Emerging Ethernet Technologies to support Industry 4.0

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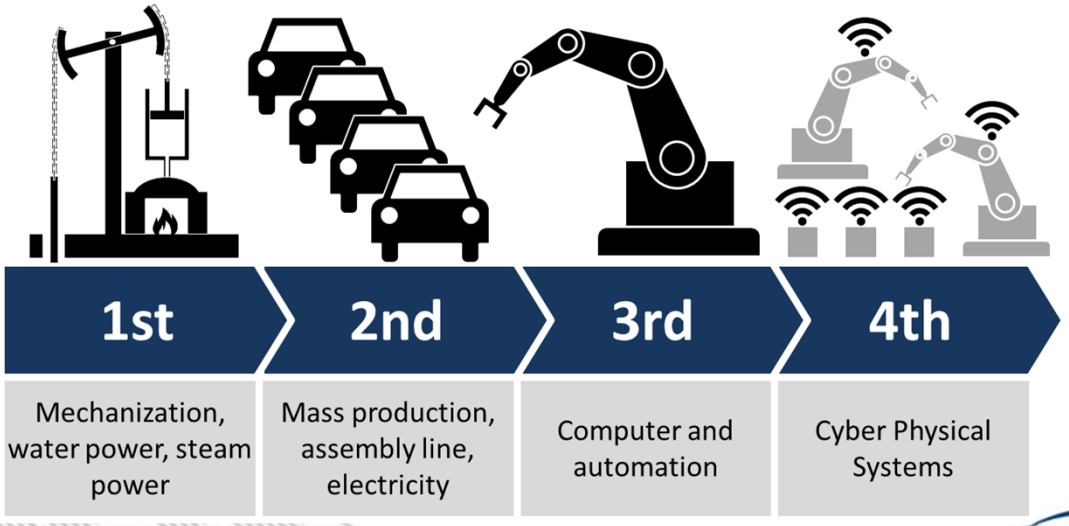
Creating the Smart Factory

- 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]

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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.

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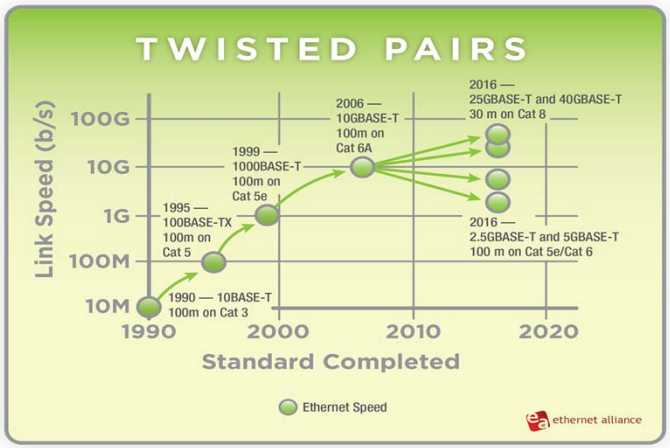
Emerging Ethernet Technologies

- 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.



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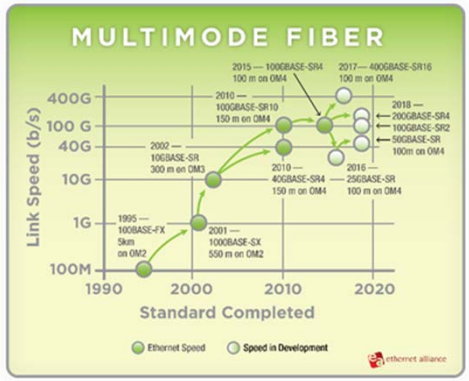
Emerging Ethernet Technologies

- 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.



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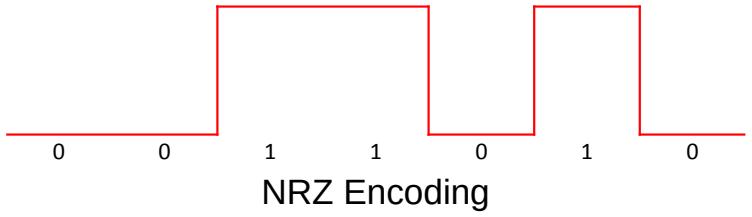
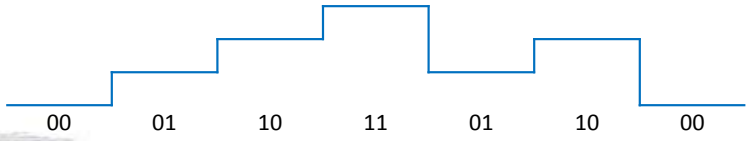
Emerging Ethernet Technologies

- 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

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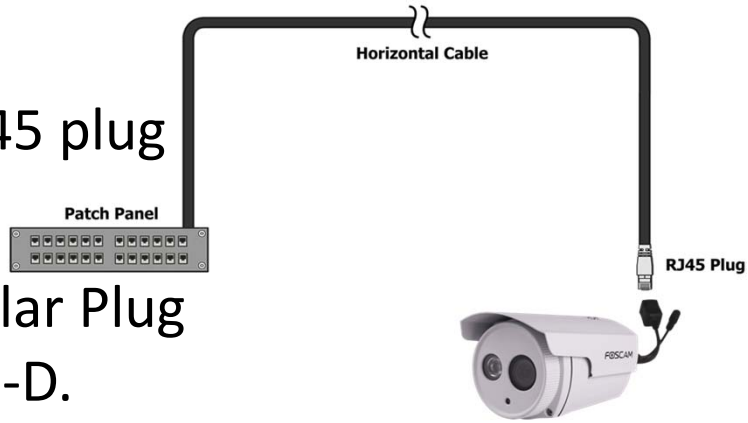
New Copper Link Models

- 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



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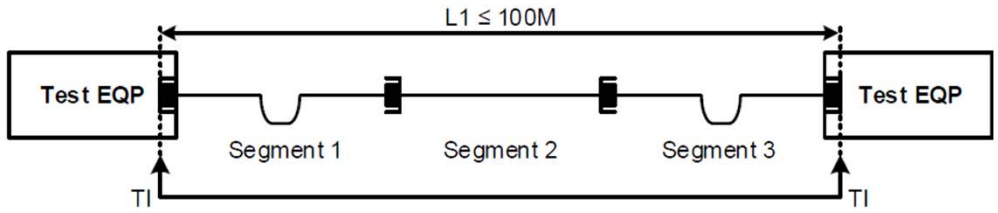
New Copper Link Models

- 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 can be either a plug or jack, the proposed standard will support this.
      - Last connector will usually be a plug

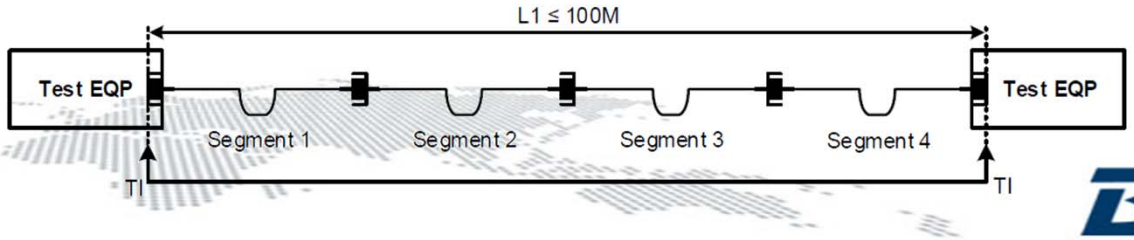
Examples of End 2 End Links

- 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



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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

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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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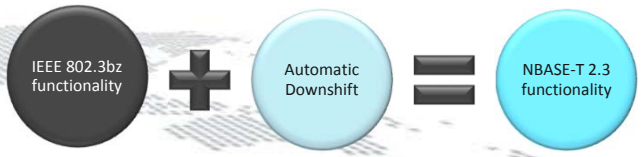
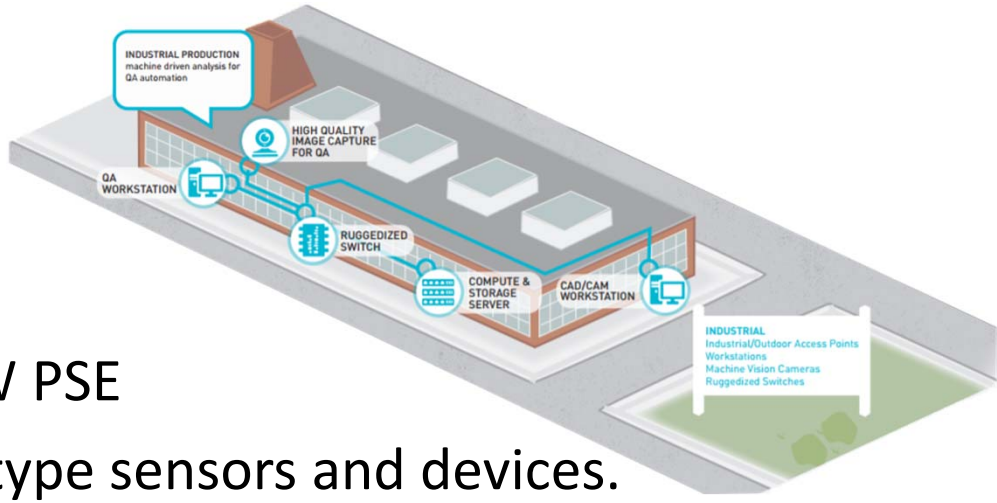
NBASE-T and 802.3bz Technology

- Based on 10GBASE-T Technology
  - PAM-16 with the same LDPC code for good performance
  - Good interoperability, improved robustness
  - Upper frequency of ½ (5G) and ¼ (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.



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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 late 2017
    - 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

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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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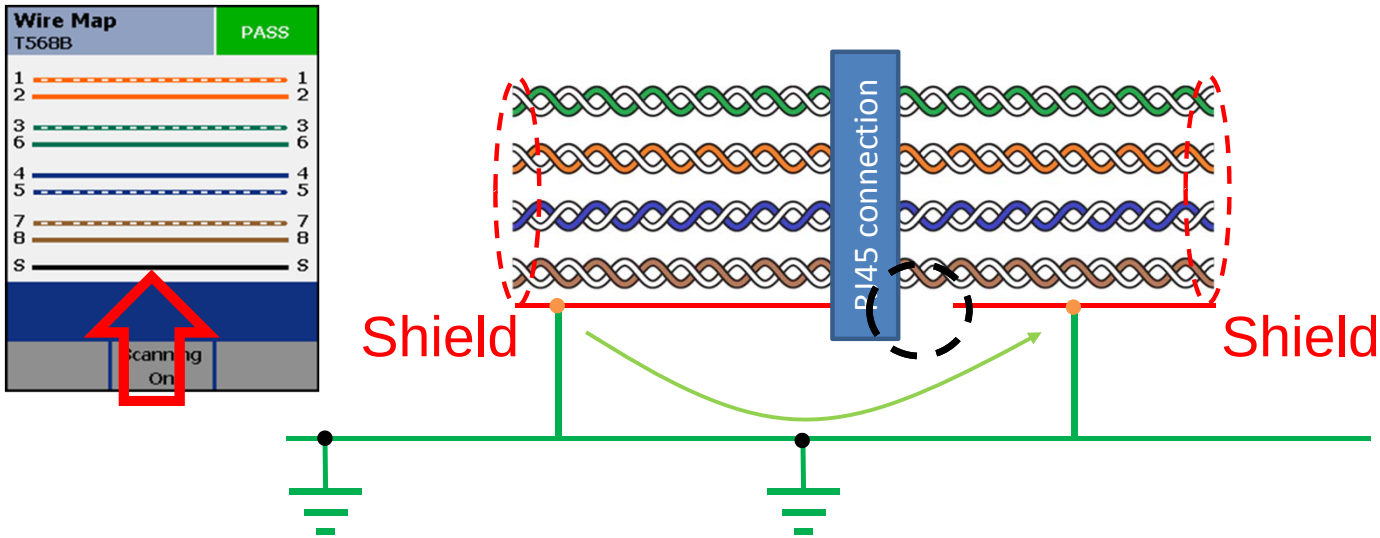
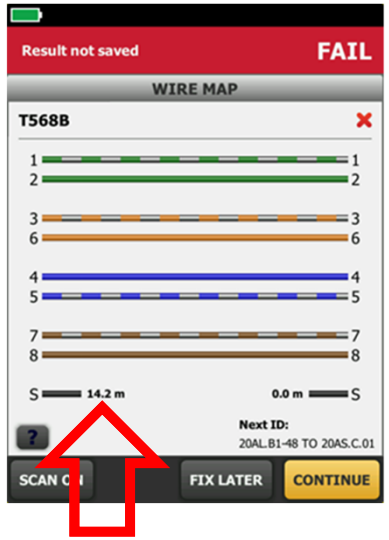
Shield Continuity (RF)

An ordinary continuity test would show this as connected.





Ground paths within the plant can fool a tester.

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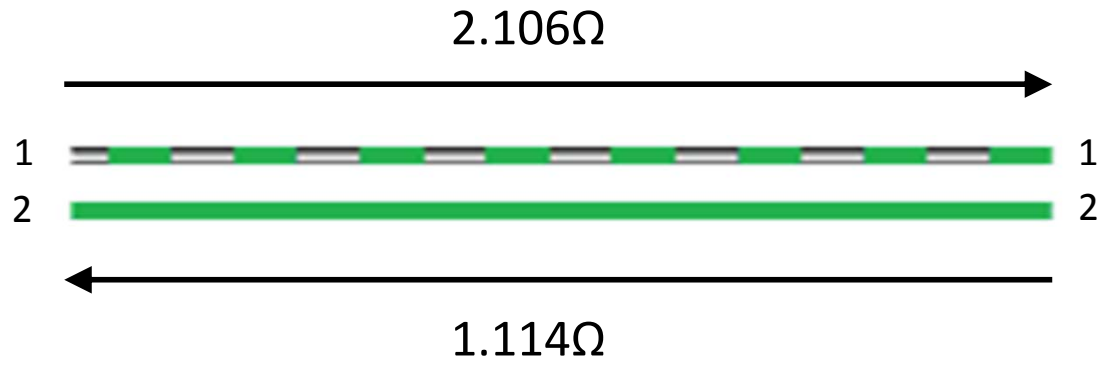
Resistance Unbalance

- 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



Loop Resistance = 2.106 + 1.114 = 3.22 Ohms

DC Resistance Unbalance = |2.106 - 1.114| = 0.992 Ohms

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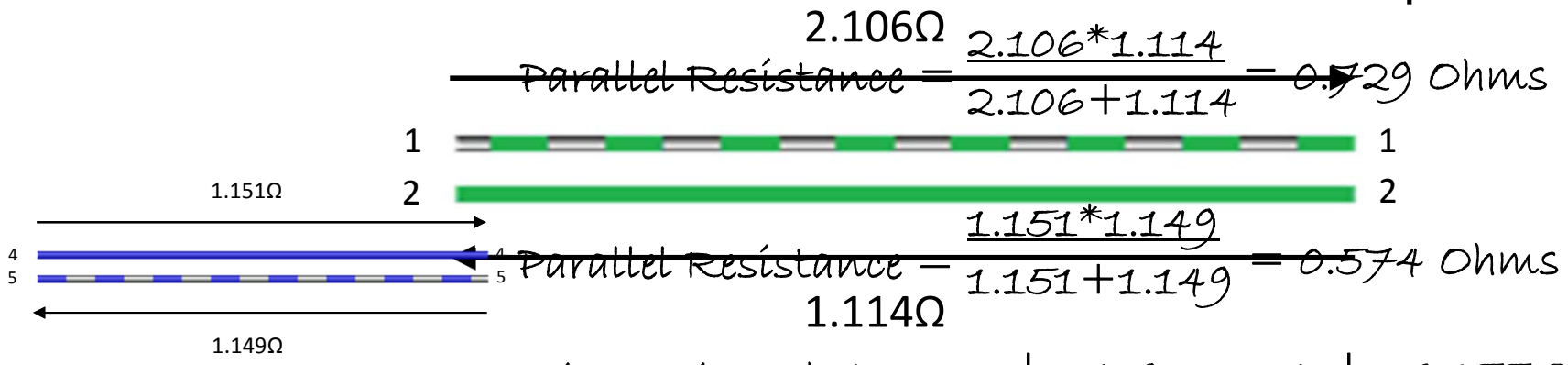

$$\text{Parallel Resistance} = \frac{2.106 * 1.114}{2.106 + 1.114} = 0.729 \text{ Ohms}$$

$$\text{Parallel Resistance} = \frac{1.151 * 1.149}{1.151 + 1.149} = 0.574 \text{ Ohms}$$

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

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

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

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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.

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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			Assured
5GBASE-T			Assured

Bundled cabling length 50m to 75m	Category 5e	Category 6	Category 6A
2.5GBASE-T			Assured
5GBASE-T			Assured

Bundled cabling length 75m to 100m	Category 5e	Category 6	Category 6A
2.5GBASE-T			Assured
5GBASE-T			Assured

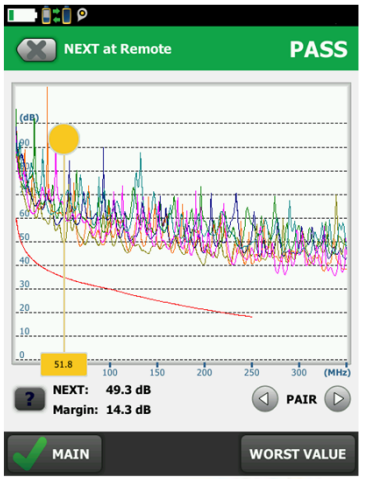
ALSNR Risk	High	Medium	Low

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.**



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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.

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Thank You!

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