

Emerging Ethernet Technologies to support Industry 4.0

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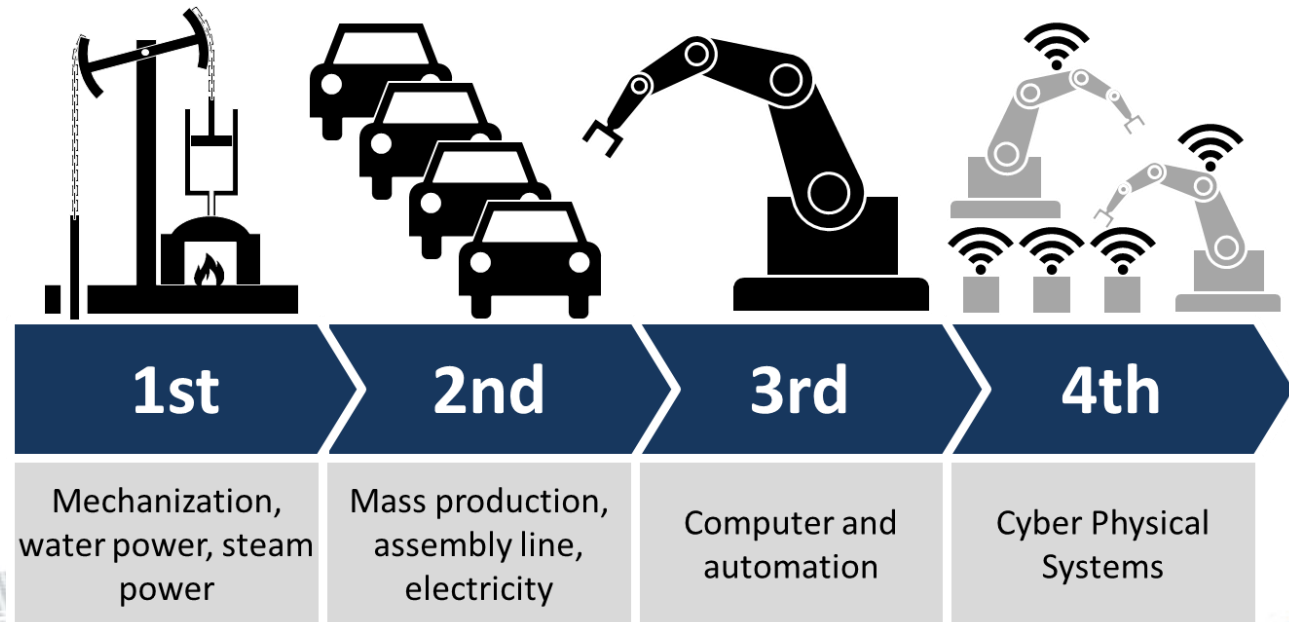
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Creating the Smart Factory

- Industry 4.0 is the term given to the current trend in industrial automation.
 - Leverages a number of technologies to create a smart manufacturing environment.
 - Cloud computing
 - The Internet of Things, IoT.
 - Cyber-physical systems
 - Cognitive computing



Source: Christoph Roser at [<http://www.allaboutlean.com>]

Common requirements?

- Industry 4.0 relies on the ability to communicate
 - Machine-to-machine communication (M2M), requires very short and stable latency times
 - Highly reliant on sensors to monitor the processes
 - Connections via copper
 - Connections via fiber
 - Connections via Wi Fi
- Emerging Industrial Ethernet solutions to play an important role.

Emerging Ethernet Technologies

- Copper based Technologies

- New speeds introduced for Copper Cables

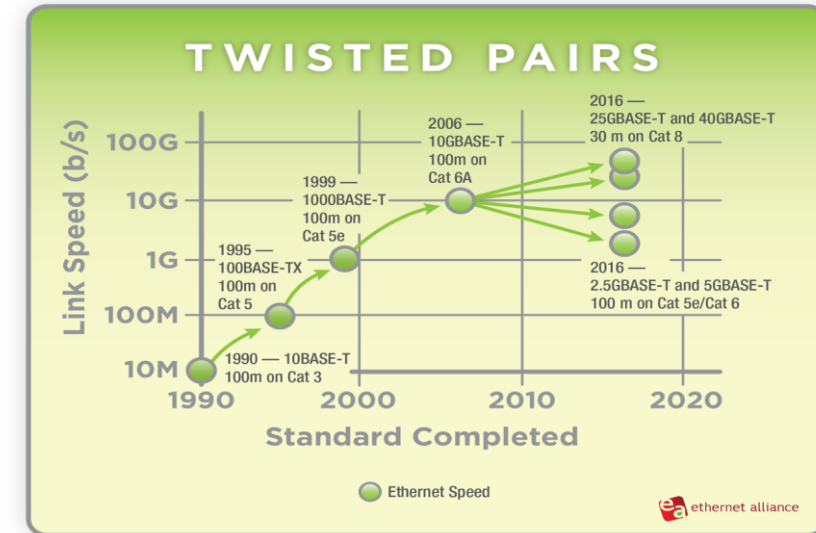
- IEEE802.3bz, sometimes referred to as NBASE-T
 - 2.5GBASE-T and 5GBASE-T on Cat 5e or Cat 6 cables
- 25GBASE-T and 40GBASE-T on Cat 8 cabling

- Longer Channels

- 200m Channel at 2.5GBASE-T is possible, happening already.

- More Power delivered

- 802.3bt will be able to deliver in excess of 90 watts.



Emerging Ethernet Technologies

- Fiber based Technologies

- New speeds introduced for Fiber Optic Cables.

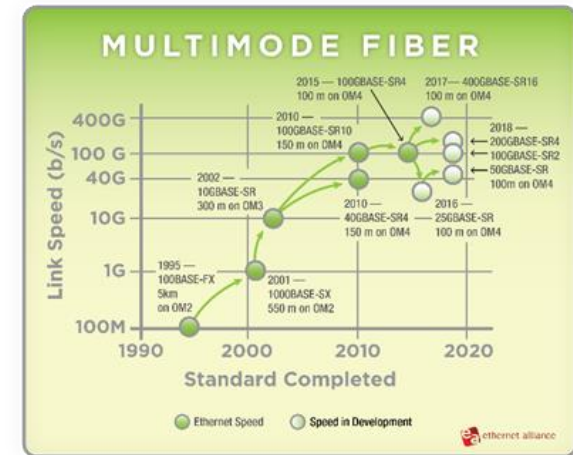
- More data with less fibers utilised

- 50G BASE-SR, 100GBASE-SR2, 200GBASE-SR4, all up to 100m on OM4

- New fibers that allow even faster speeds.

- WBMMF or OM5 that uses 4 wavelengths, Short Wavelength Division Multiplexing

- Up to 100GB on a single fiber.



Emerging Ethernet Technologies

- Fiber based Technologies

- New encoding methods to increase data rates.

- More data with the same fibre

- Traditionally we have been using forms of NRZ encoding

- » Not very efficient

- Enter PAM 4 encoding

- » More efficient

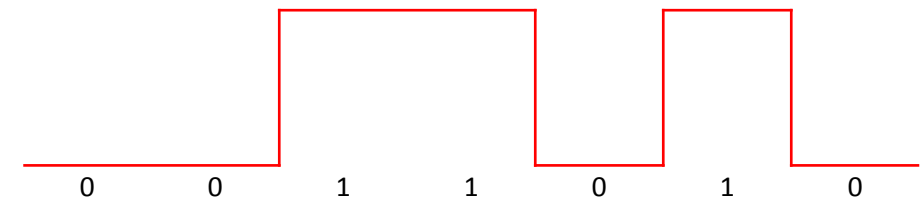
- Allows us to double the data rate

- No increase in Bandwidth required

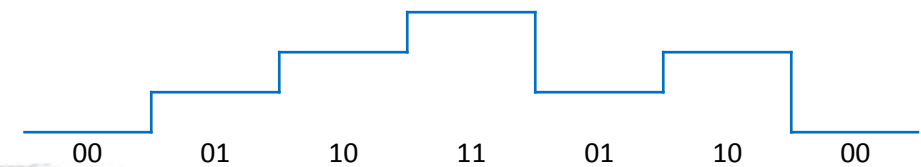
- » We do trade SNR by up to a 1/3.

- 50GBASE-SR is using this technology

- » 50GB over 100m of OM4 MMF



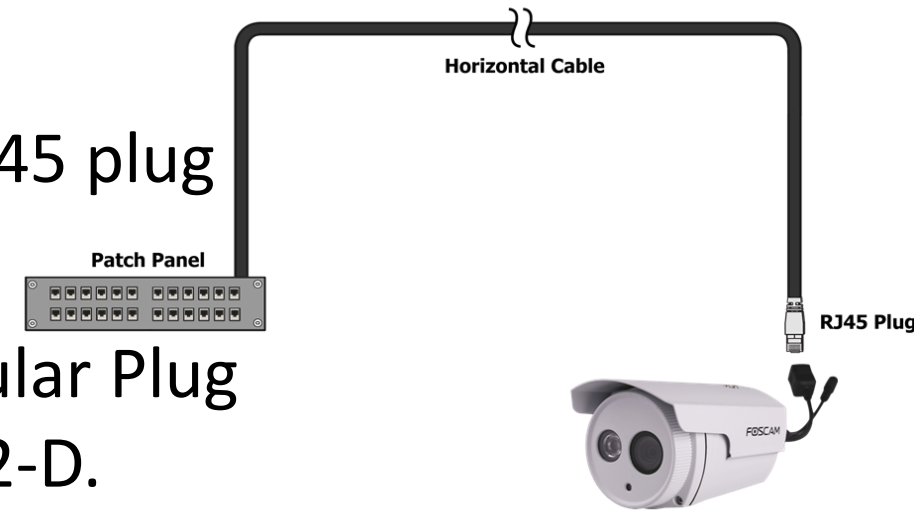
NRZ Encoding



PAM 4 Encoding

New Copper Link Models

- Modular Plug Terminated Link – MPTL
 - The far end is typically hardwired with an RJ45 plug
 - Is this a Permanent Link or Channel test?
 - Defined in ANSI/TIA recently as MPTL, Modular Plug Terminated Link. Added into ANSI/TIA-568.2-D.
 - Key point is the RJ45 plug termination has to be correctly tested



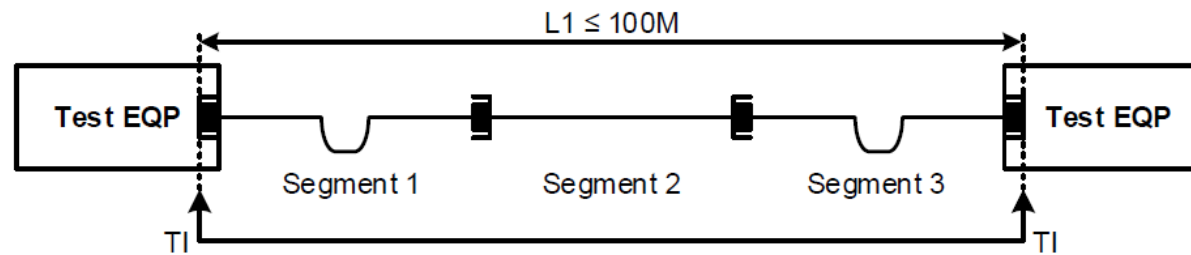
New Copper Link Models

- End 2 End Links – E2E
 - Designed to support Industrial Ethernet and IoT connectivity where a conventional channel is not used.
 - For E2E links the performance requirements have been re-computed to include the first and last connector.
 - There is also a more extensive test approach required.
 - First connector is a plug, the proposed standard will support this.
 - Last connector will be a plug

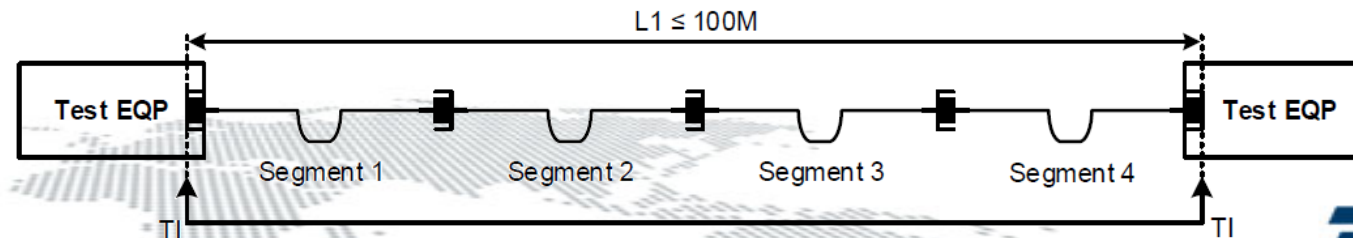
Examples of End 2 End Links

- Regular Channel Testing does not support this, no way to evaluate the mated connections at the end of the links.
 - You can have up to 5 segments, 6 connections maximum.

3 Segment, 4 Connection



4 Segment, 5 Connection



End to End (E2E) Link Testing

- The key is; the test hardware is now required to report problems found in the two end plugs.
 - End to End Links define limit lines for all the standard parameters

Test Parameters Defined				
Wiremap	Measured		ACR-N	Derived
Insertion Loss	Measured		ACR-F	Derived
Return Loss	Measured		PSACR-N	Derived
NEXT	Measured		PSACR-F	Derived
PSNEXT	Derived		TCL	Measured
FEXT	Measured		ELTCTL	Measured
Propagation Delay	Measured		DCR	Measured
Delay Skew	Measured		DCR Unbalance	Measured
Length	Derived		Coupling Attn	Lab Only

Testing points to note;

1. If the connectors are RJ-45 plugs, you will need to use Patch Cord adapters.
2. Where the connectors are RJ45 jacks, you will need to use Permanent Link Leads.
3. No Channel Adapters allowed



NEW SPEEDS EXTENDING THE USE OF COPPER CABLING FOR INDUSTRY 4.0 AND IOT

NBASE-T and 802.3bz Technology
How to make it work for you!



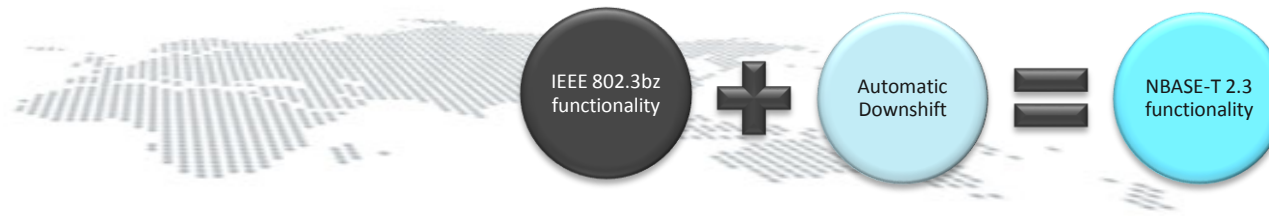
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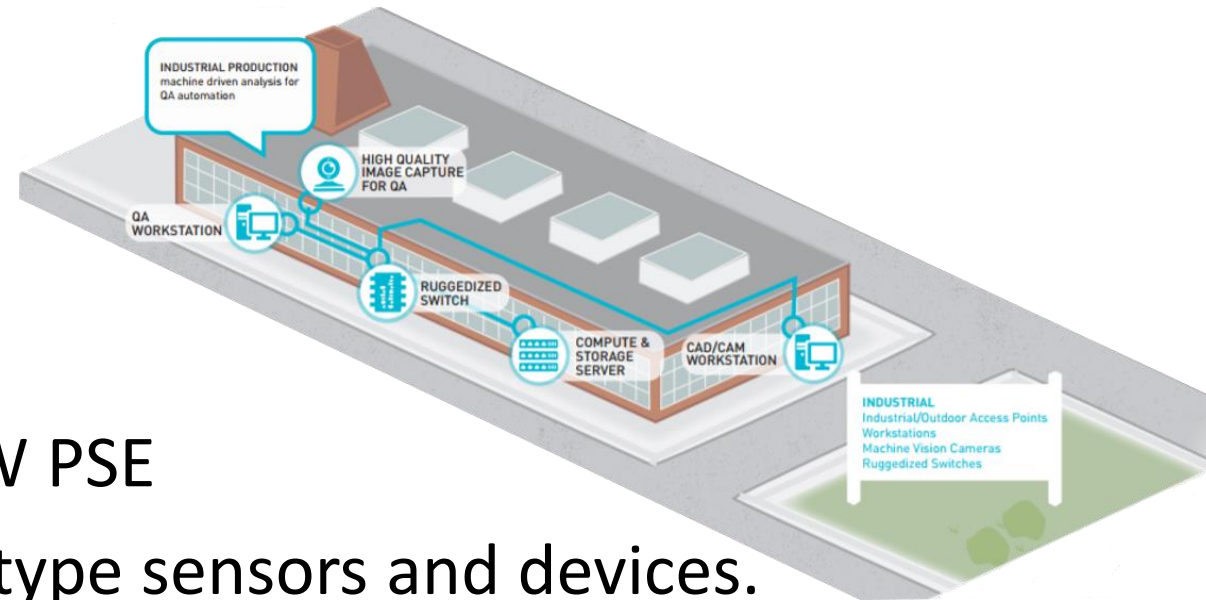
NBASE-T and 802.3bz Technology

- Based on 10GBASE-T Technology
 - PAM-16 with the same LDPC code for good performance
 - Good interoperability, improved robustness
 - Upper frequency of $\frac{1}{2}$ (5G) and $\frac{1}{4}$ (2.5G) that of 10GBASE-T
- NBASE-T and 802.3bz are interoperable with each other
 - Normal auto negotiation enables multi-mode PHY operation, irrespective of the cabling, noise or environment
 - But, in 2.5G/5GBASE-T, the speed you get may depend on other links crosstalking
 - So... “Downshift” automatically shifts the rate based on the channel noise
- Supports PoE!



NBASE-T and Industry 4.0

- Allows higher speeds on legacy cabling types
 - Upgrading of equipment
- Support of sensor technologies
- Support for new 802.11ac Wi Fi devices
- Near real time image processing
- Allows use of PoE ++, 802.3bt, up to 91W PSE
- Support channels of up to 200m for IoT type sensors and devices.



Testing the infrastructure

- ANSI/TIA has released a new field test standard.
 - ANSI/TIA-1152A
 - Includes optional tests to support PoE
- ISO/IEC will release a new field test standard.
 - ISO/IEC 61935-1 Ed. 5 mid 2018
 - Also includes optional tests to support PoE and E2E links.
 - Both standards also include requirements for a new level of field tester, Level 2G for TIA or Level VI for ISO.
 - Both will be updated to include testing for MPTL and E2E Links

New field test requirements

- With the new ANSI/TIA-1152-A and Draft IEC 61935-1 Ed. 5 we also get some changes in field testing.
 - We carry out all the usual parametric tests but now out to 2GHz, to cover all types of Cat 8.
 - Wiremap has a requirement, when testing Cat 8 installations, to check the shield continuity along the path of the cabling.
 - Prevents the field tester being fooled by ground paths via racking and the earth connections.
 - Optional tests added to support the emerging IEEE 802.3bt PoE++ standard.
 - Channel dc loop resistance is to be below 25Ω
 - 6 Ω for Cat 8 Cabling
 - Current imbalance between pairs is to be minimised. This is achieved with Resistance Unbalance measurements within the pair and between pairs.

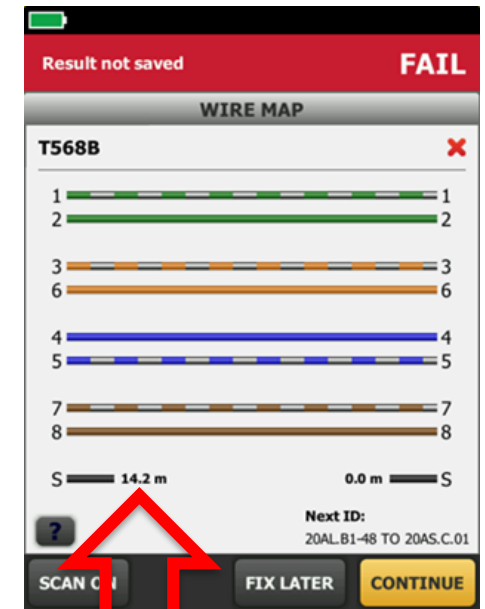
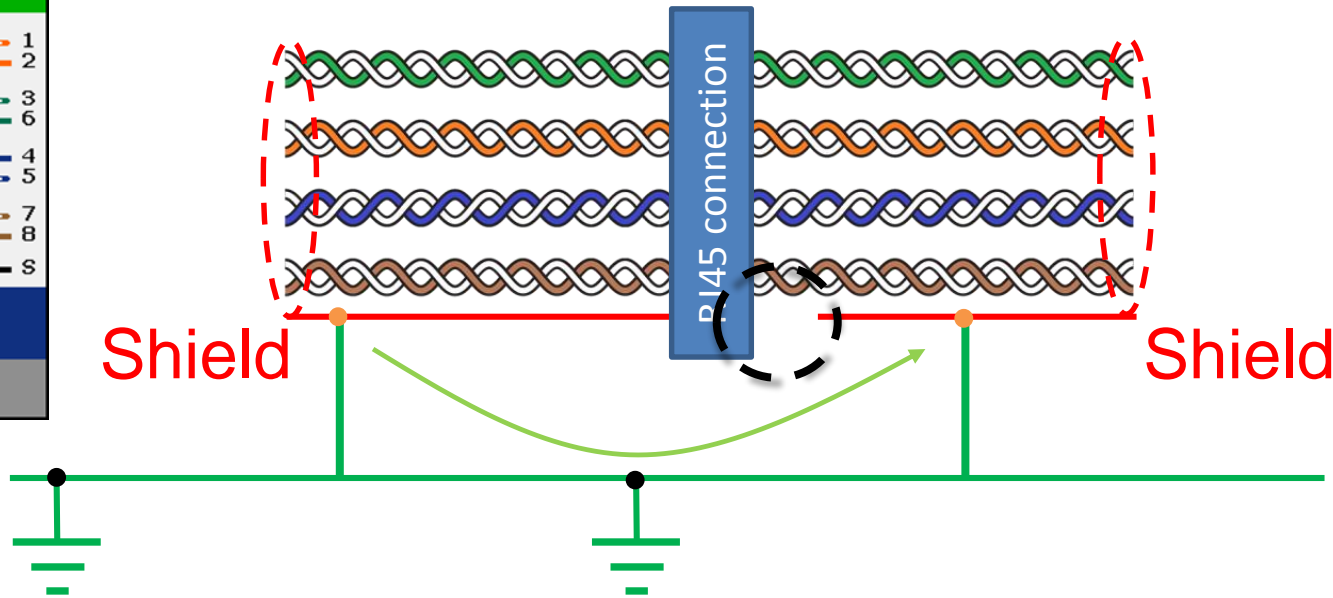
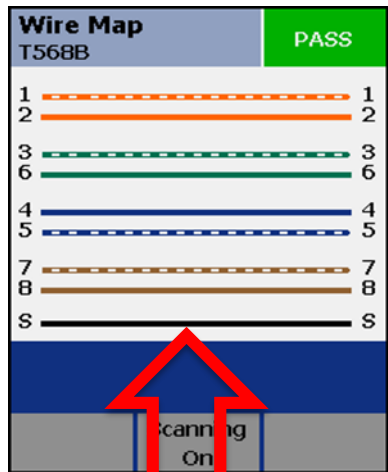
Copper Certification		
	ISO/IEC 11801 Edition 3 Conformance Requirements	IEC 61935-1 Edition 5 Field Test Requirements
Wire Map *	✓	✓
Length	✓	✓
Propagation Delay	✓	✓
Delay Skew	✓	✓
dc Loop Resistance	✓	✓
Resistance Unbalance **	✓	Optional
Insertion Loss	✓	✓
NEXT, PS NEXT	✓	✓
Return Loss	✓	✓
ACR-F, PS ACR-F	✓	✓
TCL, ELTCTL	✓	Optional
Coupling Attenuation	✓	Optional
PS ANEXT, PS AACR-F	✓	✓

* For Level 2G testers screen continuity is tested along the path of the cabling.
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** Proposed Measurement requirement to support IEEE 802.3bt DTE Power over MDI
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Shield Continuity (RF)

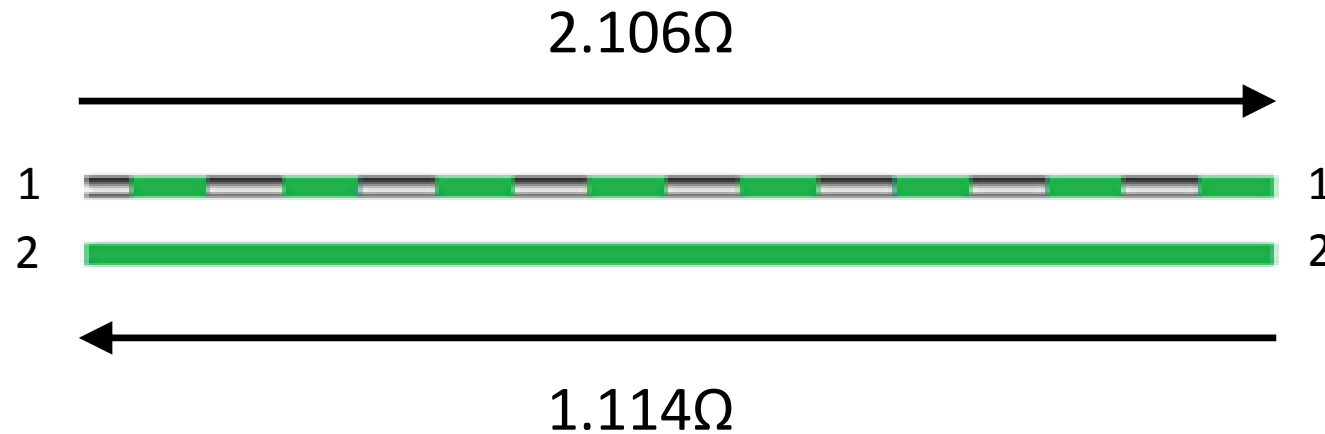
An ordinary continuity test would show this as connected.



Ground paths within the plant can fool a tester.

Resistance Unbalance

- They are optional tests for field testing that allows an installed link to be evaluated for PoE transmission.
 - Adds a Loop Resistance check (Already an ISO 11801 requirement)
 - Adds a DC Resistance Unbalance check within the pairs

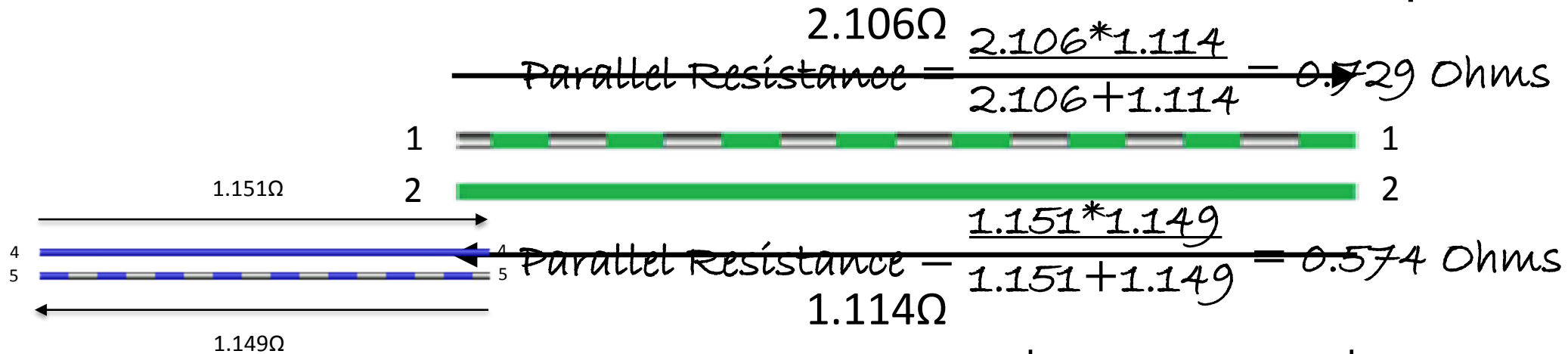


$$\text{Loop Resistance} = 2.106 + 1.114 = 3.22 \text{ Ohms}$$

$$\text{DC Resistance Unbalance} = |2.106 - 1.114| = 0.992 \text{ Ohms}$$

Resistance Unbalance

- They are optional tests for field testing that allows an installed link to be evaluated for PoE transmission.
 - Adds a Loop Resistance check (Already an ISO 11801 requirement)
 - Adds a DC Resistance Unbalance check within the pairs
 - Adds a DC Resistance Unbalance check between the pairs



$$\text{Pair 2 Pair Unbalance} = |0.729 - 0.574| = 0.155 \text{ Ohms}$$

$$\text{DC Resistance Unbalance} = |2.106 - 1.114| = 0.992 \text{ Ohms}$$

Using Cat5e and Cat6 at 2.5 and 5Gig

- Internal crosstalk (NEXT, return loss) has low risks
 - Category 5e will likely meet 5GBASE-T requirements
 - Category 6 has no risks of meeting 2.5 and 5GBASE-T internal requirements
- Alien crosstalk has elevated risks
 - **Vast majority of links have very low risks**
 - Risk with Category 5e and 6 cables on long bundled (> 75 meters) runs
 - Refer to SNR risk matrix

Cable Bundle: A group of cables that are tied together or in contact with one another in a closely packed configuration for at least 1 m.

Alien Crosstalk concerns

- ALSNR Analysis
 - Alien Limited Signal to Noise Ratio
- Low risk for bundles up to 50 meters, regardless of channel length
- Limited risk for bundles up to 75 meters
- No risk when using Category 6A

ALSNR Risk Matrix

Bundled cabling length 0m to 50m	Category 5e	Category 6	Category 6A
2.5GBASE-T	Green	Green	Assured
5GBASE-T	Light Green	Green	Assured
Bundled cabling length 50m to 75m	Category 5e	Category 6	Category 6A
2.5GBASE-T	Light Green	Green	Assured
5GBASE-T	Yellow	Light Green	Assured
Bundled cabling length 75m to 100m	Category 5e	Category 6	Category 6A
2.5GBASE-T	Yellow	Light Green	Assured
5GBASE-T	Red	Yellow	Assured
ALSNR Risk	High	Medium	Low

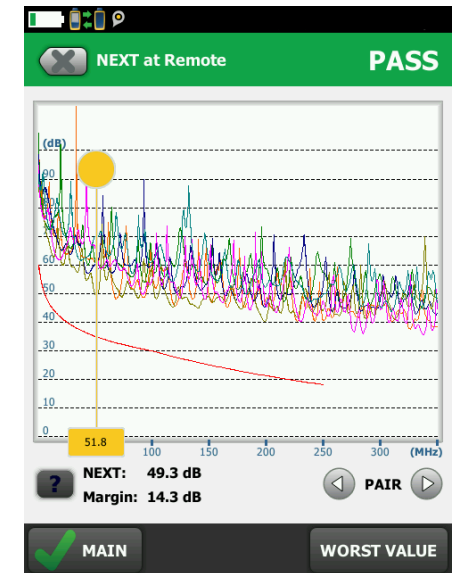
Category 5e Cabling Supports NBASE-T

- NBASE-T limits are the same as Category 5e for NEXT and Return Loss
 - However – 5 Gigabit limits are based on Category 5e limits extrapolated out to 250 MHz

	2.5G BASE-T	5G BASE-T
Installed Cat 5e	✓	Extended frequencies required
Installed Cat 6	✓	✓
Installed Cat 6A	✓	✓

- To be **sure** that your existing cabling will support 2.5 and 5 Gigabits you need to compare your test results to limits out to 250 MHz
 - Was my cabling certified correctly the first time?
 - Do I need to test again?
 - Do I know if the resistance unbalance is correct for PoE use?

- **Remember, to test is to know.**



To Conclude

- Industry 4.0 will push current Industrial Ethernet networks to their limit.
- New technologies that work with copper and fiber to increase speeds and throughput are becoming available.
- Many of these technologies can be used on copper, extending the life of copper in network situations.
- There is a downside...
 - You need to test your infrastructure correctly to make certain these new technologies will work correctly.



Thank You!

Questions?



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