Technical feasibility study: Supported reach of 100Mbit/s and 1000 Mbit/s

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  802.3 bq type B
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Basics

- Using Salz S/N theory in an AWGN Channel is the first approximation to evaluate ISO Channel possibilities. This was done.
- Formula and usage presented by Zimmerman during development of 802.3bz

Theory presented during the ISO JMTG September 7 meeting

- Prerequisite
  - This is not a tool to develop for electronics!
  - PAM2: 10^{-12} BER 17 dB S/N ratio
  - 20% additional bitrate overhead
  - Return loss compensated by other means
  - Background noise
  - External noise is link Alien noise 6 around 1
    - Less then 6 disturbers will disturb less but it is not specified. Increasing the transmit power does not help because it increases the noise too.

Modulation

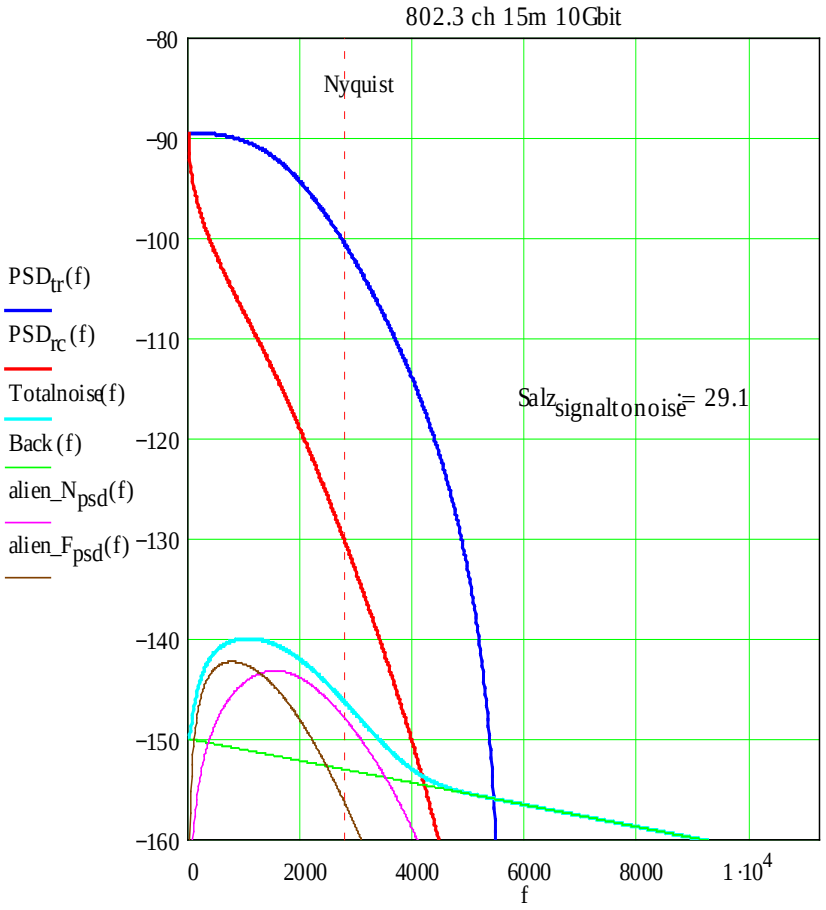
- Since this is not intended to be an electronic development, but rather only to define the framework conditions, only PAM (pulse-amplitude modulation) from 2 to 32 was investigated in order to find out the optimum. With higher PAM, the frequencies decrease, making it possible to build simpler receivers. The disadvantage, however, is the higher required power density per/baud (to be seen in the table as additional attenuation). Once the optimal bit/baud are known other modulation schemes can be investigated.

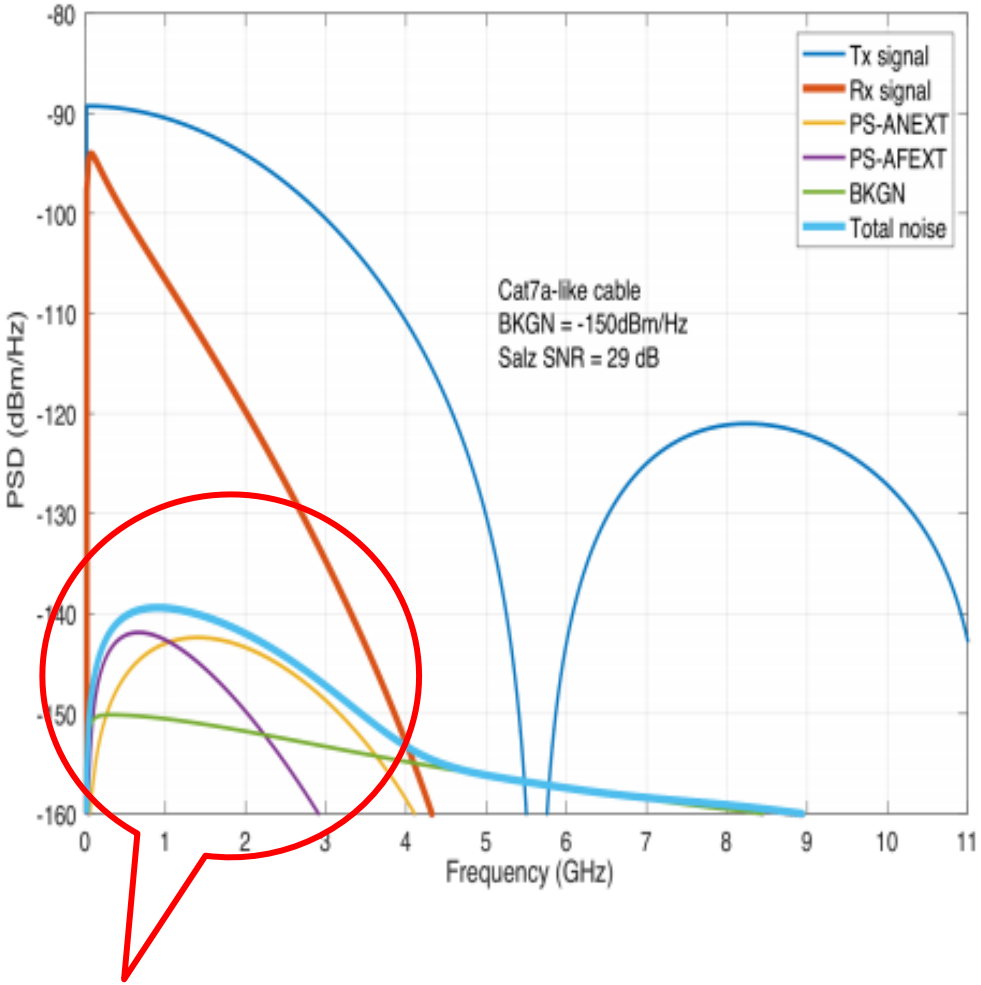
Validation

- Souvignier presented a similar calculation model which could be reproduced with our own calculation.
- See: Tom Souvignier Bandwidth, Modulation and SNR Comparison for Multi-Gigabit Automotive PHY. IEEE 802.3ch Task Force| – May 2018

Souvignier (Broadcom) presentation

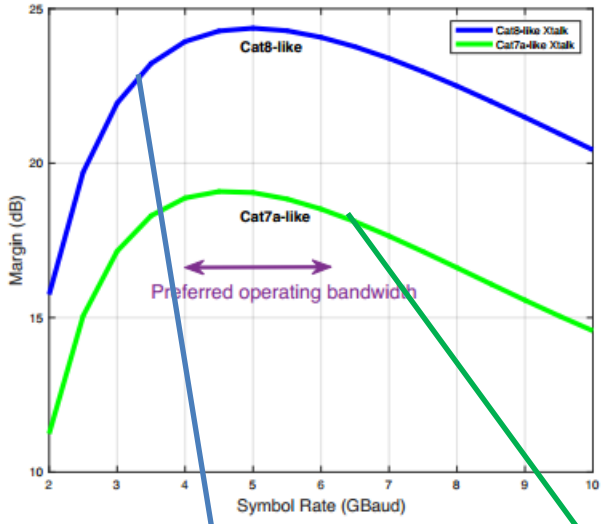
PAM4 ~cat7$_A$ Alien Noise





This calculation noise presentation

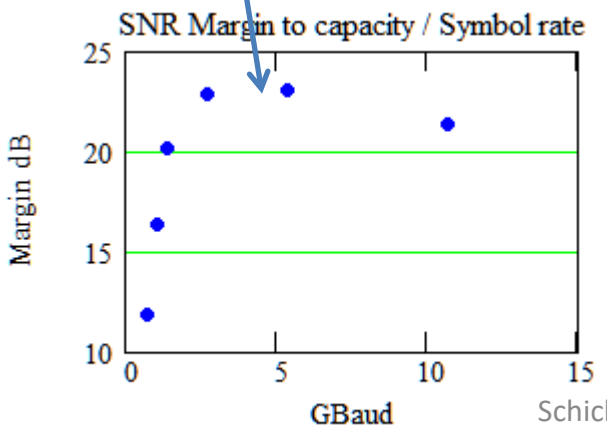
SNR Margin to Capacity

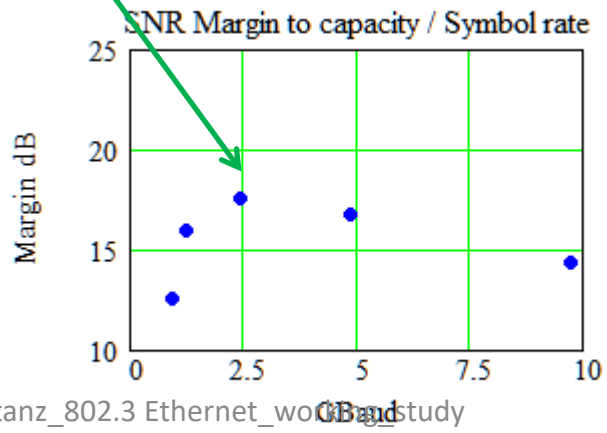


- $C = B\ log_2(1 + SNR_{Cap})$
  - $C = 10^{10}\ bits$
  - $B = Symbol\ Rate/2$
- $Margin = SNR_{Salz} - SNR_{Cap}$

- Margin relative to bandlimited 10Gb/s AWGN channel
- Highest margin in 4GBaud-6GBaud Symbol Rate (2GHz-3GHz BW) range
- Preferred bandwidth same for Cat7a & Cat8 cable models

BROADCOM



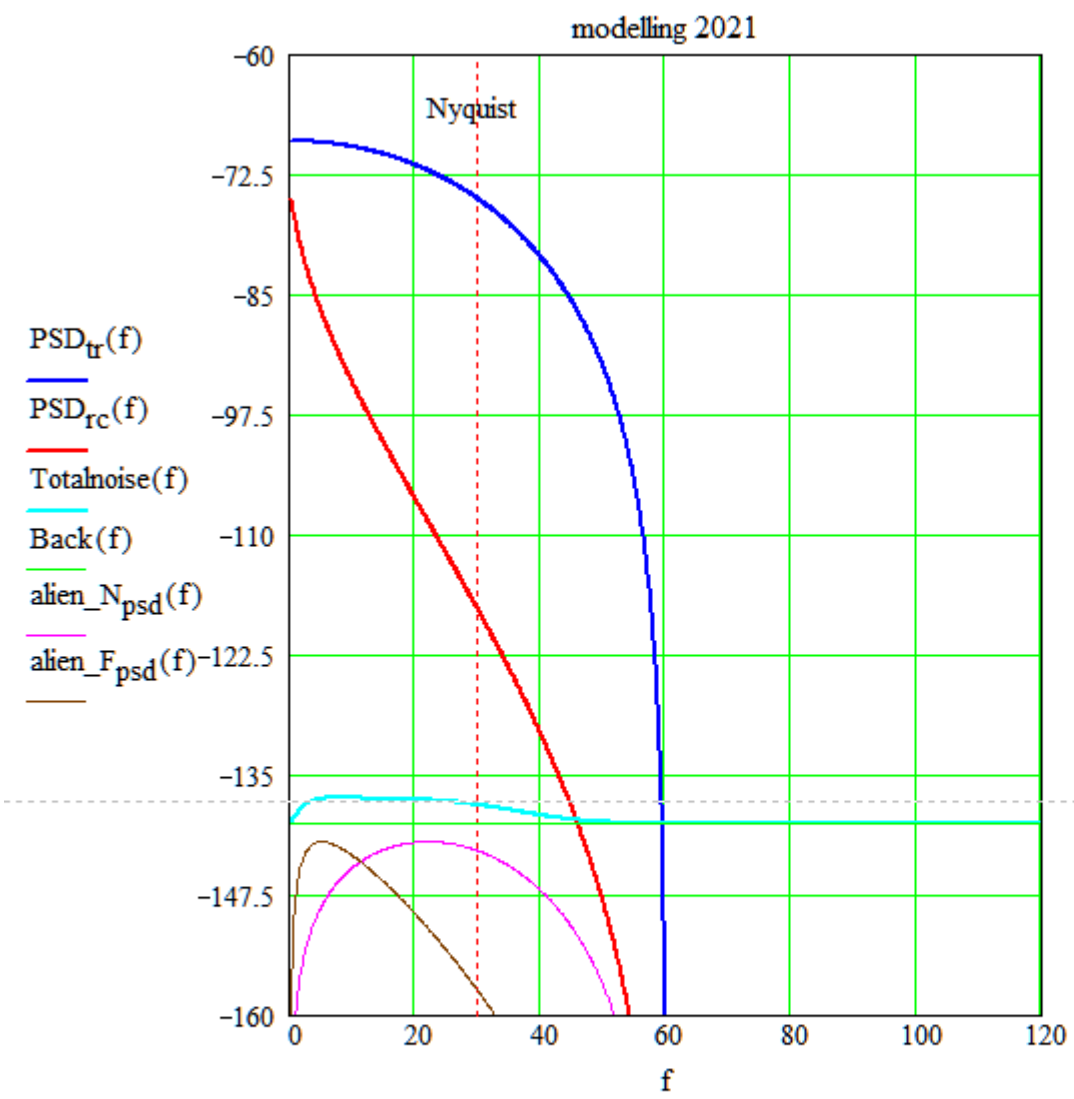


noise 7a

100 Mbit/s 590m

- The cable IL is known, but alien noise is questionable if the 20 MHz values from cg can be extrapolated up to 60 MHz.
- Therefore the alien noise limits from T1-B were used. A little to optimistic but also we are not expecting 6 cables wound around 1 victim.
- It should be doable if alien noise could be kept low (connections)

100 Mbit/s 590m, noise T1-B link



Noise = "T1-B"

Bitrate = 100 MBit/s

L = 590 m

Nyquist = 30 MHz

Tp = 8.7 dBm

Lf = 0.1 MHz

PAMx = 4

Bgn = −140 dBm/Hz

IEEE = 1.2

Connectors = 9

class = 3 cg

channel_at_Nyquist = 42.7 dB

PAM_{dB} = 24 dB

X1 = −69.1 dBm

Margin = 14.9

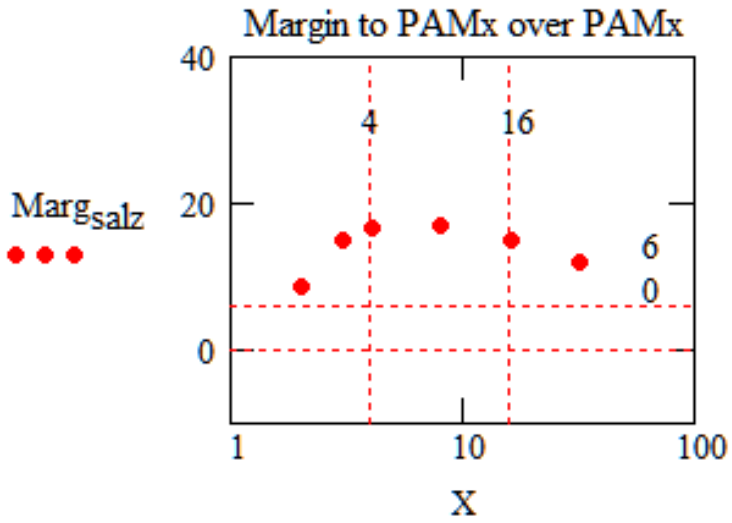
$Salz_{SNR}$ = 38.9

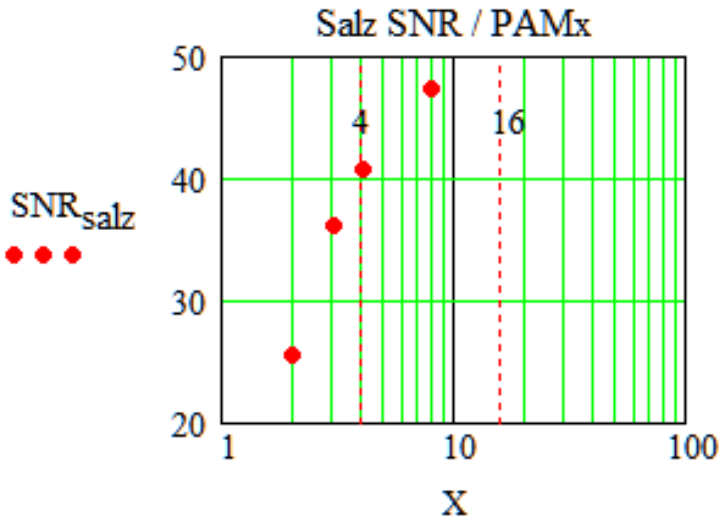
SNR_{cap} = 15

$Margin_{cap}$ = 27.2

Margin to capacity vs. reach

noise T1-B(optimistic)



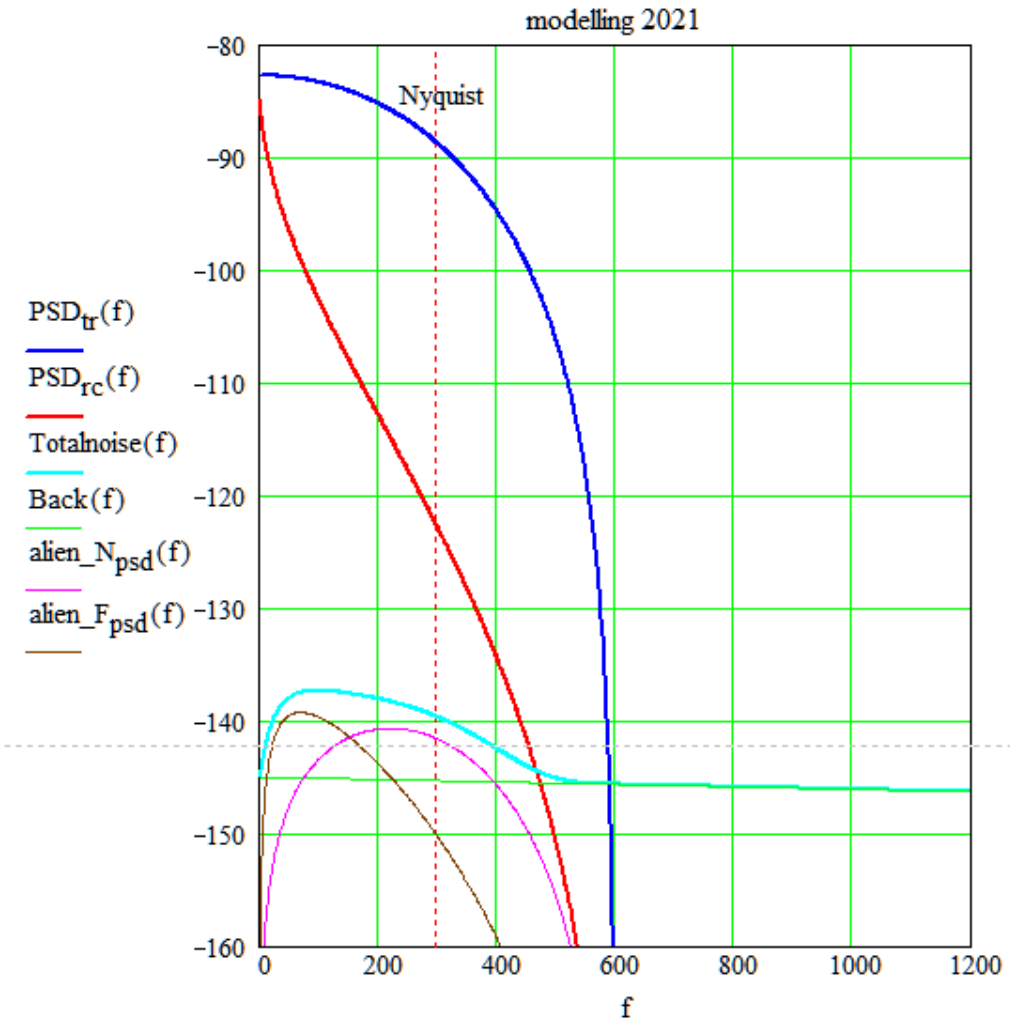


Attenuation @Nyquist and minimum bandwidth	PAM 3 37,5 MHz	PAM 4 30 MHz	PAM 8 20 MHz	
590m	48	43	35	dB
500m	41	37	30	dB
400m	33	29	24	dB
350m	29	26	21	dB
300m	25	22	18	dB

1000Mbit/s 100m

- 1000Mbit/s should run up to 100m. There we have T1-B and T1-C. Frequencies need to be fixed.
- Interesting is that it is achieved at rather low modulation levels (PAM 4)

1000Mbit/s 100m noise T1-B link



Noise = "T1-B"

Bitrate = 1000 MBit/s

L = 100 m

Nyquist = 300 MHz

Tp = 5 dBm

Lf = 1 MHz

PAMx = 4

Bgn = −145 dBm/Hz

IEEE = 1.2

Connectors = 4

class = 4

channel_at_Nyquist = 34.1 dB

PAM_{dB} = 24 dB

X1 = −82.8 dBm

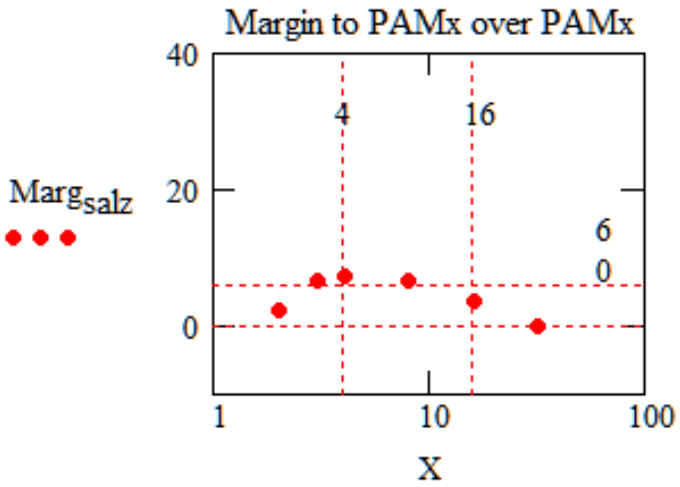
Margin = 7.2

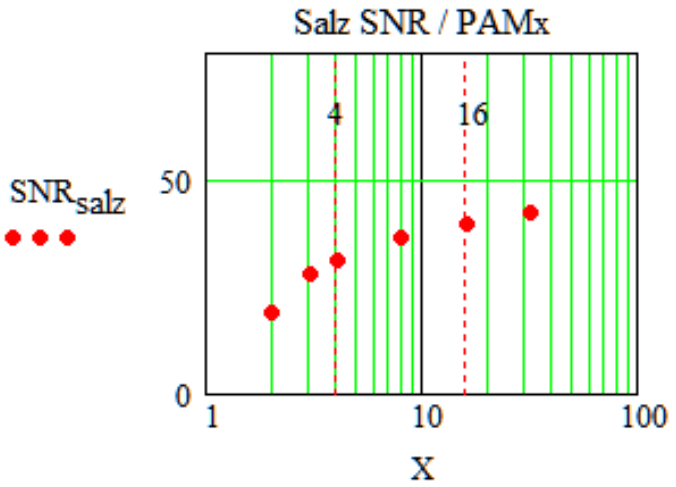
$Salz_{SNR}$ = 31.2

SNR_{cap} = 15

$Margin_{cap}$ = 19.4

Margin to capacity vs. reach, T1-B

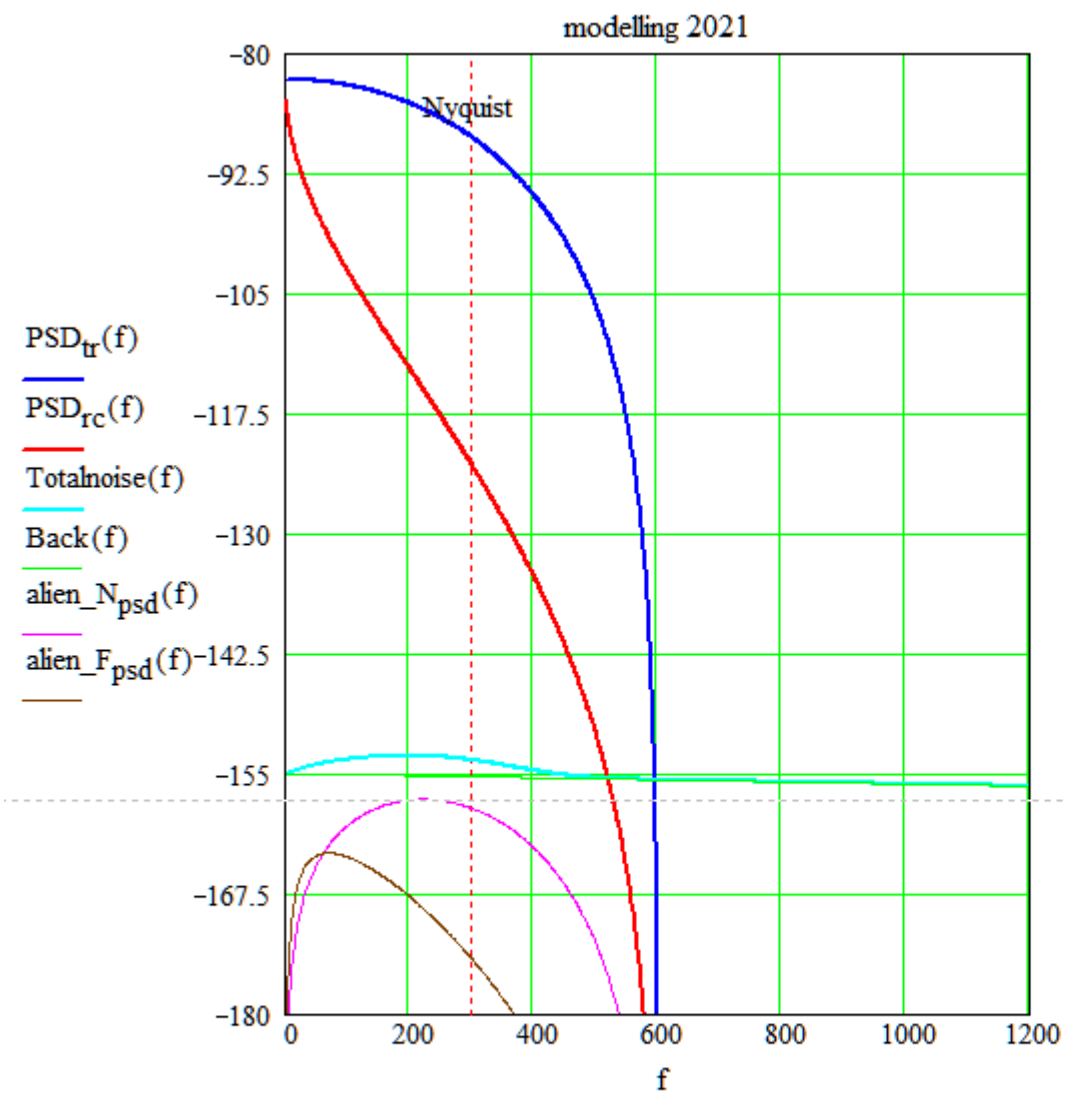




Attenuation @Nyquist and minimum bandwidth	PAM 4 300MHz	PAM 8 200MHz	
100m	34	28	dB

PAM4 with 7 dB of margin. Is that sufficient?
AFEXT and ANEXT same level, therefore power backup probably necessary.

1000Mbit/s 100m, T1-C link



Noise = "T1-C "

Bitrate = 1000 MBit/s

L = 100 m

Nyquist = 300 MHz

Tp = 5 dBm

Lf = 1 MHz

PAMx = 4

Bgn = −155 dBm/Hz

IEEE = 1.2

Connectors = 4

class = 4

channel_at_Nyquist = 34.1 dB

PAM_{dB} = 24 dB

X1 = −82.8 dBm

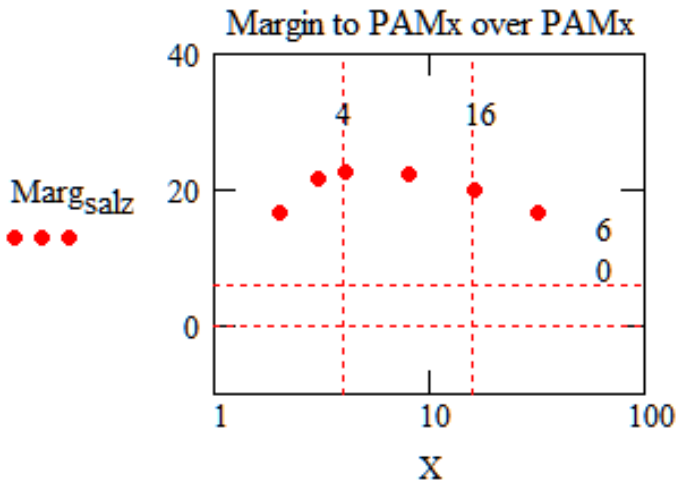
Margin = 22.3

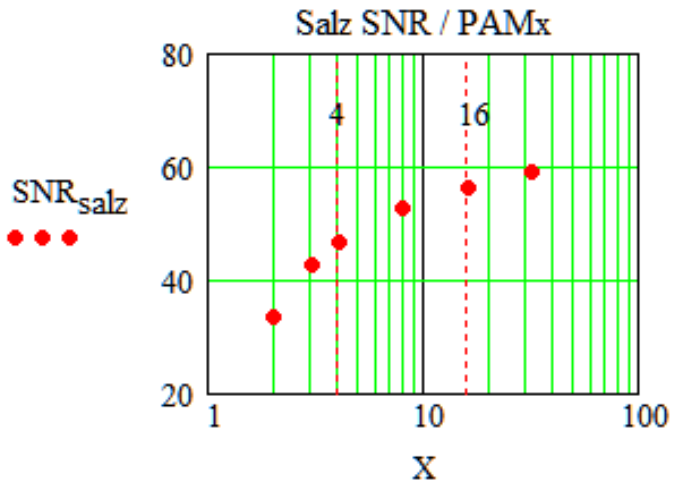
$Salz_{SNR}$ = 46.3

SNR_{cap} = 15

$Margin_{cap}$ = 34.6

Margin to capacity vs. reach T1-C





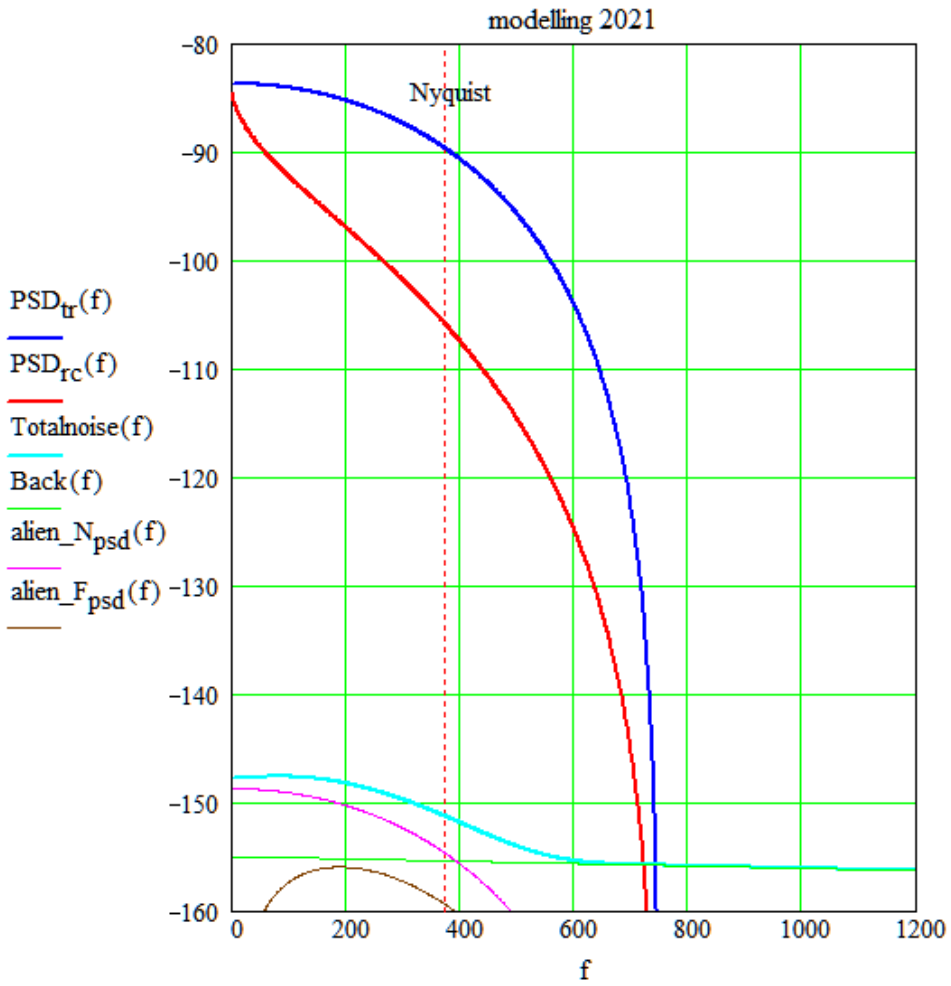
Attenuation @Nyquist and minimum bandwidth	PAM 4 300MHz	PAM 8 200MHz	
100m	34	28	dB

PAM 4 and PAM 8 with 22dB of margin. Should be sufficient to start taken it seriously. AFEXT less than ANEXT therefore Power backup probably not necessary.

1000BASET-1 40m
802.3 bq type B

- Limits as asked by bq.
- 40m

1000BASET-1 40m
802.3 bq type B



Noise 802.3 bp

Bitrate = 1000 MBit/s

L = 40 m

Nyquist = 375 MHz

Tp = 5 dBm

Lf = 1 MHz

PAMx = 3

Bgn = −155 dBm/Hz

IEEE = 1.2

Connectors = 4

class = 4 as bp

channel_at_Nyquist = 16.2 dB

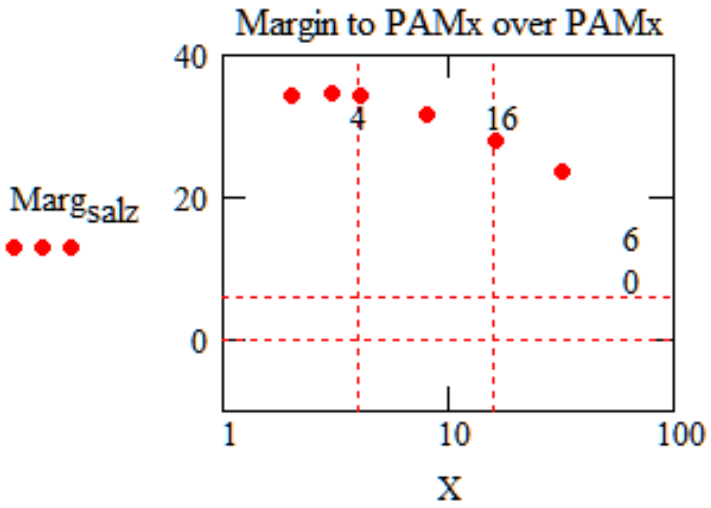
PAM_{dB} = 21.3 dB

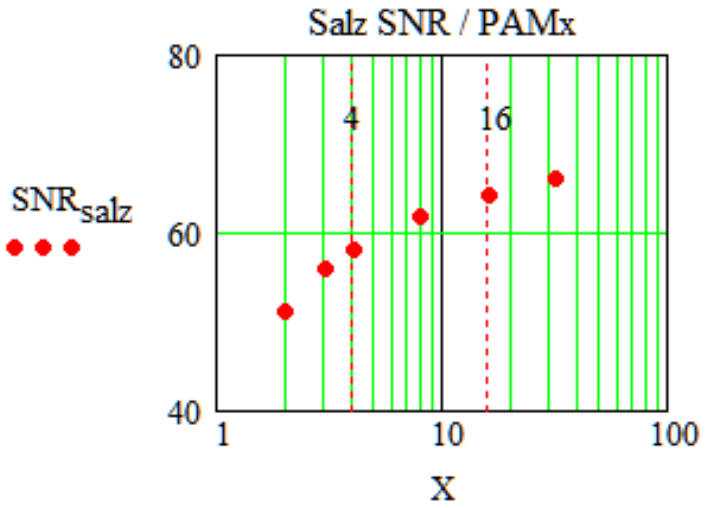
X1 = −83.8 dBm

Margin = 31

$Salz_{SNR}$ = 52.3 SNR_{cap} = 8.2 $Margin_{cap}$ = 43.1

1000BASET-1 40m
802.3 bq type B





Attenuation @Nyquist and minimum bandwidth	PAM 3 375MHz	
40m	16.2	dB

There is a huge margin of 30 dB, it could be used to extend to 100m. Optimum PAM 3 is confirmed. AFEXT higher than ANEXT.

Complexity, cost and latency

Complexity and cost

- Developing 2 speeds at the same time is more challenging as only one.
- For 4 Pair we have also multispeed developed: 2.5/5 GBase-T.
- Today's IC can support 6 speeds: 10M/ 100M/ 1000M/ 2.5G/ 5G and 10GBase-T.

Complexity, cost and latency

Complexity and cost

- With 2 speeds we can cover a much broader range of applications and an upgrade path. This increase the numbers for little more cost resulting in faster break even.
- The found optimum PAM 4 and PAM 8 are simpler as PAM 16 used for 2.5/5 and 10 GBase-T.

Complexity, cost and latency

Latency

- For latency we can take 5GBase-T, which is 4 times 1.25GBit/s. A similar SPE application does not include NEXT/ FEXT compensation as in 4 pair and error correction is faster as no NEXT/FEXT compensation has to be implemented.

Complexity, cost and latency

Latency

- Lower Alien crosstalk increases the S/N ratio per MHz, reducing the needed bandwidth and the complexity of the receiver.

78.5 Communication link access latency

Insert row into Table 78-4 with 2.5G/5GBASE-T LPI parameters following 1000BASE-KX as follows (unchanged rows not shown):

Table 78–4—Summary of the LPI timing parameters for supported PHYs

PHY type	Case	$T_{w\_sys\_tx}$ (min) (us)	T_{w_phy} (min) (us)	$T_{phy\_shrink\_tx}$ (max) (us)	$T_{phy\_shrink\_rx}$ (max) (us)	$T_{w\_sys\_rx}$ (min) (us)
2.5GBASE-T	Case-1	29.44	29.44	17.92	0	11.52
	Case-2	17.92	17.92	6.4	0	11.52
5GBASE-T	Case-1	14.72	14.72	8.96	0	5.76
	Case-2	8.96	8.96	3.2	0	5.76

Conclusion

- The study provided shows the technical feasibility for:
  - 100MBit/s over 590m with T1-B noise and AWG18 cables (This is optimistic).
  - 1000Mbit/s over 100m with links T1-B and T1-C.
  - Max frequency of the links TBD
- The complexity is manageable and at low additional cost, latency is below 5GBase-T as PAM4/8 is used and no NEXT/FEXT error correction is needed.
- The distinct identity for 1000BASE-T1 100m will be presented in an additional presentation.
- The presented options shall be considered for straw polls.