

IEEE802.3 4P Task Force
Channel Pair To Pair Resistance Imbalance
(End to End System Imbalance)
Ad Hoc

Meeting #1: Rev_001 Monday February 17, 2014
Meeting #2: Rev_002 Monday February 24, 2014

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Meeting # 1 Attendees (Monday Feb 17,2014)

- Yan Zhuang / Huawei
- Abramson David / TI
- Kousalya Balasubramanian/ Cisco
- Leonard Stencil / Bourns
- Larsen Wayne / Commscope
- Woudenberg Rob / Philips
- Picard Jean / TI
- Steinke Stephan / Molex
- George Zimmerman / CME Consulting / Commscope
- Sessa Panguluri/Broadcom
- Ken Bennett/ Sifos

- Gaoling Zou / Maxim
- Dave Dwelley / LT
- Lennart Yseboodt / Philips
- Wendt, Matthias / Philips
- Christian Beia / ST
- David Law / Hp

Proposed Agenda

- Introduction
- Summary of previous work and conclusions
 - Cable pair to pair resistance unbalance (P2PRU)
 - Channel pair to pair resistance unbalance (C_P2PRU)
 - General Channel Model and its components
 - Simulation Results
 - Sensitivity Analysis
 - Conclusions
- What are the parameters that must be define?
 - Cable Pair to Pair Resistance Unbalance (P2PRU)
 - Channel Pair to Pair Resistance Unbalance (C_P2PRU)
- Analysis Methods and Data-Base
 - Analysis Method
 - Data Base
- Do we need to specify the following additional parameters or leave it to be implementation specific as long as C_P2PRU is met?
 - PSE PI Pair to Pair Resistance Unbalance (PSE_P2PRU)
 - PD PI Pair to Pair Resistance Unbalance (PD_P2PRU)

Introduction

- The purpose of this ad-hoc is to recommend the Task-Force for what is needed to specify the channel pair to pair resistance unbalance while considering not only the formal channel components (Cable and Connector) but also the Power Interface (PI) components at both ends of the 4P PoE system.
- Patent Policy
- All attendees to send mail approving their attendance at the add-hoc today

Summary of previous work and conclusions -1

Cable pair to pair resistance unbalance (P2PRU)



- In order to specify the ***pair to pair channel resistance imbalance*** we had to know the channel ***components pair to pair*** resistance unbalance such as:
 - Cable (not defined by cabling vendors),
 - Connectors, (Specified but not represents worst case numbers)
 - Transformers, (Vendors data is available. Not part of the formal channel)
 - PSE output resistance (Vendors data is available. Not part of the formal channel)
 - PD input resistance (Vendor data is available, Not part of the formal channel)
- We have good and sufficient data for all the components **except the cable**.
- We developed a method that predicted the cable Pair to Pair resistance imbalance from the other cable parameters such Propagation delay, Skew, wire diameter, wire insulation material and other.
- The predictions showed that P2P Cable Resistance Unbalance <5%
- Lab Tests confirmed that it was <5%
- Long list of experts (including cable experts) agree with the conclusions.
- All details can be found in:
http://www.ieee802.org/3/4PPOE/public/nov13/darshan_01_1113.pdf

Summary of previous work and conclusions -2

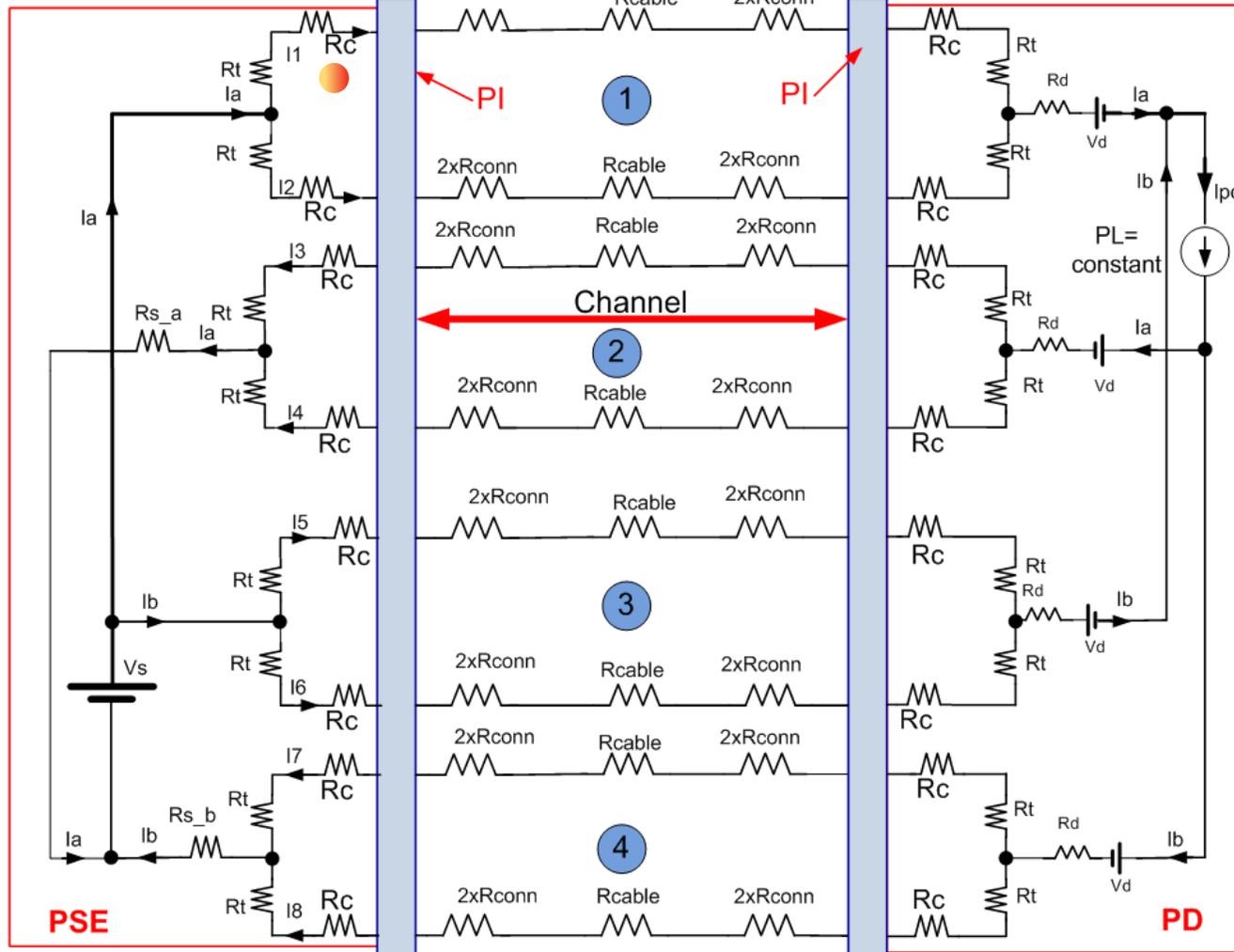
Channel pair to pair resistance unbalance (C_P2PRU)

- Initial Work to determine channel pair to pair resistance unbalance:
 - http://grouper.ieee.org/groups/802/3/4PPOE/public/jul13/beia_1_0713.pdf
 - http://grouper.ieee.org/groups/802/3/4PPOE/public/jul13/darshan_2_0713.pdf
- After getting comments from the group and using same worst-case data base and model:
 - http://www.ieee802.org/3/4PPOE/public/nov13/darshan_03_1113.pdf
 - http://www.ieee802.org/3/4PPOE/public/nov13/beia_01_1113.pdf
- General Channel Model and its components that we have used: See next slide.

Summary of previous work and conclusions -3

General Channel Model and its components that we have used.

Updated Model to include equipment connector for accurate end to end worst case analysis.



Notes for the general Model:

1. Adding resistors on positive path for general model per previous discussion (R_{sp_a} and R_{sp_b}). It can be set to zero or $>zero$ pending the case being investigated.
2. Adding equipment connectors per Wayne's comment. So total end to end channel connectors is 6.
3. The formal channel definition is marked in red arrow.
4. Our work addresses also the internal application resistance of known components that are used

Summary of previous work and conclusions

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Data set that we use as worst case numbers

From: http://www.ieee802.org/3/4PPOE/public/nov13/beia_01_1113.pdf

Table 1	Data set 1 (Max Cable resistivity)	Data set 2 (Min Cable resistivity)
Cable resistivity	117mOhm/m* (maximum value) (CAT5e) Pair resistance unbalance: 2% → Minimum wire resistance=0.98*117mΩ/m Pair to pair resistance unbalance: 5% → Pair resistance max=~(117mΩ/m)/2 → Pair resistance min=~(0.95*117mΩ/m)2	66mOhm/m* (CAT6A) Pair resistance unbalance: 2% → Minimum wire resistance=0.98*66mΩ/m Pair to pair resistance unbalance: 5% → Pair resistance max=~(66mΩ/m)/2 → Pair resistance min=~(0.95*66mΩ/m)2
Transformer winding resistance	120mOhm min, 130mOhm max	120mOhm min, 130mOhm max
Contact resistance	30mOhm min, ** 60mOhm max	30mOhm min, ** 60mOhm max
Diode bridge	0.3V+0.4Ohm*Id min; 0.4V+0.5Ohm*id max	0.3V+0.4Ohm*Id min; 0.4V+0.5Ohm*id max
PSE output resistance (e.g. Rs_a/b= Rsense+Rdson)	0.25+0.1 Ohm min 0.25+0.2 Ohm max	0.1+0.05 Ohm min 0.1+0.1 Ohm max

- Two scenarios have been identified: max wire resistivity Data set 1 (CAT5E cables) and min wire resistivity Data set 2 (CAT6/A cables)
- *Cable pair to pair resistance max unbalance is set to 5%. See darshan_1_1113.pdf. Cable resistance within pair unbalance is max 2%.
- **Connector contact aging will be addressed in other work.
- All parameters are at room temperature and further study is required to address temperature variations

Summary of previous work and conclusions

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Simulation Results (updates from last meeting)

- Results for Table 1 right column data number set (minimum resistivity cable Type).
- Pairs were not limited to 0.6A
- Numbers were taken from the pairs with highest and lowest values.
- The model that was simulated is with 4 connectors only as in the link below.
 - http://www.ieee802.org/3/4PPOE/public/nov13/darshan_03_1113.pdf

Simulation Results of worst-case analysis				
Length[m]	Pair with minimum current [mA]	Pair with maximum current [mA]	Idiff=Max-Min [mA]	P2PCRUnb [%]
1	385	659	275	26.30
10	415	636	221	21.04
100	500	626	126	11.19

$$P2PCRUNB = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

Results with 6 connectors Model.

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Simulation Results

- Results for Table 1 right column data number set (minimum resistivity cable Type).
- Pairs were not limited to 0.6A
- Numbers were taken from the pairs with highest and lowest values.
- The model used is per

Simulation Results of worst-case analysis with 4 connectors				
Length[m]	Pair with minimum current [mA]	Pair with maximum current [mA]	Idiff=Max-Min [mA]	P2PCR unb [%]
1	385	659	275	26.30
10	415	636	221	21.04
100	500	626	126	11.19

Simulation Results of worst-case analysis with 6 connectors TBD				
Length[m]	Pair with minimum current [mA]	Pair with maximum current [mA]	Idiff=Max-Min [mA]	P2PCR unb [%]
1				
10				
100				

Summary of previous work and conclusions -7

- See details:
http://www.ieee802.org/3/4PPOE/public/nov13/beia_01_1113.pdf
- What we did was a sensitivity Analysis to identify the main contributors of lesser power delivery.
- We need to do the work for sensitivity analysis for channel pair to pair resistance unbalance regardless of power delivery constrains.

Max res scenario	Component UNB[±]	Effect on power delivery [-]		
		1m	10m	100m
Cable lenght				
Rt	4%	0.17%	0.10%	0.01%
Rconn	33.30%	1.02%	0.58%	0.08%
r_cable	5%	0.20%	1.13%	1.68%
Rdiode	11.10%	3.43%	1.96%	0.32%
Vdiode	14.30%	5.72%	3.27%	0.53%

Min res scenario	Component UNB[±]	Effect on power delivery [-]		
		1m	10m	100m
Cable lenght				
Rt	4%	0.18%	0.12%	0.03%
Rconn	33.30%	1.06%	0.73%	0.16%
r_cable	5%	0.12%	0.81%	1.79%
Rdiode	11.10%	3.56%	2.48%	0.57%
Vdiode	14.30%	5.94%	4.14%	0.96%

Summary of previous work and conclusions

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Conclusions

- See details:
http://www.ieee802.org/3/4PPOE/public/nov13/beia_01_1113.pdf
- Main conclusions relevant for channel pair to pair resistance unbalance (short summary)
- P2P current imbalance increases when cable length decreases.
- P2P current imbalance increases when cable resistivity decreases i.e. CAT6A will have higher current imbalance compared to CAT5e.
- Unbalance within a pair (the famous 2% pair and 3% channel) has negligible effect on P2P unbalance.
- We need to define the requirements for P2P_{Runb} for the PD, Channel and PSE in order to meet our objectives.

Summary of previous work and conclusions

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Conclusions

- To analyzed the following scenarios:
 - How connector contact aging will affect the results i.e. if min/max contact resistance difference will be increased.
 - The current unbalance results as function of operating temperature range
 - To analyze the results when there is no hard limit of 600mA on the negative pair.

(Done: See slide “results” and see:

http://www.ieee802.org/3/4PPOE/public/nov13/darshan_03_1113.pdf

- To set a worst case conditions for evaluating maximum current imbalance through transformers.

Actually done: $I_{bias} = I_{unbalance} / 2 = CP2PRU * I_{cable_max}$.

- Consider analyzing P2P current imbalance higher category cables than CAT6A
- To perform sensitivity analysis for P2P current and resistance imbalance.

What are the parameters that must be define?

- As done in IEEE802.3-2012 (*See Annex A*) when we define the pair (wire to wire in the same pair) in the cable pair(s) and in the channel, we need to do it for the Pair to Pair Resistance Unbalance in the cable and in the channel.
- Cable Pair to Pair Resistance Unbalance (P2PRU)
 - Based on the work done at http://www.ieee802.org/3/4PPOE/public/nov13/darshan_01_1113.pdf , it is proposed to specify it to 5% until formal number will be received from TIA/EIA.
- Channel Pair to Pair Resistance Unbalance (C_P2PRU)
 - We need to decide if we can work with the worst case numbers?
 - Or we need to add the probability factors to lower them.

Analysis Methods and Data-Base

- Analysis Method
 - Worst-Case Analysis
 - We did a worst-case analysis for the channel pair to pair resistance unbalance on a proposed worst-case data
 - Any comments on the worst-case data base?
 - To considering 100BaseT Ethernet devices or switches that do not implement transformers on the spare pairs so the range should be 0 Ohm to 130mOhm.
 - In the switch and PD vendor will have to add equivalent resistor to compensate the PSE PI unbalance. To discuss this approach.
 - Any comments on the model used
 - Next Steps
 - Are we Ok with the results obtain and can live with it or we need to do a statistical analysis to lowering the numbers of worst-case analysis?

Do we need to specify PSE and PD PI P2P Resistance Unbalance or leave it to be implementation specific as long as C_P2PRU is met?

- Do we need to specify the following additional parameters or leave it to be implementation specific as long as C_P2PRU is met?
 - PSE PI Pair to Pair Resistance Unbalance (PSE_P2PRU)
 - PD PI Pair to Pair Resistance Unbalance (PSE_P2PRU)
 - In the current standard the pair resistance unbalance was defined to 2% and the channel (cable and connector only) to 3% (See Annex A).
 - It was the responsibility of the equipment vendor to make sure that his design will meet all system requirement based on the above specification.
 - In 802.3at extensive work was done and shows that the actual pair channel resistance unbalance is higher than 3% (due to other components in the system) and yet system vendors and components ensure operation under this conditions.
 - Now we are addressing the P2P channel Resistance Unbalance and we have the same question: Do we need to specify the following additional parameters or leave it to be implementation specific as long as C_P2PRU is met?
 - If we do want to define PSE_P2PRU and PD_P2PRU.
 - Should we define only PD_P2PRU since it is not always required for the PD (it is PD power dependent and if defined at PSE it will be required for every port

Discussions and conclusions

- To ask magnetic component vendors if they can handle the worst-case analysis numbers or we should do statistical analysis as well.
 - If they can, we use the results to define the end to end channel P2P resistance unbalance.
- To define 3 new parameters
 - (1) To define the channel (PI to PI) Resistance unbalance (cables and connectors) with the contributions of PSE and PD PI P2P Resistance Unbalance.
- From (1) to separately define
 - PSE PI P2PRUNB and PD P2PRUNB
 - To define the channel (PI to PI) Resistance unbalance (cables and connectors).
 - As a result component and system vendors could use it for designing their components.
- We accept that P2P Cable Resistance Unbalance is 5% until formal number will be received by TIA/EIA etc.
- Yair to work with transformer vendors to get the data we need.
- To look for the best cable (lower resistance per meter) expected in the next 10+years and use it in our worst case data base numbers.
- To verify that LDO is covered by PD constant power sink.
- To considering 100BaseT Ethernet devices or switches that do not implement transformers on the spare pairs so the range should be 0 Ohm to 130mOhm.
 - In the switch and PD vendor will have to add equivalent resistor to compensate the PSE PI unbalance. To discuss this approach.
- No other comments on previous work done nor on model or database used.
- Group to send comments on model and data base and we will update it if found.

For next meeting

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- To discuss the advantages that PD constant Power Sink allows us.
- Background material for considering:
 - Worst case Channel Pair to Pair Channel Resistance Unbalance is at short cable (<100m).
 - At short cables PD voltage is higher than at 100m channel length and pair/port current is lower
 - Not only that the port current is lower, it is <600mA for Type 3 systems below TBD channel length.
 - As a result, P2PCRUNB is not an issue.
 - At 100m the P2PCRUNB is much smaller than at short channel
 - Resulting with less significant contribution to I_{bias} due to P2PCRUNB and as a result to OCL. This approach was validated in:
http://grouper.ieee.org/groups/802/3/4PPOE/public/jul13/darshan_2_0713.pdf and requires further investigation for completing this work.

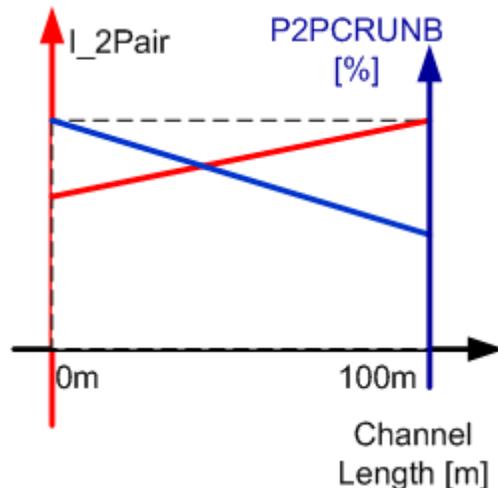


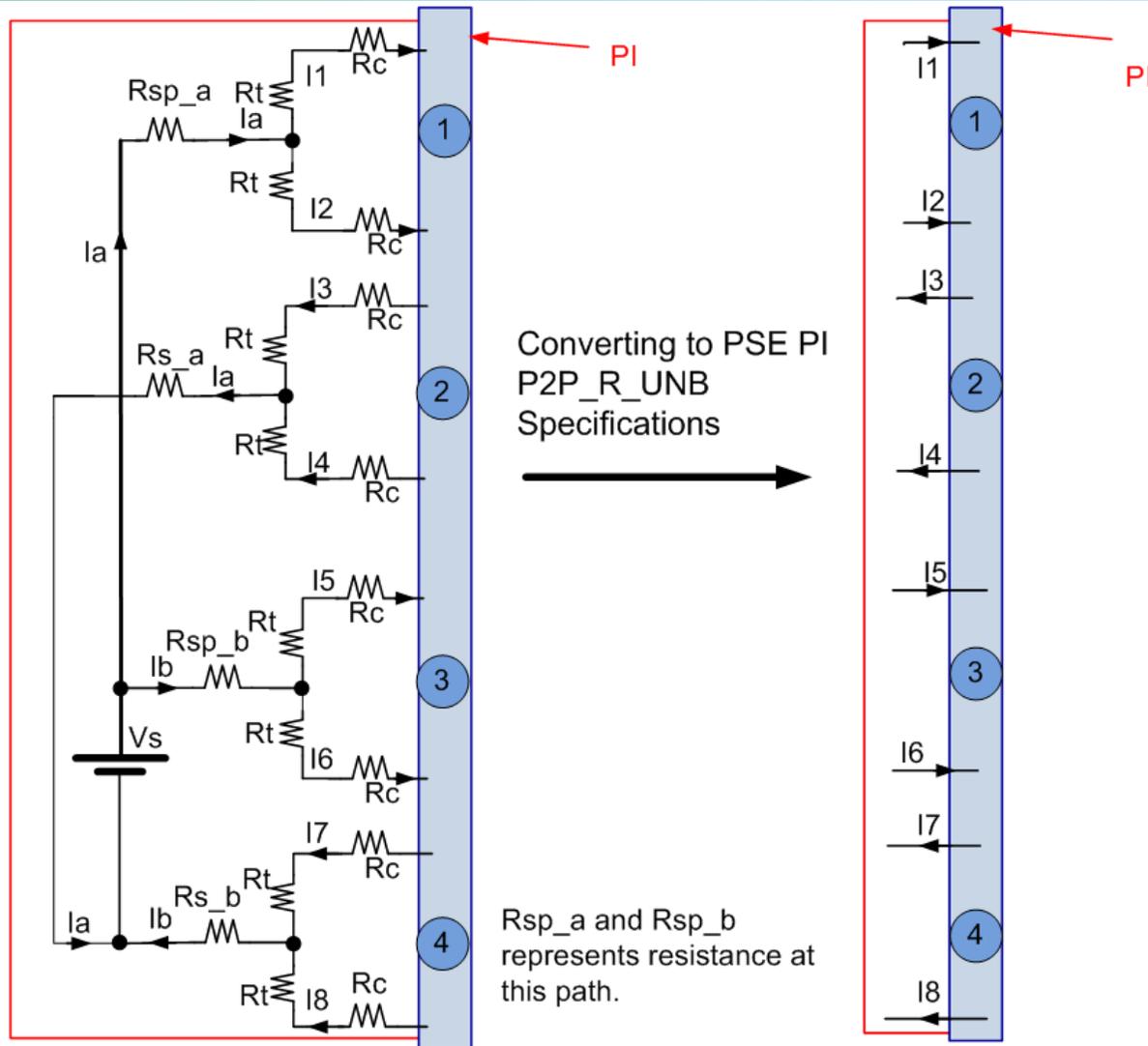
Illustration of the behavior.
(The curve is not linear. It is just describing the trend.)

For next meeting

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- We need to define the PD load current on Mode A and Mode B in which below that current, P2P requirements can be ignored.
 - Example: if Mode A requires 350mA and Mode B require 113mA than P2P discussion is not relevant to this case.

PSE_PI Pair to Pair Resistance Unbalance



- To specify test setup as well

PD_PI Pair to Pair Resistance Unbalance

- Same concept for PD PI P2P_R_UNB definitions
- To specify test setup

Annex A

33.1.4.2 Type 1 and Type 2 channel requirement

Type 1 and Type 2 operation requires that the resistance unbalance shall be 3 % or less. Resistance unbalance is a measure of the difference between the two conductors of a twisted pair in the 100 Ω balanced cabling system. Resistance unbalance is defined as in Equation (33–1):

$$\left\{ \frac{(R_{\max} - R_{\min})}{(R_{\max} + R_{\min})} \times 100 \right\} \% \quad (33-1)$$

where

R_{\max} is the resistance of the channel conductor with the highest resistance
 R_{\min} is the resistance of the channel conductor with the lowest resistance

- The way channel pair (the differences between two wires in a pair) resistance unbalance was defined.