Derivation of Rload_max, Rload_min and Rsource_max, Rsource_min.

The following is a short summary of the derivation of some of the PSE and PD pair-to-pair unbalance requirements in 802.3bt **Draft 2.1**.

End to End, Pair to Pair Resistance or Current unbalance (E2EP2PRunb or E2EP2PCunb) is specified by Equation 33D-1.
The term End to End refers to all the components that affect E2EP2PRunb, including components that are in the PSE (See Figure 33B–2 for the PSE side) and in the PD (see Figure 33A–4) (It is not just the Channel components between the PSE PI and PD PI as used in other parts of the specifications).

$$E2EP2PRunb = \frac{\left(R_{PSE\_max} - R_{PSE\_min}\right) + \left(R_{CH\_max} - R_{CH\_min}\right) + \left(R_{PAIR\_PD\_max} - R_{PAIR\_PD\_min}\right)}{\left(R_{PSE\_max} + R_{PSE\_min}\right) + \left(R_{CH\_max} + R_{CH\_min}\right) + \left(R_{PAIR\_PD\_max} + R_{PAIR\_PD\_min}\right)} \qquad (33D\text{-}1)$$

Where

E2EP2PRunb	is the end to end, pair-to-pair effective resistance unbalance between two pairs of the same polarity. The effective resistance includes transformation of pair-to-pair voltage difference (in PSE and PD) to resistance elements at the system maximum operating power. When effective resistance is used, E2EP2PRunb is equal to the end to end pair to pair current unbalance E2EP2PCunb. E2EP2PRunb is a system parameter which was derived from 4-pair model simulations using worst case values of max/min resistance elements of all system components and maximum PSE and PD pair to pair voltage difference. This resulted in worst case system pair to pair effective resistance unbalance as function of channel length in meters and maximum pair current under pair-to-pair unbalance conditions.
R_{PSE_min} , R_{PSE_max}	are defined in 33.2.8.4.1.
R_{CH_min}, R_{CH_max}	are defined in 33A.4.
$R_{PAIR\_PD\_min}$, $R_{PAIR\_PD\_max}$	are defined in 33A.5.

The use of common mode effective resistance simplifies the math used to derive pair-to-pair unbalance requirements by converting all system pair-to-pair voltage difference (such as VPort_PSE_diff which is specified in Table 33-19 or PD pair-to-pair voltage difference which is embedded in equation 33A.4 and in the values of Ipeak_2P_unb_max and in Icon-2P_unb values) to resistive elements in addition to PSE PI and PD PI resistive elements (R_{PSE_min} and R_{PSE_max} in the PSE and $R_{PAIR\_PD\_min}$ and $R_{PAIR\_PD\_max}$ in the PD).

When PSE compliance is measured according 33.2.8.4.1 and Annex B, it is verified with R_{load_max} and R_{load_min} connected to the PSE. R_{load_max} and R_{load_min} are composed of compliant channel resistances, R_{ch_min} and R_{ch_max} as specified in 33A.4, a compliant PD which is represented by the effective resistances $R_{Pair\_PD\_min}$ and $R_{Pair\_PD\_max}$ as specified in 33A.5, and is also a function of R_{PSE_min} and R_{PSE_max} according to equation **33D-2**. $R_{Pair\_PD\_min}$ and $R_{Pair\_PD\_max}$ already includes the effect of PD pair to pair voltage difference of 0.06V for Type 3 PDs and 0.05V for Type 4 PDs that will ensure that at high currents, Iport-2P will not exceed Icon-2P_unb as required when PSE is tested for compliance.

$$R_{load\_max} = U \times R_{load\_min} + U \times R_{PSE\_min} - R_{PSE\_max} \qquad (33D\text{-}2)$$

Where:

$$U = \left(\frac{1 + E2EP2PRunb}{1 - E2EP2PRunb}\right)$$

$$R_{load\_min} = R_{ch\_min} + R_{Pair\_PD\_min}$$

$$R_{load\_max} = R_{ch\_max} + R_{Pair\_PD\_max}$$

PD compliance to the pair-to-pair unbalance requirements of 33.3.8.10 is verified when connected to source voltage with a voltage range of Vport-PSE-2P through the effective resistances Rsource_max and Rsource_min. Rsource_max and Rsource_min are composed from a compliant channel resistance with R_{ch_min} and R_{ch_max} as specified in 33A.4 and a compliant PSE which is represented by the effective resistances R_{PSE_min}, R_{PSE_max} as specified in 33.2.8.4.1 and is also a function of $R_{Pair\_PD\_min}$ and $R_{Pair\_PD\_max}$ according to equation 33D-3 which ensures worst case system conditions of PSE, Channel and PD. R_{PSE_min}, R_{PSE_max} already includes the effect of PSE pair to pair voltage difference of 0.01V for Type 3 PSE and Type 4 PSE that will ensure that at high currents, Iport-2P will not exceed Icon-2P_unb as required when PSE or PD is tested for compliance. See 33A.5 for design guidelines for PD PI effective resistance $R_{Pair\_PD\_min}$ and R_{Pair_max}.

$$R_{Source\_\max} = U \times R_{Source\_\min} + U \times R_{Pair\_PD\_\min} - R_{Pair\_PD\_\max} \qquad \text{(33D-3)}$$

Where:

$$U = \left(\frac{1 + E2EP2PRunb}{1 - E2EP2PRunb} \right)$$

$$R_{Source\_\min} = R_{ch\_\min} + R_{PSE\_\min}$$

$$R_{Source\_\max} = R_{ch\_\max} + R_{PSE\_\max}$$

The E2EP2PRunb that was used to derive the U value in Equations 33D-2 and 33D-3 above, is found at short cable in order to find the worst case unbalance due to the fact that with long cables the unbalance is improved. Maximum pair current due to E2EP2PRunb is not always obtained at the maximum value of E2EP2PRunb. For Type 3 systems, maximum pair current is obtained at Rchan-2P=0.2Ω (short cable) where E2EP2PRunb is the highest. For Type 4 systems, maximum pair current is obtained at Rchan-2P=12.5Ω (at 100m channel length) where E2EP2PRunb is the lowest.

REFERENCES:
http://www.ieee802.org/3/bt/public/oct15/darshan_01_1015.pdf

Annex A: 4-pair models and its database

See pair-to-pair unbalance adhoc material.