Mode Partition Noise Handling in Spreadsheet Model

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Problem Statement and Solution

- Mode Partition Noise (MPN) penalty calculation does not take into account inter-symbol interference (ISI)
- RIN properly treated, need to **apply the same approach** for MPN
- Need to make appropriate corrections in Pcross

How do we calculate the penalties

- Spreadsheet uses well documented formulas to calculate individual penalties
  - Inter-symbol interference (ISI), relative intensity noise (RIN), mode partition noise (MPN)
- Interactions of penalties (non-linear addition) is handled by adding the cross penalty (Pcross), correcting for the effect
- Assumes all penalties have Gaussian distribution, can use error function to calculate the bit error rate

BER calculation

The worst case BER is given by:

$$BER = \frac{1}{2} * erfc\left(\frac{d_{\min}}{\sqrt{2}\sigma_{tot}}\right) = \frac{1}{2} * erfc\left(\frac{Q}{\sqrt{2}}\right)$$

d_{min} - minimum distance from "1" level to threshold (includes ISI)

σ_{tot} – standard deviation of the noise, includes all contributions (receiver noise, RIN, mode partition noise, modal noise):

$$\sigma_{tot}^2 = \sigma_{rx}^2 + \sigma_{rin}^2 + \sigma_{mpn}^2 + \sigma_{mn}^2$$

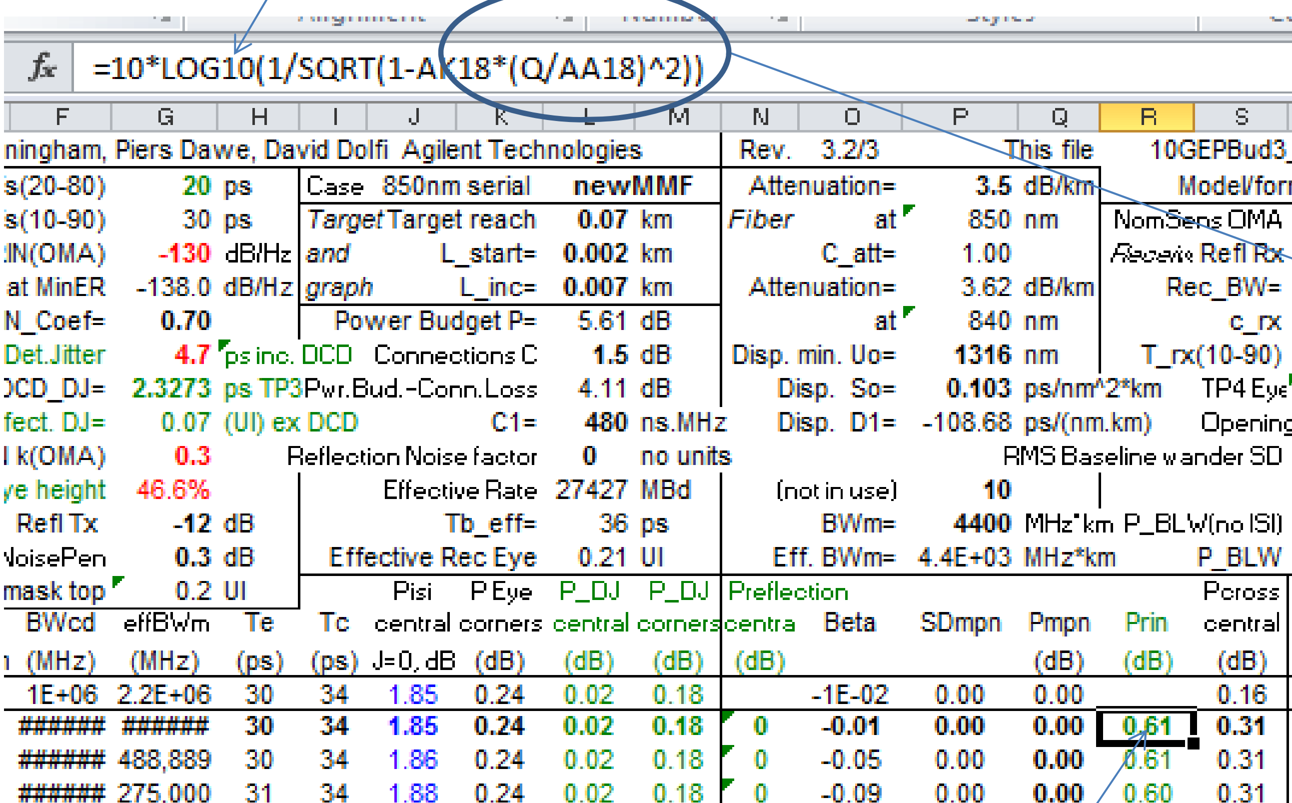
In the spreadsheet model, **RIN and mode partition noise standard deviations are calculated relative to the OMA and OMA/2 respectively [1, 2]**

To find the individual penalty for the signal dependent noises (RIN, MPN), d_{min} has to take into account the ISI **in the PENALTY formulas**

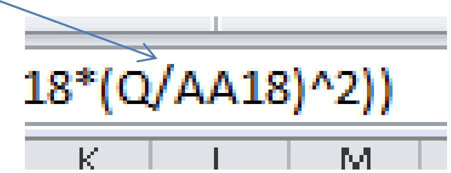
This is already done with RIN [3,4], but not with MPN, need to make appropriate changes to the spreadsheet model

Current state for RIN column

Formula shows in the cell entry area when you click in any cell (here R18) in Prin column (R)



Correction for ISI (divide by AA18)

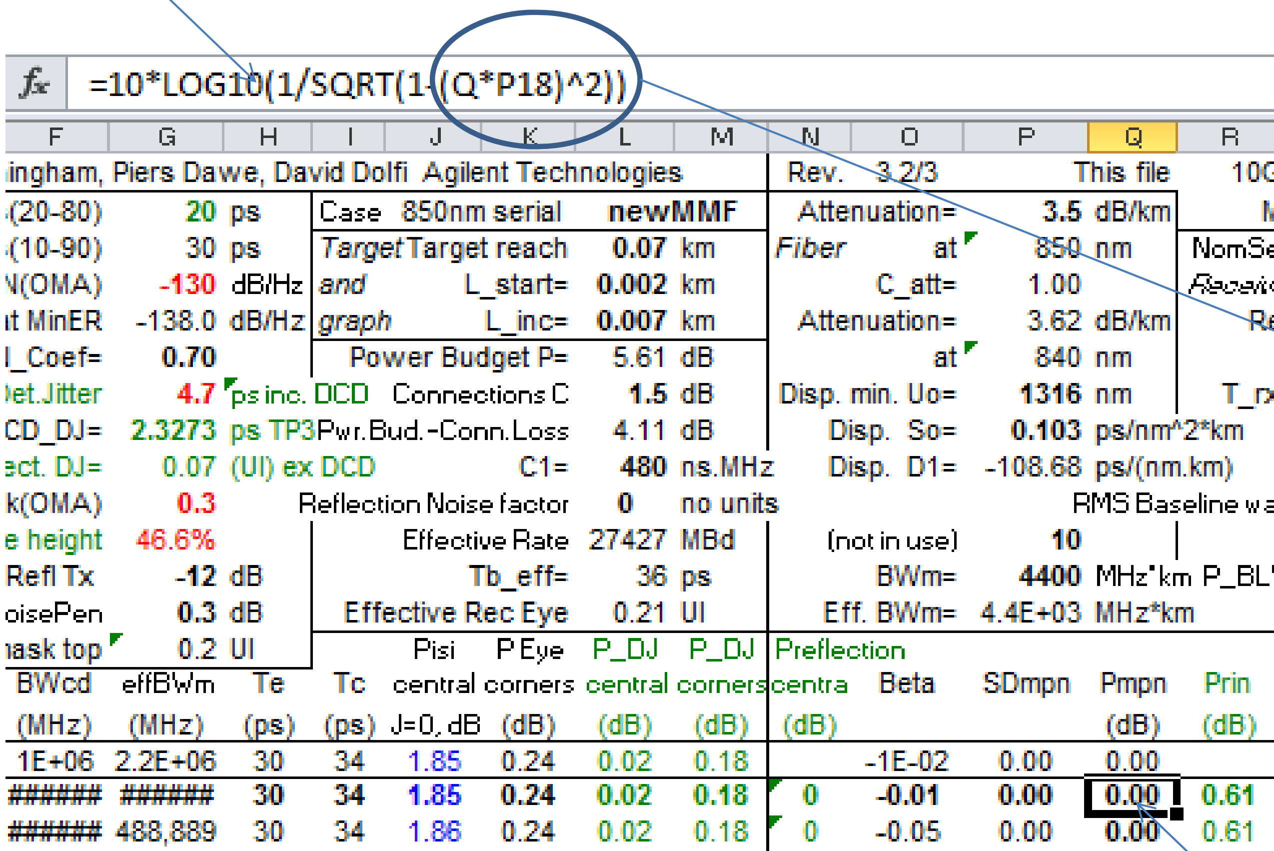


Prin cell clicked, R18 here

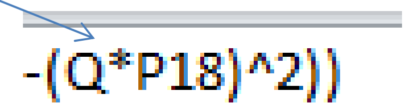
RIN is correctly handled

Current state for MPN

Formula shows in the cell entry area when you click in any cell (here Q18) in Pmpn column (Q)



Correction for ISI is missing (divide by AA18)

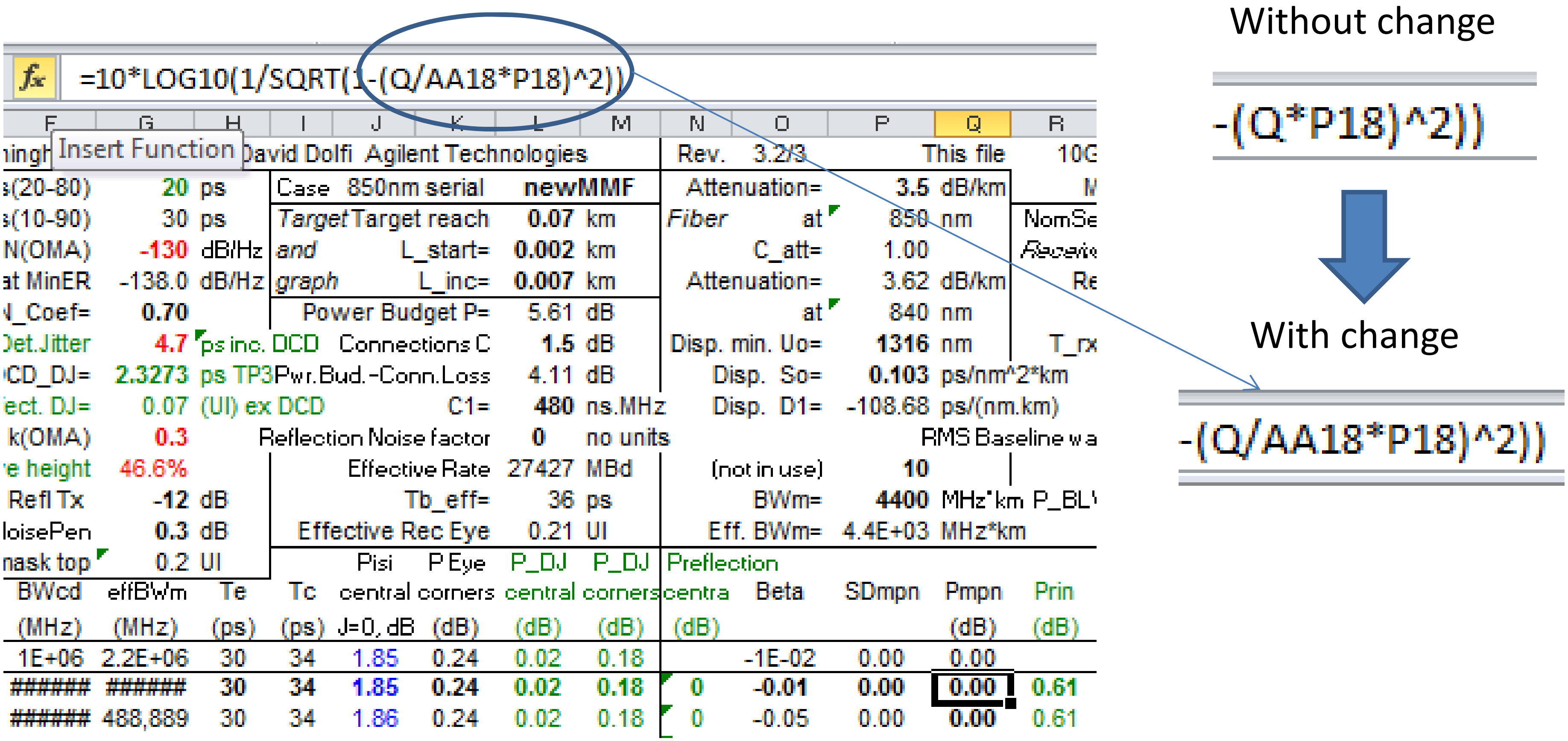


MPN is not handled correctly

Prin cell clicked, Q18 here

Proposed solution

- Apply the same modification in Q column as for RIN (divide Q value by the appropriate column AA value)



Other changes needed

- Appropriate change in Pcross needs to be made (column S):

Before:

```
=-10*LOG10(AA18*SQRT(1-Q*Q*((SD_blw^2+AK18)/AA18^2+Vmn+P18*P18)))
```

After:

```
=-10*LOG10(AA18*SQRT(1-Q*Q*((SD_blw^2+AK18+P18^2)/AA18^2+Vmn)))
```

P18 moved inside inner parenthesis, divided by AA values (ISI)

Related and Future Work

- MPN theory is valid for SMF with MMF sources only, but mistakenly also applied to MMF [5]
- Two effects working in opposite direction:
  - MPN is time and pattern dependent, worst case is at bit edges and for high ISI bits for both SMF and MMF
  - MMF reduces MPN compared to SMF, reduction proportional to effective number of mode groups (launch conditions matter!)

References

1. G. Agrawal et. al.: JLT, Vol.6, No.56, May 1988, pp. 620-625
2. K. Ogawa: IEEE JQE, Vol. QE-18, No.5, May 1982., pp. 849-855
3. http://www.ieee802.org/3/ae/public/oct01/dawe_1_1001.pdf, pages 14-15
4. *http://www.ieee802.org/3/ae/public/mar00/dawe_1_0300.pdf, page 6 (slides 11 and 12)*
5. *P. Pepeljugoski - unpublished work*