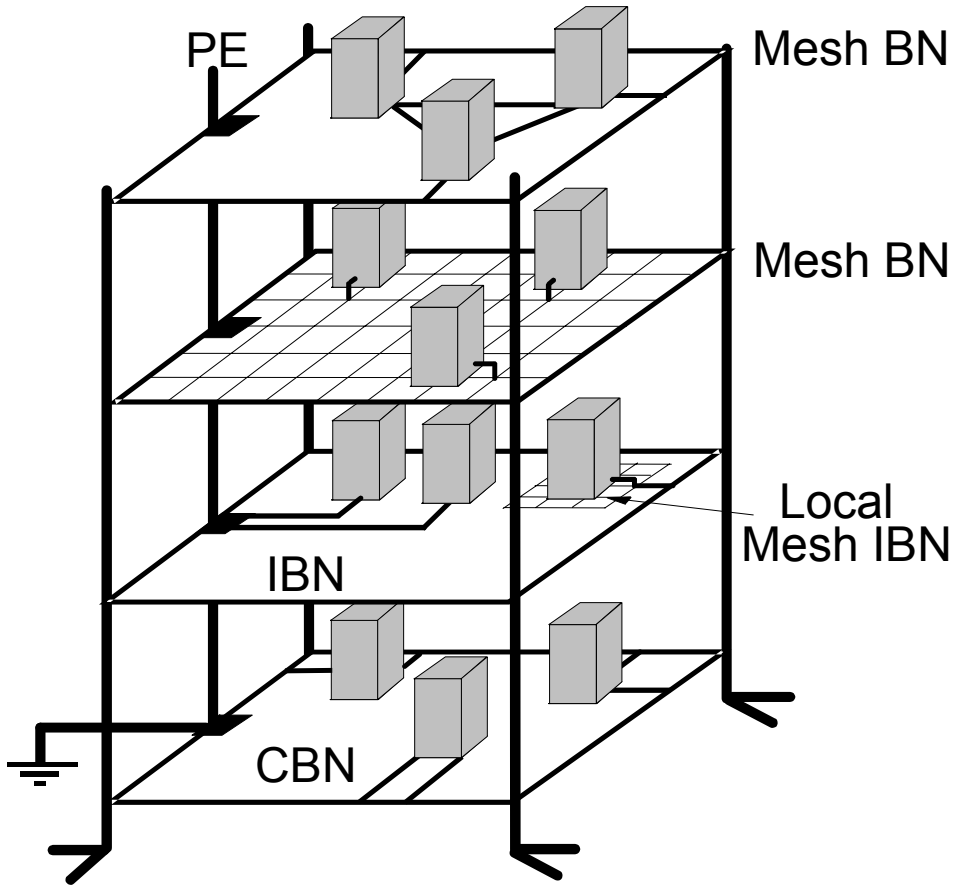
- Conductive and tin-plated
- Pre-drilled
- Isolated
- Variable length
  - TMGB min 100 x 6
  - TGB min 50 x 6

Possibilities of grounding



Types of grounding structures





Picture from EN 50174-2

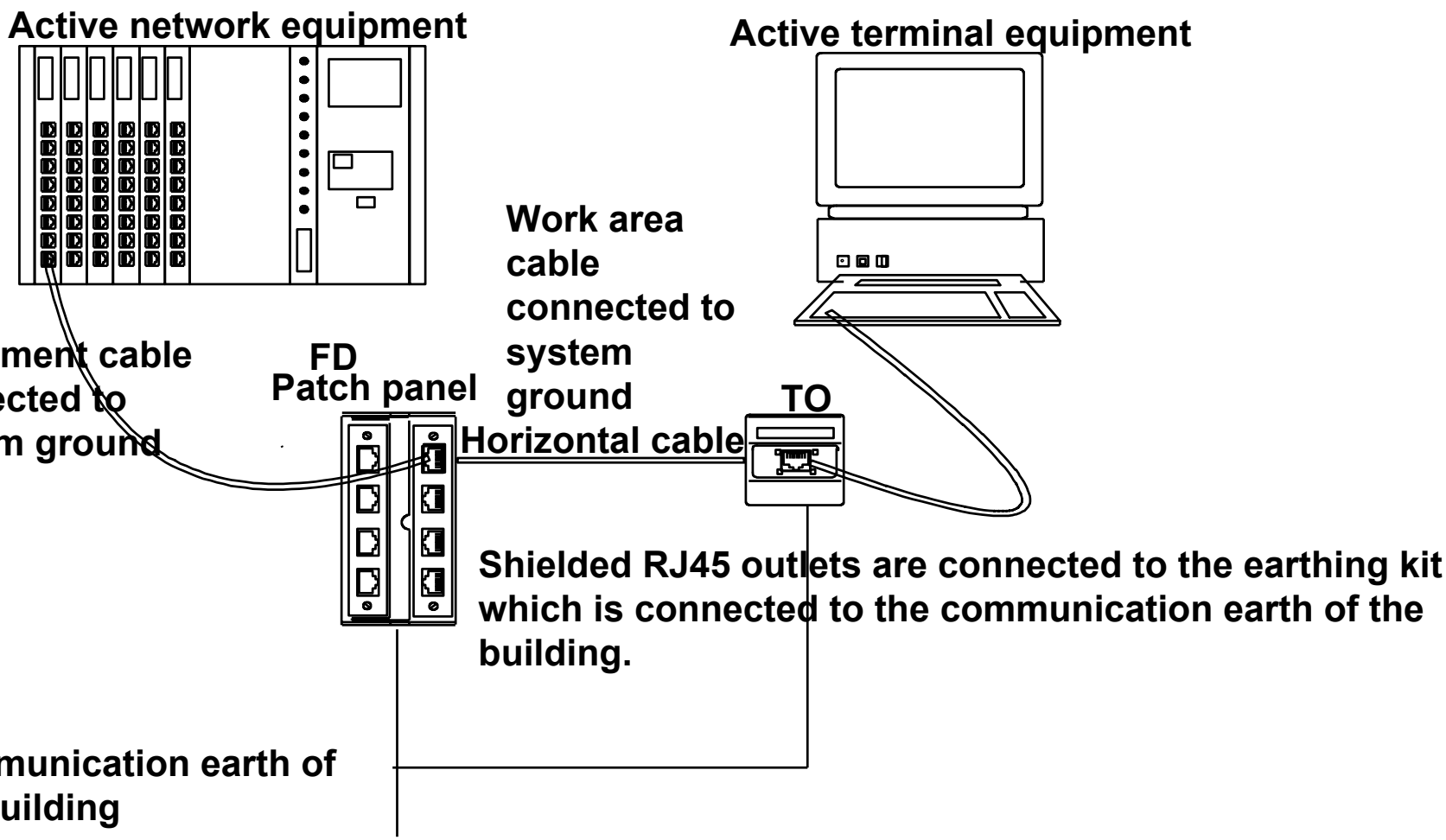
Mesh structure

Mesh structure:

- Best EMI protection
- Ideal for high bit rate networks
- Avoids ground loops and potential differences

- Negative: Installation and cost

Mesh structure



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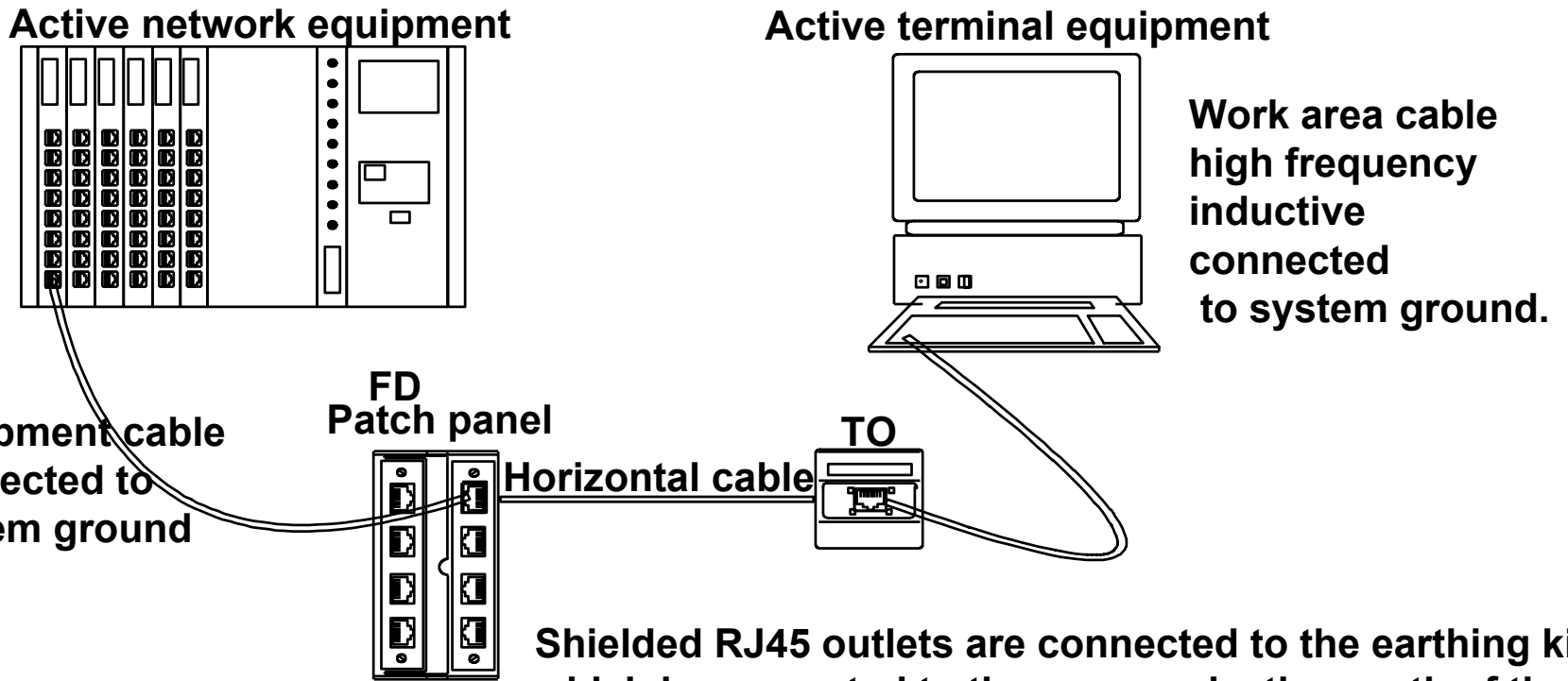
Convincing cabling solutions

Tree structure

Tree structure:

- Best if dedicated communication earth
- Good for high bit rate networks
- Active components have to be capacitive coupled to the power earth (standard) to avoid ground loops at low frequencies.

Tree structure



Floating shield

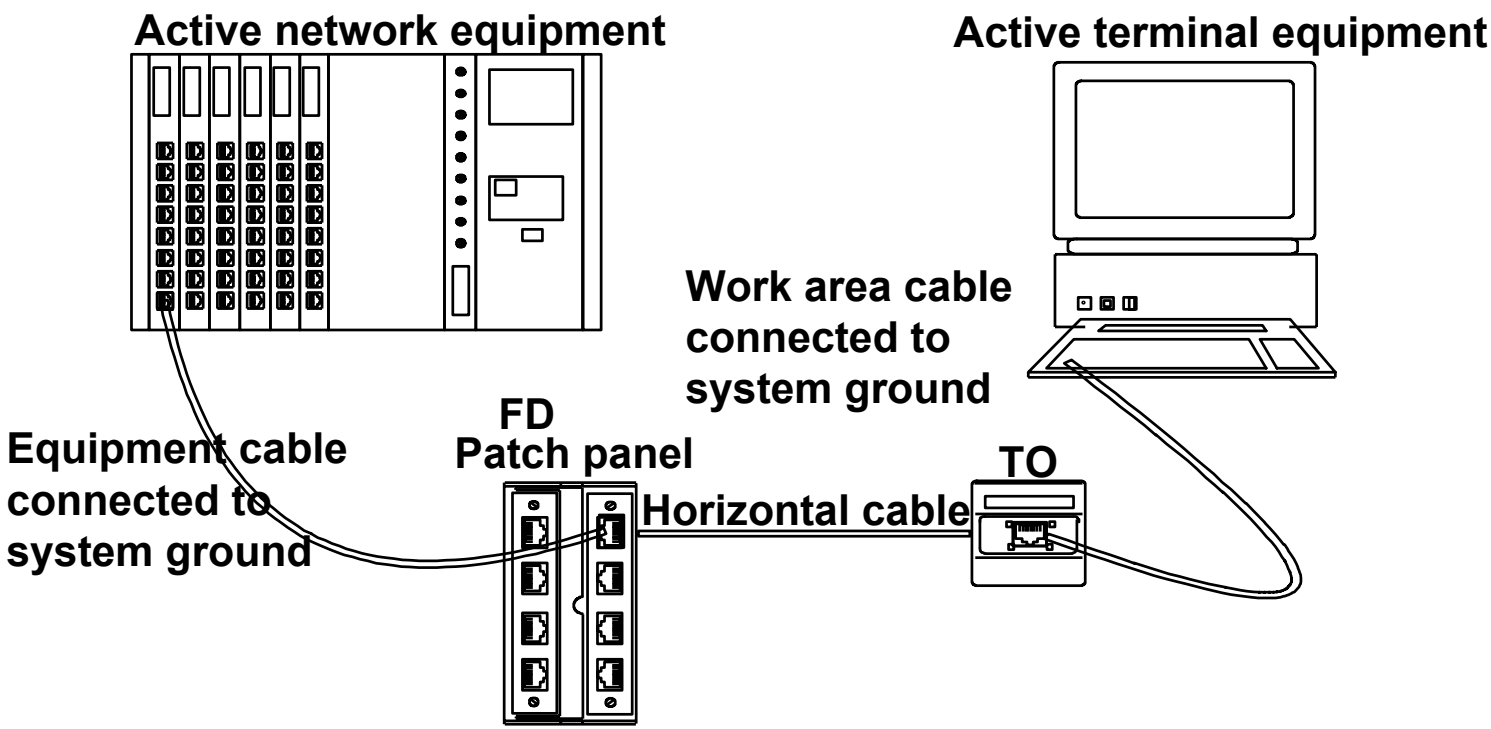
Floating shield:

- Shield is "floating" (not connected to earth)
- Capacitive coupled shield at both ends to the active components (or external patch cord)

- "Faraday cage" effect

  For building with potential differences higher than 1V rms.

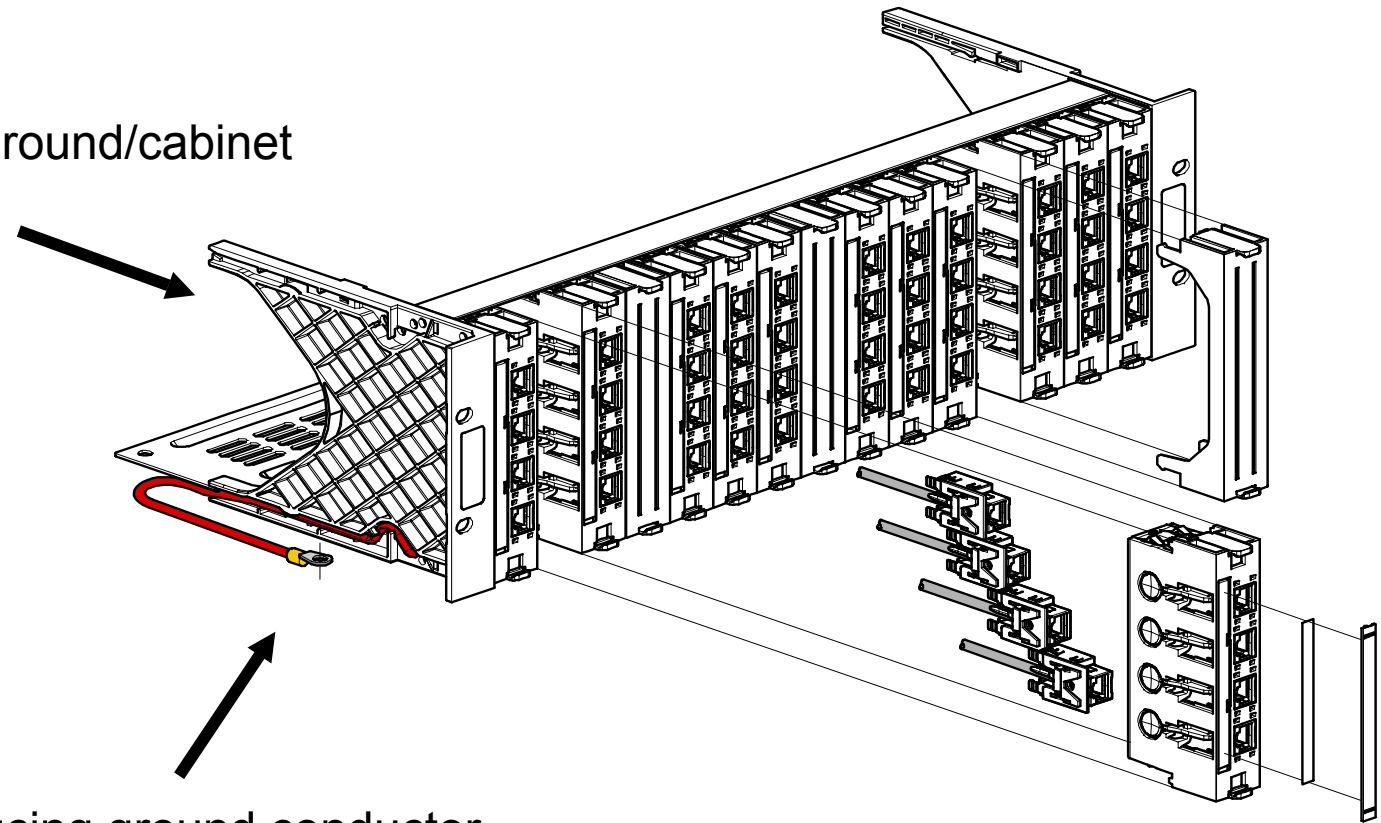
Floating shield



No earthing kit is used
-> No connection between shield and rack

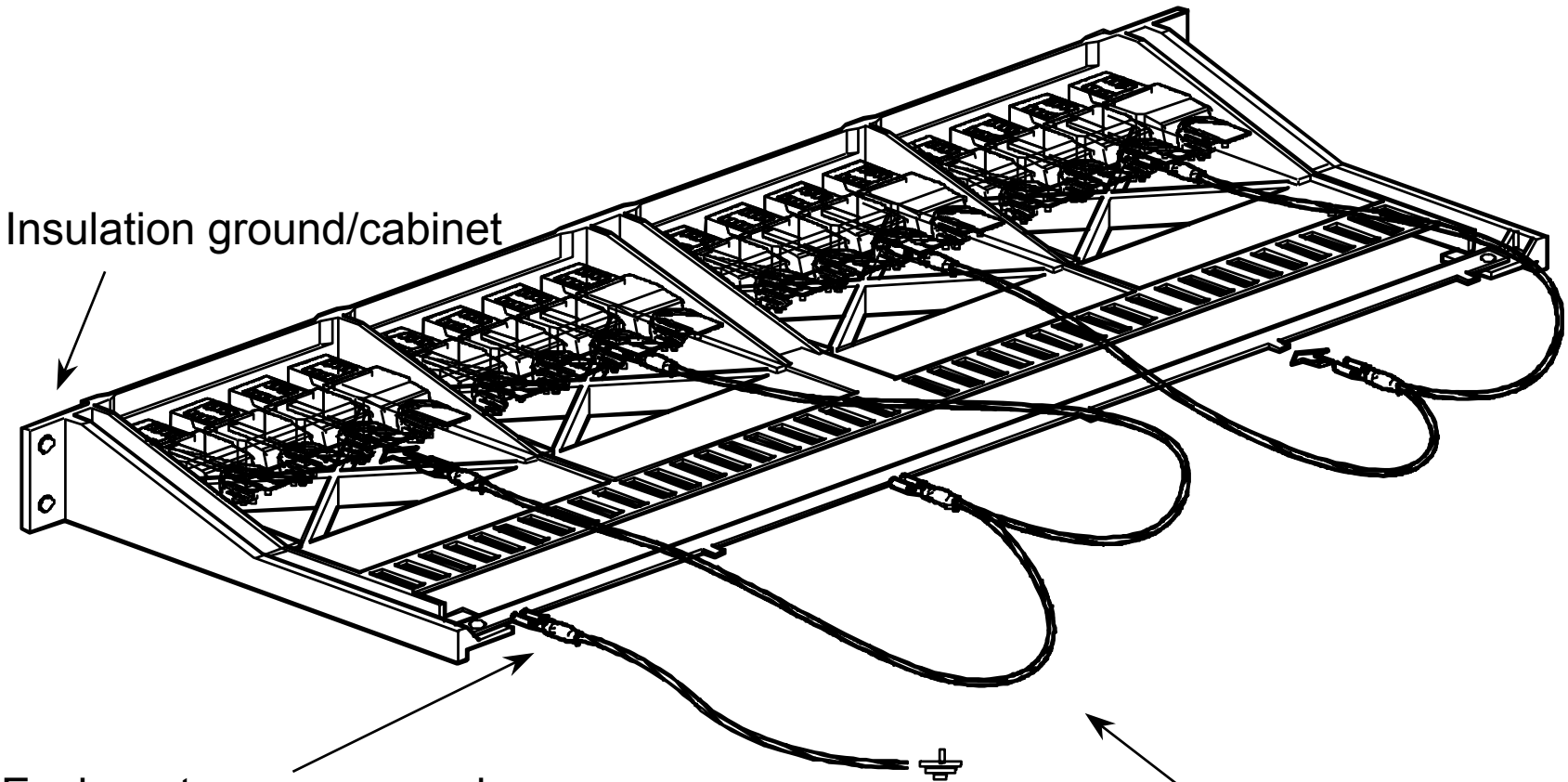
Grounding features of global panel

10kV Insulation ground/cabinet



Reducing ground conductor
impedance down to the
central main earth terminal

Grounding features of 16 ports 1U patch panel



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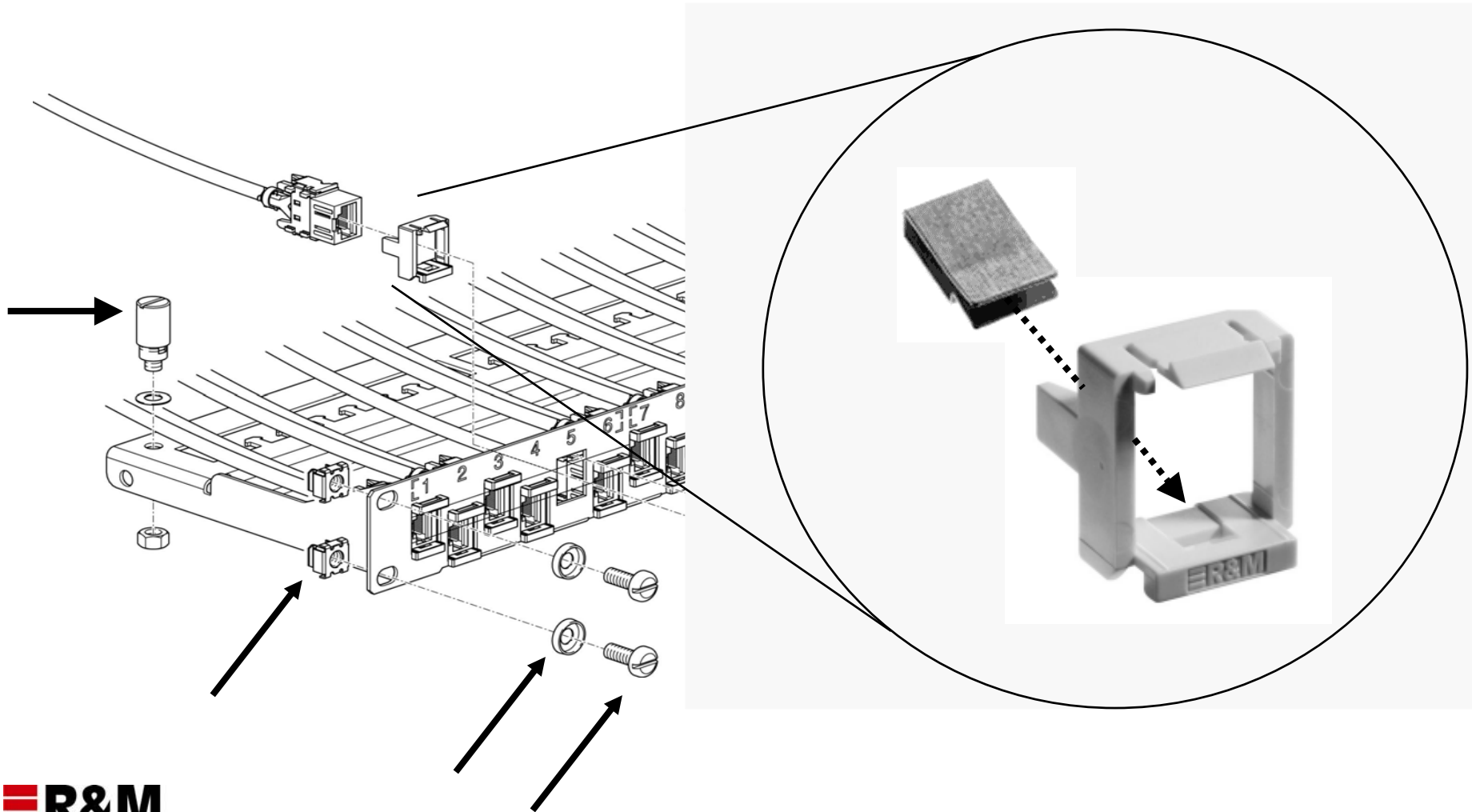
Grounding features of 24 ports 1U patch panel



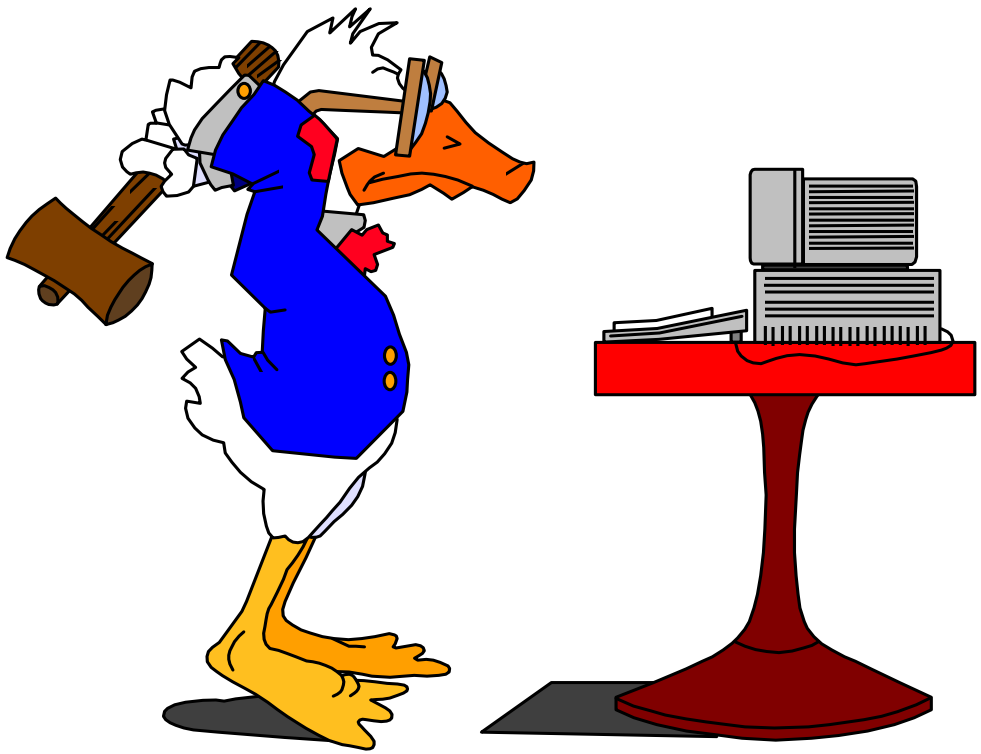
Summary: EMC features of R&Mfreenet

- Meets the most stringent EMC standard EN55022/Class B and EN55082
- Fully 360 degrees shield protection through the whole link assures high EMC performance
- Low impedance screen termination
- Ease quick and safe cable screen termination (patented)
- Supports "Tree structure", "Mesh structure" and "Floating shield"
- All accessories to implement any grounding structure
- Allow every implementation models of EN 50310 and EN 50174/2

Summary (earth and grounding)

- Proper earth bonding is an important element in EMC control.
- Keep impedance to ground and ground path low.
- Ensure low potential differences between any two grounded points (max 1V).

End of part 2



Practical EMC tests

Agenda

Practical EMC tests:

- Emission tests (laboratory)
- Immunity test (site test)
    - Eye pattern test
    - Network performance test

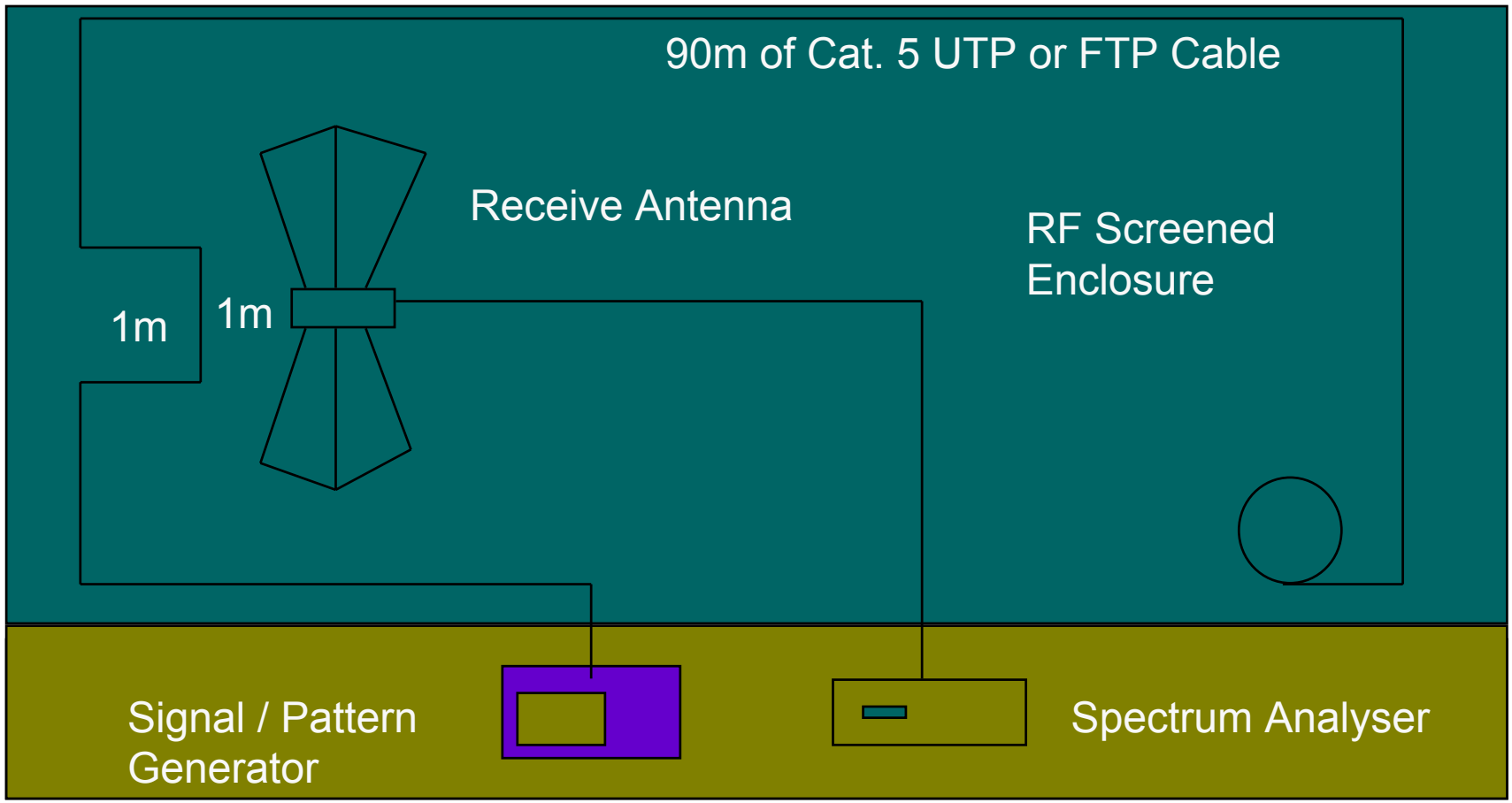
Emission tests

Performed as a comparison tests

- Cat. 5 UTP cable
- Cat. 5 FTP cable

Relate to existing emission standards (CISPR 22, EN55022B)

Setup: emission test



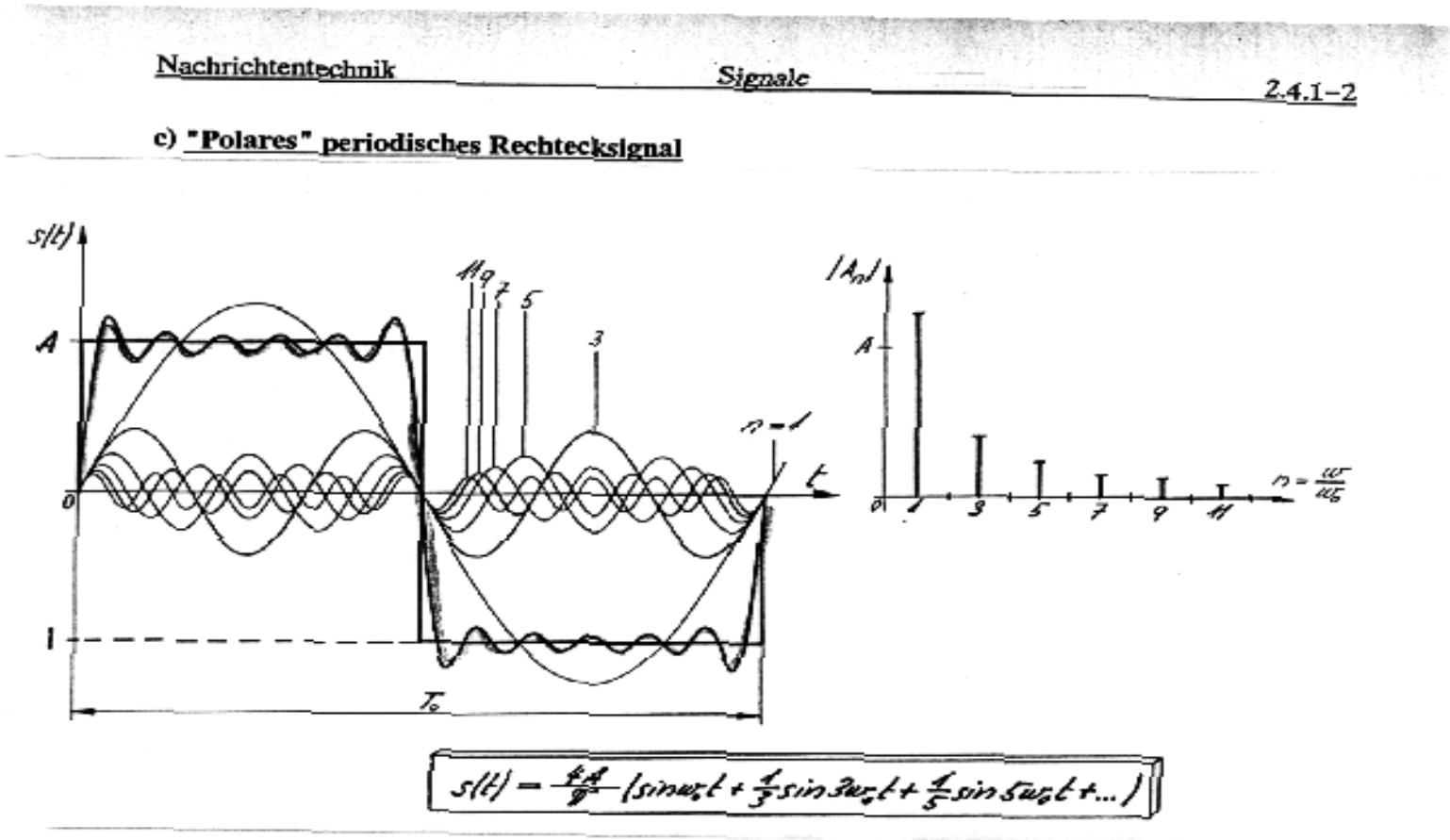
Coding schemes

- RF signal, frequency sweep 1-300 MHz
- Ethernet 10Base-T, Manchester
- 100 Mbit/s, NRZI
- 100 Mbit/s, MLT-3

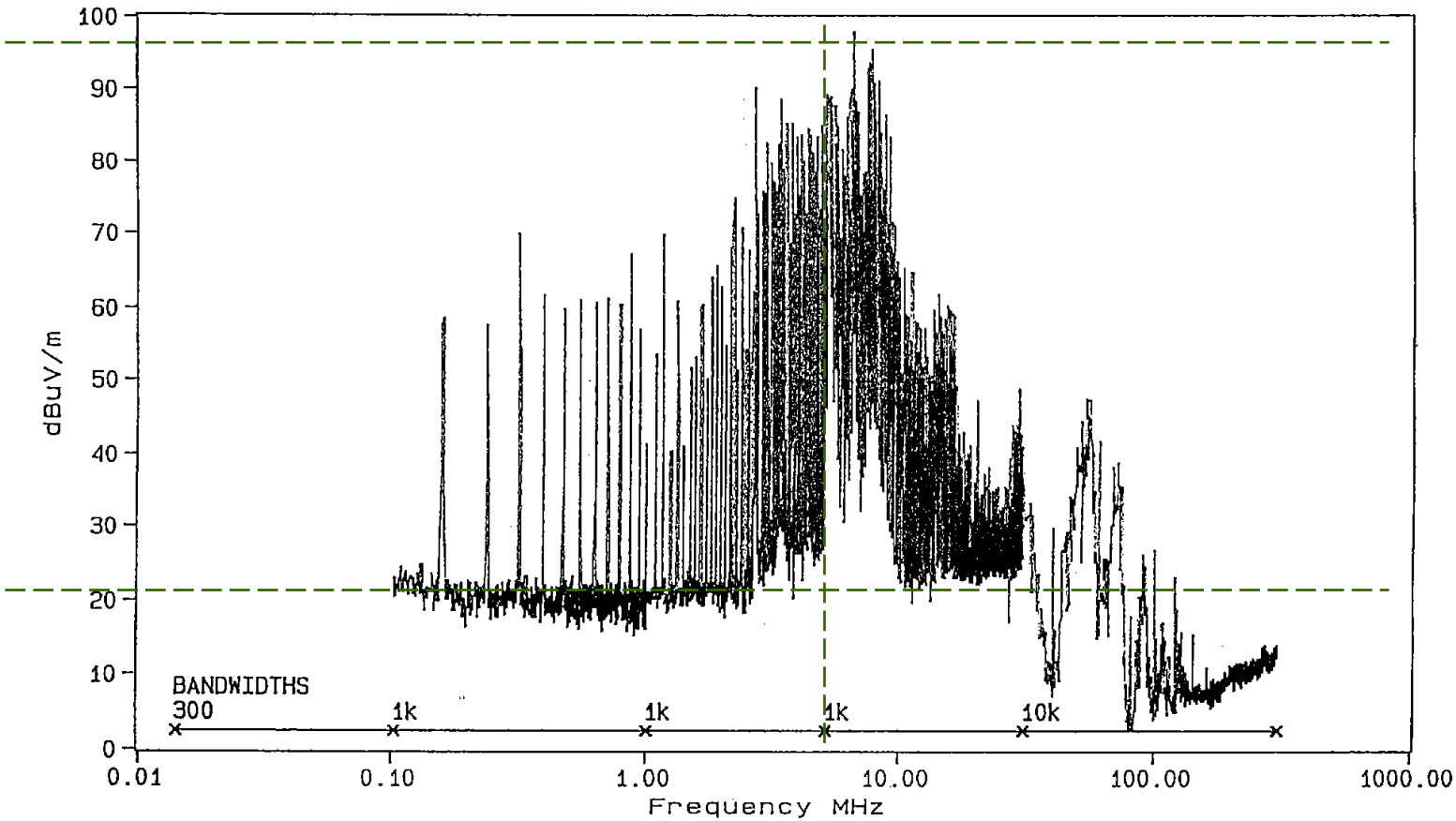
Factors which influence emission

- Data signal rise time
- Encoding
- Clock speed/pulse width
- Bit combinations

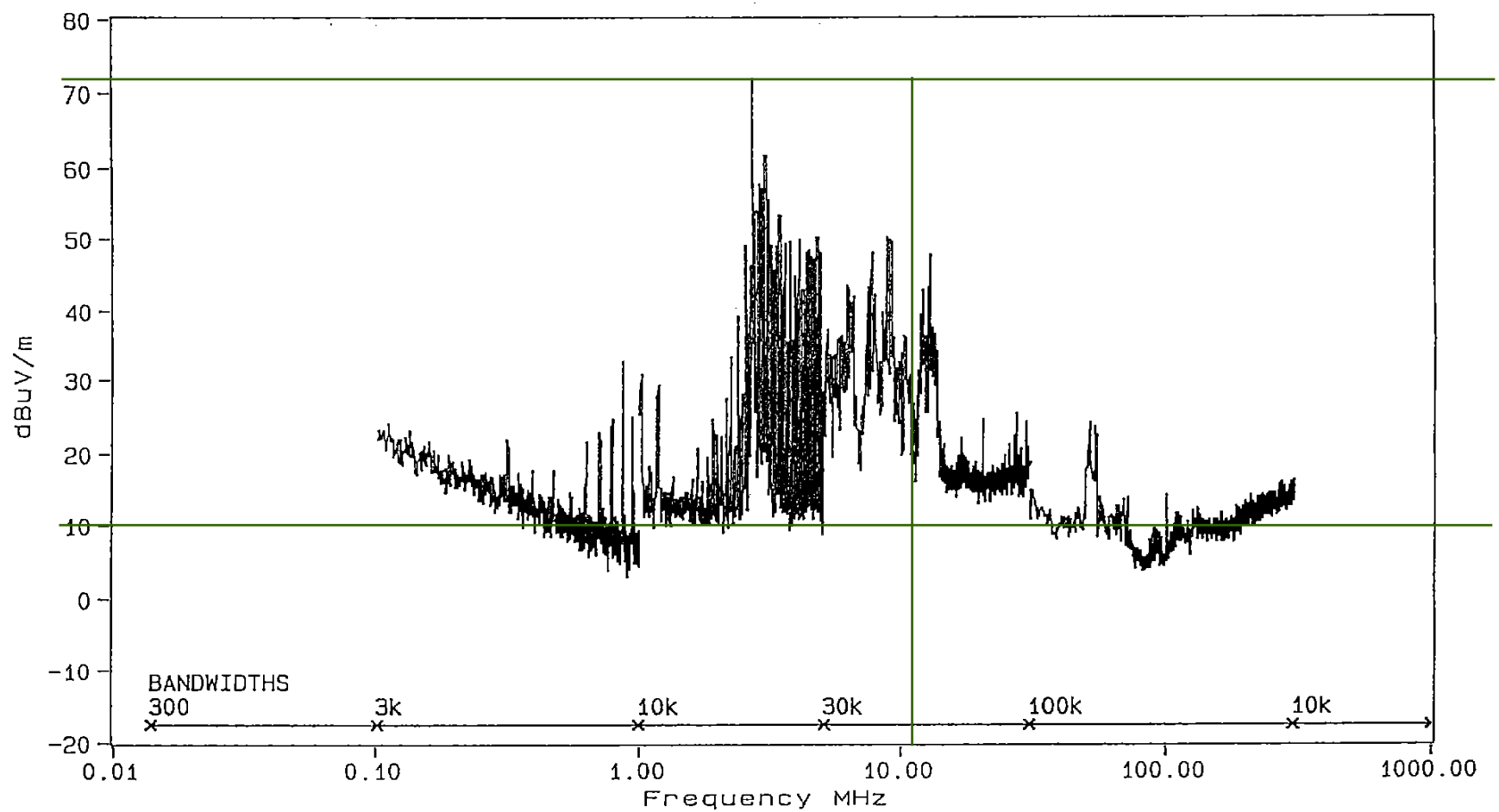
Fourier transformation



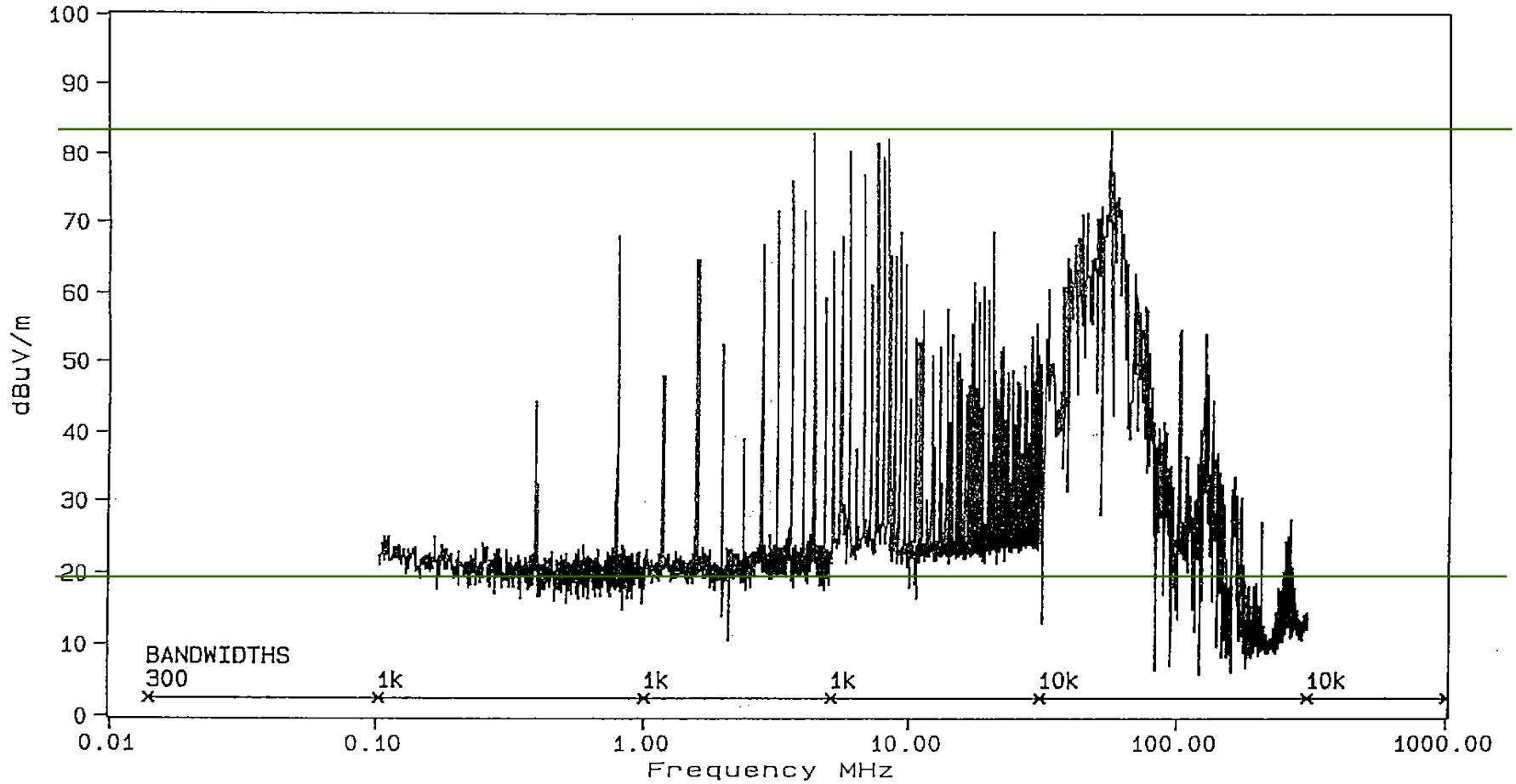
UTP - 10BaseT


100
90
80
70
60
50
40
30
20
10
0
dBuV/m
BANDWIDTHS
300
1k
1k
1k
10k
0.01
0.10
1.00
10.00
100.00
1000.00
Frequency MHz

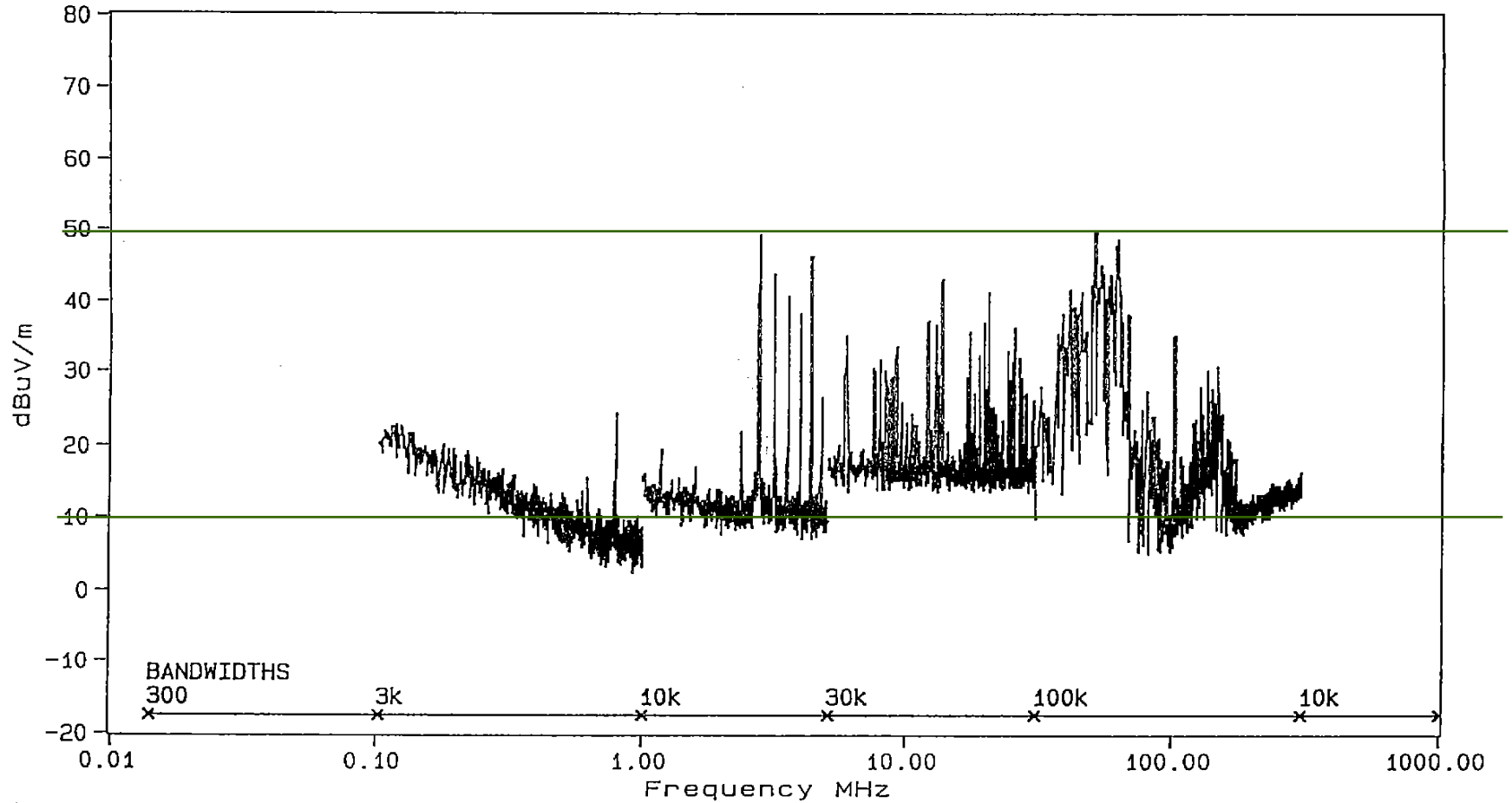
FTP - 10BaseT


80
70
60
50
40
30
20
10
0
-10
-20
dBuV/m
BANDWIDTHS
300
3k
10k
30k
100k
10k
0.01
0.10
1.00
10.00
100.00
1000.00
Frequency MHz

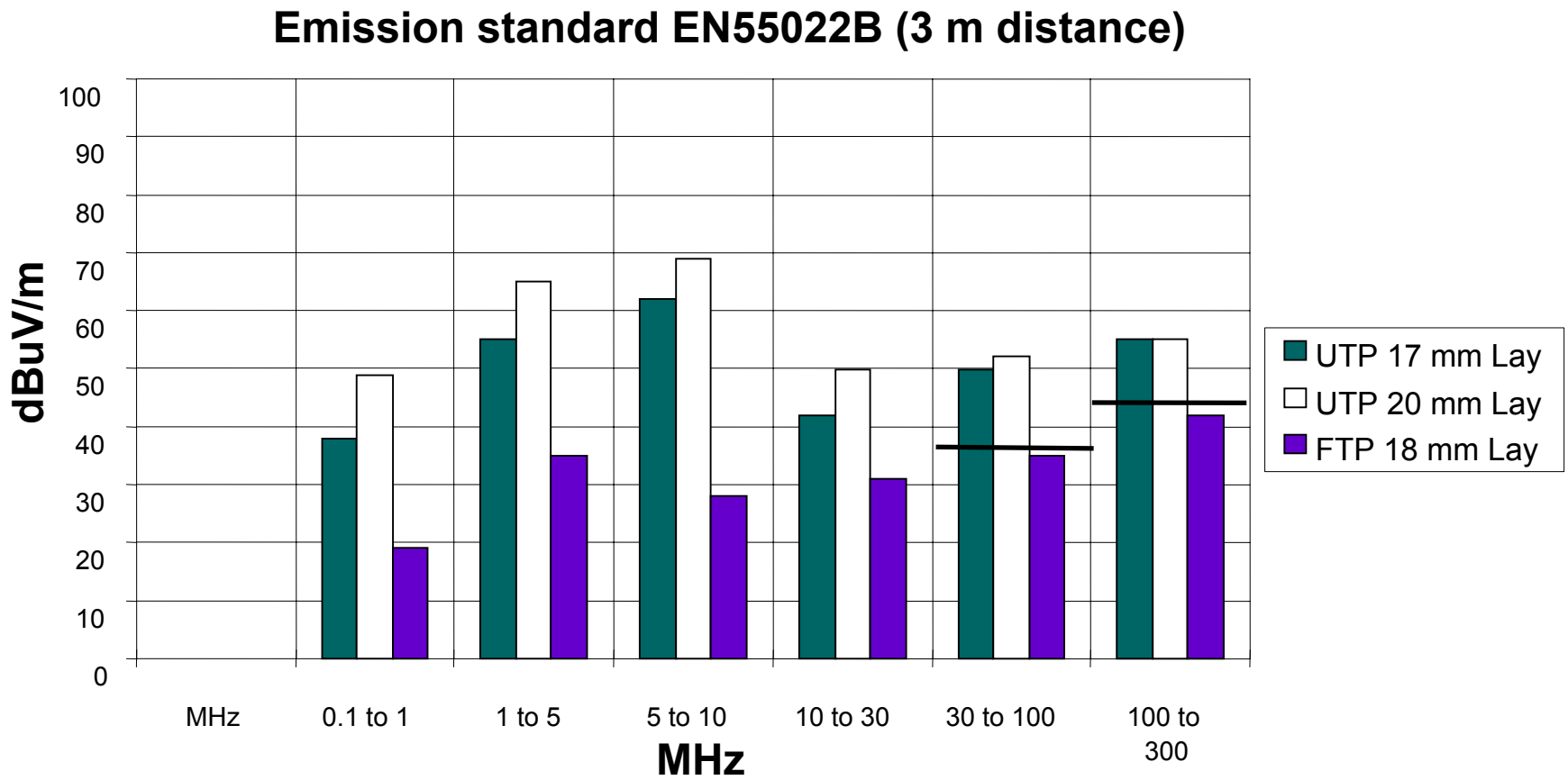
UTP - 100Mbit/s, NRZI



FTP - 100Mbit/s, NRZI



Emission comparisons



Conclusion emission tests

FTP performs always better than UTP

Short twist lays only improve emission below 30 MHz

EN55022B:

- FTP would **pass** all the requirements
- UTP would **fail** the requirements (except 10Base-T)

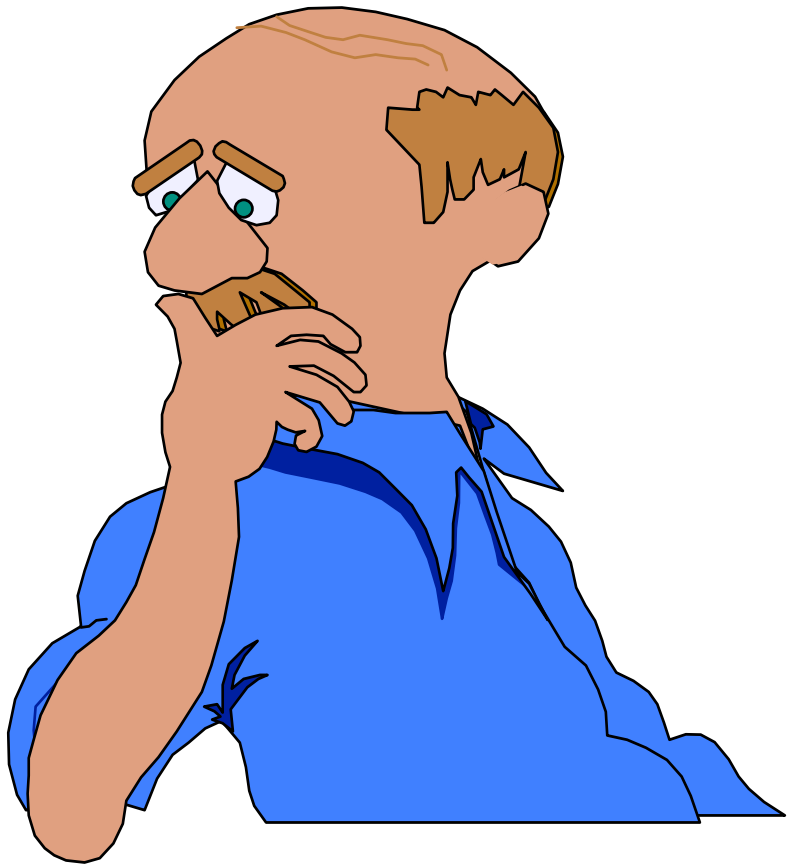
Limits for UTP?

Bandwidth:

Cat. 5 <-> 100 MHz

EMC protection:

Cat. 5 UTP <-> 30 MHz



When shielded?

Case	Data cables (Cat. 5)	Interference source	Recommended LAN cables
1	f < 30MHz	f < 30MHz	Unshielded
2	f < 30MHz	***f > 30MHz***	***Shielded***
3	***f > 30MHz***	f < 30MHz	***Shielded***
4	***f > 30MHz***	***f > 30MHz***	***Shielded***

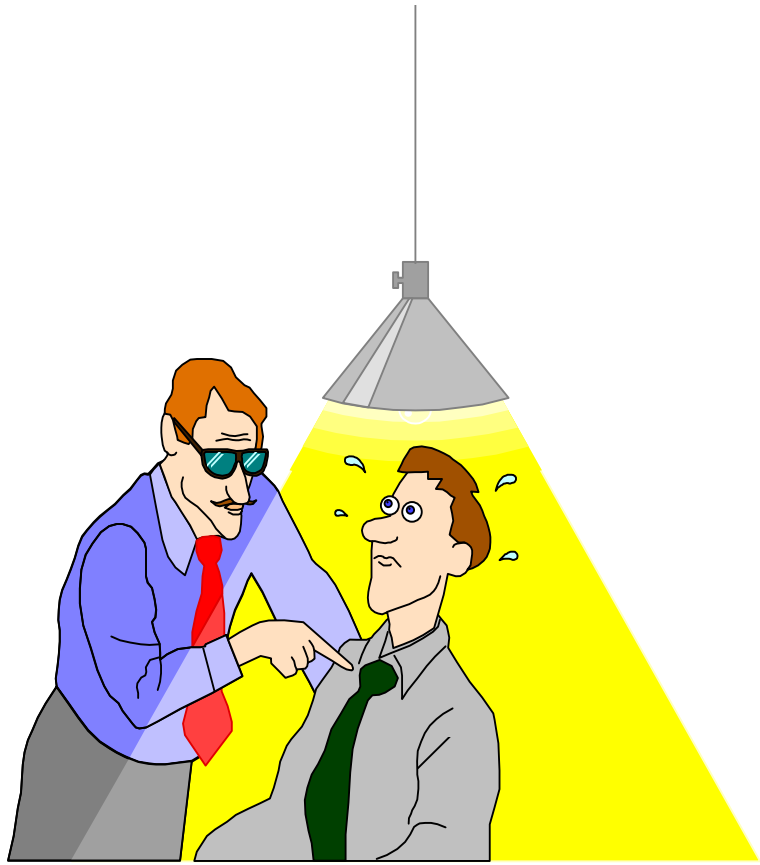
Alternatives?

Intelligent encoding:
e.g. MLT-3 instead of NRZI

Problems:
Uses only 1/3 of available bandwidth
More expensive cards
No immunity

Solution:

Electrical > optical signals



Immunity test

In laboratory:

- Eye pattern tests (signal quality)

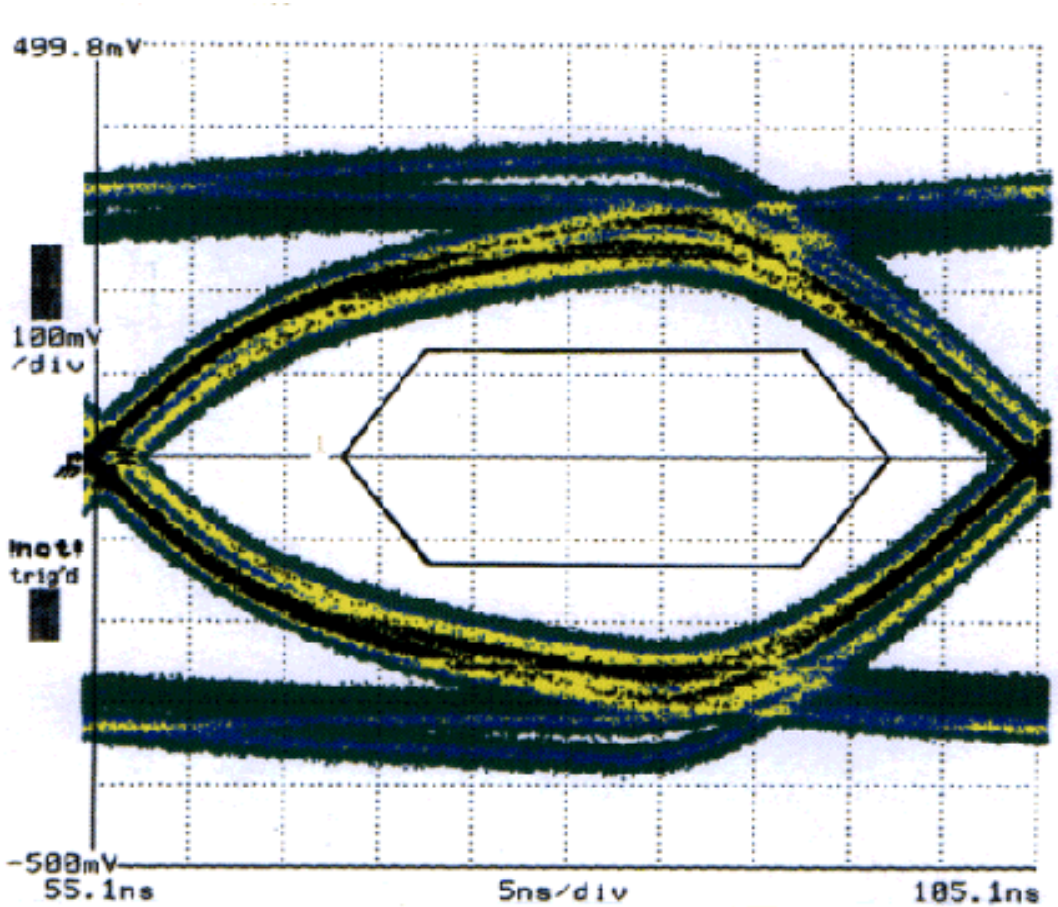
On site:

- Eye pattern tests (signal quality)
- Network analysis (counting Bits in error/ratio to transmitted one)

Eye pattern test

- Eye pattern are used to monitor "health" or quality of digital signals
- Eye pattern mask tests allow to compare received digital signals
- Eye pattern test cannot substitute for a Bit error rate test but there is a correlation between the two.

Example: eye pattern diagram



The generated mask is given by the 10-BaseT standards.

No noise is induced in this case

Total number of scans 1000
Test time 400 sec
No of mask intrusions 0

On site immunity tests

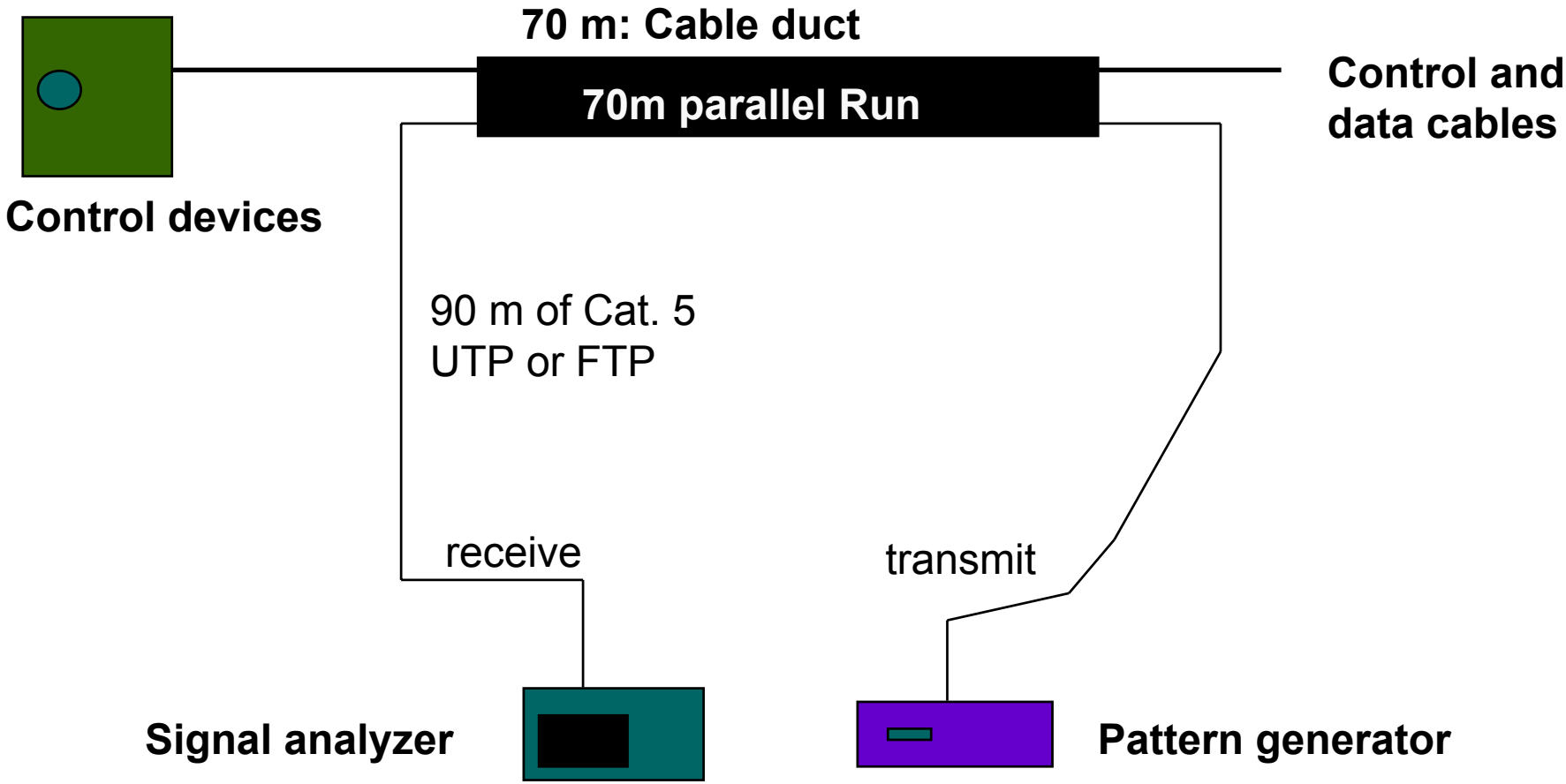
Eye pattern test

- Ethernet 10Base-T
- Ethernet 100Base-T

Network test

- Ethernet 100Base-T

Set-up: eye pattern test 2



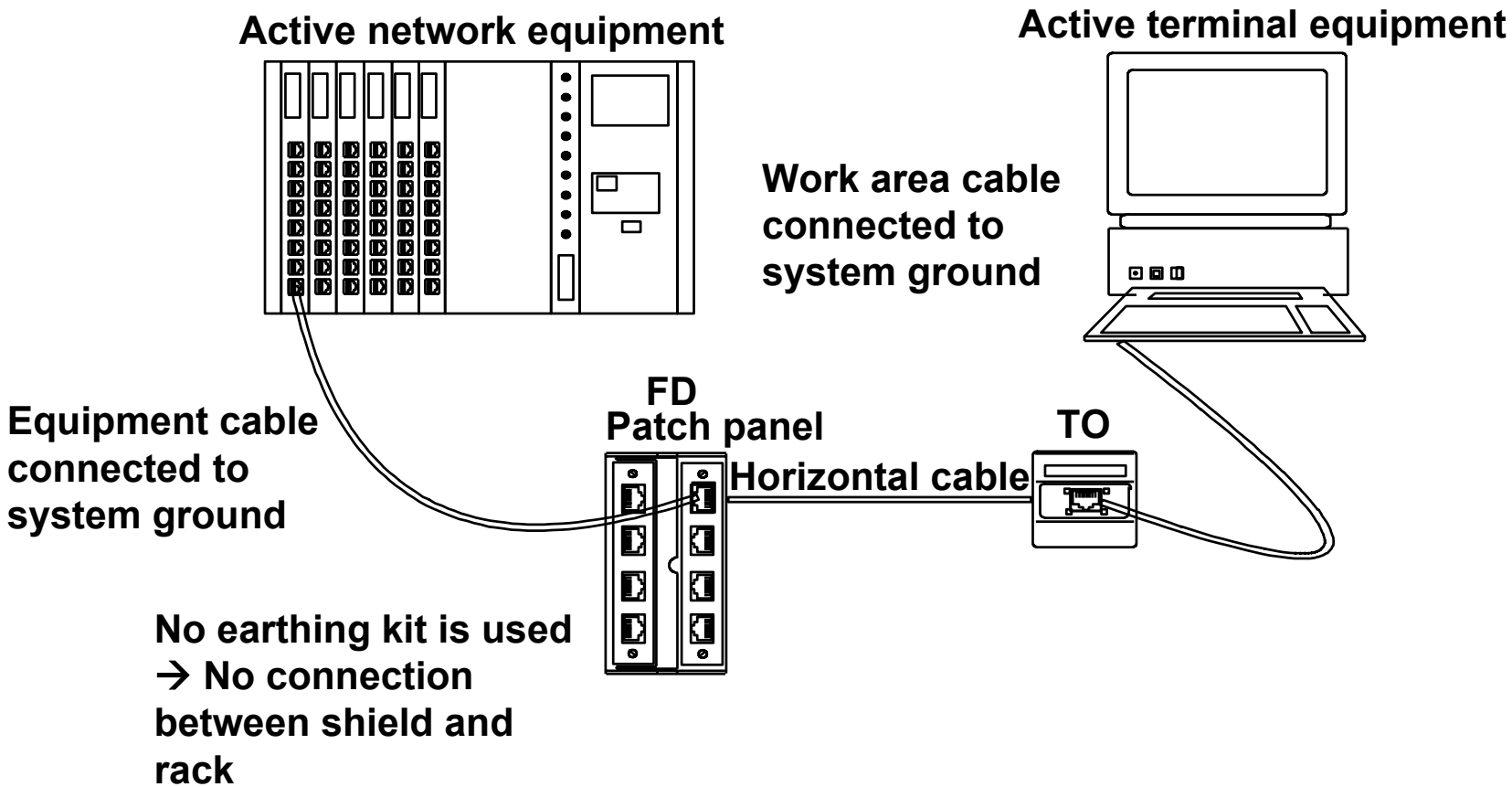
Situation

Old building

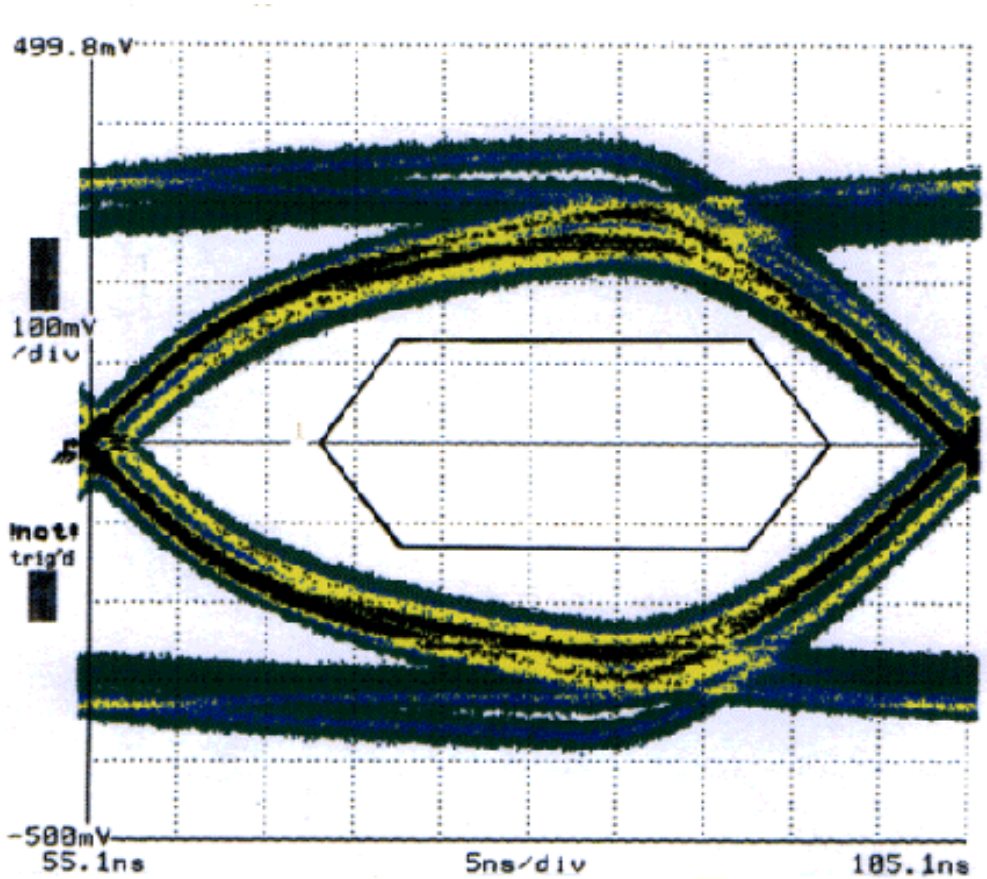
Potential difference of up to 5V rms.

- Bad earth system
- Pull in new earth -> tree structure
- Floating shield -> example

Floating shield



Eye diagram 1



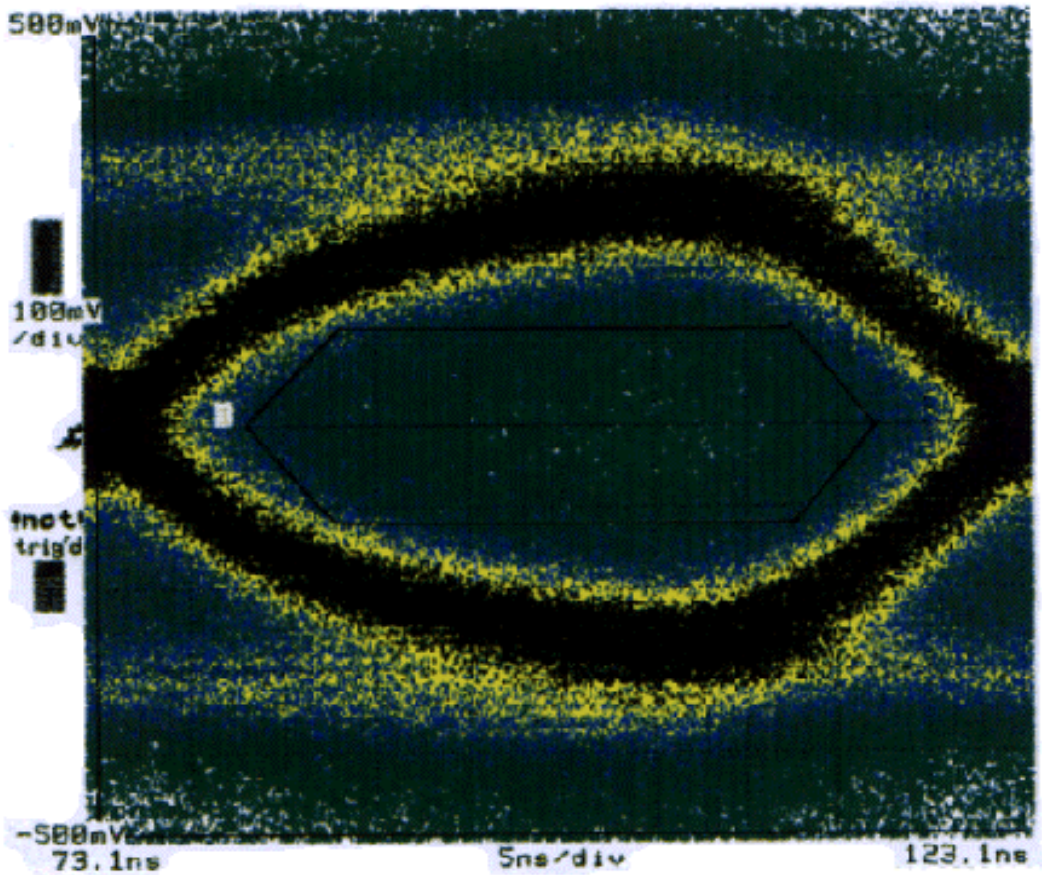
UTP

10-BaseT, Manchester code

Reference - no induced noise

Total number of scans	1000
Test time	400 sec
No of mask intrusions	0

Eye diagram 2



UTP

10-BaseT, Manchester code

With induced noise

Total number of scans	1000
Test time	400 sec
No of mask intrusions	21,936

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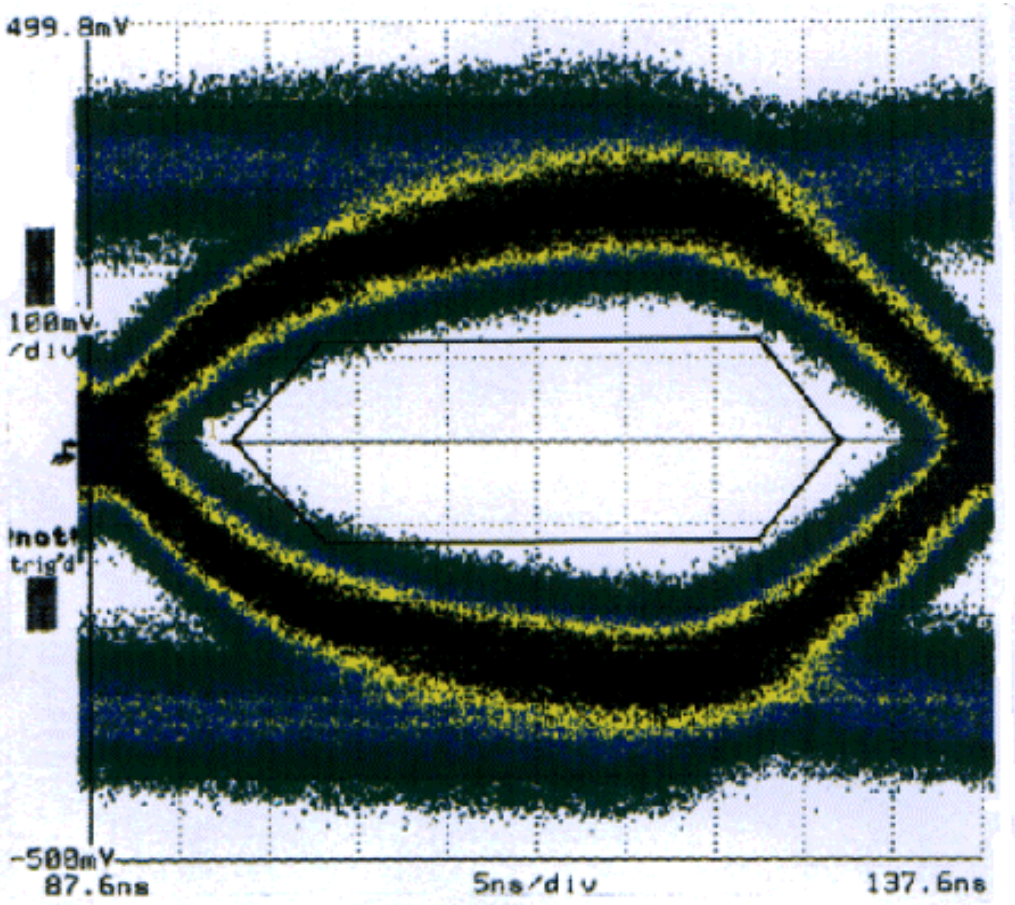
Eye diagram 3



FTP

10-BaseT, Manchester Code

Grounded at both ends

With induced noise

Total number of scans	1000
Test time	400 sec
No of mask intrusions	256

Conclusion for 10Base-T

UTP gets a high number of transitions which fall within the mask.

More transitions indicates a higher probability of received bit errors.

Note: A network with low traffic load may not immediately slow down dramatically although many retries can already be seen with a sniffer.

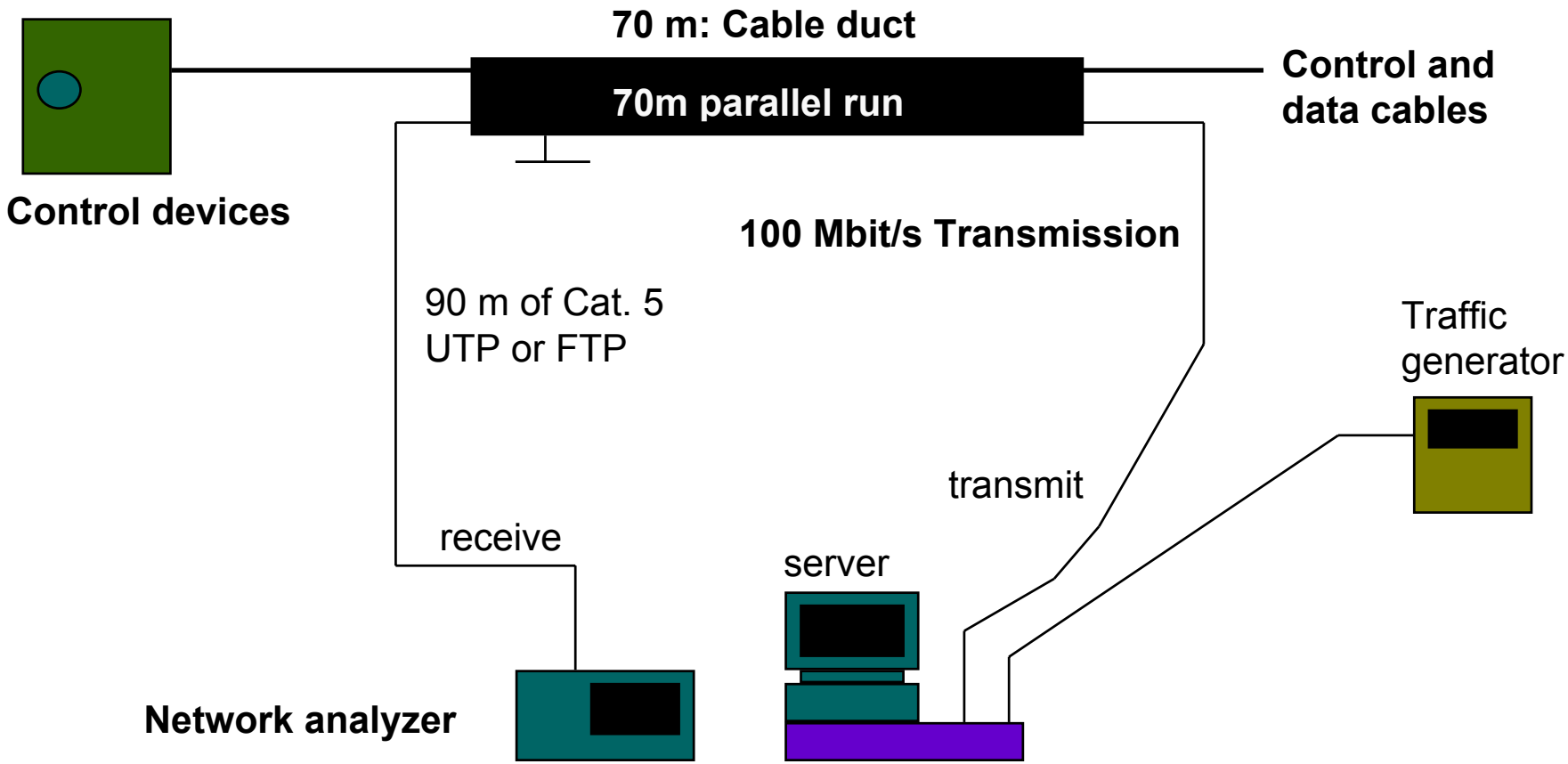
Network performance test

100 Mbit/s fast Ethernet network

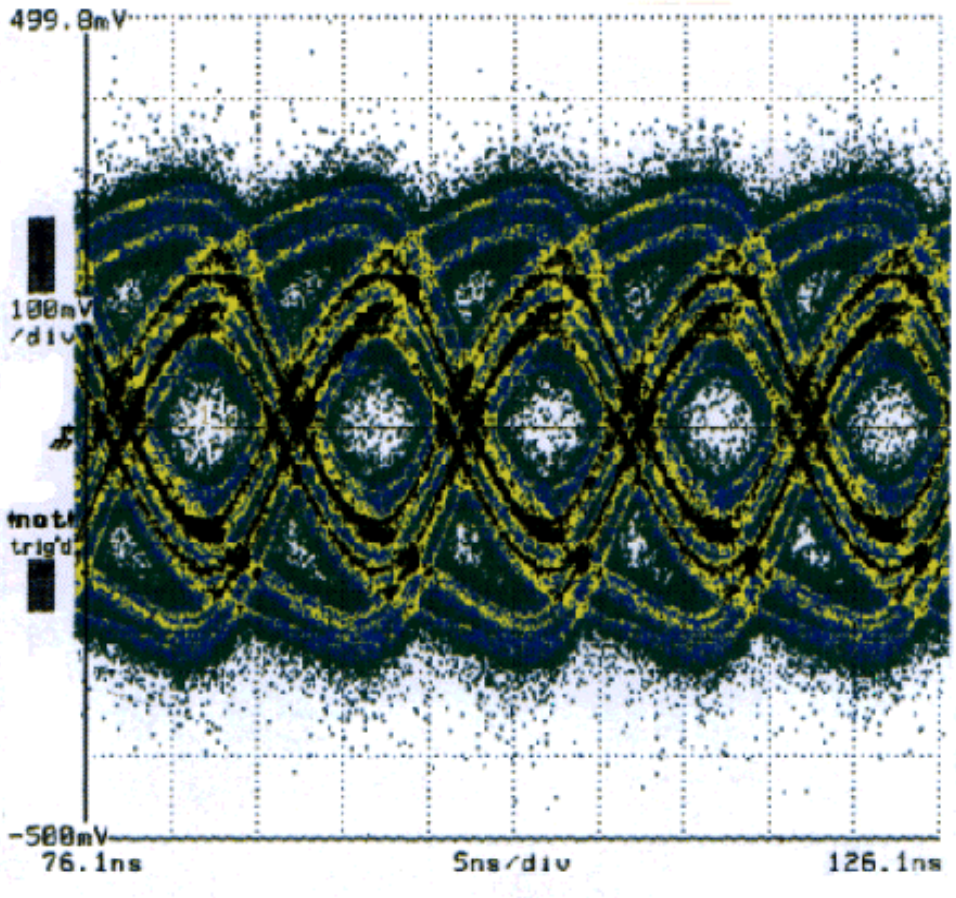
Goal of test:
Find correlation between eye pattern and number of retries/lost frames.

Based also on a comparison Test (UTP versus FTP)

Setup: eye pattern test 2



UTP / reference cable



Eye pattern test

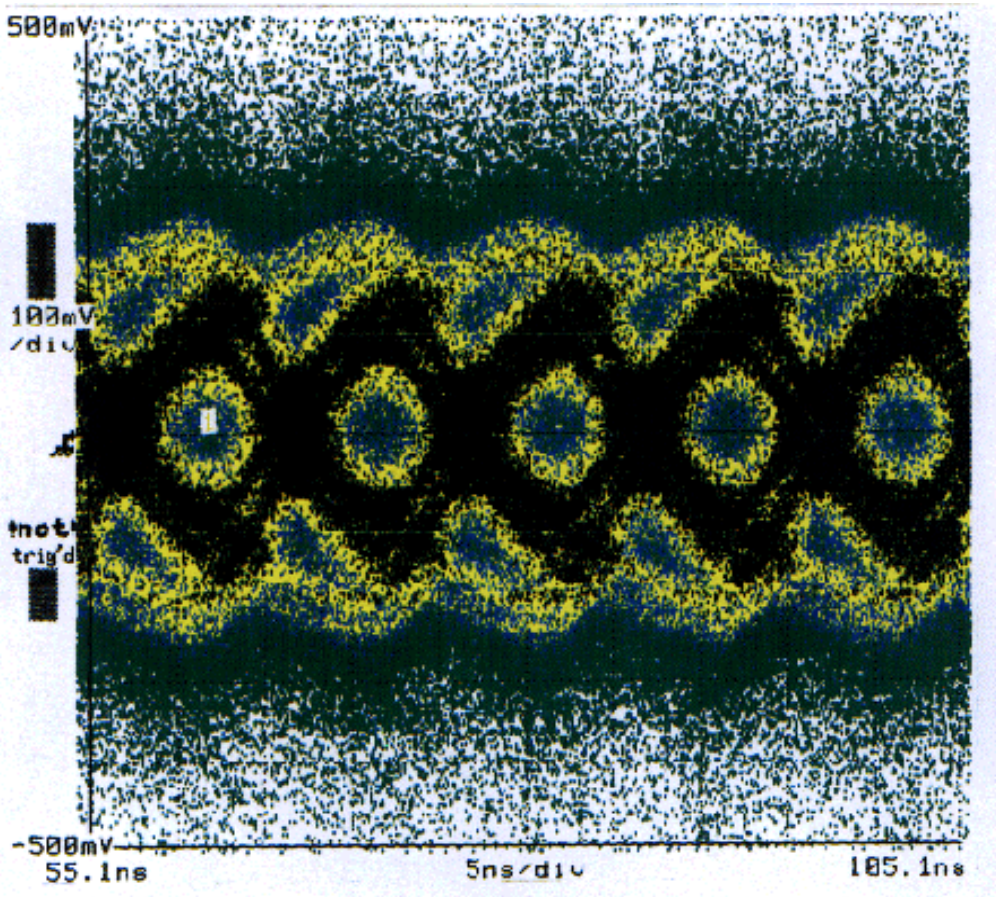
Network test 100-BaseT, NRZI

Reference - no induced noise

Frame size	450 bytes
Transmission time	405 sec
Transmitted frames	970,962
Bad CRC/retries 0	
Short/runt	0
Lost frames	0
Frame error rate	$< 10^{-10}$
Best case BER	$< 10^{-10}$

R&M
Convincing cabling solutions

UTP / with noise



Eye pattern test

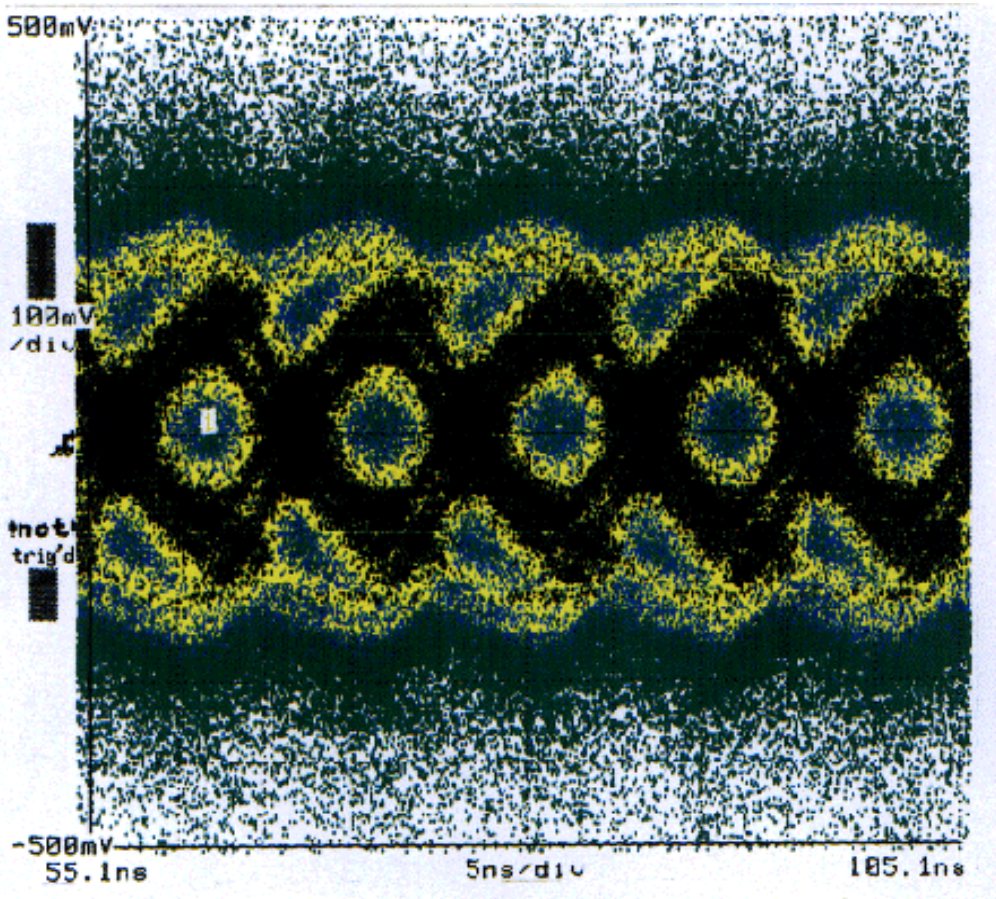
Network test 100-BaseT, NRZI

Small frame size (450 Bytes)

Frame size	450 bytes
Transmission time	405 sec
Transmitted frames	975,825
Bad CRC/retries	656
Short/runt	199
Lost frames	0

Frame error rate	$< 6.7*10^{-4}$
Best case BER	$< 1.9*10^{-7}$

UTP / with noise



Eye pattern test

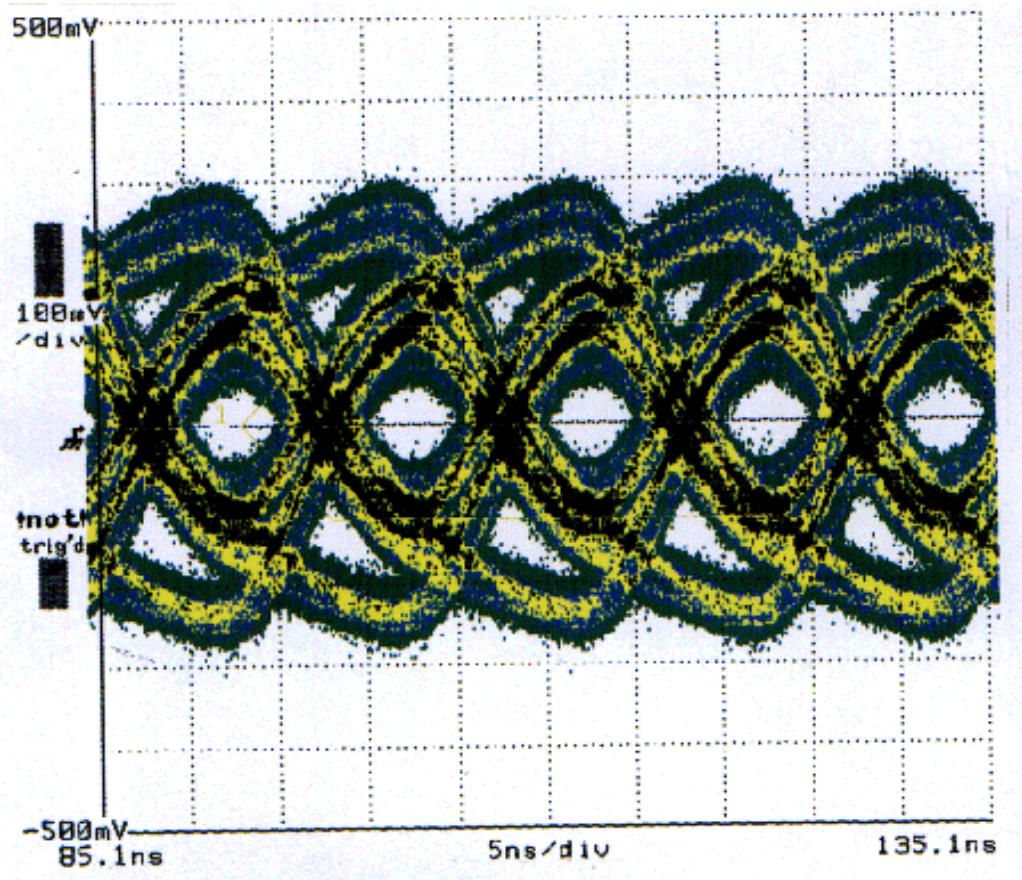
Network test 100-BaseT, NRZI

Large frame size (1000 Bytes)

Frame size	1000 bytes
Transmission time	405 sec
Transmitted frames	484598
Bad CRC/retries	6623
Short/runt	1618
Lost frames	28

Frame error rate	$< 1.4*10^{-2}$
Best case BER	$< 1.7*10^{-6}$

FTP / with noise



Eye pattern test
Network test 100-BaseT, NRZI
perfectly grounded

Frame size	1000 bytes
Transmission time	405 sec
Transmitted frames	481006
Bad CRC/retries	0
Short/run	0
Lost frame	0
Frame error rate	$< 10^{-10}$
Best case BER	$< 10^{-10}$

Conclusion

Results show a correlation between eye pattern (signal quality) and number of retries (errors which occurred on the network)

100Base-T / UTP

Acceptable for fast Ethernet:

BER<=10^{-10}

For a Bit rate of 100 Mbit/s this means less than one Bit error in one minute.

The calculated BER for UTP cable is up to 17000 times higher than **accepted.**

100Base-T / FTP

- The BER<=10^{-10} can be achieved with the FTP cable in a noisy environment.

- Even for the large frame size (1000Bytes) the FTP cable performs perfectly.

Conclusion: network test

- Best network performance in a noisy environment can be achieved with the R&Mfreenet **screened cabling system.**

- A UTP cabling system, running high frequency signals, shows **unacceptable** high **B**it **E**rror **R**ates which can result in high access times or network crashes.

Our confidence

Our statements:

- Based on practical EMC tests
- Comparison tests: UTP versus FTP
- Similar conclusion reached by other independent labs

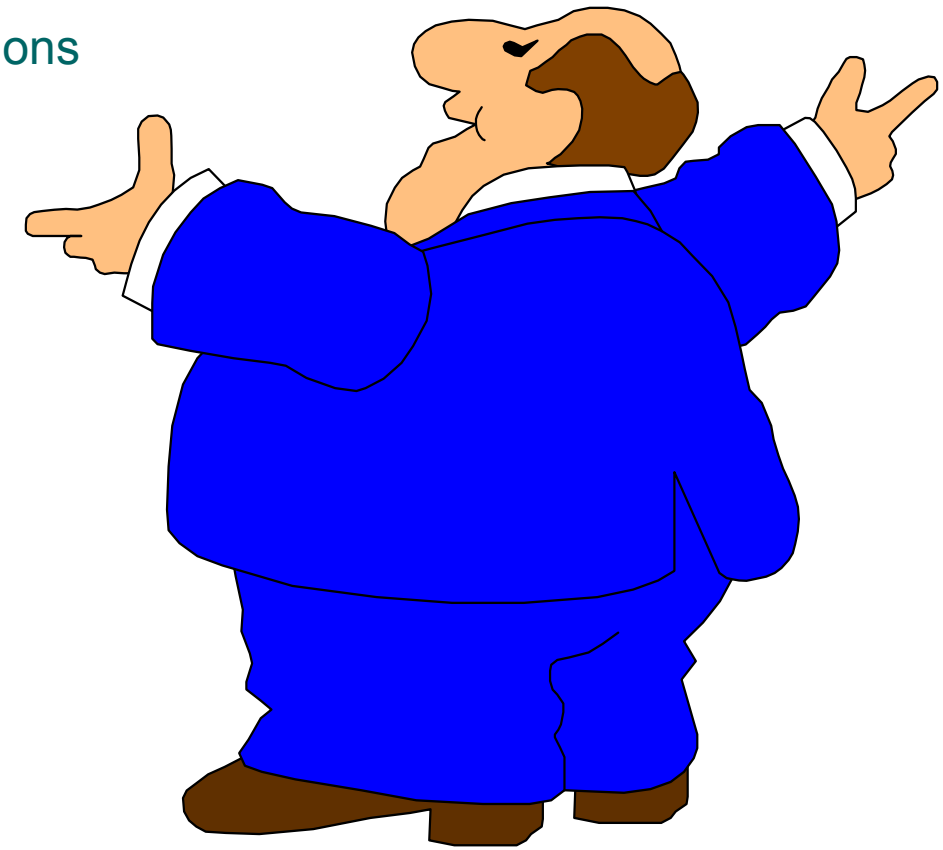
Announcement

Our strength:

- Our product range including all solutions
- Our expertise

Your freedom:

- We suggest, **you choose**



Any Questions?