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CABLEMASTER Series

NETXPERT XG2-Series

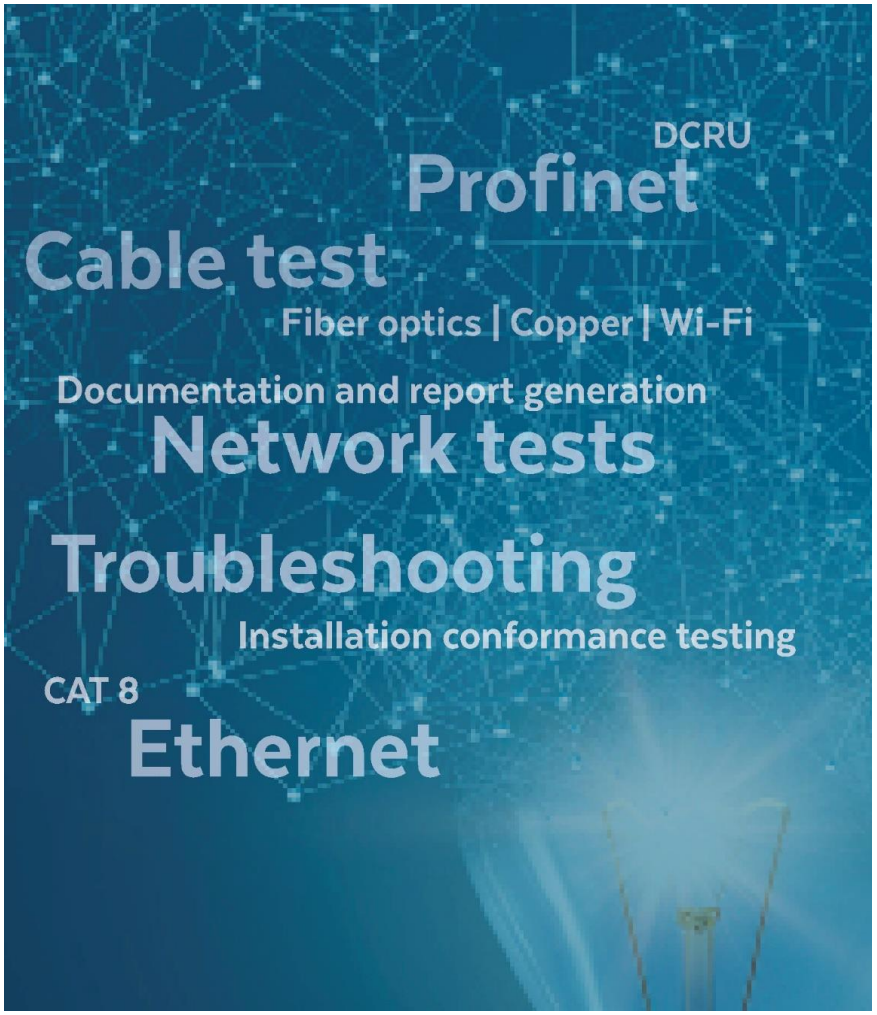
LINKXPERT Series

WireXpert Series

FiberXpert OTDR 5000

FIBERXPERT 700

LAN Networks – Cable Testing best practice



1. LAN environment
2. LAN Test & Measurement Types
3. LAN Copper cables test methods
4. LAN Copper Cabling Standards
5. LAN Fiber cables
6. LAN Fiber cables test methods
7. LAN Fiber cables standards
8. Q&A

LAN environment

Tertiary

Horizontal cabling, Floor cabling

Preferably implemented in Copper (*Twisted Pair*)

Version with or without consolidation point

Secondary

Backbone, Riser Area, Vertical cabling

Preferably implemented in FO (*Multimode/Singlemode*)

Primary

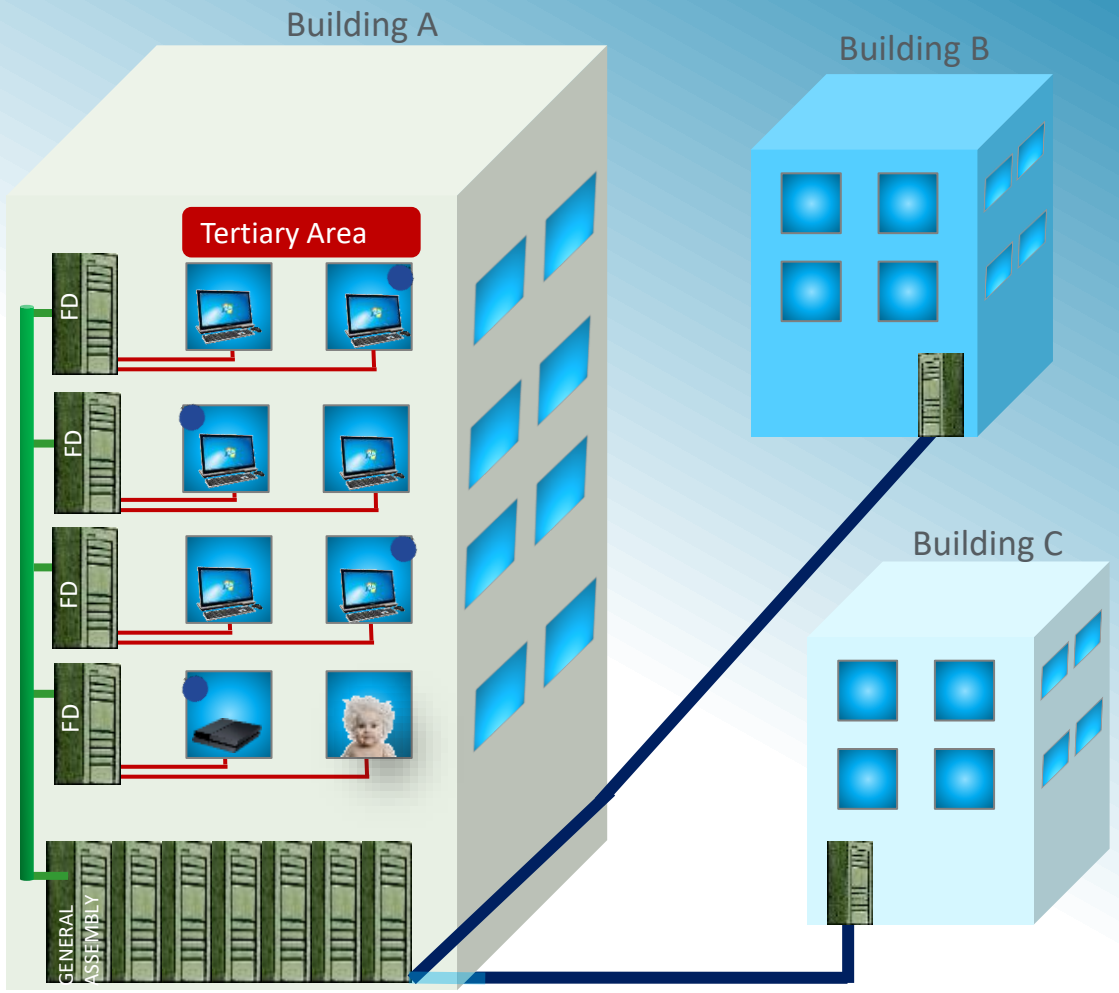
Campus, Between the buildings

Preferably implemented in FO (*Singlemode/Multimode*)

WiFi

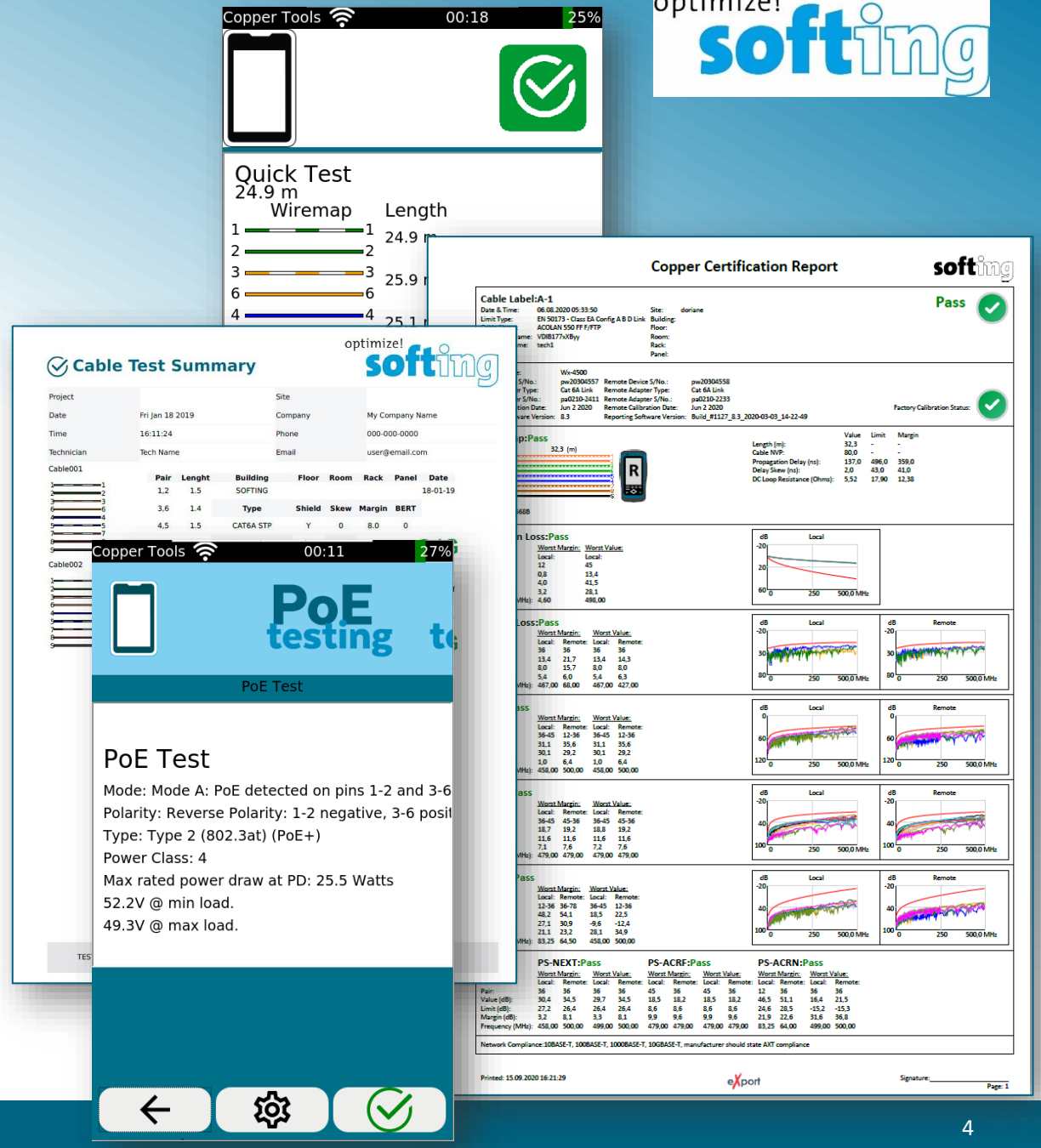
Still: IEEE802.11n max. 600 MBit/s

New: IEEE802.11ax 5-10 Gb/s

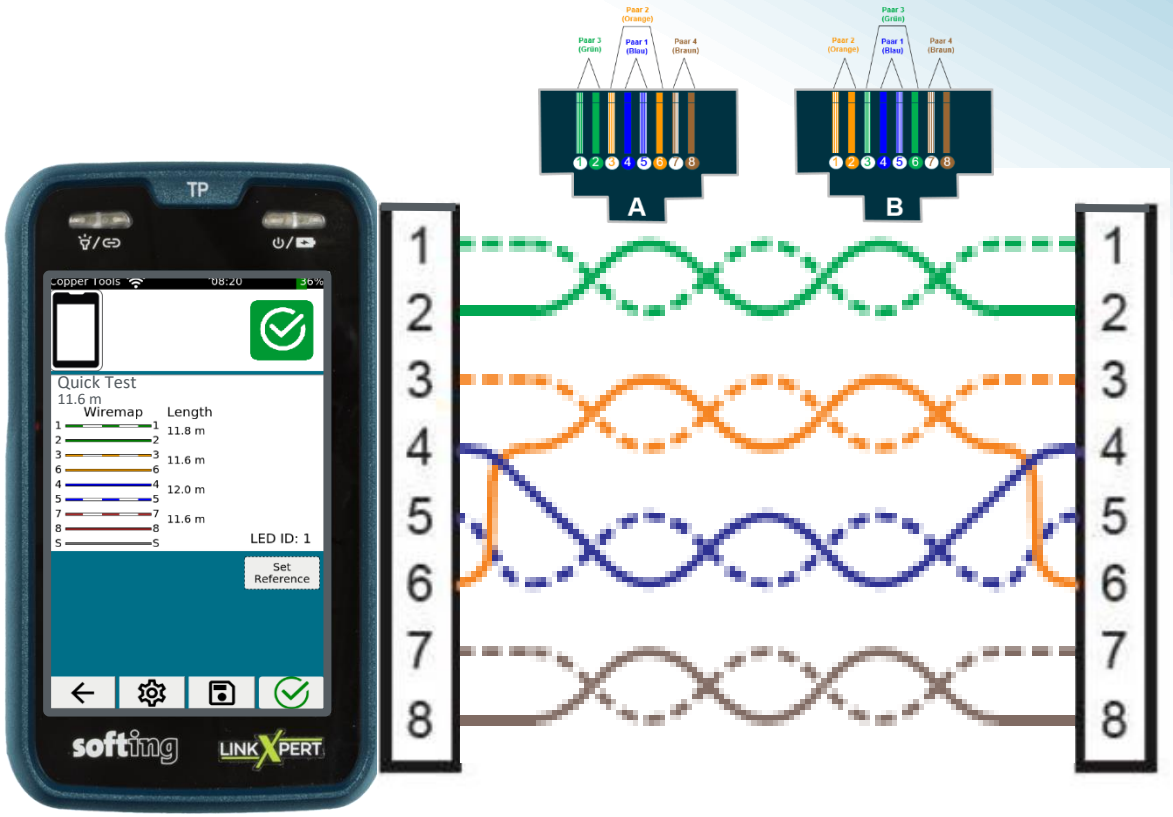


LAN Test and measurement types

- **Verification**
  - Basic test of the cabling
  - Check for correct wiring
- **Qualification**
  - Determining the transmission capabilities of data links
- **Certification**
  - Acceptance measurements of networks
  - Assessment against standards
  - Different link definitions
  - Number of LF/HF measurement and calculated parameters
- **Active/troubleshooting**
  - Typical Ethernet problems
  - Standardized transmission test, e. g. RFC 2544, EtherSAM
  - Special testers for troubleshooting or functions included in verifier or qualifier



Verifying Copper cables



- Advanced Pro versions provide in addition Network testing features:
  - Switch speed, PoE measurement
  - DHCP, Ping, Traceroute, Network Map, Duplicate IPs, MAC spoof, Switch LED blink, CDP & LLDP port discovery and Reporting

Tone Probe

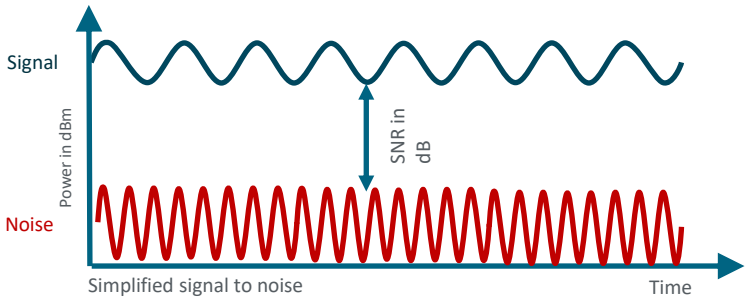
Basic PRO Wire mapper
With screen backlight

LED Wire mapper

Qualifying Copper cables

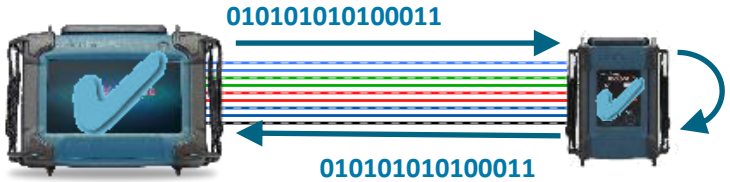
SNR
Signal-to-Noise Ratio

- The ratio of Signal to Noise power
- If the signal power becomes too low and the noise power is too high, data cannot be detected by the receiver.



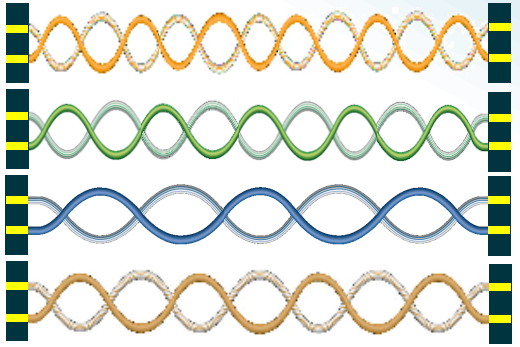
BERT
Bit Error Rate Test

- 'Try and Error' principle
- Load generation from
  1 GBit/s (Standard Application)
  2.5 and 5 Gbit/s (WiFi APs)
  10 Gbit/s (Cat.6A/Class E_A)
  with simultaneous checking for transmission errors.



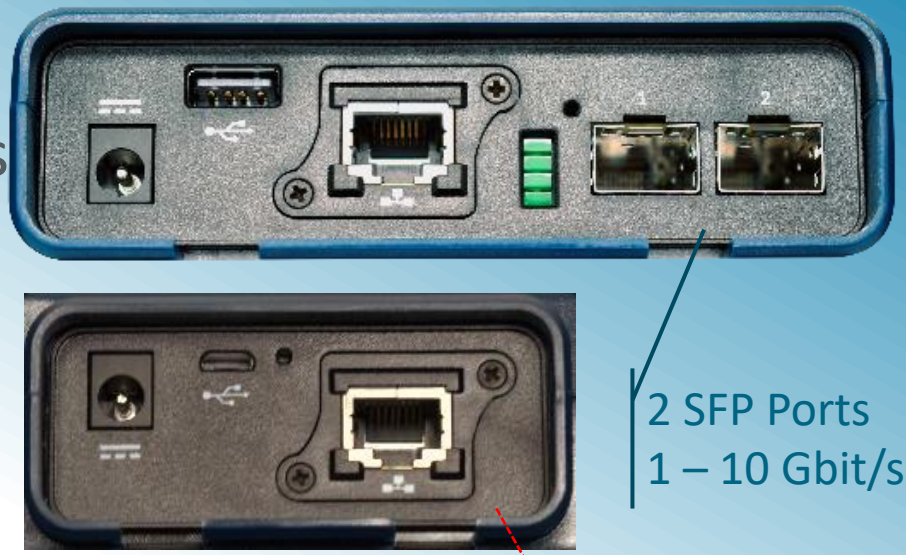
Delay Skew

- Difference in signal propagation time between the pairs
- If the delay is too high, data packets cannot be recovered by the recipient.



Important factors to consider

- Replaceable RJ45 ports, as PoE measurements kills connections
  - PoE / PoE+ / PoE++ up to 90W burns connections mostly when disconnecting
- All tests with a single port
- Open source SFP‘s (MSA – Multi Source Agreement)
- End-to-end testing



Connect/disconnect zone

Permanent contact zone

Certifying Copper cables

- Standardized acceptance measurement of networks
  - The electrical properties of a data link are determined by means of low and high frequency measurements and calculations based on the measured values
- Standards
  - The adherence to specified limit values of a performance class guarantees the problem-free transmission of a wide range of applications
- Link definitions
  - A distinction is made between installation and transmission paths, E2E and MPTL paths
  - Number of connectors may vary

Copper Networks Standards

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Certification | *Qualification*

USA | International | Europe

Cable	Components	Cabling	Installation	Testing	Application
ANSI/TIA 568.2-D	ANSI/TIA 568.2-D	ANSI/TIA 568.2-D		ANSI/TIA 1152-A	IEEE (e.g. 802.3) Ethernet Fast Ethernet Gigabit Ethernet ...
IEC 61156	IEC 60603-7	ISO/IEC11801-1		IEC 61935-1	
EN 50288-1 Basic specification **... 50288-2** Cat 5 shielded **... 50288-3** Cat 5 unshielded **... 50288-4** Cat 7 shielded **... 50288-5** Cat 6 shielded **... 50288-6** Cat 6 unshielded **... 50288-7** Control cable **... 50288-8** Type 1 Cable up to 2 MHz **... 50288-9** Cat 7A shielded **... 50288-10** Cat 6A shielded **... 50288-11** Cat 6A unshielded **... 50288-12** **Cat 8 shielded**	**EN 60603-7** RJ45 unshielded **... 60603-7-1** RJ45 shielded **... 60603-7-2** Cat 5 unshielded **... 60603-7-3** Cat 5 shielded **... 60603-7-4** Cat 6 unshielded **... 60603-7-41** Cat 6A unshielded **... 60603-7-5** Cat 6 shielded **... 60603-7-51** Cat 6A shielded **... 60603-7-7** Cat 7 shielded **... 60603-7-71** Cat 7A shielded **... 60603-7-81/82 (E)** "Cat 8" shielded **(... 61076-3-104** TERA)	**EN 50173-1** General **... 50173-2** Office **... 50173-3** Industry **... 50173-4** Homes **... 50173-5** Data Center **... 50173-6** Distributed building services	**EN 50174-1** Installation Specs/ Quality assurance **... 50174-2** Planning/ Installations in buildings **... 50174-3** Planning/ Installations Outdoors	**EN 50346** Testing of installed cabling	

IEEE

Additionally "ISO/IEC TR ..." (Technical Reports):

11801-9901: „40G“
- -9902: "End-to-end link"
- -9903: "Modeling"
- -9904: "2.5 / 5 GBE"
- -9905: "25 GBE" (30m)

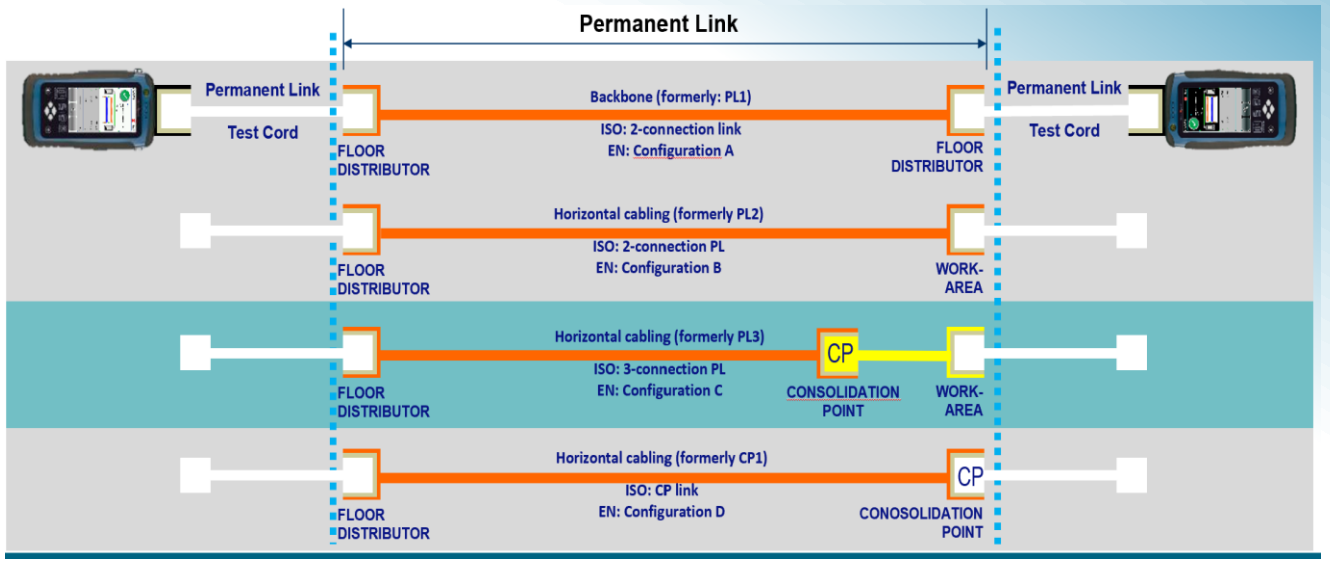
Draft -9906: SPE to 600 MHz
Draft -9907: Direct Attach
Draft -9908 High Speed Fiber Channel
Draft -9909 Cabling for 25G over >50m
Draft -9910 MPTL

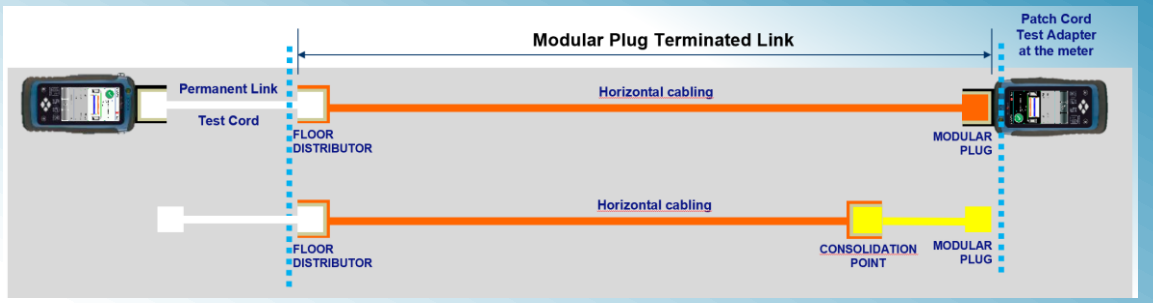
Copper Cabling Systems - Testing Standards

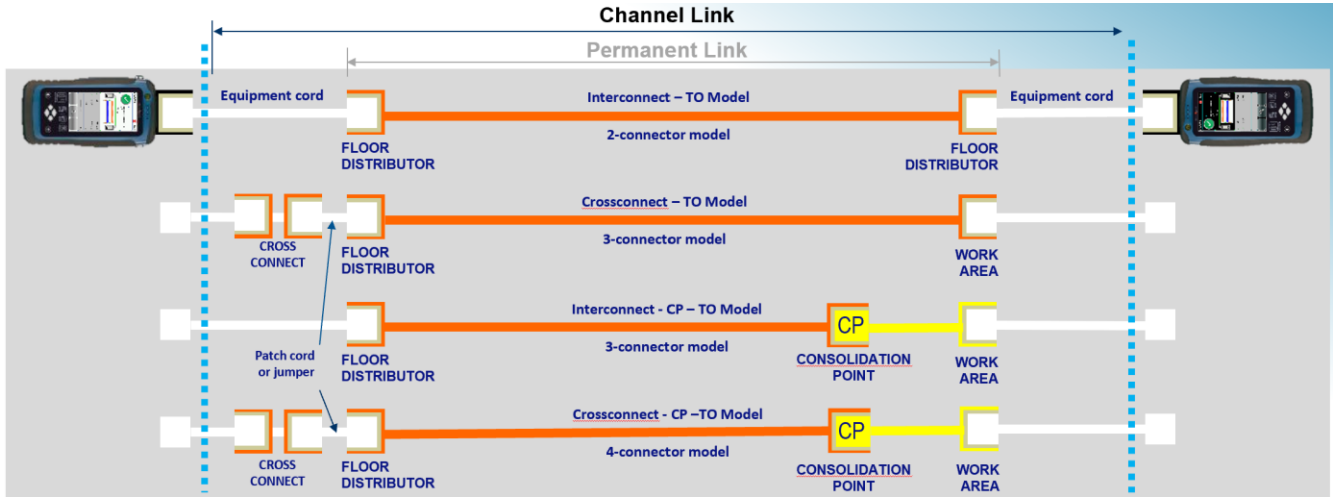
Bandwidth/ Region	100 MHz	250 MHz	500 MHz	600 MHz	1000 MHz	2000 MHz
USA	ANSI/TIA 568.2-D Category 5e	ANSI/TIA 568.2-D Category 6	ANSI/TIA 568.2-D Category 6A			ANSI/TIA 568.2-D Category 8
International	ISO/IEC11801-1 3rd edition Class D	ISO/IEC11801-1 3rd edition Class E	ISO/IEC11801-1 3rd edition Class E_A	ISO/IEC11801-1 3rd edition Class F	ISO/IEC11801-1 3rd edition Class F_A	ISO/IEC11801-1 3rd edition Class I & II
Europe	CENELEC EN50173-1 Class D	CENELEC EN50173-1 Class E	CENELEC EN50173-1 Class E_A	CENELEC EN 50173-1 Class F	CENELEC EN 50173-1 Class F_A	CENELEC EN 50173-1 Class I & II

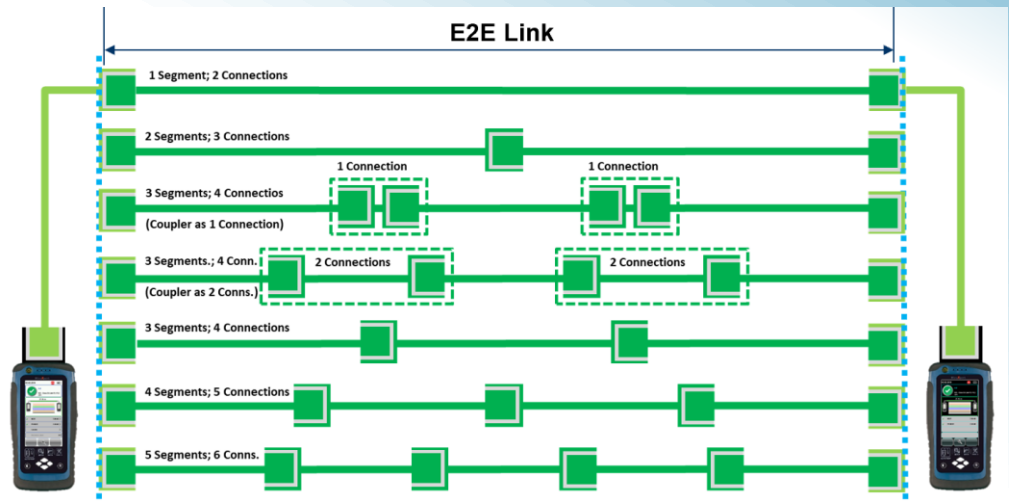
Grey background identifies identical limit values in the respective classes

Link definitions (ISO 11801-1 & EN 50173-1)



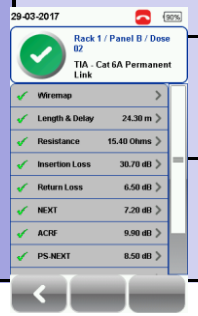






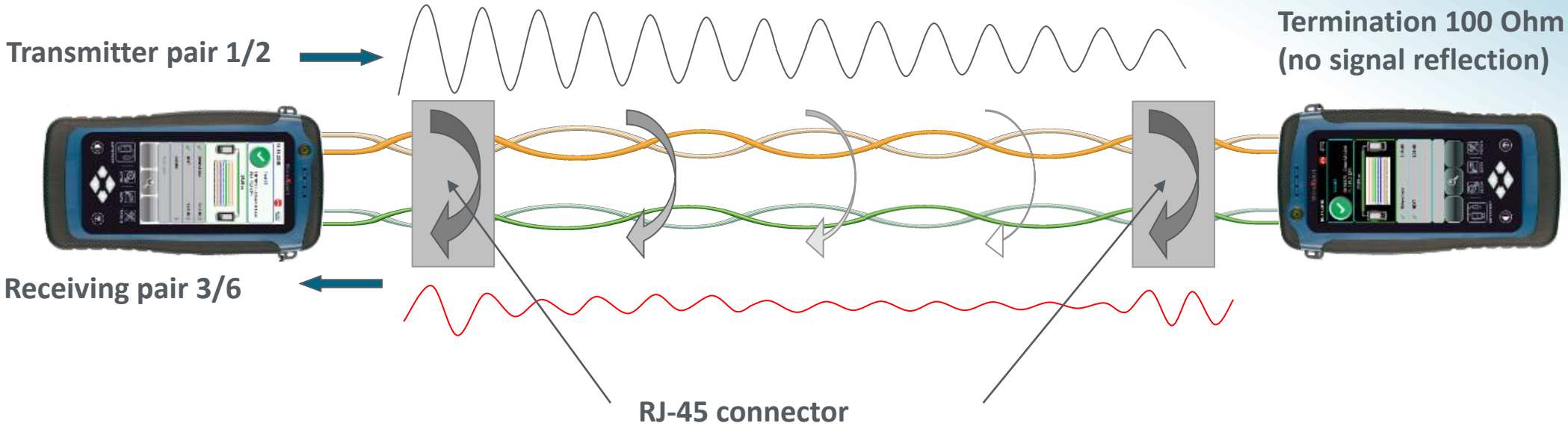
Cable certification parameters

Dominant Element / Type of Parameter	Installation Quality	Cable	Components	Matching of Cable & Components	Optional Parameters
LF Parameters	Wire-map	Propagation Delay			Direct Current (DC) Resistance Unbalance within a pair / between pairs
	Direct Current (DC) Loop Resistance				
RF Parameters		Insertion Loss (IL)	Pair-to-pair Near End Crosstalk (NEXT)	Return Loss (RL)	Unbalance attenuation, near end (TCL)
			Far End Crosstalk (FEXT) (not reported)		Unbalance attenuation, far end (ELTCTL)
					Coupling Attenuation (CA)
					Alien Near End Crosstalk (ANEXT) (not reported)
					Alien Far End Crosstalk (AFEXT) (not reported)
Calculated Parameters		Length (informative in ISO/IEC)	Power Sum Near End Crosstalk (PS NEXT)	Pair-to-pair Attenuation-Crosstalk-Ratio @ Near End (ACR-N)	Power Sum Alien Near End Crostalk (PS ANEXT)
		Delay Skew		Pair-to-pair Attenuation-Crosstalk-Ratio @ Far End (ACR-F)	Average Power Sum Alien Near End Crostalk ($PSANEXT_{avg}$)
				Power Sum Attenuation-Crosstalk-Ratio @ Near End (PS ACR-N)	Power Sum Attenuation-Alien Crosstalk-Ratio @ Far End (PS AACR-F)
				Power Sum Attenuation-Crosstalk-Ratio @ Far End (PS ACR-F)	Average Power Sum Attenuation-Alien Crosstalk-Ratio @ Far End (PS $AACR\text{-}F_{avg}$)



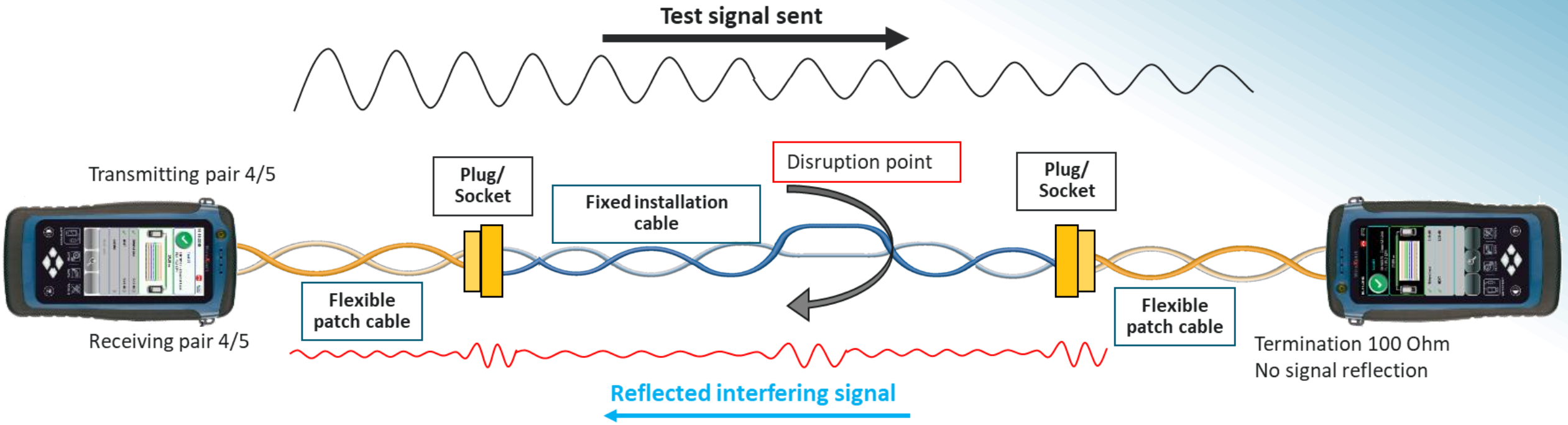
NEXT (Near End Cross Talk)

- Good **isolation between pairs & Good quality components** => Good (low) NEXT
- NEXT is the electromagnetic coupling (induction) from wire pair to wire pair.
- This is called near-end crosstalk, because the measurement is made at the same end where the power is fed in.
- (Too) high crosstalk makes it difficult or impossible to correctly recognize the signal at receiver side.
- NEXT measurement usually only affects 30-40m into the cable.
- In order to be able to detect errors at the end, measuring devices are required at both ends.



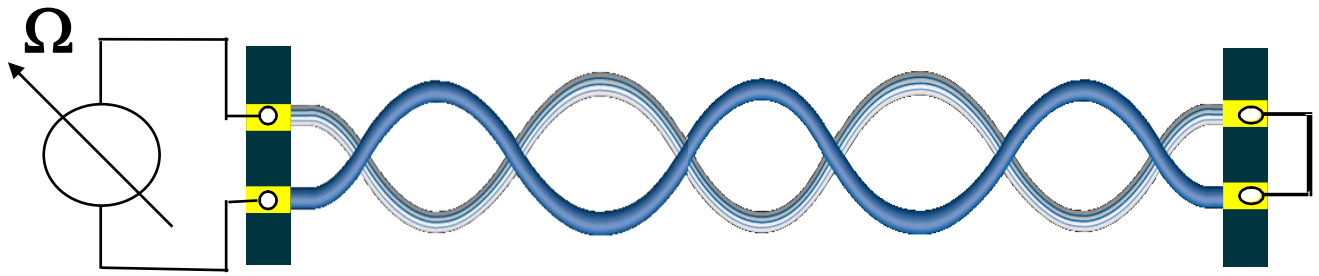
Return Loss

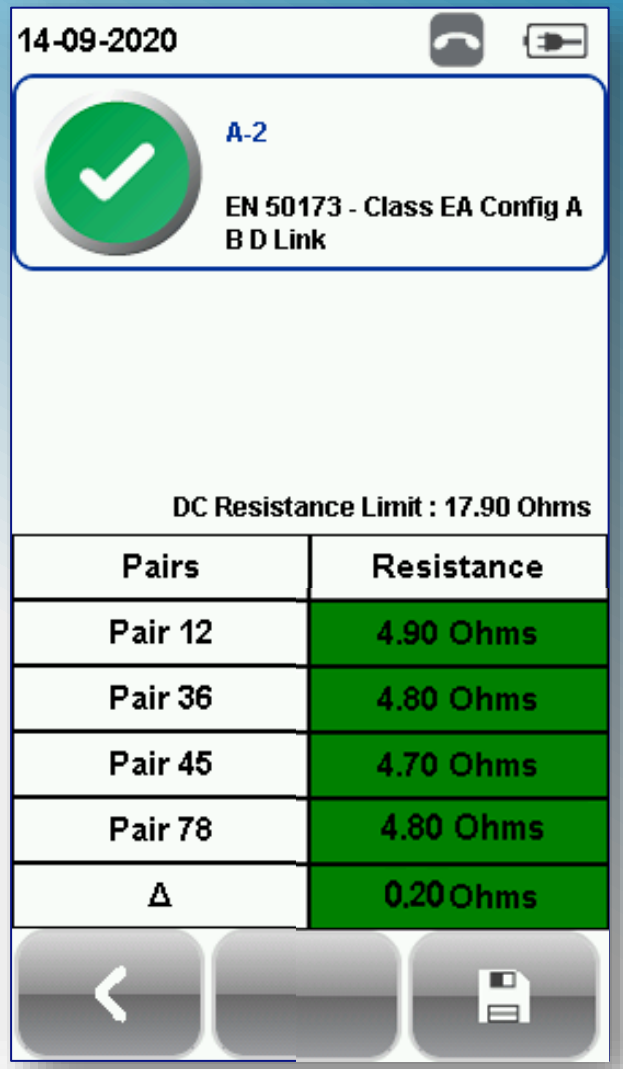
- High Return Loss typically => Possible **Components impedance mismatch** or **damage on the cable**
- Measure of the uniformity of the impedance on a transmission path
- Determination of the signal reflection due to impedance changes
- Reflected signals disturb the transmission



DC loop Resistance

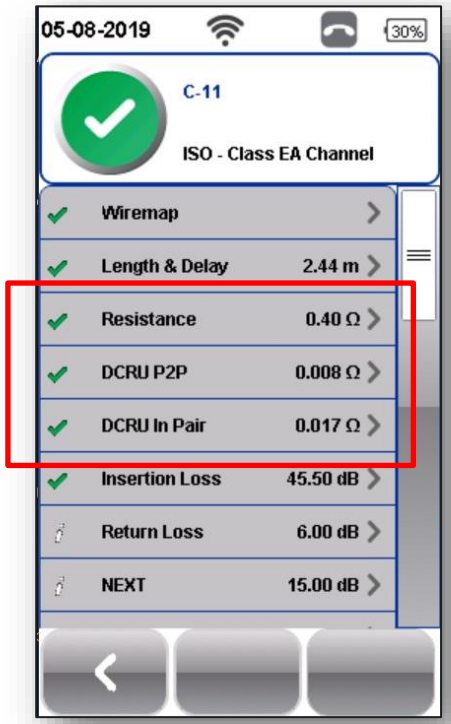
- **Good contact in the crimping at both ends** of the cable => Good (low) Resistance
- Determination of the DC loop resistance of each pair of wires
  - Limit values must be observed
  - Resistance delta between the pairs is determined
- As low and symmetrical resistance values as possible are important to
  - Power over Ethernet (remote power supply of active components, e.g. surveillance cameras, telephones, terminals, etc.)
  - to generate as little power loss as possible
- DC Resistance values are a measure of the uniformity of contact and should therefore be in the same dimension for each pair of wires, i.e. the smallest possible delta



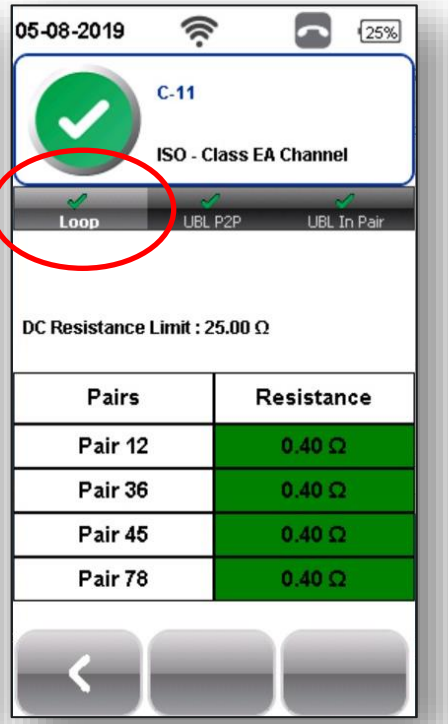


DCRU – DC Resistance Unbalanced

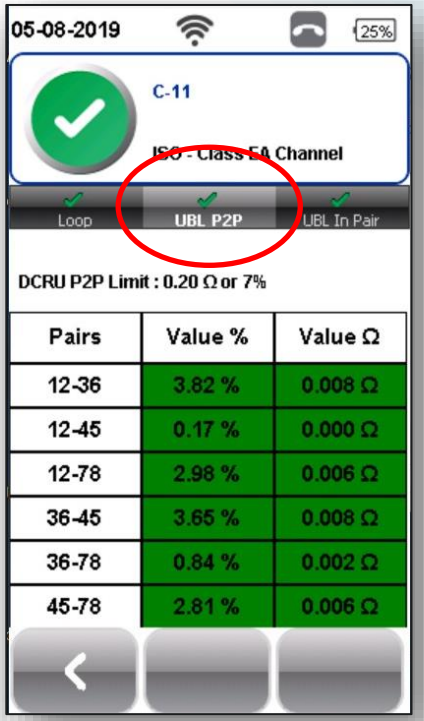
Overview



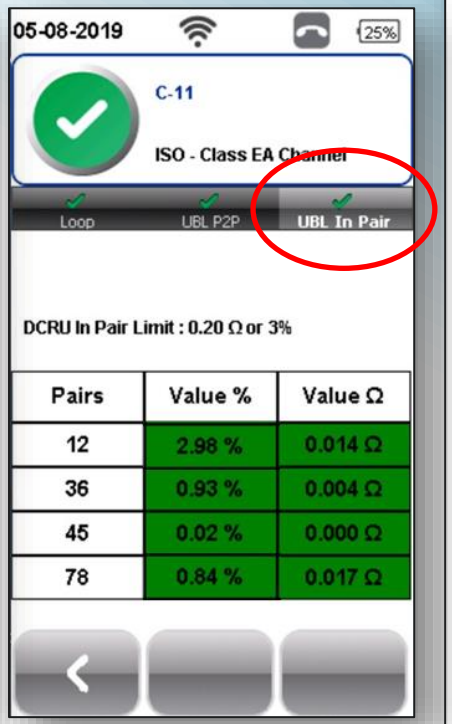
Direct current loop resistance

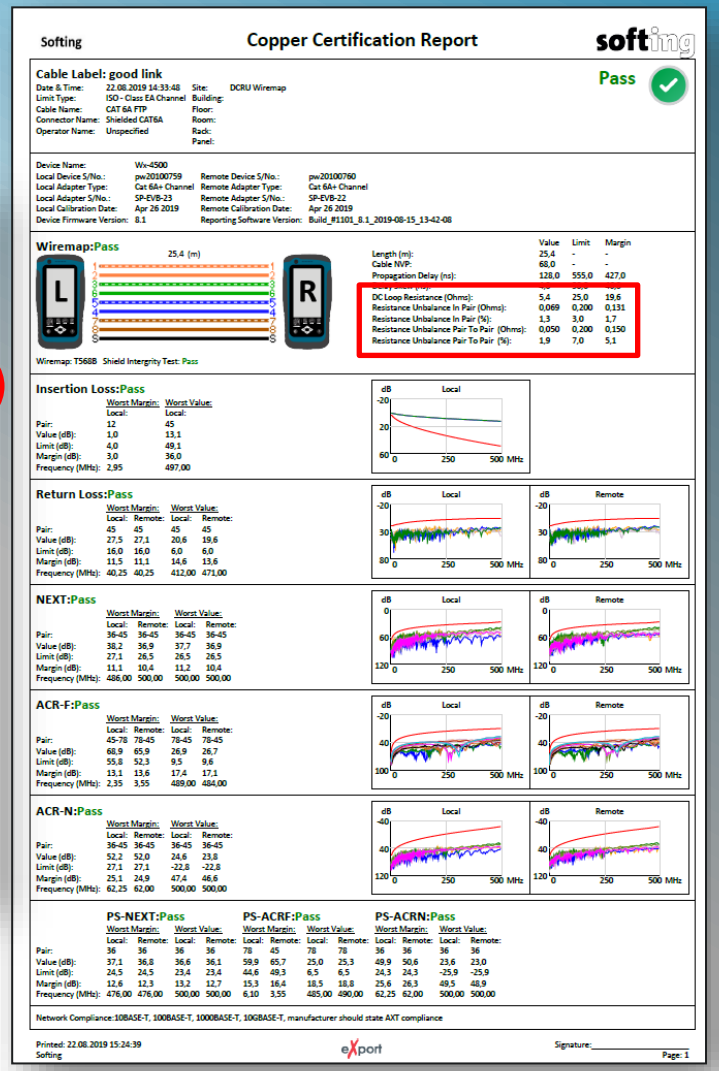


Direct current resistance unbalance between the pairs

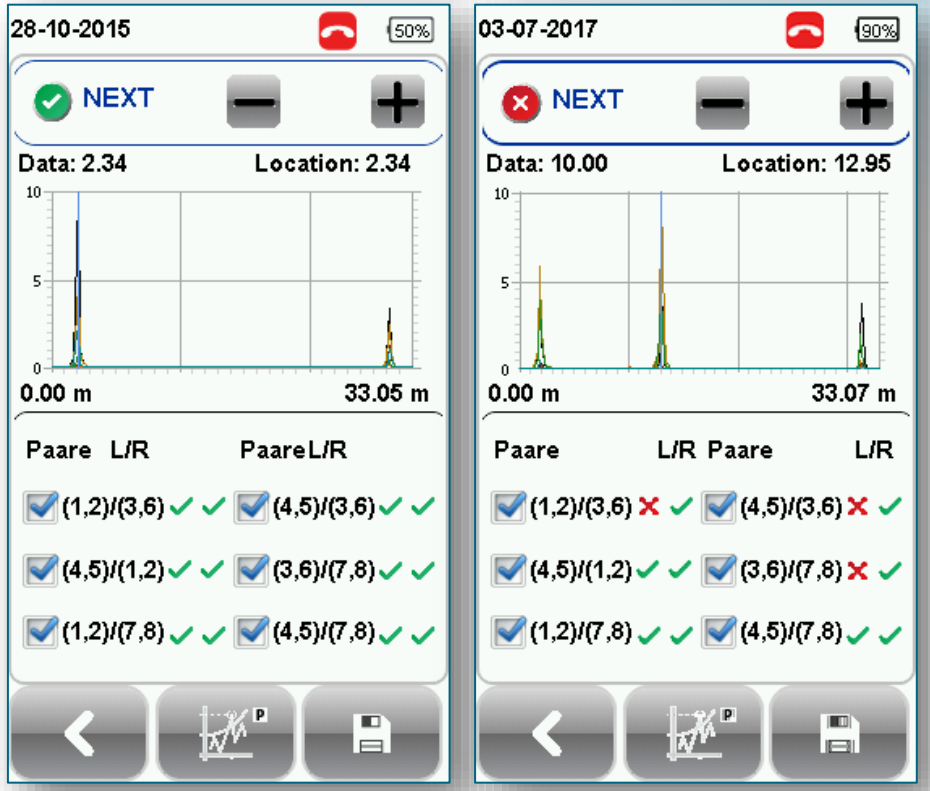


Direct current resistance unbalance within a pair

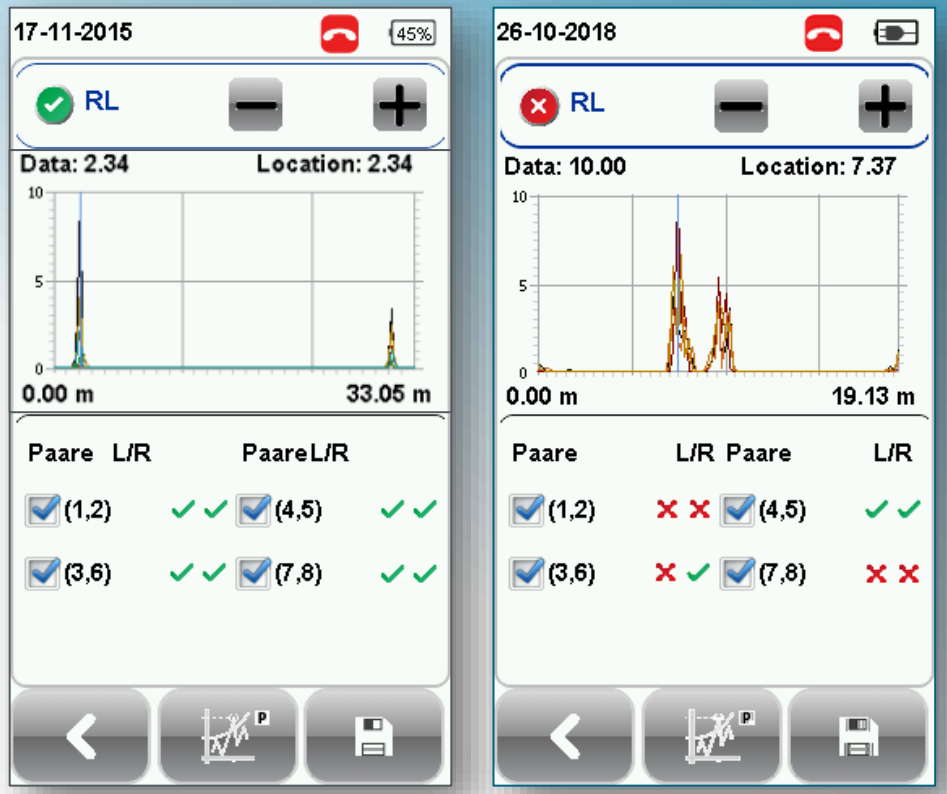




Fault locator



NEXT failed because cable was "patched" after approx. 13m with luster terminal



Return Loss failed because cable was run over and crushed by forklift truck after approx. 7m

Cable certification - Faults overview

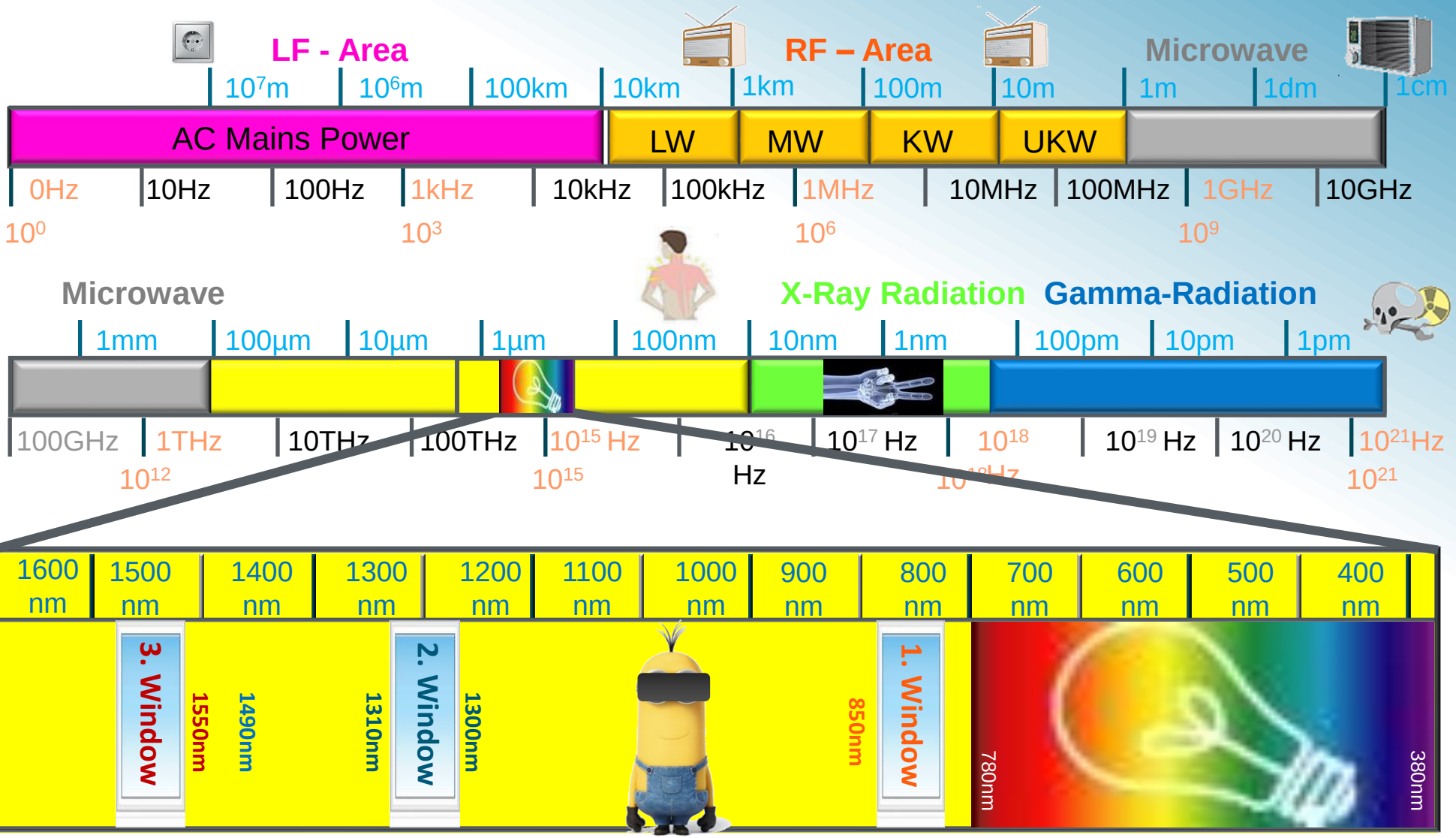
Fault in Parameter	Unit	Value	Possible Causes of Faults	Hints using Certifier
Wiremap	graphical representation	T568A/B	Opens, Shorts, Crossovers	Reliable localization important
DC Resistance	Ohms	preferable low, all pairs similar values	Cables too long, wrong cable type, bad IDC connection, defective components, mended cable	
Length	m (ft)	in "ft" or "m" (informative only in ISO/IEC)	cable too long, wrong NVP value, defective cable	Ensure proper NVP value
Delay	ns (nano seconds)	preferable low, all pairs similar values	cable too long, defective cable	Used to determine length value
Delay Skew	ns (nano seconds)	preferable low	cable too long, defective cable	
Insertion Loss	dB over Frequency	preferable low, all pairs similar course	cable too long, bad termination, wrong cable type, defective cable	
NEXT (Near End Crosstalk)	dB over Frequency	preferable high	Twist opened too much, Pair Screen insufficient, wrong or insufficient components or cables, worn out test cords or adapters	NEXT Locator Function important, Short Link compensation in ISO/IEC (4dB rule)
Return Loss	dB over Frequency	preferable high	Overstreched installation cable, defective cable, impedance mismatch between components	RL Locator Function important, Low Frequency compensation (3dB rule)
ACR-N	dB over Frequency	preferable high	NEXT and/or Insertion Loss	Calculated parameter based on NEXT and Insertion Loss
ACR-F (formerly ELFEXT)	dB over Frequency	preferable high	Crosstalk and/or Insertion Loss	Calculated parameter based on FEXT and Insertion Loss
PS-NEXT, PS-ACR-N, PS-ACR-F	dB over Frequency	preferable high	refer to basic parameters	Summing up of individual pair values of basic parameters

LAN - Fiber cable testing

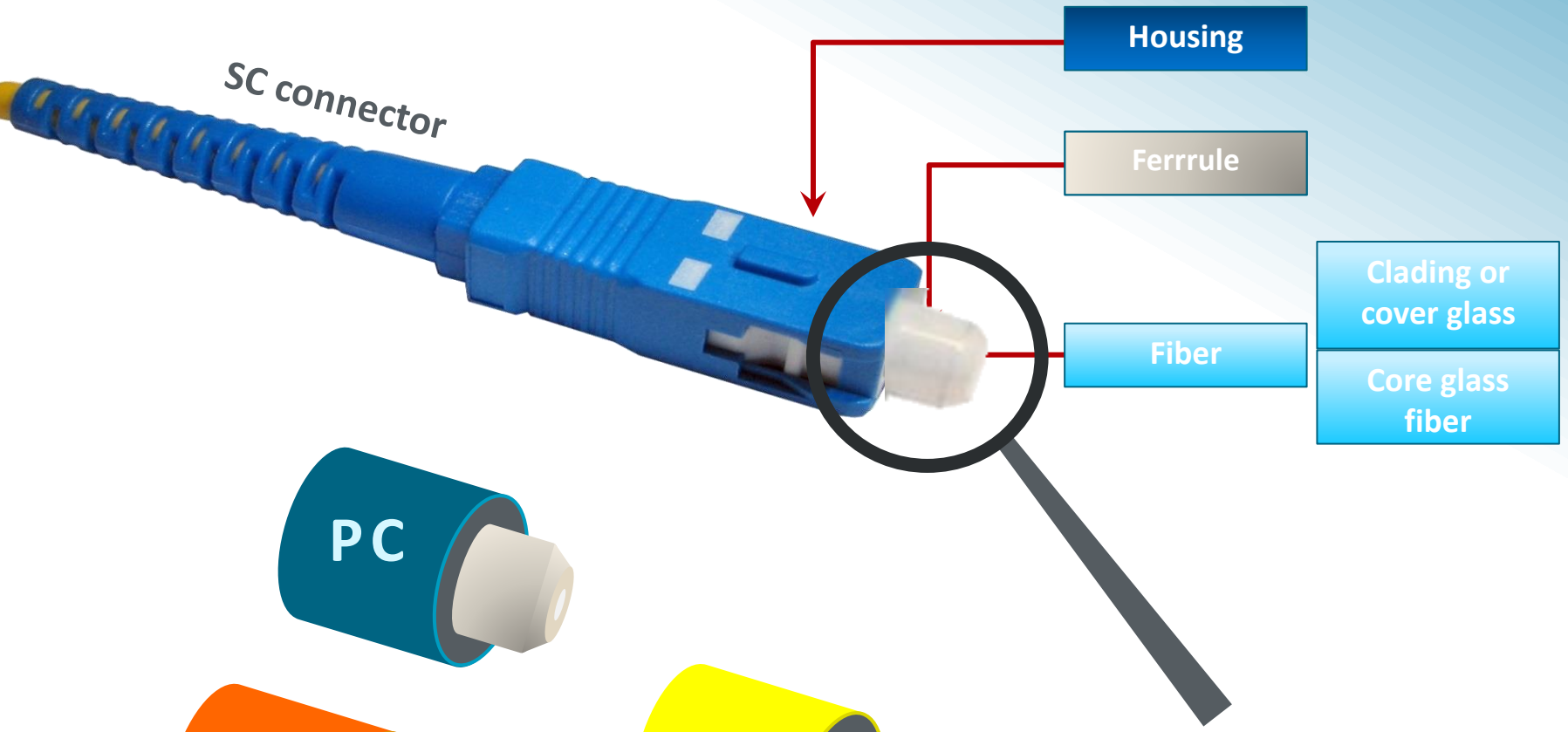
Fiber (LAN & WAN):

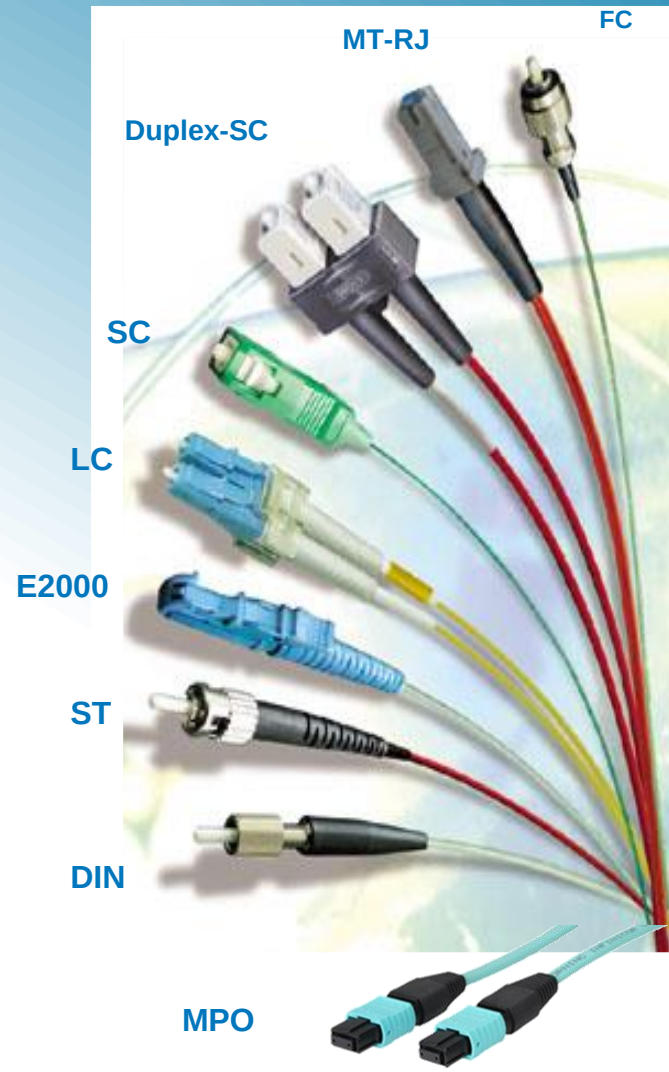
- LAN & WAN Networks **Multimode & Singlemode**
- Tier 1 – Power Loss + Length (some standards don‘t require Length)
- Tier 2 – Power Loss + Length + Reflectometry (OTDR)

Electro Magnetic Spectrum



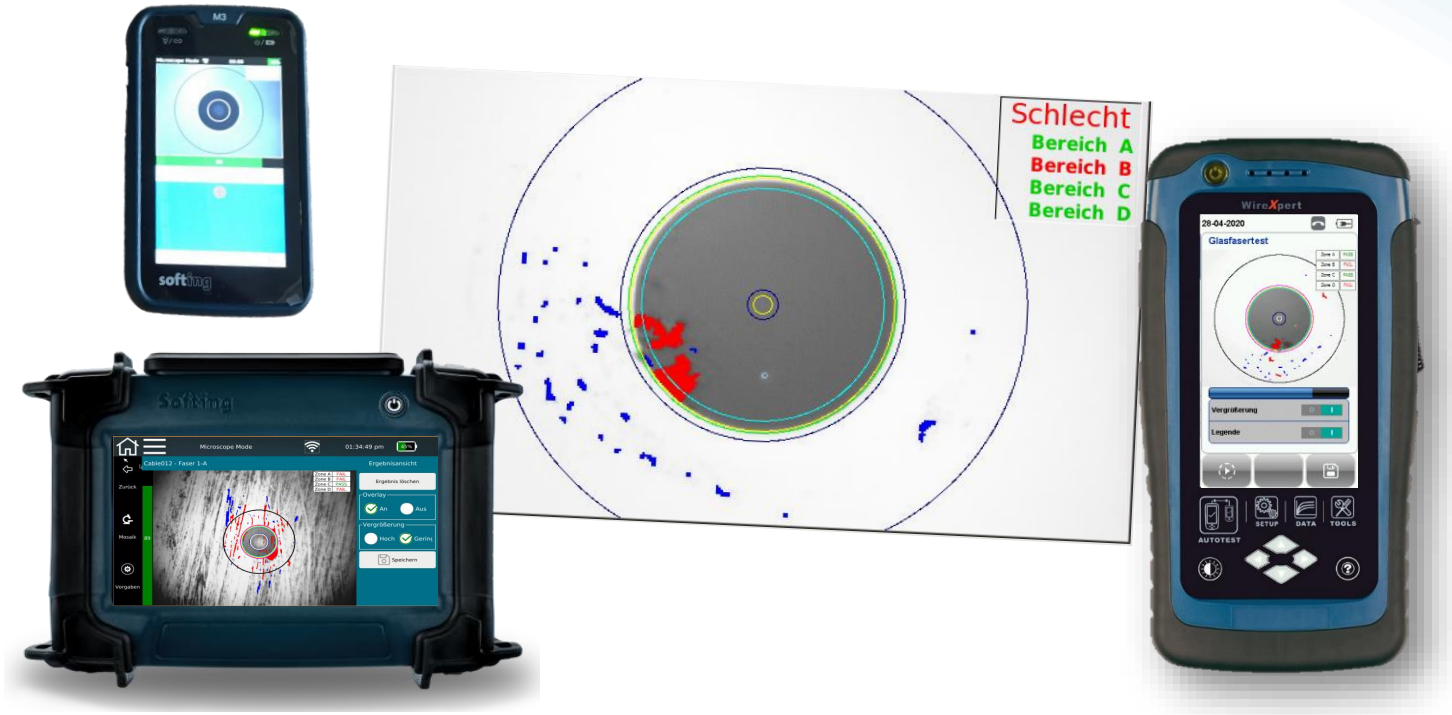
Structure of a Fiber Optic connector





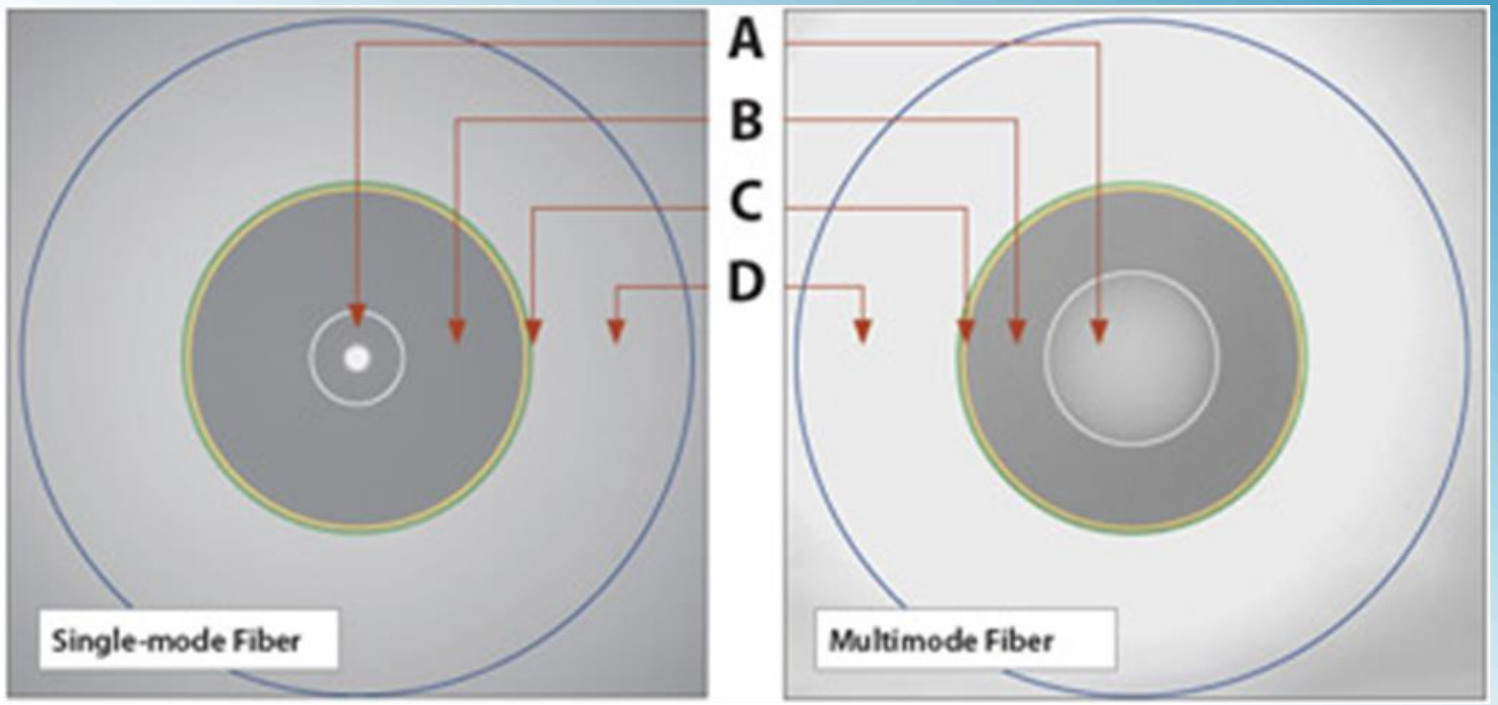
Inspection and cleaning of connector end faces

- **Dirt is the biggest enemy in the FO area!**
  - Clean the connector end faces before each measurement or connection!
  - Only use suitable cleaning tools!
    - Lint-free wipes, Cleaning liquids (water based), Special cleaning pencils
  - Use Video Probe to inspect the end face! Not a microscope
  - Remove protective caps on connectors only for Taes/patching



When is a connector endface "clean"?

- The **IEC 61300-3-35 standard** clearly defines when a connector is "clean“
  - Classification of individual evaluation zones radially around the fibre core
  - Differentiation between multimode and singlemode



Zones	Description	Radius	Radius
		SM	MM
A	Core	0 µm to (15) 25 µm	0 µm to 65 µm
B	Cladding	(15) 25 µm to 115 µm	65 µm to 115 µm
C	Adhesive	115 µm to 135 µm	115 µm to 135 µm
D	Contact	135 µm to 250 µm	135 µm to 250 µm

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Standardized cleaning methods

- Suitable cleaning methods are defined in International Standards

- IEC TR 62627-01:2016
  - Fibre optic interconnecting devices and passive components - Part 01: Fibre optic connector cleaning methods
    - Influence of dirt on connector end surfaces
    - General handling of optical connectors
    - Importance of dust caps
    - Various tools and aids for the correct cleaning of connector end surfaces
    - Cleaning procedures

- DIN IEC/TR 62572-4:2013-09
  - Fibre optic active components and devices - Reliability standards - Part 4: Guideline for optical connector end-face cleaning methods for receptacle style optical transceivers
    - Details on the handling of optical transceivers in socket design
    - Internal structure of optical transceivers
    - Information about cleaning tools and machines
    - Suitable cleaning procedures and cleaning processes

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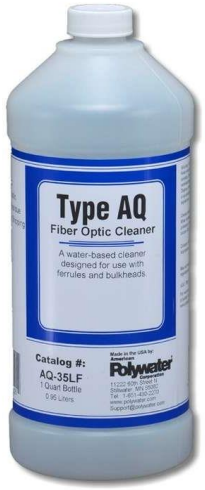
Typical cleaning tools



Fiber - Test and measurement types

- Fibre continuity test

- Qualification test

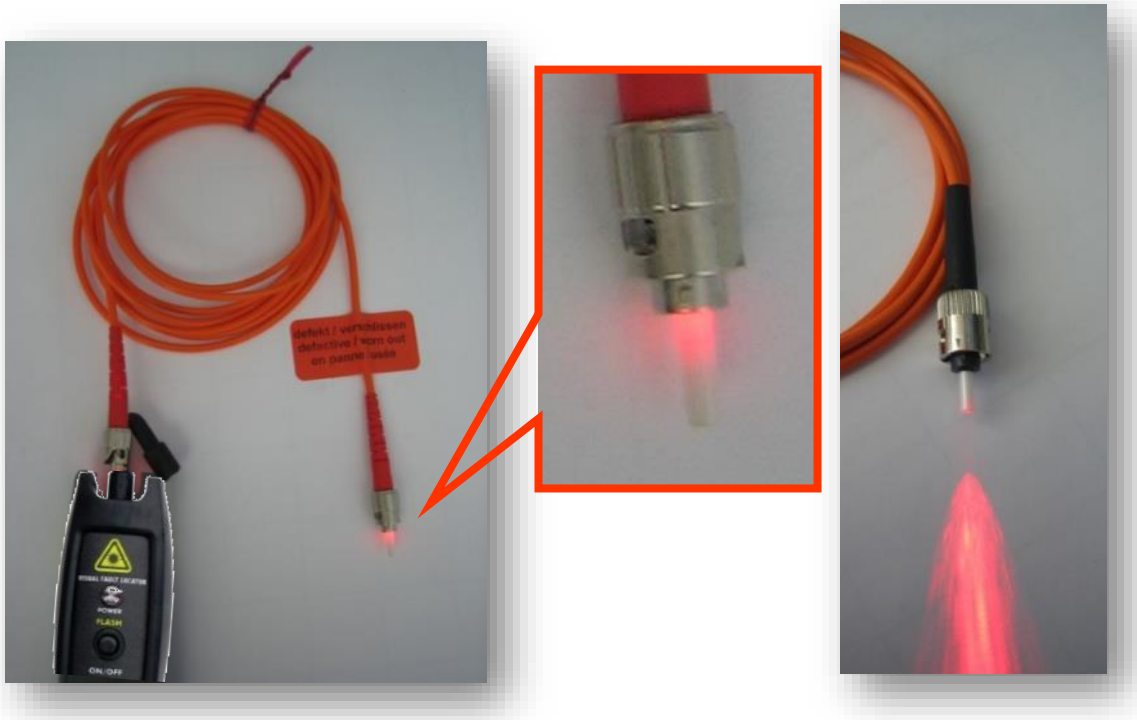
- Loss measurement
  - Standalone Optical Loss Test Systems (OLTS)

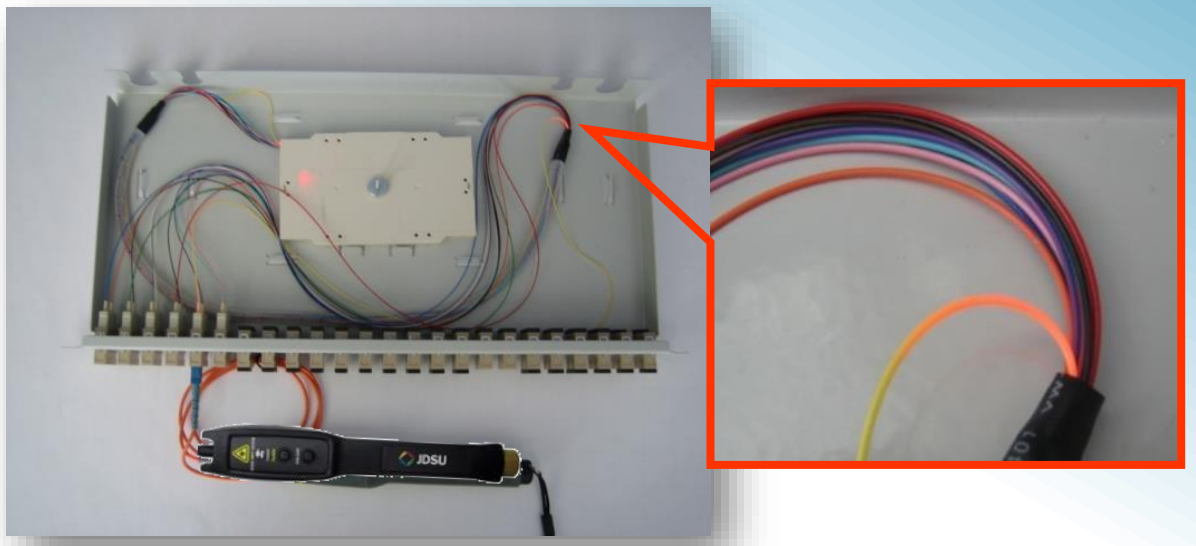
  - Integrated modules for LAN certifiers

- Reflection (OTDR)

Continuity test – VFL Visual Fault Liocator

- Allocation and detection of mechanical defects by means of visible laser red light
  - Find end of fiber
  - Find breaks in the fiber or connectors, etc.

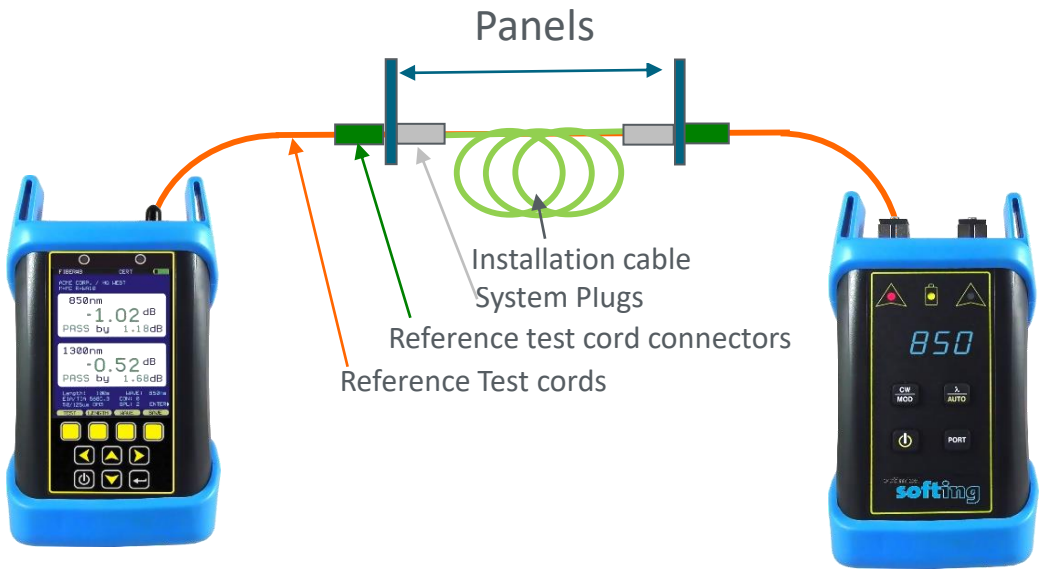




Power Loss Measurement – Apples to apples

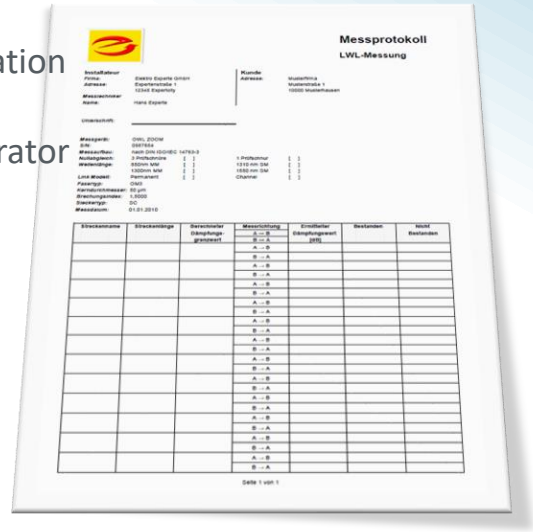
Pass/Fail results & Tier 1 Certification

Loss budget	MM @850nm	MM @ 1300nm	SM @ 1310/1550nm
Overall length = 100m	0,1 x 3,50 dB	0,1 x 1,50 dB	0,1 x 1,00 dB
Test cord attenuations (2 reference cords)	2 x 0,30 dB	2 x 0,30 dB	2 x 0,50 dB
Total Loss Budget	**0,95 dB**	**0,75 dB**	**1,1 dB**



Test report details:

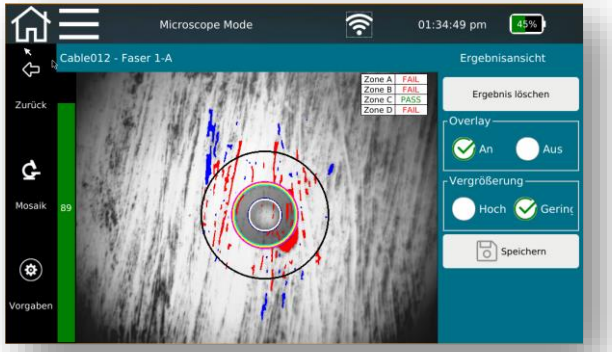
- Specification of the Link tested
- Test device used, type and manufacturer
- Serial number and calibration status of the tester
- Nominal wavelengths tested
- Fiber core diameter (50µm, 62.5µm, 9µm)
- Fiber Type (OM1, OM2, OM3, OM4, OM5, OS1, OS2)
- Connector type (SC, ST, LC, FC or other)
- Measurement result with measurement direction (A>>E, E>>A)
- Limits
- route designation
- Test Date
- Name of operator



Qualification - Testing against application

- Qualification test types for fiber optic links
  - BERT (Bit Error Rate Test) or Packet Error Rate Test
    - Sending of real physical layer data packets and analysis of transmission errors
    - Evaluation based on Ethernet fault tolerance according to IEEE 802.3
      - E.g. 1 Gigabit Ethernet: no bit in 10s Data transmission may be lost
  - Determination of Optical Loss
    - Reading registers of SFP modules
    - Real time detection -> LiveLight
  - Fiber Video Probe
    - Inspection and assessment of the connector end faces according to IEC 61300-3-35

Transmission format	Standards reference	Required Bit Error Rate in standards reference	Test time for 10% confidence level	Test time for 63% confidence level	Test time for 95% confidence level
1G	IEEE Std 802.3ab	10^{-10}	1 second	10 seconds	30 seconds
2.5G	IEEE Std 802.3bz	10^{-12}	42 seconds	6 minutes 38 seconds	19 minutes 58 seconds
5G	IEEE Std 802.3bz	10^{-12}	21 seconds	3 minutes 19 seconds	9 minutes 59 seconds
10G	IEEE Std 802.3an	10^{-12}	11 seconds	1 minute 39 seconds	5 minutes 0 seconds



Certifying against Standards

- Normative foundations
  - Limit values of the cabling are defined ...
    - Application-neutral
      - ISO/IEC 11801 or EN 50173-1
      - TIA-568.3-D

Connector (mated)

	Maximum attenuation [dB]			Return Loss [dB]	
Quality of Connector	Random against Random	Reference against Random	Reference against Reference	Random against Random	Reference against Reference
Multimode	**0.75**	**0.3** (ISO/IEC) **0.5** (ANSI/TIA)	**0.1**	**20**	**35**
Singlemode					
PC	**0.75**	**0.5**	**0.2**	**35**	**45**
APC	**0.75**	**0.5**	**0.2**	**55**	**60**

Splice

	Maximum attenuation [dB]	Return Loss [dB]
Multimode	**0.3**	**20**
Singlemode	**0.3**	**35**

FO from ISO/IEC 11801-1

Optical waveguide - Type - based on IEC (EN) 60793-2-...	Category of used optical fibre waveguide	Maximum cabled optical fibre attenuation (dB/km)		
Multimode				
		850 nm	953 nm	1300 nm
62,5/125 µm Multimode IEC (EN) 60793-2-10 A1b	OM1	3,5		1,5
50/125 µm Multimode IEC (EN) 60793-2-10 A1a.1	OM2	3,5		1,5
50/125 µm Multimode IEC (EN) 60793-2-10 A1a.2	OM3	3,5		1,5
50/125 µm Multimode IEC (EN) 60793-2-10 A1a.3	OM4	3,5		1,5
50/125 µm Multimode IEC (EN) 60793-2-10 A1a.4	OM5	3,0		1,5
Singlemode				
				1550 nm
9/125 µm Singlemode IEC (EN) 60793-2-50 B1.1	OS1			1,0
9/125 µm Singlemode IEC (EN) 60793-2-50 B1.3/B6_a	OS1a			
9/125 µm Singlemode IEC (EN) 60793-2-50 B1.3/B6_a	OS2			

Fiber cable certification - Methods

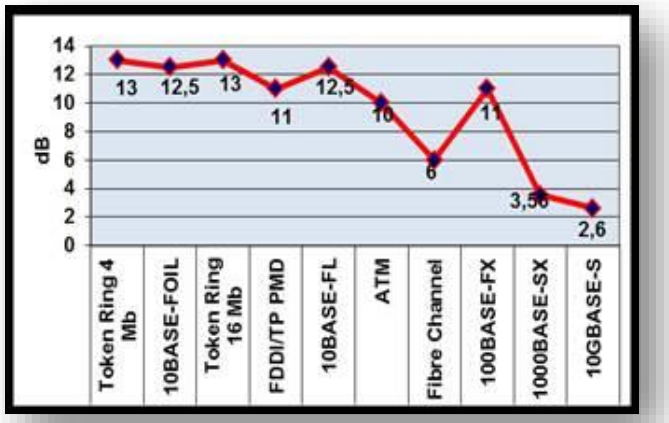
- Two measuring levels (tiers):
  - "Tier 1“ - LSPM
    - Light source and power meter (LSPM)
      - Loss
      - Length (not always required, depending on standard)
  - "Tier 2“ - LSPM & OTDR
    - Optical time domain reflectometer (OTDR)
      - OTDR trace
      - Connector end faces

Challenge - accurate measurements!

Problem

Solution

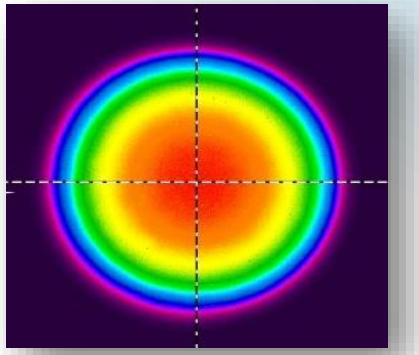
- The allowed attenuation budgets of the applications are becoming smaller and smaller!



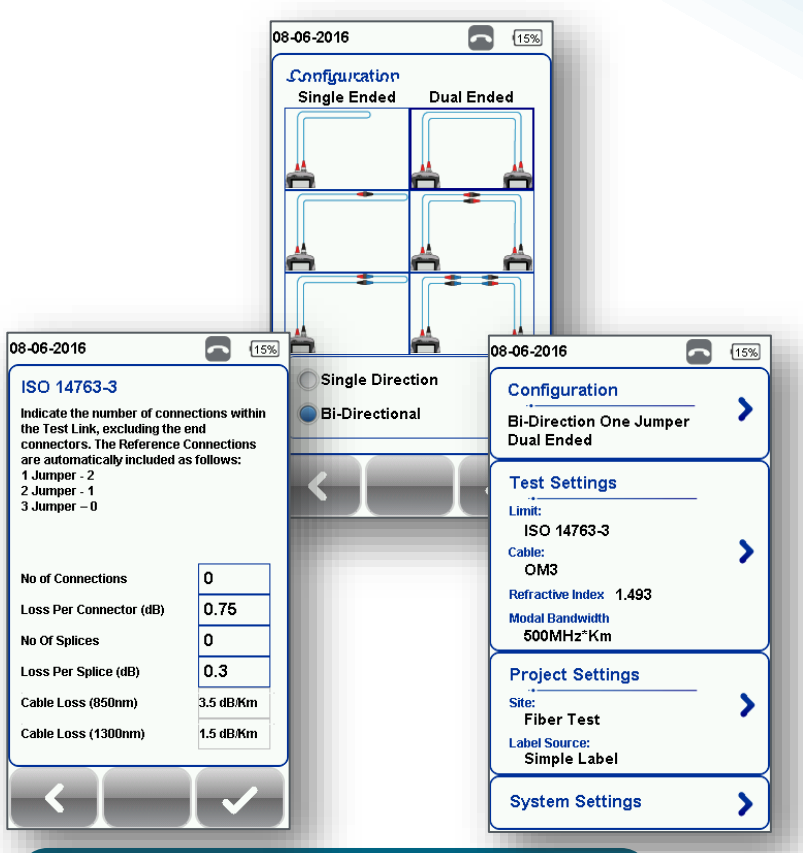
- Causes for (large) uncertainties
  - Poor quality test cords/adapters
  - Undefined test signal
  - Uncalibrated instruments

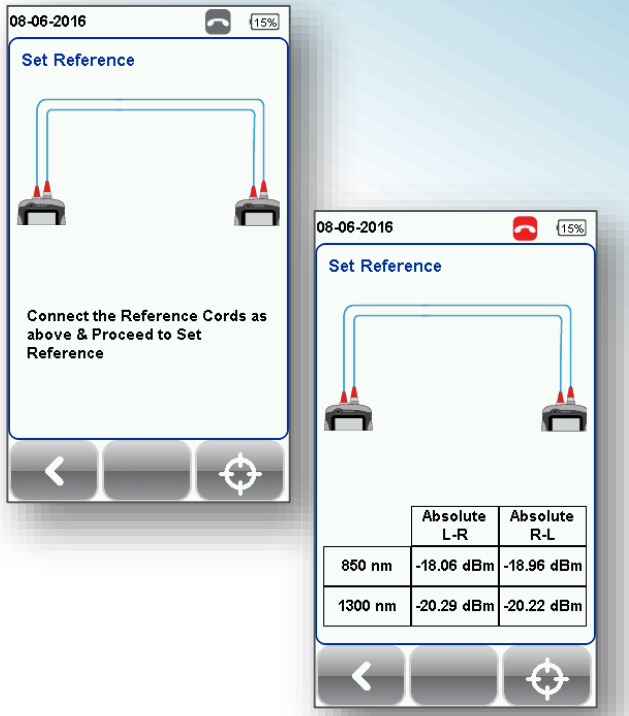
- Remedies
  - Compliance with the relevant Regulations, e.g. IEC 14763-3
    - Use high-quality components and test cords
  - Defined test signals
    - EF (Encircled Flux) Compliance
  - Regular factory calibration of the measuring equipment

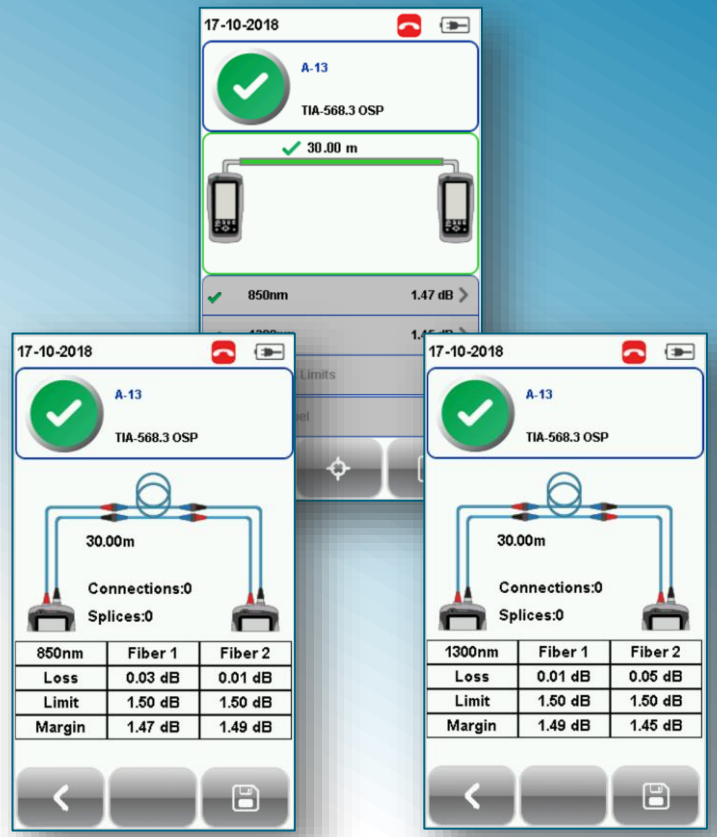
EF Adapter



Tier 1 – Certifier GUI







Configuration

- Reference method
- Loopback or Loop
- Uni-/bidirectional
- Number of connectors and splices
- Cable parameters / Standard

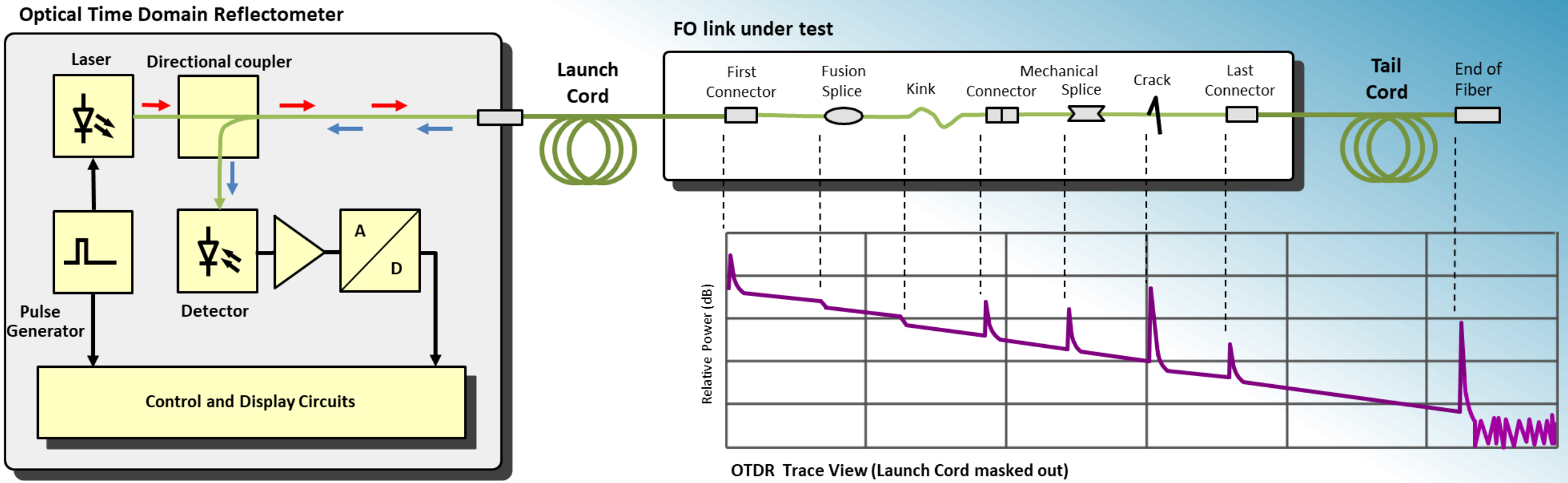
Set Reference

- Screens depending on selected reference method
- Results as control values for measuring modules

Measurement

- Number of measurement results depending on configuration
- Pass/Fail depending on calculated limit values and/or selected fiber application(s)

Tier 2 - How does an OTDR work?

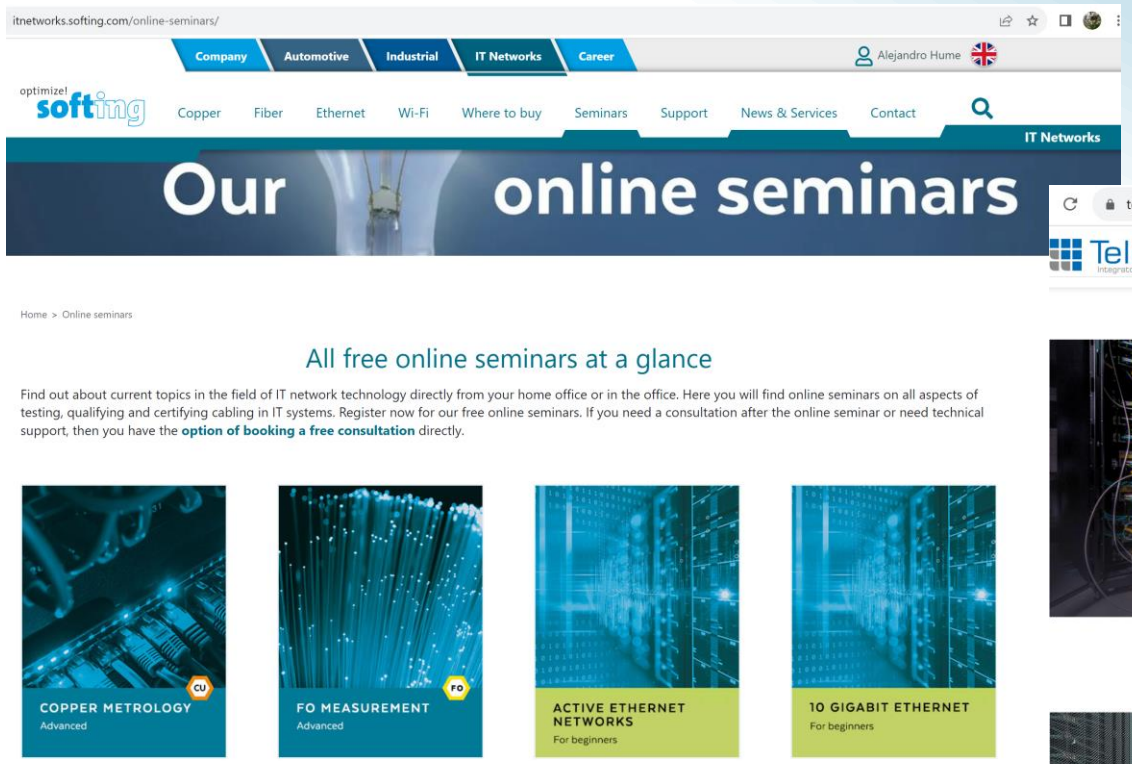


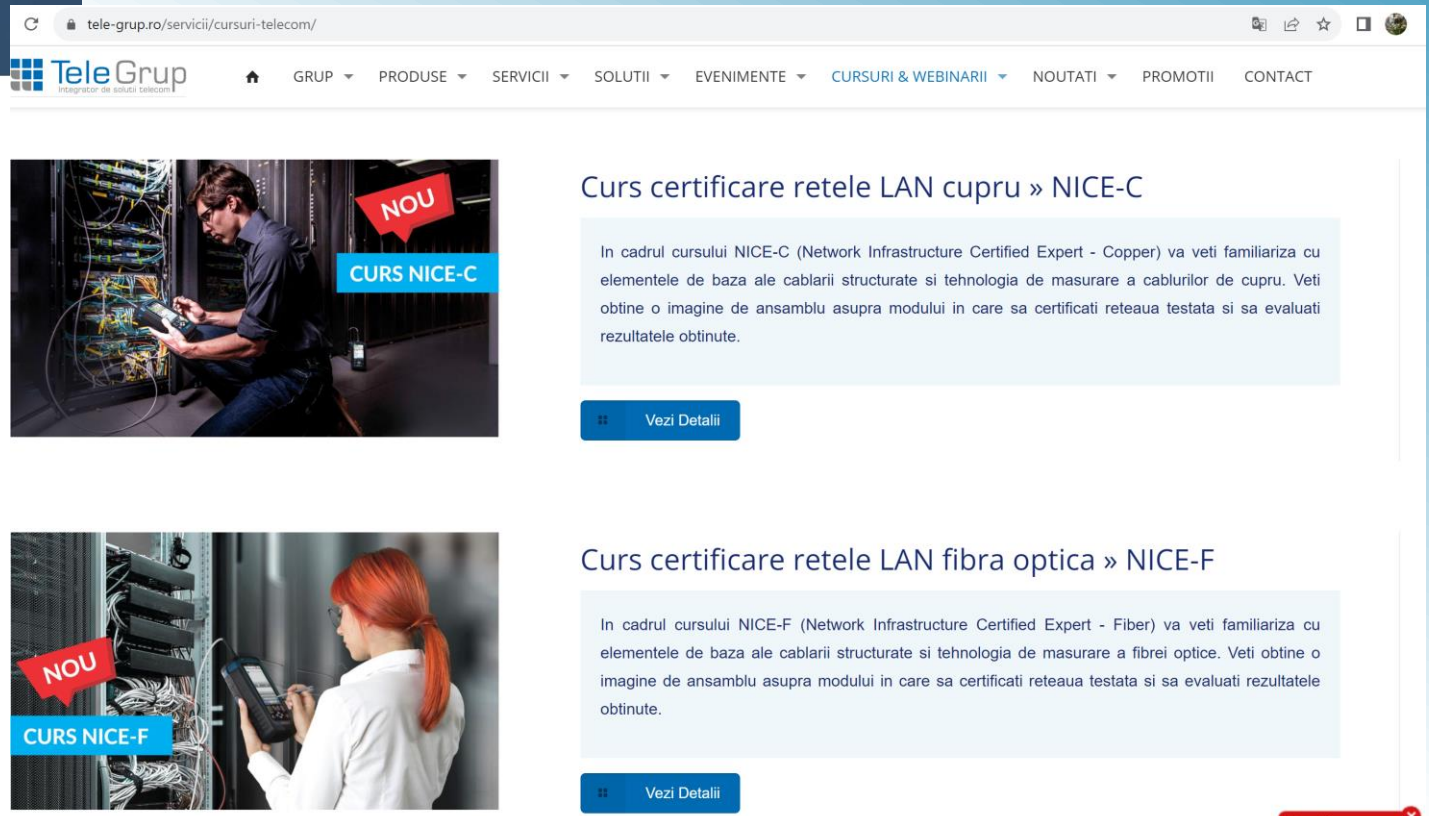
WiFi Networks

Wi-Fi generations					
	Wi-Fi 4	Wi-Fi 5	Wi-Fi 6	Wi-Fi 6E	Wi-Fi 7 (expected)
Launch date	2007	2013	2019	2021	2024
IEEE standard	802.11n	802.11ac	802.11ax		802.11be
Max data rate	1.2 Gbps	3.5 Gbps	9.6 Gbps		46 Gbps
Bands	2.4 GHz and 5 GHz	5 GHz	2.4 GHz and 5 GHz	6 GHz	1–7.25 GHz (including 2.4 GHz, 5 GHz, 6 GHz bands)
Security	WPA 2	WPA 2	WPA 3		WPA3
Channel size	20, 40 MHz	20, 40, 80, 80+80, 160 MHz	20, 40, 80, 80+80, 160 MHz	20, 40, 80, 80+80, 160 MHz	Up to 320 MHz
Modulation	64-QAM OFDM	256-QAM OFDM	1024-QAM OFDMA		4096-QAM OFDMA (with extensions)
MIMO	4x4 MIMO	4x4 MIMO, DL MU-MIMO	8x8 UL/DL MU-MIMO		16x16 MU-MIMO

Source: IEEE, Intel Corporation, Wi-Fi Alliance

Education & Training





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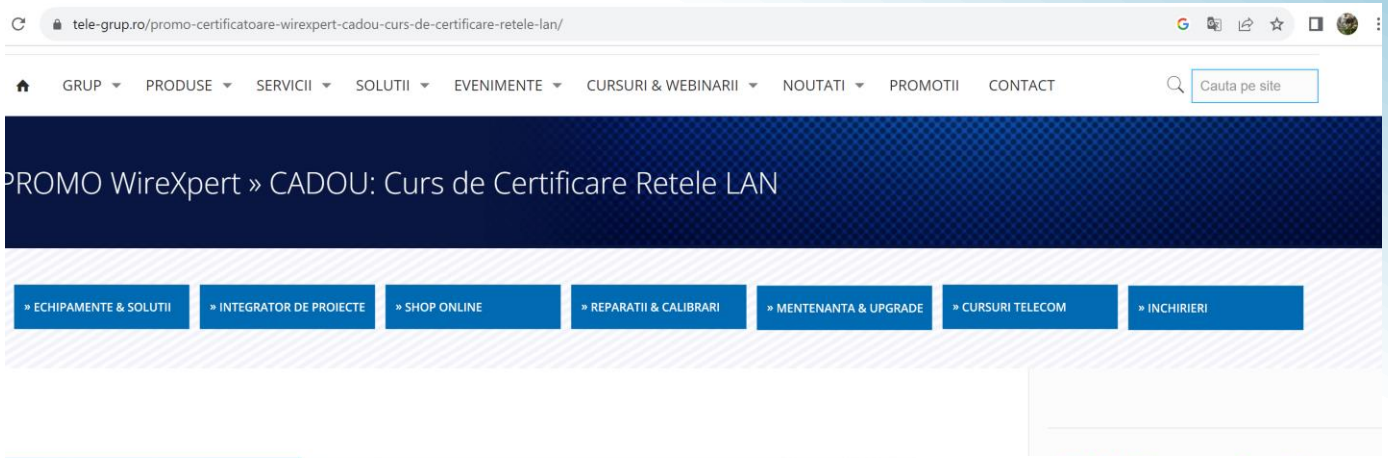
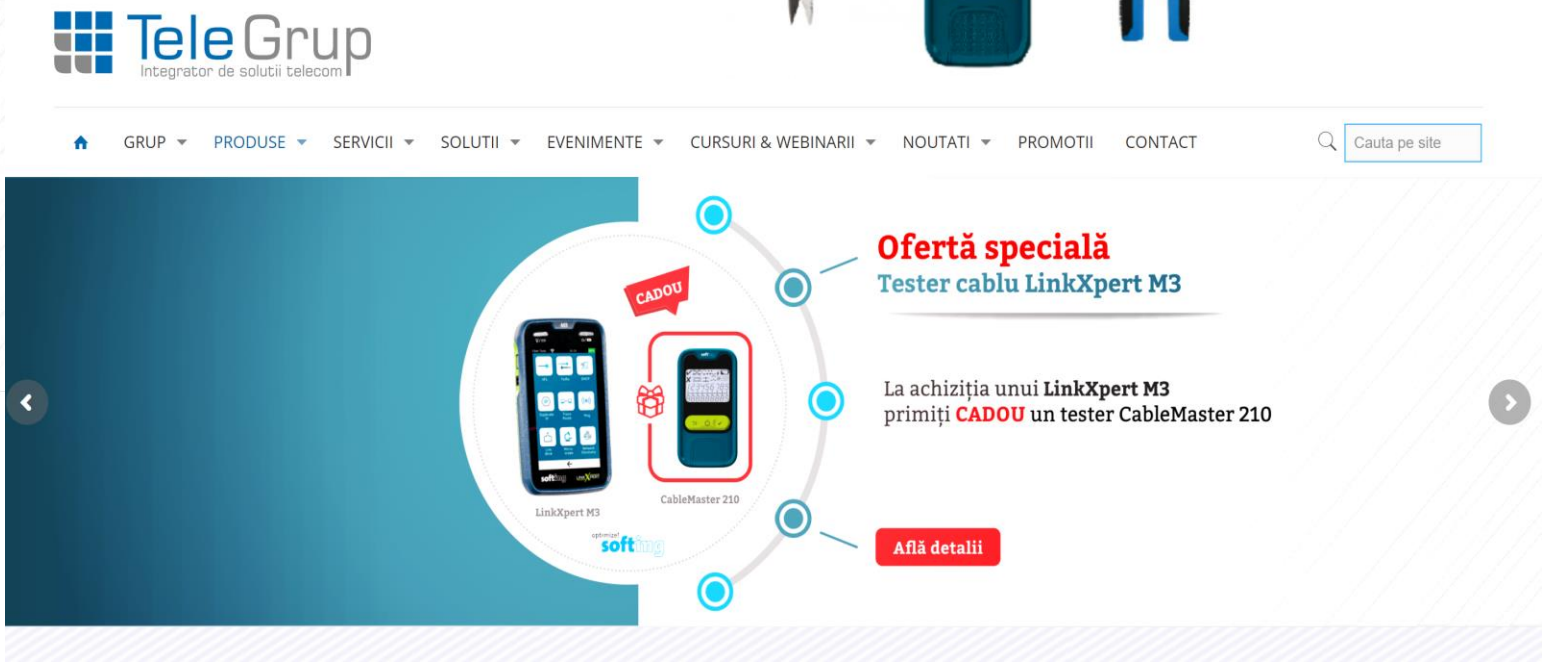
Promotions





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