Addressing Opinions/Questions/Inputs from Meeting #11

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Contribution for 802.3bt End to End Channel Pair to Pair Resistance Unbalance Adhoc.
Rev 000.

- The incentive of the following work is to emphasis work that we already done during the last year and in latest work.
- It includes results of email exchange and phone conference between adhoc meeting #11 and #12 as agreed according the meeting minutes.
- All results were confirmed in at least two independent tools (PSPICE and MATLAB and lately with Excel).

Comparison between Channel P2PRUNB and End to End Channel P2PRUNB

See details in:
http://www.ieee802.org/3/bt/public/unbaladhoc/Meeting_11_IEEE802_3bt_Channel_Pair_To_Pair_Resistance_Imbalance_ad_hoc_rev_015a.pdf
http://www.ieee802.org/3/bt/public/unbaladhoc/Analzing_Channel_Pair_To_Pair_Resistance_Unbalance_use_cases_rev_5a.pdf

Channel Definition and its equation

$$C\_P2PRUNB = \left(\frac{\sum_{R_{\max}}^{CH} - \sum_{R_{\min}}^{CH}}{\sum_{R_{\max}}^{CH} + \sum_{R_{\min}}^{CH}} \right) = \frac{\left(R_{\max} + N \cdot Rc_{\max}\right) - \left(R_{\min} + N \cdot Rc_{\min}\right)}{R_{\max} + N \cdot Rc_{\max} + R_{\min} + N \cdot Rc_{\min}} = \frac{\left(R_{\max} - R_{\min}\right) + 0.08}{\left(R_{\max} + R_{\min}\right) + 0.32} \qquad \text{EQ-1}$$

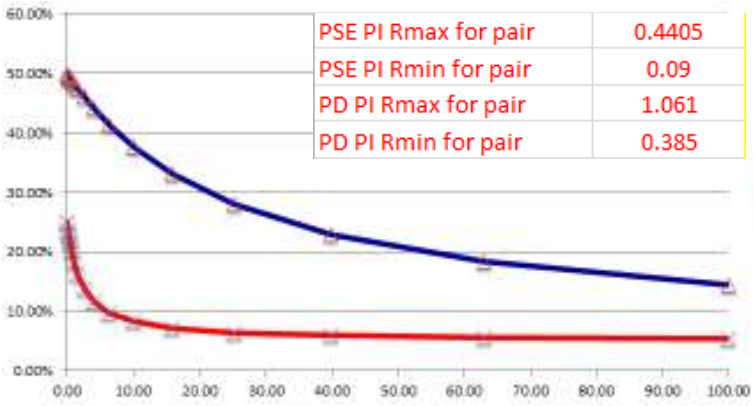
The Channel Equation is already in the End to End Channel P2PRUNB equation.
As a result, there is zero margins left on the table when the maximum pair current will be determined which is our goal. As a result of maximum current that we want to allow, the PSE PI and PD PI unbalance parameters will be determined.

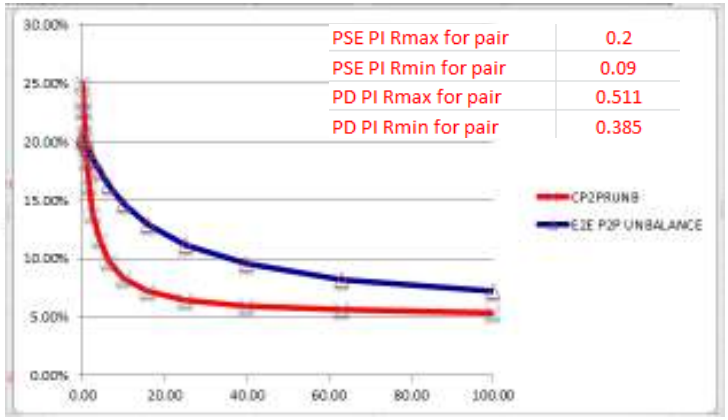
System definition and Channel Definition and its equation

See below in EQ-2 how the channel equation fits into the system equation.

$$E2E\_C\_P2PRUNB = \left(\frac{\left(\sum \frac{PSE}{R_{max}} - \sum \frac{PSE}{R_{min}}\right) + \left(\sum \frac{PD}{R_{max}} - \sum \frac{PD}{R_{min}}\right) + \left(\sum \frac{CH}{R_{max}} - \sum \frac{CH}{R_{min}}\right)}{\sum \frac{PSE}{R_{max}} + \sum \frac{PSE}{R_{min}} + \sum \frac{PD}{R_{max}} + \sum \frac{PD}{R_{min}} + \sum \frac{CH}{R_{min}} + \sum \frac{CH}{R_{max}}} \right) \qquad \text{EQ-2}$$

- Using adhoc database values for components. Annex G1.
- The high C_P2PRUNB at short cable is dominating by PSE PI and PD PI components.
- PSE and PD PI affect also the system unbalance at 100m.
- We can see that while channel at 100m is only 5.5%, the end to end P2PRUNB (system) is 15%.
- The End to End Channel P2PRUNB was simulated at 51W load. Confirmed with MATLAB and Excel tools.
- If mistakenly someone runs system simulations with only the channel, the current over the pair with the lower resistance will be more sensitive to channel margins at 100m and will be resulted with wrong conclusions.



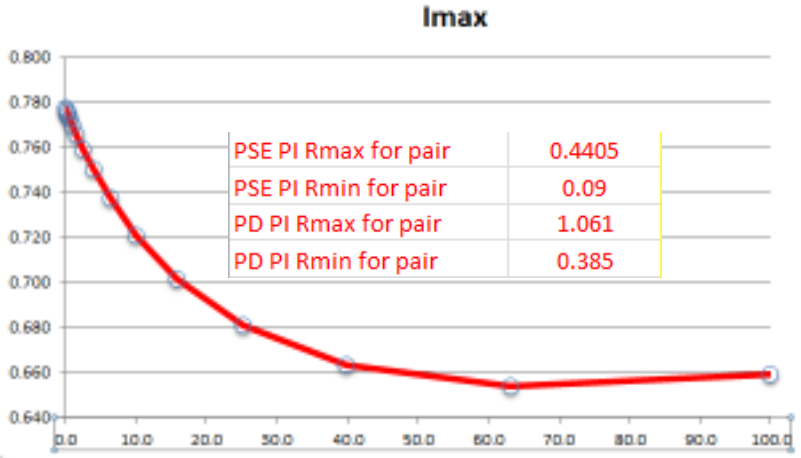


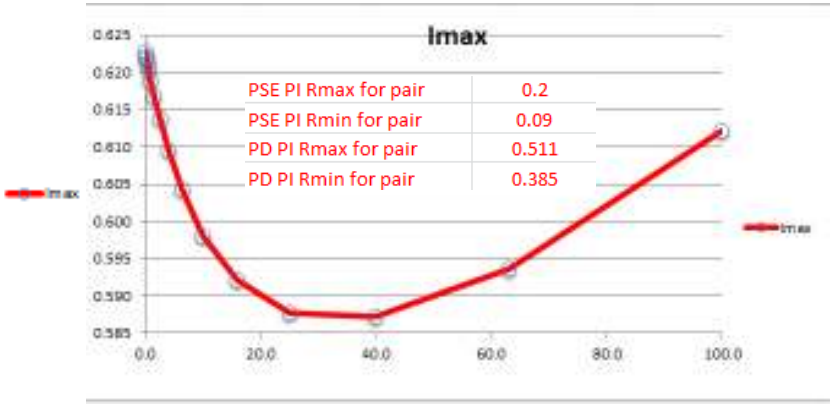
The maximum pair current with the lowest resistance equation

The maximum pair current as function of system equation that includes channel behavior in its equation form will be:

$$\mathrm{Im}ax = \frac{It \cdot (1 + E2E\_P2PRUNB)}{2} = \frac{It \cdot \left[1 + \left(\frac{\left(\sum \frac{PSE}{R_{max}} - \sum \frac{PSE}{R_{min}}\right) + \left(\sum \frac{PD}{R_{max}} - \sum \frac{PD}{R_{min}}\right) + \left(\sum \frac{CH}{R_{max}} - \sum \frac{CH}{R_{min}}\right)}{\sum \frac{PSE}{R_{max}} + \sum \frac{PD}{R_{max}} + \sum \frac{CH}{R_{max}} + \sum \frac{PSE}{R_{min}} + \sum \frac{PD}{R_{min}} + \sum \frac{CH}{R_{min}}} \right)\right]}{2} \quad \text{EQ-3}$$

- Using adhoc database values for components. Annex G1.
- The high C_P2PRUNB at short cable is dominating by PSE PI and PD PI components.
- PSE and PD PI affect also the system unbalance at 100m.
- We can see that if Channel P2PRUNB=5.5% or 7.5% at 100m YOU will not notice the differences!
- The End to End Channel P2PRUNB was simulated at 51W load. Confirmed with PSPICE and MATLAB and Excel tools.
  (Differences of <between tools results negligible for the purpose of drawing conclusions and mainly are results of diode model approximation used with MATLAB and Excel).





- See Annex G5 and G6 in the adhoc material for meeting #12, for spice simulation results per database presented in Annex G1 with better diode unbalance parameters resulting with 40% unbalance at short channel and 11% at 100m.
- Other interesting use cases for **identical diodes** and **Ideal Diode Bridge** are demonstrated.
- PSPICE Model was validated with lab tests and with MATLAB for typical system with typical components.

Do we have margins left on the table between compared to "Equation form" specification?

When system equation contains channel equation but use "100 milliohms or 7.5% whichever is greater" specifications?

(This is what we do in our process.)

No!. It can be seen from the equation and procedure we are using to define system parts.

- As a result the "100 milliohms or 7.5% whichever is greater" has a zero margins left on the table! (And it was confirmed by simulation as well)
- The "100 milliohms or 7.5% whichever is greater" is a Channel Only specification and not system specification!

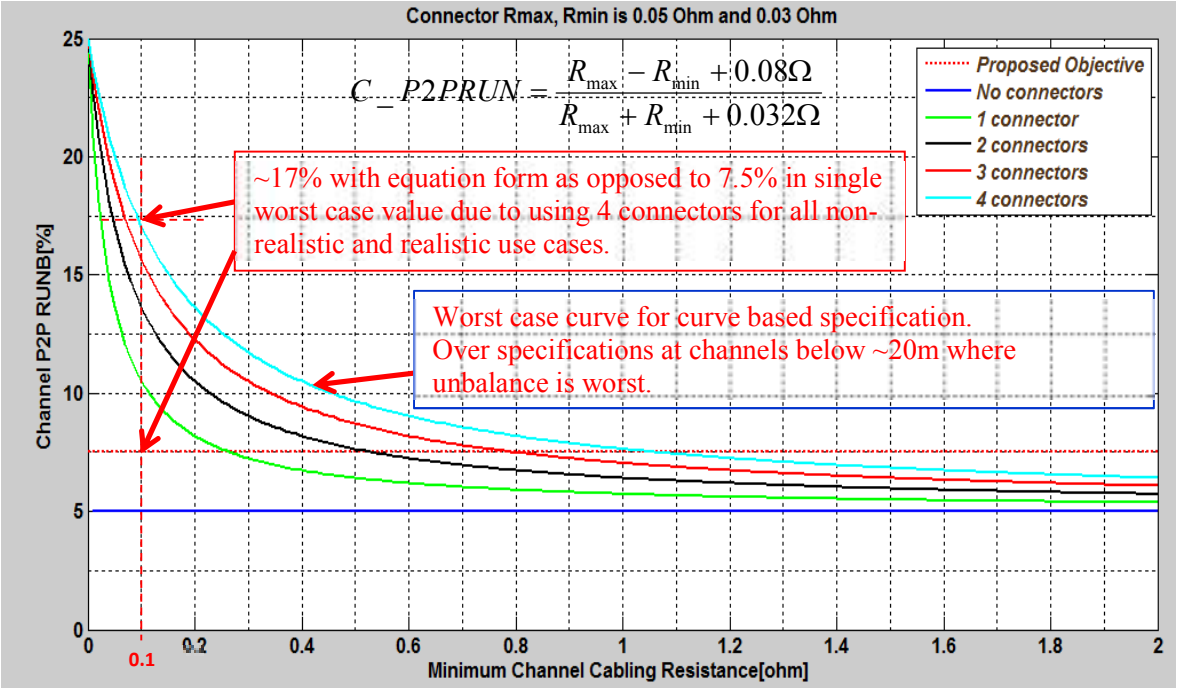
What if the 7.5% will be used in the system equation (EQ-2) instead of channel equation (EQ-1)?

In this case the effect will be not significant as well.

- AT 100m, The 2% margin will be overtaken by the PSE PI and PD PI which are>>5.5% (10-20% at system level pending PSE/PD PI components).
- It is easy to quick calculate it:
- The system has 15% unbalance at 100m. The current is per simulation 659mA.
- The Channel unbalance at 100m increases from 5.5% to 7.5%=2%.
- The current in system level was increased to just 668mA. **This is only 9mA** at 51W.
    - 14mA at 80W.
- Only 1.4% increase in pair current due to 2% margin in the channel level.
  (Higher effects as claimed at adhoc meeting #11 was due to error in the commenter's model and calculations as expected. The source of the error is that the commenter use only channel in the system level for calculating the pair current without accounting for PSE and PD PI. <u>It will be also incorrect if it will be argued in the future that there is a PSE or PD that has unbalance qualities similar to the channel i.e. 5.5%. This is not practical. PSE PI and PD PIs have connector and transformers and other components that has>>5% unbalance.</u> See adhoc database for details.
- The effect on magnetic is also insignificant. 1.4%*3%/2=0.21%. =>0.21%*9mA=0.0189mA ➔ <<<1mA.
- The effect on magnetic power loss: 2.8% ➔ Don't care.
- The effect on magnetic package power loss all 4 pairs magnetics inside): -0.2% (Improvement..!!!)

Why Equation form for the specification is a problem?

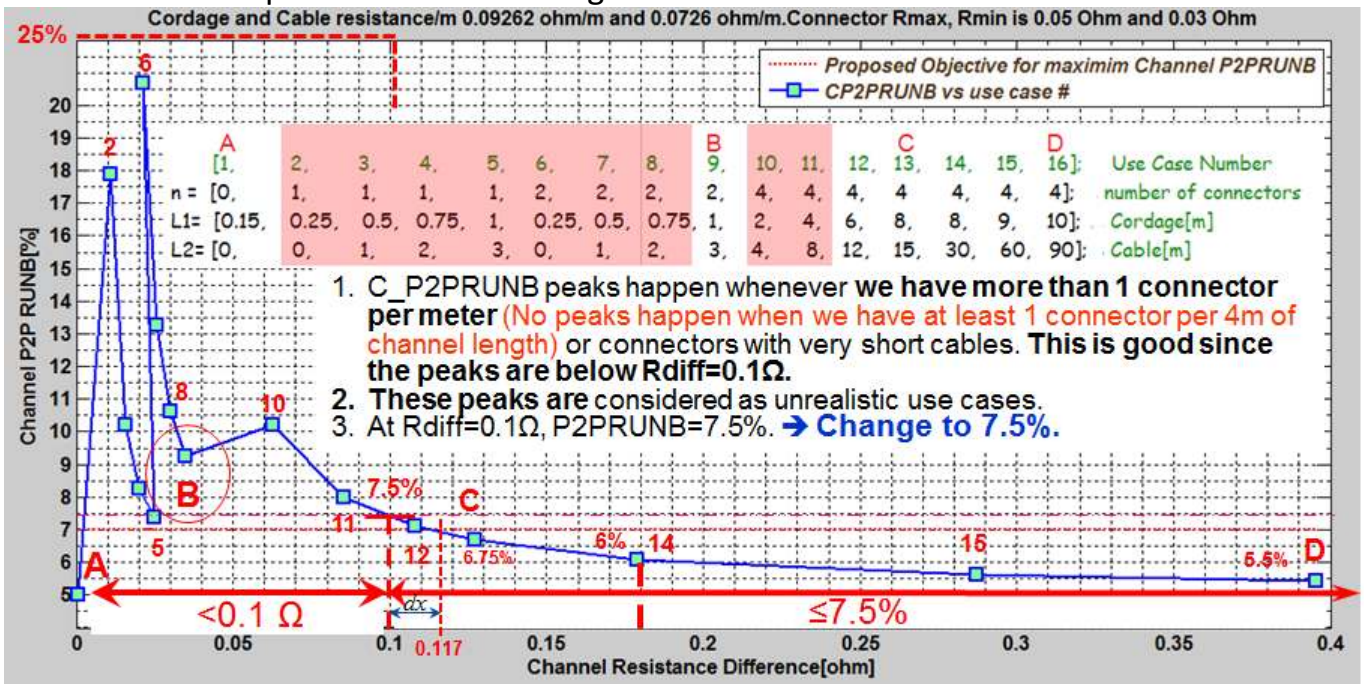
- As we can see below, equation form is Implementation Dependent
  - We need to know the channel length , The number of connectors?, Cordage length?, Cable length?
- This is a problem for compliance tests first
- We can improve it by setting it to maximum connectors=4 (see equation below), but then all the worries of margin on the tables will go to short channel length were we have more problems!!!!!!
  - We will have 4 connectors to channel with 1m or 10m ➔ unrealistic – wasted margins.
  - Still it is implementation dependent!
- How PSE or PD designers design their systems? They design for the worst case in the curve correct?
  So why not to use "100 milliohms or 7.5% whichever is greater" which is use case based optimized specification that is the worst case.



http://www.ieee802.org/3/bt/public/jul14/darshan_01_0714.pdf

Why proposed base line text is better specification?

- The base line proposal main part: “100 milliohms or 7.5% whichever is greater
- Use Case optimized and yet based on Channel Equation!
- No wasted margins. This is only Channel spec. System specification is not affected with any way we go.
- Optimized margins at short and long channels
- Simple specification.
- Single worst case value.
- Below 100 milliohms, C_P2PRUNB is limited by 25% (worst case connector data). (Slide 22 in the link below)
  - It can be part of the normative text or as a note.
  - Group to discuss at meeting #12.



http://www.ieee802.org/3/bt/public/jul14/darshan_01_0714.pdf

Reference material for FAQ

How maximum pair current and E2EP2PCRUNB affects magnetics bias current

See at:
http://www.ieee802.org/3/bt/public/unbaladhoc/Meeting_11_IEEE802_3bt_Channel_Pair_To_Pair_Resistance_Imbalance_ad_hoc_rev_015a.pdf

How Ibias is tested: See annex D
Negligible effect on Ibias: See Annex D1.
See Stud Group presentation showing negligible effect on Ibias through Spice simulations for E2ECP2PRUNB=26-30% .
http://www.ieee802.org/3/4PPOE/public/jul13/beia_1_0713.pdf
http://www.ieee802.org/3/4PPOE/public/jul13/darshan_2_0713.pdf
http://www.ieee802.org/3/4PPOE/public/nov13/beia_01_1113.pdf
http://www.ieee802.org/3/4PPOE/public/nov13/darshan_02_1113.pdf
http://www.ieee802.org/3/4PPOE/public/nov13/darshan_03_1113.pdf

#	Parameter	Concepts		Consensus
	Concept	Single worst case value to any unbalance parameter	A Function	
1	Concept parameters	100 milliohms or 7.5% whichever is greater	$C\_P2PRUNB = \frac{R_{max} - R_{min} + 0.08\Omega}{R_{max} + R_{min} + 0.032\Omega}$	YES
2	Reference Material	See links to a work covering both concepts at: Slide 56 at: http://www.ieee802.org/3/bt/public/unbaladhoc/Meeting_11_IEEE802_3bt_Channel_Pair_To_Pair_Resistance_Imbalance_ad_hoc_rev_015c.pdf slides 14-21,35 at: http://www.ieee802.org/3/bt/public/unbaladhoc/Analzing_Channel_Pair_To_Pair_Resistance_Unbalance_use_cases_rev_5a.pdf		
3	Optimization	- **Optimized P2PRUNB Use case driven**. - 1m channel cannot use 4 connectors. - No margins at short channels. - Optimized margins for short channels. - - See plot demonstrating it. -	-Worst case driven. -4 connectors are used everywhere (e.g. 4 connectors for 1m Channel!!) -High margins left on the table at short channel. -Depend on channel length or channel resistance. -Implementation dependent.	
3	Pass Fail criteria	Simple	Complex. Implementation dependent	Yes
4	How PSE and PD designer will use channel specifications?	PSE Need to meet PSE PI unbalance parameter under channel with worst case conditions. The 7.5% point is aligned to the Channel_Rdiff=0.1Ω which is the worst case point at the equation too.	Equation became not relevant since we need to design to the worst case any way so move to current concept….. ☺.	

#	Parameter	Concepts		Consensus
	Concept	Single worst case value to any unbalance parameter	A Function	
5	Doe's it affects cable P2P RUNB specification	No. Cable P2PRUNB is 5% max. This is a channel specification only. We can add a note that the above requirements based on a cable with 5% maximum of pair to pair resistance unbalance.	Same.	Yes
6	Doe's it affects End to End Channel P2PRUNB? Or maximum current	**Case 1:** **No effect on E2E_CP2PRUNB**. In the End to End Channel P2PRUNB, the channel equation is used and not "100 milliohms or 7.5% whichever is greater" so there is no wasted margin at 100m **(there is no 7.5% -5% = 2% added to the End to End Channel P2PRUNB).**	No. The channel Equation is also part of the End to End unbalance equation.	Yes.
		Case 2 Not significant even if we will use channel P2PRUNB=7.5% instead of 5.5% in the End to End Channel P2PRUNB. **End to End C_P2PRUNB may reach ~15%-20% at 100m and can reach to ~50% at short channel pending components** **(We can use tighter PSE and PD PI unbalance parameters and the results may be half of the above)** -The 2% difference will increase the max pair current in the system from 659mA to 668mA. **This is only 9mA** difference (at 51W PD load. 14mA at 80W). **0nly 1.4% increase.** **As a result,** -Transformer bias current will increase by 1.4%*3%/2=**0.21%.** -Power loss increase on transformer located on max current pair: (1+0.014)^2-1=**2.8%** -Total power loss change on transformer package: **-0.02%**		

Regarding the proposal made in the minority report for (5% + 0.1ohms).
Dave Explains that he agreed that (5% + 0.1ohms) is not equation and cannot be a valid equation but the intention was a "MAX" or logical "OR" of the greater of 5% or 0.1ohms.
Yair review of the above proposal:
5% OR 0.1 whichever is greater is the same format of current proposal at the motion. The difference is 5% instead of 7.5%.
This proposal will not work too. See slide 16 at
http://www.ieee802.org/3/bt/public/unbaladhoc/Analzing_Channel_Pair_To_Pair_Resistance_Unbalance_use_cases_rev_5a.pdf
that show clearly under estimation of the use cases for worst case analysis at C_P2PRUNB=5%.
Since there is single correct mathematical solution, any other solution is incorrect. In addition to the fact that equation form vs. single worst case value form doesn't leave margins on the table and it is much better due to long list of parameters per the table above.

It was shown above and demonstrates to Dave Dwelley that in our OOO conference meeting that:

1. The curve is accurate representation of the channel. This was the basis for the work.
2. Equation form is not the optimum choice.
   - 2.1 It doesn't reduce margins at 100m.
   - 2.2 Equation form leaves margins on the table at short channel were we have much higher unbalance than at 100m. It is due to the fact that it uses 4 connectors for any use case, even for short cables.
   - 2.3 End user has to design its PSE or PD for the worst case channel conditions.

     How he will use equation?

     Subject to interpretation of vendors, test houses etc.

     And he will have to use equation worst case since user doesn't have control on installation.
   - 2.4 Therefore equation form should not be use in the specification.
3. Equation form is implementation dependent specification. This alone argument is a big problem.
4. It was shown that the effect on **pair current** (with lowest resistance) at 100m is <1.4% in all methods.
5. It was shown that the effect on **transformer bias current** is 0.14%.
6. It was shown the effect on transformer **power loss** is -0.02%.
7. It was show that the higher current may happen at short cable and not at 100m

8. It was shown that a power system with 50-99W with active diode bridge in the PD which has a better balance than typical diodes, and using Purely resistive PSE at maximum channel length of 100m (where we expected that the imbalance in the cable and cordage would dominate) the PSE PI and PD PI still have tremendous effect that cause the whole channel to increase its unbalance from 5.5% actual at 100m channel to 15% at system level! In this case it was shown that the transformer bias current will be changed by 0.14% maximum which is insignificant.
   As a result, the 5.5% to 7.5% differences don't exist in system level. See case 1 and 2 in the table above.

   As a result of the above, the adhoc approach of "100 milliohms or 7.5% whichever is greater " that was based on detailed analysis and reviewed many times, for long time, and supported by cabling and connector experts and system experts and based on extensive field experience is the best choice.

9. The error in the analysis that suggested that the 2% difference is important was confirmed.
   -All errors were corrected and the analysis was sync with Yair's work.
   (The PSE PI and PD PI were missing (due to Dave assumption that in Ideal diode bridge in the PD and resistive PSE PI with R<<Rcable) will make the channel only main contributor to unbalance at the system. This is incorrect since PSE and PD PI have other components such connectors, transformers and other that will make PSE PI and PD PI with higher unbalance than the channel).
   Calculating the real maximum pair current requires adding actual PSE and PD PI components.
   -I bias need to multiplied by 3%/2 which makes all arguments about transformers a non-issue.

10. As a final result, no value in using equation. Moreover it causes issues in many aspects. See table above.

11. **So eventually the whole discussion came down to what really bothers Dave: He agrees that differences are negligible regarding the 7.5% compared to 5.5%. But the concerns are as follows:**

    We may have interpretations issue of the proposed specification: "100 milliohms or 7.5% whichever is greater"

    11.1 It may be interpreted as allowing cabling (not including connectors) P2P resistance unbalance of 7.5%, and the cable manufacturers may loosen their specs accordingly.

    My proposal: We remove this worry by adding the following notes.
    Notes:
    a) The above requirements are based on cable with pair to pair resistance unbalance of 5% maximum.

11.2 It can also be interpreted as allowing nearly infinite mismatch for a short channel since we don't define (in section 33.1.4.3) what the minimum connector resistance is. Because of the complex relationship between % mismatch and cable length, it's very easy to misinterpret this seemingly simple spec!

My response:

- Infinite mismatch is impossible. The maximum possible unbalance is 100%.
- So if you meant 100% maximum, I agree and I have addressed it in my work see: http://www.ieee802.org/3/bt/public/jul14/darshan_01_0714.pdf slide 22 that address it and suggest that it will be a subject for later work based on the analysis we already done and we have all the information in this link were we see red dashed border limits at 25%. To handle this I suggest using the following text as a note or as part of the normative text.

Proposed updates to base line text from May 2014.

33.1.4.3 Pair Operation Channel Requirement for Pair to Pair Resistance Unbalance

4P pair operation requires the specification of resistance ~~unbalance~~ difference between each two pairs of the channel, not greater than 100 milliohms or resistance unbalance of 7.5% 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 equation 33-1.1:

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

Channel pair to pair resistance difference is defined by equation 33-1.2:

$$R_{ch\_\max} - R_{ch\_\min} \qquad \text{33.1.2}$$

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.

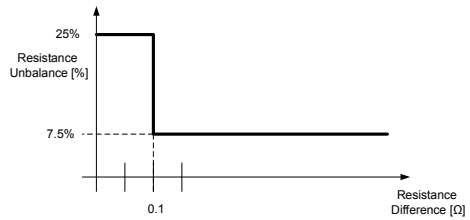
Notes:

b) The above requirements are based on cable with pair to pair resistance unbalance of 5% maximum.

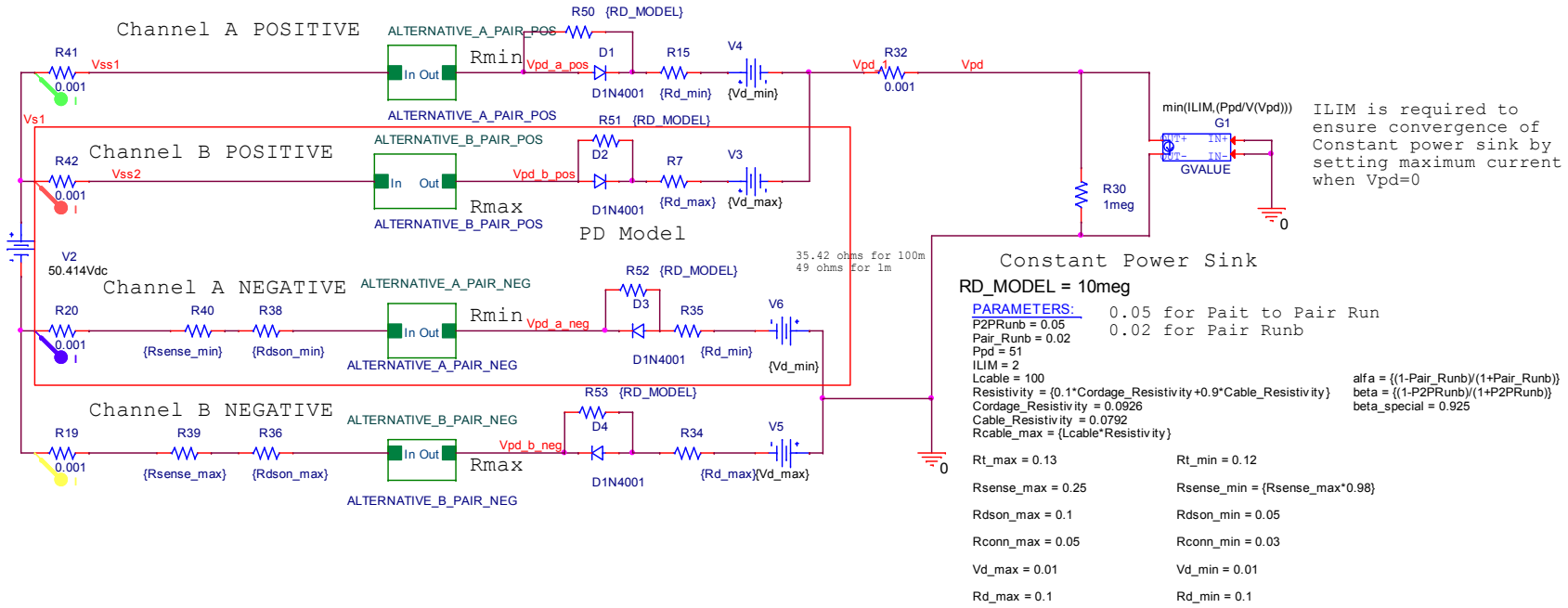
c) The resistance unbalance for resistance difference < 100 milliOhm should not exceed 25%.

d) See details in informative section TBD.

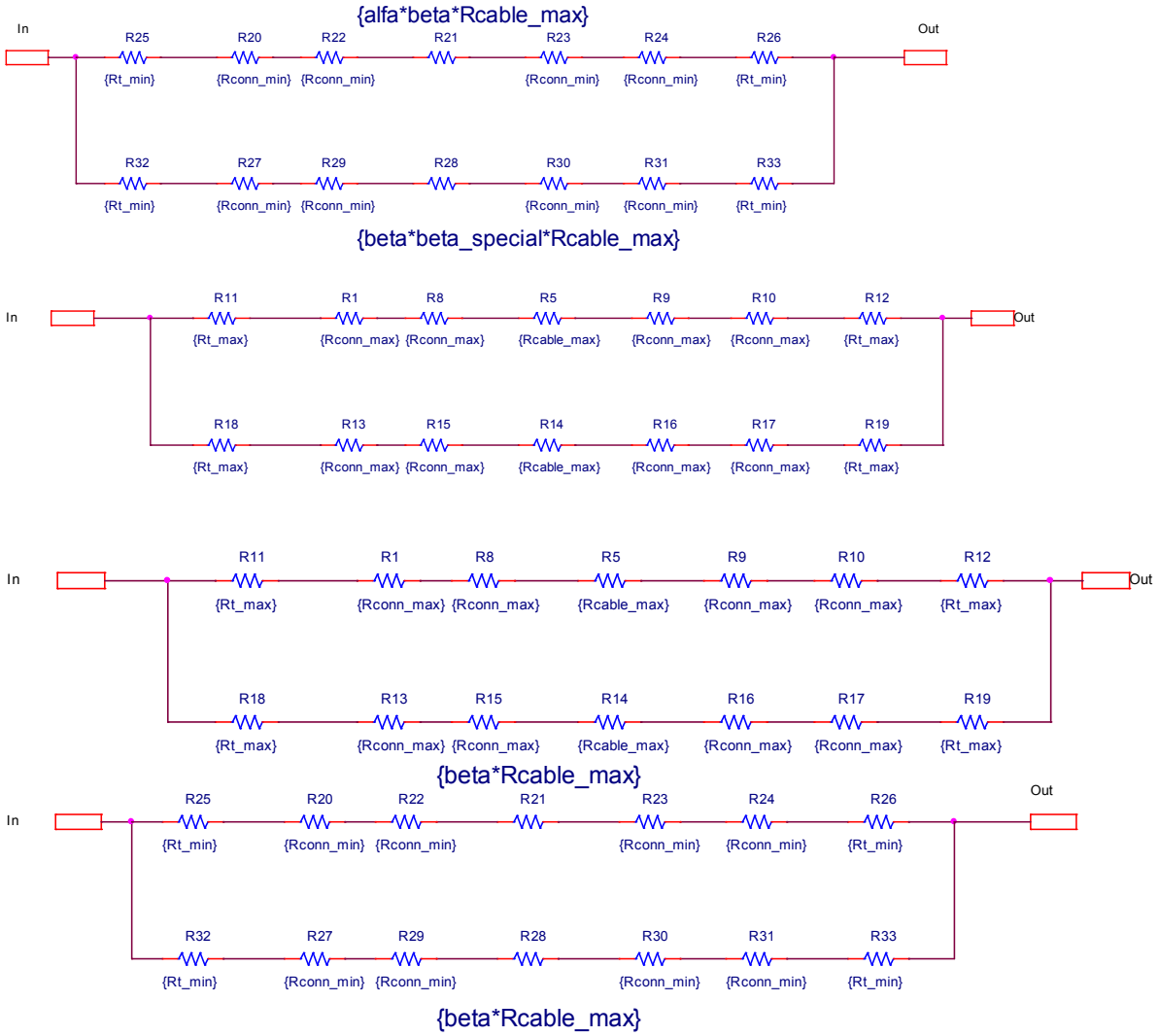
Illustration of how specification will look like:



Spice Model used during the End to End P2PRUNB adhoc.



The parameters above are used in the example in Annex G6 at the adhoc material of meeting #12.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