

# Estimation of Required Filter Complexity

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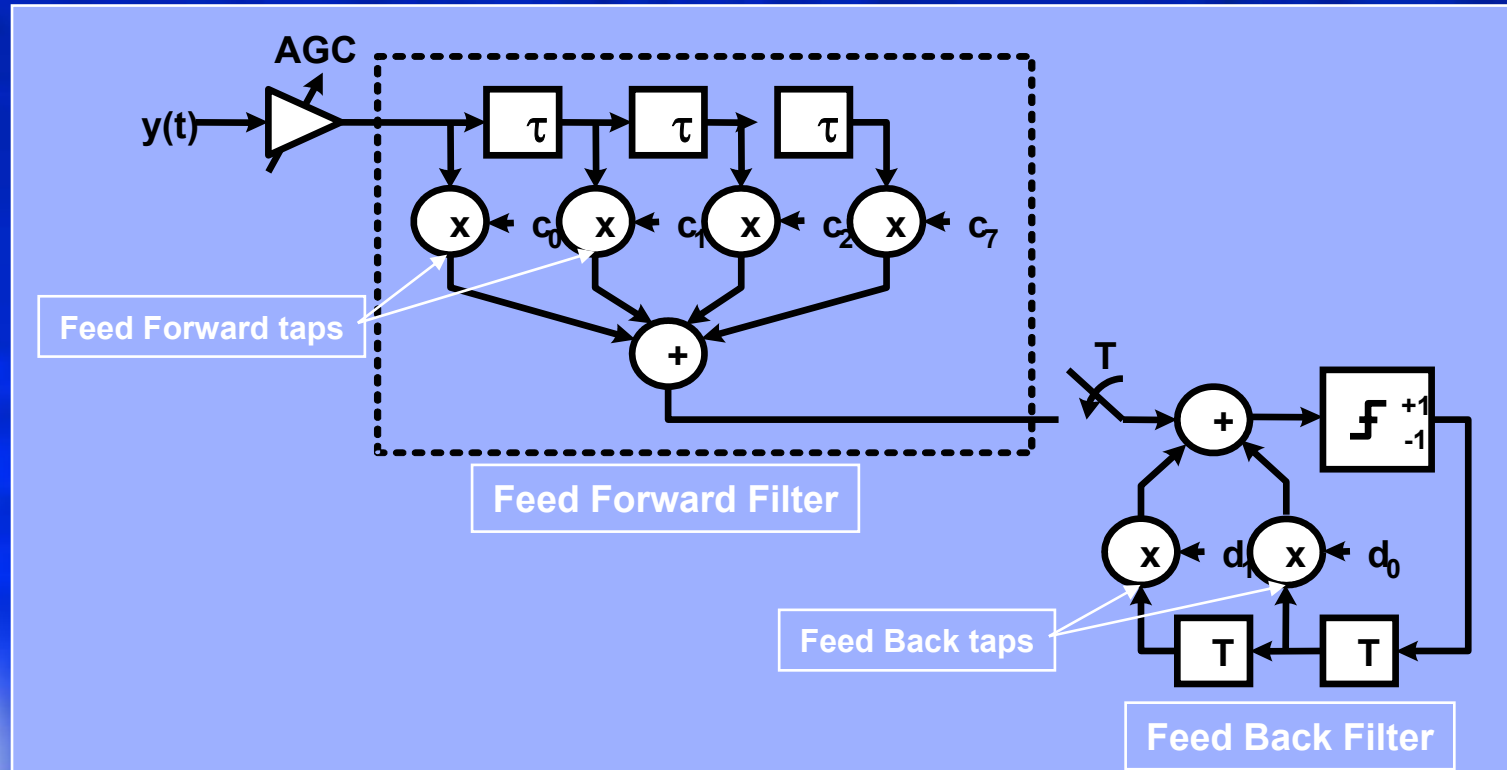
# Outline

- **Filter complexity**
- **Simulation approach**
- **Data sets**
- **Simulation results**
- **Conclusion**

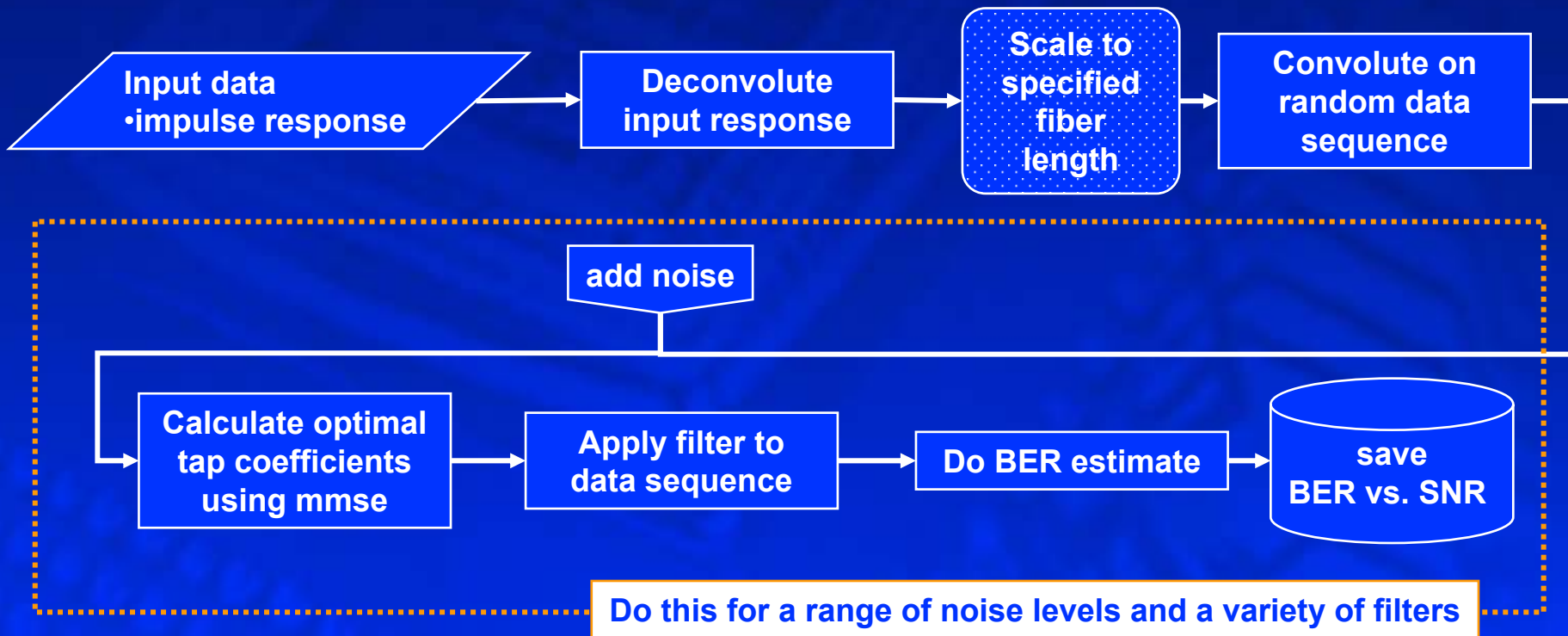


# Investigated filter complexity

- Up to 9 taps in Feed forward filter (FFE)
  - T/2 spaced only
- 0-2 taps in Feedback filter (FBE)
  - Error propagation penalty included in results



# EDC simulation path



Gaussian noise added in 7.5 GHz BW

Intel Communications Group

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# Data sets investigated

- **Infineon measured impulse responses**
  - Different fiber lengths
- **IEEE MMF data**
  - Use only Overfill Launch data (L3 files) with BW > 500 MHz km (1300 nm)
  - Impulses scaled to different fiber lengths 50-300 m
- **Cambridge computed statistical dataset**
  - All 195 files. 300 m - 17, 20, 23  $\mu$ m offset launch



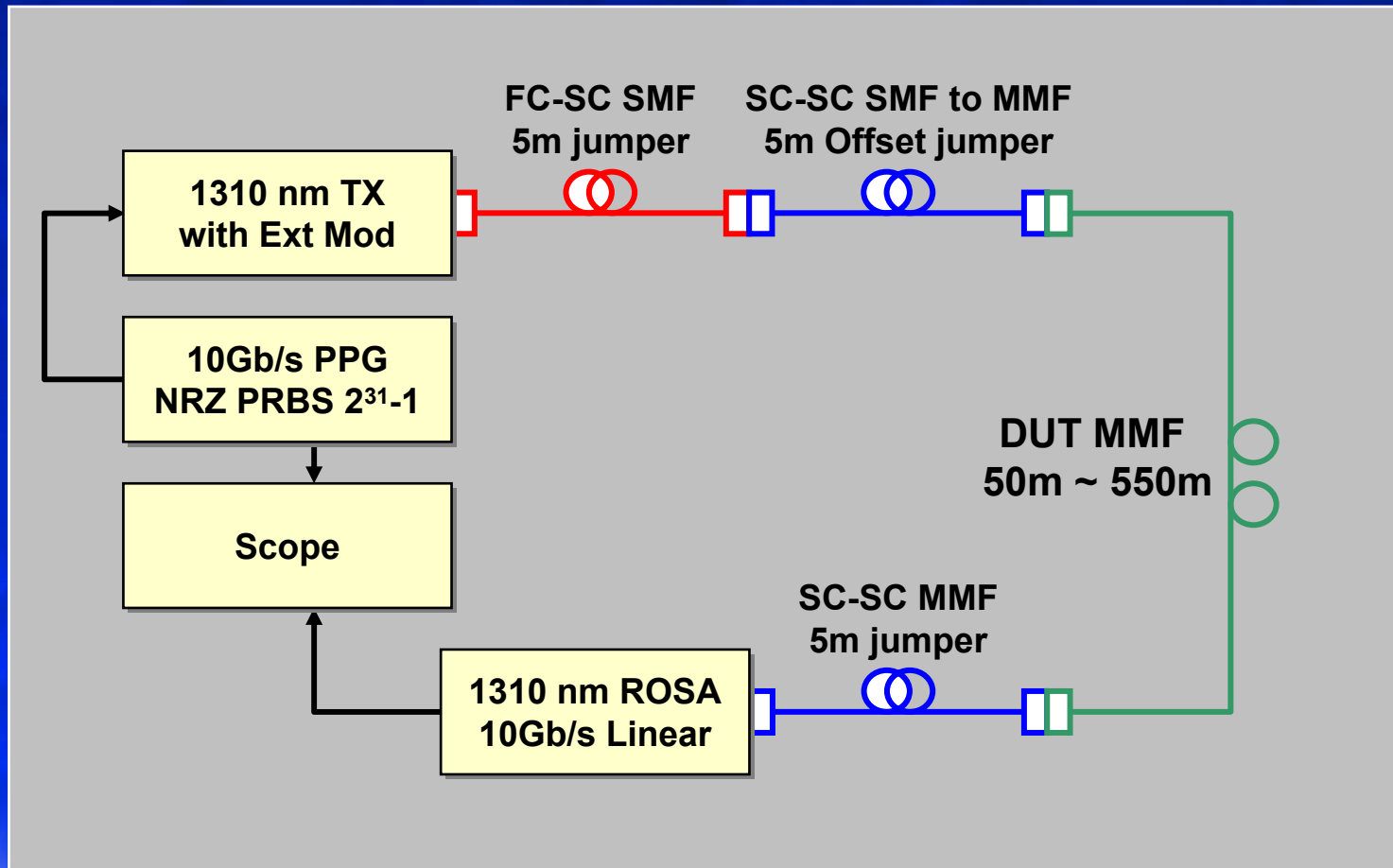
# Infineon\* measured dataset

- One fiber type
  - Siecor 62.5  $\mu\text{m}$
  - Approx. 500 MHz km bandwidth (Overfill launch)
- Fibers with lengths from 50 m - 550 m
  - Taken from same fiber spool
- Two types of test setup
  - Directly modulated DFB laser
  - External modulated laser (EML)
- Pulse pattern 0000000100000000
- Dataset includes calibration pulse measurements

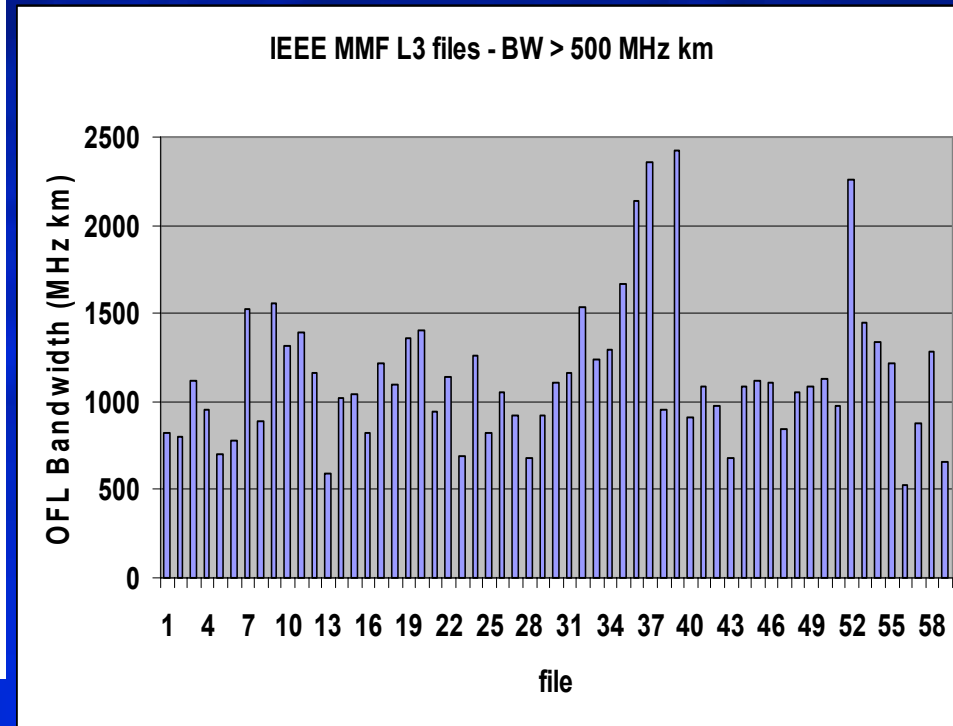
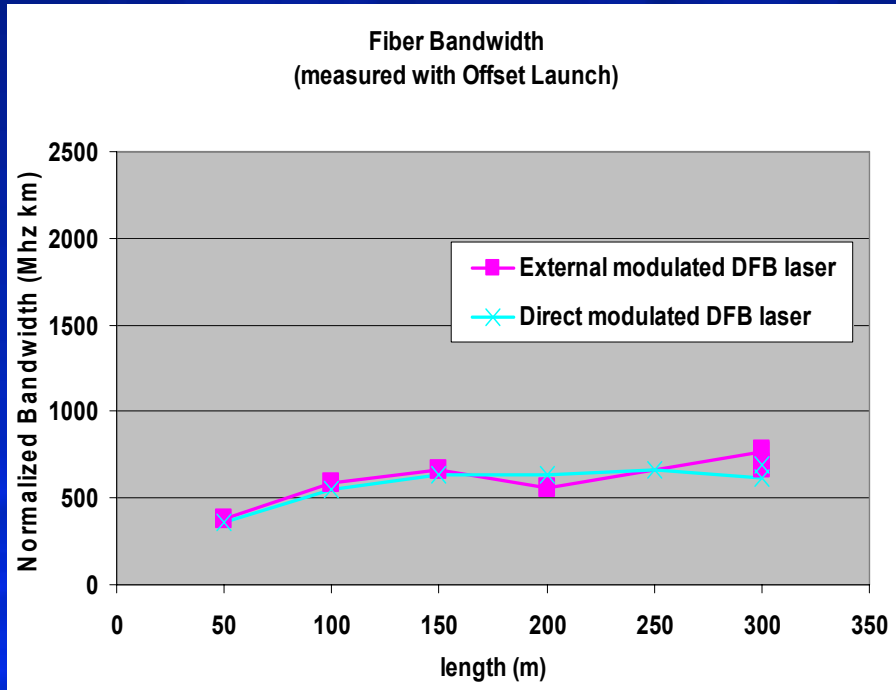


\*Stefano.Bottacchi@infineon.com

# Infineon measurement setup



# Fiber characteristics of Infineon data



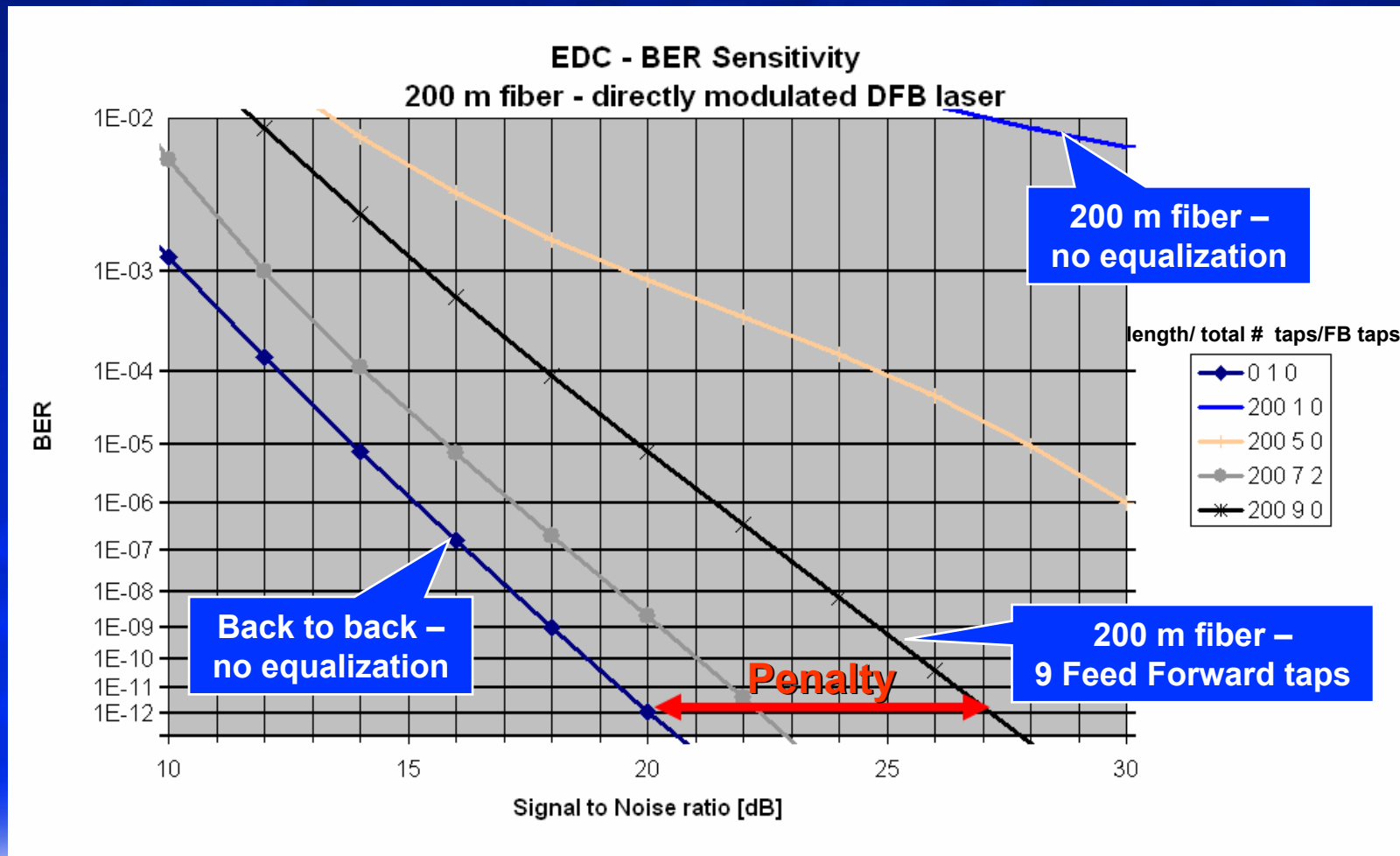
Bandwidth of Siecor 62.5  $\mu\text{m}$  fiber is less than average of IEEE L3 files





# BER vs. SNR

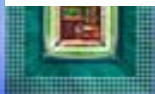
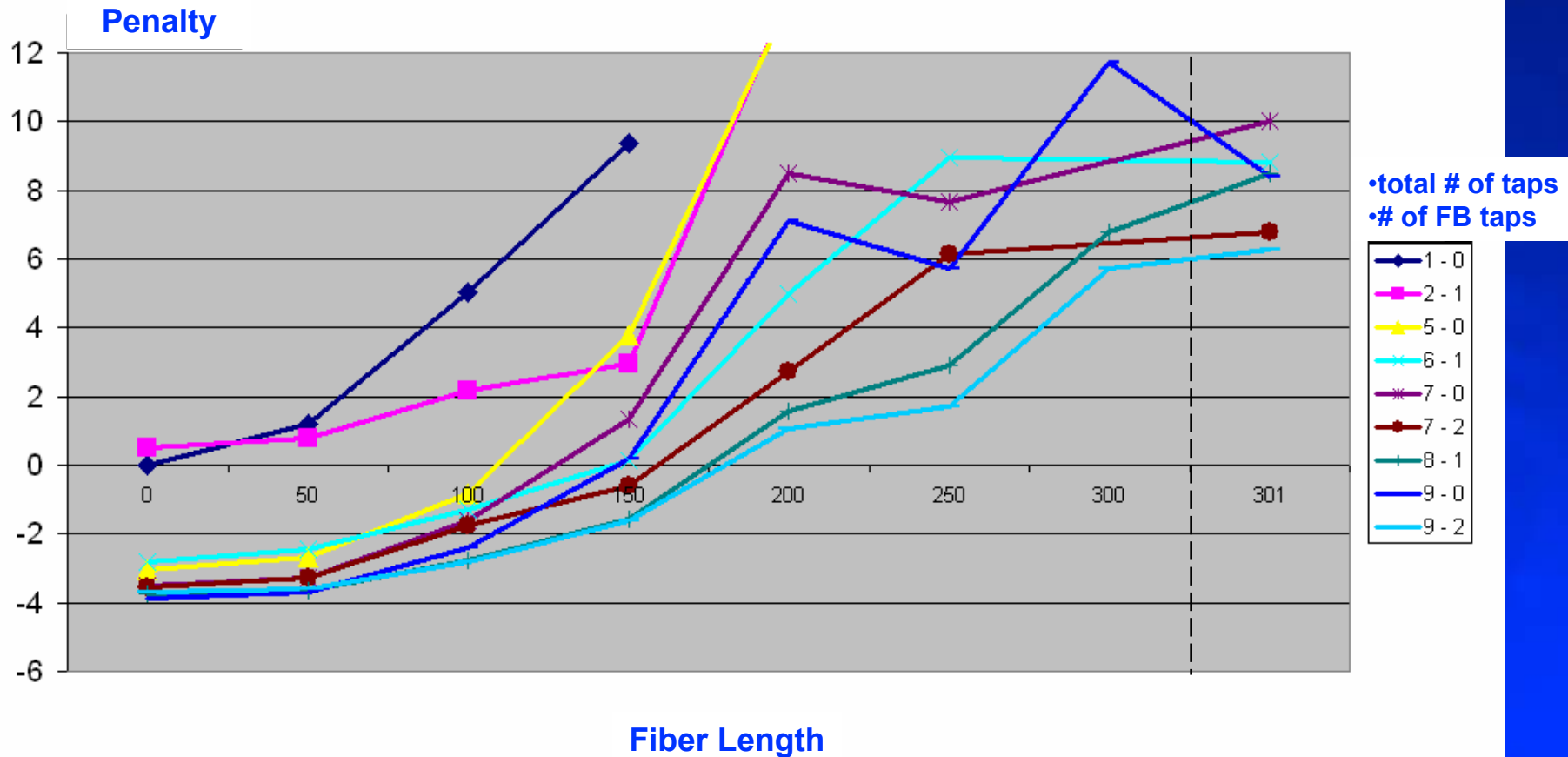
## for Direct Modulated DFB laser data files



Evaluation procedure as described by Infineon at Vancouver meeting

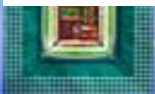
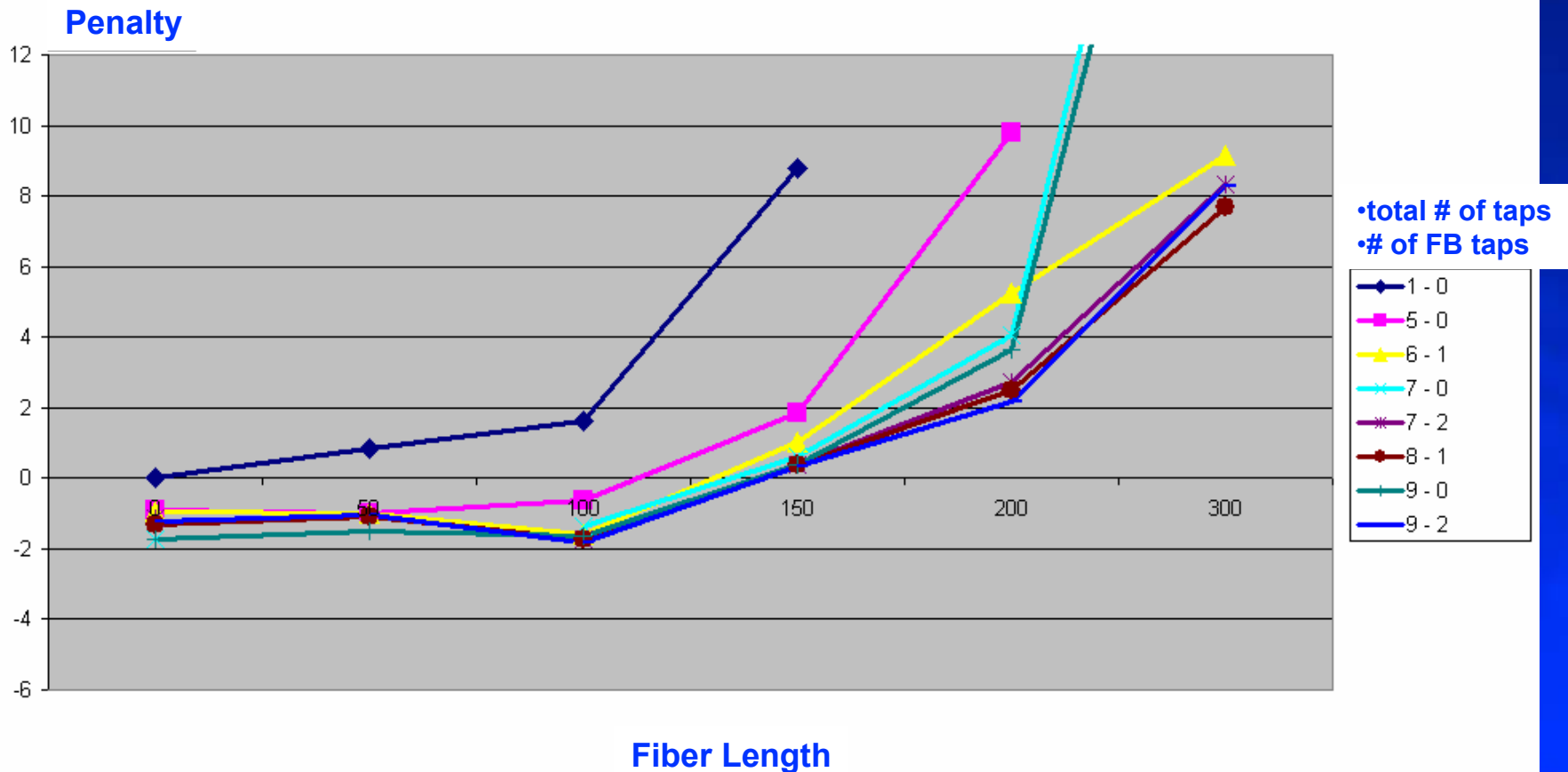
# Penalty vs. length for different filter configurations

## Direct modulated DFB laser



# Penalty vs. length for different filter configurations

## External modulated DFB laser

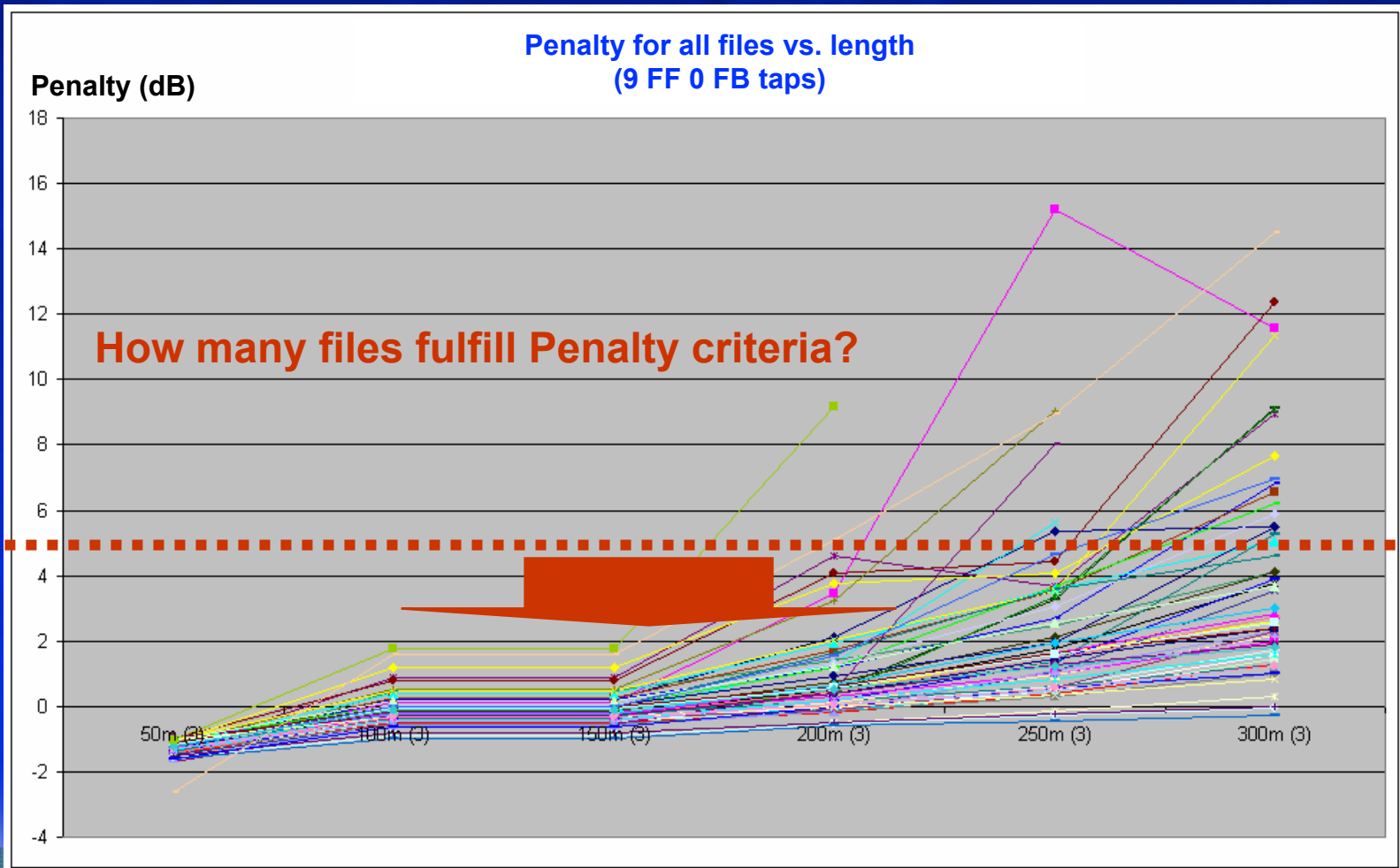


# Infineon data summary

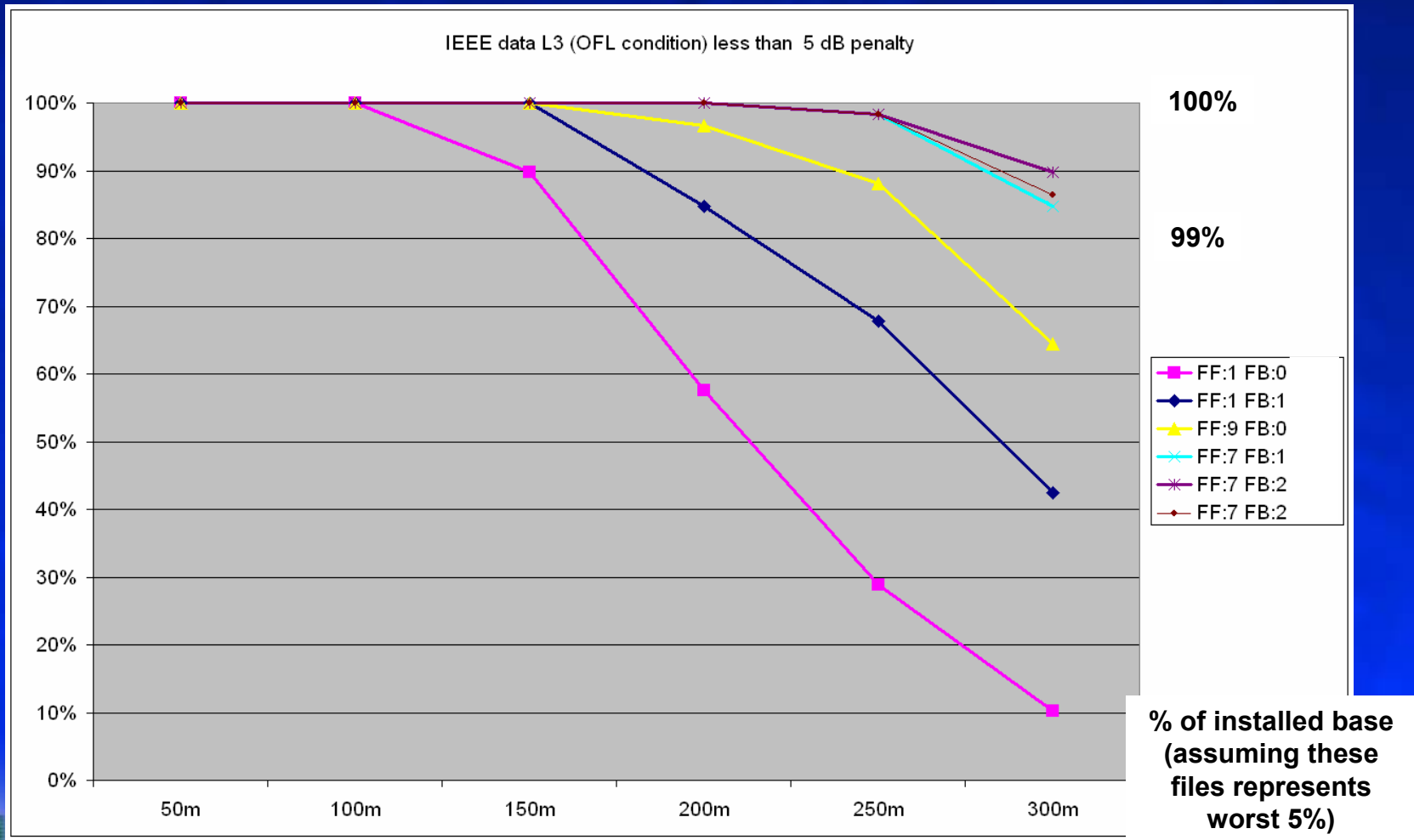
- Used fiber has bandwidth comparable to lower end of IEEE L3 worst case fibers
- Equalization possible up to at least 250m fiber length independent of transmitter type
- Results suggest filter consisting of 7 Feed Forward and 1 Feed Back tap as necessary and sufficient



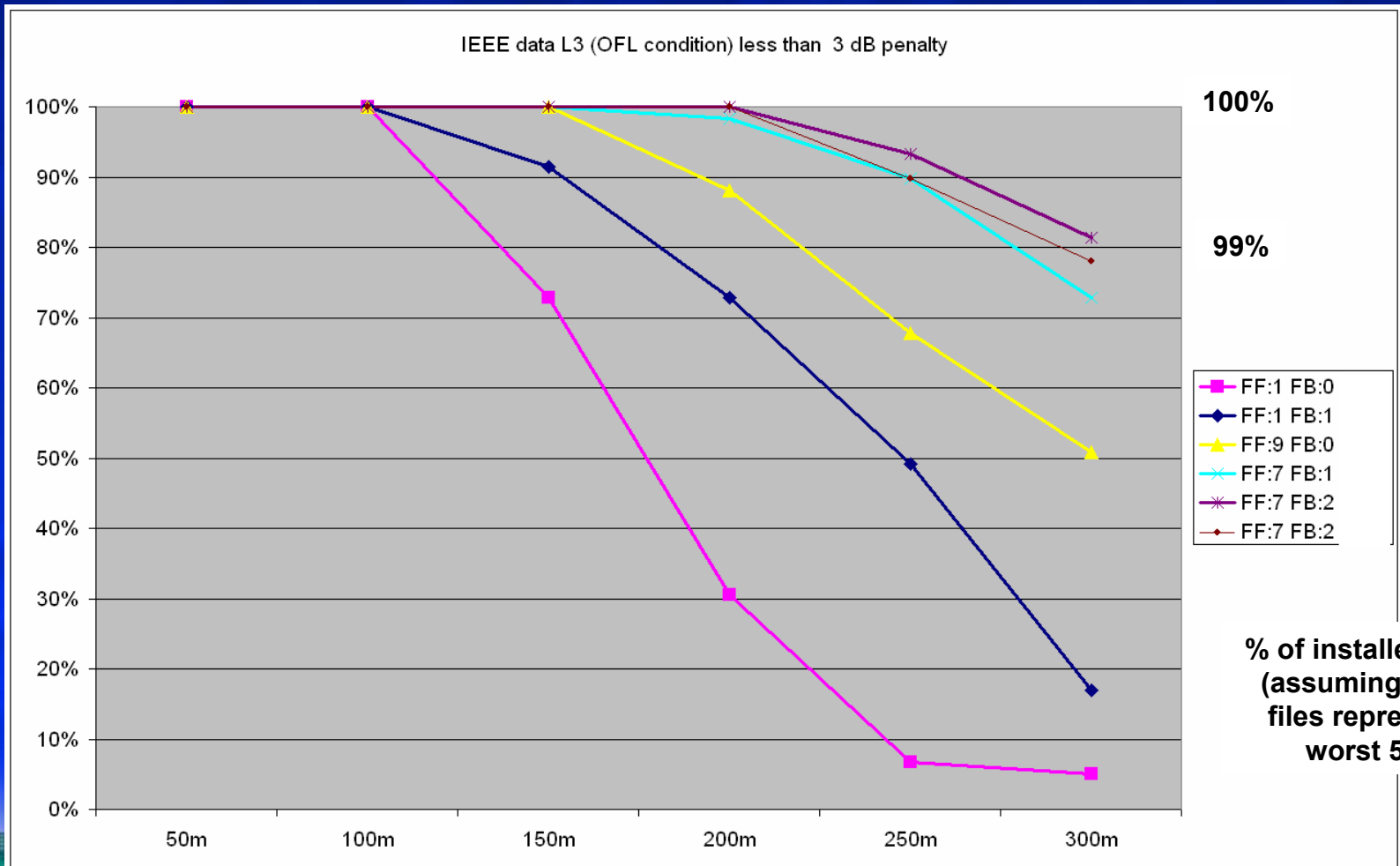
# IEEE fibers L3 (1300nm OFL) scaled length, 59 files with OFL >500 MHz km



# Percent of files vs. Fiber length having penalty below 5 dB criteria



# Percent of files vs. Fiber length having penalty below 3 dB criteria



# IEEE MMF data summary

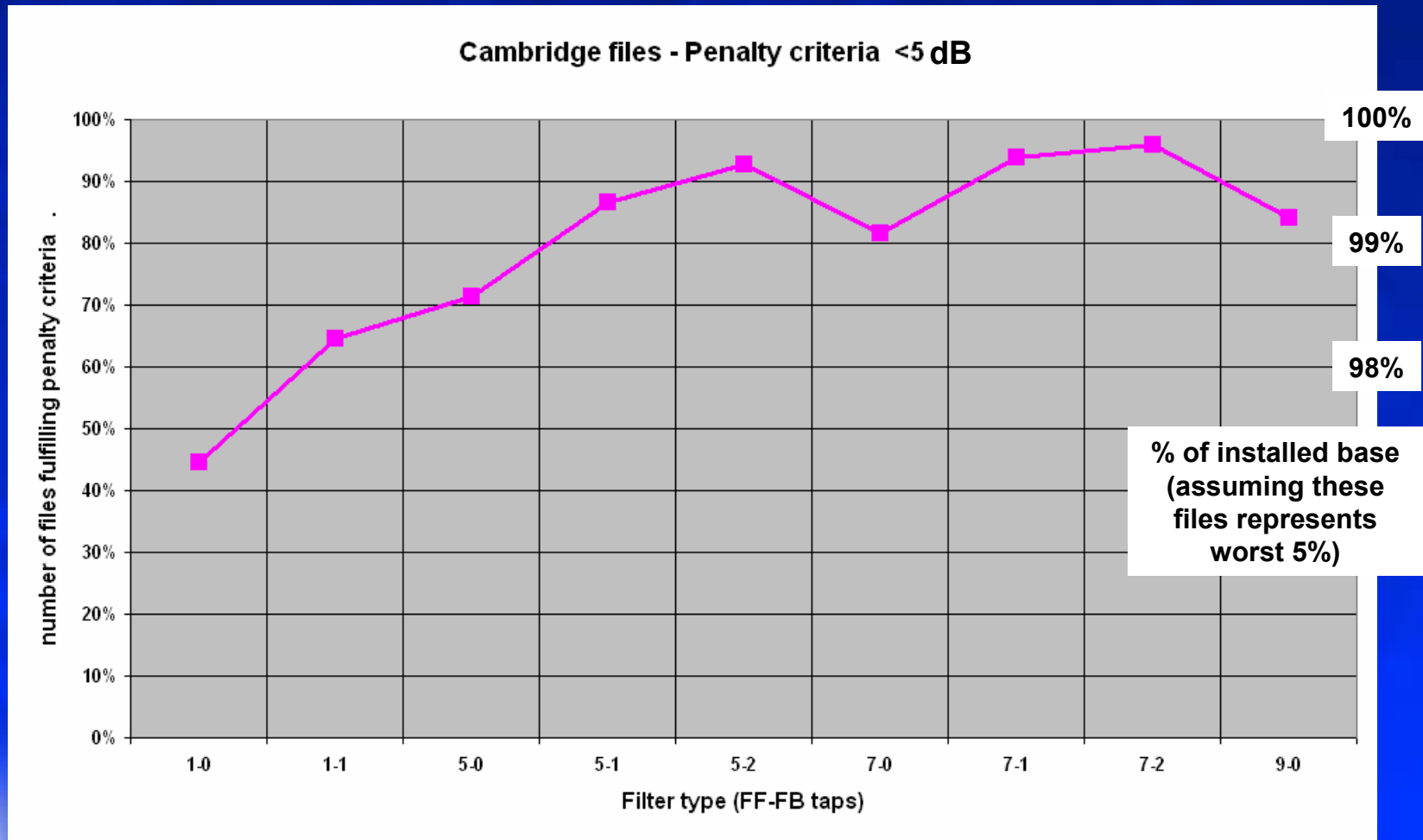
- Equalization is possible at 300 m for most fibers (~90% of these worst case fibers)
- Feed forward taps alone does not do the job
- 7 Feed Forward and 1 FB tap is adequate
- Limited gain by using 2 FB taps over 1 FB tap.





# Cambridge data

(300 m fiber length – all 195 files)



# Summary

Penalty <5 dB	Filter 9-taps FF and 0-tap FB		Filter 7-taps FF and 1-tap FB	
	250 m	300 m	250 m	300 m
IEEE MMF	99.4 %	98.2 %	99.9 %	99.3 %
Cambridge	-	99.2 %	-	99.7 %
Infineon	yes	no	yes	no

**Assumption for statistical estimation:  
fibers represent worst 5% of installed base**



# Closing remarks

- **Conclusions for different datasets points in same direction**
- **Simulations should be compared to measurements to verify model**
  - **Work in progress**

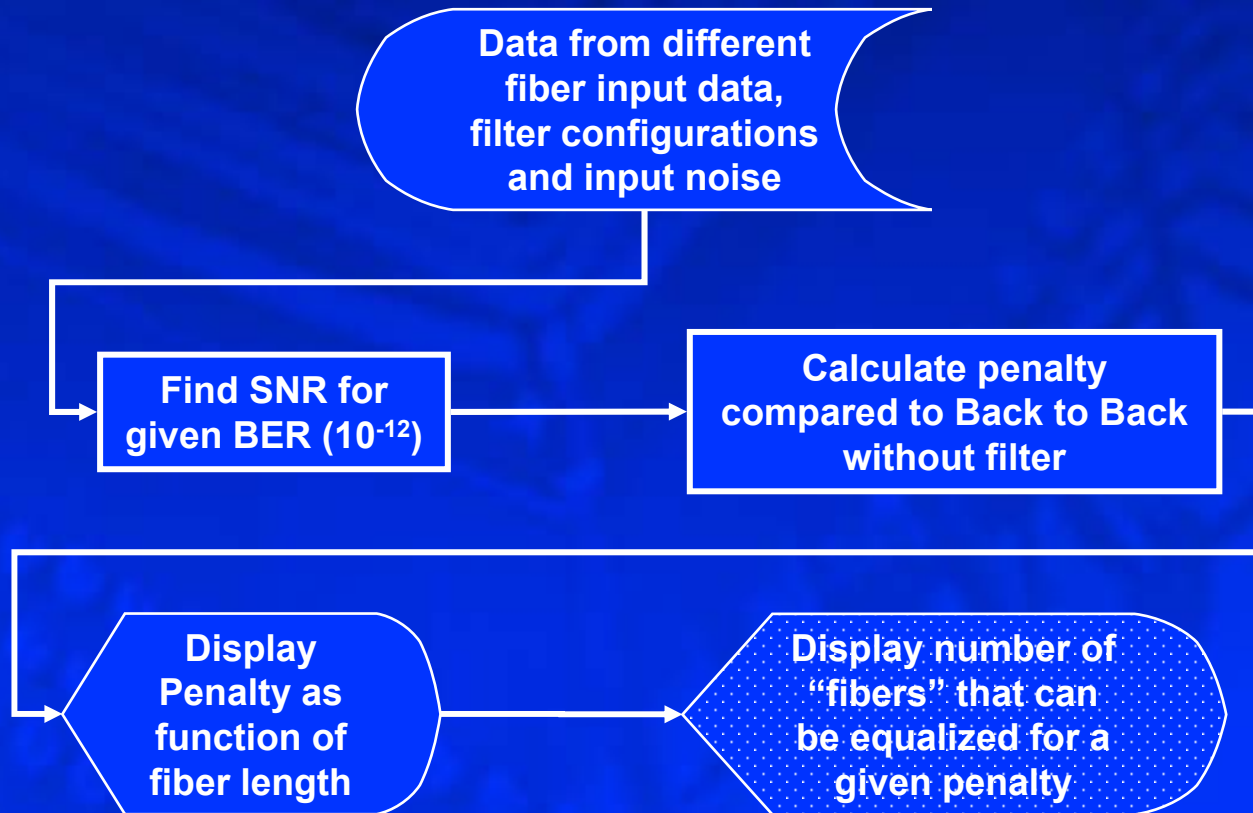


# Backup



# Evaluation of simulation data

- Follows procedure suggested by Infineon



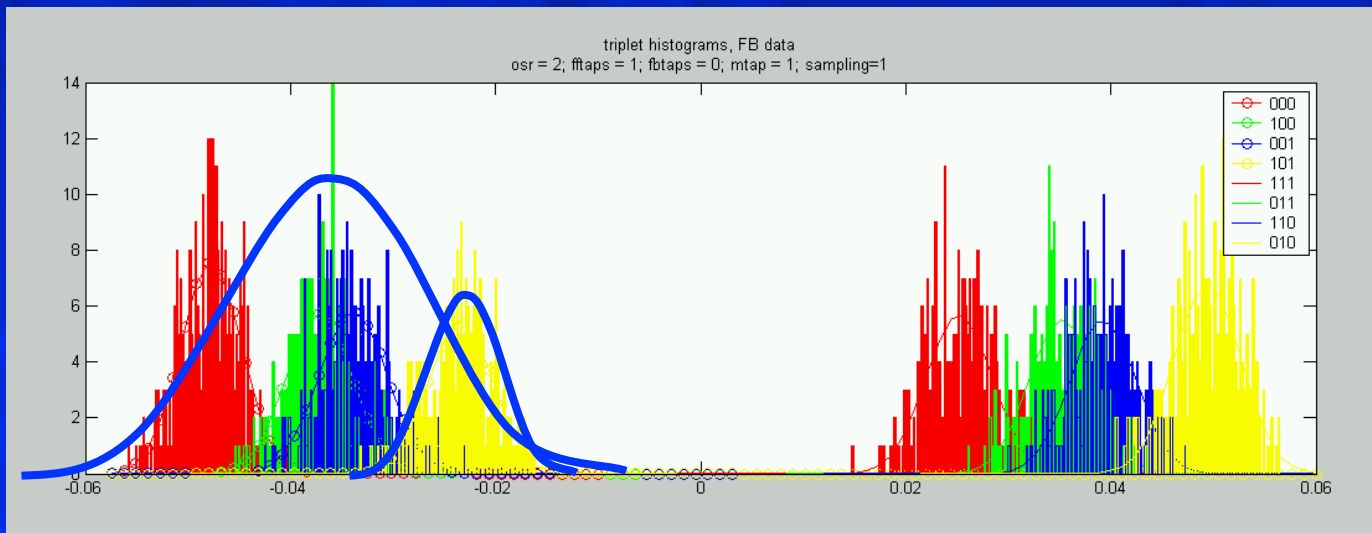
# Limitations of simulation model

- **Filter is ideal**
  - no bandwidth limitations
  - no noise contribution from filter
- **Jitter not considered in BER estimates**
- **Only thermal noise considered (7.5 GHz BW)**



# BER estimation

- Divide bit-pattern up into different bit-sequences:  
000 001 100 101 010 011 110 111  
and use Gaussian distribution on each of these



Ref. C. J. Anderson and J.A. Lyle Electronics letter jan. 1994 vol 30 no 1 p 71

