NOISE XT

Noise eXtended Technologies

Ultra-low Phase Noise measurement technique using Innovative optical delay lines

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Study Context

- Noise XT was previously known as the Aeroflex Phase Noise division, we have 20 years of experience in Phase Noise measurements

- Femto-ST is a world known Research Lab who collaborated to this study and received grants from Aeroflex

- Eastern OptX and Thalès provided expertise in fiber spools and target specifications

Phase Noise measurements

- 2 phase noise measurement types:
  - Absolute also called total phase noise or output phase noise
  - Residual also called added phase noise

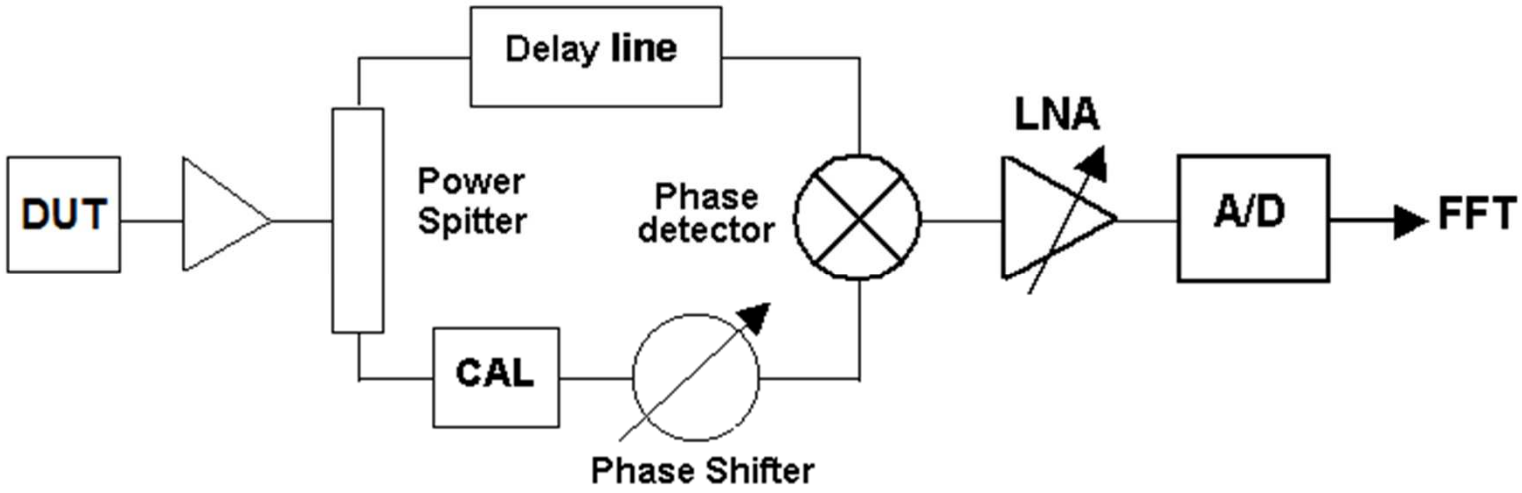
- 2 types of DUT:
  - Oscillators, Synthesizers, frequency translation devices viewed as a frequency sources (their Local Oscillator)
  - Amplifiers, cables, frequency translation devices, all viewed as a 2 ports phase coherent device (output vs input)

State of the Art Oscillators

- Electro-optical oscillators
  - Main spec driver : -150 at 10kHz offset in X band
- Cryo-cooled Oscillators
  - The lowest noise with about -170dBc/Hz at 10kHz offset for an X band frequency
- ULN crystal oscillators and SAW based devices
  - -185 dBc/Hz noise floor for 10MHz to 500MHz frequencies

Frequency discriminator

- Phase Noise measurement based on Frequency Noise Measurement



Phase to Voltage Conversion

τ: Time Delay between the 2 paths, Delay-line length

$K\phi$: phase detector demodulation factor

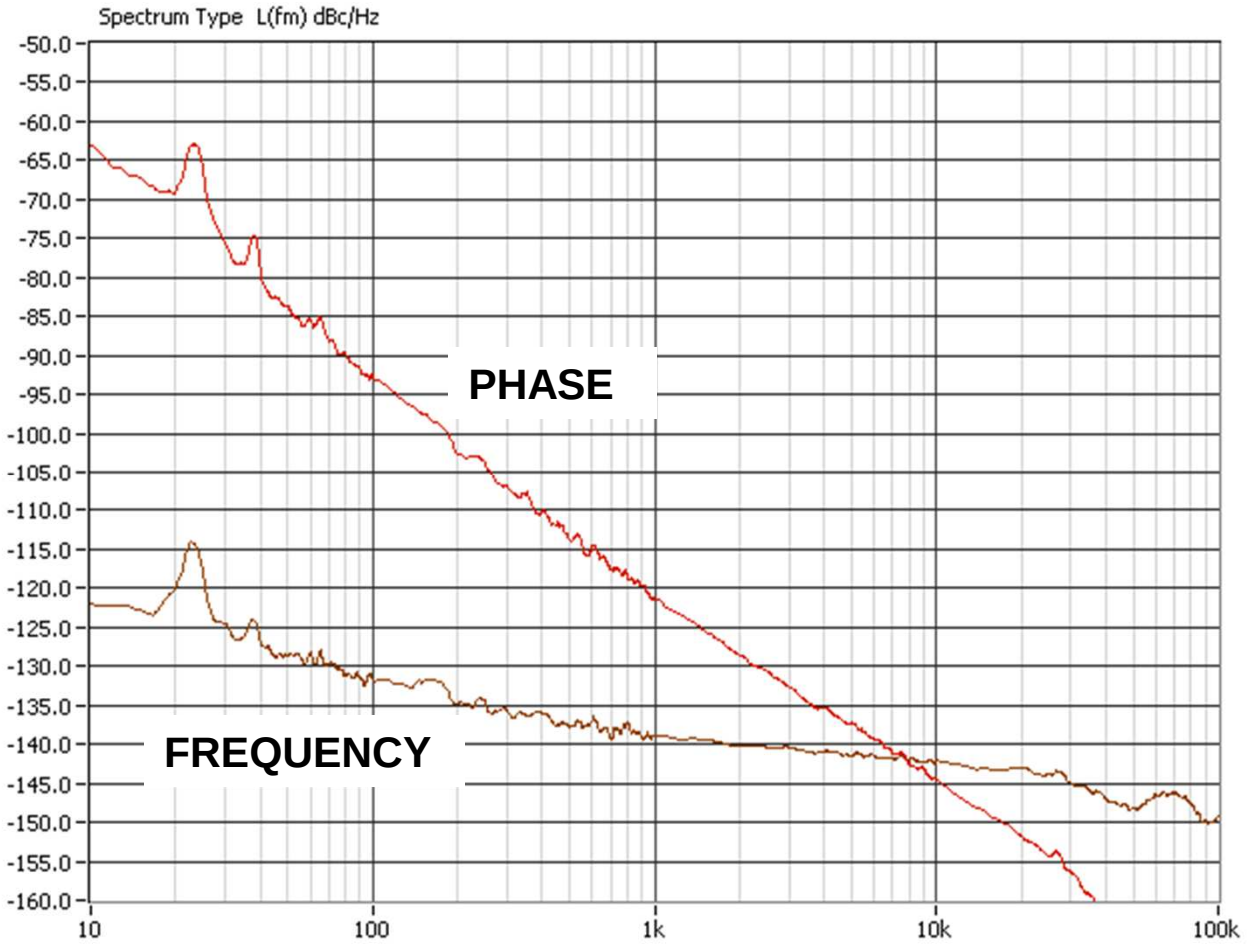
Noise voltage(fm) = noise at the output of the phase detector

$$\text{Noise voltage (fm)} = K\phi\, 2\pi\tau\Delta f(\text{fm})\, \frac{\sin(\pi\tau fm)}{\pi\tau fm}$$

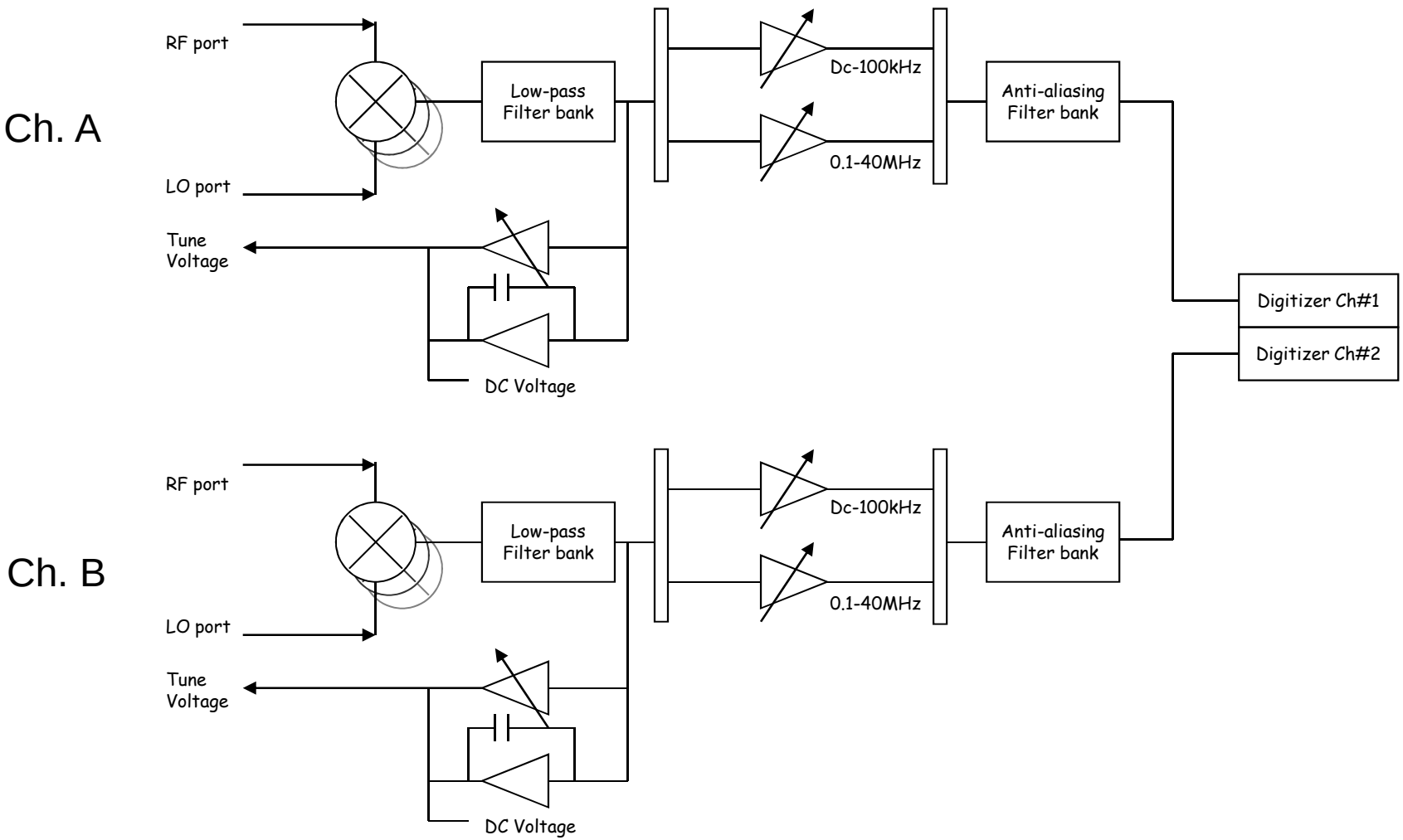
By correcting (fm) $\frac{\sin X}{X}$ Up to about Fm= $\frac{1}{2\tau}$

$$\text{Noise Voltage (fm)} = K\phi\, 2\pi\tau\ \Delta f(\text{fm})$$
$$= K\phi\, 2\pi\tau\ \text{fm}\ \Delta\phi(\text{fm})$$

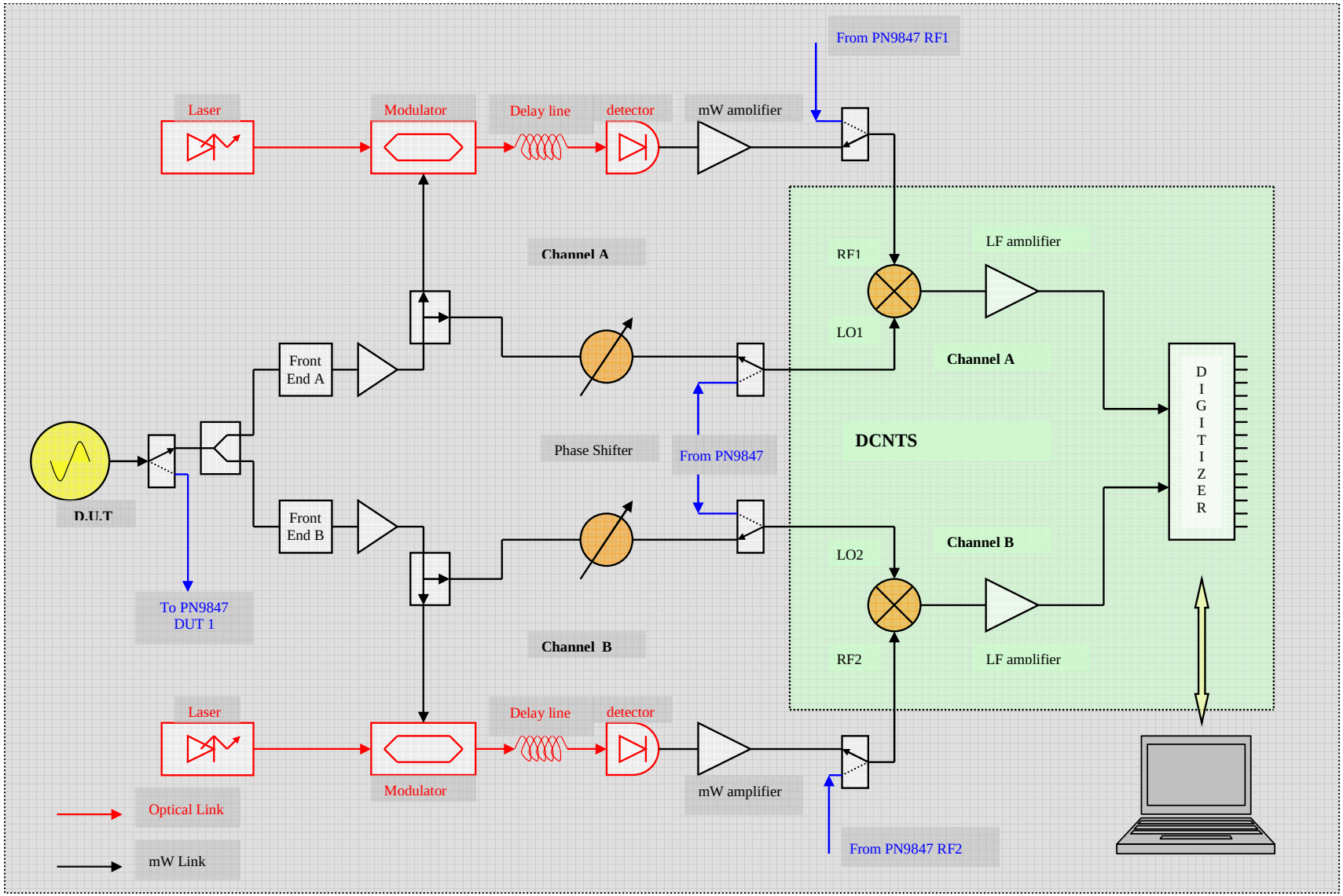
Frequency to Phase Conversion



Cross-Correlation PNTS



Complete Phase Noise Test Set



Keys to success

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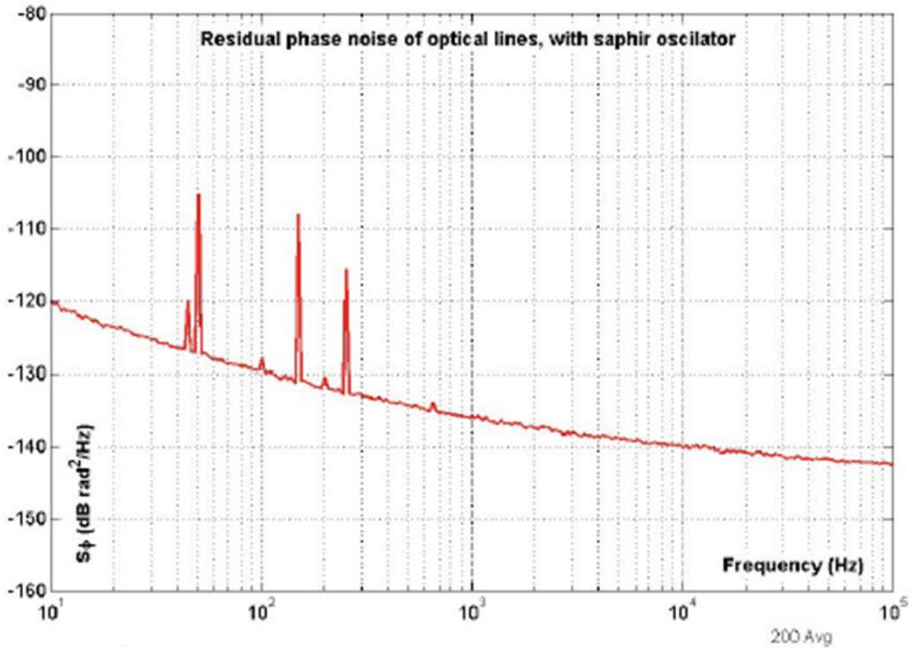
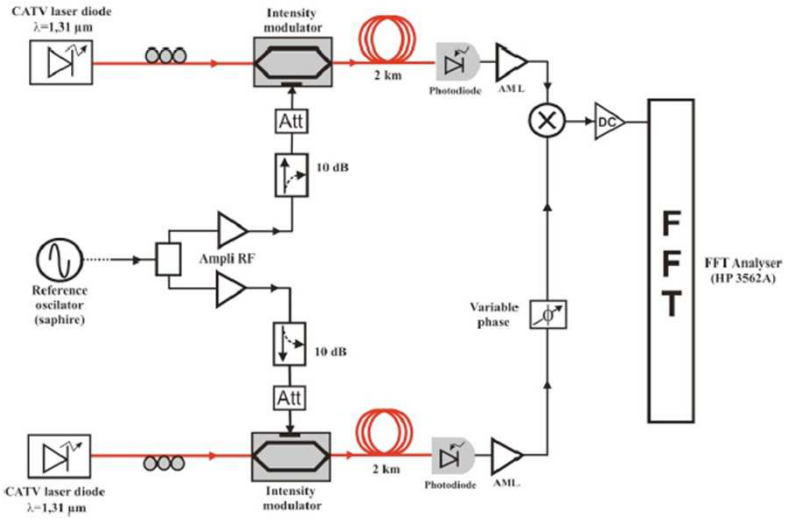
- Lasers with low Rin and low noise external modulator
- Thermally stabilized fiber spools
- Ultra low noise amplifiers (after photodiodes)
- Uncorrelated channels, no cross-talk
  - Use of Innovative Fiber Spools with orthogonal behavior
- Software controlled Phase shifters
- Optimized Signal Processing Flow

Fiber Delay Residual Phase Noise

Prototype Data

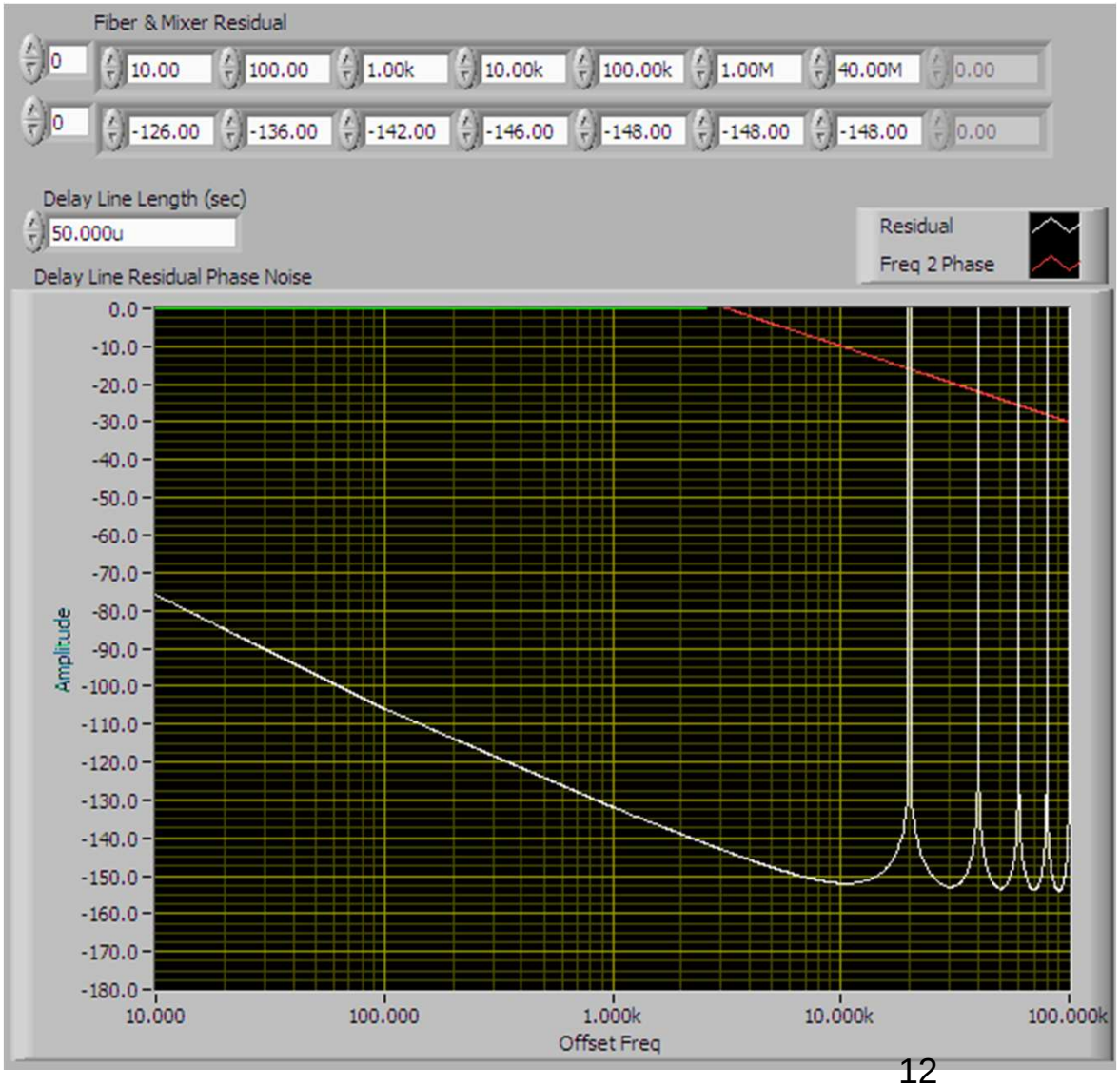




L(fm) for 1 fiber link:	**10 Hz**	**-126 dBc/Hz**
	100	**-136**
	1k	**-142**
	10k	**-146**
	100k	**-148**

Absolute Phase Noise floor

Simulation



L(fm) for 50 us (10 km) single fiber channel:

10 Hz	**-75 dBc/Hz**
100	**-107**
1k	**-132**
10k	**-152**
100k	**N/A for 50 us**

Still with no cross-correlations !

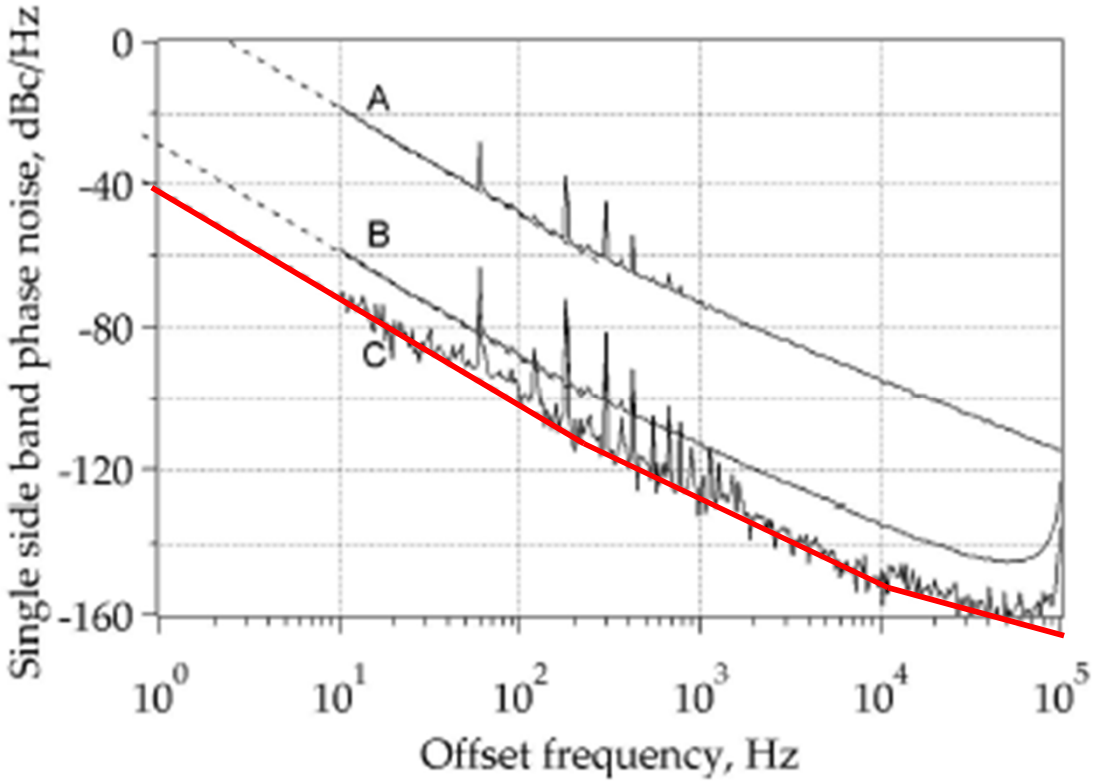
But 10,000 xcor = 20dB better

Possible floor:

-172 dBc/Hz @10kHz offset

Absolute Phase Noise floor

Measured



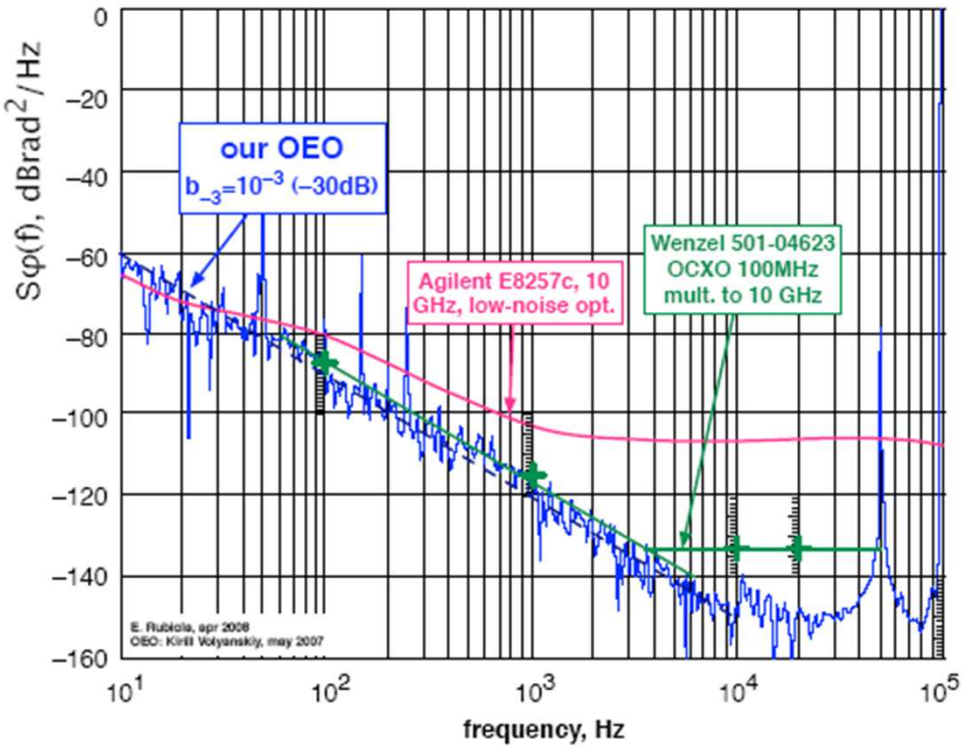
L(fm) for 10 us (2 km) and 200 xcor, simulation is:

10 Hz	**-75 dBc/Hz**
100	**-105**
1k	**-132**
10k	**-155**

Measurement matches Simulation within 2 dB

Note: Measurement is from an older prototype than actual measured data used in simulation and fiber link had a higher residual noise but matches Simulation on old data within 2 dB.

DUT measurement



OEO oscillator

Measured:
–153 dBc/Hz at 10kHz

System Theory Floor:
–155 dBc/Hz (10us, 200 xcor)

Conclusion

- Fiber Optics can help measure Ultra-low Phase Noise
- State of the Art Phase Noise measurements can be done without the need of expensive reference sources
- The design of the Fiber Optics links is key in obtaining high performance
- Noise XT is looking for partners and customers to put such instrument on the market:

  -170dBc/Hz @10kHz offset for an X band signal

Thank you !

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Questions and Answers