S/N comparison for NRZ and PAM4

Using the method described in moore_01_0311.pdf

Charles Moore: Avago Technologies

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For this comparison I used the method and values from from moore_01_0311.pdf except the values of g_{ip}, which is set to 1.0 and σ_{ip}, which is set to 0.0.

In particular, I used the rule that the computed SNR ratio for PAM_L must be higher than the PAM_2 (NRZ) SNR ratio by the factor

$$SNR_L = SNR_2 \cdot \sqrt{\frac{L^2 - 1}{3}}$$

to achieve the same SER. (note there is an error in the equation on page 15 of moore_01_0311.)

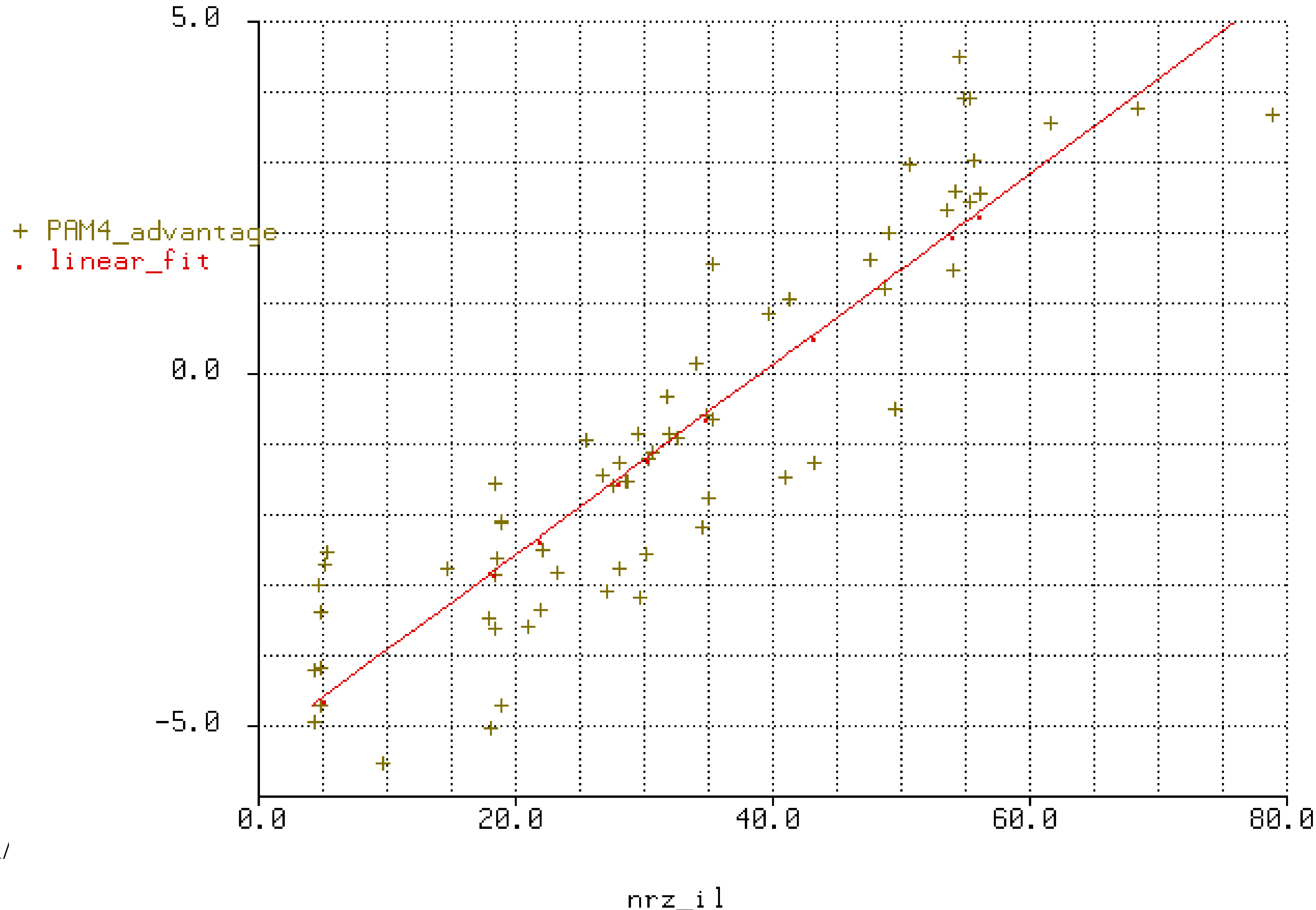
For the backplane comparison I used all of Backplane the data sets from www.ieee802.org/3/100GCU/public/channel.html:

- Long and Short links from Vittal Balasubramanian of FCI
- 27 In Channel from Megha Shanbhag of TE Connectivity (Updated version)
- 29.8” and 42.8” 4000-6 and Megtron 6 channels from Megha
- Alternate Architecture Backplanes from Megha
- Experimental Backplane from Pravin Patel of IBM
- 1m Backpane from Pravin
- ATCA Backplanes from Wolfgang Meier and Armin Jacht of Emerson Network Power
- Degraded 1m Channel from Mike Dudek of Qlogic (2 versions, one no longer available)

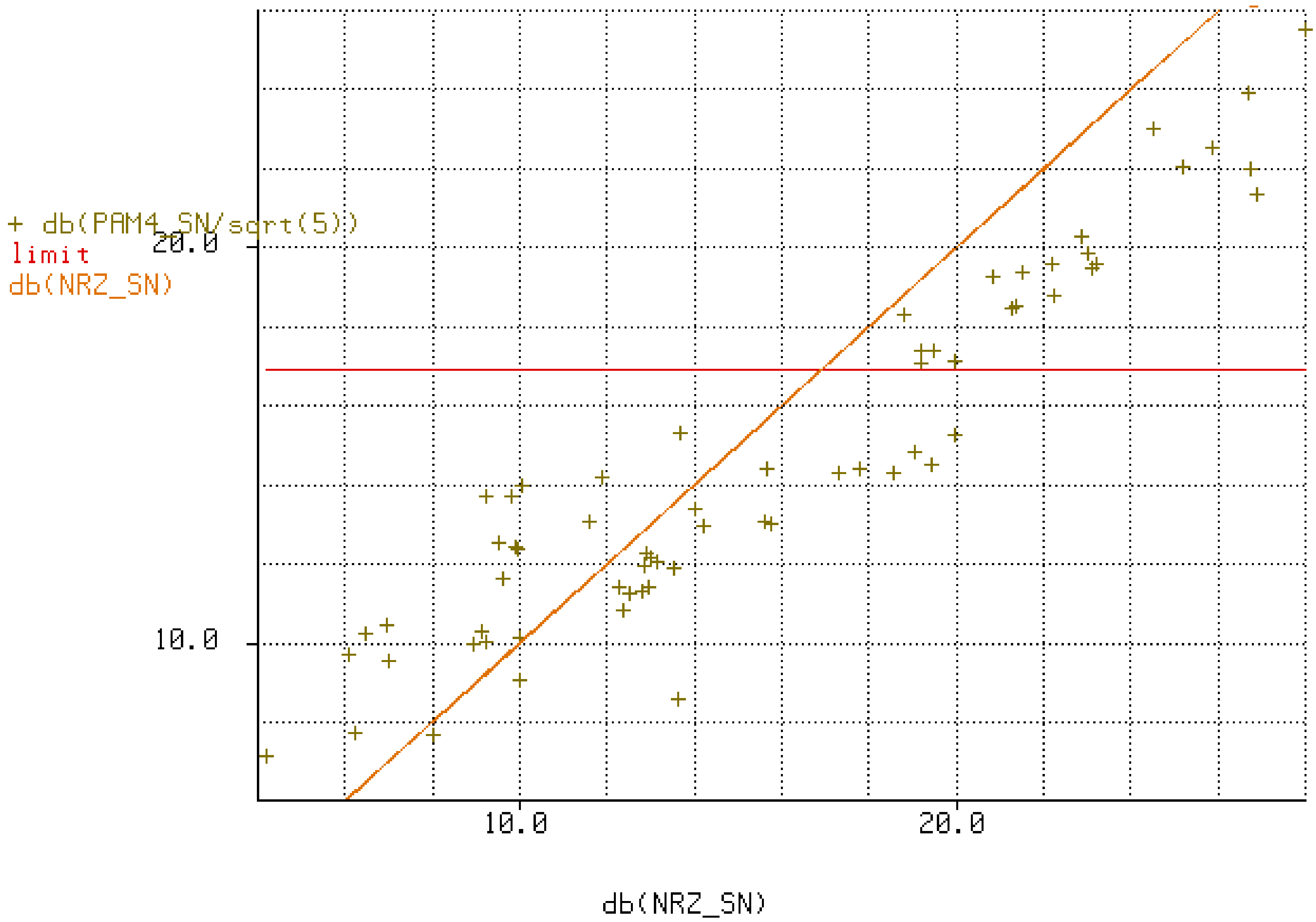
I also used Backplanes from the ap group from www.ieee802.org/3/ap/public/channel_model/index.html:

- Cases1-7 of Channels from John d'Ambrosia of Tyco Electronics
- M and B channels from William Peters of Intel (I omitted T channels which were far from ap compliant.)
- 4 Inbound and 4 Outbound channels form Gourgen Oganessyan of Molex (dropping FEXT since it pushed the parts well outside the ICR limits)
- 2 improved channels from Gourgen, also with FEXT removed

SNR advantage (in dB) for using PAM4 over NRZ
for available Backplane channels
vs
Insertion loss at 13 GHz



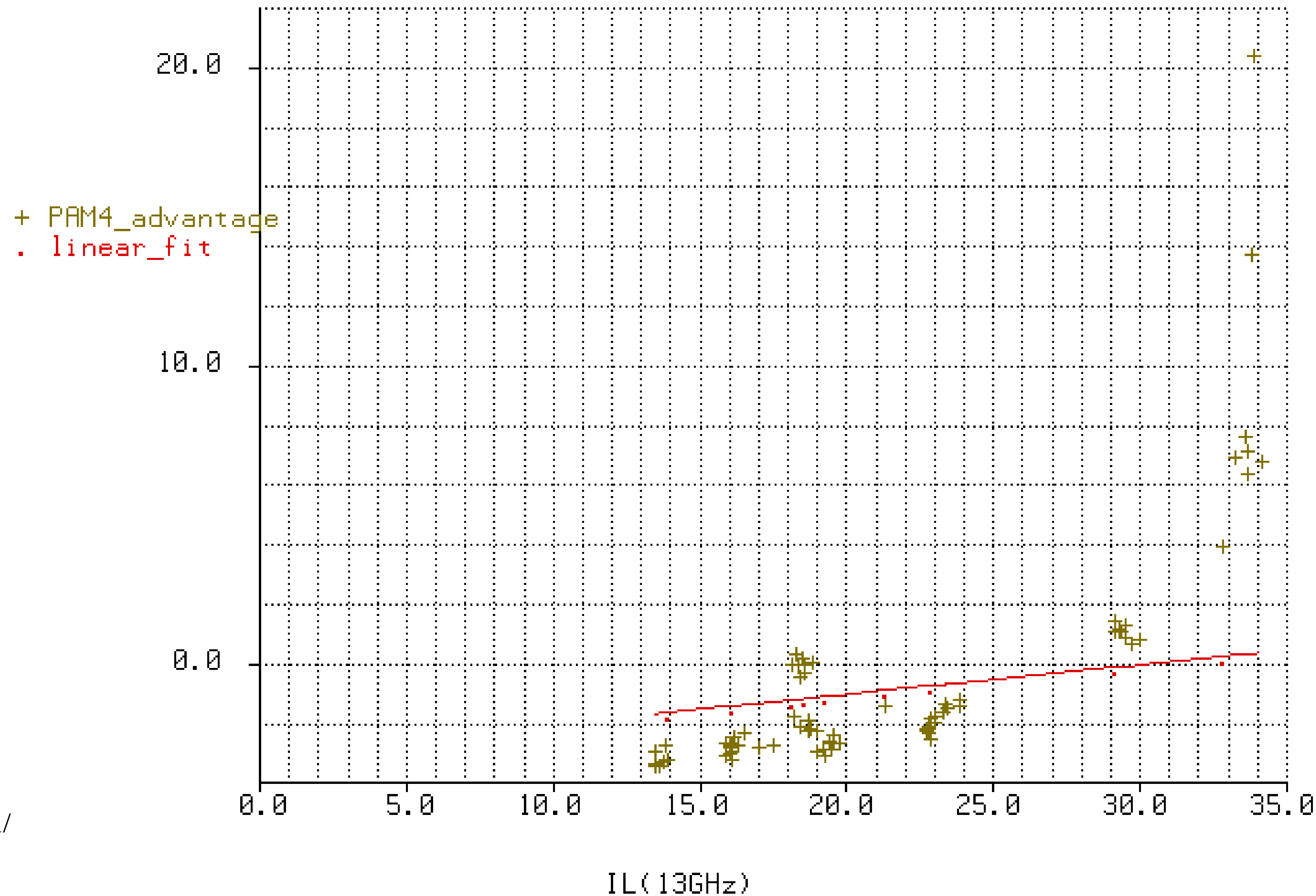
For available Backplanes
PAM4 SNR
(corrected for reduced EYE opening and reduced noise generation)



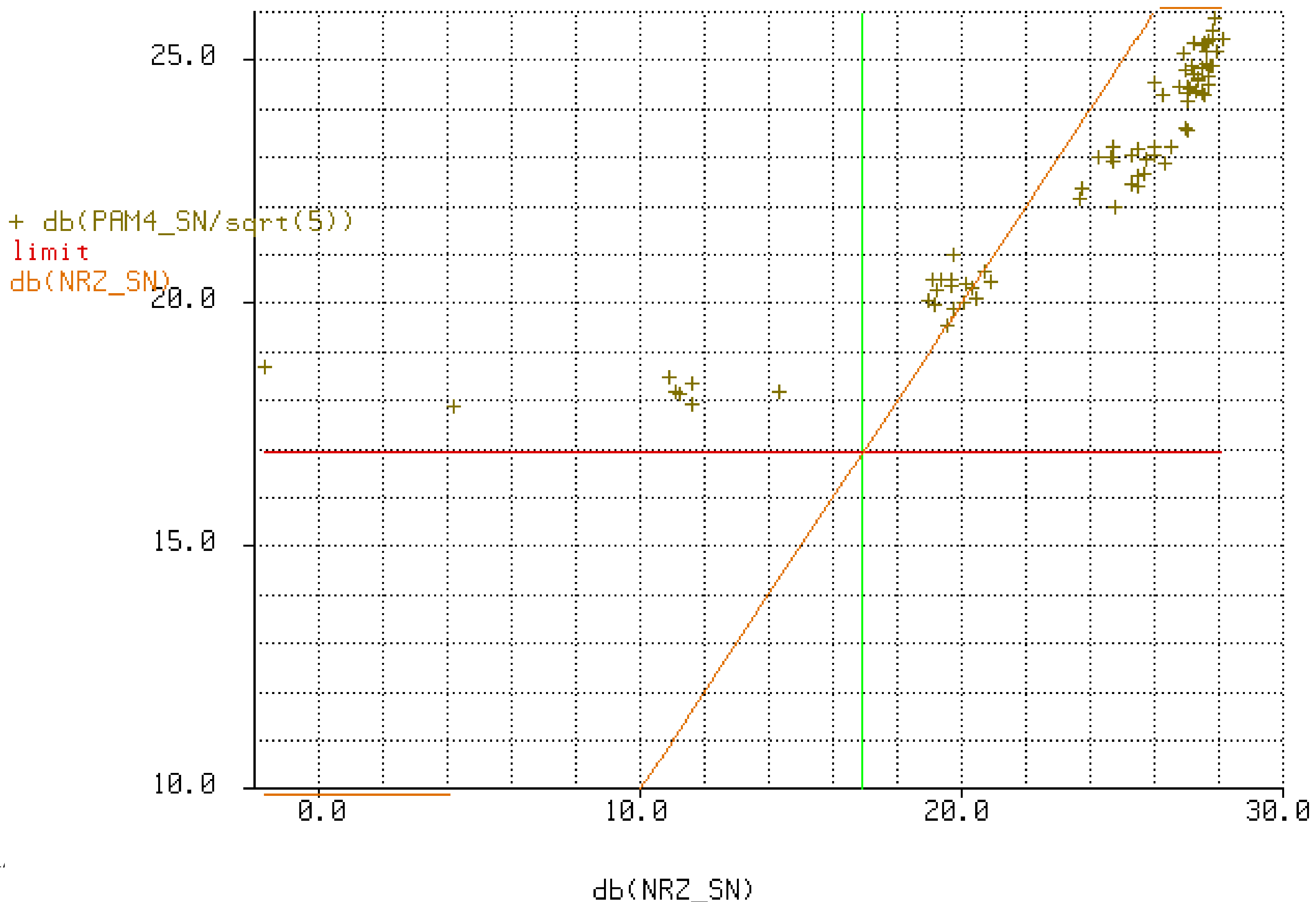
For the Cable comparison I used all the of Cable data sets from www.ieee802.org/3/100GCU/public/channel.html:

- 3m Cables (8) from Mark Bugg of Molex
- 5m Cables (8) also from Mark
- Sets of 2m, 4m, and 5m cables and 2 sets of 3m cables of different gauges from Mark
- 1m, 3m, and 5m cables from Chris DiMinico, of MC Communications representing LEONI Cables & Systems

SNR advantage (in dB) for using PAM4 over NRZ
for available Cable channels
vs
Insertion loss at 13 GHz



For available Cables
PAM4 SNR
(corrected for reduced EYE opening and reduced noise generation)
Vs
NRZ SNR



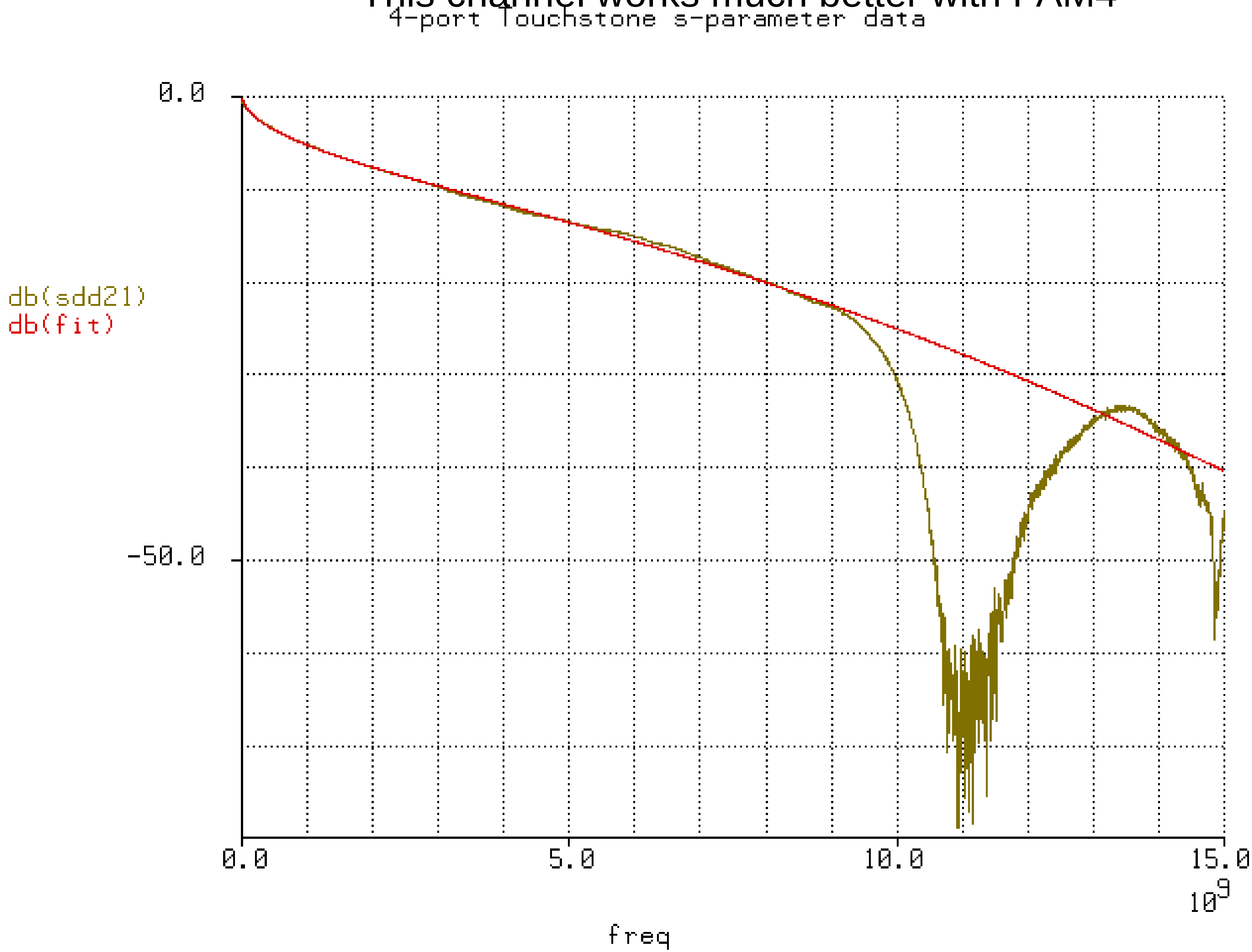
Something is going on with some of the cables so they work with PAM4 but not NRZ.

What would you expect? A big perturbation between 6.5 GHz and 13 GHz but closer to 13 GHz? Of course!

Here is an example:

5m cable from Leoni

This channel works much better with PAM4



Note: This data is from measurements of 802 3ba compliant QSFP cable assemblies for the purpose of establishing baseline noise impairments beyond those currently specified in 802.3ba, and not for consideration as channels for 25 Gb/s.

Conclusions: Backplanes

These plots show negative advantage for PAM4 for most Backplanes with less than about 39 dB loss at 13 GHz. Above this attenuation PAM4 looks better. Unfortunately for the Backplanes where PAM4 has an advantage, the SNR for both codings seems to be insufficient for BER=10^{-12} .

So it seems that the copper does not prefer PAM4. However the silicon may work better at the lower data rate that PAM4 allows.

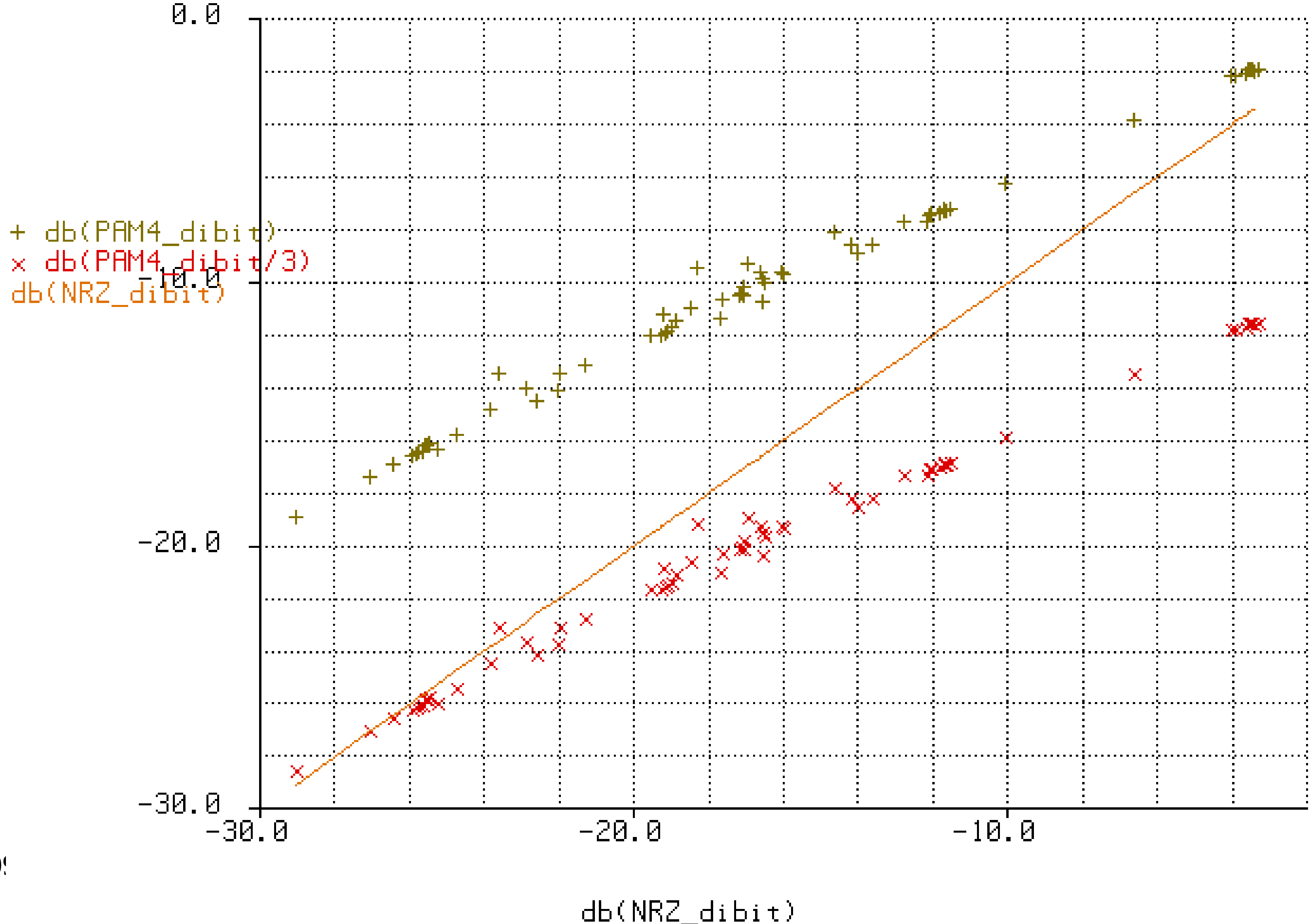
Conclusions: Cables

Cables show mixed results except for some cables where PAM4 shows a strikingly large advantage. The large PAM4 advantage shows up in cables with large drops in channel gain a little below NRZ Nyquist. This drop causes major amounts of ILD noise in the NRZ channel but, since the drop occurs at a natural null in the PAM4 power spectrum, has almost no effect on the PAM4 channel.

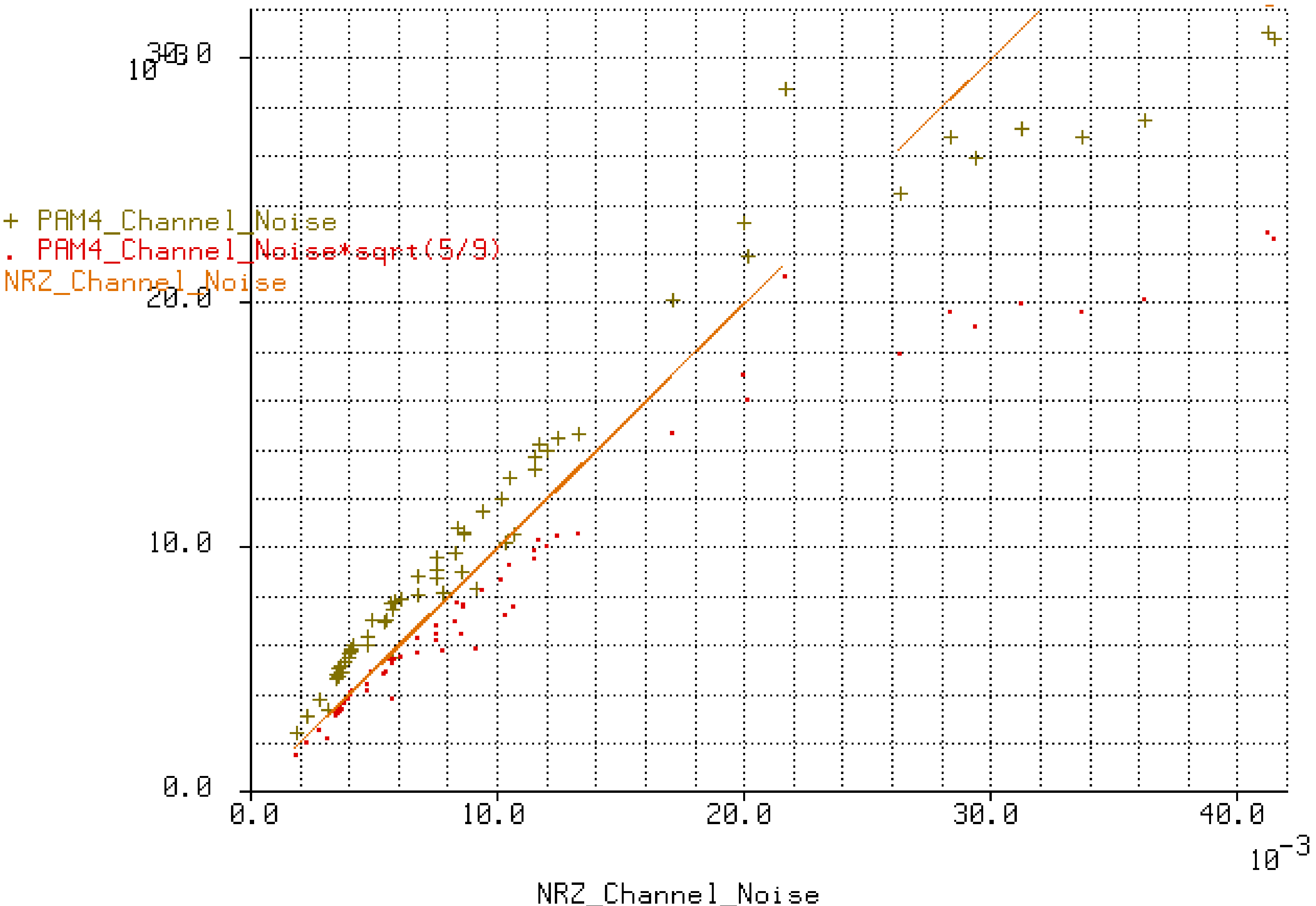
So with cables an important question is: How prevalent is the transmission drop around 13 GHz. Can we get rid of it?

Backup Slides

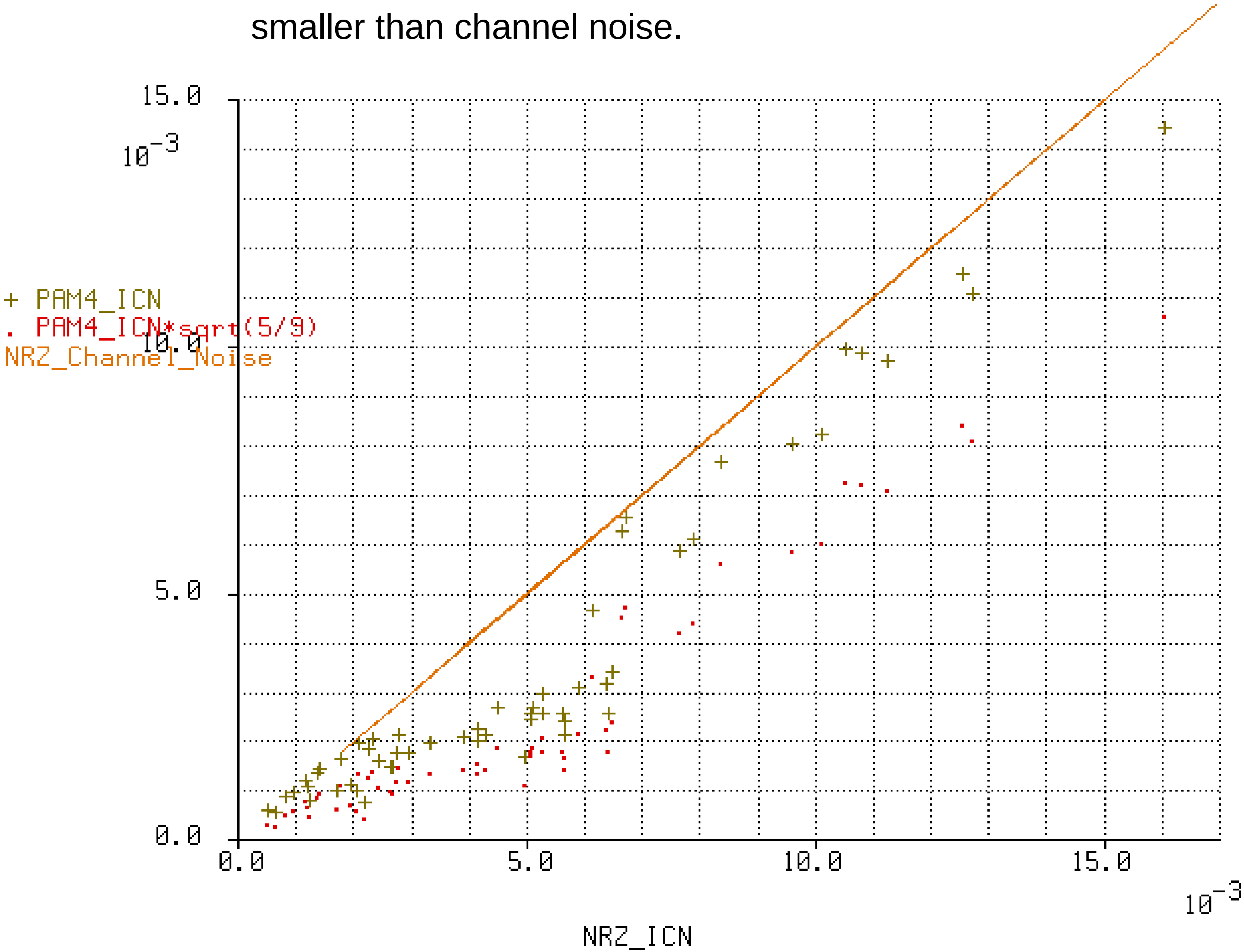
Dibit gain for PAM4 is higher than for NRZ but almost never by a factor of 3



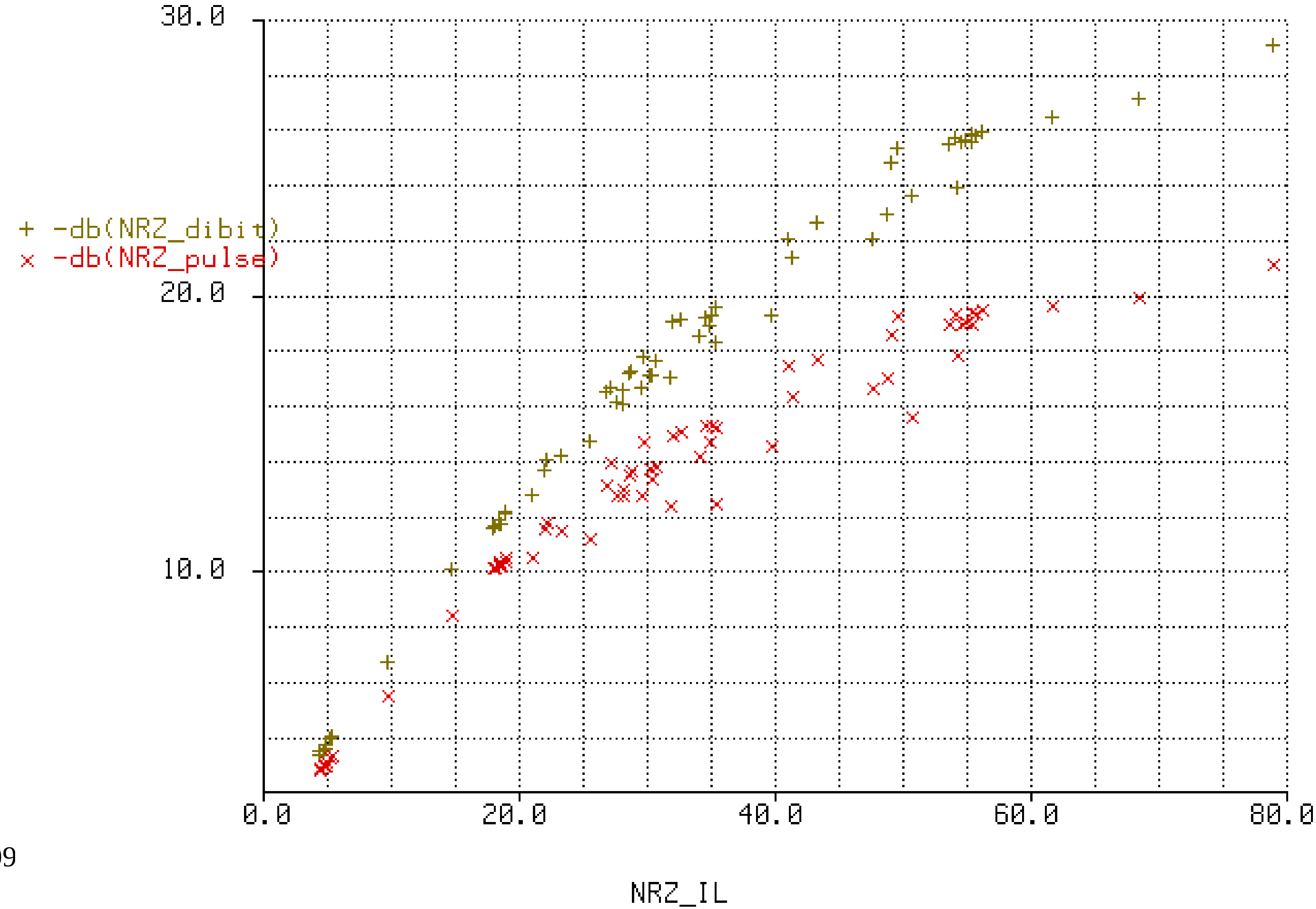
The channel noise coupling for PAM4 is greater than for NRZ (Why?) but since PAM4 generates less noise, the net effect is (a little) less noise for PAM4.



Crosstalk channels for PAM4 are smaller than for NRZ. Add in the fact that PAM4 makes less noise PAM4 looks much better for crosstalk. However crosstalk seems smaller than channel noise.



Dibit gain seems to track insertion loss at 13 GHz well
Pulse gain also seems to track, just not as well



I also looked at PAM3. It looks a little better than PAM4.
Any interest? I didn't think so.