Outline

- Introduction
- Main topics of my thesis
- Problem Solving
- Publications
  - Is your work novel?
- Useful hints
- Tools for better productivity
- Conclusion
Introduction

- PhD started in October 2006
- Thesis Title: “Compensation of Fiber Impairments in Coherent Optical Systems”
- Supervision of:
  - Prof. Henrique Salgado (Inesc Porto / FEUP)
  - Prof. Izzat Darwazeh (University College London)
- Total of 6 publications so far, including:
  - 1 IEEE Letter (Photonics Society PTL)
  - 3 IEEE International Conferences
- Expected finish in September 2010 (4 years)
Main Topics

- Study of coherent optical receivers
- Modulation techniques and formats
- Implementation of fiber simulation models:
  - Chromatic Dispersion
  - Polarization Mode Dispersion: dual polarization systems
  - Laser phase noise
  - Modulation / Demodulation algorithms
- Study and application of adaptive algorithms: LMS and RLS
- Study and simulation of laser phase noise compensation:
  - Comparison of Wiener filter and Kalman filter approaches (FIR and IIR)
  - Integration of laser PN compensation with channel estimation
  - Techniques for real-time parallel implementation
- Study and application of joint linear and nonlinear impairment compensation
  - Extension to dual polarization systems
  - Extension to WDM and OFDM
Problem solving

- “Make the calculus!”
  - Stuck understanding how an author made a derivation in a paper
  - Starting from the fundamental theory
  - e.g. Often, I need to derive an equation for a specific communications problem starting from the general theory of electric field expressions.

- Discussion with PhD colleagues
- Teach the problem
- Ask to the paper author!
Problem solving

Hi Luis,

Your answers:

1. The noise figure definition I used is the one by Haus in PTL vol 10, pp 1002-1004, 1998. According to this NF definition, the NO at the output of an amplifier is:

   \[ \text{NO} = (F-1)*G*h*nu \]

   I did not use the F/2 definition because that definition (based on SNR_in = optical, SNR_out = electrical) does NOT allow you to use the amplifier concatenation formula. The definition in Haus enabled me to use a simple formula to find the total noise figure of the system:

   \[ (\text{Nf_{total}}) = N_{span}*((F_{1}-1)+(F_{2}-1))/(G^{*\exp(-\alpha_{dch}d_{L_{dcf}})), \text{ referenced to the output of the first span of SMF}. \]

   The total noise at the receiver is then:

   \[ \text{NO_{total}} = \text{Nf_{total}h*nu*exp(alpha_{smf}L_{smf})} \]

   And therefore the received OSNR is \( \text{Ptx/(NO_{total}R_s)} \). The theoretical phase error variance will be \( 1/(2^{*\text{OSNR}}) \) -- because only half the noise variance contributes to phase error.

2. Typo: I was referring to BP1S with \( M\kappa=3 \), 100% undercompensation, not 10%

3. I neglected to mention the setup was slightly different in Fig. 12. Previously, I had two EDFAs with the gains set as per Table 1. For 100% undercompensation (no DCF), I still had two EDFAs - just that there is no DCF in between. This setup was appropriate because it makes the system comparable going from 0% undercomp., to 5%, to 10%, to 100%. For Fig. 12 however, because I'm now only considering no DCF, there is no need for the second EDFA so I took out. The resulting system therefore has less noise overall.

4. You have to simulate with different zeta values until you minimize your phase error s.d. You'll find that the optimum zeta depends on the launched power, the amount of undercompensation of dispersion, the oversampling rate, etc. I don't know a rule of thumb.
Publications

- Research should always be focused on publishing:
  - It is the first indicator of productivity
  - You will not waste your time! If your work is complete enough it can eventually be almost copy-pasted to your final thesis.

- Thinking BIG. Invest your time only in IEEE conferences and top impact factor journals.
Is your work novel?

• It's a mistake not publishing because you think the work isn’t novel enough.

• Several times I found someone else's work, in a good journal, having similar degree of novelty, with an analysis which was essentially:
  – Comprehensive
  – Thorough
  – In depth
Useful Hints

• Be registered at “ScholarOne Manuscripts”
  – If you get the chance to review a paper don’t waste it!

• Try to meet the leaders of your area when you go to international conferences
  – At least they will be familiar with your name when reviewing a paper you submitted!

• Keep up the pace
  – Know the most important conferences of your area
  – Read the relevant papers as soon as they are available
Tools for better productivity

- LaTeX
- JabRef
- Evernote
- Adobe illustrator
For postcompensation using T-NLSE, each detected channel has to be upsampled so that the bandwidth of the reconstructed full-optical field is wide enough to avoid aliasing of newly generated PM products. The sampled bandwidth has to be twice the optical WDM bandwidth.

Alternatively, XFE compensation using C-NLSEs does not create new frequency components. Hence, an accurate backward

- In the past, the primary motivation for studying coherent detection was because it offered optical gain. Today there are several optical amplifier technologies that provide optical gain, and we are more interested in the features of coherent detection that were previously of secondary importance.

- Although we can study the true optimal estimate, the maximum a posteriori (MAP) estimate, it is not feasible to calculate it in a real-time DSP, and it is shown that the power law-average estimate using a Wiener filter is a practical alternative which is a near-optimal estimate.

- The optimal phase estimate is the MAP. For BPSK and QPSK, a phase estimate with power law nonlinearity followed by Wiener filter gives a result that is almost as good as MAP estimate. The laser linewidth for +1dB Q-factor penalty is high enough to accommodate DFB lasers, assuming 10Gb/s baud signaling rate.

- However, although not studied in this paper, the decision feedback estimate may be the best choice for modulation formats where the power law nonlinearity cannot be applied, such as QAM, in which case the feedback path delay and consequent low laser linewidth must be tolerated.

- The recent algorithms have identical behavior to the original, but requires more computations to implement. Further techniques may be applied such as iterative block processing and power-of-2 decomposition to bring the number of computations down to a level close to the original. Thus, while the issue of delay in feedback paths was a key constraint on the laser linewidth for the old generation of coherent receivers, it is not important for today’s DSP-based receivers detecting PSK modulation formats.
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Conclusion

- Bottom-up approach for problem solving
- Publication oriented research
- Making the work always as comprehensive and complete as possible (later it will be useful for thesis writing)
- Sometimes we can feel frustrated when doing research, not knowing which direction to follow. Supervisor and most times PhD colleagues help is key.
Thank you for your attention!