Channel Metrics: Benchmarking with TIA OM3 model results & recent IEEE work

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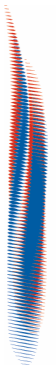
IEEE 802.3aq meeting at July 2004 Portland plenary



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Summary of *.pdf files (Part1, Part2)

Part1

1. Introduction to ISI vs EMB & TIA OM3 results, Phyworks/Cambridge81 results plotted similarly; Limiting Curve
2. "Figure of merit for a Figure of merit" (the Channel Metric)
3. Two "BW metrics" used for TIA OM3 analysis, comparison to Phyworks/Cambridge81 results
4. IFR & PE metrics compared on TIA OM3 & Phyworks/Cambridge81 data
5. Discussion/Conclusion/ Loose Ends

Part2

Corrections in BW metric results added, will circulate revised version Tues. pm.

TIA 300m 10GbE (OM3-850nm) modeling

40,000 links were modeled; this presentation focuses on the 10,000 “no-connector” links for which analysis is simplified. There were no conclusions from the full data set which were not apparent from the no-connector subset.

5,000 fibers simulated with mode delay sets τ_m

2,000 laser sources simulated with mode power distributions (MPDs) P_m

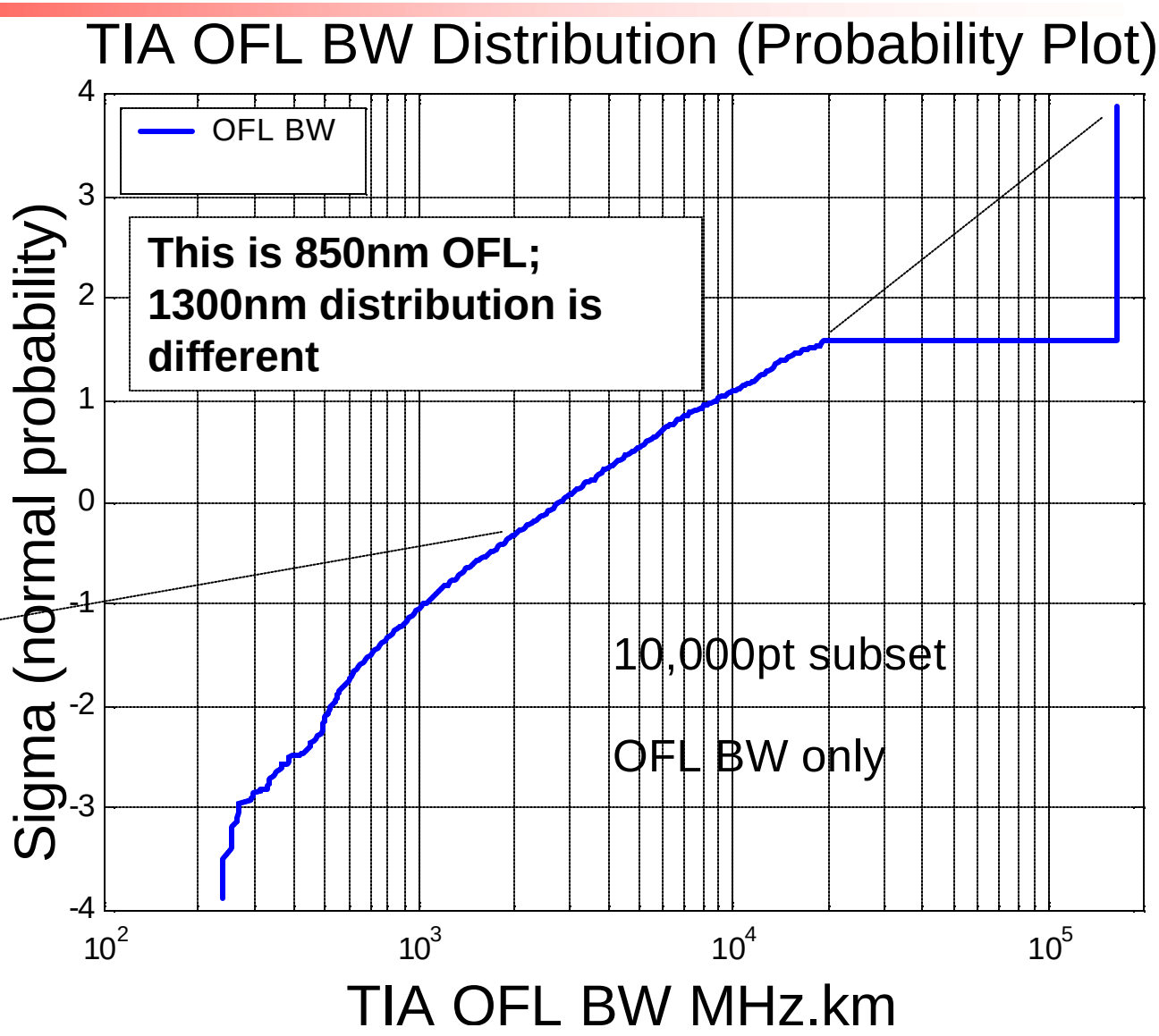
Fibers randomly matched with sources to span the parameter space.

ISI requirement was 2.6dB or smaller (leaving 1.0dB for other sources to the total ISI budget of 3.6dB)

TIA 300m 10GbE SR: OM3 modeled OFL

TIA modeling for OM3 development generated a model fiber distribution median ~3GHz.km

The effective modal bandwidth (EMB) of interest is 1500-2500

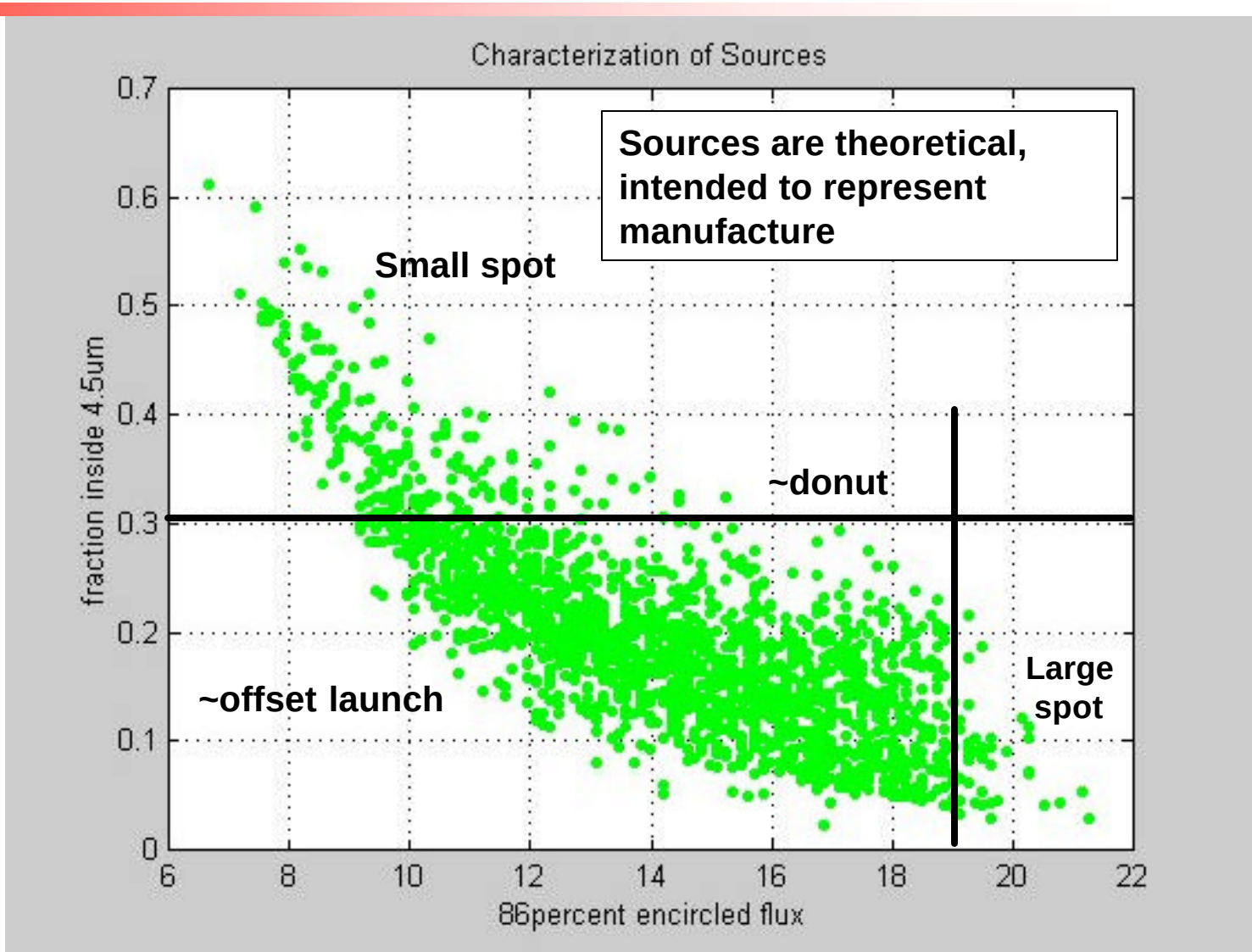


TIA 300m 10GbE SR: Encircled Flux

The 2000 850nm laser sources are characterized by the encircled flux:

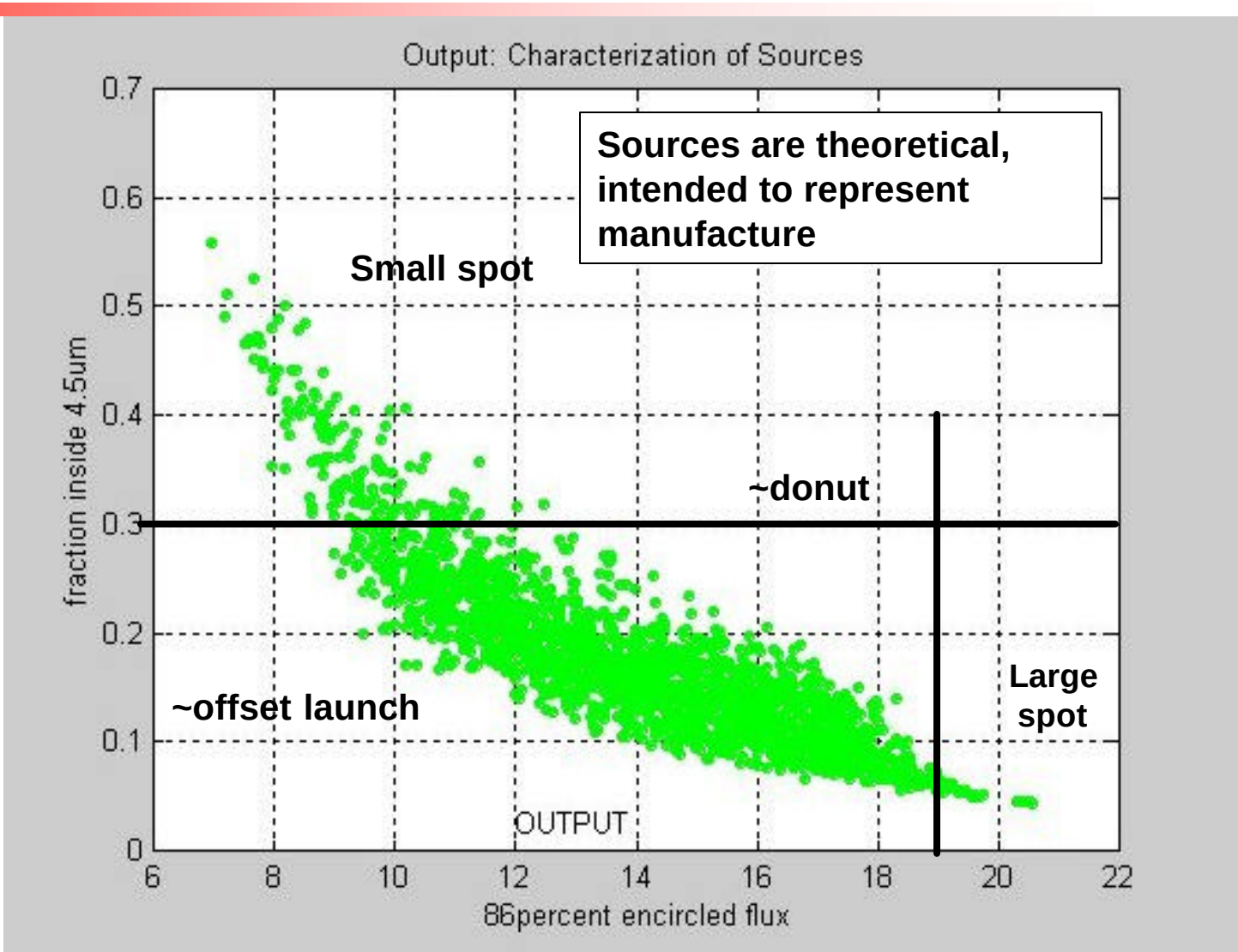
(1) Fraction inside of 4.5um

(2) Radius containing 86% of the power.



TIA 300m 10GbE SR: **Transmitted** Encircled Flux

- **The encircled flux distribution on the previous page represents the input, after mode coupling the transmitted encircled flux (which is important for the system) looks like this plot.**
- **Donut launches couple some power into the center so the distribution narrows;**
- **Offset launch couples power into spiral modes**

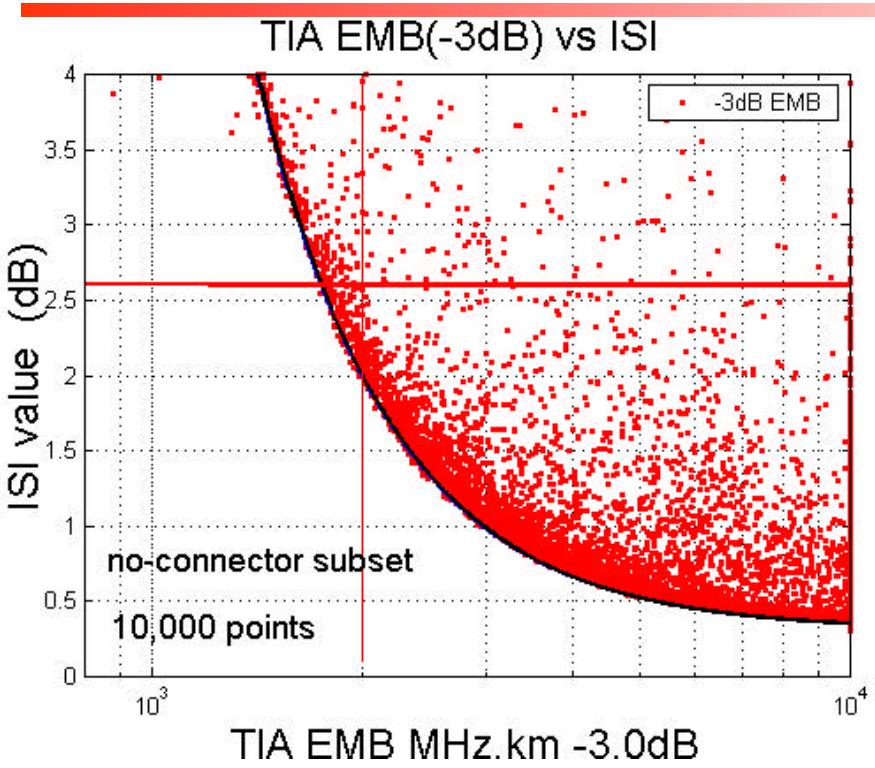


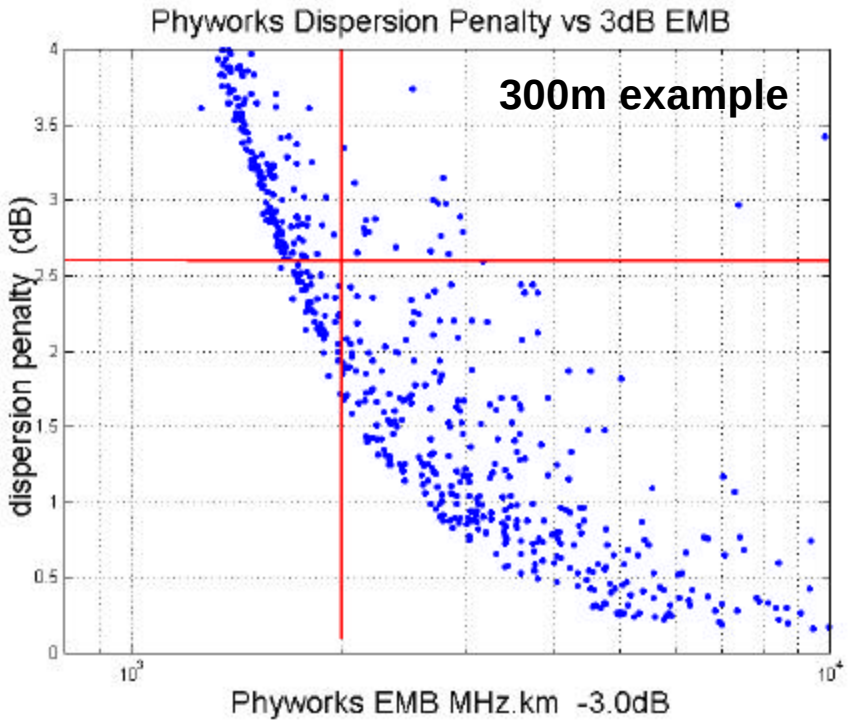
Additional Phyworks modeling

After the May 2004 IEEE meeting at which Phyworks/Cambridge presented modeling results & the IFR metric, Phyworks was kind enough to **re-run the simulation for 300m** to provide a parallel example to the TIA OM3 analysis

Note TIA work was at **850nm** with different sources and different fibers. The use of different mode delays and MPDs is not a concern because the goal is to have a robust metric. The effective modal bandwidth (EMB) does not include chromatic dispersion and hence is wavelength-independent. However, the IBM ISI model used for TIA analysis includes chromatic dispersion.

ISI vs EMB: TIA & Phyworks/Cambridge

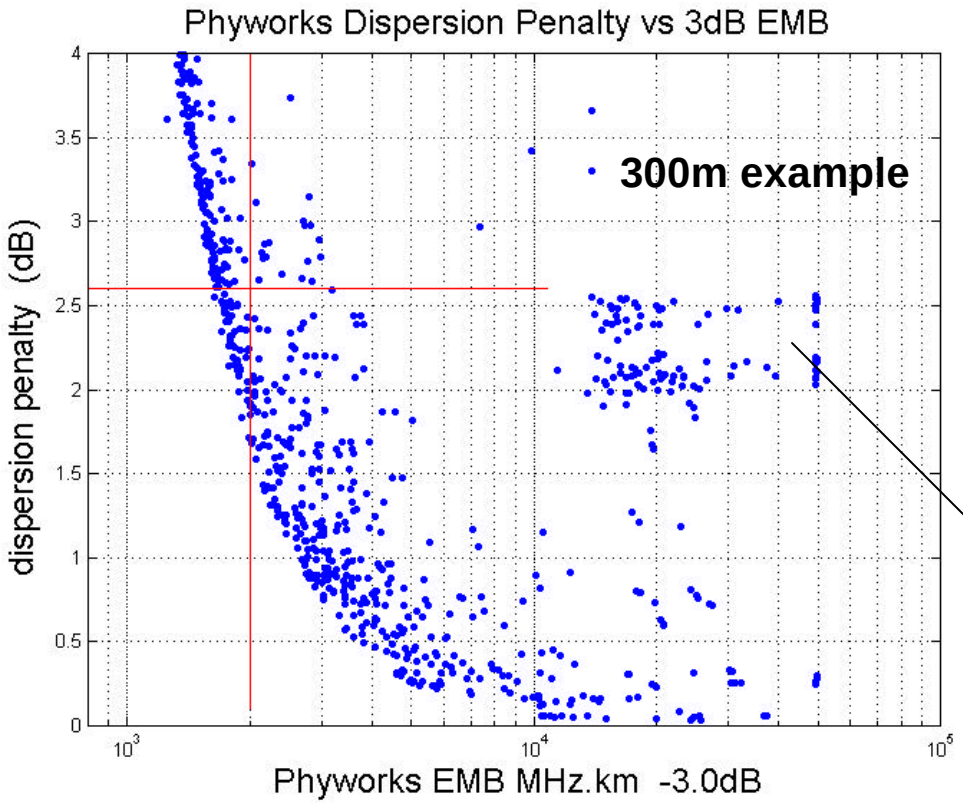




TIA model (IBM) has minimum ISI of 0.31dB (850nm); P/C81 model & IEEE link model have no minimum ISI.

Both models show a limiting curve and outliers with -3dB BW overpredicting performance. <u>The limiting curve corresponds to a double pulse.</u>

Note on Phyworks/Cambridge results



Other outliers with 'fully closed eye' have dispersion penalty set to 1000dB

EMB outliers (EMB too high for the ISI)

Although in general the Phyworks/Cambridge data lies closer to the 'limiting curve', there are a number of points which lie far off – these have small side pulses so that |H(f)| has a plateau. These points lie below 2.6db but there are other similar outliers at higher ISI levels as well.

These points show up on the previous analyses of 220 m results as well.

Discussion of limiting curve

1. If we examine the pulse shapes of points near the limiting curve they will not be Gaussian; rather they will show multiple pulse structure.
2. If we compute the -1.5dB BW and then extrapolate to -3dB, the new limiting curve overlaps the old one if we use a factor of 1.335 corresponding to a double pulse but not 1.414 (corresponding to Gaussian)

Study of additional Metrics

Metrics studied for TIA & P/C81:

a. -3.0, -1.5, -1.0dB BWs

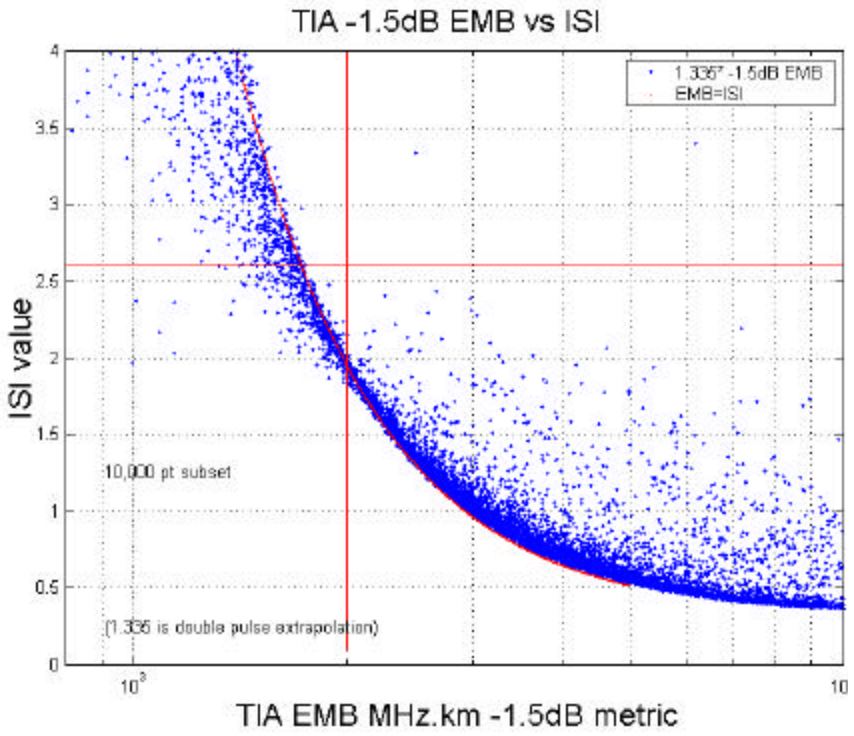
b. BW based on Real part of H(f)

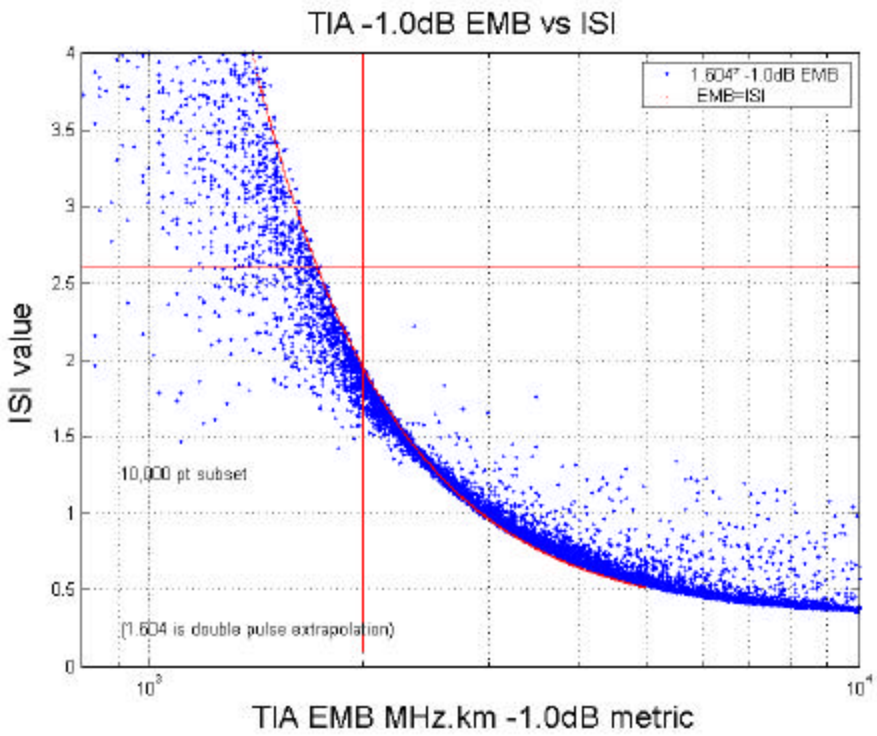
c. BW based on |H(f_bit)| where f_bit related to bit rate & length (i.e. f_bit = 5GHz or 1500MHz.km for 300m)

d. IFR metric suggested by Phyworks/Cambridge

e. P_E metric suggested in Cunningham Jan2004 presentation.

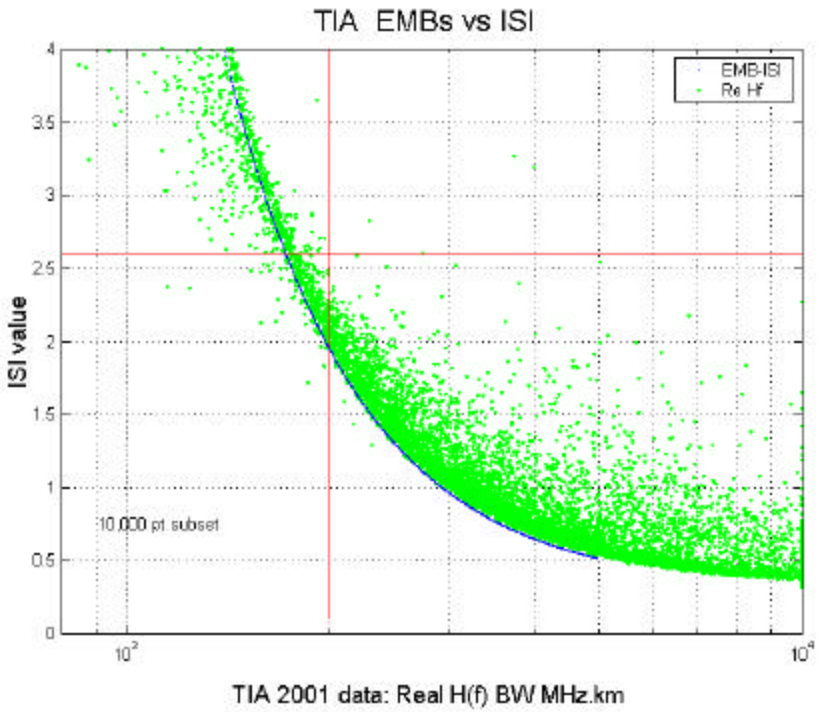
-1.5dB and -1.0dB metrics (TIA)

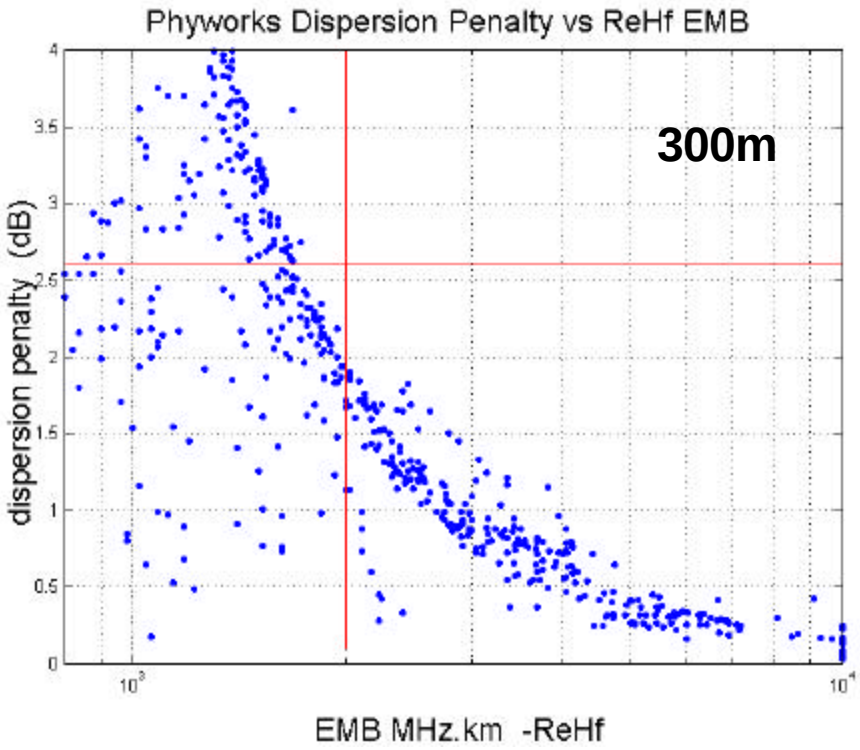




The -1.5dB metric eliminates the outliers in the upper right quadrant and results in a tight distribution for EMB in the range 1700<EMB<2000 corresponding to the critical EMBs for the 300m 10GbE spec. However, it does not collapse the points to the limiting curve. It is also motivated as the -3dB electrical BW. -1.5dB metric used in OM3 spec (minEMBc)

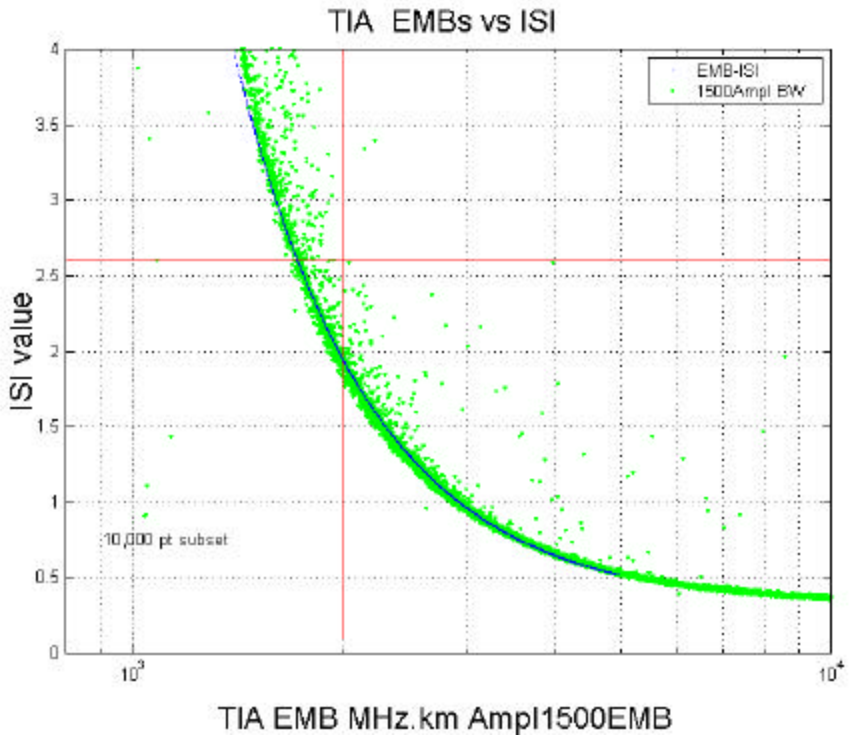
Real H(f) metric: TIA vs Phyworks/Cambridge

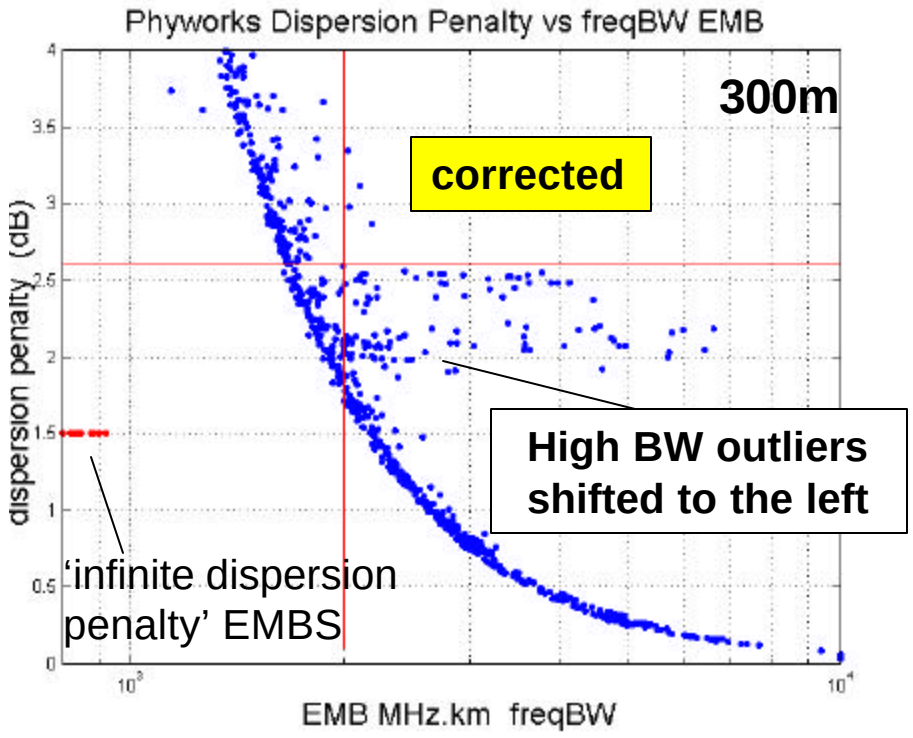




The ReHf metric is defined by the frequency where Real H(f) drops to -3dB. This is the transform of the symmetric part of the impulse response. For the TIA modeling ReHf shifted points closer to the 'limiting curve' and for points with ISI<2.6dB. The fact that it seems to have a different effect on the IBM ISI model vs the Phyworks dispersion penalty model suggests some difference between the models. [OR JSA error needing debugging]

f_bit metric: TIA vs Phyworks/Cambridge





The f_bit or freqBW metric takes a single value on the |H(f)| curve corresponding to half the bit rate (5000MHz for a 10GHz bit rate) and extrapolates to the -3dB level to generate a metric with units of MHz or MHz.km . If the amplitude itself is used a metric similar to IFR or P_E arises.

The f_bit metric is <u>similar for Phyworks data</u> except outliers don't fully map.