

Power Separation and 10 Gigabit Ethernet

Herbert V. Congdon II, PE
Tyco Electronics



Preview

- Basic tenets of separating communication cables from power cables
- New separation considerations for 10 Gigabit Ethernet
- Testing electromagnetic, radio and power noise on 10 Gigabit Ethernet networks
- Now what?

Basic Tenets of Power Separation

- Safety
 - Article 800.52 of ANSI/NFPA 70 (now in article 800.133)
 - Separation from power conductors
 - Separation and barriers within raceways
 - Separation within outlet boxes or compartments

Basic Tenets of Power Separation

- Electromagnetic Noise
 - TIA Documents (ANSI/TIA-568C.2, J-STD-607-A, etc.)
 - Balance performance requirements
 - Alien crosstalk
 - Grounding and bonding
 - Noise reduction

Basic Tenets of Power Separation

- Electromagnetic Noise Mitigation (Power)
 - Separation to minimize inductive coupling into telecommunications cabling
 - Cable installed close to a grounded metallic surface to limit inductive noise coupling
 - Surge protectors in branch circuits to limit the propagation of electrical surges
 - Fully enclosed, grounded metallic raceway or grounded conduit

Basic Tenets of Power Separation

- Electromagnetic Noise Mitigation (Cabling)
 - Pair Twist
 - Minimizes crosstalk
 - Shield
 - Minimizes noise to boost signal-to-noise ratio
 - Separation
 - Noise weakens with square of distance

Power Separation: 1000BASE-T

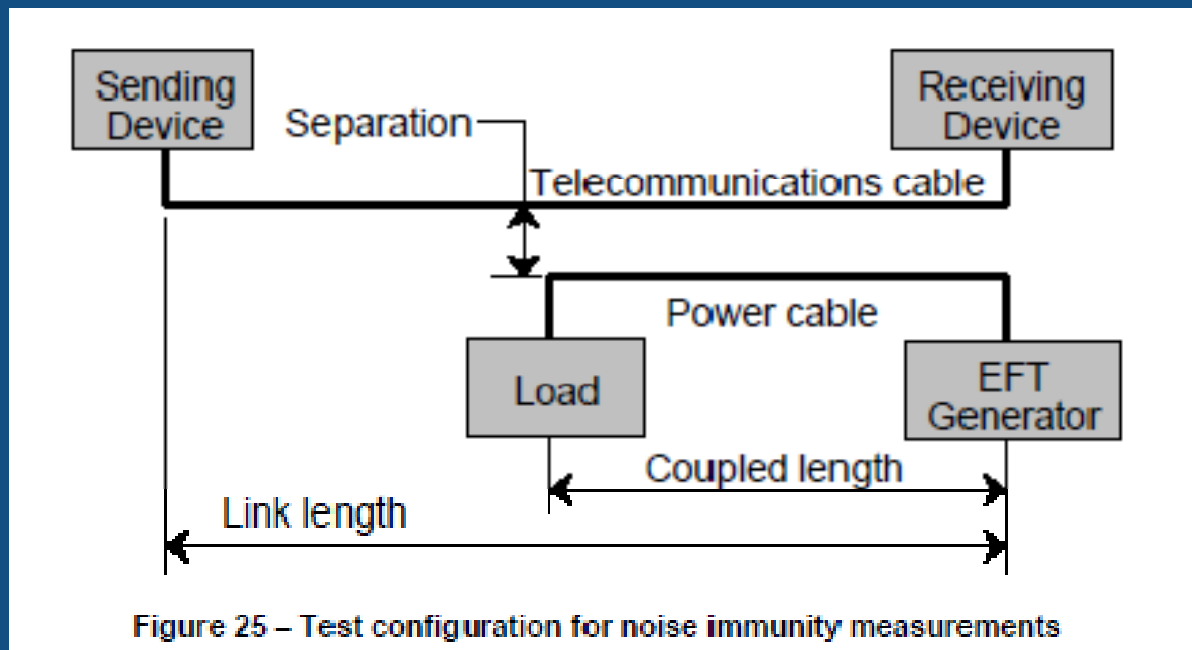


Figure 25 from TIA-569-B, *Commercial Building Standard for Telecommunications Pathways and Spaces*

Power Separation: 1000BASE-T

Table 17 – Noise reduction factors under different test variables

| Test Variable | Reduction Factor |
|------------------------------------------------|------------------|
| Effect of cable balance | |
| LCL/TCL > 40 dB from 1 to 30 MHz | 1 |
| LCL/TCL > 50 dB from 1 to 30 MHz | 0.5 |
| Effect of cable category | |
| Category 5e | 1 |
| Category 6 | 0.5 |
| NIC performance | |
| Good | 1 |
| Poor | 2 |
| Effect of coupled length near equipment | |
| Length = 90m | 1 |
| Length = 10m | 1 |
| Length < 2m | 0.7 |
| Effect of horizontal link length | |
| Length = 90 m | 1 |
| Length = 60 m | 0.7 |
| Length = 40 m or less | 0.6 |
| Effect of separation distance | |
| Zero (~ 6 mm) | 1 |
| 1 inch (25 mm) | 0.8 |
| 2 inch (50 mm) | 0.6 |
| 3 inch (75 mm) | 0.5 |
| 6 inch (150 mm) | 0.3 |
| Effect of Power Cabling | |
| Unbundled power conductors | 1.0 |
| Bundled power conductors | 0.7 |

NOTES

1 The noise reduction factor is the ratio of the relative noise immunity between two different test conditions, as measured using a digital oscilloscope or using packet error rate measurements.

2 As a reference benchmark (Reduction Factor = 1), a 500V EFT burst pattern on the power cable (figure 25) is the threshold voltage level for the onset of errors under the following conditions:

- 90 meter link length between two 1000BASE-T Ethernet switch ports;
- Zero separation;
- ≥ 10 meter coupling length; and,
- Category 5e cabling.

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• “...a 500V EFT burst pattern on the power cable (figure 25) is the threshold voltage level for the onset of errors under the following conditions:

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Table 17 from TIA-569-B, *Commercial Building Standard for Telecommunications Pathways and Spaces*

New Considerations for Cabling Media and 10 Gigabit Ethernet

10GBASE-T and EMI

- 10GBASE-T
 - Distances are limited due to greater influence of electromagnetic interference

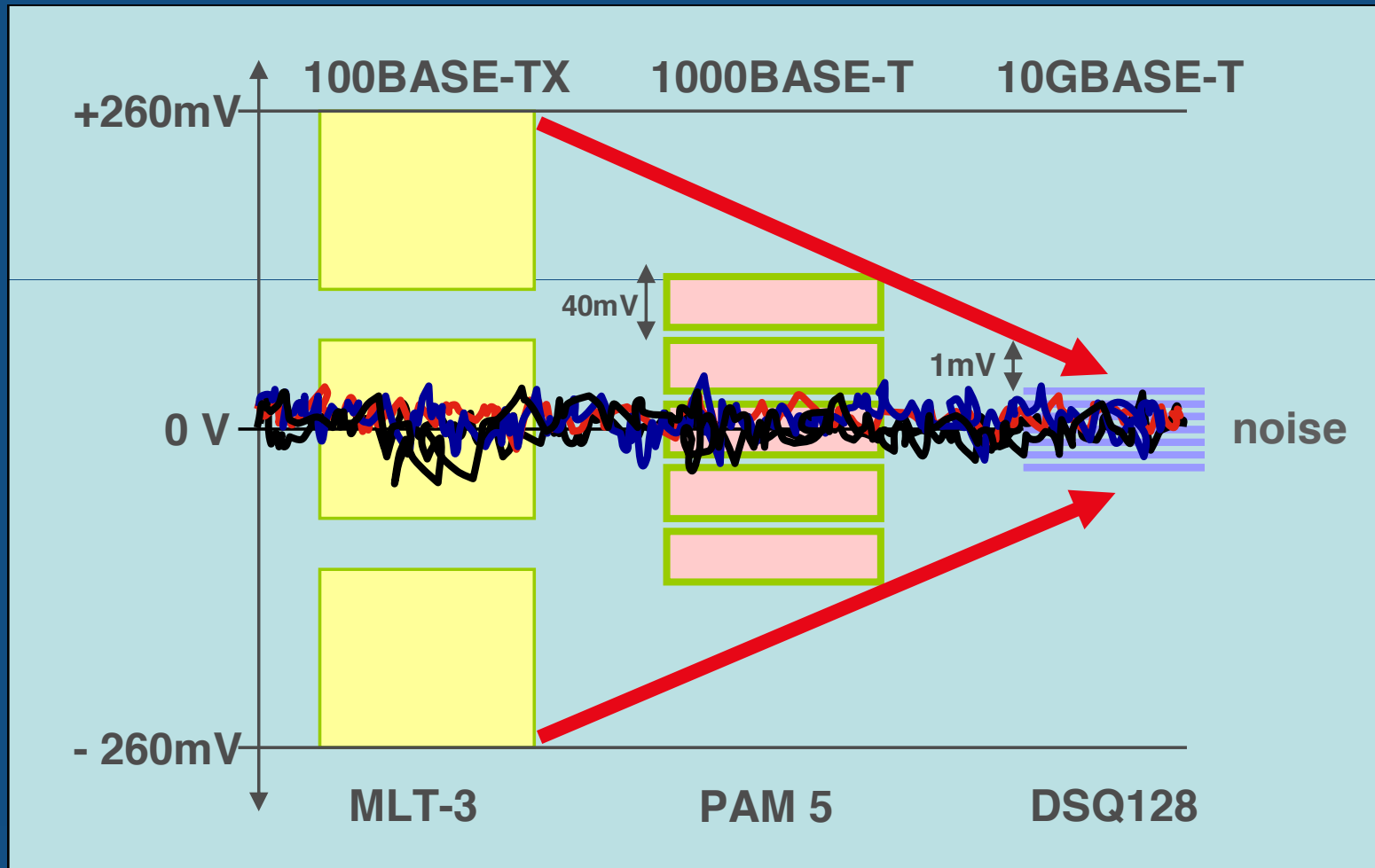
Table 55–12— Cabling types and distances

| Cabling | Supported link segment distances | Cabling references |
|---------------------------------------------|----------------------------------|------------------------------------------|
| Class E / Category 6 | 55 m to 100 m ^a | ISO/IEC TR-24750 / TIA/EIA TSB-155 |
| Class E / Category 6: unshielded | 55 m | ISO/IEC TR-24750 / TIA/EIA TSB-155 |
| Class E / Category 6: shielded | 100 m | ISO/IEC TR-24750 / TIA/EIA TSB-155 |
| Class F | 100 m | ISO/IEC TR-24750 |
| Class E _A / Augmented Category 6 | 100 m | ISO/IEC 11801 Ed 2.1 /TIA/EIA-568-B.2-10 |

^aSupported link segments up to 100 m shall meet the alien crosstalk to insertion loss requirements specified in 55.7.3.1.2 and 55.7.3.2.2.

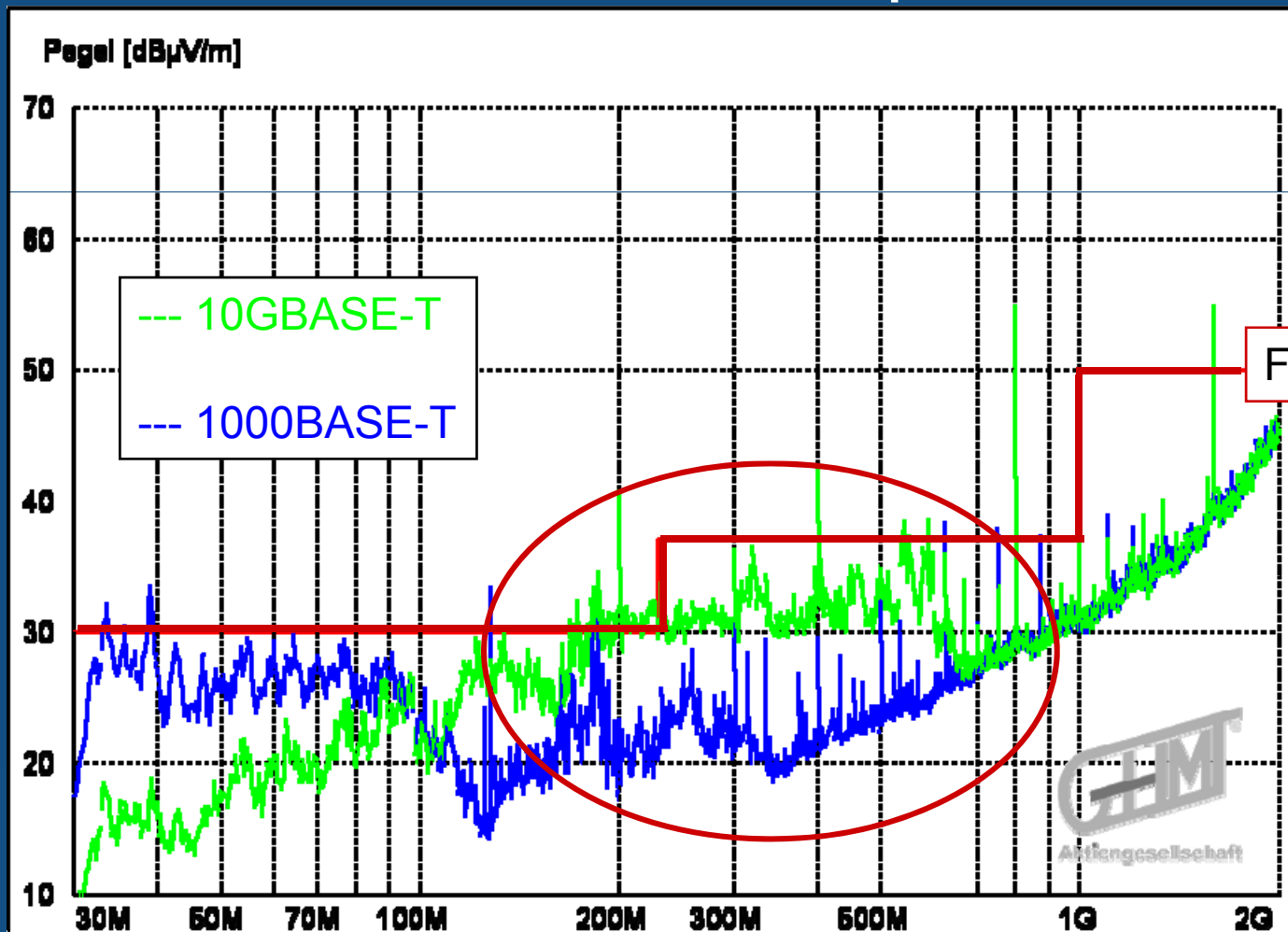
Table 55-12 from IEEE 802.3an, Amendment 1: Physical Layer and Management Parameters for 10 Gb/s Operation, Type 10GBASE-T

10GBASE-T and EMI



10GBASE-T and EMI

- Radiated Noise Comparison



FCC Class B Limit

GEM
Anfangsgesellschaft

Bicsi

10GBASE-T and EMI

- 10GBASE-T is more sensitive to noise
 - Protocol (DSQ128) has a very low signal level
 - The environment is filled with noise sources
 - Mobile phones, radar stations, WLAN, CT, MRI, radio
- 10GBASE-T is prone to radiate radio frequency noise
 - Higher operating frequency than 1000BASE-T
- The system is self-disturbing

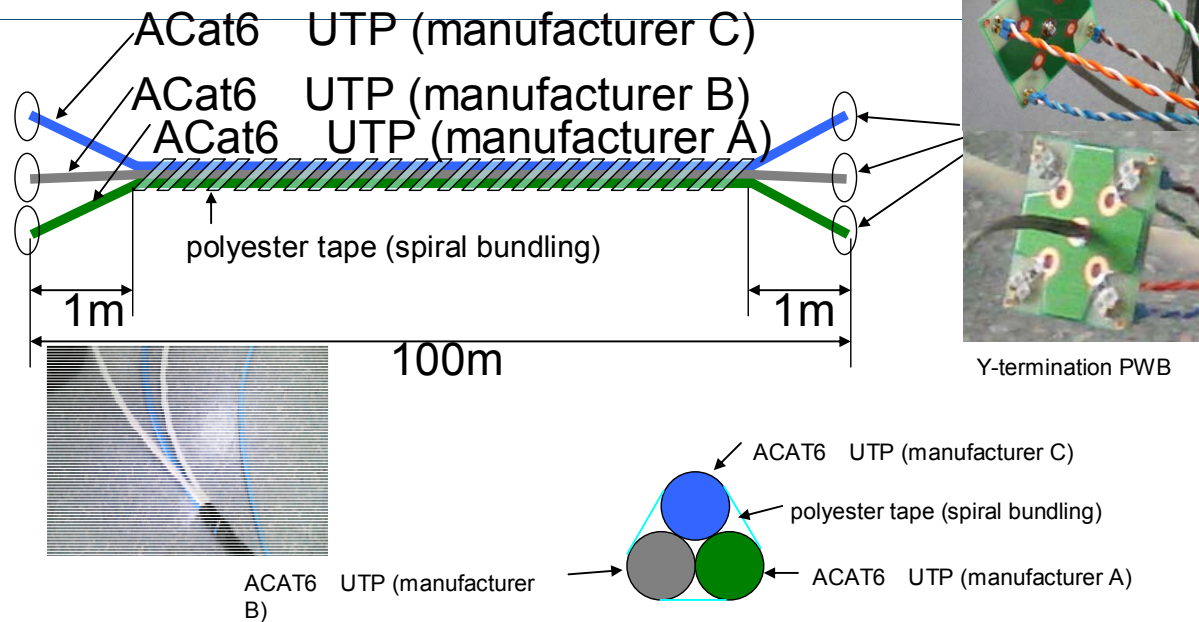
10GBASE-T and EMI

- 10 Gb/s Ethernet requires improved Alien Crosstalk performance
 - mitigate self-disturbing cable-to-cable noise under certain conditions
- Alien crosstalk testing based on “worst case” cable-to-cable noise configuration (6-around-1)
 - Manufacturers have developed different ways to try and meet these alien crosstalk performance requirements for their products

10GBASE-T and EMI

Measurement set up for mixed up
3 cables of different design

1. Sample mixed up bundled cable

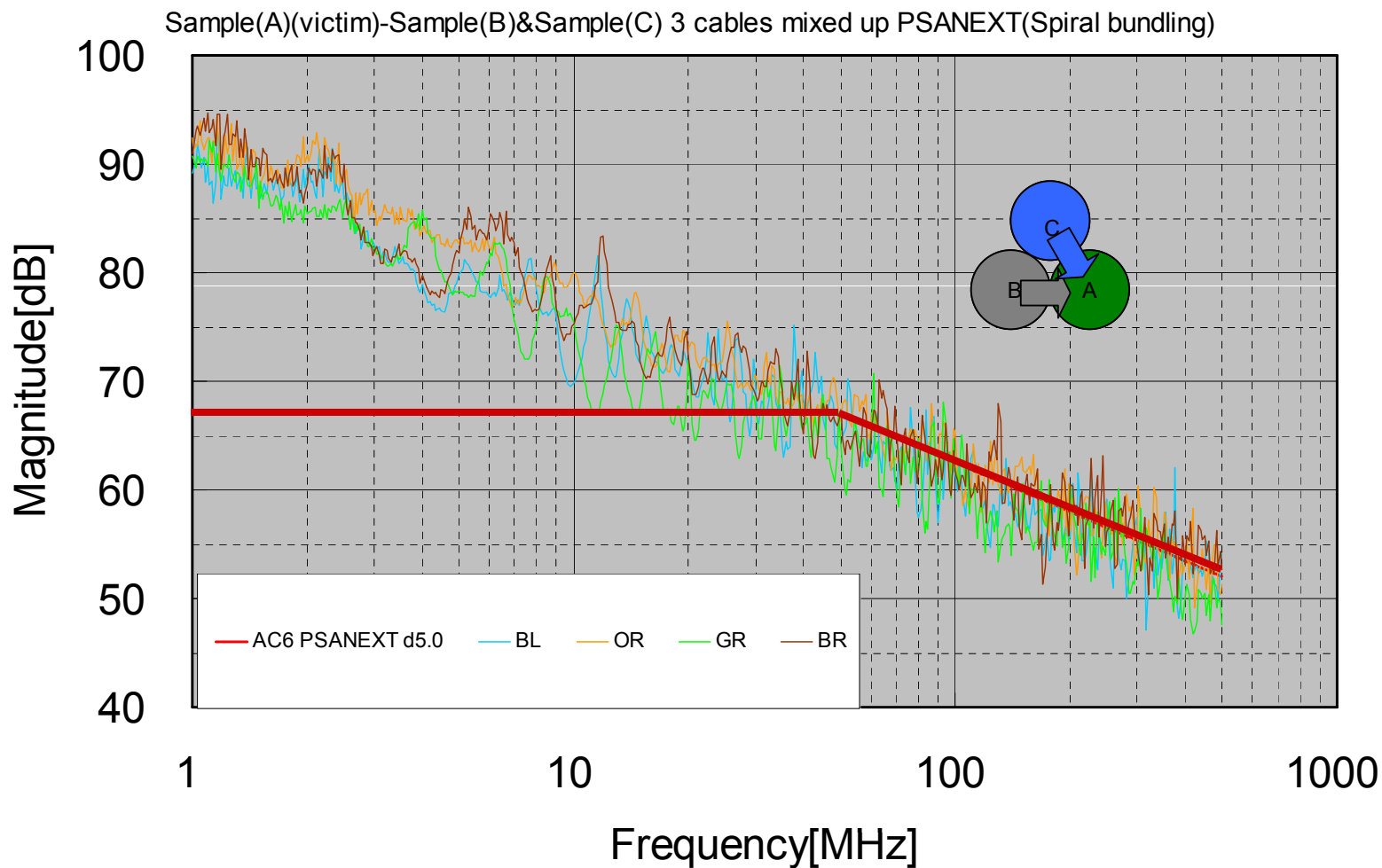


- Third party testing conducted by JEITA

3

Hitachi Cable Ltd. Japan

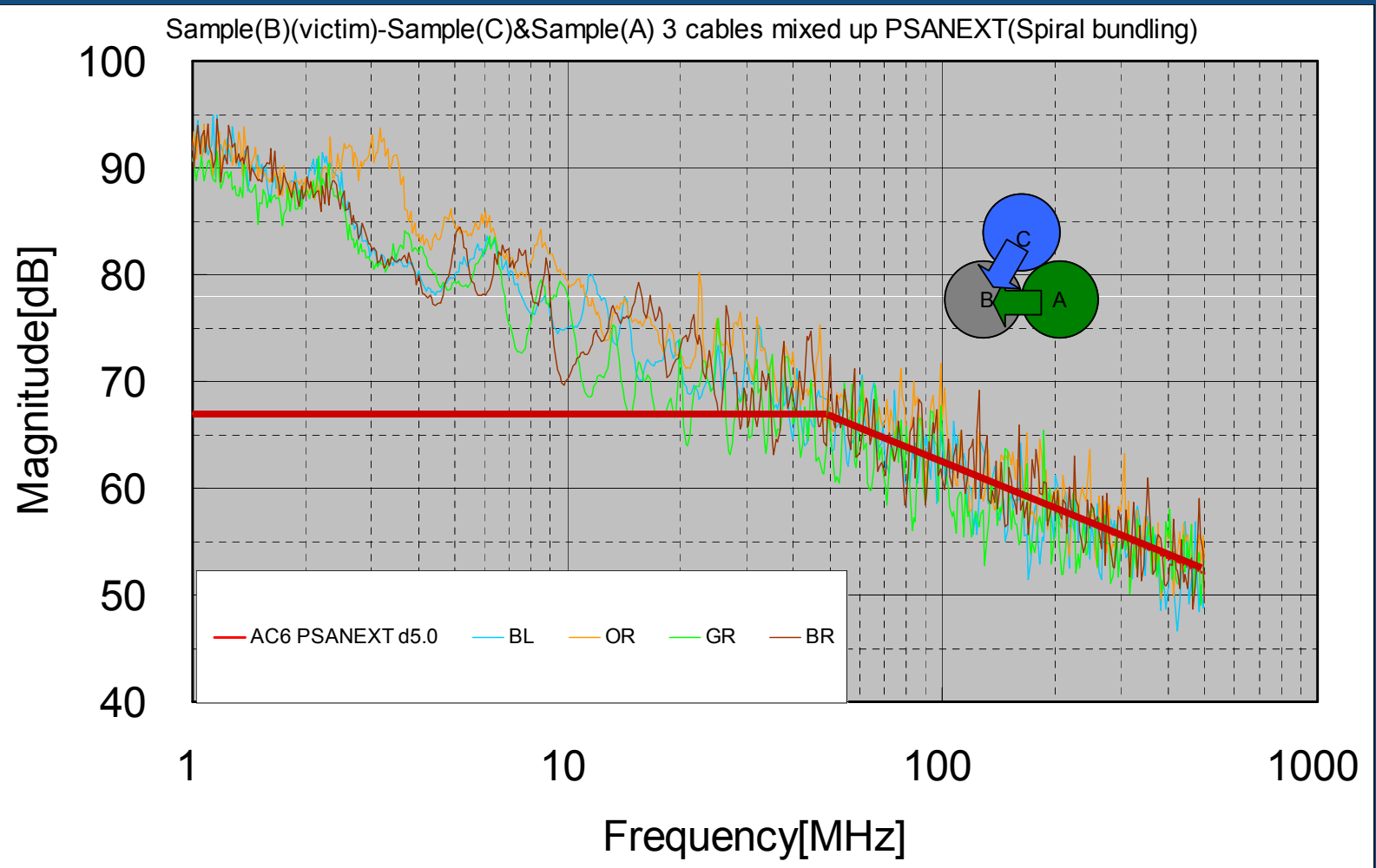
10GBASE-T and EMI



- Cable A is victim cable

10GBASE-T and EMI

- Cable B is victim cable
- Cable C as victim cable passed



TR42.7-2007-07-076-JEITAcablePSANEXT.ppt – contributed by Hitachi Cable Manchester, Ltd.

10GBASE-T and EMI

- TSB-190 (draft) draws conclusions for alien crosstalk performance based on some limited testing
 - Three category 6A 6-around-1 bundles from three different manufacturers
 - a) coupling into the center cable
 - b) coupling into the outer cable

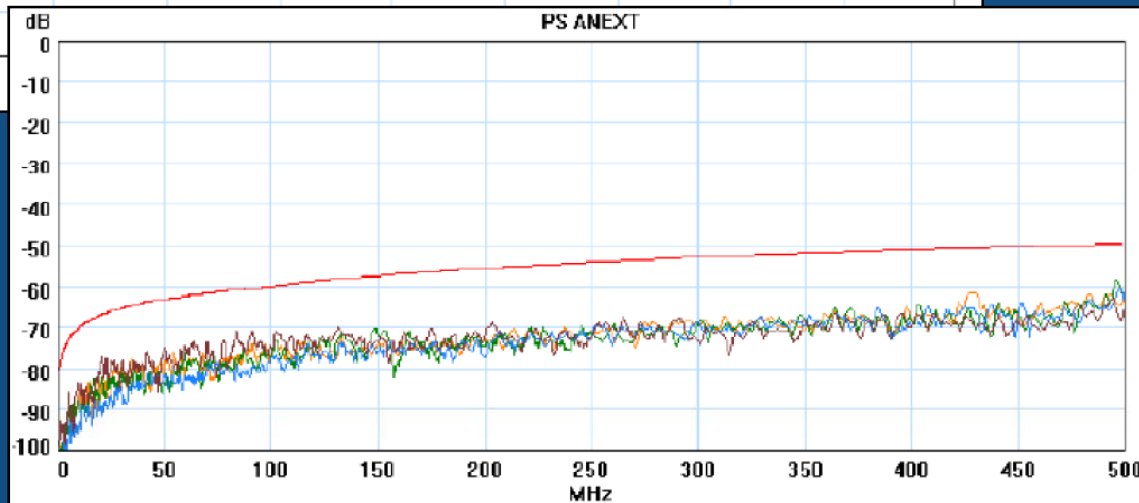
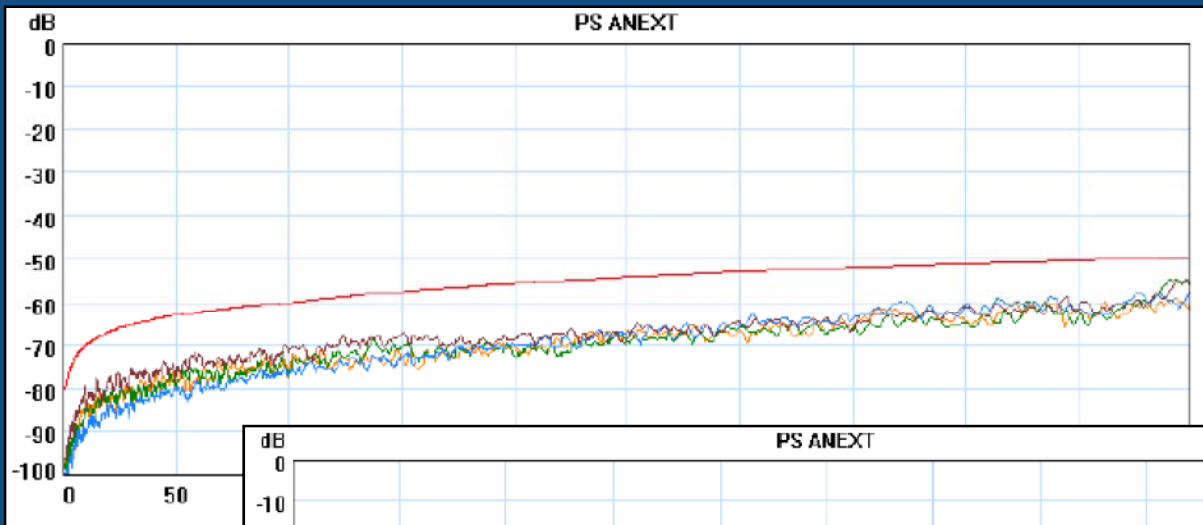


TR42.7-2010-02-025-SharedPathwaySheath d0.4.txt

10GBASE-T and EMI

Coupled to center cable of one bundle

Coupled to outer cable of one bundle



10GBASE-T and EMI

- Alien crosstalk performance can mitigate cable-to-cable crosstalk
 - Testing is still ongoing
 - Power separation
 - Noise separation
 - Mixing applications
 - Mixing vendors
- What about other noise sources?

MICE

- The MICE tables serve as the reference for environmental conditions, test parameters and procedures
- What is MICE?
 - Four “Classifications”, each with multiple parameters
 - Mechanical
 - Ingress
 - Climatic
 - Electromagnetic

MICE

- What is MICE?
 - Three levels: 1, 2 and 3
 - 1 has the most benign conditions and 3 has the harshest conditions for each parameter
 - Office environments (controlled) associated with Level 1
 - Office/enterprise buildings and data centers associated with Level 2
 - Industrial environments associated with Level 3
 - Note: For some facilities (e.g. hospitals, airports) a combination of different levels may be appropriate (M1, I2, C2, E3)

The E in MICE

| Electromagnetic | E ₁ | E ₂ | E ₃ |
|--------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| Electrostatic discharge – Contact (0,667 µC) | 4 kV | 4 kV | 4 kV |
| Electrostatic discharge – Air (0,132 µC) | 8 kV | 8 kV | 8 kV |
| Radiated RF - AM | 3 V/m at (80 to 1 000 MHz) 3 V/m at (1 400 to 2 000 MHz) 1 V/m at (2 000 to 2 700 MHz) | 3 V/m at (80 to 1 000 MHz) 3 V/m at (1 400 to 2 000 MHz) 1 V/m at (2 000 to 2 700 MHz) | 10 V/m at (80 to 1 000 MHz) 3 V/m at (1 400 to 2 000 MHz) 1 V/m at (2 000 to 2 700 MHz) |
| Conducted RF | 3 V at 150kHz to 80MHz | 3 V at 150kHz to 80MHz | 10 V at 150kHz to 80MHz |
| EFT/B (comms) | 500 V | 1 kV | 1 kV |
| Surge (transient ground potential difference) - signal, line to earth | 500 V | 1 kV | 1 kV |
| Magnetic Field (50/60 Hz) | 1 Am ⁻¹ | 3 Am ⁻¹ | 30 Am ⁻¹ |
| Magnetic Field (50 Hz to 20 000 Hz) | ffs | ffs | ffs |

NOTES

1 – Bump: the repetitive nature of the shock experienced by the channel shall be taken into account.

2 – This aspect of environmental classification is installation-specific and should be considered in association with IEC 61918 and the appropriate component specification.

3 – A single dimensional characteristic, i.e. Concentration x 10⁻⁶, was chosen to unify limits from different standards.

The E in MICE

| | |
|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| Electrostatic discharge - contact | Static shock a person experiences after walking across a carpet and then touching a metallic object |
| Electrostatic discharge - air | |
| Radiated RF (radio frequency) - AM (amplitude-modulated) | 9 KHz – 80 MHz frequency range (e.g. AM/FM radio, broadcast TV) |
| Conducted radio frequency | 80 MHz – 2 GHz frequency range (e.g. mobile telephones, wireless networks) |
| ETF/B (comms) (Fast Transient/Burst) | Fast transients and bursts from switching on/off electrical devices |
| Surge (transient ground potential difference) – signal, line to earth | |
| Magnetic Field (50/60 Hz) | Transformers and areas where power is distributed – usually low frequency from power distribution |
| Magnetic Field (60 to 20 kHz) | |

Third-party, Independent Testing
Evaluating Noise on 10 Gigabit
Ethernet Networks

Noise and 10GBASE-T

- Independent, third party (no vested interest) evaluation of the effects of power and noise sources
- Objectives:
 - Evaluate 10GBASE-T
 - Use standards-based conditions (MICE)
 - Consider practical conditions and disturbers
 - Evaluate different cabling types

The Independent Third Party

- GHMT AG in Bexbach, Germany
- Independent test laboratory
- ISO/IEC 17025 accredited (2000)
- All tests in an EMC chamber

The Channels

- Six Vendors
 - 3 UTP systems Class E_A (Cat 6A)
 - 3 STP systems Class E_A (Cat 6A)
 - F/UTP, S/FTP (standard), S/FTP (high end)
- Qualification Criteria
 - ISO/IEC 11801 Class E_A channel
- Open market purchase

Qualification Results (Margin)

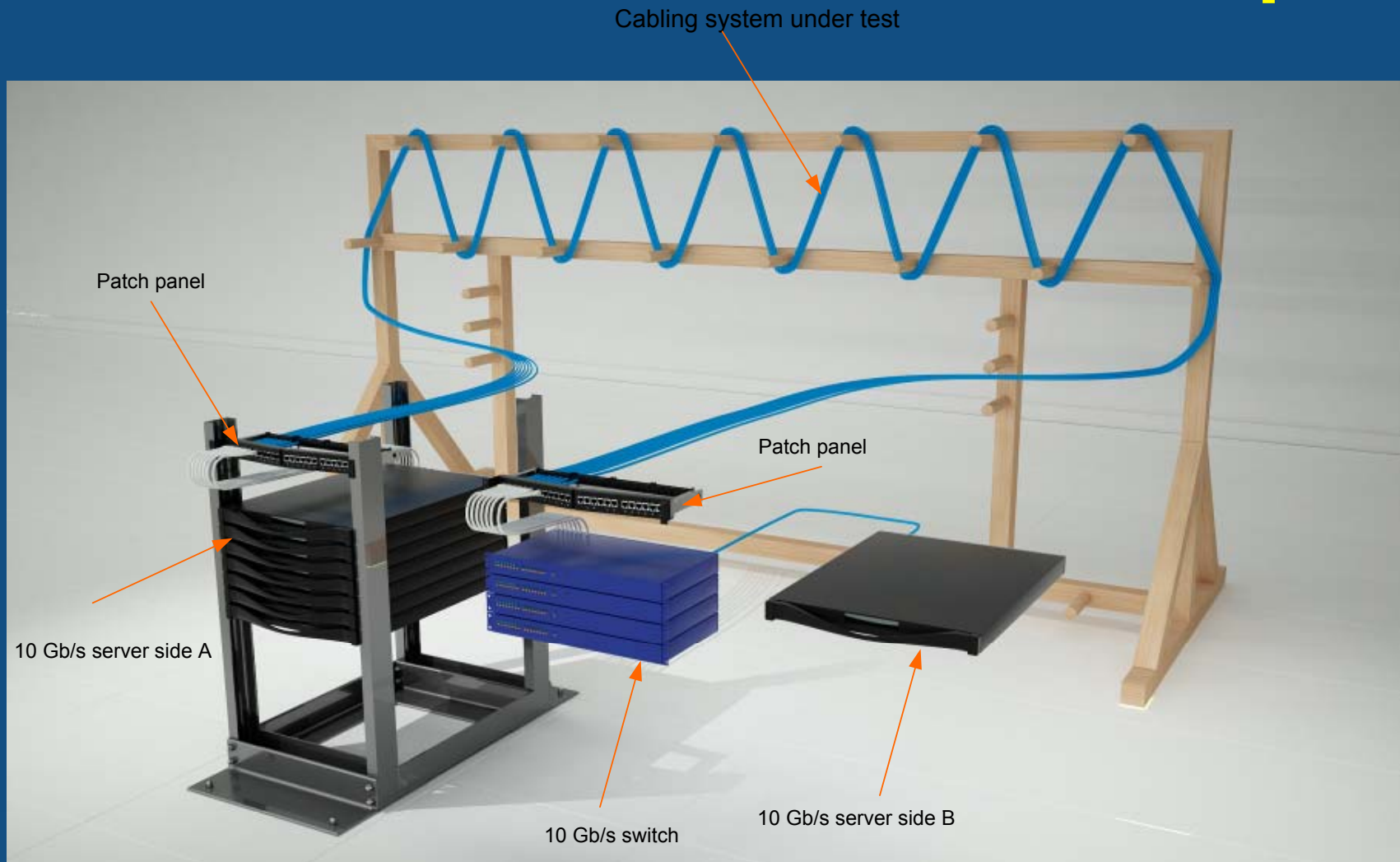
| | System 00 | | System 01 | | System 02 | | System 03 | | System 04 | | System 05 | |
|----------------------------------|--------------|-------|-------------|-------|-------------|-------|--------------|-------|--------------|-------|--------------|-------|
| Type | U/UTP | | U/UTP | | U/UTP | | F/UTP | | S/FTP | | S/FTP | |
| channel | long | short | long | short | long | short | long | short | long | short | long | short |
| Insertion loss (margin) [dB] | 8.4 | 34.4 | 8.8 | 35.4 | 8.6 | 35.3 | 8.6 | 35.5 | 10.5 | 34.9 | 15.5 | 36.5 |
| NEXT (margin) [dB] | 1.1 | 1.2 | 4.2 | 4.2 | 6.2 | 7.4 | 7.3 | 7.5 | 5.6 | 4.6 | 5.0 | 5.4 |
| PS NEXT (margin) [dB] | 3.2 | 3.8 | 5.5 | 5.3 | 8.2 | 8.0 | 7.8 | 7.6 | 5.8 | 4.8 | 6.2 | 6.0 |
| TCL (margin) [dB] | 6.4 | | 9.2 | | 8.9 | | 9.6 | | 5.45 | | 10.4 | |
| RL (margin) [dB] | 4.3 | 6.6 | 8.8 | 8.1 | 9.5 | 8.5 | 3.4 | 3.0 | 6.9 | 9.4 | 8.2 | 7.2 |
| PS ANEXT (margin) [dB] | -17.7 | | -7.6 | | 0.93 | | 27.44 | | 31.37 | | 37.92 | |
| Coupling Attenuation (abs.) [dB] | 21.5 | | 45.0 | | 47.5 | | 78.0 | | 76.0 | | 79.0 | |

Qualification Results (Margin)

| | System 00 | | System 01 | | System 02 | | System 03 | | System 04 | | System 05 | |
|----------------------------------|--------------|-------|-------------|-------|-------------|-------|--------------|-------|--------------|-------|--------------|-------|
| Type | U/FTP | S/FTP | U/UTP | | U/UTP | | F/UTP | | S/FTP | | S/FTP | |
| channel | long | short | long | short | long | short | long | short | long | short | long | short |
| Insertion loss (margin) [dB] | 1.4 | 1.4 | 8.8 | 35.4 | 8.6 | 35.3 | 8.6 | 35.5 | 10.5 | 34.9 | 15.5 | 36.5 |
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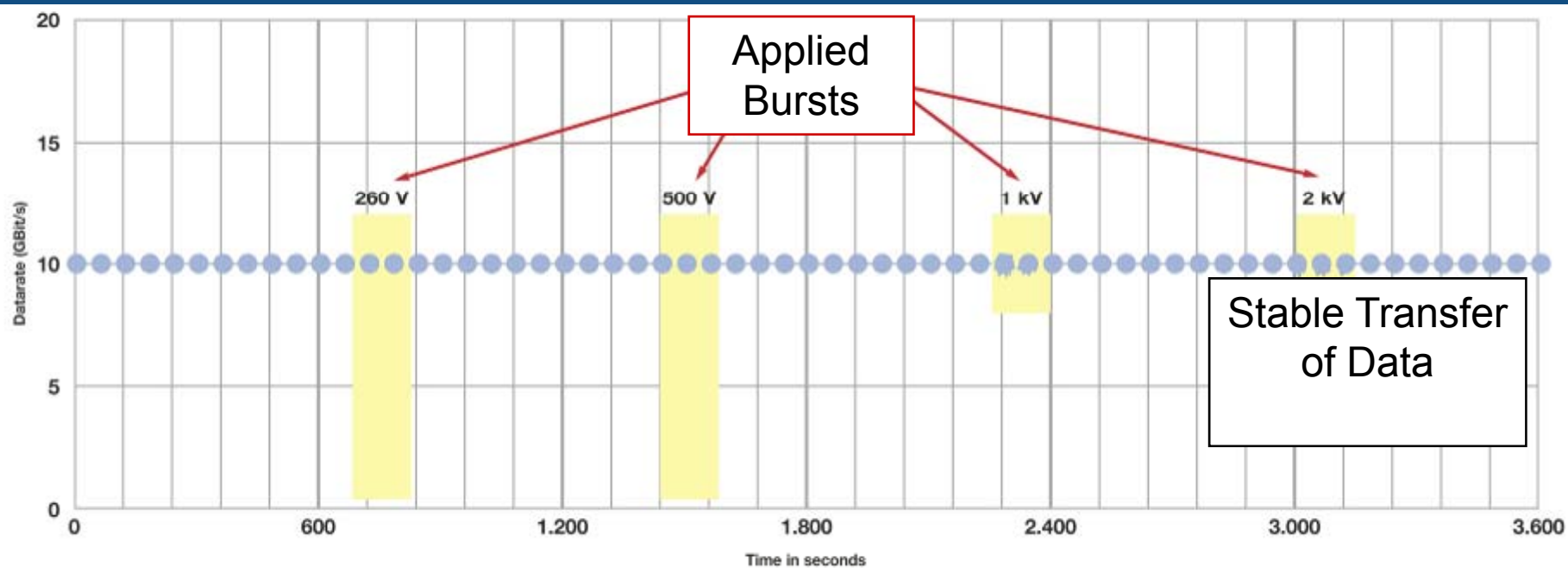
- Cut: Because of insufficient PS ANEXT performance, system 00 was excluded from further tests in the study

10GBASE-T - Live Test Setup



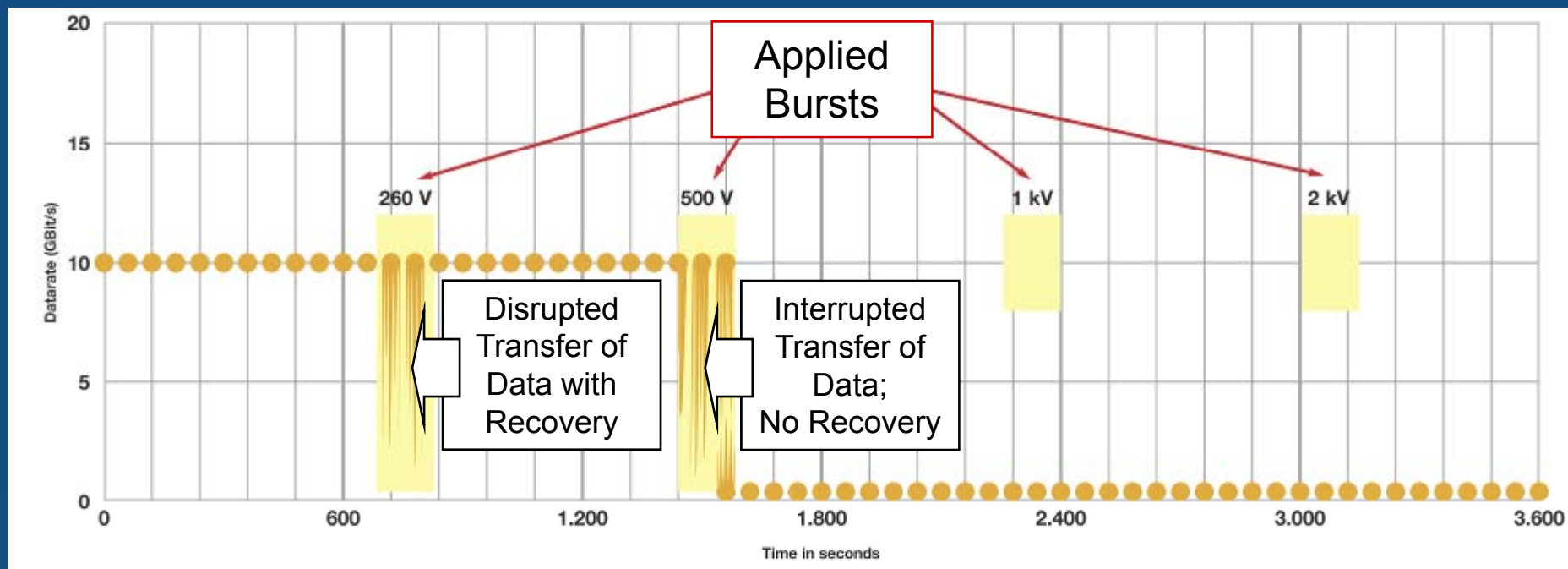
Data Impact

- What happens to the data?
 - Best case – no effect



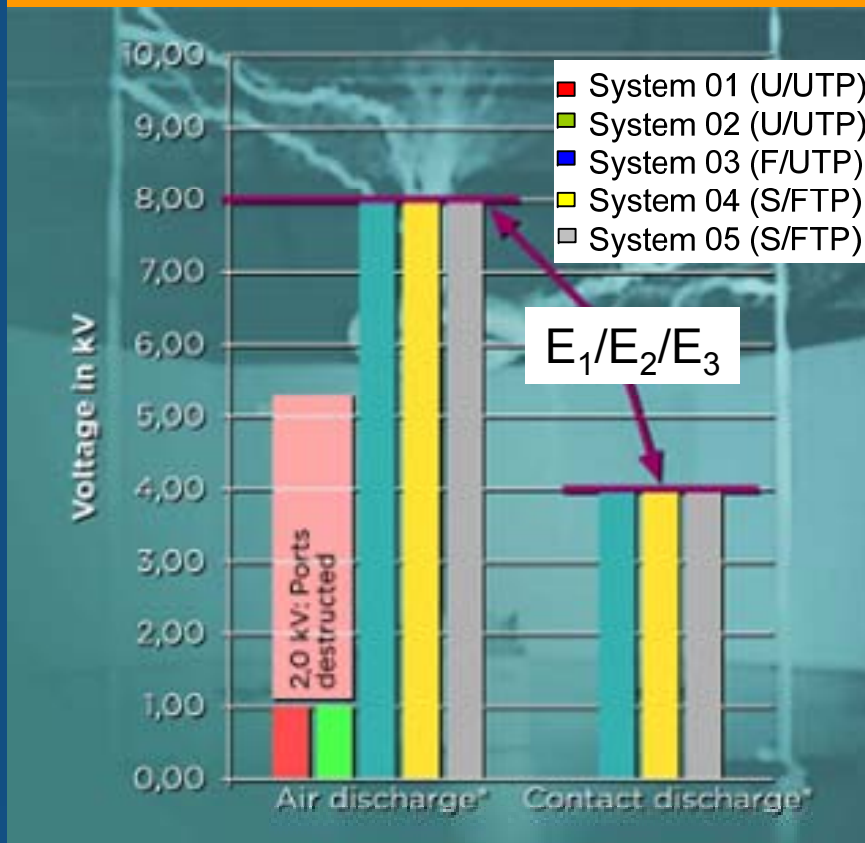
Data Impact

- What happens to the data?
 - Bad case - disrupted transmission
 - Worst case – complete interruption



Standards: Electrostatic Discharge - Contact and Air

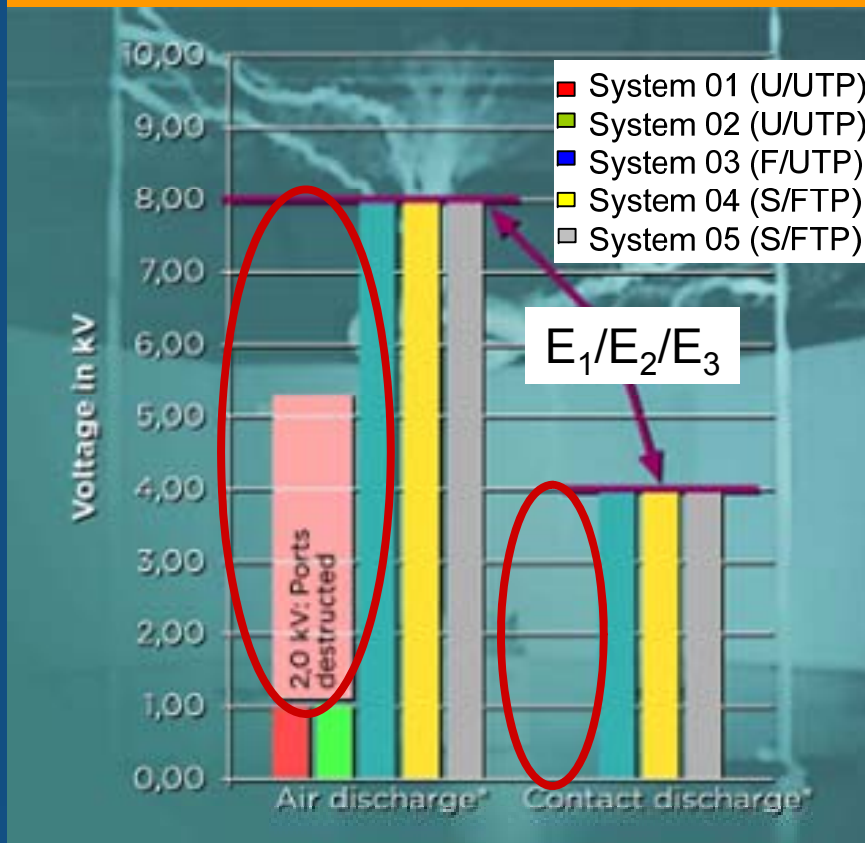
Electrostatic discharge



- IEC-EN 61000-4-2
- Determine system immunity against ESD caused by
 - low relative humidity
 - low-conductivity floor coverings
 - operator clothing

Standards: Electrostatic Discharge - Contact and Air

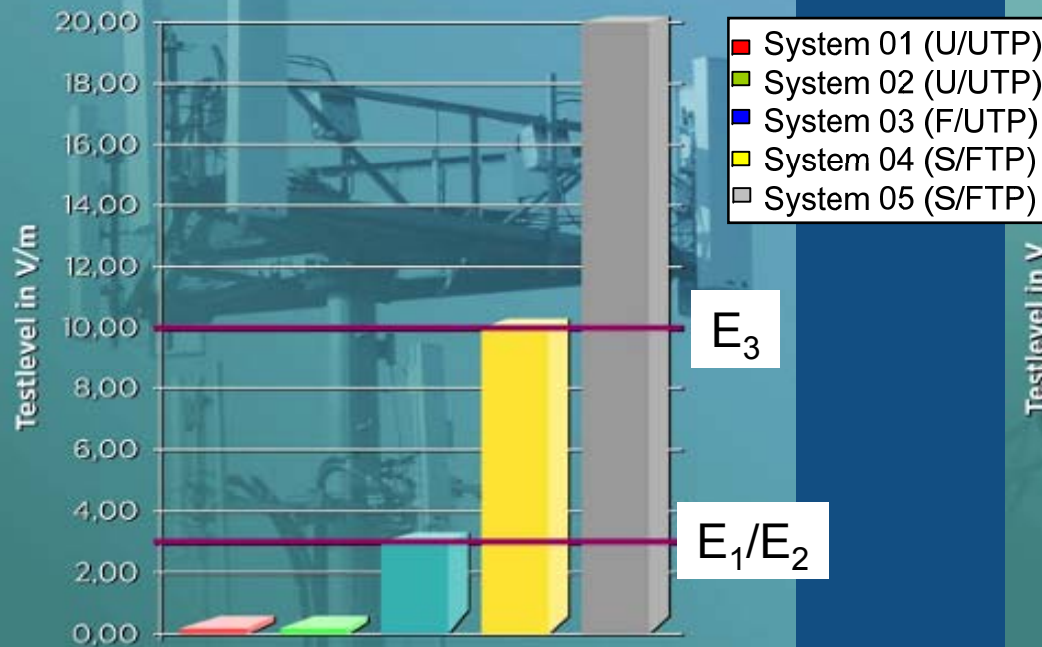
Electrostatic discharge



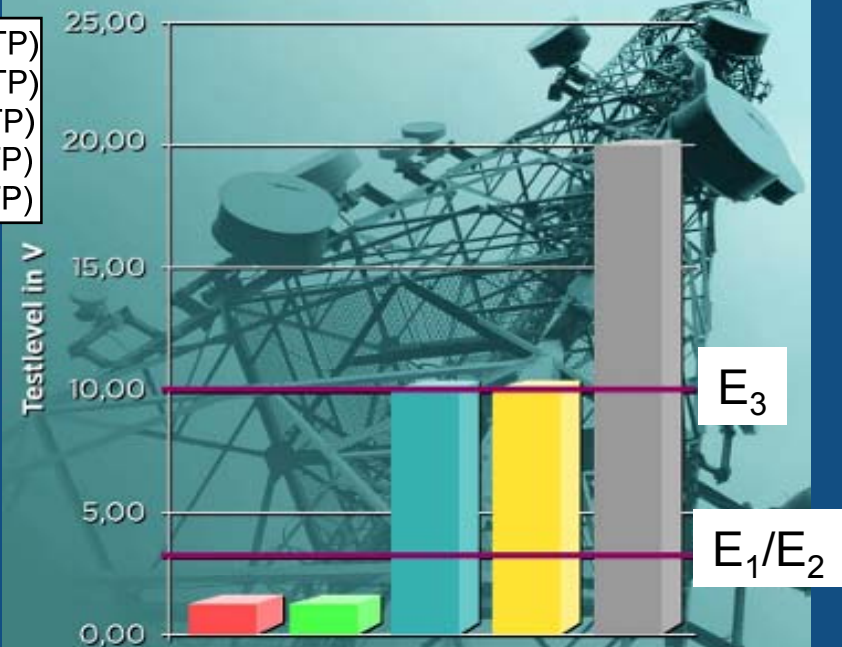
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Standards: Radiated RF - AM and Conducted Radio Frequency

Radiated High Frequency



Conducted High Frequency

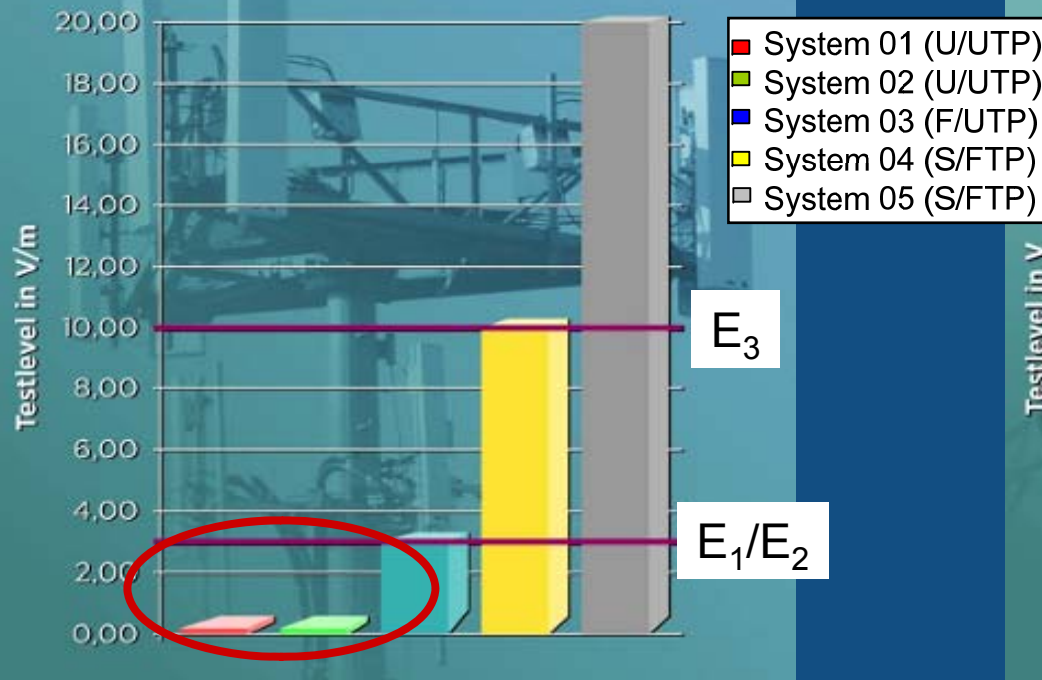


- IEC-EN 61000-4-3
- Immunity of the overall system to 80.0 MHz to 2.0 GHz
- Antenna

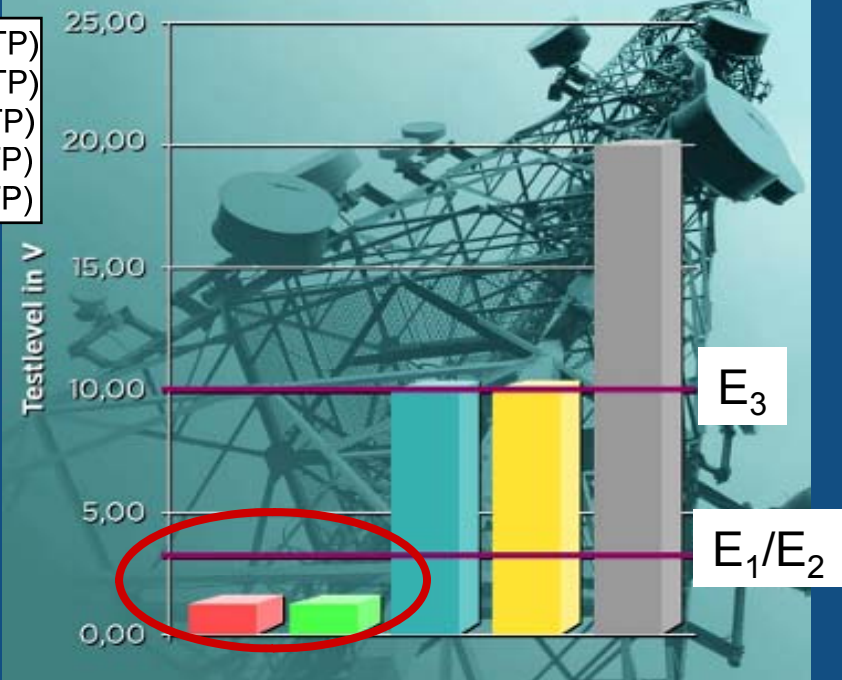
- IEC-EN 61000-4-6
- Immunity of the overall system to 150 kHz to 80 MHz
- Coupling clamp

Standards: Radiated RF - AM and Conducted Radio Frequency

Radiated High Frequency



Conducted High Frequency



- IEC-EN 61000-4-3
- Immunity of the overall system to 80.0 MHz to 2.0 GHz
- Antenna

- IEC-EN 61000-4-6
- Immunity of the overall system to 150 kHz to 80 MHz
- Coupling clamp

Practical Test: Mobile Phones

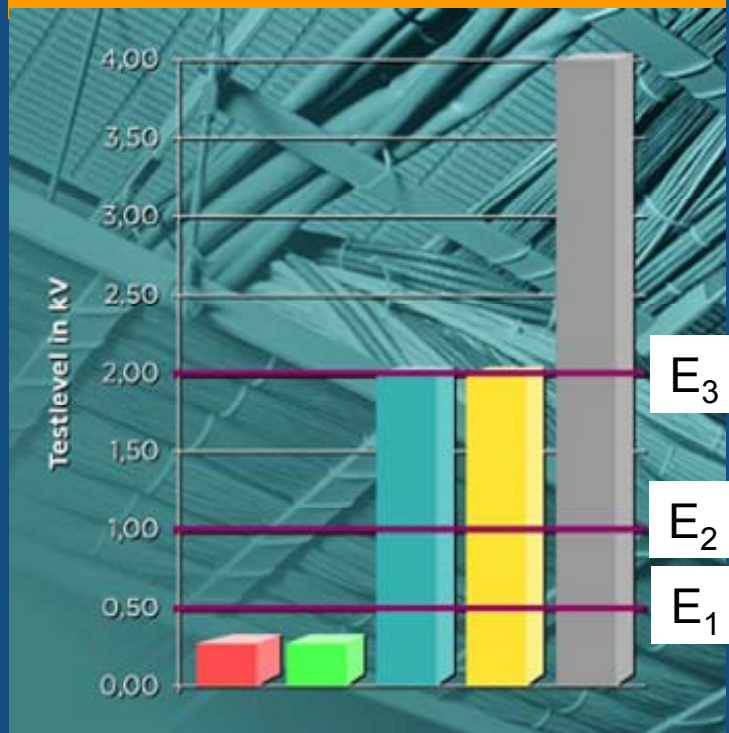
- 10GBASE-T data traffic was monitored while disturbers active near cables

| | Sys 01 UTP | Sys 02 UTP | Sys 03 F/UTP | Sys 04 S/FTP | Sys 05 S/FTP |
|-------------|---------------|---------------|-----------------|-----------------|-----------------|
| Cell Phones | ✘ | ✘ | ✓ | ✓ | ✓ |
| 2-way Radio | ✘ | ✘ | ✓ | ✓ | ✓ |

✘ = 10GBASE-T data transfer disrupted or interrupted

Standards: Fast Transients and Bursts

Fast Transients/Burst

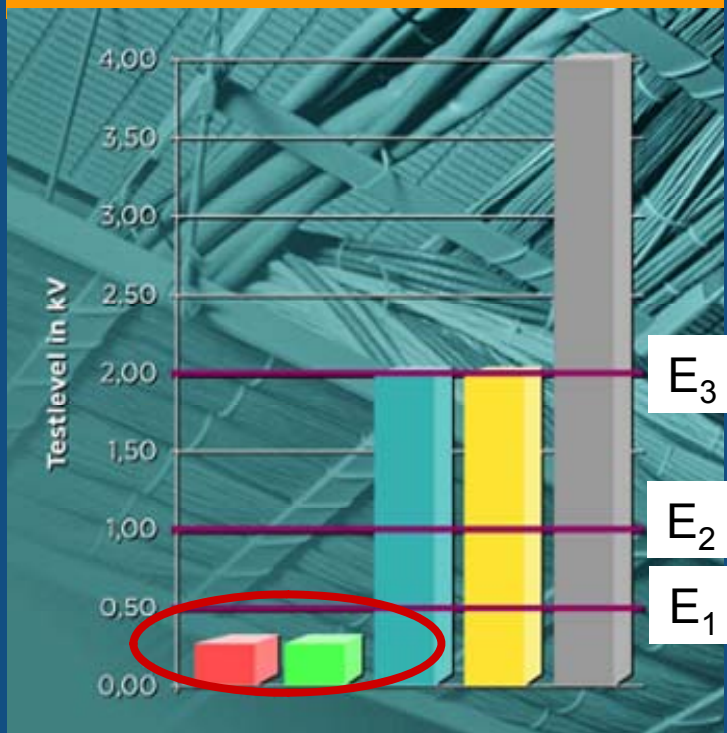


- System 01 (U/UTP)
- System 02 (U/UTP)
- System 03 (F/UTP)
- System 04 (S/FTP)
- System 05 (S/FTP)

- IEC-EN 61000-4-4
- Determine system immunity against fast transient electrical disturbances as generated by transient switching
 - Cut-off of inductive loads
 - Relay contact chatter
 - Illuminating fluorescent lamps

Standards: Fast Transients and Bursts

Fast Transients/Burst



- System 01 (U/UTP)
- System 02 (U/UTP)
- System 03 (F/UTP)
- System 04 (S/FTP)
- System 05 (S/FTP)

- IEC-EN 61000-4-4
- Determine system immunity against fast transient electrical disturbances as generated by transient switching
 - Cut-off of inductive loads
 - Relay contact chatter
 - Illuminating fluorescent lamps

Practical Test: Fluorescent Lamps

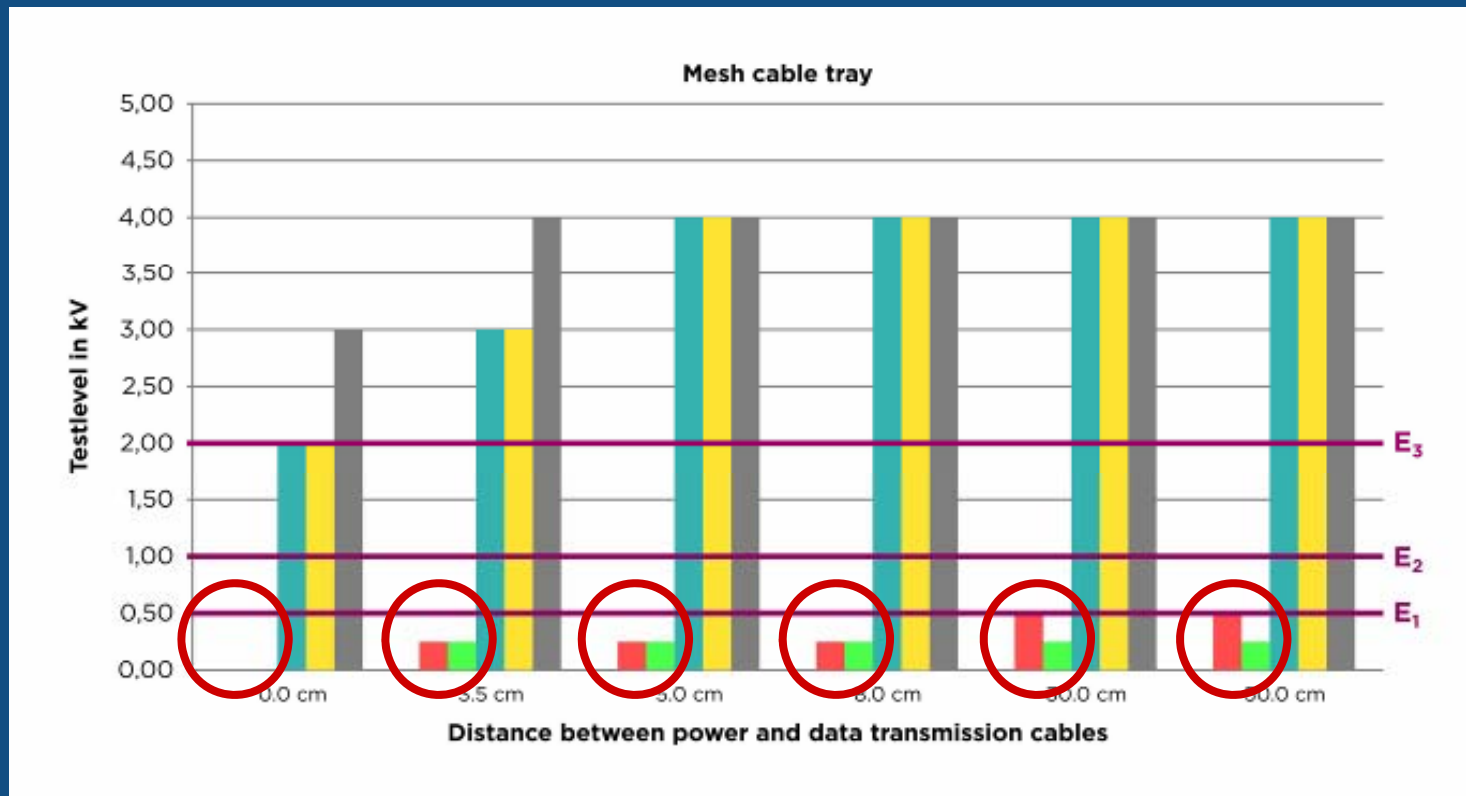
| | System 01 UTP | System 02 UTP | System 03 F/UTP | System 04 S/FTP | System 05 S/FTP |
|------------------|------------------|------------------|--------------------|--------------------|--------------------|
| Fluorescent Lamp | ✘ | ✘ | ✓ | ✓ | ✓ |

- ✘ = 10GBASE-T data transfer disrupted or interrupted, even at distances beyond 0.5m
- Effect observed during on/off and off/on transitions
 - Off-to-on had a greater effect
 - Proximity to power feed cable had greater effect than proximity to light fixture

Practical Test: Power Cable Separation Distance

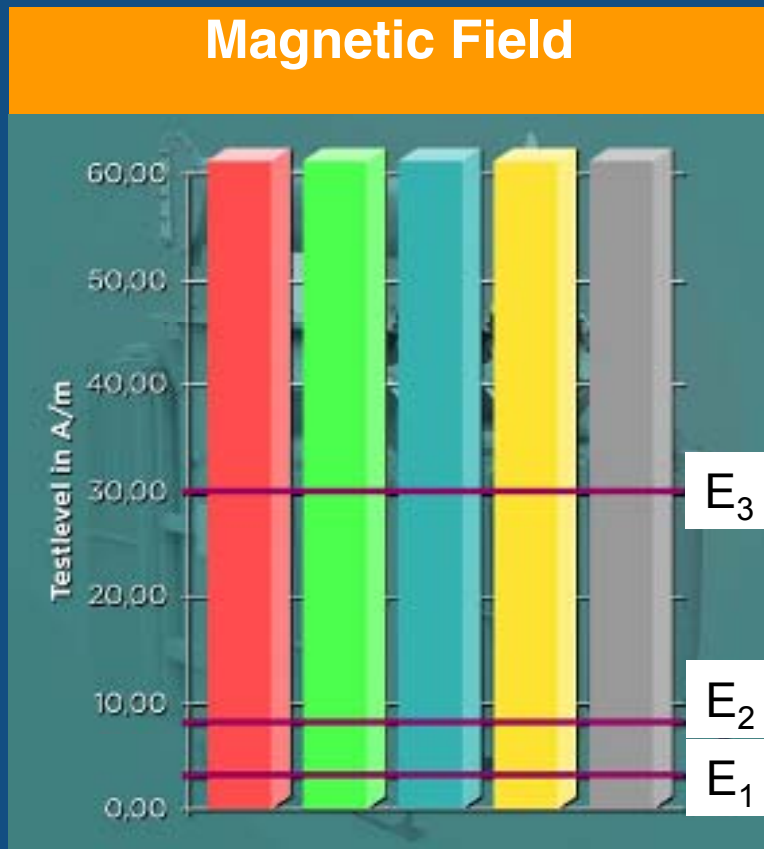
- Distances up to 50 cm in mesh tray
- Simulation of common installation
- Bursts placed on power cables

Practical Test: Power Cable Separation Distance



Standards: Magnetic Fields

Magnetic Field



- System 01 (U/UTP)
- System 02 (U/UTP)
- System 03 (F/UTP)
- System 04 (S/FTP)
- System 05 (S/FTP)

- IEC-EN 61000-4-8
- Determine system immunity against
- Simulates disturbances of 50/60 Hz magnetic fields (e.g. currents in lines and busbars, transformers, low-voltage main distributors)

Conclusion

Summary of 10 Gb/s Test Results

| Parameter | System 1 | System 2 | System 3 | System 4 | System 5 |
|--------------------------|----------|----------|----------|----------|----------|
| | U/UTP | U/UTP | F/UTP | S/FTP | S/FTP |
| Radiated high frequency | -- | - | + | ++ | +++ |
| Conducted high frequency | - | - | ++ | ++ | +++ |
| Fast transient | -- | - | ++ | ++ | +++ |
| Magnetic fields | +++ | +++ | +++ | +++ | +++ |
| Electrostatic discharge | -- | -- | ++ | ++ | ++ |
| PS ANEXT | -- | 0 | ++ | ++ | +++ |

+++ = excellent
++ = very good
+ = good

0 = marginal
- = poor
-- = very poor

What does all this mean?

- Current guidance on power separation is not enough
- Balance is no longer enough
 - More noise sources
 - Worse EMI environment
- Alien crosstalk is not enough
 - May be adequate for cable-to-cable noise for cables from the same vendor
 - Does not address other external noise sources

What Now?

- EMC awareness becoming more important
- More testing is in order
 - Power Separation Task Group
 - Separation Table Edits
 - TSB-190 on shared pathways and shared sheath
 - Newer electronics
 - Identification of the right parameters

What Now?

- Coupling Attenuation
 - Measurement of emission and immunity
 - Ratio of power into the pair to the power into the environment
 - UTP Cables: balance only
 - F/UTP and S/FTP cables: balance and shielding effectiveness
 - correlates to alien crosstalk and noise immunity

What can I do until then?

- Be sensitive to alien crosstalk
 - Recognize it may not be enough
- Be sensitive to coupling attenuation
 - Per ISO – a shielded, balanced, twisted-pair cable coupling attenuation of 40+10dB meets alien crosstalk requirements by design
 - no testing necessary
 - Alien crosstalk and EMC performance

Power Separation and 10 Gigabit Ethernet

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