IEEE802.3 4P Task Force

Channel Pair To Pair Resistance Imbalance

(End to End System Imbalance)

Ad Hoc

July 2014

Meeting #1: Rev_001 Monday February 17, 2014
Meeting #2: Rev_001b Monday February 24, 2014
Meeting #3: Rev 004, Thursday April 24, 2014
Meeting #4: Rev 005, Thursday May 1, 2014
Meeting #5: Rev 006, Thursday May 8, 2014
Meeting #5: Rev 008, Thursday May 8, 2014, Ad-hoc report for May 2014 meeting.
Meeting #6: Rev 009, Thursday May 15,2014 , Norfolk VA.
Meeting #7: Rev 010, Tuesday June 10, 2014 ,
Meeting #8: Rev 011a, Tuesday June 24, 2014.
Meeting #9: Rev 012b, Tuesday July 1, 2014.
Adhoc report for July 2014 San Diego Rev 013.

Yair Darshan
Microsemi
ydarshan@microsemi.com

Adhoc report – July 2014 (1)

- 8 adhoc meetings since March 2014 meeting
- Unbalance parameters will be calculated at 20°C. For more details see Annex M.
- Agreement on the need to specify PSE PI, PD PI and Channel P2P unbalance parameters.
- 6 presentations: Ken (1) , Jeff (1) , Yair (4) with the following content:
  - PSE PI Model, based on mathematical model and practical test setup (Ken)
  - PSE PI Model, implementation independent mathematical model. (on going)
  - How to extract PSE PI and PD PI unbalanced parameters from channel and End to End Channel P2PRUNB requirements (Yair)
  - Channel Pair To Pair Resistance Unbalance (CP2PRUNB) (only cables and connectors) Analysis of ad-hoc proposed use cases. (Yair)
  - What are the minimum parameters set required to specify PSE/PD/Channel unbalanced parameters (+additional new material added for discussion at the July meeting) Yair
  - PSE PD PI Models, simulations of Imax vs parameters, Proposing PSE Rdiff only for PSE PI, diodes unbalanced parameters (Jeff)

Adhoc report – July 2014 (2)

- Discussion on what are the parameters required to be defined in PSE PI and PD PI.
  - We need to close it this meeting to allow focusing on one direction and make progress.
    - Propose to close minimum set of parameters for PSE PI and PD PI that are within our consensus.
    - Decide on model and how to test it later.
- Ready for motion to close TBDs of channel P2PRUNB base line text from May.
- To consider other motions for moving forward.

- See more in the plane table for July meeting at the adhoc material slide 8.

- All meetings material

Meeting # 9 Attendees (July 24, 2014)

Larsen, Wayne / Commscope

Sterling Vaden / charter.net

Wendt, Matthias / Philips

Ken Bennett / Sifos

Picard Jean / TI

George Zimmerman/ CME Consulting, Affiliations: Commscope & Aquantia

Koussalya Balasubramanian / Cisco

Jeff Heath / LT

Paul VANDERLAAN/ Nexans

Ronald Tellas / Panduit

Gaoling Zou / Maxim

Paul VANDERLAAN/ Nexans Zhuang / Huawei

Ronald Tellas / Panduit

Larsen, Wayne / Commscope

Jeff Heath / LT

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Brian Buckmeier / BEL

Rick Frosch / Phihong

Christian BEIA / ST

Leonard Stencel / Bourns

Fred Schindler / Seen Simply

Koussalya Balasubramanian / Cisco

David Tremblay / HP

David Abramson / TI

Rimboim Pavlik / Microsemi

Yair Darshan / Microsemi

Ken Bennett / Sifos

Victor Renteria / BEL

George Zimmerman/ CME Consulting, Affiliations: Commscope & Aquantia

Steinke, Stephan / Molex

Robert Wagner/ Panduit

Gaoling Zou / Maxim

Jean Picard / TI

Wendt, Matthias / Philips

Proposed Agenda, Meeting #9, July 1, 2014.

- Introduction, Patent policy (1 minute)
- Reviewing A.I. from meeting #8. (4 minutes)
- Planes for July 2014 IEEE meeting (5 minutes)
- Where we are and where we are going? (5 minutes)
- Reviewing Yair Darshan Presentation (20minutes)
- Reviewing Jeff Heat Presentation (20 minutes)
- Summary and Action Items (5 minutes)
- Reviewing Yair, Ken others presentation regarding

  PSE and PD PI models was postpone to next adhoc

  meeting or during IEEE July meeting pending available time.

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

-Please read the Patent Policy slides at http://www.ieee802.org/3/patent.html prior the meeting.

Reviewing A.I status from meeting #8

#	A.I.	Status
1	Group to send any questions to the reflector.	
2	To clearly state what will be the PSE and PD parameters that will be define. Group to review and comment over the reflector.	Done.
3	Updated Data Base Table was reviewed and approved by the ad-hoc on meeting #8. See Annex G1, G2 and G3. Diode parameters final range is under investigation. Mean while we will use the current values.	Done. Any questions to send to reflector.
4	How we address P2PRUNB vs Temperature. See annex M.	Done
5	To comment on Ken presentation over the reflector	

Planes for July 2014 IEEE meeting

#	Item
1	To have a motion to that specifies the TBDs in the Channel P2PRUNB base line text.
2	To have a motion on the test conditions of how the channel P2PRUNB will be tested (Not required July 7, 2014)
	New items added after the meeting. To be discussed at the ad-hoc meeting on July (I have asked Chad for time)
3	To discuss PSE PI and PD PI possible models based on solid math that covers the affecting parameters with implementation independent approach.
4	*To have motion that PSE_PI and PD_PI will be specified by at least two parameters: P2PRUNB and P2P voltage difference. Each parameter will have single number that represent its maximum value.*
5	*To have motion to allow 802.3bt PDs that works at Type 1 and Type 2 power levels to be exempt of meeting PSE PI PD PI unbalance requirements.*
6	*To discuss Ken proposal and other proposals for defining the unbalanced parameters for PSE PI and PD PI.*
7	*??*

Group to propose other issues that we should discuss. (To be discuss again with the group on July meeting for inputs)

Where we are and where we are going -1

Ad-hoc response, July 1, 2014. TBD

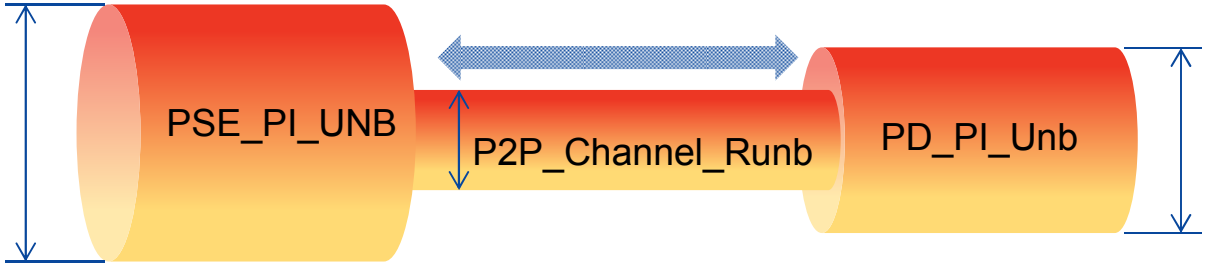
For PSE and PD PIs P2P UNB parameters.

-a single maximum number for each parameter.

-Parameters are: Voltage difference and resistance unbalance.

-For improved spec, we may need to defined additional parameter: Rmin (TBD under research).

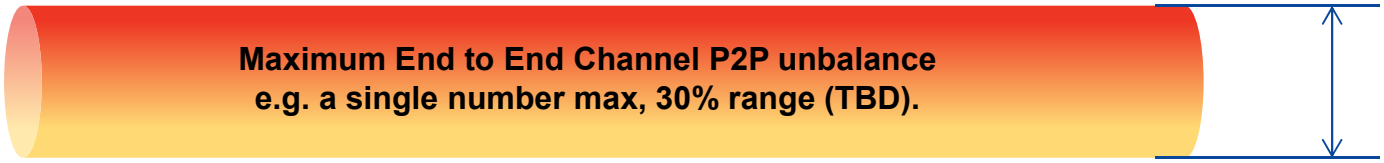
-Test setup TBD.



For Channel P2PRUNB:

-Variable Channel Length, number of connectors up to 4.

-A single maximum number representing maximum C_P2PRunb. (Target 7.5% (TBD) or 0.1Ω which ever is greater. See details in Annex K.



- Channel is capable of reducing the end to end unbalance as function of channel length.
  - PSE PI and PD PI need to be better than the channel maximum P2PRUNB.
    - PSE PI and PD PI needs larger unbalance range than channel P2PRUNB to allow different implementations

Where we are and where we are going -2

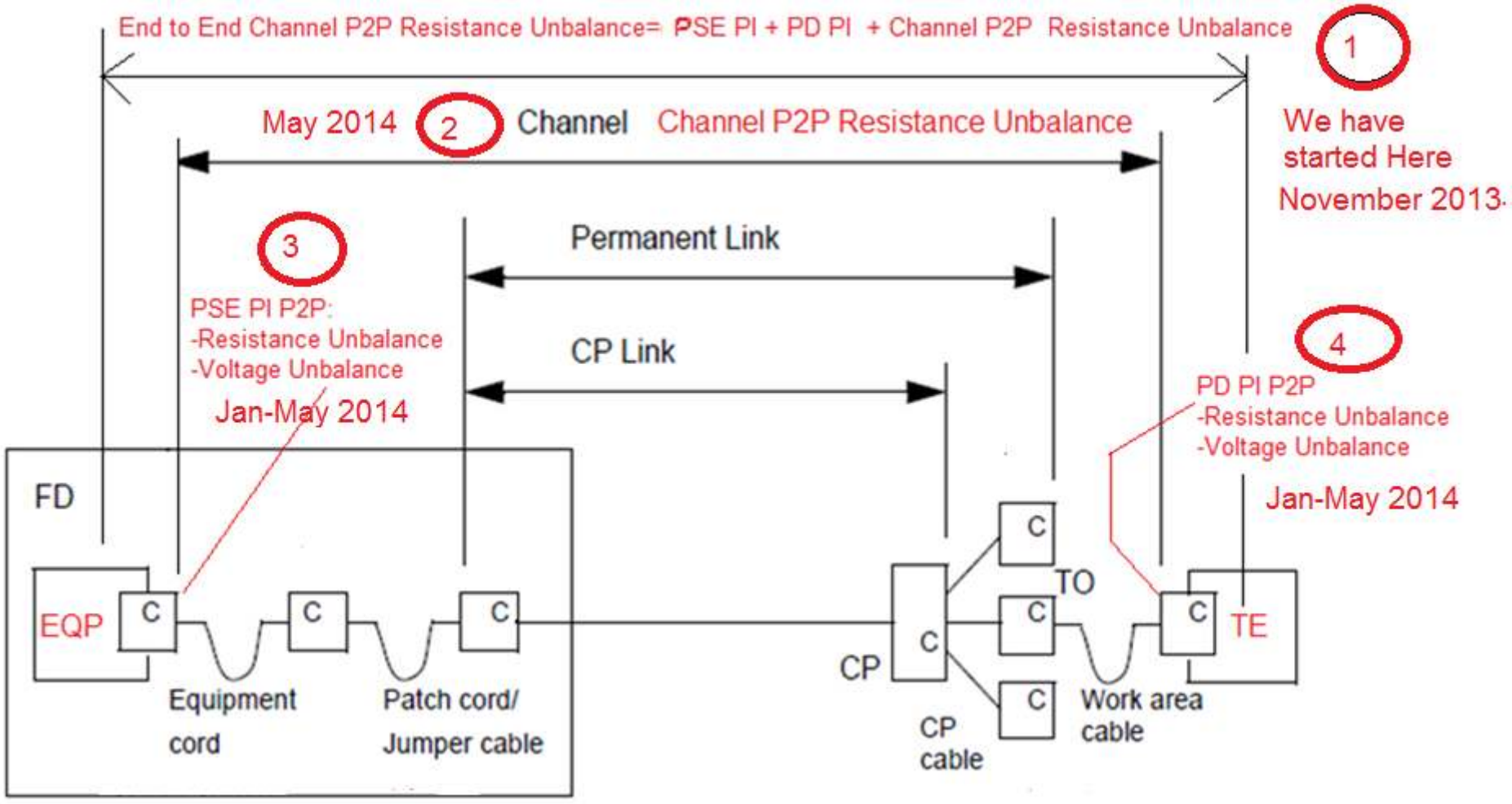


Figure 1. May 27, 2014

Ad-hoc response, June 24, 2014. No comments.

Source: Yair Darshan. Based on model used in IEEE802.3-2012.

Where we are and where we are going? -3

#	Parameter	Part of the spec.	Status
1	End to End Channel Pair to Pair Resistance Unbalance	No	-We have worst case numbers based on worst case data base. -Database is updated on the fly.
2	Channel Pair to Pair Resistance Unbalance. See figure 1	Yes. We hope also to reference cabling standard when its ready.	-Baseline text motion passed. numbers 0.2Ω, 6% max (TBD) -To change to 7% (TBD) and 0.1Ω.
3	PSE PI Pair to Pair Resistance Unbalance	Yes	-Consensus that P2P resistance unbalance need to be specified together with Voltage unbalance. -Models being discussed for testing, no complete work yet. -Numbers need to be derived from (1) and (2).
4	PD PI Pair to Pair Resistance Unbalance	Yes	

We agree that the above parameters will be calculated/defined at room temperature or close to it (see details next slide).
There is a consensus that the temperature will be 20°C. Ad-hoc to confirm on meeting #7

Ad-hoc response, June 10, 2014. Ad hoc agrees to set temperature of P2PUNB numbers at 20degC.

Where we are and where we are going? -4

- End to End Channel P2P RUNB.
  - Using Annex F model.
  - Ignoring Vdiff in PSE PI and PD PI for simplicity. Later their effects will be added.

$$E2E\_C\_P2PRUNB = \frac{\sum R\max - \sum R\min}{\sum R\max + \sum R\min} =$$

$$= \frac{R_{pse\_\max} + R_{pd\_\max} + R_{ch\_\max} - R_{pse\_\min} - R_{pd\_\min} - R_{ch\_\min}}{R_{pse\_\max} + R_{pd\_\max} + R_{ch\_\max} + R_{pse\_\min} + R_{pd\_\min} + R_{ch\_\min}} =$$

$$= \frac{(R_{pse\_\max} - R_{pse\_\min}) + (R_{pd\_\max} - R_{pd\_\min}) + (R_{ch\_\max} - R_{ch\_\min})}{\sum R\max + \sum R\min} =$$

$$E2E\_C\_P2P\_RUNB = \frac{(R_{pse\_\max} - R_{pse\_\min})}{\sum R\max + \sum R\min} + \frac{(R_{pd\_\max} - R_{pd\_\min})}{\sum R\max + \sum R\min} + \frac{(R_{ch\_\max} - R_{ch\_\min})}{\sum R\max + \sum R\min}$$

Source: Yair Darshan.

Where we are and where we are going? -5

Analytical Calculations.

Voltage difference is set to 0 for simplicity. Later we can add Vdiff effect on the analytical calculations.

$$E2ECP2P\_Runb = \frac{\left(\sum \frac{PSE}{R_{max}} - \sum \frac{PSE}{R_{min}}\right) + \left(\sum \frac{CH}{R_{max}} - \sum \frac{CH}{R_{min}}\right) + \left(\sum \frac{PD}{R_{max}} - \sum \frac{PD}{R_{min}}\right)}{\sum \frac{PSE}{R_{max}} + \sum \frac{PSE}{R_{min}} + \sum \frac{CH}{R_{max}} + \sum \frac{CH}{R_{min}} + \sum \frac{PD}{R_{max}} + \sum \frac{PD}{R_{min}}} =$$

$$= Kpse \cdot \frac{\left(\sum \frac{PSE}{R_{max}} - \sum \frac{PSE}{R_{min}}\right)}{\sum \frac{PSE}{R_{max}} + \sum \frac{PSE}{R_{min}}} + Kch \cdot \frac{\left(\sum \frac{CH}{R_{max}} - \sum \frac{CH}{R_{min}}\right)}{\sum \frac{CH}{R_{max}} + \sum \frac{CH}{R_{min}}} + Kpd \cdot \frac{\left(\sum \frac{PD}{R_{max}} - \sum \frac{PD}{R_{min}}\right)}{\sum \frac{PD}{R_{max}} + \sum \frac{PD}{R_{min}}}$$

Find Kpse and Kpd that meets the limits of step the required E2E_C_P2P_RUNB.

a) Channel max P2PRUNB[%] and Channel Rdiff max or {Rmax, Rmin} value set per table in annex G1 component values and chennel length use cases.

b) Kpse and Kpd can be varied per the target requirements of PSE and PD PI for covering PD and PSE implementations.

c) Kpse, Kpd and Kch may be a Vandermonde matrix for perfect fitting or scalar (single equation) for worst case points only.

d) Kch=need to be set to 1 due to the fact that it is know per channel given physics. See Table in annex G1.

Source: Yair Darshan.

IEEE802.3 4P Task Force

Channel Pair To Pair Resistance Unbalance

(CP2PRUNB)

(only cables and connectors)

Analysis of ad-hoc proposed use cases

July 2014

rev 12b

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Supporters

- Larsen, Wayne / Commscope
- David Tremblay / HP
- Fred Schindler / Seen Simply
- Lennart Yseboodt / Philips
- Pavlick Rimboim / MSCC
- Christian Beia / ST
- Matthias Wendt / Philips
- George Zimmerman/ CME Consulting, Affiliations: Commscope & Aquantia

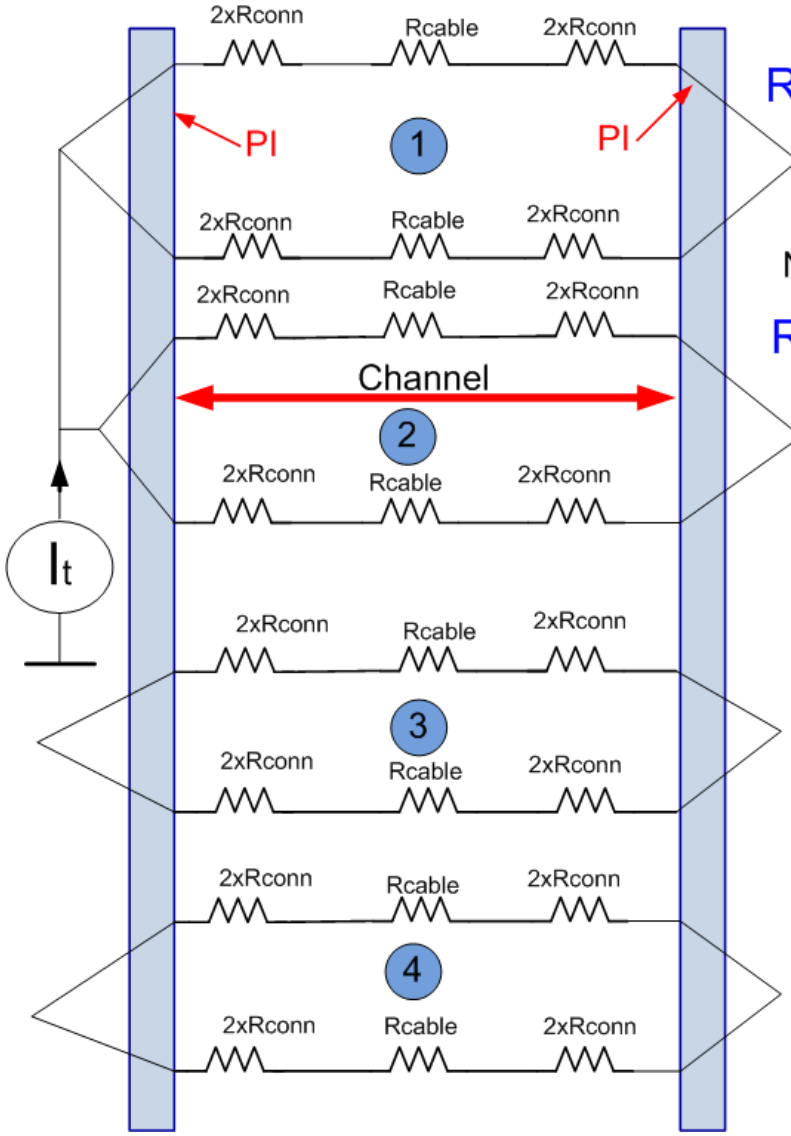
Objectives

- To close the TBDs (P2PRUNB and Resistance Difference) from base line text motion from May 2014 meeting.

- To verify that during Channel P2PRUNB compliance tests we can pass the above requirements with realistic use cases while what is considered not typical or realistic use cases are covered too by the above requirements in a clear way and not subject to confusion or false interpretation.

The Channel Only. See Annex F for the entire system

Annex K3



Rmax=(Rcables_max+N*Rc_max)/2

I1

N= number of connectors, 0 to 4

Rmin=(Rcables_min+N*Rc_min)/2

I2

C_P2PRUNB is defined between any two pairs
Each pair has two wires in parallel from power delivering point of view

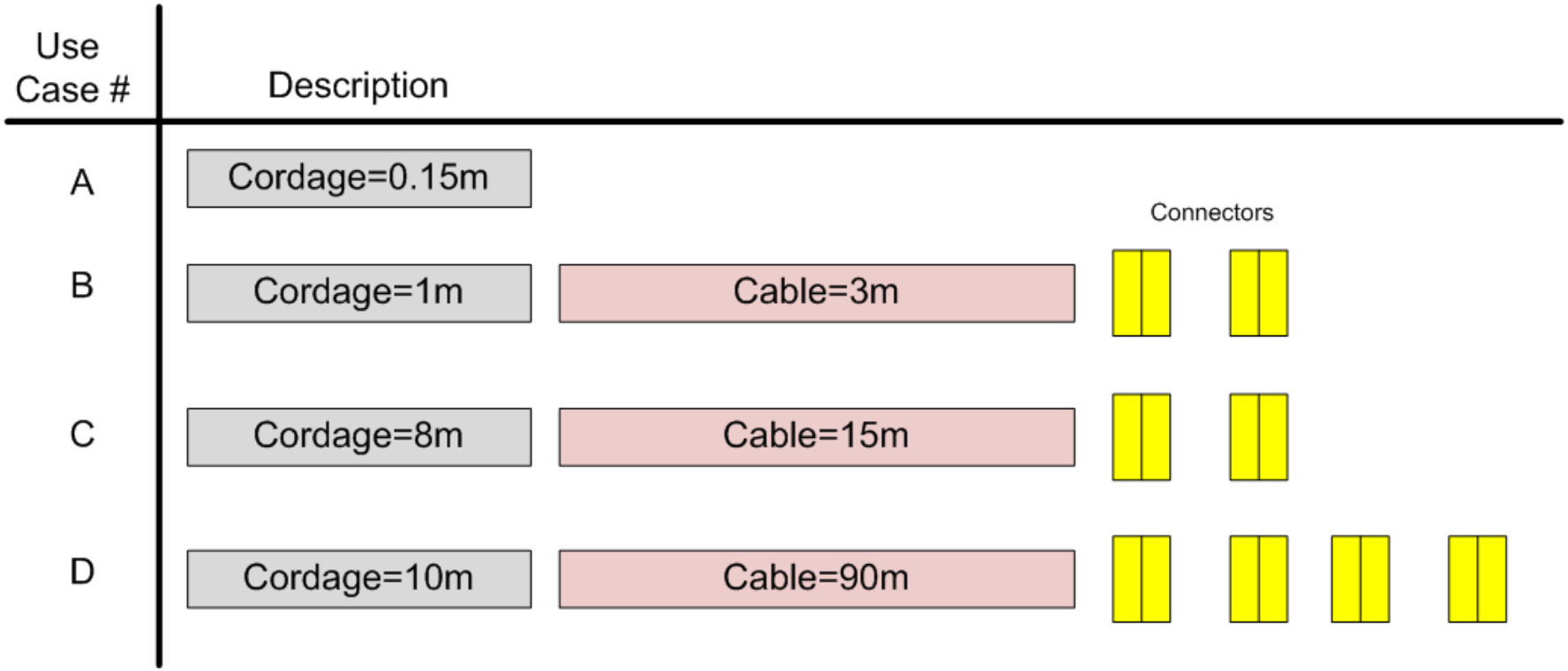
$$\frac{I2-I1}{I}=\frac{\sum R_{max}-\sum R\min}{\sum R_{max}+\sum R\min}=$$

$$C\_P2P\_R\_UNB=C\_P2P\_Current\_UNB$$

```
Rcables_max=(L1.*L1_r_m_max+L2.*L2_r_m_max)/2;
Rcables_min=Rcables_max*(1-P2P_Cable_RUNB)/(1+P2P_Cable_RUNB);
Rmin=n*rc_min/2 +Rcables_min;
Rmax=n*rc_max/2 +Rcables_max;
Ch_P2P_Runb=100*(Rmax-Rmin)./(Rmax+Rmin);
```

Adhoc proposed channel use cases

Annex K4



- Due to the fact that we cannot force the typical use case, other use cases, that exhibit high number of connectors per channel length, that are considered not typical or unrealistic ones, were analyzed to verify our sensitivity to such use cases.
- The results will help us to verify if our channel spec is complete and robust.

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Channel P2P RUNB-Addressing TBDs

Annex K5

- **In May 2014 we vote for the following base line text highlighting the TBD areas.**

33.1.4.3 Pair Operation Channel Requirement for Pair to Pair Resistance Unbalance

4P pair operation requires the specification of resistance unbalance between each two pairs of the channel, not greater than 200 milliohms or 6%(TBD) whichever is greater. Resistance unbalance between the channel pairs is a measure of the difference of resistance of the common mode pairs of conductors used for power delivery. Channel pair to pair resistance unbalance is defined by ….."

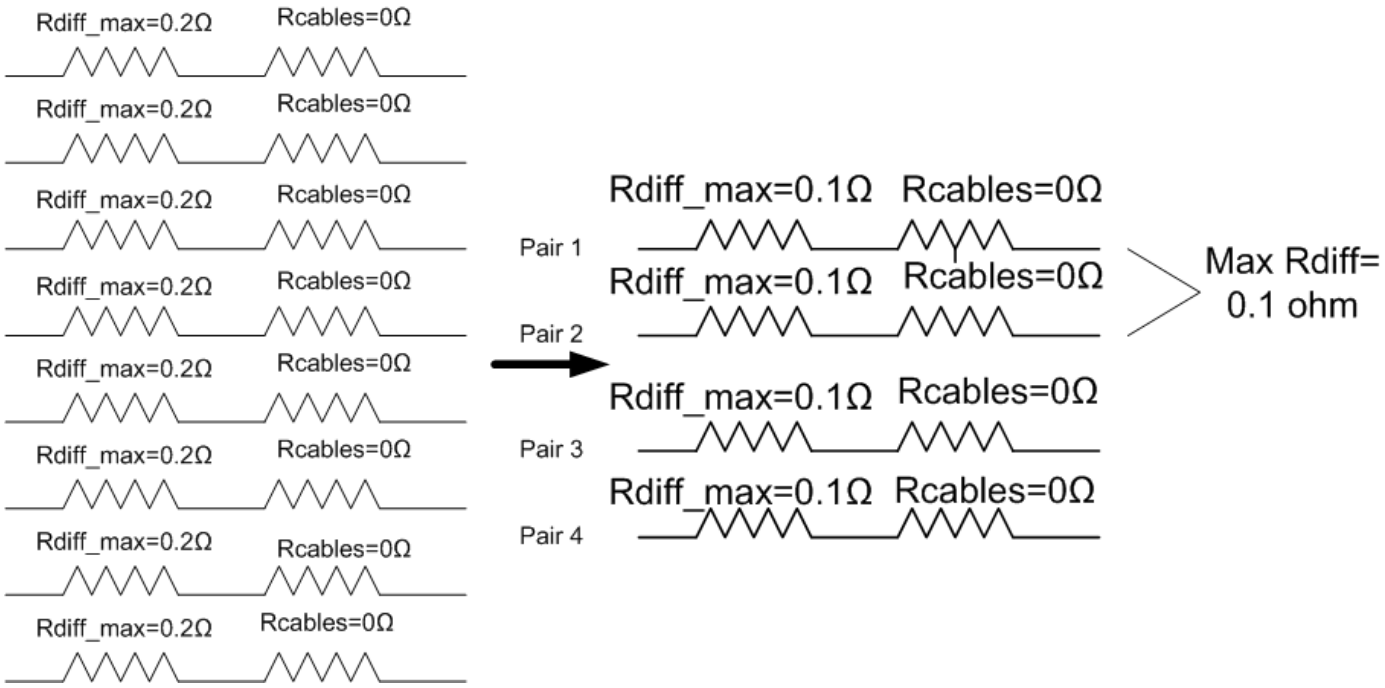
- **We need to address two numbers:**

  C_P2PRUNB=6%(TBD) and Resistance Difference=200milliOhm.

The value of channel maximum Rdiff

Annex K6

- The 200milliohm in the channel base line text from May 2014 above should be 0.1Ω. Why?
- Connector max Rdiff= 0.05Ω. 4 connectors is 4*0.05Ω=0.2Ω on each Wire. As a result, a pair is two connectors in parallel ➔ 0.1Ω
  - Connector maximum resistance is 0.2Ω and is not related to the discussion here which is pair to pair resistance difference.



Source: Yair Darshan.
Confirmed by Wayne Larsen

Presentation Flow

Annex K7

Step	Analyzing the proposed use cases
1	a) Compare analysis results of proposed use case A,B,C and D to 6%
	b) Checking other use cases near the proposed use cases to check the Channel P2PRUNB sensitivity from deviation from the proposed use cases.
2	Understanding the reasons and rationale behind the results from different angle and as function of channel parameters
3	Checking if P2PRUNB and Rdiff is sufficient to specify the channel for any use case.
4	Checking if Rdiff alone is sufficient to define the channel
5	Conclusions and information obtained from this work regarding: -Channel -Future work on PSE and PD PI.

Channel Component Data used in this work

Annex K8

#	Component	Value	Reference
1	Patch Cord	0.0926Ω/m	Adhoc for worst case analysis (Cable with AWG#24 wire)
		0.14Ω/m	Adhoc, Standard.
2	Horizontal Cable	CAT6A AWG23	1. Adhoc 2. See Annex G1, G2, G3, E1 3. See Slide “Annex K20”
3	Connector	Rmin=0.03Ω Rdiff_max=0.02Ω Rmax=0.06Ω	1. Rdiff (TBD) : Adhoc 2. Rmin, Rmax: Adhoc 3. See Annex G1, G2, G3, E1-E6 4. See Slide “Annex K20”

Table 1

Questions such:

1. Why not to use 0.098 Ω/m as per standard etc. are answered in annexes above. If more data is needed, please addressee this question to the reflector.
2. Why not use Rmax=0.2Ω and Rdiff_max=0.05Ω for connector? Answer: It is maximum values and for worst case analysis we need minimum values for Rmax and Rmin and a maximum practical values for Rdiff.
3. The conclusions that was derived from the analyzed topics in this work topics, will not change dramatically for other practical data number sets.

Use cases to be checked during analysis

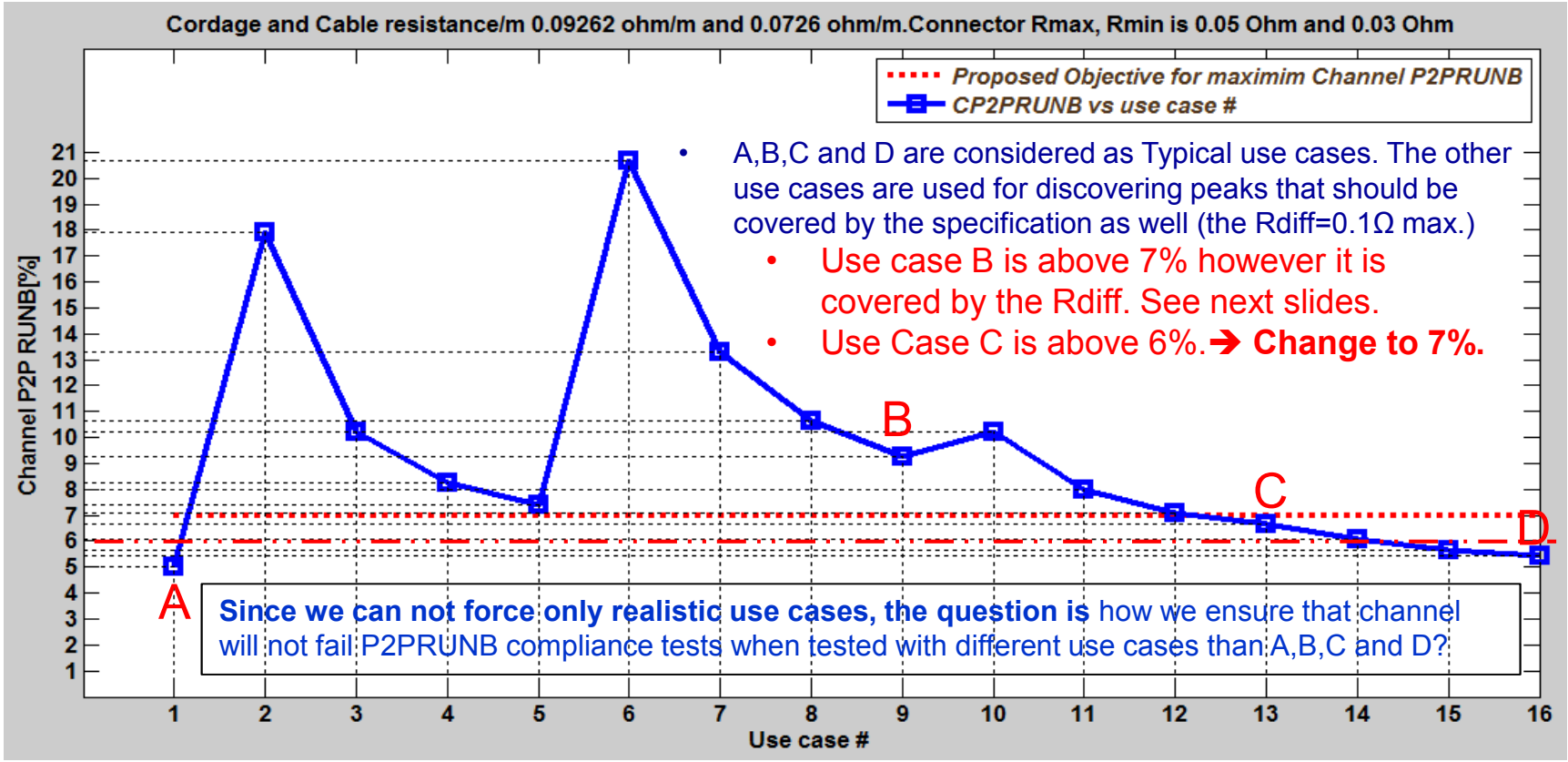
Annex K8

- **From previous ad-hoc meetings decisions:** To check use cases A, B, C and D per the table below for Channel P2PRUNB specification derivation.
- Additional use cases were added (total 16 at a time) after running the simulations in order to find Channel P2PRUN hidden peaks for specification sensitivity analysis.
- Table below provides a summary. **See details next slides.**

Use case	Connectors	Cordage[m]	Cable[m]	Max. Channel P2PRUN
A	0	≥0.15	0	5% (equal to Cable P2PRUNB)
	0	0	≥0.15	
B	2	1	3	9.2% (Covered by the Rdiff requirement)
C	4	8	15	6.47%
D	4	10	90	5.45%
2-4, 6-8 10	1 2 4	See curve next slide. Considered as unrealistic use cases		10% - 20% (Covered by the Rdiff requirement)

See curve next slide for more data

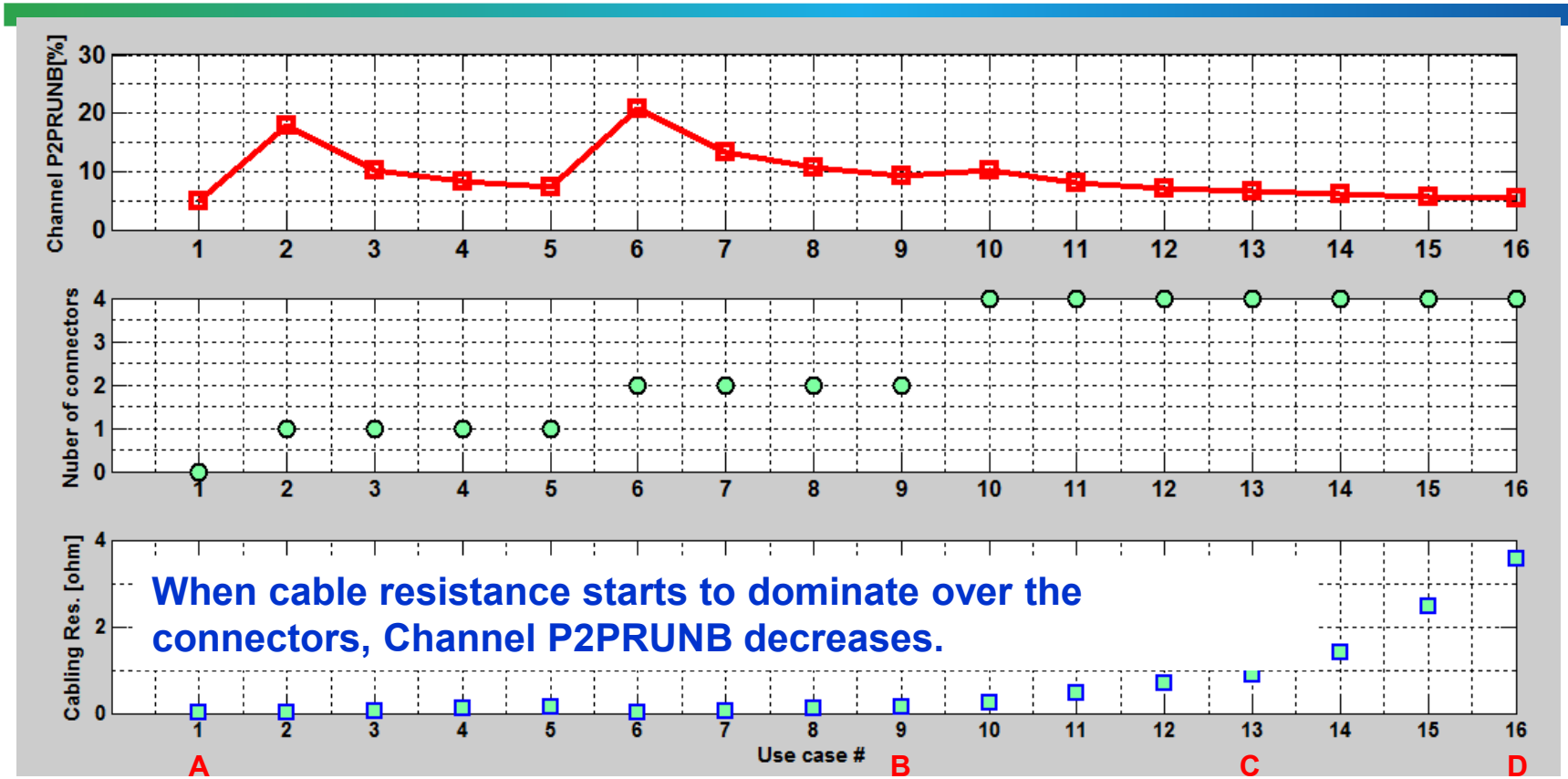
Use case analysis results and proposed objective



	A								B			C				D	
	[1,	2,	3,	4,	5,	6,	7,	8,	9,	10,	11,	12,	13,	14,	15,	16];	Use Case Number
n =	[0,	1,	1,	1,	1,	2,	2,	2,	2,	4,	4,	4,	4	4,	4,	4];	number of connectors
L1=	[0.15,	0.25,	0.5,	0.75,	1,	0.25,	0.5,	0.75,	1,	2,	4,	6,	8,	8,	9,	10];	Cordage[m]
L2=	[0,	0,	1,	2,	3,	0,	1,	2,	3,	4,	8,	12,	15,	30,	60,	90];	Cable[m]

Channel P2PRUNB vs. Use case parameters

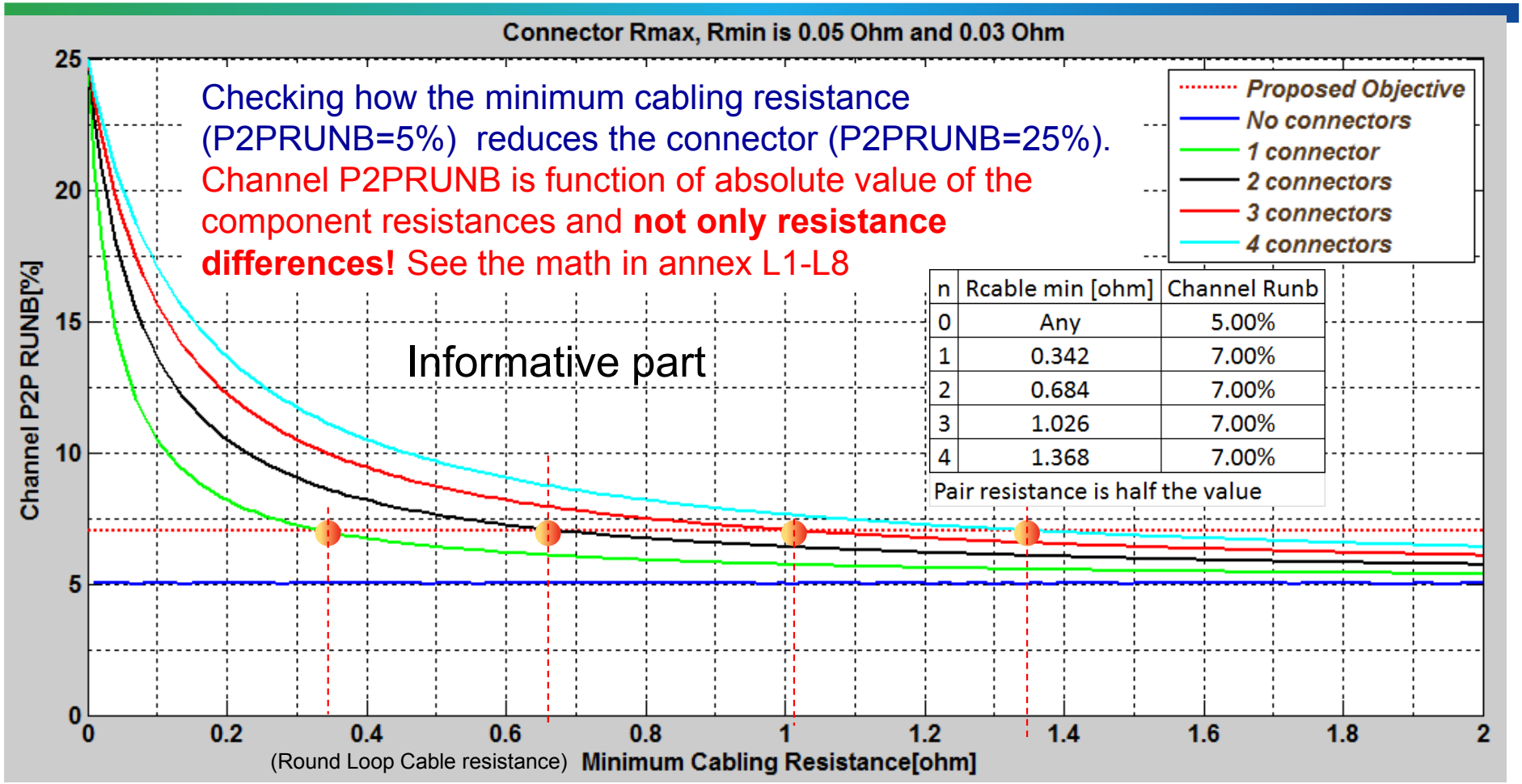
Annex K9



	A							B			C				D	
	[1,	2,	3,	4,	5,	6,	7,	8,	9,	10,	11,	12,	13,	14,	15,	16];	Use Case Number
n =	[0,	1,	1,	1,	1,	2,	2,	2,	2,	4,	4,	4,	4	4,	4,	4];	number of connectors
L1=	[0.15,	0.25,	0.5,	0.75,	1,	0.25,	0.5,	0.75,	1,	2,	4,	6,	8,	8,	9,	10];	Cordage[m]
L2=	[0,	0,	1,	2,	3,	0,	1,	2,	3,	4,	8,	12,	15,	30,	60,	90];	Cable[m]

Channel P2PRUNB vs. Cable resistance and connectors

Annex K10

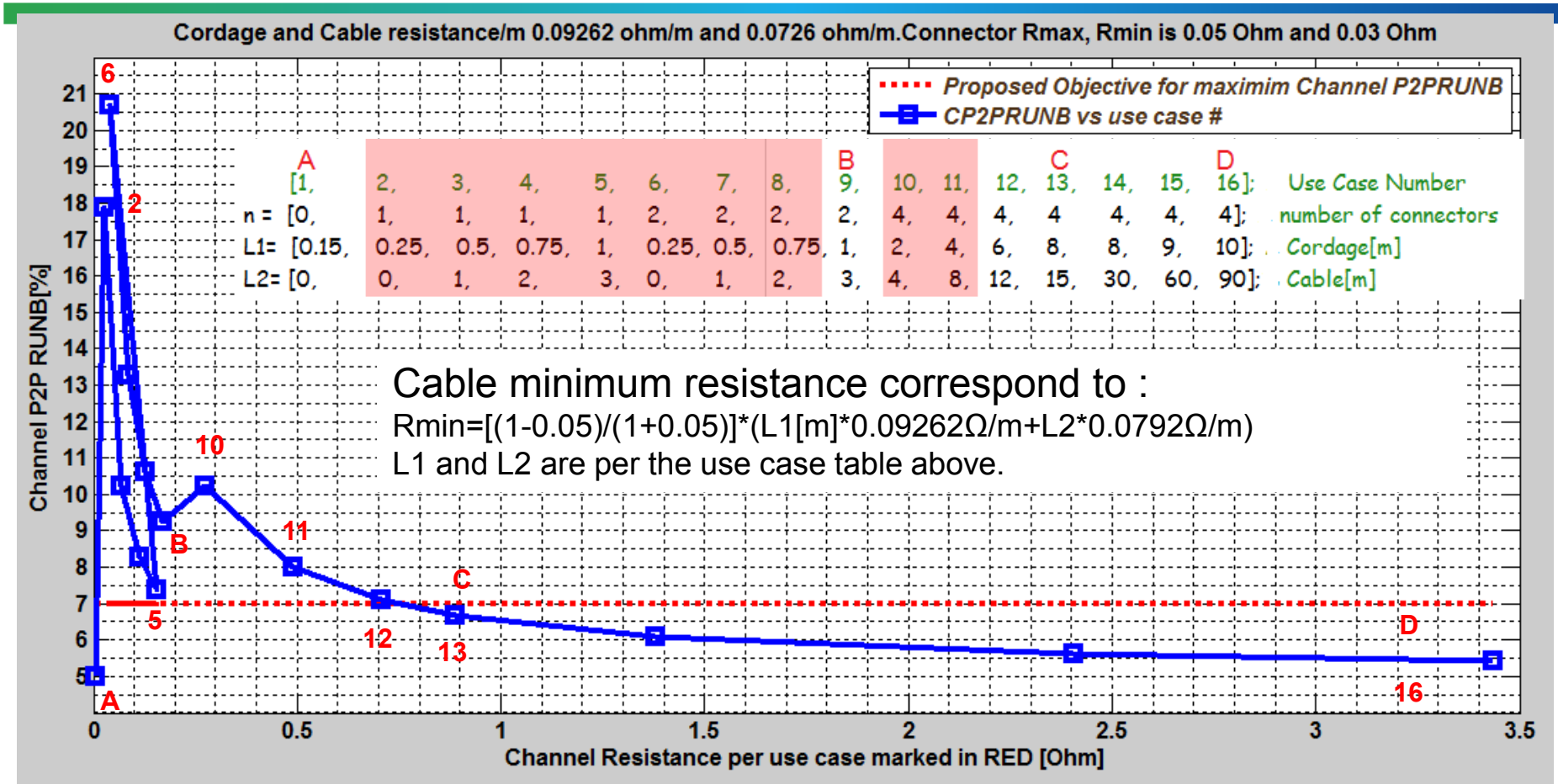


- Connector P2PRunb=100%*(50-30)/(50+30)=25%
- Cable P2PRUNB=5%.
- Channel P2PRUNB: See 5 curves with different connector numbers

Annex K11

Use case analysis results – Sanity Check -1

Zooming on the peaks by ***Changing X axis for Cabling Minimum resistance***

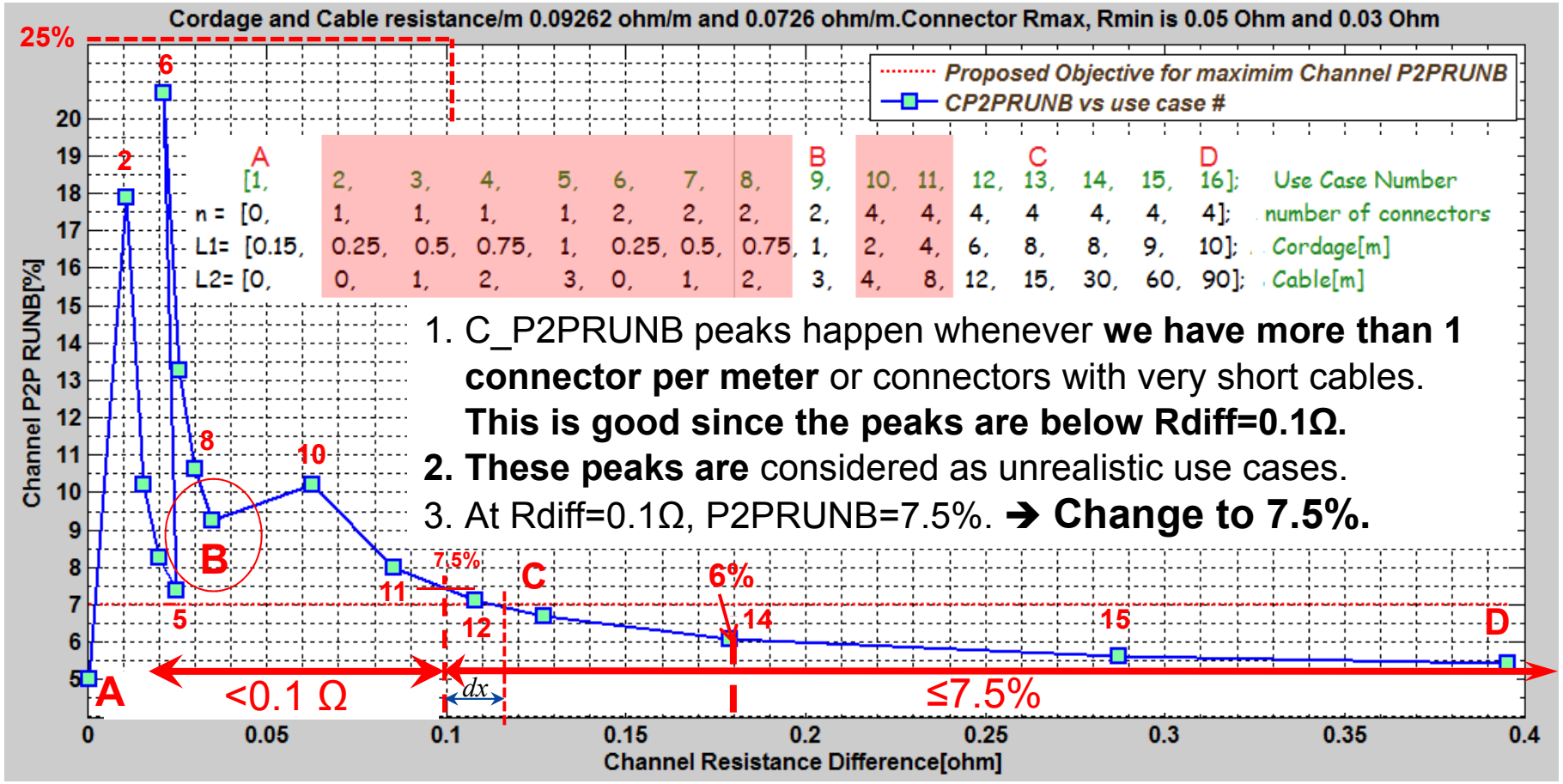


- Unrealistic use cases are now concentrated in minimum cabling resistance region.
- 0.7Ω minimum cabling resistance for a channel with 4 connectors, is required to reduce all CP2PRUNB peaks to below 7% (L1+L2~=12m total per use case # 12 in the table above).
- *We may not need to require minimum channel length of 12m however it is nice to know that above 12m the channel is acting as ballast resistor to the PSE and PD PI.*

Annex K12

Use case analysis results – Sanity Check -2

Zooming on the peaks by ***Changing X axis for Channel Resistance Difference***



- The realistic use cases A,B,C, and D looks good. B is below Resistance Difference=0.1Ω
- Rdiff is increased as cable total resistance is increased. As a result Rdiff **alone** cannot be used for specifying the channel we must have the C_P2PRUNB[%] too as expected.

  See Annex L7-L8 for details.

Conclusions regarding Channel Unbalance Requirements -1

Annex K13

- We can see that the high C_P2PRUNB peaks happen when:
  - There are more than 1 connector per 1m of cabling (ratio of 0.22 to 0.25) and/or:
  - The cables and patch cords are short and exhibit low resistance compared to total connector resistance
  - The above use cases are considered "unrealistic" ones, covered by Rdiff=0.1Ω (was 0.2 Ω).
  - Use Case B is considered to be realistic, and exceeds the initial proposed 7% but it is covered by Rdiff=0.1Ω (was 0.2 Ω) requirement.
    - It has 2 connectors over 4m channel which is 2/4=0.5 ratio which is way different that the general behavior above of 0.25 ratio. So all is good
- We saw that:
  - Per the Rdiff curve: we can select the specification numbers between:
  - (a) Rdiff=0.1Ω, P2PRUNB=7.5%. (b) Rdiff=0.117Ω, P2PRUNB=7%. (c) Rdiff=0.1Ω, P2PRUNB=7%.
  - **Option (a) is the correct one from worst case analysis point of view.**
  - Option (b) is not matching the maximum P2P Rdiff per connector standards =0.1 Ω
  - **Option (c) is possible if counting on the fact that it is worst case analysis and we have design margins for small deviation of 0.5%/0.025Ω. which may be the best optimized cost effective set of parameters.**
- We may need informative section that says that for 4P operation, it is recommended to use a channel that has ≤1 connector per meter (maximum 4 connectors per standard). Anyway, unrealistic use cases are covered by Rdiff part in the spec.

Conclusions regarding Channel Unbalance Requirements -2

Annex K14

- 4P operation with minimum cable resistance help us:
  (a) It will reduce some of the burden on PD PI and PSE PI
  (b) It helps to reduce overall End to End Channel P2P RUNB and as a result will reduce the maximum current over the pair with lowest end to end resistance.
  - The implication of the above is equivalent to minimum cable length.

- This work shows clearly (by analytical proof and simulations) the following facts:
- **Only Resistance Difference Requirement** for Channel specifications (Rdiff=|Rmax-Rmin|) is mathematically and practically insufficient. See L1 –L8 for analytical derivation. This requirement leads to clear interoperability issues. See L7 and L8. In channel, in particular, it will contradict cable 5% P2PRUNB maximum limit. So we need at least both Rdiff and P2PRUNB parameters for the channel as we have already in the base line text. Moreover inexplicitly, for channel Rdif≤0.1Ω , P2PRUNB is bounded by the connector P2PRUNB (25% per the data used in this work).

Summary

Annex K15

- The proposed unbalanced parameter values for the base line text are:
  - Channel P2PRUNB max.: 7.5% (option a) or 7% (option c)
  - Resistance Difference max: 0.1Ω
    - (P2PRUNB for Rdiff≤ 0.1Ω is bounded by Connectors actual Rmin, Rmax values i.e. 25% in our analysis. Theoretically it can be higher and it will be bounded by system unbalanced parameters)
- Adhoc use cases proposals covers:
  - Realistic use cases with short cables and long cables
  - "unrealistic" use cases with short and long cables as well that we actually cannot control or limit their use.
  - It is worst case analysis, therefore contain inherent margins
  - It is complete.

Proposed update to Channel base line text

Annex 16

Specify Channel Unbalance parameters to:
C_P2PRUNB=7.5% max.
Channel Resistance Difference=0.1Ω max.

Notes:

1. 7% is the cost effective choice per the conclusions slides.
2. 7.5% is the accurate solution.

Group to discuss.

Q&A

Backup slides

Proposed Next steps for the PSE and PD PI models - 1

Annex K17

The following is the subject for future work:

In TIA/EIA/ISO/IEEE specifications, for pair Runb (wire to wire within a pair), only Runb and Rdiff was specified. For P2P definition especially for short channels, it will be advantageously specifying:

- P2PRUNB≤25%(TBD) for Rdiff ≤0.1Ω **or** alternatively:
- specifying Rmin for the channel with Rdiff ≤0.1Ω.

See Annex L1-L8, P, P1.

This will put upper bound for P2PRUNB at Rdiff ≤0.1Ω region.

Proposed Next steps for the PSE and PD PI models - 2

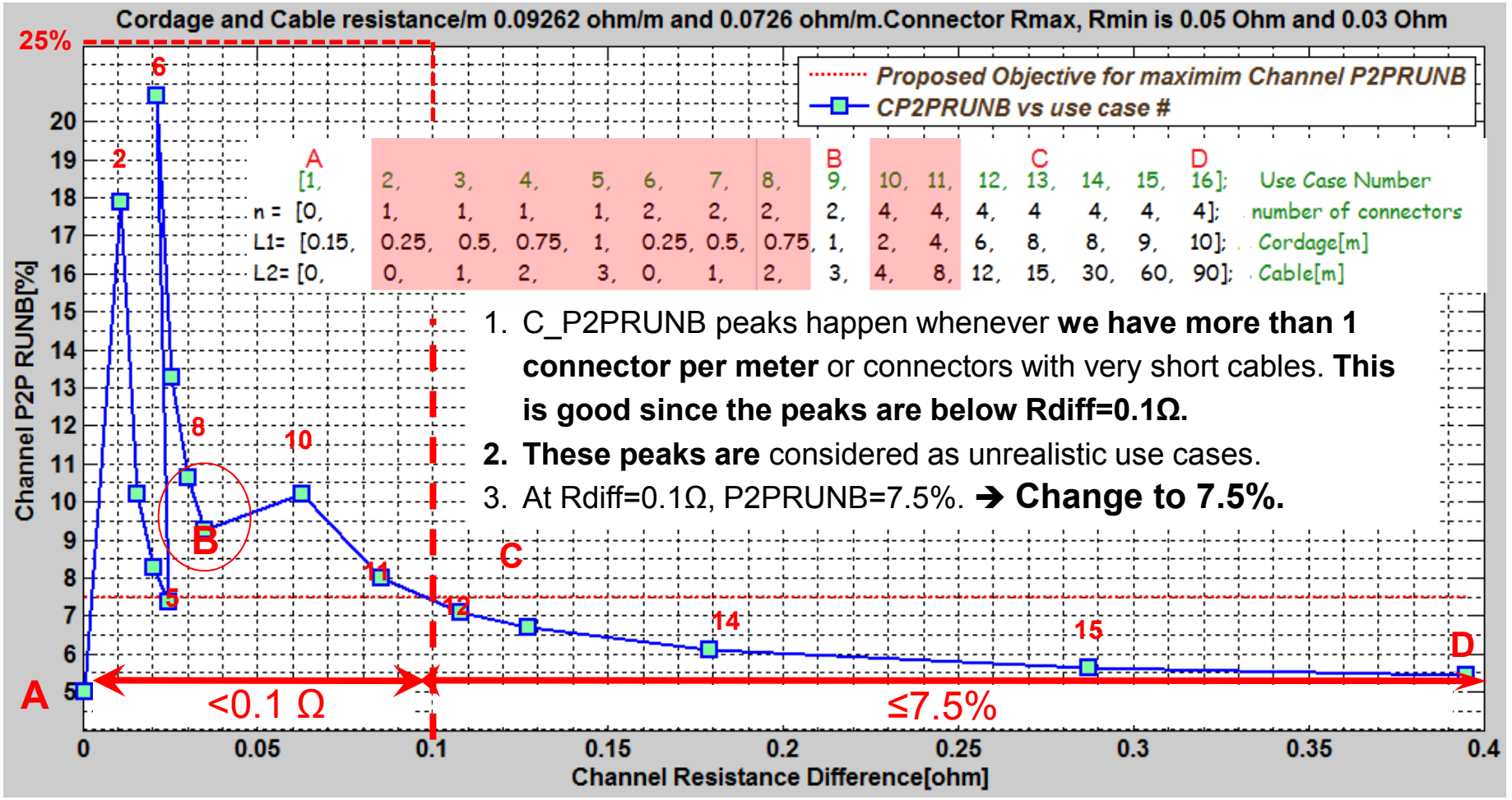
Annex K18

- PSE PI unbalance parameters
- PSE PI unbalance parameters shall include:
  - P2PRUNB[%]
  - Voltage Difference.
- For complete spec, check if adding Rmin is needed or we can satisfied with only the above 2. See Annex L1 –L6 for our options.

- PD PI unbalance parameters
  - P2PRUNB[%]
  - Voltage Difference.
- For complete spec, check if adding Rmin is needed or we can satisfied with only the above 2. See Annex L1 –L6 for our options.

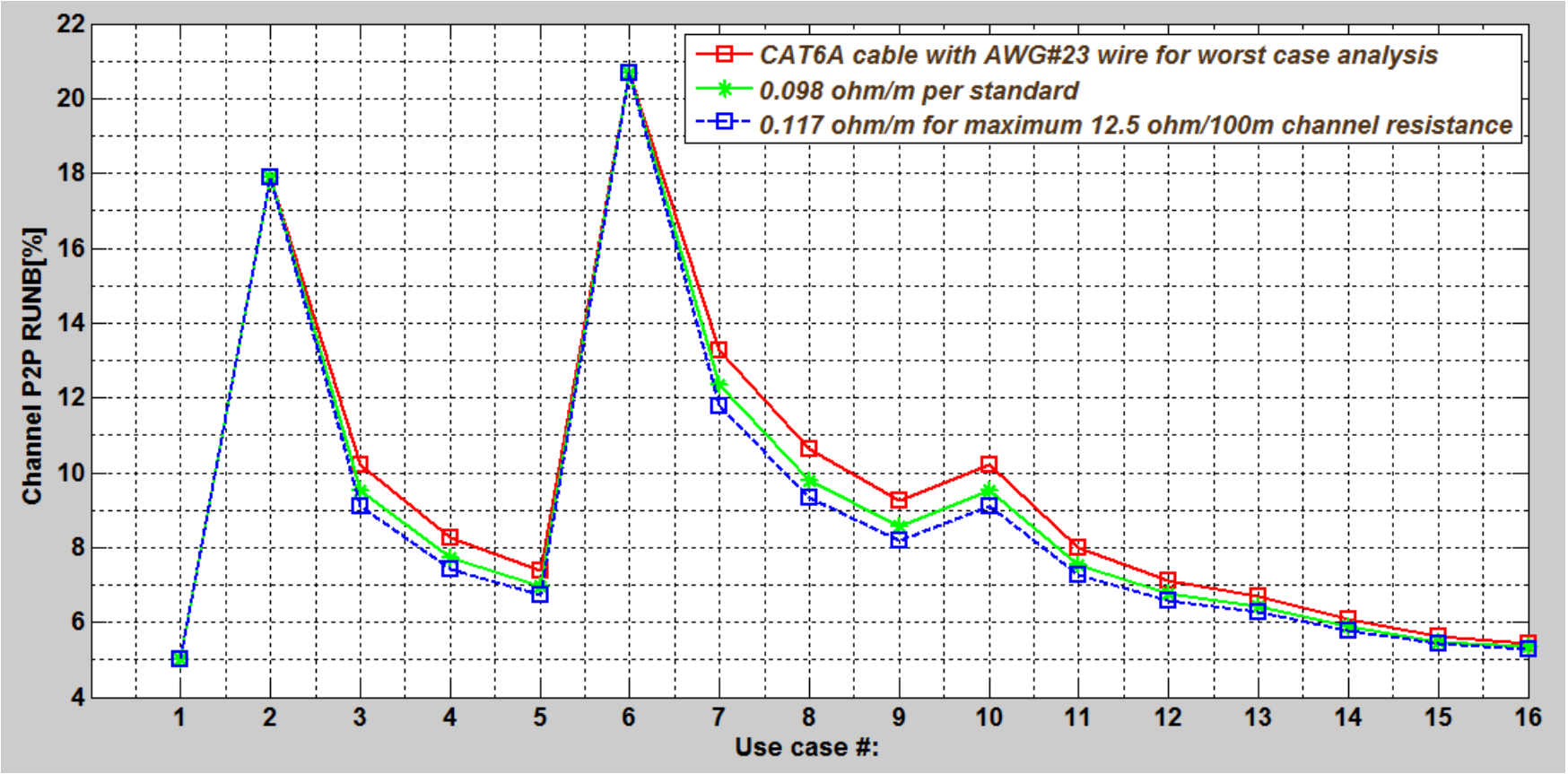
Use case analysis results – Sanity Check

Zooming on the peaks by ***Changing X axis for Channel Resistance Difference***



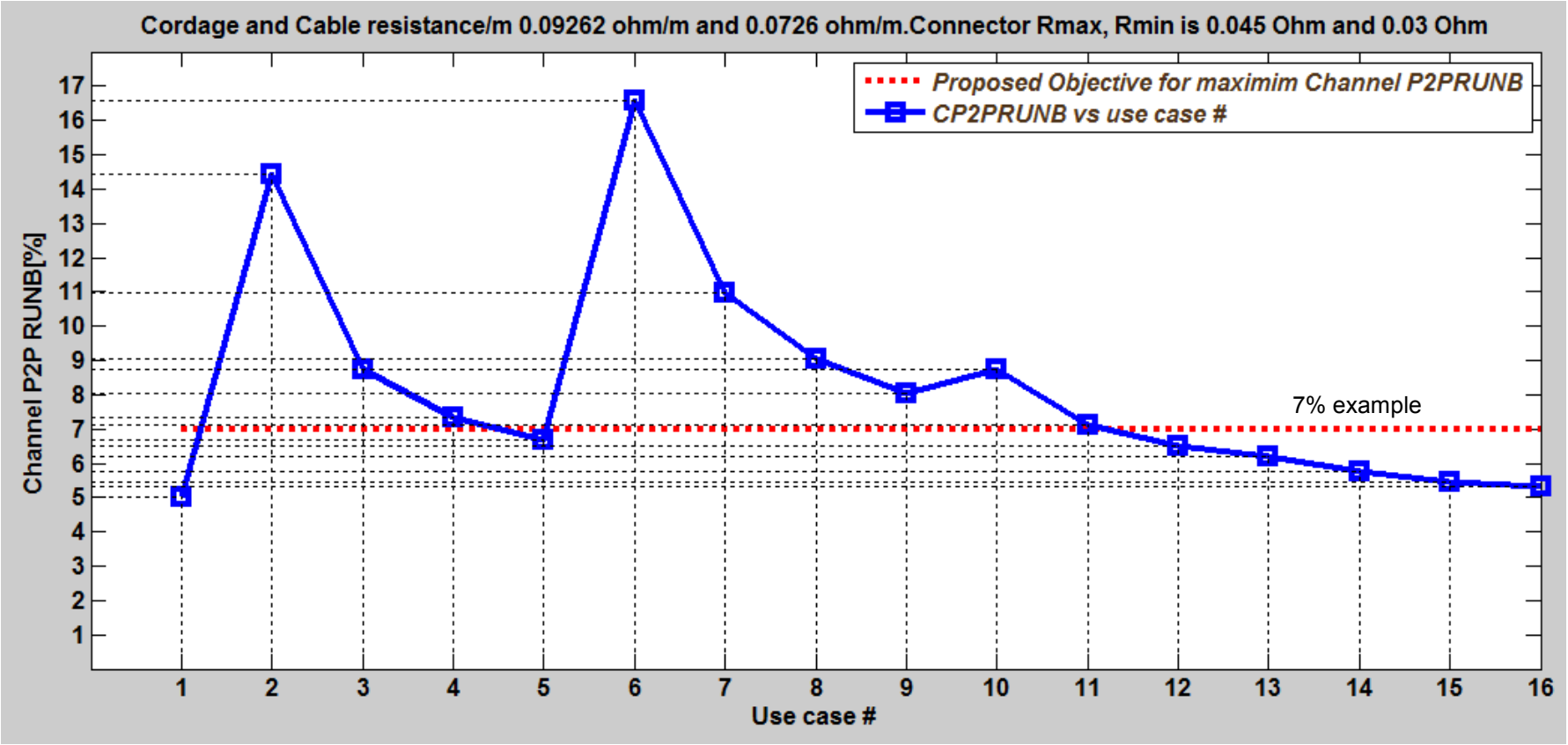
- With 7.5% C_P2PRUNB limits.

Channel P2PRUNB use cases vs. Cable resistance per meter.



- As can be seen, CAT 6A cable with AWG#23 need to be selected for worst case analysis.
  - When we analyze the end to end Channel P2PRUNB, the 0.117Ω/m will be used too for generating maximum channel current.
- Standard value 9.8Ω/100m is maximum value which is between the two other cables. As a result, it will not be used for the purpose of this work.

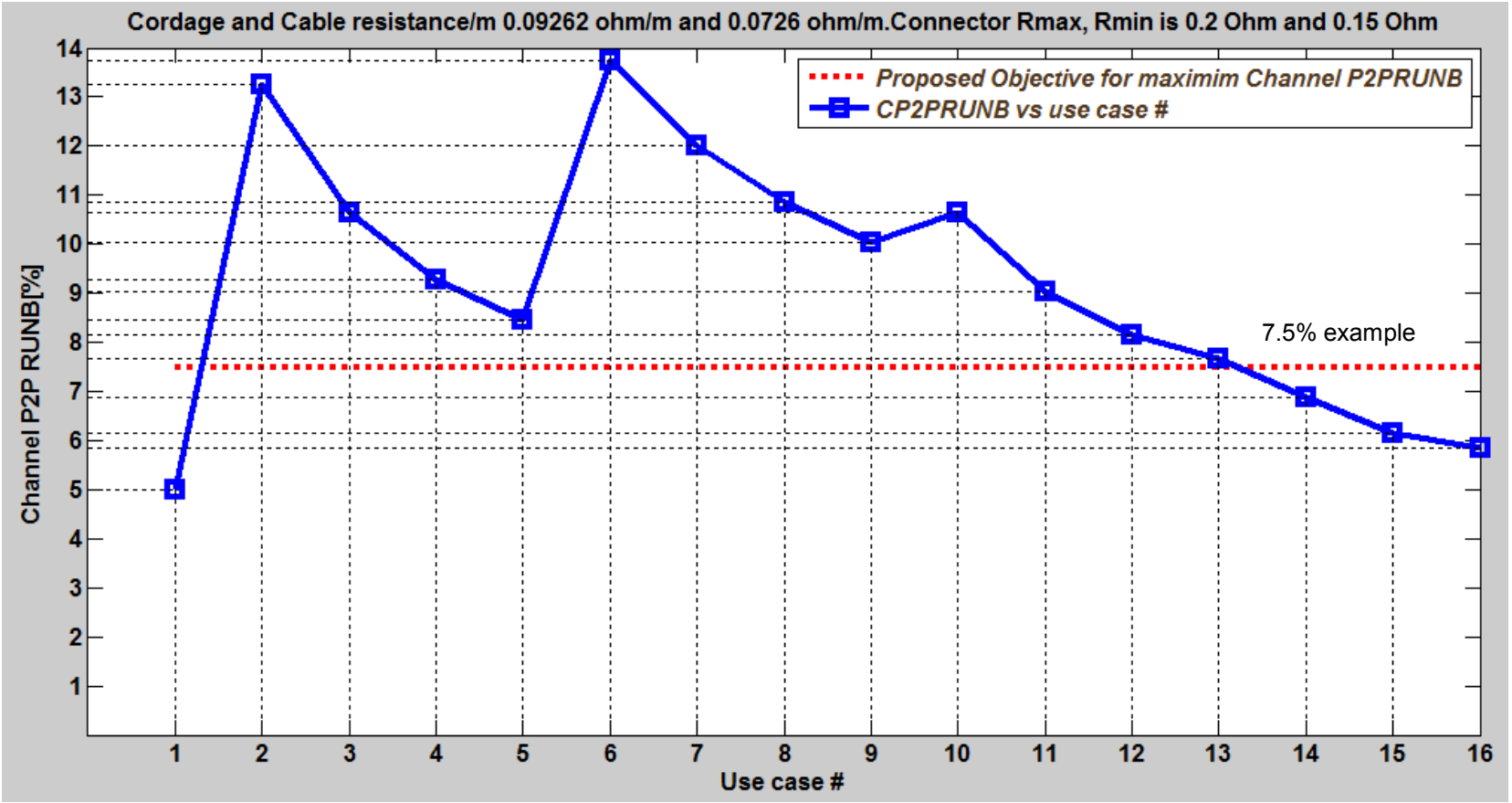
Use case analysis results with connector Rdiff=0.015Ω instead 0.02 Ω.



- Lower peaks received with using connector Rdiff=0.015Ω instead of 0.02 Ω compared to previous run.

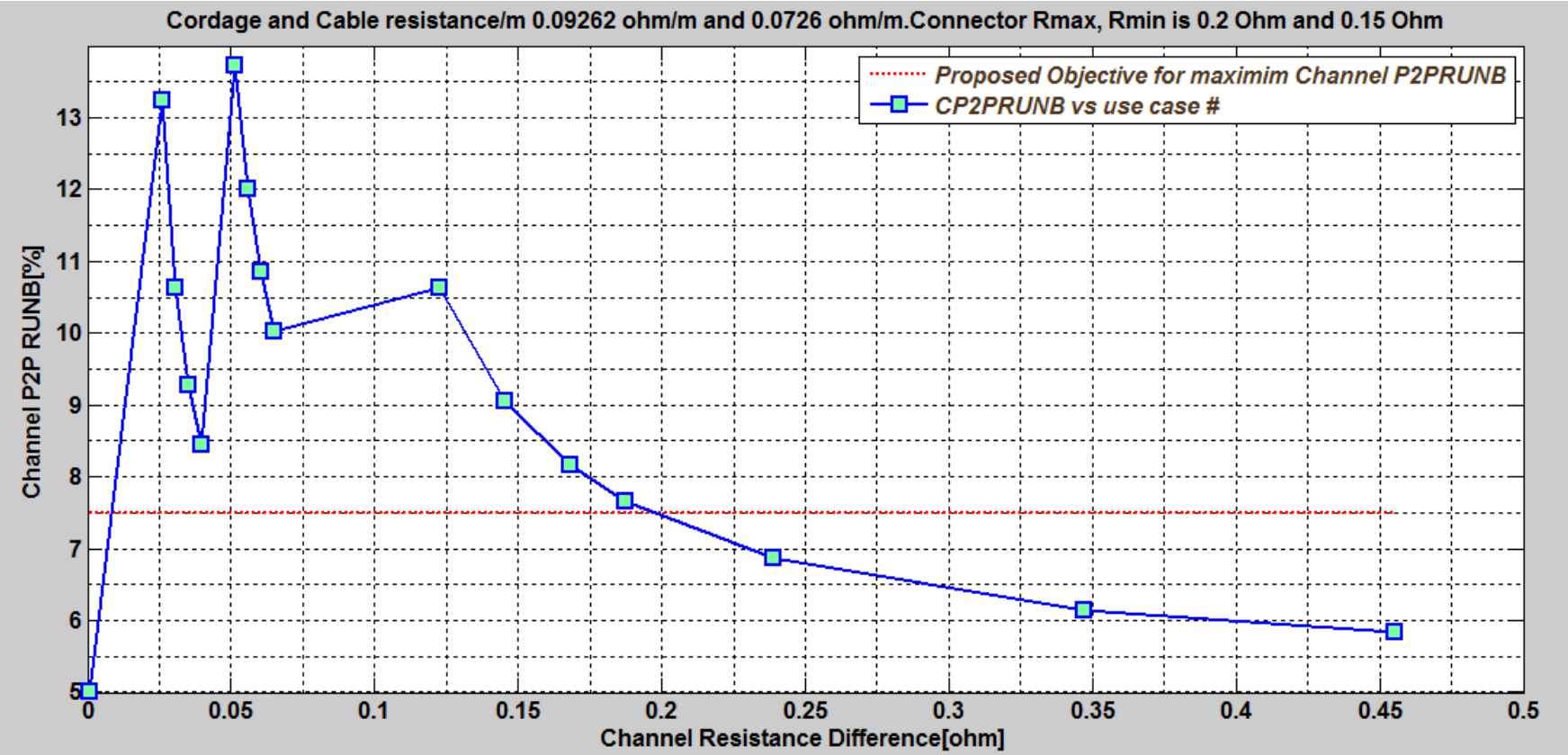
	A								B			C			D	
	[1,	2,	3,	4,	5,	6,	7,	8,	9,	10,	11,	12,	13,	14,	15,	16]; Use Case Number
n =	[0,	1,	1,	1,	1,	2,	2,	2,	2,	4,	4,	4,	4	4,	4,	4]; number of connectors
L1=	[0.15,	0.25,	0.5,	0.75,	1,	0.25,	0.5,	0.75,	1,	2,	4,	6,	8,	8,	9,	10]; Cordage[m]
L2=	[0,	0,	1,	2,	3,	0,	1,	2,	3,	4,	8,	12,	15,	30,	60,	90]; Cable[m]

Use case analysis results with connector Rmax=0.2Ω Rdiff=0.05Ω -1



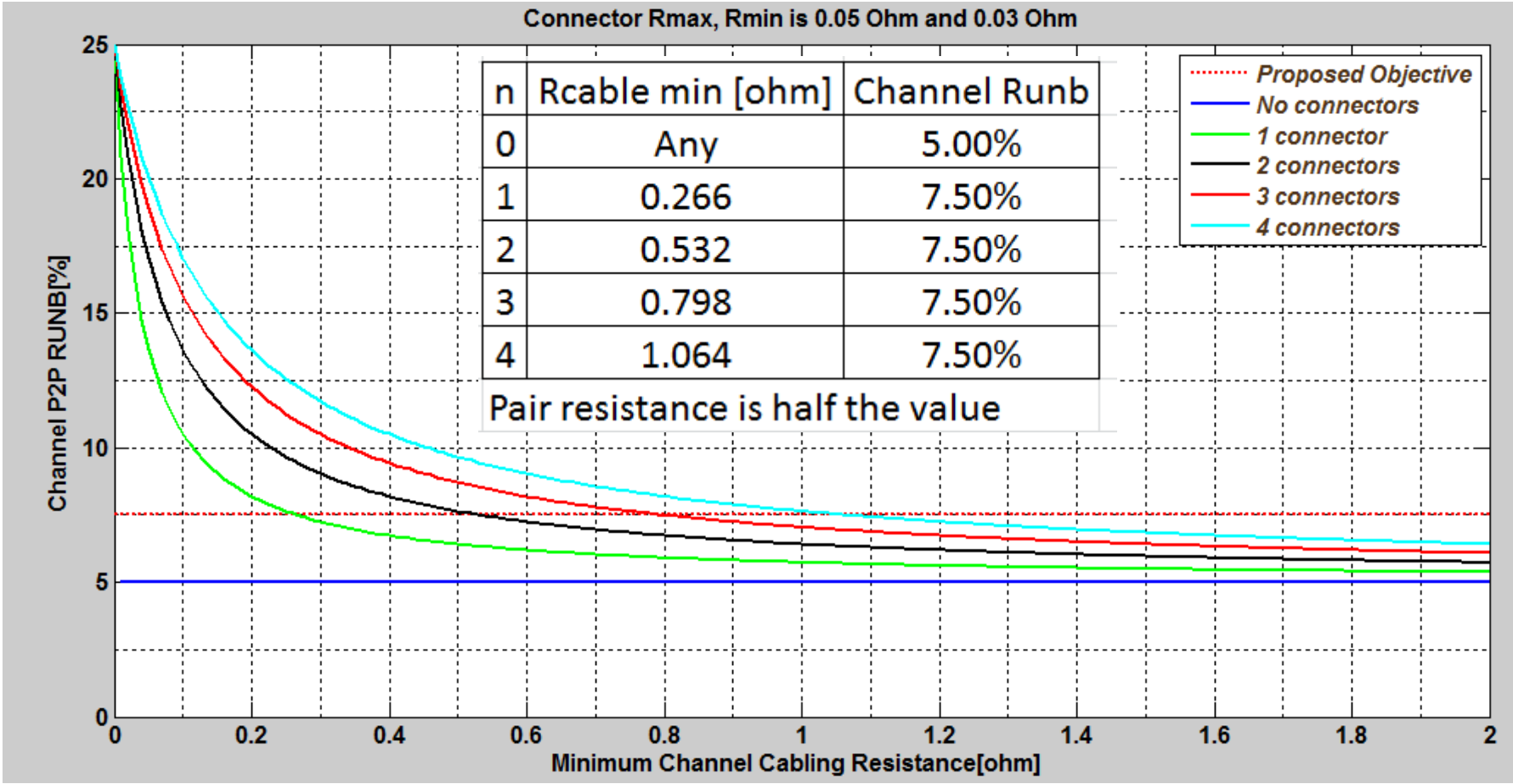
- This use case is unlikely to happen although it represent connector Rmax and Rdiff maximum values per standard while we are looking for minimum values for worst case analysis.
- Peaks are lower than Rmax=0.05Ω and Rdiff=0.02Ω .
- See more effective view when It will require higher Rdiff e.g. 0.2 instead of 0.1 to cover all use cases including use case B which is considered to be realistic one.

Use case analysis results with connector Rmax=0.2Ω Rdiff=0.05Ω -2 C_P2PRUNB vs Rdiff



- Confirming that using connector maximum standard numbers contradicts P2P Rdiff=0.1Ω. It generates higher peaks above Rdiff=0.1Ω and requires ~10.5% C_P2PRUNB definition instead of 7.5% at Rdiff=0.1Ω which is highly unlikely to happen per connector data and process evaluation when converting process parameters (mean, sigma etc.) of Rmax=0.2Ω Rdiff=0.05Ω to actual worst case minimum/maximum/Rdiff of connectors used in this work (0.05/0.2 ➔ 0.02/0.06. See worst case data base)

Channel P2PRUNB vs. Cable resistance and connectors

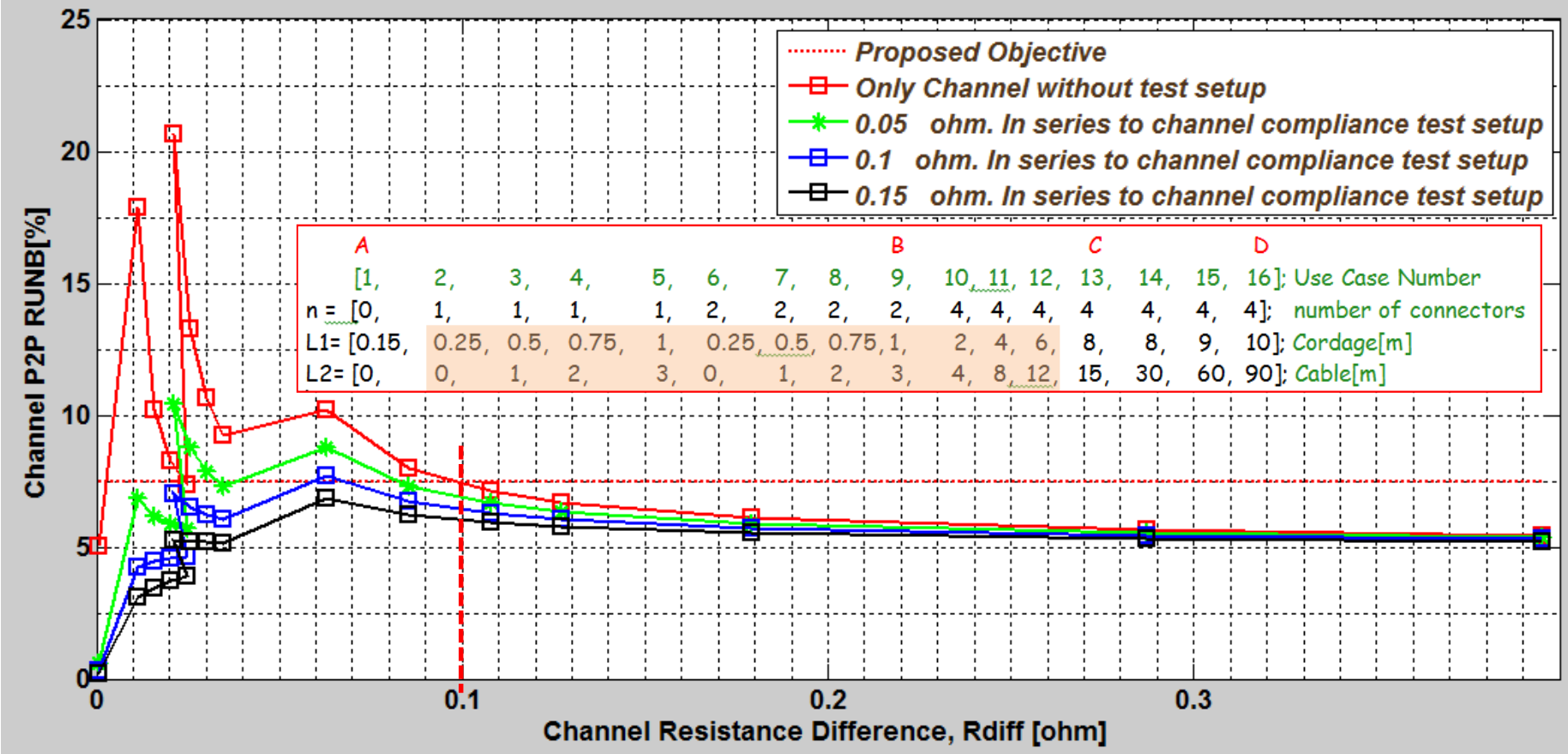


n	Rcable min [ohm]	Channel Runb
0	Any	5.00%
1	0.266	7.50%
2	0.532	7.50%
3	0.798	7.50%
4	1.064	7.50%

Pair resistance is half the value

- With 7.5% C_P2PRUNB limits.

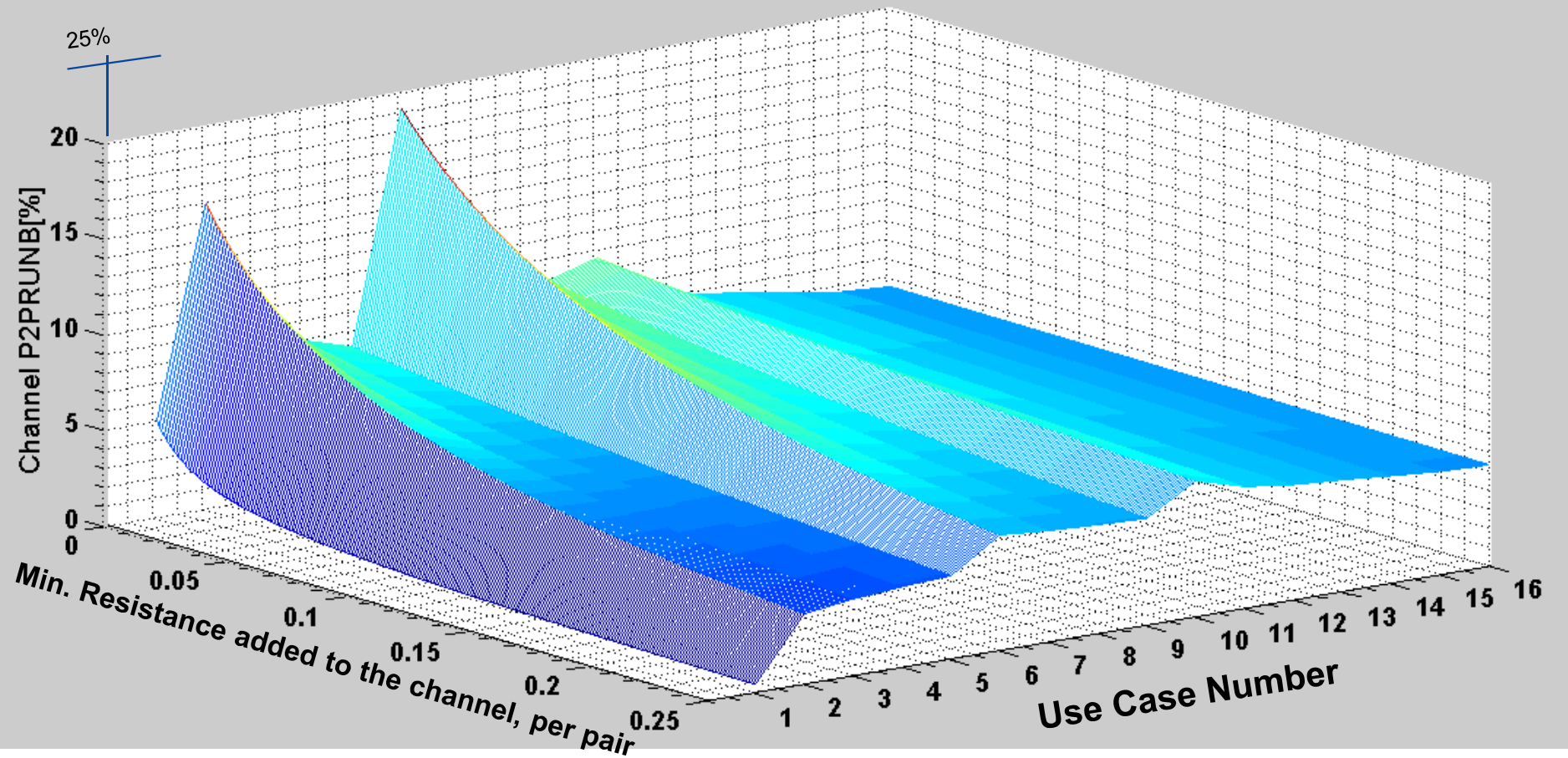
Previous work: Using setup that filters unrealistic use cases -1



- All peaks of unrealistic use cases of the channel is located below Rdiff=0.1Ω.
- This is inline with the rational of 7.5% or 0.1 Ω which ever is greater.
- The peaks are filtered when channel is tested with some minimum resistance.

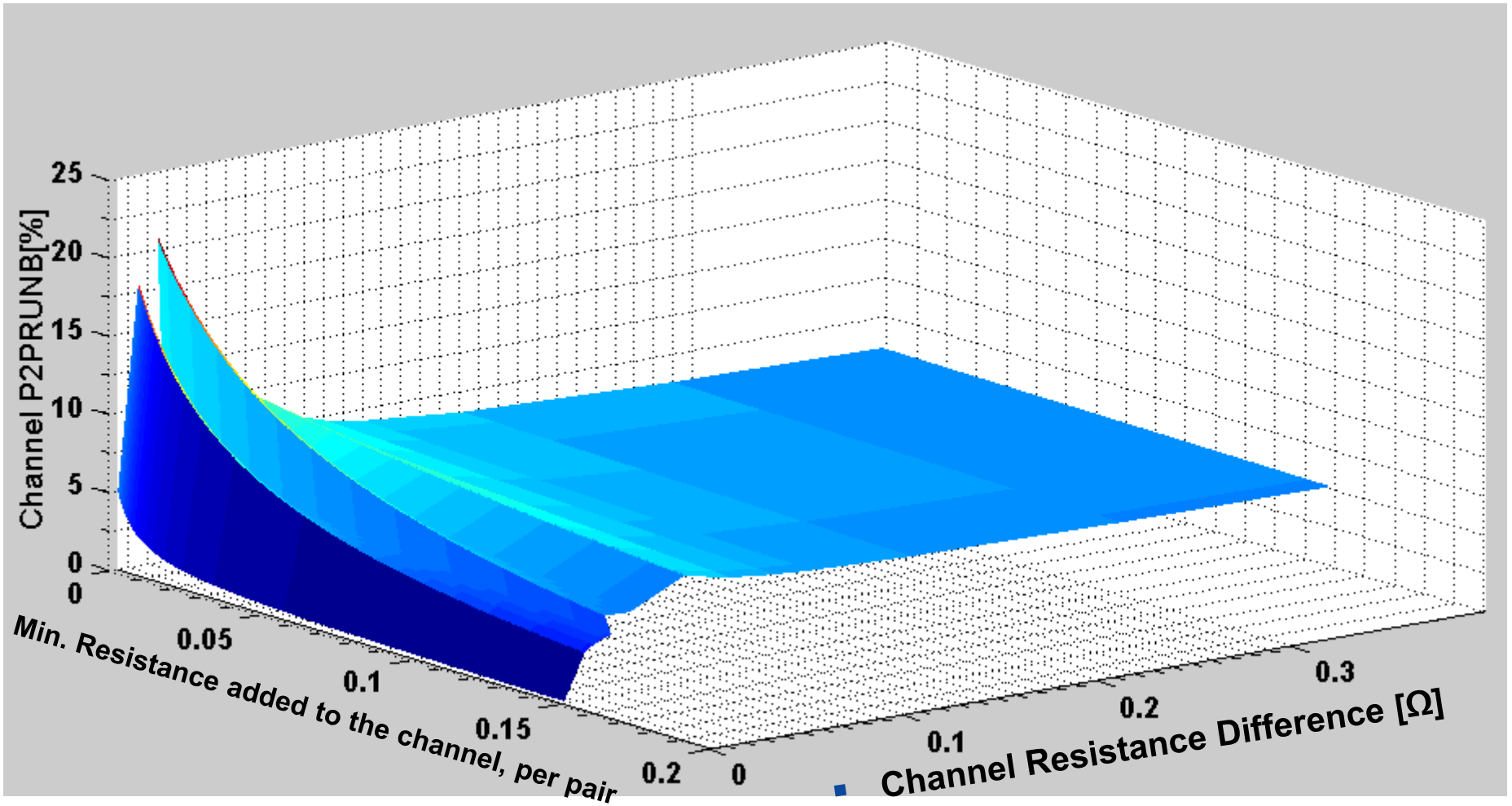
Previous Work: Using setup that filters unrealistic use cases -2

Annex K22



- Originally, the additional resistance added, was for channel compliance test to "filter" use cases that are considered as "not typical". Further work showed that the set up may not be required since realistic use case such B is falling into Rdiff=0.1Ω max while the other realistic use case falls within the 7% proposed limit. More over below Rdiff=0.1Ω max, the C_P2PRUNB is bounded by connectors Runb=25% per the worst case data used in this work

Previous Work: Using setup that filters unrealistic use cases -3



We can see that all peaks are located below 0.1 ohm requirement. As a result, setup may not be required. P2PRUNB and Rdiff cover all use cases.

- For July SD ad-hoc meeting

IEEE802.3 4P Task Force

Generating the PSE and PD PI models and their unbalance requirements

July 2014

Rev 000 adhoc meeting # 2, March 2014
Rev 009 adhoc meeting # 7, June 2014
Rev 012b adhoc meeting # 8,9, July 2014
Rev 013 adhoc July 2014 San Diego

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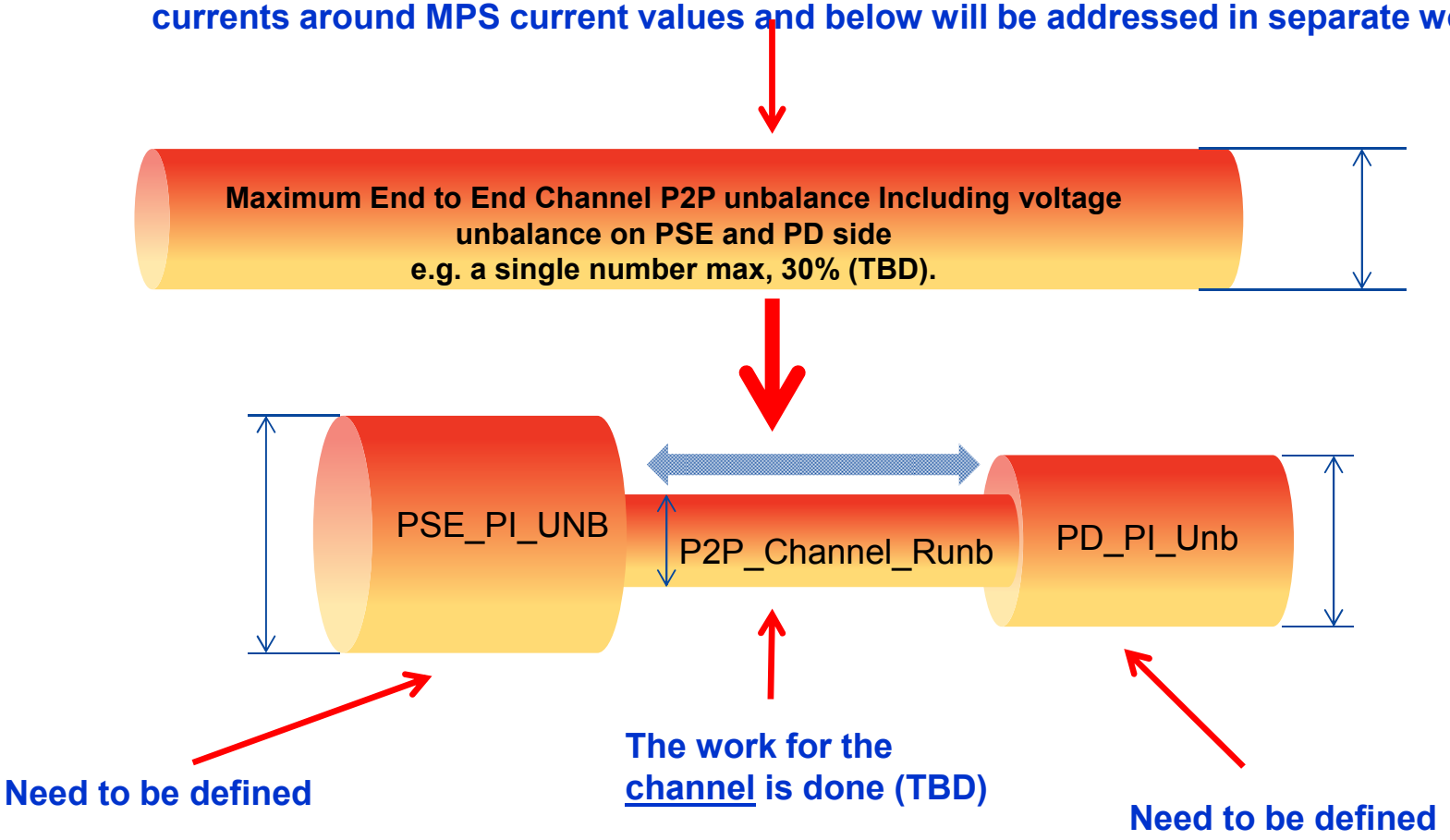
Objectives

- Generating PSE and PD PI models addressing the following:
  - Minimum set of parameters required for complete, interoperable and flexible solution.
  - Implementation independent as much as possible.
  - Based on End to End Channel Target performance i.e. maximum current over the minimum resistance pair represented by P2PRUNB numbers and additional parameters as required.
- Maximum pair current as function of
  - End to End (E2E) Channel P2P unbalance parameters:
    - E2E_C_P2PRUNB (function of Rmax, Rmin elements)
    - P2P voltage difference.
- End to End (E2E) Channel P2P unbalance parameters (*):
  - The channel P2PRUNB 7.5%(TBD) or 0.1Ω which ever is greater
  - Transformed PSE PI unbalanced parameters to meet (*)
  - Transformed PD PI unbalanced parameters (*)

Where we are and where we are going

End to End Channel P2P Resistance Unbalance: We understand the behavior, the effect of all channel parameters and for a given set of parameters we can define target unbalanced parameters for a given maximum pair current at ON_STATE. Low currents around MPS current values and below will be addressed in separate work.



The End to End Channel P2P maximum pair current

$$\mathrm{Im}ax = \frac{It}{2} + \frac{It \cdot E2E\_P2PRUNB}{2} = \frac{It \cdot (1 + E2E\_P2PRUNB)}{2}$$

$$\mathrm{Im}in = \frac{It}{2} - \frac{It \cdot E2E\_P2PRUNB}{2} = \frac{It \cdot (1 + E2E\_P2PRUNB)}{2}$$

$$\mathrm{Im}in + \mathrm{Im}ax = It = \frac{It}{2} - \frac{It \cdot E2E\_P2PRUNB}{2} + \frac{It}{2} - \frac{It \cdot E2E\_P2PRUNB}{2}$$

- It=Total PD current
- E2E_P2PRUNB=The end to end effective channel P2PRUNB
  - The **effective** value incudes P2P voltage difference effects for simplicity.
  - In final model P2P voltage difference will be separate parameter for the purpose of testing for compliance.

The End to End Channel P2P Resistance Unbalance

- Current Unbalance between any two pairs is determined by the following:

$$\frac{Idiff}{It} = \left(\frac{\sum R_{\max} - \sum R_{\min}}{\sum R_{\max} + \sum R_{\min}} \right) = E2ECP2P\_Runb = E2ECP2P\_Iunb$$

- The Rmax/min sum are the sum of all component s resistance from PSE PI to PD PI circutry i.e. Hence forming End to End Channel P2PRUNB.
- The E2ECP2PRUNB can be separated to PSE and PD PI and Channel.

- Important: PSE PI P2PRUNB=P2PCUNB is not equal to

- Show the differences between terms

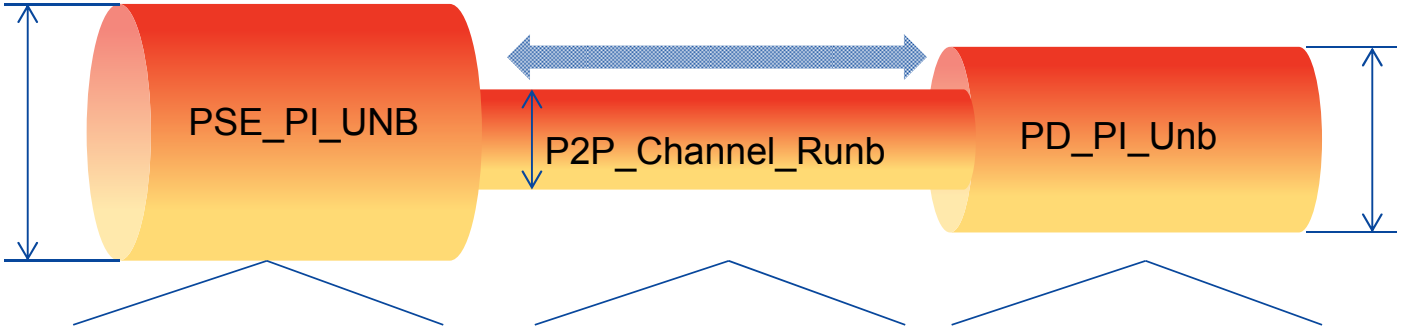
- See annex … meeting … for references.

The End to End Channel P2P Resistance Unbalance system parts

- The E2ECP2P_RUNB

$$E2ECP2P\_Runb = \left(\frac{\sum R_{\max} - \sum R_{\min}}{\sum R_{\max} + \sum R_{\min}} \right)$$

- Can be break into the 3 system parts



$$E2ECP2P\_Runb = \frac{\left(\sum R_{\max}^{PSE} - \sum R_{\min}^{PSE}\right) + \left(\sum R_{\max}^{CH} - \sum R_{\min}^{CH}\right) + \left(\sum R_{\max}^{PD} - \sum R_{\min}^{PD}\right)}{\sum R_{\max}^{PSE} + \sum R_{\min}^{PSE} + \sum R_{\max}^{CH} + \sum R_{\min}^{CH} + \sum R_{\max}^{PD} + \sum R_{\min}^{PD}}$$

Sum of end to end Rmax+Rmin Resistances

Transformation of The End to End Channel P2P Resistance Unbalance to PSE PI and PD PI unbalance parameters

- It is obvious from the previous mathematical expression that:

  (confirmed by simulations since Feb 2013 presentations:

  - http://www.ieee802.org/3/4PPOE/public/nov13/beia_01_1113.pdf
  - http://www.ieee802.org/3/4PPOE/public/nov13/darshan_03_1113.pdf
  - http://grouper.ieee.org/groups/802/3/4PPOE/public/jul13/darshan_2_0713.pdf

- PSE_PI_P2PRUNB:

$$PSE\_PI\_P2P\_Runb = \frac{\left(\sum \frac{PSE}{R_{\max}} - \sum \frac{PSE}{R_{\min}}\right)}{\sum \frac{PSE}{R_{\max}} + \sum \frac{PSE}{R_{\min}}}$$

- In not equal PSE_PI_P2PRUNB effective effect in the total E2ECP2P_RUNB

$$PSE\_Effective\_CP2P\_Runb = \frac{\left(\sum \frac{PSE}{R_{\max}} - \sum \frac{PSE}{R_{\min}}\right)}{\sum \frac{PSE}{R_{\max}} + \sum \frac{PSE}{R_{\min}} + \sum \frac{CH}{R_{\max}} + \sum \frac{CH}{R_{\min}} + \sum \frac{PD}{R_{\max}} + \sum \frac{PD}{R_{\min}}}$$

Transformation of The End to End Channel P2P Resistance Unbalance to PSE PI and PD PI unbalance parameters to Extract PSE and PD PI models

- So how to define PSE PI unbalance parameters (and later PD PI) based on E2ECP2P_R_UNB/E2ECP2P_C_UNB?.

$$E2ECP2P\_Runb = \frac{\left(\sum \frac{PSE}{R_{\max}} - \sum \frac{PSE}{R_{\min}}\right) + \left(\sum \frac{CH}{R_{\max}} - \sum \frac{CH}{R_{\min}}\right) + \left(\sum \frac{PD}{R_{\max}} - \sum \frac{PD}{R_{\min}}\right)}{\sum \frac{PSE}{R_{\max}} + \sum \frac{PSE}{R_{\min}} + \sum \frac{CH}{R_{\max}} + \sum \frac{CH}{R_{\min}} + \sum \frac{PD}{R_{\max}} + \sum \frac{PD}{R_{\min}}} =$$

$$= Kpse \cdot \frac{\left(\sum \frac{PSE}{R_{\max}} - \sum \frac{PSE}{R_{\min}}\right)}{\sum \frac{PSE}{R_{\max}} + \sum \frac{PSE}{R_{\min}}} + Kch \cdot \frac{\left(\sum \frac{CH}{R_{\max}} - \sum \frac{CH}{R_{\min}}\right)}{\sum \frac{CH}{R_{\max}} + \sum \frac{CH}{R_{\min}}} + Kpd \cdot \frac{\left(\sum \frac{PD}{R_{\max}} - \sum \frac{PD}{R_{\min}}\right)}{\sum \frac{PD}{R_{\max}} + \sum \frac{PD}{R_{\min}}}$$

Find Kpse and Kpd that meets the limits of step the required E2E_C_P2P_RUNB.

a) Channel max P2PRUNB[%] and Channel Rdiff max or {Rmax, Rmin} value set per table in annex G1 component values and chennel length use cases.

b) Kpse and Kpd can be varied per the target requirements of PSE and PD PI for covering PD and PSE implementations.

c) Kpse and Kpd may be a **Vandermonde matrix** for perfect fitting or scalar (single equation) for worst case points only.

d) Kch=need to be set to 1 due to the fact that it is know per channel given physics. See Table in annex G1.

- See Ken Bennett presentation at the adhoc meeting #8 for example implementing a derivative of the above general concept for PSE PI transformation.

Transformation of The End to End Channel P2P Resistance Unbalance to PSE PI and PD PI unbalance parameters to Extract PSE and PD PI models

- As a result of the previous procedure we can see that PSE PI unbalanced behavior is defined by:

$$PSE\_PI\_P2P\_R\_UNB = Kpse \cdot \frac{\left(\sum_{R_{\max}}^{PSE} - \sum_{R_{\min}}^{PSE}\right)}{\sum_{R_{\max}}^{PSE} + \sum_{R_{\min}}^{PSE}}$$

- Kpse may be a matric or constant (pending type of curve fitting needed (continues or single worst case value etc. (TBD)).
- Kpse is a function depending on the channel and PD affecting parts as shown in previous slide.
- Example for general Kpse: $Kps = \left(\frac{\alpha + \beta}{\gamma + \delta}\right)$

What are the minimum parameters set?

- Assuming we did the previous procedure and we got NEW converted form of PSE_PI_RUNB that is equivalent to its real contribution in the system.
- We need to see what are the minimum parameters that we need to define?
- From previous transformed PSE_PI equation model:

$$PSE\_PI\_P2PRUNB = \frac{\sum_{R_{\max\_new}}^{PSE} - \sum_{R_{\min\_new}}^{PSE}}{\sum_{R_{\max\_new}}^{PSE} + \sum_{R_{\min\_new}}^{PSE}}$$

- PSE PI P2P voltage difference is required.
  - Until this point of the analysis, its effect was lumped in the element resistance values for simplicity.
  - Now it is separate again.

- What else is required?

What are the minimum parameters set?

$$PSE\_PI\_P2PRUNB\_new = \frac{\sum PSE_{R_{\max\_new}} - \sum PSE_{R_{\min\_new}}}{\sum PSE_{R_{\max\_new}} + \sum PSE_{R_{\min\_new}}}$$

- By definition the PSE unbalanced parameters are controlled by knowing either one of the parameters sets:
- 1. P2P_RUNB_new (see option 4 which is an improved version due to the effect of transformation)
- 2. Rmax and Rmin
- 3. P2P_RUNB and Rmax
- 4. P2P_RUNB and Rmin
- 5. P2P_RUNB and Rdiff

- All of the above can be considered as complete solutions.

What are the minimum parameters set?

$$PSE\_PI\_P2PRUNB\_new = \frac{\sum PSE_{R_{\max\_new}} - \sum PSE_{R_{\min\_new}}}{\sum PSE_{R_{\max\_new}} + \sum PSE_{R_{\min\_new}}}$$

- The following cannot be used:
- 6. Rdiff= $PSE\_Rdiff = \sum PSE_{R_{\max\_new}} - \sum PSE_{R_{\min\_new}}$
  - Can not be used alone.
  - Cannot solve two parameter equation with single parameter. Leads to interoperability issues.
  - **See annex L1-L8 for details**
- Examples:
- Rdiff=Rmax-Rmin=0.2=X:
  - P2PRUNB=(0.2-0)/(0.2+0)=100%
  - P2PRUNB=(0.23-0.03)/(0.23+0.03)=77%
  - P2PRUNB=(0.3-0.1)/(0.3+0.1)=50%
  - P2PRUNB=(1-0.8)/(1+0.8)=11%

Interoperability Issue:
Different UNBALANCE
For the same Rdiff resulting
With different Imax for the
Same channel and PD

Absolute values of Rmin or Rmax are extremely important.

What are the most implementation independent minimum parameters set?

- Options 1 -5 are mathematically complete solutions.

- What is best for implementation independent?
  - Option 1: P2PRUNB_new is a ratio, hence implementation independent. But may need Rmin for complete solution (TBD)
  - Option 2: Rmax, Rmin is highly implementation dependent.
  - Option 3: P2PRUNB_new, Rmax limits implementations when ballast means may be needed.
  - Option 4. P2P_RUNB and Rmin. Same as 1 but a bit less implementation independent
  - Option 5. P2P_RUNB and Rdiff. Highly implementation independent.

Summary -What are the minimum parameters set?

Option	PSE PI P2PRUNB	Rmax	Rmin	Rdiff	Notes
1	Yes	-	-	-	1. Ratio. Fully implementation independent . 2. Need two parameter to solve equation with two variables. Need more research to verify completeness with or without Rmin.
2	-	Yes	Yes	-	1. Complete solution. 2. Not flexible, Implementation dependent.
3	Yes	Yes			1. Complete solution. 2. Not flexible, Implementation dependent. Problem to limit Rmax
4	Yes	No	Yes	-	1. Complete solution. 2. Rmin is exists anyway. 3. Not fully Implementation in dependent but tolerable.
5	Yes	NO	NO	YES	1. Complete solution. 2. Implementation dependent.
6	NO	NO	NO	YES	1. Not complete 2. Implementation dependent 3. Interoperability issues

Summary

- It is recommended that the The PSE PI minimum model parameters required to define complete PSE PI unbalance behavior are:
  - PSE PI P2P Voltage difference =(TBD)
  - PSE PI P2PRUNB =(TBD)
  - To research the need for Rmin.
- It is recommended that the adhoc will focus on the above option first.
- The test setup and electrical model drawing will be addressed after the above are agreed.

References

1. Adhoc material: presentations and simulation results.

Q&A

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):

$$\left\{ \frac{(R_{max} - R_{min})}{(R_{max} + R_{min})} \times 100 \right\}_{\%} \qquad (33\text{–}1)$$

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.

Source: Yair Darshan per IEEE802.3-2012

Annex A1

- Inputs from Pete Johnson:
- 3% DC Unbalance comes from ISO / IEC.
- **TIA 568** has DC Unbalance specified as 5% using **ASTM D 4566** definition of DC Unbalance that is different from that used by ISO.
- The ASTM method is % Runb = 100 * (Max R – Min R) / Min R
-
- Yair Response (to be discussed by the group) next (3rd meeting):
  - Since cables vendor wants to meet "all standards" they meets the 2% cable. System and component vendors count on the 3% channel.
  - Our IEEE POE standard is counting on the 3% max.
  - The ASTM method that calculates % Runb = 100*(Max R – Min R) / Min R is familiar but has no practical physical meaning related to current unbalance that we can use e.g. for transformers. The equation that we are using is a derivation of the current unbalance definition and rationale.
  - As a result, I believe we should stay with current 3% pair resistance unbalance and our IEEE equation for Unbalance.
- Pete agrees to this response.
- Group agreed to Yair proposed response as well.

Annex A2 - ANSI/TIA-568-C.2

- Resistance unbalance of a channel

6.2.1 DC loop resistance

DC loop resistance for category 3, 5e, 6, and 6A channels shall not exceed 25 Ω. Refer to TIA TSB-184 for additional information on channel resistance related to guidance on delivering power.

6.2.2 DC resistance unbalance

DC resistance shall be measured for all channel conductors. DC resistance unbalance shall be calculated for each pair of the channel in accordance with equation (14) and shall not exceed the greater of 3% or 200 milliohms. DC resistance unbalance is not specified for category 3 channels.

$$Resistance\_Unbalance_{pair} = \left(\frac{|R_1 - R_2|}{R_1 + R_2} \right) \cdot 100\% \qquad (14)$$

where:

R_1 is the DC resistance of conductor 1.

R_2 is the DC resistance of conductor 2.

Source: Yair Darshan per ANSI/TIA-568-C.2

Annex A3 - ANSI/TIA-568-C.2

- Connecting Hardware requirements

6.8.1 DC resistance

DC resistance shall be measured in accordance with ASTM D4566 at 20 ℃ ± 3 ℃ for all connecting hardware cable pairs.

NOTE – DC resistance is a separate measurement from contact resistance as specified in Annex A. Whereas DC resistance is measured to determine the connector's ability of transmit direct current and low frequency signals, contact resistance is measured to determine the reliability and stability of individual electrical connections.

Category 3 connecting hardware DC resistance between the input and the output connections of the connecting hardware (not including the cable stub, if any) used to terminate 100 Ω twisted-pair cabling shall not exceed 0.3 Ω.

Category 5e, 6, and 6A connecting hardware DC resistance between the input and the output connections of the connecting hardware (not including the cable stub, if any) used to terminate 100 Ω twisted-pair cabling shall not exceed 0.2 Ω.

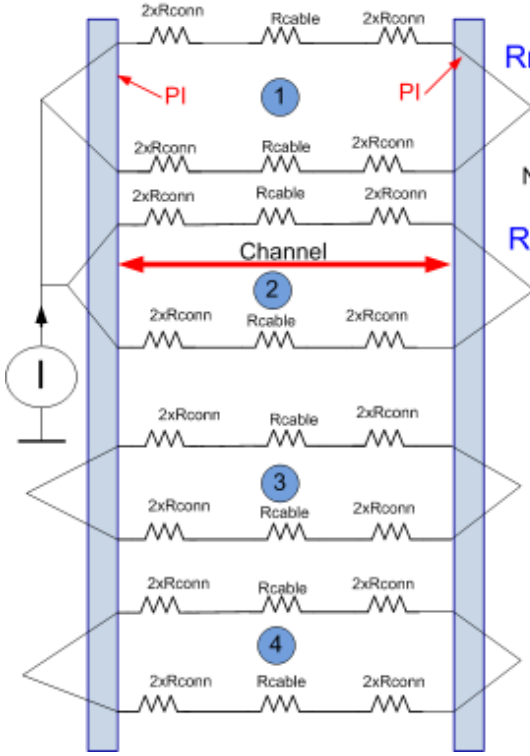
6.8.2 DC resistance unbalance

DC resistance unbalance shall be calculated as the maximum difference in DC resistance between any two conductors of a connector pair measured in accordance with IEC 60512, Test 2a.

Category 3 connecting hardware DC resistance unbalance should not exceed 50 mΩ. Category 5e, 6 and 6A connecting hardware DC resistance unbalance shall not exceed 50 mΩ.

Source: Yair Darshan per ANSI/TIA-568-C.2

Annex A4 – Channel P2P Resistance Unbalance



Rmax=Rcables_max+N*Rc_max

I1

N= number of connectors, 0 to 4

Rmin=Rcables_min+N*Rc_min

I2

C_P2PRUNB is defined between any two pairs
Each pair has two wires in parallel from power delivering point of view

$$\frac{I2-I1}{I}=\frac{\sum R_{max}-\sum R\min}{\sum R_{max}+\sum R\min}=$$

$$C\_P2P\_R\_UNB=C\_P2P\_Current\_UNB$$

$$Channel\_P2P\_Current\_DIFFERENCE=$$

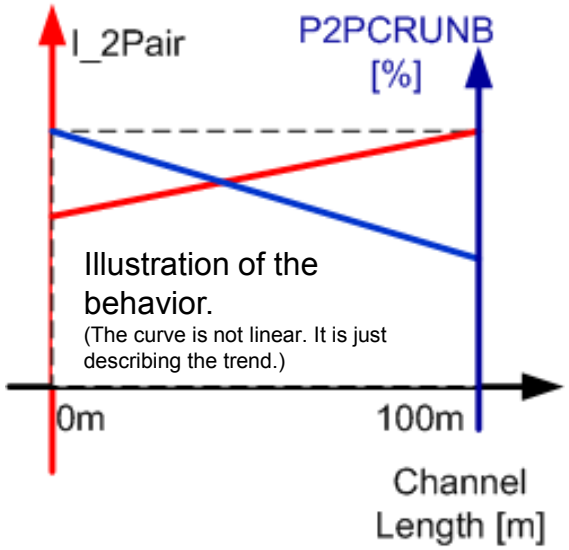
$$=I1-I2=I\cdot\frac{\sum R_{max}}{\sum R_{max}+\sum R_{min}}-I\cdot\frac{\sum R_{min}}{\sum R_{max}+\sum R_{min}}=I\cdot\frac{\sum R_{max}-\sum R_{min}}{\sum R_{max}+\sum R_{min}}$$

As a result, Channel P2P Resistance or Current Unbalance ratio is::

$$\frac{I2-I1}{I}=\frac{\sum R_{max}-\sum R\min}{\sum R_{max}+\sum R\min}=C\_P2P\_R\_UNB=C\_P2P\_Current\_UNB$$

Annex B: What is more important P2PRUNB or Current increase/pair due to at worst case conditions?

- To discuss the advantages that PD constant Power Sink allows us. Source: Yair Darshan
- Background material for considering (P2PRUNB in this slide refer to the end to end channel P2PRUNB):
  - Worst case End to End Channel Pair to Pair Channel Resistance Unbalance is at short cable (<100m).
  - At short cables PD voltage is higher that 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 max may not an issue (pending the P2PCRUNB value).**
  - At 100m the P2PCRUNB is much smaller than at short channel
  - Resulting with less significant contribution to Ibias 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.



The answer is: In order to answer the question we need to check both data sets 1 and 2 in the worst case data base. We need to check the following equation:

$$0.5\cdot(1+\alpha_{(L=100m)})\cdot I_{total\_100m} < or > 0.5\cdot(1+\alpha_{(L=0.15m)})\cdot I_{total\_0.15m}$$

$$\alpha_{(L=100m)} = End2End\_C\_P2PRUN\_at\_100m$$

$$\alpha_{(L=0.15m)} = End2End\_C\_P2PRUN\_at\_0.15m$$

Source:
1. See link above, from July 2013.
2. Adhoc meeting #2, February 24, 2014.

Annex C1: Why we care for P2P resistance unbalance parameters

Source: Yair Darshan

- In 4P system:

- If P2PRUNB>0 the PD current over each 2P will not be the same.
  - 51W PD with maximum total current of 1.2A, the current will split to 0.6A+0.18A=0.78A over the 2pairs with minimum resistance and 0.42A with the pair with maximum resistance.
- In general: The pair with the highest current will be: It*(1+P2PRUNB)/2
  - This will require to overdesign the magnetics for high P2PRUNB values.
  - Watching limits of connector pins, PCB traces and power components on the DC current path at PSE and PD and overdesign accordingly.
  - So there is interest to have components with lower P2PRUNB along the channel as possible by cost and manufacturability limitations to result with lower End to End Pair to Pair RUNB.

Annex C2: Why we care for P2P resistance unbalance parameters

- Other concerns was how it will affect on PD minimum available power for a 60W system (two times the 802.3at power). The decision was that for our current data base we can supply 49W for the PD (instead of 51W). See 802.3bt objective.
  - This was done by calculating what will be the power at the PD if we keep maximum 600mA at the pair in order not to cause issues to Type 2 component/ devices that can work with 4P
- Other concern was if P2PRUNB will increase power loss on the cable. We show that now it will not. Moreover we show that if P2PRUNB increased, the power loss is decreased.

$$Trise = 0.5 \cdot N \cdot It^2 \cdot R_{loop\_\max} \theta_N \cdot [1 - P2PCRUNB]$$

- See: http://www.ieee802.org/3/4PPOE/public/nov13/darshan_02_1113.pdf for more details.

Source: Yair Darshan

Annex D1: Calculations of CP2PRUNB with constant power sink model and the effect on transformer bias current.

Equation	Symbol	Units	Channel Length	
			1m	100m
End to End Pair to Pair Channel Resistance Unbalance: $CP2PRUNB = \frac{\sum R\max - \sum R\min}{\sum R\max + \sum R\min}$	CP2PRUB	-	0.26	0.112
	I	A	1.02	1.2
	I/2	A	0.51	0.6
I*CP2PRUNB	DI	A	0.2652	0.1344
I*CP2PRUNB/2	DI/2	A	0.1326	0.0672
I*(1+CP2PRUNB)/2	Imax=(I+di)/2	A	0.643	0.667
I*(1-CP2PRUNB)/2	Imin=(I-di)/2	A	0.377	0.533
Ibias=3%*Imax/2		A	0.0193	0.02
Sanity Check	I	A	1.02	1.2
Effect on Ibias of transformer: 3%*(Imax-0.6)/2	d(Ibias)	mA	0.639	1.008

Source: Yair Darshan

Annex D2: Affecting parameters on Transformer Ibias

- PSE Rsense and Rdson are out of the loop for pair unbalance
  - They affect only on P2P unbalance
    - Which affect Iport (increase or decrease) which affect Ibias by 3%*(Iport_max-Iport_nominal)
- How to reduce Ibias?
  - Adding Rballast on transformers reduces Ibias directly
  - Defining minimum cable length reduces P2PRUNB_max. The effect on Ibias is 3%*(Iport_max-Iport_nominal).
  - Adding in PD ballast resistors (cost effective in PD and not in PSE)
    - May not be needed for PD power below TBD.
  - Using matched diode bridges, significantly reduces P2PRUNB and as a result, the current unbalance

Source: Yair Darshan

Annex E1 – Connector and Cabling standard data

- Summary of resistivity and resistance unbalance (Source Wayne Larsen)
- specifications in TIA cabling standards
- Resistivity of cable and “cordage” from cabling standards
- – Cable DC resistance is 9.38 Ohms / 100 meters, ANSI/TIA-568-C.2, 6.4.1, page 58. Cat 5e, 6, and 6A are all the same.
- – Cordage DC resistance is 14 Ohms / 100 meters, ‘568-C.2, 6.6.1,page 74. Cat 5e, 6, and 6A are all the same.
- – Cable and cordage resistance unbalance with a pair is 2.5 % per IEC 61156-1, ‘568-C.2-1 6.4.2 page 58. All categories are the same.
- – Cable and cordage resistance unbalance between pairs is not specified, but has been studied and found to be less than 5 %.
- – Connectors are allowed 200 milliohms resistance and 50 milliohms resistance unbalance between any conductor. They actually have much less resistance.
- Yair Darshan notes:
- These values are maximum values, pre PoE standard.
- There are no specifications for minimum values as needed for P2P unbalance analysis. As a result, to cover both angles of P2PRUNB at short and long channel, maximum 12.5Ω channel was used for generating maximum pair current and channel with horizontal cable resistivity of 0.066 Ω/m was used to generate worst case P2PRUNB. Later this number was updated to 0.079 Ω/m to include twist rate effect.
- As for connectors: less than 0.06 Ω connector resistance was used. See worst case data base for details.

Annex E2 – Connectors terms.

- **Source Yakov Belopolsky / BEL**
- The term used in the connector industry is LLCR (Low Level Contact Resistance)- Bulk R_{LLCR-B}
- Low Level Contact Resistance (LLCR-Bulk) consists of four components
- Plug Conductor Resistance R_{CR}
- Plug Blade/Conductor Contact Resistance R_{PBCR}
- Plug Blade/Jack Wire Contact Resistance or TRUE LLCR R_{CRTRUE}
- Jack Wire Resistance R_{JWR}
- $R_{LLCR-B} = R_{CR} + R_{PBCR} + R_{CRTRUE} + R_{JWR}$
- However, it is easy to measure and subtract $(R_{CR} + R_{PBCR})$ from the Bulk so many connector vendors use the Contact resistance $(R_{CRTRUE} + R_{JWR})$
- **A typical differential between two types measurements is less than 20 milliohm**
- The reason is that the $(R_{CRTRUE} + R_{JWR})$ is affected by environmental exposure and defines the quality of the connector design separately from the plug blade termination quality

Annex E3: Connector data from vendors datasheet

Source: Yair Darshan

	Vendor	Resistance per datasheet
CAT6	A	30 milliohm max ,Jack only[1]
CAT6	B	35 milliohm max ,Jack only[1]
CAT6	C	30 milliohm max ,Jack only[1]

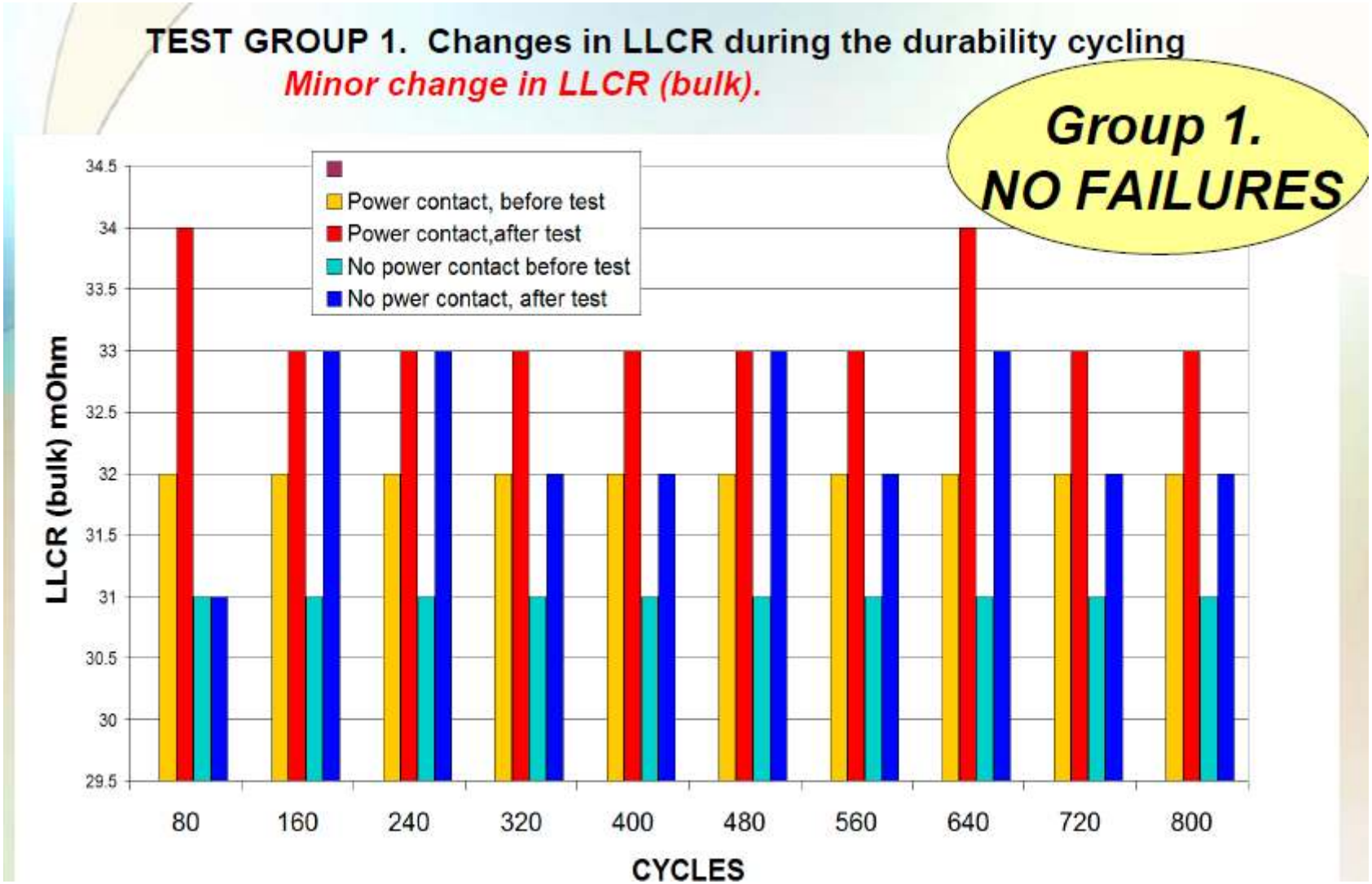
1. It is per datasheet so actual values are lower.

Source: Yair Darshan

Annex E4 - Connector data – Source BEL

http://www.ieee802.org/3/at/public/2006/07/belopolsky_1_0706.pdf slide 22.

30milliohm connector resistance shown by BEL



Annex E5: Connectors test data

- Source: Microsemi
- Each number in the table is the average resistance of all pins from end to end (Plug and Jack) for each connector.

Connector #	Vendor A	Vendor B	Vendor C	Vendor D	
	CAT6	CAT6	CAT6A	CAT6A	
1	45	43	39	42	45
2	43	43	40	49	46
3	48	42	40	40	39
4	48	46	42	39	44
5	43	45	39	38	47
6	46	39	43	50	44
7	45	42	39	38	43
8	49	46	42	41	44
9	46	45	39	44	45
10	42	45		51	44
11	43	46		44	43
12	43	43		50	39
13		46		54	40
14		42		39	47
15		46		55	42
16		46		51	48

	Vendor A	Vendor B	Vendor C	Vendor D
Average	45.08	44.06	40.33	44.53
Max	49	46	43	55
min	42	39	39	38
Rdiff	7	7	4	17

Average connector resistance	43.50
Max	55
Min	38
Rdiff	17

- **All connector resistance: 55**milliΩ max.
  - **Vendors approve 60milliΩ** max.
  - There are high quality connector that get to **30**milliΩ.
  - The average resistance of these samples: **43.5milliΩ**
- **Additional Information (not shown from the tables attached):**
- Within a connector, **pair to pair resistance difference**≤20milliΩ was confirmed.
- Most results were below 15milliΩ, therefore this number chosen to be at the worst case data base table.
- Simulations will be done for 15 and 20 milliohms as well.

Source: Yair Darshan

Annex E6: Connectors test data

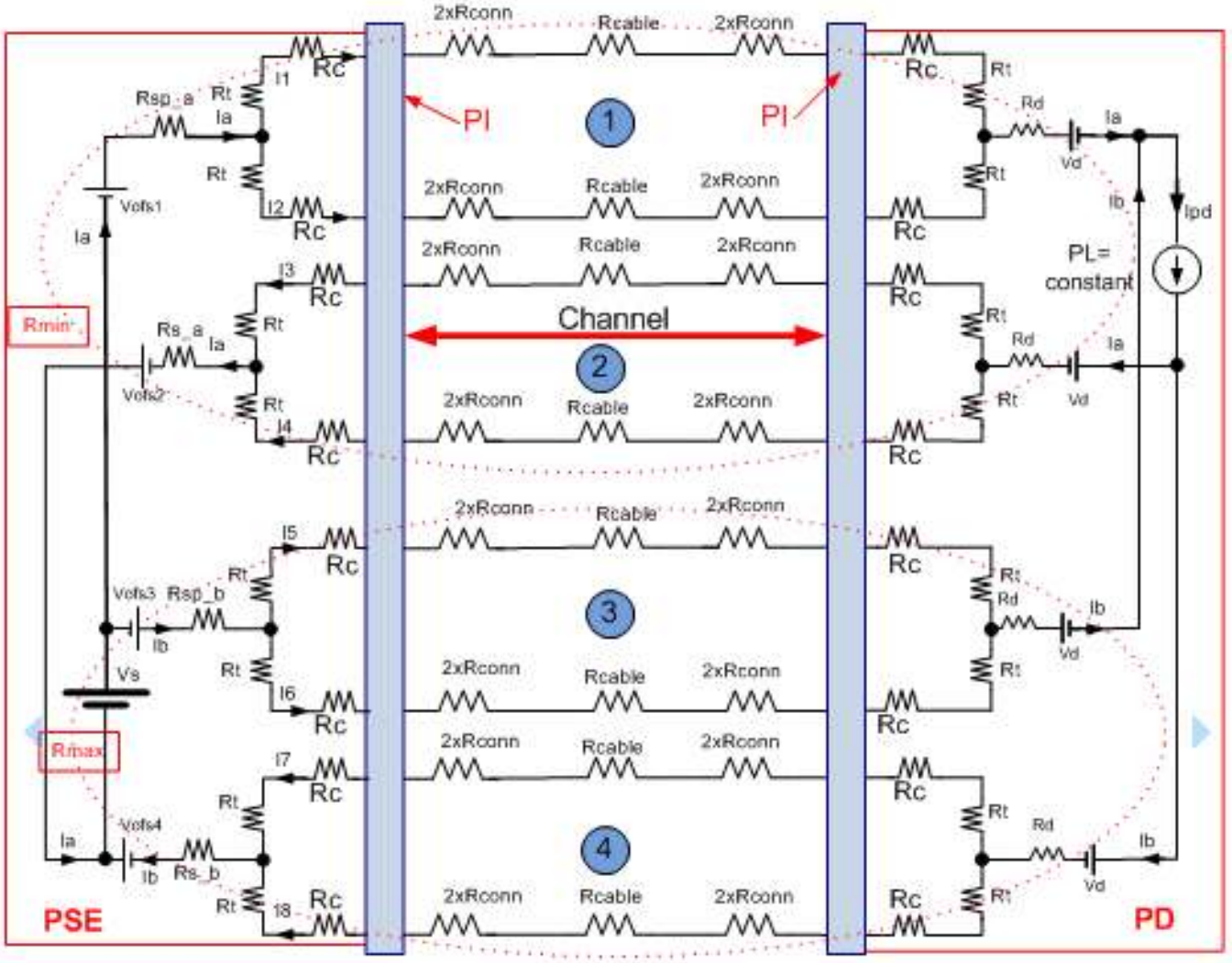
http://www.vtiinstruments.com/Catalog/Technotes/RJ-45_Excels_For_Stria_Gage_Connection.pdf

- See above link page 12.
- 45milliohm connector resistance of 40 connector samples.
- See page 13 at the above link for connector resistance over temperature

Source: Yair Darshan.
Based on the above link.

Annex F – End to End P2P Resistance Unbalance Model

General Channel Model and its components that we have used.



Notes for the general Model:

1. Total end to end channel connectors is 6 max.
2. The formal channel definition is marked in red arrow and is with up to 4 connectors.
3. Our work addresses also the internal application resistance of known components that are used
4. In simulations, pairs 1 and 2 components were set to minimum and pairs 3 and 4 were set to maximum values. See simulation results on previous meetings
5. Vofs1/2/3 and 4 was added. To update the group. July 3, 2014.

Source: Yair Darshan and Christian Beia

Annex G1:Worst Case Data Base (updates) -1

See notes to the table in next slide

#	Parameter	Data set 1	Data set 2
1	Cordage resistivity[1]	0.14Ω/m	
		0.09262Ω/m for AWG#24 for worst case analysis	
2	Horizontal cable resistivity option 1[2]	11.7Ω/100m=(12.5Ω - 4*0.2Ω) / 100m which is the maximum resistance resulting with maximum Iport.	7.92Ω/100m (CAT6A, AWG23) This is to give us maximum P2PRunb
3	option 2[3]	0.098Ω/m.	
4	Unbalance parameters	• Cable Pair resistance unbalance: 2%. Channel pair resistance unbalance: 3% • Cable P2P Resistance Unbalance: 5%. Channel P2P Resistance Unbalance: 0.2Ω/6% max TBD.	
5	Channel use cases to check. See figure 1 for what is a channel.	A. 6 inch (0.15 m) of cordage, no connectors. B. 4 m channel with 1 m of cordage, 3 m of cable, 2 connectors C. 23 m channel with 8 m of cordage, 15 m of cable, 4 connectors D. 100m channel with 10 m of cordage, 90 m of cable, 4 connectors	
6	End to End Channel[6]	The Channel per figure 1 + the PSE and PD PIs.	
7	Transformer winding resistance	120mOhm min, 130mOhm max	
8	Connector resistance[8]	40mOhm min, 60mOhm max	30mOhm min, 50mOhm max
9	Diode bridge[9]	Discreet Diodes: 0.39V+0.25Ω*Id min; 0.53V+0.25Ω*id max. (TBD)	
10	PSE output resistance [10]	0.25+0.1 Ohm min, 0.25+0.2 Ohm max	0.1+0.05 Ohm min, 0.1+0.1 Ohm max

Ad-hoc response, June 24, 2014. Adhoc accept this table

Source: Yair Darshan, Christian Beia, Wayne Larsen

Annex G2: Worst case data base- Notes. -2

1	Per standard. It is maximum value for solid and stranded wire. The maximum value is close to AWG#26 wire resistance/meter including twist rate effects. **See annex E1.** Due to the fact that patch cords may use AWG#24 cables with stranded (for mechanical flexibility) or solid wire (for improved performance), we will use the AWG#24A for worst case analysis as well. Cordage with AWG#24 wire has 0.0842Ω/m for solid wire and with 10% twist rate it will be 0.09262 Ω/m.
2	We need both data sets (data set 1 and data set 2) to find where is the worst condition for maximum current unbalance. **See Annex B curve and data** showing that at short channel we get maximum P2PRUNB but it may has less concern to us since the current is lower. We need to do all use cases calculation to see where is the maximum current over the pair; at short channel or long channel. The CAT6A cable with AWG#23 has 0.066 Ω/m. Including 12% increase on cable length due to twist rate, the effective cable resistance per meter will be 1.12*6.6 Ω/100m= 0.0792 Ω/m.
3	Standard definition per Annex E1. We will check how results will be differ when AWG#23 is used for worst case results (lower resistance than standard definition for horizontal cable which is a maximum value.
4	
5	
6	PSE PI and PD PI includes: connector, transformer, resistors. PD PI includes diode bridge.
7	
8	Connector resistance was changed since the difference (60-30) milliohm is not representing Rdiff, it is representing maximum and minimum results of connector resistance of different connectors. To correct it, we change the numbers according to inputs from connector vendors and measured data. See Annex E1-E6 for confirmation.
9	Vf and Rd are worst case numbers of discrete diode which there is no control on Vf and Rd. It needs more investigation to verify that we are not over specify. (Christian is checking it). Normally match components (e.g. matched two diode bridges) are used for 4P operation. Any how ,PD PI spec. will eventually set the requirement.
10	PSE output resistance e.g. Rs_a/b=Rsense+Rdson in addition to winding resistance. See model I Annex F for reference.

Adhoc response, June 24, 2014. Adhoc accept this table

Source: Yair Darshan and Christian Beia

Annex G3: Deciding on Channel components data

Connector data combinations that don't make sense.				
#	Rmax milliΩ	Rdif milliΩ	Rmin milliΩ	Notes
1	201	-	-	200milliΩ max, standard
2	-	51	-	50milliΩ max, standard
3	60	50	10	Meets the standard however doesn't make sense to have 71.4% P2PRUNB.
4	61	-	-	Field results, 60milliΩ max
5	-	30	-	Field results, 20milliΩ max
Connector data combinations that make sense.				
6	60	20	40	OK
7	50	20	30	OK for worst case.

- Connector vendors: connector resistance rage of different connectors for worst case lowest numbers: 0.03Ω to 0.06 Ω. (Standard is 200milliohm max and Rdiff=50milliohm max which is not helping us).
- With in a connector (pin to pin or pair to pair), the difference between Rmax and Rmin (=Rdiff) is 0.02Ωmax, Typically it is not more than 0.015Ω. (instead 0.03Ω).
- As a result, for worst case calculation we will use for connectors:
  - Connector Rmax=0.05Ω, Connector Rdiff=0.02Ω max.
- Cordage: 0.14 Ω/m per standard. Cable: 0.0792Ω/m for CAT6A AWG#23 cable for worst case analysis.

Adhoc response, June 24, 2014. Adhoc accept this table

Source: Yair Darshan

Annex G4: Minimum resistance existing in PSE and PD Pis, Example based on Annex G1 database.

- Calculating existing minimum resistance in PSE and PD PI.

All numbers calculated for a pair = two wires in parallel.

	PSE PI minimum resistance range		
	Max	Min	
Connectors	0.015	0.015	0.03 ohm per connector divided by 2
Diodes	0.25	0	If AC disconnect then higher e.g. 0.25 ohm
Transformers	0.06	0	For 1000BT and up, otherwise 0. transformer winding from center tap to outer leg=0.12ohm/2
EMI Filters	0.1	0.1	
PCB traces	0.01	0.01	
Total	0.435	0.125	

	PD PI minimum resistance range		
	Max	Min	
Connectors	0.015	0.015	0.03 ohm per connector divided by 2
Diodes	0.25	0.05	If active diodes are used (Mosfets) the resistance is lower (*)
Transformers	0.06	0	For 1000BT and up, otherwise 0. transformer winding from center tap to outer leg=0.12ohm/2
EMI Filters	0.1	0.1	
PCB traces	0.01	0.01	
Total	0.435	0.175	

Total minimimum PSE and PD resistance per pair	0.125	+	0.175	=	0.3

Source: Yair Darshan

Annex J1-Acronyms used in the ad-hoc activity

- **(1) Pair resistance unbalance :** Is the resistance unbalance between two wires in the same pair as specified by IEEE802.3 and other standards. This is 2% for cable and 3% maximum for the channel. Channel is a 4 connector model (cables and connector only).
- **(2) Pair to Pair resistance unbalance**: is the resistance unbalance between two wires of the same pair connected in parallel to another two wires of other pair connected in parallel. It is 5% for a cable.

(The resistance of the two wires of the pair is know also as the common mode resistance of the pair)

- **(3) End to End channel pair to pair resistance unbalance** it is the 26.2% (TBD) worst case calculation on a worst case data base that we have generated. The 26.2% (TBD) was calculated at 20degC. The channel is including components at PSE PI and PD PI that affects the whole end to end channel.
- **(4) PSE PI Pair to Pair resistance unbalance** is the P2P DC Common Mode PSE Output Resistance Unbalance measured at the PSE PI and include PI interface circuitry such RDSON, Current sense resistor, equipment connector, magnetic winding resistance. This is included in the " end to end channel resistance unbalance" and need to be extracted from it to be separate definition for PSE PI P2PRUNB.
- (4.1) PSI PI Pair to Pair voltage difference is the P2P DC Common Mode PSE Output Voltage Difference measured at the PSE PI under TBD conditions.

Source: Yair Darshan

- End to End Channel Pair To Pair Resistance Imbalance Ad Hoc rev 013. Yair Darshan, July 2014

Annex J2-Acronyms used in the ad-hoc activity

- **(5) PD PI Pair to Pair resistance unbalance** is the P2P DC Common Mode PD input Resistance Unbalance measured at the PD PI and include PI interface circuitry such Diode bridge voltage offset and dynamic resistance, equipment connector, magnetic winding resistance. This is included in the "end to end channel resistance unbalance" and need to be extracted from it to be separate definition for PD PI P2PRUNB.
- **(5.1) PD PI Pair to Pair voltage difference** is the P2P DC Common Mode PD input Voltage Difference measured at the PD PI under TBD conditions.
- **(6) Channel Pair to Pair resistance unbalance** is the P2P resistance unbalance of the cables and 4 connector model. This need to be excreted from the " end to end channel resistance unbalance" and specified separately.
- So (PSE PI +Channel + PD PI)p2prunb all together is 26.2% (TBD).
- Items 4,5 and 6 will be specified in the standard, (item 2 is covered by item 6).
- Meeting #4: Adhoc response: ok. Meeting #5: To discuss changes in RED. Done.

Source: Yair Darshan

Annex K:Same-Pair Current Unbalance vs. DC bias on Transformers

- Source: Dinh, Thuyen, Pulse.

- Current unbalance on cable pair: $\Delta I = I_1 - I_2$
- This ΔI is the net current difference between the 2 half windings of the cable side of the transformer, it only flows in one of the 2 half windings
- Since transformers are tested with bias current injected through both windings, as specified in clause 25 (sub-clause 9.1.7 of ANSI X3:263:199X), a DC bias of ($\Delta I/2$) injected into both windings will produce the same DC flux as that produced by ΔI flowing through one half winding.
- Transformers are, therefore, tested with ($\Delta I/2$) DC bias current to simulate current unbalance of ΔI.

Annex L1: What are the options for complete specification for unbalance PSE PI and PD PI models parameters

Source: Yair Darshan. June 25, 2014

- Current unbalance is a function of Voltage unbalance and resistance unbalance between pairs.
  - These are the only parameters that affect the current unbalance and as a result the maximum pair current due to the unbalance situation.
- For simplicity let's assume Voltage unbalance is zero. We will address the effect of Voltage difference later.
- By definition, the current unbalance between any two pairs is:

$$Idiff = |I_1 - I_2| = It \cdot \frac{\sum R_{max}}{\sum R_{max} + \sum R_{min}} - It \cdot \frac{\sum R_{min}}{\sum R_{max} + \sum R_{min}} = It \cdot \left(\frac{\sum R_{max} - \sum R_{min}}{\sum R_{max} + \sum R_{min}} \right)$$

$$\frac{Idiff}{It} = \left(\frac{\sum R_{max} - \sum R_{min}}{\sum R_{max} + \sum R_{min}} \right) = Runb = Iunb$$

Drawing

- Since we are discussing P2P unbalance the Runb and Iunb is between Pair to Pair and the sum of R1 and the sum of R2 represents two wires in parallel including all components connected to each wire.
- The above equations are the same for PSE PI, Channel and PD PI unbalance. The difference is the content of R1 and R2 e.g. for channel it is just cables and connectors. For PSE and PD PIs it contains additional other components such MOSFETs, Diodes, Transformers etc.

Annex L2: What are the options for complete specification for unbalance PSE PI and PD PI models parameters

- The maximum pair current is function of the total End to End Channel Resistance and Voltage Unbalance.
- The PSE PI and PD PI are affecting Imax at short and long channels.
- By definition for maximum pair current Imax as function of P2PRUNB and P2P Voltage Difference of the system from end to end:

$$\mathrm{Im}\,ax = \frac{It}{2} + \frac{It \cdot E2E\_P2PRUNB}{2} = \frac{It \cdot (1 + E2E\_P2PRUNB)}{2}$$

$$\mathrm{Im}\,ax = \frac{It \cdot (1 + E2E\_P2PRUNB)}{2} = \frac{It \cdot \left[1 + \left(\frac{\left(\sum \frac{PSE}{R_{\max}} - \sum \frac{PSE}{R_{\min}}\right) + \left(\sum \frac{PD}{R_{\max}} - \sum \frac{PD}{R_{\min}}\right) + \left(\sum \frac{CH}{R_{\max}} - \sum \frac{CH}{R_{\min}}\right)}{\sum \frac{PSE}{R_{\max}} + \sum \frac{PD}{R_{\max}} + \sum \frac{CH}{R_{\max}} + \sum \frac{PSE}{R_{\min}} + \sum \frac{PD}{R_{\min}} + \sum \frac{CH}{R_{\min}}} \right)\right]}{2}$$

$$\mathrm{Im}\,ax = \frac{It \cdot (1 + E2E\_P2PRUNB)}{2} = \frac{It \cdot \left[1 + \left(\frac{\sum \frac{PSE}{R_{diff}} + \sum \frac{PD}{R_{diff}} + \sum \frac{CH}{R_{diff}}}{\sum \frac{PSE}{R_{\max}} + \sum \frac{PD}{R_{\max}} + \sum \frac{CH}{R_{\max}} + \sum \frac{PSE}{R_{\min}} + \sum \frac{PD}{R_{\min}} + \sum \frac{CH}{R_{\min}}} \right)\right]}{2}$$

- **The PSE PI P2PRUNB can be defined in similar way by similarity.**
- Note: PSE PI P2PRUNB is not equal to E2E_CPWPRUNB nor to PD PI P2PRUN. It requires additional mathematical procedure to find this parameters so it will be equal to the E2E_CP2PRUNB target.

Source: Yair Darshan

Annex L3: What are the options for complete specification for unbalance PSE PI and PD PI models parameters

- We can see that Imax is function of Rmax and Rmin and Rdiff=Rmax-Rmin

$$\mathrm{Im}\,ax = \frac{It \cdot (1 + E2E\_P2PRUNB)}{2} = \frac{It \cdot \left[1 + \left(\frac{\sum_{R_{diff}}^{PSE} + \sum_{R_{diff}}^{PD} + \sum_{R_{diff}}^{CH}}{\sum_{R_{\max}}^{PSE} + \sum_{R_{\max}}^{PD} + \sum_{R_{\max}}^{CH} + \sum_{R_{\min}}^{PSE} + \sum_{R_{\min}}^{PD} + \sum_{R_{\min}}^{CH}} \right) \right]}{2}$$

- From the above, PSE PI P2PRUNB upper limit can be extracted and it will have the same effect on Imax with the same exact concept.

$$PSE\_PI\_P2PRUNB = \frac{\sum_{R_{diff}}^{PSE}}{\sum_{R_{\max}}^{PSE} + \sum_{R_{\max}}^{PD} + \sum_{R_{\max}}^{CH} + \sum_{R_{\min}}^{PSE} + \sum_{R_{\min}}^{PD} + \sum_{R_{\min}}^{CH}}$$

$$PSE\_PI\_P2PRUNB = \frac{(k+\alpha) \cdot \sum_{R_{diff}}^{PSE}}{\sum_{R_{\max}}^{PSE} + \sum_{R_{\min}}^{PSE} + \beta} = \frac{\sum_{R_{diff\_new}}^{PSE}}{\sum_{R_{\max\_new}}^{PSE} + \sum_{R_{\min\_new}}^{PSE}}$$

- The terms k, a and b are used to transform the true PSE PI P2PRUNB to PSE PI P2PRUNB as stand alone function.
- Now we can see what are the necessary unbalanced properties that are needed to uniquely specify the PSE PI?

Source: Yair Darshan

Annex L4: What are the options for complete specification for unbalance PSE PI and PD PI models parameters

$$PSE\_PI\_P2PRUNB = \frac{\sum PSE\ R_{diff\_new}}{\sum PSE\ R_{\max\_new} + \sum PSE\ R_{\min\_new}} = \frac{\sum PSE\ R_{\max\_new} - \sum PSE\ R_{\min\_new}}{\sum PSE\ R_{\max\_new} + \sum PSE\ R_{\min\_new}}$$

$$\mathrm{Im}ax = 0.5 \cdot It \cdot \left(1 + \frac{\sum PSE\ R_{diff\_new}}{\sum PSE\ R_{\max\_new} + \sum PSE\ R_{\min\_new}}\right)$$

- Conclusions: In order to limit Imax_pair you must have in addition to voltage difference and maximum load current It, two additional parameters.
- Firs and fast observation: Imax is equation with 3 parameters. Total current, It is given. We need two variable to solve equation with two parameters
- So specifying only Rdiff and Vdiff for PSE PI or PD PI will not work. It leads to interoperability issues. (one parameter is loose..)

Source: Yair Darshan

Annex L5: What are the options for complete specification for unbalance PSE PI and PD PI models parameters

- Imax is direct function of PSE PI RUNB and Channel and PD parts.
- The transformed PSE_PI_P2PRUNB_new control Imax.

$$\mathrm{Im}\,ax = 0.5 \cdot It \cdot \left(1 + PSE\_PI\_P2PRUNB\_new\right) = 0.5 \cdot It \cdot \left(1 + \frac{\sum R_{diff\_new}^{PSE}}{\sum R_{\max\_new}^{PSE} + \sum R_{\min\_new}^{PSE}}\right)$$

- If we specify PSE PI by only Rdiff and Vdiff we will have the following interoperability issues:

- Examples:
- Rdiff=Rmax-Rmin=0.2=X:
  - P2PRUNB=(0.2-0)/(0.2+0)=100%
  - P2PRUNB=(0.23-0.03)/(0.23+0.03)=77%
  - P2PRUNB=(0.3-0.1)/(0.3+0.1)=50%
  - P2PRUNB=(1-0.8)/(1+0.8)=11%

Interoperability Issue:
Different UNBALANCE
For the same Rdiff resulting
With different Imax for the
Same channel and PD

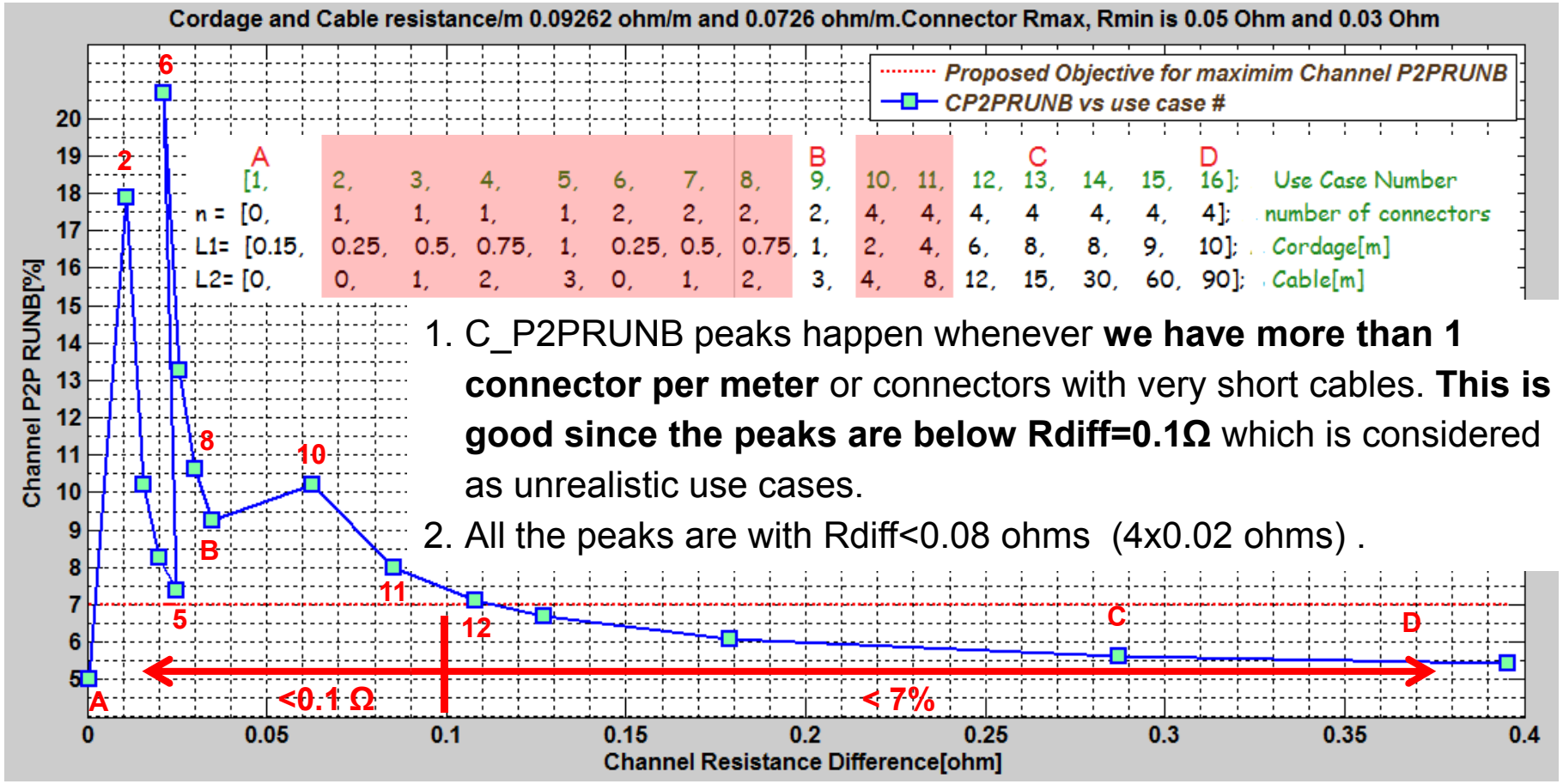
Source: Yair Darshan

Annex L6: What are the options for complete specification for unbalance PSE PI and PD PI models parameters

Source: Yair Darshan

Option	PSE PI P2PRUNB	Rmax	Rmin	Rdiff	Notes
1	Yes	-	-	-	1. Ratio. Fully implementation independent . 2. Need two parameter to solve equation with two variables. Need more research to verify completeness.
2	-	Yes	Yes	-	1. Complete solution. 2. Not flexible, Implementation dependent.
3	Yes	Yes			1. Complete solution. 2. Not flexible, Implementation dependent. Problem to limit Rmax
4	Yes	No	Yes	-	1. Complete solution. 2. Rmin is exists any way. 3. Not fully Implementation in dependent but tolerable.
5	Yes	NO	NO	YES	1. Complete solution. 2. Implementation dependent.
6	NO	NO	NO	YES	1. Not complete 2. Implementation dependent 3. Interoperability issues

Annex L7: Why Channel Rdiff=Delta R is not sufficient to define channel unbalance.



1. C_P2PRUNB peaks happen whenever **we have more than 1 connector per meter** or connectors with very short cables. **This is good since the peaks are below Rdiff=0.1Ω** which is considered as unrealistic use cases.
2. All the peaks are with Rdiff<0.08 ohms (4x0.02 ohms) .

- The mathematical basics are the same as explained for PSE and PD PIs. See Annex L1-L6 for details. In the channel it is further more obvious per next slide.

Source: Yair Darshan

Annex L8: Why Channel Rdiff=Delta R is not sufficient to define channel unbalance.

- If we will specify Channel P2P RUNB by its Rmax-Rmin=Rdiff=0.1Ω (or any number) property only we will end with the following undesired results:
- (a) At long channel (high resistance) the unbalance is converging to lowest possible value. It is bounded by the P2PRUNB[%] property which is much lower than the connectors unbalance property.
- (b) At short channel when resistance is low, the P2PRUNB property is bounded by the connectors Rmax, Rmin which results with 25% unbalance for Rmax=0.05Ω, Rmin=0.03Ω ➔ Rdiff=0.02 Ω ➔ (50-30)/(50+30)=25%

- So it is obvious that best and optimized performance will be achieved with two properties needed for the channel: P2PRUNB and Rdiff.

Source: Yair Darshan

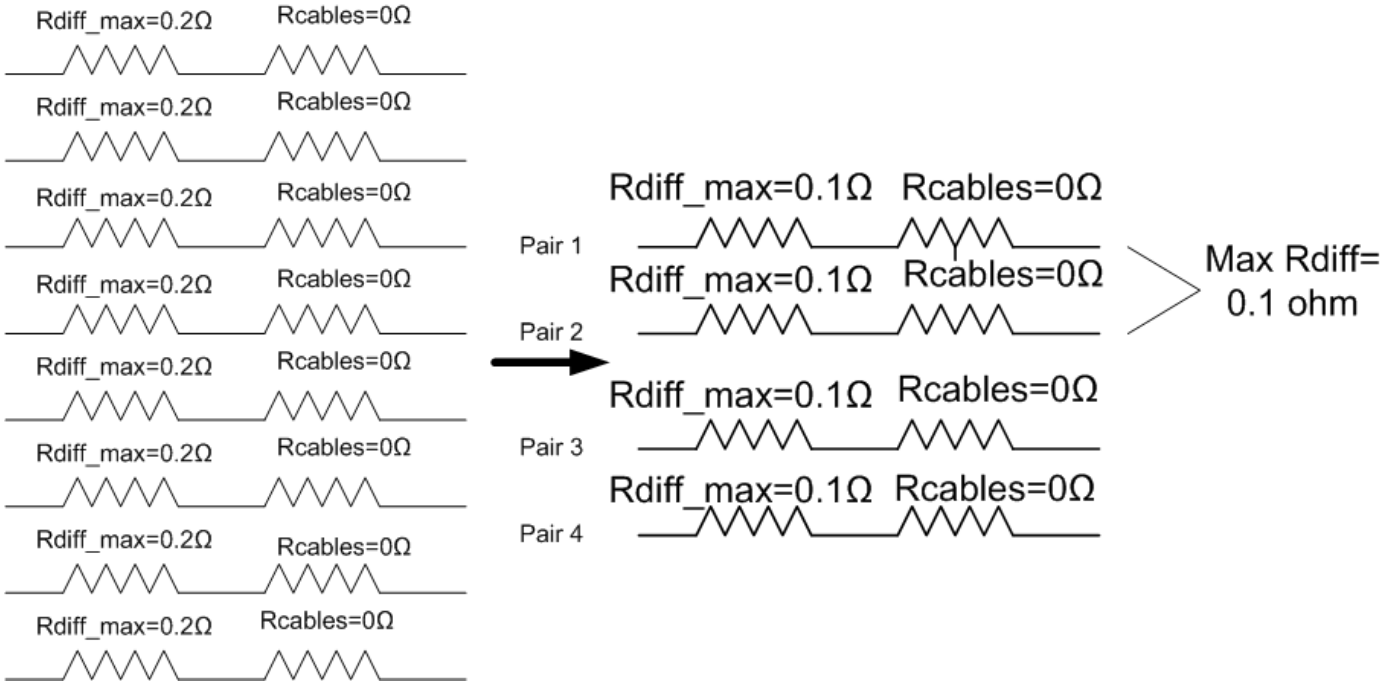
Annex M: How we address P2PRUNB vs Temperature

- Adhoc has recommended the following approach (meetings 5,6,7)
  - How to handle PSE PI, PD PI Pair to Pair unbalance parameters and Channel P2RUNB as function of temperature?
    - Adhoc response:
    - Use PSE PI, PD PI pair to pair Unbalance parameters and Channel P2PRUNB that was calculated at 20°.
    - Set it as the number to meet without saying at what temperature it is.
    - Vendors will have to assure that they meet it at their operating temperature range spec.
    - How they will do it, we don't care. The rest is per 33.7.7.

Ad-hoc response, June 10, 2014. Ad hoc agrees to set temperature of P2PUNB numbers at 20degC.

Annex P: The value of channel maximum Rdiff

- On May 2014 we vote for the following base line text highlighting the TBD areas.
  33.1.4.3 Channel Requirement for Pair to Pair Resistance unbalance
  4P pair operation requires the specification of resistance unbalance between each two pairs of the channel, not greater than 200 milliohms or 6%(TBD) which ever is greater. Resistance unbalance between the channel pairs is a measure of the difference of resistance of the common mode pairs of conductors used for power delivery. Channel pair to pair resistance unbalance is defined by ….."
- The 200milliohm above should be 0.1Ω. Why?. Connector max Rdiff= 0.05Ω. 4 connectors is 4*0.05Ω=0.2Ω on each Wire. As a result, a pair is two connectors in parallel ➔ 0.1Ω
  - Connector maximum resistance is 0.2Ω and is not related to the discussion here which is pair to pair resistance difference.



Source: Yair Darshan.
Confirmed by Wayne Larsen

Annex P1: Channel P2PRUNB at Rdiff point

- Channel only Equation:

$$C\_P2PRUNB = \left(\frac{\sum R_{\max} - \sum R_{\min}}{\sum R_{\max} + \sum R_{\min}} \right) =$$

$$= \left(\frac{0.5 \cdot \left(L1 \cdot \rho_1 + L2 \cdot \rho_2 + N \cdot Rc \right)_{\max} - 0.5 \cdot \left(L1 \cdot \rho_1 + L2 \cdot \rho_2 + N \cdot Rc \right)_{\min}}{0.5 \cdot \left(L1 \cdot \rho_1 + L2 \cdot \rho_2 + N \cdot Rc \right)_{\max} + 0.5 \cdot \left(L1 \cdot \rho_1 + L2 \cdot \rho_2 + N \cdot Rc \right)_{\min}} \right)$$

- The factor 0.5 was left intentionally.
- When L1+L2 approaching to zero:

$$C\_P2PRUNB = \left(\frac{0.5 \cdot \left(N \cdot Rc_{\max} - N \cdot Rc_{\min} \right)}{0.5 \cdot \left(N \cdot Rc_{\max} + N \cdot Rc_{\min} \right)} \right) =$$

$$= \left(\frac{0.5 \cdot N \cdot Rdiff}{0.5 \cdot \left(N \cdot Rc_{\max} + N \cdot Rc_{\min} \right)} \right) = 25\% \max$$

For Rc_min=0.03Ω and Rc_diff=0.02 Ω
Rdiff_max for channel: 0.1Ω

Source : Yair Darshan

Annex P2: Channel P2PRUNB at Rdiff point

$$C\_P2PRUNB = \left(\frac{0.5 \cdot N \cdot Rc_{\max} - 0.5 \cdot N \cdot Rc_{\min}}{0.5 \cdot \left(N \cdot Rc_{\max} + N \cdot Rc_{\min} \right)} \right) = \left(\frac{0.5 \cdot C\_Rdiff\_\max}{0.5 \cdot \left(N \cdot Rc_{\max} + N \cdot Rc_{\min} \right)} \right)$$

- Looking at the above equation:
- For C_P2PRUNB, as a parameter that specify the channel behavior, the number of connectors became irrelevant:

$$C\_P2PRUNB = \frac{\left(Rc_{\max} - Rc_{\min} \right)}{\left(Rc_{\max} + Rc_{\min} \right)}$$

Ratio ➔ Implementation independent

- However for Rdiff it is relevant:

$$C\_P2PRUNB = \left(\frac{0.5 \cdot C\_Rdiff\_\max}{0.5 \cdot \left(N \cdot Rc_{\max} + N \cdot Rc_{\min} \right)} \right)$$

$$C\_Rdiff = 0.5 \cdot N \cdot \left(Rc_{\max} - Rc_{\min} \right) =$$

$$= 0.5 \cdot N \cdot Conn\_Rdiff\_\max$$

ABS number ➔ Implementation dependent

Source : Yair Darshan

Annex P3: Channel P2PRUNB at Rdiff point

Complete Channel specification:

- (Complete specification is like defining the behavior of equation for its entire operating range and as close as possible to implementation independent)
- For $C\_Rdiff > 0.5 \cdot N \cdot Conn\_Rdiff\_\max = 0.1\Omega$

$$C\_P2PRUNB = \left(\frac{\left(L1 \cdot \rho_1 + L2 \cdot \rho_2 + N \cdot Rc\right)_{\max} - \left(L1 \cdot \rho_1 + L2 \cdot \rho_2 + N \cdot Rc\right)_{\min}}{\left(L1 \cdot \rho_1 + L2 \cdot \rho_2 + N \cdot Rc\right)_{\max} + \left(L1 \cdot \rho_1 + L2 \cdot \rho_2 + N \cdot Rc\right)_{\min}} \right) = 7.5\% \max$$

- For $C\_Rdiff \le 0.5 \cdot N \cdot Conn\_Rdiff\_\max = 0.1\Omega$

$$C\_Rdiff\_\max = 0.5 \cdot N \cdot Conn\_Rdiff\_\max = 0.1\Omega$$

$$C\_P2PRUNB\_\max = \frac{\left(Rc_{\max} - Rc_{\min}\right)}{\left(Rc_{\max} + Rc_{\min}\right)} = 25\%$$

Which ever is greater

Numbers are based on worst case data base numbers

Source : Yair Darshan

Annex Q: Channel Rmin vs. Channel P2PRUNB and number of connectors

$$Channel\_P2PRUNB = \alpha$$

$$Cable\_P2PRUNB = \beta$$

$$Rcable\_\min = R_{\min}$$

$$Rcable\_\max = R_{\max} = R_{\min} \cdot \frac{(1+\beta)}{(1-\beta)} = R_{\min} \cdot \delta$$

$$\alpha = \frac{\left(R_{\max} + N \cdot Rc_{\max}\right) - \left(R_{\min} + N \cdot Rc_{\min}\right)}{R_{\max} + N \cdot Rc_{\max} + R_{\min} + N \cdot Rc_{\min}} =$$

$$\alpha = \frac{N \cdot \left(Rc_{\max} - Rc_{\min}\right) + R_{\min} \cdot (\delta - 1)}{N \cdot \left(Rc_{\max} + Rc_{\min}\right) + R_{\min} \cdot (\delta + 1)} =$$

$$\alpha \cdot \left(N \cdot \left(Rc_{\max} + Rc_{\min}\right) + R_{\min} \cdot (\delta + 1)\right) = N \cdot \left(Rc_{\max} - Rc_{\min}\right) + R_{\min} \cdot (\delta - 1)$$

$$\alpha \cdot N \cdot \left(Rc_{\max} + Rc_{\min}\right) + \alpha \cdot R_{\min} \cdot (\delta + 1) = N \cdot \left(Rc_{\max} - Rc_{\min}\right) + R_{\min} \cdot (\delta - 1)$$

$$\alpha \cdot R_{\min} \cdot (\delta + 1) - R_{\min} \cdot (\delta - 1) = N \cdot \left(Rc_{\max} - Rc_{\min}\right) - \alpha \cdot N \cdot \left(Rc_{\max} + Rc_{\min}\right)$$

$$R_{\min} \cdot \left(\alpha \cdot (\delta + 1) - (\delta - 1)\right) = N \cdot \left(Rc_{\max} - Rc_{\min}\right) - \alpha \cdot N \cdot \left(Rc_{\max} + Rc_{\min}\right)$$

$$R_{\min} = \frac{N \cdot \left(Rc_{\max} - Rc_{\min}\right) - \alpha \cdot N \cdot \left(Rc_{\max} + Rc_{\min}\right)}{\alpha \cdot (\delta + 1) - (\delta - 1)}$$

Source : Yair Darshan.
Verified by analytical solution and simulations

- Rmin is given as round loop value.
- Rc_max=0.05 ,Rc_min=0.03, β=Cable_P2PRUNB=5%
- Channel_P2PRUNB=α=7% as an example.

$$R_{\min} = \frac{N \cdot \left(Rc_{\max} - Rc_{\min}\right) - \alpha \cdot N \cdot \left(Rc_{\max} + Rc_{\min}\right)}{\alpha \cdot (\delta + 1) - (\delta - 1)}$$

n	Rcable min [ohm]	Channel Runb
0	Any	5.00%
1	0.342	7.00%
2	0.684	7.00%
3	1.026	7.00%
4	1.368	7.00%

Pair resistance is half the value

Last meetings material

Meeting # 8 Attendees (June 24, 2014)

- Please send email after the meeting to confirm your attendance.

Larsen, Wayne / Commscope
Jeff Heath / LT
Brian Buckmeier / BEL
Sterling Vaden / charter.net
Koussalya Balasubramanian / Cisco
David Tremblay / HP
David Abramson / TI
Rimboim Pavlik / Microsemi
Yair Darshan / Microsemi
Ken Bennett / Sifos
Victor Renteria / BEL
Gaoling Zou / Maxim
Robert Wagner/ Panduit
Tobias Greulich

Meeting # 7 Attendees (June 10, 2014)

Meeting # 7

Jeff Heath / LT
Brian Buckmeier / BEL
David Abramson / TI
Rimboim Pavlik / Microsemi
Yair Darshan / Microsemi
Ken Bennett / Sifos
Victor Renteria / BEL
Gaoling Zou / Maxim

If you attend meeting #7 on June 10, 2014, please verify your name is recorded.

PSE PI Model

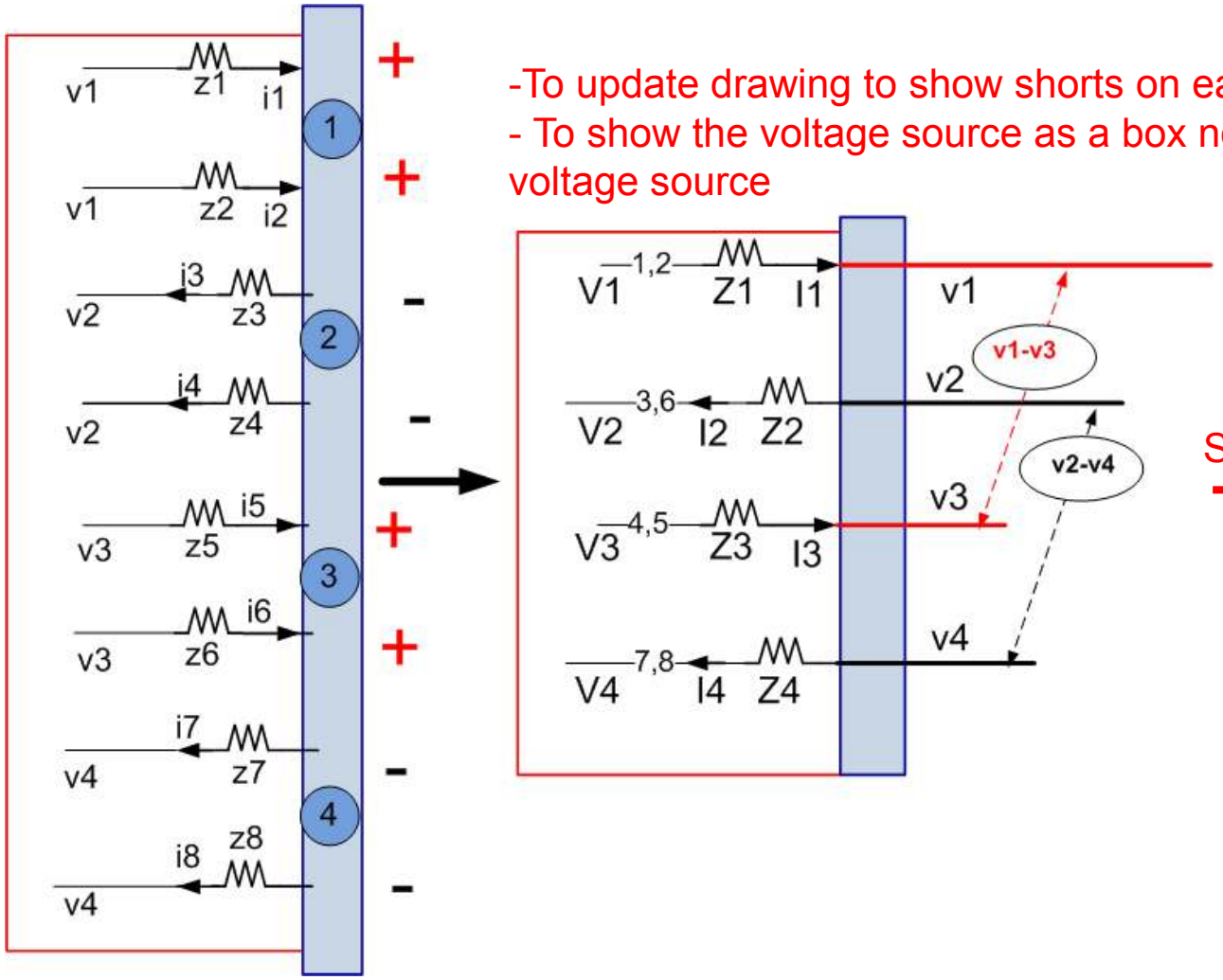
- **PSE PI affects the End to End Channel P2P resistance unbalance and as a result, the current unbalance.**
  - It is resulted from:
    - The PSE PI pair output resistance and
    - The PSE PI pair to pair output resistance unbalance and
    - The PSE PI pair to pair output open voltage difference.

- **The objectives are:**
  - How to specify the PI unbalance parameters?
  - How to test it

- **The difficulties to resolve:**
  - PSE PI unbalance parameter as stand alone parameter, has value to our research.
    - Different resistance, P2PRUNB and voltage unbalance will result with different results
    - Limiting resistance to minimum or maximum value doesn't make sense since it limits implementations e.g more dissipative ,less dissipative interfaces, where to locate control circuitry and how many pairs current to sense and control etc.
  - The value of this parameter became apparent when connected to a channel and to a PD with specified maximum resistance unbalance and current unbalanced. .

Source: Yair Darshan.

PSE PI model derivation–implementation independent approach -1



-To update drawing to show shorts on each pair output.
- To show the voltage source as a box not as a single or dual voltage source

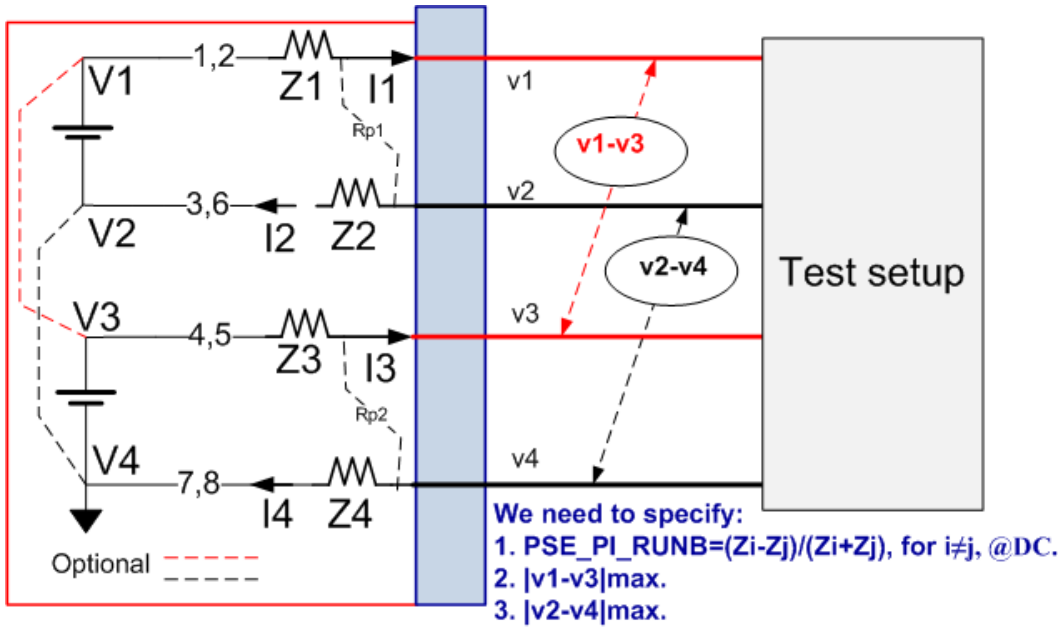
Simplifying on next slide

Source: Yair Darshan.

Requirement Derivation – 1 (To update drawing per previous comments)

- By definition:
- I1=(V1-v1)/Z1 ➔ Z1=(V1-v1)/I1
- I2=(V2-v2)/Z2 ➔ Z2=(V2-v2)/I2
- I3=(V3-v3)/Z3 ➔ Z3=(V3-v3)/I3
- I4=(V4-v4)/Z4 ➔ Z4=(V4-v4)/I4

- By definition:
- P2P PSE PI Zunbalance=



In one typical application: V1=V3, V2=V4=0.
As a result, open load voltages: v1-v3➔ 0, v2-v4 ➔ 0

$$= \frac{Z_i - Z_j}{Z_i + Z_j} = \frac{\frac{V_i}{I_i} - \frac{V_j}{I_j}}{\frac{V_i}{I_i} + \frac{V_j}{I_j}} = TBD\max$$

Between any two pairs i≠j .

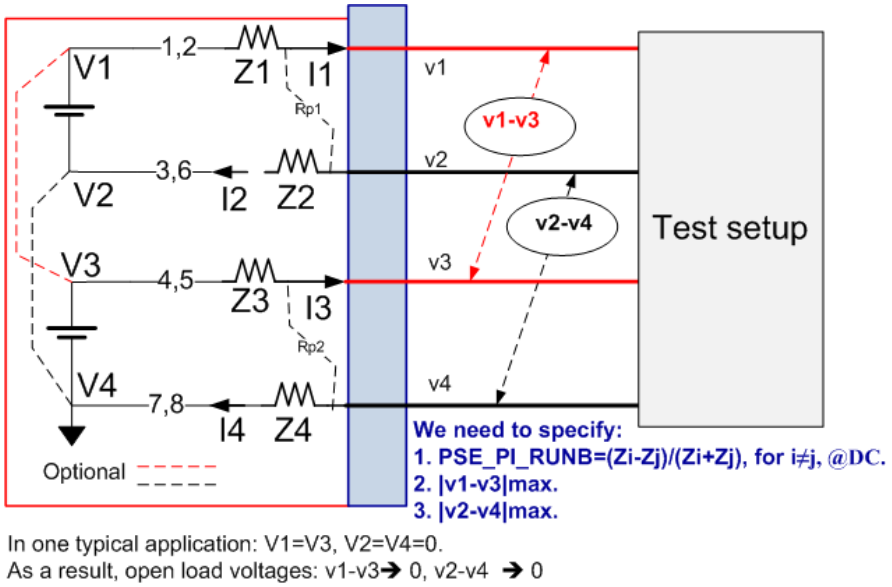
Source: Yair Darshan.

Requirement Derivation – 2 (To update drawing per previous comments)

- P2P PSE PI Zunbalance=

$$= \frac{Z_i - Z_j}{Z_i + Z_j} = \frac{\frac{V_i - v}{I_i} - \frac{V_j - v}{I_j}}{\frac{V_i - v}{I_i} + \frac{V_j - v}{I_j}} = TBD \max$$

Between any two pairs i≠j.
Since we need Z in DC ➔ Z➔R



In one typical application: V1=V3, V2=V4=0.
As a result, open load voltages: v1-v3➔ 0, v2-v4 ➔ 0

$$(1)\ \frac{Z_i - Z_j}{Z_i + Z_j} = \frac{R_i - R_j}{R_i + R_j} = P2PRUNB \max,$$

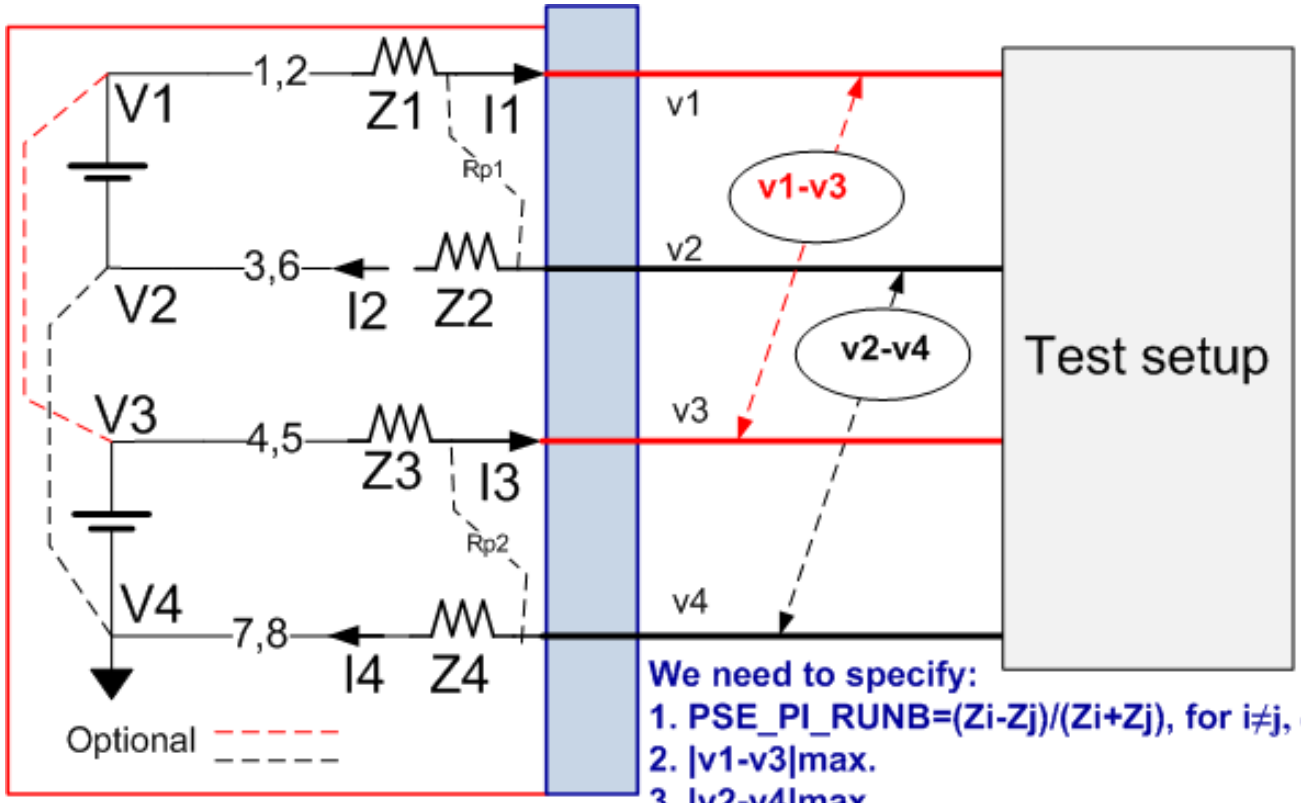
$$(2)\ \left|v_1 - v_3\right| < TBD$$

$$(3)\ \left|v_2 - v_4\right| < TBD$$

Ri is function of Vi/Ii which addresses non linear circuitry at worst case unbalance operating point defined by PSE vendor.

Source: Yair Darshan.

PSE PI P2P model concept -3 (update drawing)



Source: Yair Darshan.

In one typical application: V1=V3, V2=V4=0.
As a result, open load voltages: v1-v3➔ 0, v2-v4 ➔ 0

- In the test setup, it is possible to find P2PRUNB by measuring currents at PSE normal powering state. But this is test setup implementation issue and not part of the specification. The spec defines Voltage and Resistance to maintain implementation independent specifications.

PSE PI P2P model concept -4 (To Update)

- Part A:
- Specifying PSE P2P_R_UNB and PSE_P2P Voltage Difference
  - PSE P2P Voltage difference at no load condition.
    - Voltage difference between the two positive voltage rails
    - Voltage difference between the two negative voltage rails
  - P2P_R_UNB, will be single number, maximum number.

- Part B:
- Defining test model and test conditions.

- Ad hoc response: TBD

Source: Yair Darshan.

PSE PI P2P model concept -5

- Proposed base line text:
- **33.1.4.xx Type 3 and Type 4 PSE PI Requirement for Pair to Pair unbalance**
- 4P pair operation requires the specification of resistance unbalance between each two pairs of the PSE PI, not greater than TBD milliOhms or TBD% which ever is greater. The resistance unbalance requirements between each two pairs of the PSE PI shall be met for a maximum voltage difference TBDmVdc between the two positive pairs and between the two negative pairs. The Resistance unbalance between the PSE PI pairs is a measure of the difference of resistance of the common mode pairs of conductors used for power delivery. See figure TBD for PSE PI model. PSE PI pair to pair resistance unbalance is defined by equation 33-1.XX:

- **Insert Equation here that ties Resistance and voltage unbalance together or other description TBD.**
- Equation TBD 33-1.xxx

Where:

Rpse_max is the sum of PSE PI pair elements with highest common mode resistance.

Rpse_min is the sum of PSE PI pair elements with lowest common mode resistance

Common mode resistance is the resistance of the elements over each PSE PI wires in the PI pair connected in parallel.

Source: Yair Darshan.

PD PI P2P model concept

- TBD
- Looking for volunteers to do it.

Meeting # 6 Attendees (Thursday May 15, 2014)

- Gaoling Zou / Maxim
- Christian BEIA / ST
- David Tremblay / HP
- Yair Darshan / Microsemi
- George Zimmerman/ CME Consulting, Affiliations: Commscope & Aquantia
- Peter Johnson / Sifos
- Rick Frosch / Phihong
- Yan Zhuang / Huawei
- Larsen, Wayne / Commscope
- Jeff Heath / LT
- Dave Dwelley / LT
- Fred Schindler / Seen Simply
- David Abramson / TI
- Rimboim Pavlik / Microsemi
- Victor Renteria / BEL
- Dave Dwelley / LT
- Heat Stuart / LT
- Sterling Vaden /
- Fred Dawson / duPont
- Shahar Feldman / Microsemi
- Wendt, Matthias / Philips
- Picard Jean / TI
- Lennart Yseboodt / Philips

Adhoc report May 15, 2014 Norfolk VA.

- 18 attendees
- Topics discussed:
  - How to handle PSE PI, PD PI Pair to Pair unbalance parameters and Channel P2RUNB as function of temperature?
    - Adhoc response:
    - Use PSE PI, PD PI pair to pair Unbalance parameters and Channel P2PRUNB that was calculated at 20°C (or pick a number at other temperature).
    - Set it as the number to meet without saying at what temperature it is.
    - Vendors will have to assure that they meet it at their operating temperature range spec.
    - How they will do it, we don't care. The rest is per 33.7.7.
  - Two motions to specify Channel P2PRUNB and its base line text
    - Adhoc proposed the following two motions:
- Motion #1:
  - Move that 802.3bt specify the Channel Pair to Pair resistance unbalance for operating 4P systems

Motion #2. Motion to add the following text to clause 33 after 33.1.4.2.

- **33.1.4.3 Type 3 and Type 4 Channel Requirement for Pair to Pair Resistance unbalance**
- 4P pair operation requires the specification of resistance unbalance between each two pairs of the channel, not greater than 200 milliOhms or 6%(TBD) which ever is greater. Resistance unbalance between the channel pairs is a measure of the difference of resistance of the common mode pairs of conductors used for power delivery. Channel pair to pair resistance unbalance is defined by equation 33-1.1:
- $$\left\{\frac{\left(R_{ch\_\max}-R_{ch\_\min}\right)}{\left(R_{ch\_\max}+R_{ch\_\min}\right)}\times 100\right\}_{\%}$$ 33-1.1

Where:

Rch_max is the sum of channel pair elements with highest common mode resistance.

Rch_min is the sum of channel pair elements with lowest common mode resistance

Common mode resistance is the resistance of the two wires in a pair (including connectors), connected in parallel.

Open issues - 1

- Proposal for motion for specifying PSE PI Pair to Pair Output resistance unbalance and pair to pair output voltage unbalance during Power ON state for operating 4P systems.
  - Waiting for completion of test model.
  - Test model was presented see Annex E, inputs were received:
    - To consider changing voltage source load with current load

- What is the PD load current on Mode A and Mode B in which below that current, P2P requirements can be ignored.
  - Responses:

    (1) Below 25W no need for P2PRUNB requirements

    (2) We may care below 25W to optimize transformers for 4W loads

    (3) *Response (2) checked, negligible difference between Type 1 and 2, probably no incentive for special magnetics for below Type 1 power. See annex D shown in previous meeting.*

Source: Yair Darshan.

Open issues - 2

- Worst case Data Base
  - Comments:
    - Replace connector contact resistor with Connector resistance.
    - Yair to send Jeff connector test results.
    - To check results with connector resistance per standard with Rcmax=200miliOhm and 50miliOhms difference.
      - Response: No value. We are looking for worse case.
    - Connector resistance: 10miliom minimum – 60miliohm max.
      - Sterling to supply information for connector resistivity.
  - To check CAT6A cable resistance per the actual cable length
    - Cabling spec requires CAT6A resistance for 100m will be as defined for CAT5/e. In reality it will be lower for AWG23. To verify.
  - Diode bridges are worst case components compared to no diode or active diode bridge.
  - Clarify title of the two column use cases

Open issues - 3

- Test models for PD and baseline text:
  - Not started yet.

Adhoc meeting May 15, 2014, Norfolk VA

- Agenda
- Concept of how to address P2P unbalance as function of temperature (20 minutes)
- Discussing proposed motions from the adhoc (30 minutes)
- The PD power limits in which P2P requirements are not relevant.
- New Presentations? (10 minutes)

Adhoc report -1

- 5 adhoc meetings since March 2014 meeting
- 15 attendees in average each meeting
- See adhoc recommendations for:
  - How to handle temperature: See slide 19.
  - Discussion and straw poll slides 14-18.
- Agreement on which parameters need to be defined in the standard (PSE PI, PD PI and Channel P2P unbalance related parameters: Slide 8. Discussion slides 7-8.
- Agreement on terms and acronyms to be used in adhoc discussions: slides 7-8
- Motions drafts are ready for:
  - Channel P2P Resistance Unbalance are ready: Slides 10 and 11
  - PSE PI P2PRUNB and PSE P2P Voltage Difference: Slide 12
- Agreement on 4 channel length scenario to be calculate worst-case: Slide 24-25
  - Need to specify conditions for compliance based on cabling performance suggested by Wayne. Need farther discussion (9.38 ohms and 14 ohms data on slide 25)
- Worst Case data base was updated (2,4,6 connectors, different channel lengths: Slide 27.
  - Simulation results: Slide 28-31.
  - Conclusions: Slide 32 to be discussed.
- Motions need to be closed soon
  - PD PI P2P unbalance requirements
  - In which temperature we will calculate spec P2P unbalance parameters? See slide 21
- Open issues
  - What is the PD power/current that below it, P2P requirements are not important?
    - Good discussions. Yair & Christian (and Ken?) will work on proposal.
- More relevant material and discussions on the rest of the slides

Meeting # 5 Attendees (Thursday May 8, 2014)

- Ronald Tellas / Panduit
- Gaoling Zou / Maxim
- Brian Buckmeier / BEL
- Christian BEIA / ST
- Steinke, Stephan / Molex
- Koussalya Balasubramanian / Cisco
- David Tremblay / HP
- Yair Darshan / Microsemi
- George Zimmerman/ CME Consulting,
  Affiliations: Commscope & Aquantia
- Ken Bennett / Sifos
- Rick Frosch / Phihong
- Yan Zhuang / Huawei

Meeting # 3 and # 4 Attendees (April 24, May 1, 2014)

Meeting # 3

- Yan Zhuang / Huawei
- Ronald Tellas / Panduit
- Larsen, Wayne / Commscope
- Jeff Heath / LT
- Brian Buckmeier / BEL
- Rick Frosch / Phihong
- Christian BEIA / ST
- Leonard Stencel / Bourns
- Fred Schindler / Seen Simply
- Koussalya Balasubramanian / Cisco
- David Tremblay / HP
- David Abramson / TI
- Rimboim Pavlik / Microsemi
- Yair Darshan / Microsemi
- Ken Bennett / Sifos
- Victor Renteria / BEL
- George Zimmerman/ CME Consulting, Affiliations: Commscope & Aquantia

Meeting # 4

- Steinke, Stephan / Molex
- Gaoling Zou / Maxim
- Jean Picard / TI
- Larsen, Wayne / Commscope
- Jeff Heath / LT
- Brian Buckmeier / BEL
- Christian BEIA / ST
- Koussalya Balasubramanian / Cisco
- David Abramson / TI
- Yair Darshan / Microsemi
- Ken Bennett / Sifos
- Wendt, Matthias / Philips

Proposed Agenda, Meeting #4, May 1, 2014.

- Introduction

- Planes for today, May 8, 2014
  - Introduction (1 minute)
  - Approving slide 6 and 7 updates (5 minutes)
  - Finalizing Motion 1 and/or 1.1. (10 minutes)
  - Approving slide 19 proposal (temperature issue) (10 minutes)
  - Christian Presentation – Data results from updated data base model (10m)
  - Discussion on other proposed motions. (10 minutes)

  - Discuss proposed baseline text (Moved to IEEE meeting next week)

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

-Please read the Patent Policy slides at http://www.ieee802.org/3/patent.html prior the meeting.

Acronyms used in the ad-hoc activity (1)

Adhoc: OK

- **(1) Pair resistance unbalance :** Is the resistance unbalance between two wires in the same pair as specified by IEEE802.3 and other standards. This is 2% for cable and 3% maximum for the channel. Channel is a 4 connector model (cables and connector only).
- **(2) Pair to Pair resistance unbalance**: is the resistance unbalance between two wires of the same pair connected in parallel to another two wires of other pair connected in parallel. It is 5% for a cable.

(The resistance of the two wires of the pair is known also as the common mode resistance of the pair)

- **(3) End to End channel pair to pair resistance unbalance** it is the 26.2% (TBD) worst case calculation on a worst case data base that we have generated. The 26.2% (TBD) was calculated at 20degC. The channel is including components at PSE PI and PD PI that affects the whole end to end channel.
- **(4) PSE PI Pair to Pair resistance unbalance** is the P2P DC Common Mode PSE Output Resistance Unbalance measured at the PSE PI and include PI interface circuitry such RDSON, Current sense resistor, equipment connector, magnetic winding resistance. This is included in the " end to end channel resistance unbalance" and need to be extracted from it to be separate definition for PSE PI P2PRUNB.
- (4.1) PSI PI Pair to Pair voltage difference is the P2P DC Common Mode PSE Output Voltage Difference measured at the PSE PI under TBD conditions.

Acronyms used in the ad-hoc activity (2)

Adhoc: OK

- **(5) PD PI Pair to Pair resistance unbalance** is the P2P DC Common Mode PD input Resistance Unbalance measured at the PD PI and include PI interface circuitry such Diode bridge voltage offset and dynamic resistance, equipment connector, magnetic winding resistance. This is included in the "end to end channel resistance unbalance" and need to be extracted from it to be separate definition for PD PI P2PRUNB.
- **(5.1) PD PI Pair to Pair voltage difference** is the P2P DC Common Mode PD input Voltage Difference measured at the PD PI under TBD conditions.
- **(6) Channel Pair to Pair resistance unbalance** is the P2P resistance unbalance of the cables and 4 connector model. This need to be excreted from the " end to end channel resistance unbalance" and specified separately.
- So (PSE PI +Channel + PD PI)p2prunb all together is 26.2% (TBD).
- Items 4,5 and 6 will be specified in the standard, (item 2 is covered by item 6).
- Meeting #4: Adhoc response: ok. Meeting #5: To discuss changes in RED. Done.

Proposal text for Motion (1) (From meeting #4). See next slides: Breaking to separate motions

- Move that 802.3bt specify the following parameters for operating 4P systems during Power ON state:

a) PSE PI Pair to Pair resistance unbalance and pair to pair voltage unbalance. (Adhoc-done)

(The model is the same, two voltage sources V1, V2 or single voltage source in the model is implementation issue. What we care is the voltage difference measured at the PI (max|V1-V2|). (Group response: ??)

b1) Specify test circuit/procedure for specifying PD PI Pair to Pair resistance unbalance (For this motion, a2 on separate motion after doing some work).

b2) PD PI Pair to Pair resistance unbalance and voltage unbalance.

(For next meeting to present PD test circuit for PD PI P2PRUNB)

c) Channel Pair to Pair resistance unbalance (Adhoc-done)

The above parameters will be analyzed and specified based on the End to End Channel Pair to Pair Resistance Unbalance model as proposed by the ad-hoc. See slide N, link..

A.I.: Jeff, Jean and interested parties for closing item b. Please prepare presentation with your comments and Suggested remedies to be discuss over the reflector and we help with our inputs.

Proposal text for Motion (1)

Adhoc: OK

- Motion to require that the 802.3bt Task force will specify the requirements for Channel Pair to Pair resistance unbalance for operating 4P systems.
- Meeting #5:Adhoc-done.

- (Better language suggested by George, send during the meeting)
- Move that 802.3bt specify the Channel Pair to Pair resistance unbalance for operating 4P systems
- Adhoc ok: 15/5/2014

Proposal text for Motion (1.1) (ad-hoc. Move Yair, 2nd :Christian)

Adhoc: OK 15/4/2014

Motion to add the following text to clause 33 after 33.1.4.2.

- **33.1.4.3 Type 3 and Type 4 Channel Requirement for Pair to Pair Resistance unbalance**
- 4P pair operation requires the specification of resistance unbalance between each two pairs of the channel, not greater than 200 milliOhms or 6%(TBD) which ever is greater. Resistance unbalance between the channel pairs is a measure of the difference of resistance of the common mode pairs of conductors used for power delivery. Channel pair to pair resistance unbalance is defined by equation 33-1.1:
- 33-1.1

$$\left\{ \frac{\left(R_{ch\_\max} - R_{ch\_\min}\right)}{\left(R_{ch\_\max} + R_{ch\_\min}\right)} \times 100 \right\}_{\%}$$

- Where
- Rch_max is the sum of channel pair elements with highest common mode resistance.
- Rch_min is the sum of channel pair elements with lowest common mode resistance
- Common mode resistance is the resistance of the two wires in a pair (including connectors), connected in parallel.

Proposal text for Motion (2)

- Move that 802.3bt specify PSE PI Pair to Pair Output resistance unbalance and pair to pair output voltage unbalance during Power ON state for operating 4P systems.

The above was item a in meeting #4.

Adhoc-done

(The model is the same, two voltage sources V1, V2 or single voltage source in the model is implementation issue. What we care is the voltage difference measured at the PI (max|V1-V2|). (Group response: ??)

The above parameters will be analyzed and specified based on the End to End Channel Pair to Pair Resistance Unbalance model as proposed by the ad-hoc. See slide N, link..

A.I.: Jeff, Jean and interested parties for closing item b. Please prepare presentation with your comments and Suggested remedies to be discuss over the reflector and we help with our inputs.

Proposal text for Motion (4)

Motion to add the following text to informative section.

Cable Requirement for Pair to Pair Resistance unbalance

4 pair operation, requires the additional specification of resistance unbalance between each two pairs of the cable. The cable pair to pair resistance unbalance was studied and found to be 5% or less. Resistance unbalance between the pairs is a measure of the difference of resistance of the common mode pairs of conductors used for power delivery. Cable pair to pair resistance unbalance is defined by equation 33-1.1:

$$\left\{ \frac{\left(R_{cm\_\max} - R_{cm\_\min} \right)}{\left({}_{cm\_\max} + R_{cm\_\min} \right)} \times 100 \right\}_{\%} \qquad \text{33-1.1}$$

where

*Rcm*_max is the pair with highest common mode resistance.

*Rcm*_min is the pair with lowest common mode resistance.

Common mode resistance is the resistance of the two wires in a pair, connected in parallel.

Issues to be discussed in #3/4 meeting 24/April/ May 1, 2014 (1)

- How to address temperature effect on P2PCRUNB?
  - We agree that we don't care of high temperature since it works for us (high temperature higher resistance lower P2PCRUNB)
  - So the question is narrowed to below room temperature (20-24°C)?.

Yair response:

1. All parameters in the standard are tested for compliance at room temperature.

System and component vendors are responsible to design the parts/system to meet their spec over their spec of operating temperature range.

1.1 We can study and supply the guidelines/equations in informative annex to help decide what to do in temperatures below room temperature but it can't be part of the standard. (not high priority)

Please see what IEEE802.3-2012 says about this topic:

33.7.7 Temperature and humidity

The PD and PSE powered cabling link segment is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling. Specific requirements and values for these parameters are beyond the scope of this standard.

Recommendation: To focus on results at room temperature for the baseline.

Anything else could be:

a) left for the informative section of the standard

b) per 33.7.7

Source: Yair Darshan.

Issues to be discussed in #3/4 meeting 24/April/ May 1, 2014 (2)

Please see what IEEE802.3-2012 says about this topic:

33.7.7 Temperature and humidity

The PD and PSE powered cabling link segment is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling. Specific requirements and values for these parameters are beyond the scope of this standard.

Yair's Recommendation: To focus on results at room temperature for the baseline.

Anything else could be:

a) left for the informative section of the standard

b) per 33.7.7

--- DISCUSSION ----------

(1) Yair: Define at 25degC and the rest put in the informative section

(2) Jeff/Wayne: Mandatory section we need to define at 25degC and (–TBD)

(3) Jeff: To define one number which is the worst case and will include low temperature (similar to a worst case of insertion loss at high temp.)

Yair: (May 1, 2014) During reflector discussion we saw that insertion loss is define at 20degC and at higher temperature derating is allowed by using shorter cable which means that insertion loss is not specified for worst case operating temperature (ANSI/TIA 568-C.2 Annex G Clause 6.4.7.

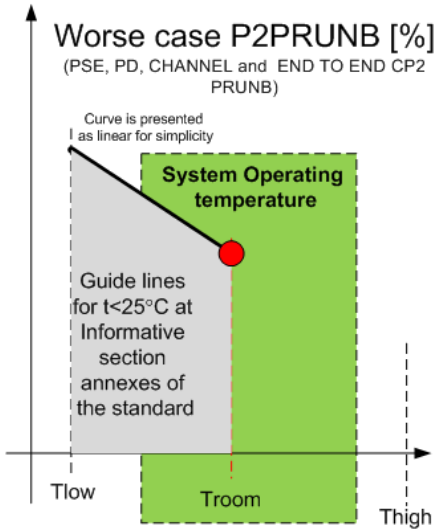
-Christian: Testing cost issues in (2)

–Ad hoc agree to vote by mail and result will be our recommendation to task force to move forward.

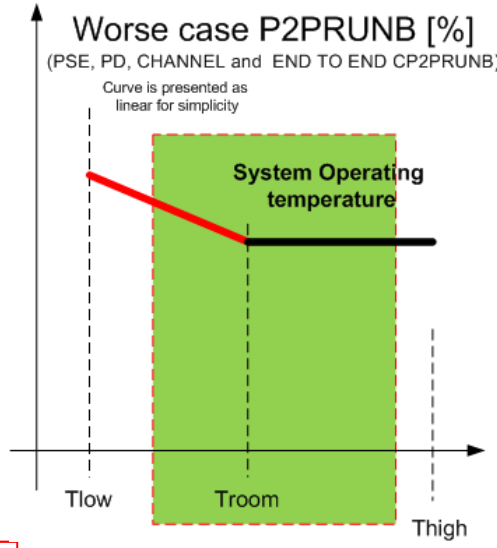
Straw poll material was sent. See details next slides.

Options for CP2PRUNB vs Operating temperature

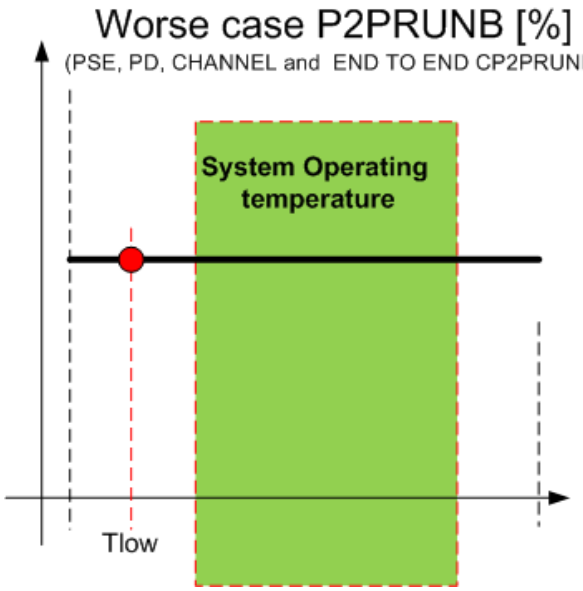
Source: Yair Darshan.



- Option1
- Defining single point at e.g. Troom=20°C and:
- (a) add information for T<Troom at the informative section **and/or**
- **(b)** follow Clause 33.7.7
- No Over Design since system vendor responsible to design their system to meet requirements.
- It may increase interoperability concerns???. This concern is valid in all options whenever there is no single worst case number that covers Tlow of 100% of use cases.
  - The remedy for it is specify the requirement and it is up to box designer to meet it over its operating temperature range.



- Option 2
- Defining curve from Tlow to Troom
- Tlow need to cover most of applications known to us.
- Prevents over design. (Allow system vendor to design for its operating temperature range)
- Tlow need to be investigated
- See interoperability concerns discussion in option 1



- Option 3
- Defining single point at Tlow which will be single worst case point.
- Tlow need to cover most of the applications min. temperature.
- This option may be overdesign for equipment with T>Tlow. (To investigate)
- Equipment that need to work at T<Tlow shall follow Clause 33.7.7
- See interoperability concerns discussion in option 1

Straw Poll Results

Adhoc: OK

- Select one option only.
- If possible, add rational for your selection, any concerns etc., new suggestions in the notes column.

	Options			Notes
Name	1	2	3	
Yair Darshan / Microsemi	x			Without having the informative part and using clause 33.7.7 instead (Option 1b or name it option 4)
Fred Schindler / Seen Simply			x	
Ken Bennett / Sifos	x			
Yseboodt, Lennart / Philips	x			
Jeff Heat / LT				Accept suggested proposal for option 4 (see mail) which is option 1b (to ask for email confirmation).
Wendt, Matthias / Philips	x			
Dave Dwelley / LT	x			
Rimboim Pavlik / MSCC	x			
Christian Beia / ST	x			Without having the informative part and using clause 33.7.7 instead (Option 1b or name it option 4)
Belopolsky Yakov / BEL	x			
Gaoling Zou / Maxim	x			

Note: **Option 4** language from reflector email exchange (short summary): "use the P2PRUNB for PSE, PD and Channel number that was calculated (total sum=26.2%(TBD)) at room temperature (or pick number at other temperature), set it as THE number to meet without saying at what temperature it is, and vendors will have to assure that they meet it at their operating temperature range spec. How they will do it, we don't care." The rest is per 33.7.7. This option is covered by 1b.

Issues to be discussed in #3/4 meeting 24/April/ May 1, 2014 (3)

- Results of the straw poll
- 9 for option 1 (7 for 1a or 1b, 2 for 1b)
- 1 for option 3
- 1 for 1b ?? (waiting for confirmation)

- Additional information:
- Base on reflector discussion it is summarized to:
- Use the P2PRUNB for PSE, PD and Channel number that was calculating (total sum=26.2%) at room temperature (or pick number at other temperature), set it as THE number to meet without saying at what temperature it is, and vendors will have to assure that they meet it at their operating temperature range spec. How they will do it, we don't care." The rest is per 33.7.7.
- This summary is covered by options 1b and 3.

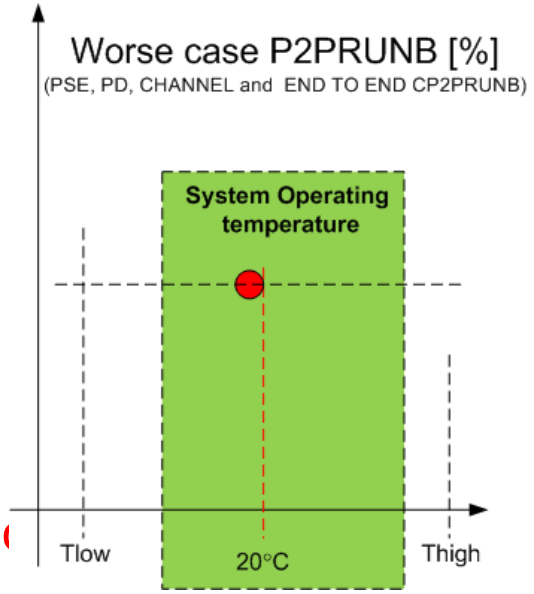
  (Option 1 says room temperature or other temperature
- Option 3 says lower temperature than room temperature)

Ad-hoc proposal for the Task force

Adhoc: OK

- To follow the following proposed concept:
- Use PSE PI, PD PI and Channel UNB parameters that was calculated 20°C (or pick a number at other temperature).
- Set it as the number to meet without saying at what temperature it is.
- Vendors will have to assure that they meet it at their operating temperature range spec.
- How they will do it, we don't care. The rest is per 33.7.7.
- Add accepts this proposal. May 15, 2014, Norfolk VA.

- Note: Channel P2PUNB is not affected by temperature is fixed



- Ad-hoc response: Agree.
- Next question will be, OK, what is that temperature p

Next question will be, OK, what is that temperature point?

- Questions
  - Is it correct to assume that for Environment A all system parts (Switch, PSE , PD cablings etc.) are at near room temperature?
  - If bad ventilation it will be going up?
  - Is there situations that for Environment A temperature will be near zero degC? Or stay around 20°C and above?

- Proposals
  - A) T= 20°C
  - B) T= 0°C
  - C) The Typical minimum temperature at enterprise environment, Environment A or equivalent
  - Ad-hoc response:
  - Yair: It looks that the answer is not important. If we specify a number. The PSE vendor and PD vendor will have to meet it for the entire system op temperature.

Issues to be discussed in #3 meeting April 24, 2014

- 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.
- We agree that wee need to investigate it and address it.
  - Dave Dwelley made a comment about this issue which I didn't record.
  - Dave please send us your comment about this topic to be recorded and addressed.
  - No response. Removing this item from the agenda.
- **Proposals:**

(1) For PD total power below 25.5 Watts (that ensures pair current <600mA/pair), for any pair, meeting Channel Pair to Pair Resistance Unbalance is not required.

Yair: I agree with it. It helps for low cost PDs.

Adhoc response:

(2) For PD total power below TBD Watts that ensures pair current <600mA/pair, for any pair, meeting Channel Pair to Pair Resistance Unbalance is not required.

- (To discuss this face to face at May meeting.)
- What is the TBD number ? Next question.

What is the PD power/current where P2P requirements for a given P2P limit numbers are not changing system/components performance as it was not important for Type 2 systems?

- To be discuss during face to face meeting at Norfolk VA.
- Analytical results showing:
  - It_max=1.2A - P2PCRUNB*It. (The decision break point of Type 3 systems)
  - If It>Itmax, CP2PRUNB requirements shall be met for Type 3 and up systems.
  - If It<Itmax for Type 3 system, CP2PRUNB requirements are not required to be met.
- It_max s total PD current over all 4 pairs that is the P2PRUNB requirements are not affecting 4P operation similar to that it is not affecting 2P operation.

- Example: It_max=1.2A-0.262*1.2A=0.885A.
- 4P PD with a power level that requires maximum 0.885A total on all 4 pairs, doesn't need to be concern by P2P requirements. To work with adhoc if this is true statement.

Issues to be discussed in #3 meeting April 24, 2014

- (1) What is the minimum resistance in the channel that above it, we don't care? In other words, what is the minimum resistance in the PD that makes the diodes, connectors, transformers less important in the total channel P2PRUNB?
- (2) Do we need to specify minimum length?.

  Yair Response: we will know the answer based on (1) and running simulations/calculations per Wayne proposal for 4 channel length options.
- What will be minimum Ω/m for patch cords?
- Yair: I suggest to use the 9.38Ω/100m (93.8mΩ/m as max value and 5% less as the minimum value since patch cords normally need to be flexible than the horizontal cable so their wire diameter is smaller that horizontal cables such as CAT6A.
- Yair: I remember that Wayne said that the 0.15m channel length option is with 14 Ω/100m.

  -Wayne to confirm.

  -Wayne: What is your opinion to the above proposal?
- **Wayne response: See next slide.**

Source: Yair Darshan.

Issues to be discussed in #3 meeting April 24, 2014

- **Wayne response:** Thinking about possible use cases, it seems to me it is possible, someone may provide PSE equipment in a rack and PD equipment in the rack unit below it in the same rack. If we agree this is a possible use case, it could be connected by a patch cord 0.15 m long. Patch cords have a de-rated DC resistance requirement of 14Ω/100m, as Yair states. In finding the absolute minimum, someone could also use un-de-rated patch cord material.
- In any case, for this use case, I think the DC resistance, and the DC resistance unbalance, of the cabling system, is low enough that the equipment MDI, and other elements of the equipment circuit, will dominate.
- Yair response: Yes, in very short channel the equipment MDI, and other elements of the equipment circuit, will dominate i.e. it will be almost similar to the PSE PI and PD PI P2PRUNB that we agree that we need to define anyway. I will simulate results with 0.15m cable with 0.14 Ω/m when simulation only PSE and PD PIs.
- Group OK. 0.15m minimum. Follow Wayne proposal for 4 different channel length for calculation/analysis.

Adhoc: OK

Issues to be discussed in #3 meeting April 24, 2014

- See inputs from Pete Johnson and Yair Darshan response regarding the method of calculating Runb at Annex A1. (If you disagree send email and we will discuss in next meeting. Other wise we agree to this response)
- Adhoc agrees (no responses, removed from the agenda).
- ----
- In IEEE802.3 March 2014 meeting , Jeff Heat had a comment for the PD model. Jeff to send the details of it to the ad-hoc if you want us to discuss it. (Jeff to send data and Dave response to next meeting).
- No response. Removing this item from the agenda.

- See new data for P2PCRUN with out limiting the current to 600mA /pair with 6 connectors (See Christian presentation)

- See previous data presented again on Annex C on issues reminding us why we are working on P2P issues and what was the concerns that we had to addressed.

Updated Worst Case Data Base

Adhoc: OK

Table 1	CAT5E Cable resistivity	CAT6/A Cable resistivity
Cable resistivity	117mOhm/m	66mOhm/m
Transformer winding resistance	120mOhm min, 130mOhm max	120mOhm min, 130mOhm max
2-connector Contact resistance	15mOhm min, 30mOhm max	15mOhm min, 30mOhm max
4-connector Contact resistance	30mOhm min, 60mOhm max	30mOhm min, 60mOhm max
6-connector Contact resistance*	45mOhm min, 90mOhm max	45mOhm min, 90mOhm max
Diode bridge	0.39V+0.25Ohm*Id min; 0.53V+0.25Ohm*id max	0.39V+0.25Ohm*Id min; 0.53V+0.25Ohm*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

- Source: Christian presentation on May, 8 2014 adhoc meeting.
- Diode model was changed
- **Replace connector contact resistor with Connector resistance. May 15, 2014**
- To supply Yair tests for connector tests
- To check what will be with 50miliom max difference. So it could be 10miliom minimum – 60miliohm max.
- Sterling to supply information for connector resistivity.
- To check CAT6A cable resistance per the actual cable length
- Change titels of the two columns

CAT6/A, 2-connector model

Length [m]	PD power [W]	Pair with max current [mA]	Pair with min current [mA]	Idiff [mA]	P2PCRunb [%]
0.15	51	713.09	333.59	379.51	**36.26%**
1	51	703.75	343.54	360.21	**34.39%**
10	51	647.97	405.83	242.14	**22.98%**
100	51	612.77	516.87	95.89	**8.49%**
0.15	75	975.35	571.98	403.37	**26.07%**
1	75	966.43	582.25	384.18	**24.81%**
10	75	915.09	648.09	267.00	**17.08%**
100	75	937.66	810.77	126.89	**7.26%**

- Source: Christian presentation on May, 8 2014 adhoc meeting.

CAT6/A, 6-connector model

Length [m]	PD power [W]	Pair with max current [mA]	Pair with min current [mA]	Idiff [mA]	P2PCRunb [%]
0.15	51	711.42	337.09	374.33	**35.70%**
1	51	703.83	345.29	358.54	**34.17%**
10	51	654.98	400.77	254.21	**24.08%**
100	51	617.65	514.68	102.96	**9.09%**
0.15	75	987.44	564.02	423.42	**27.29%**
1	75	979.68	573.15	406.53	**26.18%**
10	75	931.34	636.24	295.10	**18.83%**
100	75	947.13	808.59	138.54	**7.89%**

- Source: Christian presentation on May, 8 2014 adhoc meeting.

CAT5E, 2-connector model

Length [m]	PD power [W]	Pair with max current [mA]	Pair with min current [mA]	Idiff [mA]	P2PCRunb [%]
0.15	51	713.08	336.22	376.86	**35.91%**
1	51	697.53	352.86	344.67	**32.81%**
10	51	628.90	433.31	195.58	**18.41%**
100	51	653.74	568.96	84.78	**6.93%**
0.15	75	977.02	576.14	400.88	**25.81%**
1	75	962.23	593.34	368.89	**23.71%**
10	75	901.66	680.49	221.17	**13.98%**
100	75	1087.30	961.05	126.25	**6.16%**

- Source: Christian presentation on May, 8 2014 adhoc meeting.

CAT5E, 6-connector model

Length [m]	PD power [W]	Pair with max current [mA]	Pair with min current [mA]	Idiff [mA]	P2PCRunb [%]
0.15	51	711.75	339.41	372.33	**35.42%**
1	51	698.99	353.28	345.72	**32.85%**
10	51	636.67	427.56	209.10	**19.65%**
100	51	658.14	568.37	89.77	**7.32%**
0.15	75	989.47	567.90	421.57	**27.07%**
1	75	976.47	583.37	393.10	**25.20%**
10	75	917.08	669.74	247.35	**15.59%**
100	75	1099.57	964.24	135.33	**6.56%**

- Source: Christian presentation on May, 8 2014 adhoc meeting.

Conclusions

- Worst case condition for P2PCRunb is:
  - Single 0.15m CAT6A cable between PSE and PD (2-connector model)
- The max P2PCRunb is 36.26%, i.e. 380mA over 1.05A
- Increasing the number of connector has a ballasting effect, decreasing P2PCRunb.
  - 4-connector results are in the middle between 2 and 4 connector models
- ----------
- With CAT6/A cabling it is possible to deliver 75W to the PD without exceeding 1A per pair (for any cable length and # of connectors)
- A 100m CAT5E cable in a 6-connectors environment would require up to 1.1A to deliver 75W to the PD
- Yair comment: This part is not final conclusions since it is worst case analysis. We need to check if with statistical analysis were lower P2P numbers are obtained, we can work with CAT5e as well and getting 75W at the load. There is benefit to use CAT5e as well for Type 4.

Comparison between 4 connectors and 6 connectors Model. -6

Simulation Results

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

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]	P2PCRunb [%]
0.15m				
1	385	659	275	26.30
10	415	636	221	21.04
100	500	626	126	11.19

Table 2

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]	P2PCRunb [%]
0.15m				
1				
10				
100				

Table 3

Summary of open/closed issues -1

P=priority. P=1:Required for generating baseline draft numbers. P=2: May be part of informative section. P=3: Nice to know.

#	Subject	Reference/Conclusions	Status	P
1	Model for simulations/calculations	Figure 1	Ad-hoc OK.	1
2	Worst case data base	Table 1	Ad-hoc OK.	1
3	Cable Channel P2PRUNB 5% max	Meeting #1	Ad-hoc OK.	1
4	Worst case End to End Channel P2P resistance/current unbalance results with 4 connectors	Table 2	Ad-hoc OK.	1
5	What is the equation to calculate Resistance unbalance and Current unbalance?	Physic's, Meeting #1 and 2. Annex a, A1 Iunb=Runb*Total load current.	Ad-hoc OK	1
6	sensitivity Analysis to identify the main contributors of lesser power delivery.	Table 4 and 5	Ad-hoc OK	3
7	Do we need to specify minimum length?	Meeting #2. See Wayne proposal for 4 channel length options	Ad-hoc OK	1
8	To define PSE PI P2PRUNB	Meeting #1 and 2	Ad-hoc OK	1
9	To define PD PI P2PRUNB	Meeting #1 and 2	Ad-hoc OK	1
10	To set equation for evaluation maximum current unbalance through transformers	Ibias=Iunbalance/2=CP2PRU*Icable_max	Ad-hoc OK	2
11	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, vendors will have to add equivalent resistor to compensate the PSE PI unbalance	Group response: This is implementation issue of PSE PD which needs to meet P2P channel resistance unbalance anyway.	Ad-hoc OK.	2

Summary of open/closed issues -2

P=priority. P=1:Required for generating baseline draft numbers. P=2: May be part of informative section. P=3: Nice to know.

#	Subject	Reference/Conclusions	Status	P
12	How the constant power model at the PD helps us in regard to Channel P2PRUNB and specifically its effect on transformers?	Drawing 2. See the whole slide for details.	Ad-hoc OK.	1
13	sensitivity Analysis to identify the main contributors of resistance unbalance	Need to be done.	On going	1
14	Worst case End to End Channel P2P resistance/current unbalance results with 6 connectors	Table 3	On going	1
15	Statistical analysis results based on worst case data base in Table 1. Do we need to do it or we can live with worst case analysis?		On going	1
16	Channel P2PRUNB vs. operating temperature	Meeting #2 and #3. >room temperature: We don't care. Room temperature important for the standard. <Room temperature: Informative but not part of the standard	????	1
17	How connector contact aging will affect the results i.e. if min/max contact resistance difference will be increased	Meeting #1	???	1
18	Consider analyzing P2P current imbalance higher category cables than CAT6A.	Meeting #1 Response was: what will be the end of it? When to stop?	???	1

Summary of open/closed issues -3

P=priority. P=1:Required for generating baseline draft numbers. P=2: May be part of informative section. P=3: Nice to know.

#	Subject	Reference/Conclusions	Status	P
19	What is the load current that below it we don't care about Channel, PD PI and PSE PI P2PRUNB	Meeting #2 and 3	???	1
20	What is the minimum resistance in the channel that above it, we don't care about END TO END CHANNEL P2PRUNB?	Meeting #2		2
21	What is the wire resistance per meter for patch cords?	Meeting #2 and 3. Proposed 0.14Ω/m	????	1
22	To generate worst case analysis curve of maximum pair current vs cable length for Type 3 PD (51W max.)	Drawing 2. See the whole slide for details.	On going.	1
23	To investigate worst case results the 4 options proposed by Wayne	Summary of 2nd meeting.	On going.	2

- Previous Meeting Material

Meeting # 1 Attendees (Monday Feb 17,2014)

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

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

Meeting # 2 Attendees (Monday Feb 24,2014)

- Yan Zhuang / Huawei
- Kousalya Balasubramanian/ Cisco
- Leonard Stencel / Bourns
- Larsen Wayne / Commscope
- Ken Bennett/ Sifos
- Dave Dwelley / LT
- Jeff Heath / LT
- Christian Beia / ST
- Steinke Stephan / Molex
- George Zimmerman / CME
- Victor Renteria/BEL
- Abramson David / TI
- Gaoling Zou / Maxim
- Tremblay David/ HP
- Lennart Yseboodt / Philips
- Rob Woudenberg / Philips

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)

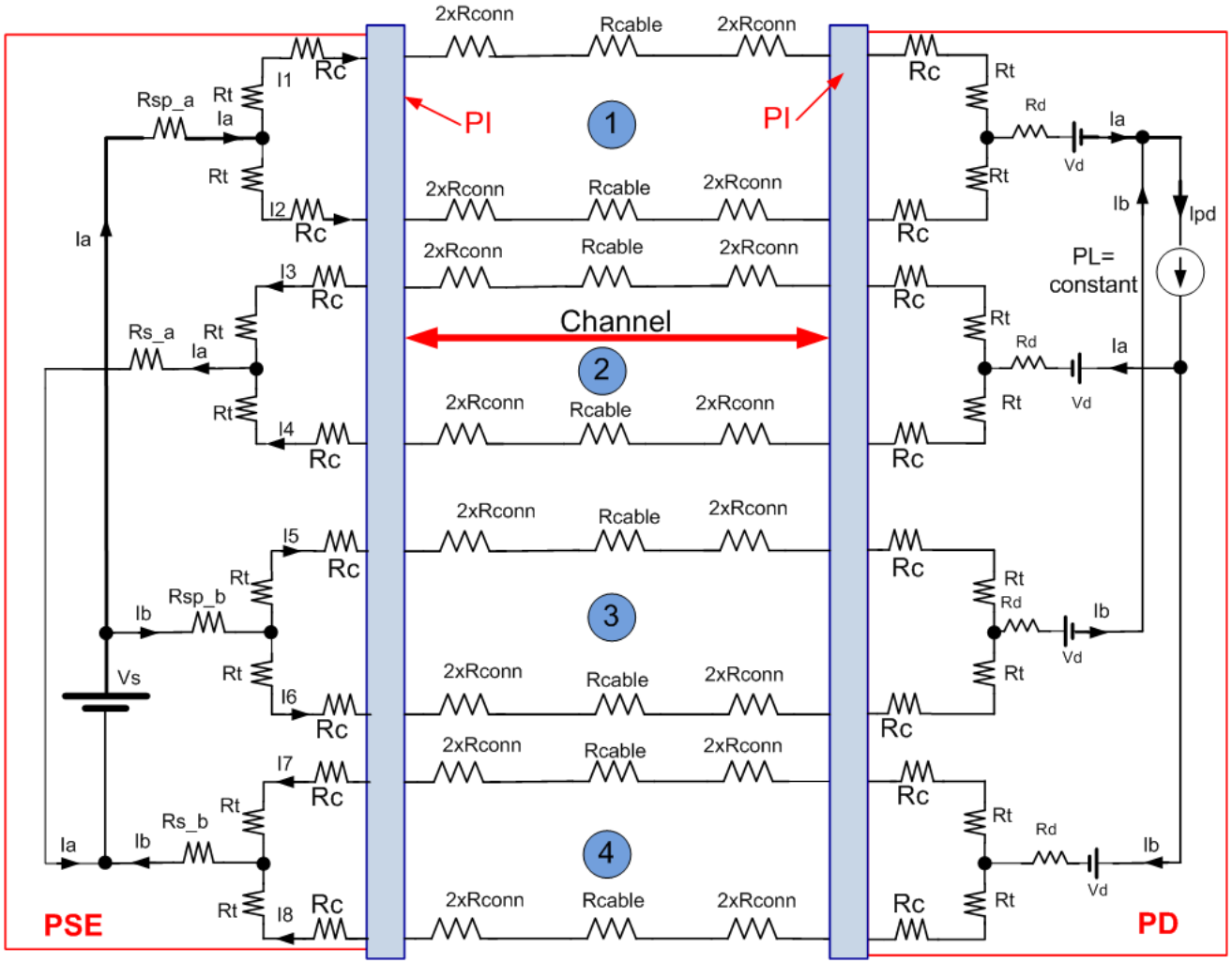
- Initial Work to determine channel pair to pair resistance unbalance:
  - http://grouper.ieee.org/groups/802/3/4PPOE/public/jul13/beia_1_0713.pdf
  - http://grouper.ieee.org/groups/802/3/4PPOE/public/jul13/darshan_2_0713.pdf

- 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.



Drawing 1

Notes for the general Model:

1. Adding resistors on positive path for general model (Rsp_a and Rsp_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 max.
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 -4

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	0.39V+0.25Ohm*Id min; 0.53V+0.25Ohm*id max	0.39V+0.25Ohm*Id min; 0.53V+0.25Ohm*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 -5

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 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

Table 2

$$P2PCRUNB = \frac{\mathrm{Im}ax - \mathrm{Im}in}{\mathrm{Im}ax + \mathrm{Im}in}$$

Source: Yair Darshan. November 2013.

Summary of previous work and conclusions -6

- See details: http://www.ieee802.org/3/4PPOE/public/nov13/beia_01_1113.pdf
- What we did was a 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 [-]		
Cable lenght		1m	10m	100m
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%

Table 4

Min res scenario	Component UNB[±]	Effect on power delivery [-]		
Cable lenght		1m	10m	100m
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%

Table 5

Summary of previous work and conclusions -7

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 P2PRunb for the PD, Channel and PSE in order to meet our objectives.

Summary of previous work and conclusions -8
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 Table 2 and see: http://www.ieee802.org/3/4PPOE/public/nov13/darshan_03_1113.pdf
  - Consider analyzing P2P current imbalance higher category cables than CAT6A
    - Response at the meeting was: what will be the end of it? When to stop?
  - To perform sensitivity analysis for P2P resistance (current) imbalance.
  - To set a worst case conditions for evaluating maximum current imbalance through transformers.

Done: Ibias=Iunbalance/2=CP2PRU*Icable_max.

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. (group OK with recommendation)

- 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.
    - To add probability factors and move on (request from magnetic vendors for lowest number).

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.
      - Group response: This is implementation issue of PSE PD which needs to meet P2P channel resistance unbalance anyway.
    - Any comments on the model used (Group response: No.)
- Next Steps

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?

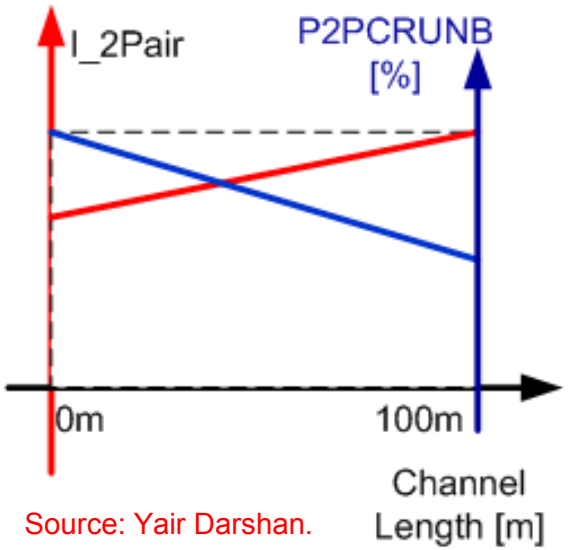
- Do we need to specify the following additional parameters or leave it to be implementation specific as long as C_P2PRU is met?
  - PSE PI Pair to Pair Resistance Unbalance (PSE_P2PRU)
  - PD PI Pair to Pair Resistance Unbalance (PSE_P2PRU)
  - In the current standard the pair resistance unbalance was 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. Done. It is covered.
- To consider 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 -1

- To discuss the advantages that PD constant Power Sink allows us.
- Background material for considering:
  - Worst case End to End Channel Pair to Pair Channel Resistance Unbalance is at short cable (<100m).
  - At short cables PD voltage is higher that 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 Ibias 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.



Source: Yair Darshan.

Source:
1. See link above, from July 2013.
2. Adhoc meeting #2, February 24, 2014.

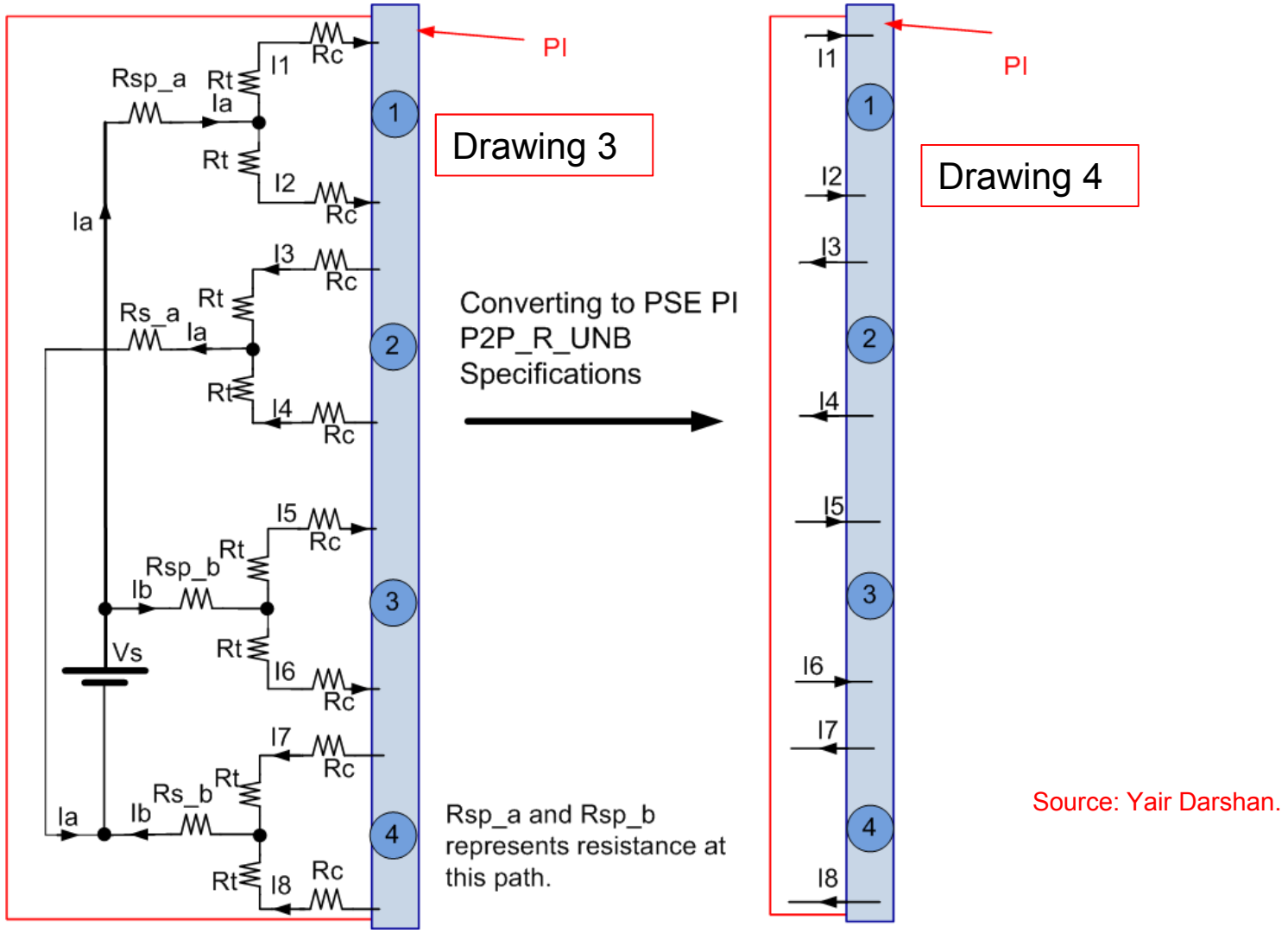
Illustration of the behavior.
(The curve is not linear. It is just describing the trend.)

Drawing 2

For next meeting -2

- 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.

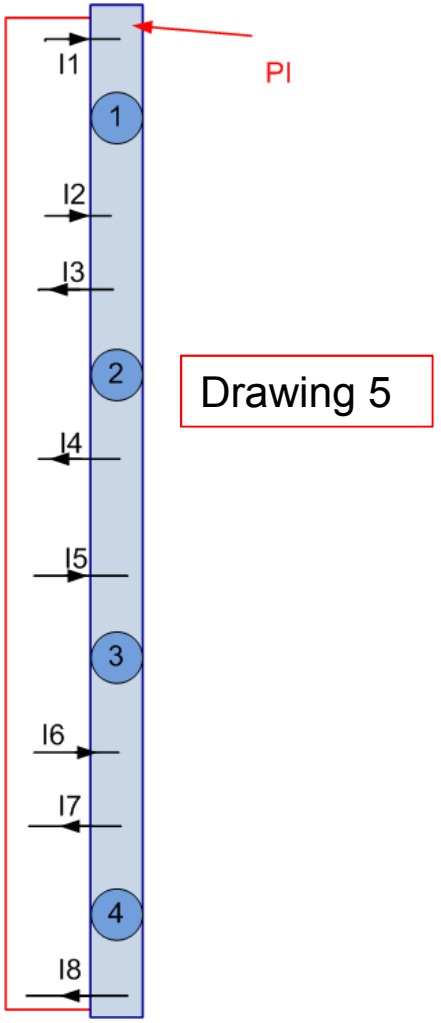
PSE_PI Pair to Pair Resistance Unbalance



- 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
- We may need to define P2P voltage offset difference in addition to P2P resistance unbalance



Drawing 5

Source: Yair Darshan.

Summary of 2nd meeting - 1

- (Text marked blue was added after the meeting and is not part of the meeting summary. It will be discussed on our 3rd meeting to be approved.)
- Wayne Larsen present data regarding:
  - Summary of resistivity and resistance unbalance specifications in TIA cabling standards
  - **Suggested topologies to study**
    - A. 6 inch (0.15 m) of cordage, no connectors.
    - B. 4 m channel with 1 m of cordage, 3 m of cable, 2 connectors
    - C. 23 m channel with 8 m of cordage, 15 m cable, 4 connectors
    - D. 100 m channel with 10 m of cordage, 90 m of cable, 4 connectors
  - Calculated channel resistance and unbalance (not including PSE and PD components) for the above topologies and the calculation details in separate Excel file done for maximum TIA numbers.
- Yair notes for the calculation results
  - The results reflects maximum cable (9.38Ω/100m) and connectors (300mΩ) resistance specified by TIA. *We are looking for lower cable resistance and connectors to reflect real life and also worst case in terms of P2PCRUB.*
  - *Christian and Yair proposed to use cable with* 66mOhm/m and connectors with 30mOhm min, 60mOhm max per the data in slide 9.
  - Proposed channel length options to investigate looks reasonable.

Summary of 2nd meeting - 2

- We review the updated model and we agree to use it as our base line for simulating different operation scenarios.
- Until other worst case numbers regarding cables and other components in the channel from end to end, we will use the numbers in the table slide 9, minimum resistivity cable model column.
- We adopt the 5% cable P2PRUNB until formal number will be received from TIA/EIA etc.
- We add two additional connectors to the model to investigate the effect of it on the end to end P2PCRUNB.

  (formal channel is 4 connectors maximum)
- To consider 100BaseT Ethernet devices or switches that do not implement transformers on the spare pairs so the range should be 0 Ohm to 130mOhm.
  - Yair note: In the Switch/Midspan and PD vendors will have to add equivalent resistor to compensate the PSE PI unbalance.
  - Group: This is implementation issue of PSE PD which needs to meet P2P channel resistance unbalance anyway. We will craft the optimum wording when the time comes.

Summary of 2nd meeting - 3

- The following questions and issues were raised
- (1) What is the minimum resistance in the channel that above it, we don't care? In other words, what is the minimum resistance in the PD that makes the diodes, connectors, transformers less important in the total channel P2PRUNB?
- (2) Do we need to specify minimum length?.

  Yair: we will know the answer based on (1) and running simulations/calculations per Wayne proposal for 4 channel length options.
- What will be minimum Ω/m for patch cords?
- Yair: I suggest to use the 9.38Ω/100m (93.8mΩ/m as max value and 5% less as the minimum value since patch cords normally need to be flexible than the horizontal cable so their wire diameter is smaller that horizontal cables such as CAT6A.
- Yair: I remember that Wayne said that the 0.15m channel length option is with 14 Ω/100m.

  -Wayne to confirm.

  -Wayne: What is your opinion to the above proposal?

Summary of 2nd meeting - 4

- 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.
- We agree that wee need to investigate it and address it.
- **Dave Dwelley made a comment about this issue which I didn't record.**
- **Dave please send us your comment about this topic to be recorded and addressed.**

- We need to conduct sensitivity analysis for P2PCRUNB with constant power sink and without limitations on current per pair. What we had is for determining the PD minimum available power.

Summary of 2nd meeting - 5

- How to address temperature effect on P2PCRUNB?
  - We agree that we don't care of high temperature since it works for us (high temperature higher resistance lower P2PCRUNB)
  - So the question is narrowed to below room temperature (20-24°C)?.

Yair:

1. All parameters in the standard are tested for compliance at room temperature. (to confirm)
2. System and component vendors are responsible to design the parts/system to meet their spec over their spec operating temperature range.
3. We can study and supply the guidelines/equations in informative annex to help decide what to do in temperatures below room temperature but it can't be part of the standard.
4. Please see what IEEE802.3-2012 says about this topic:

33.7.7 Temperature and humidity

The PD and PSE powered cabling link segment is expected to operate over a reasonable range of environmental conditions related to temperature, humidity, and physical handling. Specific requirements and values for these parameters are beyond the scope of this standard.