Universidade do Porto
FEUP Faculdade de Engenharia

PDEEC

luis.pessoa@ieee.org

Personal Perspective from PhD experience

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)

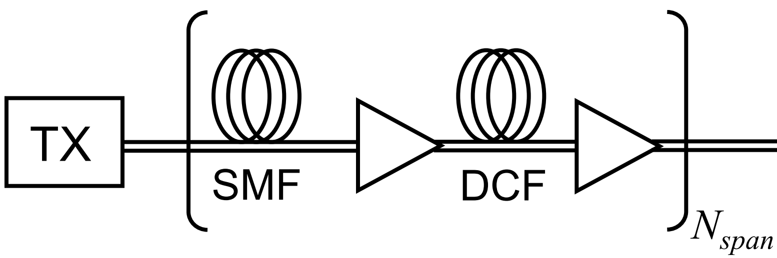
Main Topics

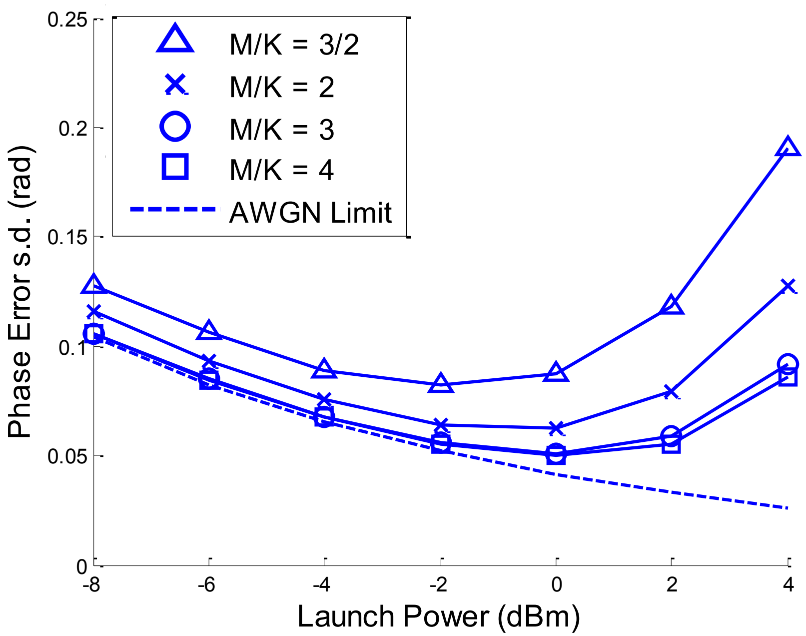
- Study of coherent optical receivers
- Modulation techniques and formats
- Implementation of fiber simulation models:
  - Chromatic Dispersion
  - Polarization Mode Dispersion: dual polarization systems
  - Laser phase noise
  - Modulation / Demodulation algorithms
- Study and application of adaptive 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

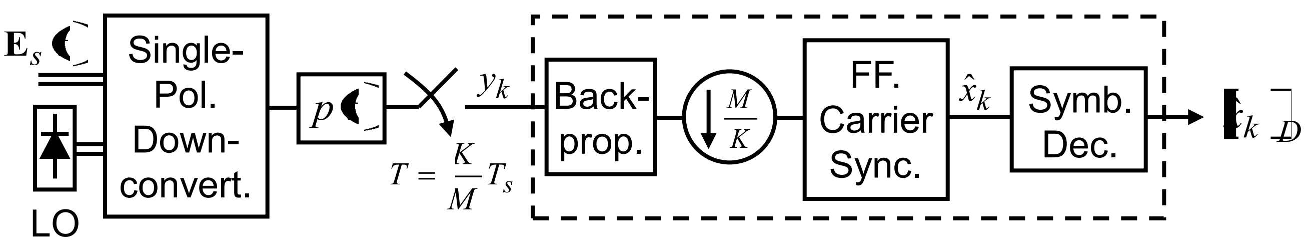
Problem solving

- "Make the calculus!"
  - Stuck understading 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







Ip, E. & Kahn, J. M., Compensation of Dispersion and Nonlinear Impairments Using Digital Backpropagation *Journal of Lightwave Technology*, **2008**, *26*, 3416-3425

Problem solving

Ezra Ip to Luís — show details Mar 6 — Reply

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 N0 at the output of an amplifier is:

N0 = (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:

(Nf_total-1) = Nspan*((F1-1)+(F2-1)/(G*exp(-alpha_dcf*L_dcf)), referenced to the output of the first span of SMF.

The total noise at the receiver is then:

N0_total = Nf_total*h*nu*exp(alpha_smf*L_smf)

And therefore the received OSNR is Ptx/(N0_total*Rs). The theoretical phase error variance will be 1/(2*OSNR) -- because only half the noise variance contributes to phase error.

2. Typo: I was referring to BP1S with M/K=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 I. 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?

- Its 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 essetially:
  - Comprehensive
  - Thorough
  - In depth

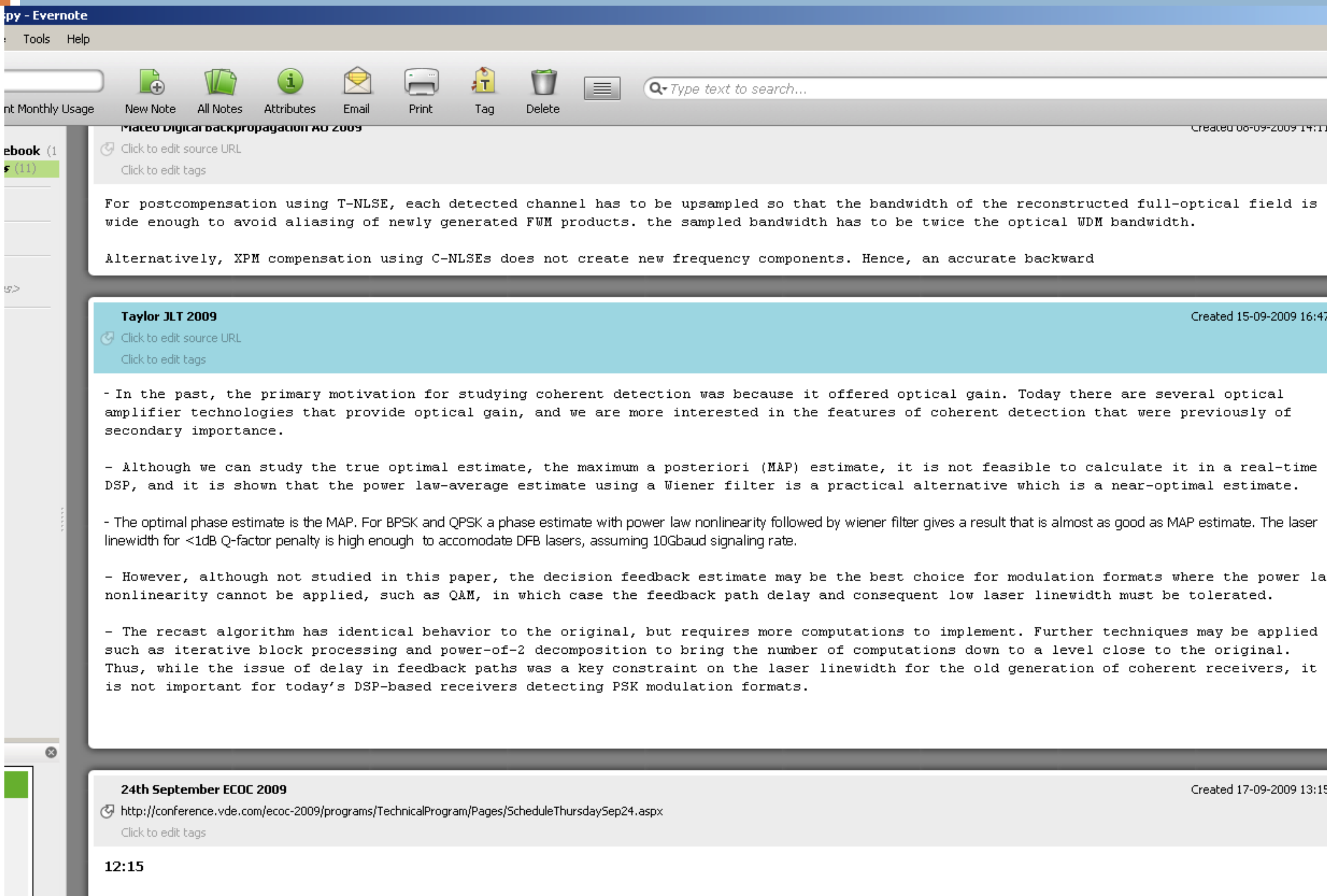
Useful Hints

- 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 familar 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

Evernote



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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 FWM products. the sampled bandwidth has to be twice the optical WDM bandwidth.
Alternatively, XPM compensation using C-NLSEs does not create new frequency components. Hence, an accurate backward
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- 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 accomodate DFB lasers, assuming 10Gbaud 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 recast algorithm has 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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#	Entrytype	Author	Title	Year	Journal	Owner	Timestamp	Bibtexkey
1	Inproceedings	Pessoa et al.	Assessment of parallel equalizer/phase estimation algorithms in coherent ...	2009		lpessoa	2009.09.17	Pessoa2009a
2	Article	Banovi{\'c} et al.	{A configurable fractionally-spaced blind adaptive equalizer for QAM demod...	2007	Digital Signal Proces...			banovi?2007configur
3	Book	Brown and Hwang	{Introduction to random signals and applied Kalman filtering: with MATLAB ...	1996				brown1996introducti
4	Article	Carena et al.	A time-domain optical transmission system simulation package accountin...	1997	#IEEE_J_JSAC#	lpessoa	2009.08.03	Carena1997
5	Inproceedings	Crivelli et al.	Adaptive digital equalization in the presence of chromatic dispersion, PMD,...	2004		lpessoa	2009.08.03	Crivelli2004
6	Article	Curri et al.	{Dispersion Compensation and Mitigation of Nonlinear Effects in 111-Gb/s...	2008	IEEE Photonics Tech...			curri2008dispersion
7	Article	Dal Forno et al.	Experimental and theoretical modeling of polarization-mode dispersion in ...	2000	#IEEE_J_PTL#	lpessoa	2009.08.03	DalForno2000
8	Book	Ho	{Phase-modulated optical communication systems}	2005				ho2005phase
9	Article	Ip and Kahn	{Feedforward carrier recovery for coherent optical communications}	2007	Journal of Lightwave ...			ip2007feedforward
10	Article	Ip and Kahn	Digital Equalization of Chromatic Dispersion and Polarization Mode Disper...	2007	#IEEE_J_JLT#	lpessoa	2009.08.03	Ip2007
11	Article	Ip et al.	{Coherent detection in optical fiber systems}	2008	Opt. Express			ip2008coherent
12	Article	{Ip} and {Kahn}	{Compensation of Dispersion and Nonlinear Impairments Using Digital B...	2008	Journal of Lightwave ...			2008JLwT...26.3416I
13	Article	Kazovsky	Phase- and polarization-diversity coherent optical techniques	1989	#IEEE_J_JLT#	lpessoa	2009.08.03	Kazovsky1989
14	Article	Li et al.	{Electronic post-compensation of WDM transmission impairments using c...	2008	Opt. Express			li2008electronic
15	Inproceedings	Ly-Gagnon et al.	Unrepeated 210-km transmission with coherent detection and digital sign...	2005		lpessoa	2009.08.03	Ly-Gagnon2005
16	Article	Marcuse et al.	Application of the Manakov-PMD equation to studies of signal propagation i...	1997	#IEEE_J_JLT#	lpessoa	2009.08.03	Marcuse1997
17	Article	Noe	PLL-free synchronous QPSK polarization multiplex/diversity receiver conce...	2005	#IEEE_J_PTL#	lpessoa	2009.08.03	Noe2005
18	Article	Noe	Phase noise-tolerant synchronous QPSK/BPSK baseband-type intradyne r...	2005	#IEEE_J_JLT#	lpessoa	2009.08.03	Noe2005a
19	Inproceedings	Pessoa et al.	Simplified backpropagation equalization in WDM coherent polarization mult...	2009		lpessoa	2009.08.03	Pessoa2009
20	Article	Pessoa et al.	Performance Evaluation of Phase Estimation Algorithms in Equalized Coh...	2009	#IEEE_J_PTL#	lpessoa	2009.08.03	Pessoa_PTL2009
21	Inproceedings	Pessoa et al.	{Algorithms for DSP implementation in coherent optical systems}	2008		lpessoa	2009.09.17	pessoa-algorithms
22	Inproceedings	Pessoa et al.	Joint mitigation of optical impairments and phase estimation in coherent o...	2008		lpessoa	2009.07.30	Pessoa2008
23	Inproceedings	Pessoa et al.	Adaptive Electrical Equalization of Optical Impairments in Coherent Optical ...	2007		lpessoa	2009.08.04	Pessoa2007seon
24	Article	Pfau et al.	{Coherent optical communication: Towards realtime systems at 40 Gbit/s ...	2008	Opt. Express			pfau2008coherent
25	Inproceedings	Pinto et al.	FPGA Implementation of Signal Processing Algorithms in Coherent Optical...	2009		lpessoa	2009.08.04	pinto2009seon
26	Article	Savory	{Digital filters for coherent optical receivers}	2008	Optics Express			savory2008digital
27	Inproceedings	Savory	Digital Signal Processing Options in Long Haul Transmission	2008		lpessoa	2009.08.03	Savory2008
28	Inproceedings	Savory et al.	Ultra Long-Haul QPSK Transmission using a Digital Coherent Receiver	2007		lpessoa	2009.08.03	Savory2007
29	Inproceedings	Seimetz	Laser Linewidth Limitations for Optical Systems with High-Order Modulatio...	2008		lpessoa	2009.08.03	Seimetz2008
30	Inproceedings	Seimetz	Performance of coherent optical square-16-QAM-systems based on IQ-tra...	2006		lpessoa	2009.08.03	Seimetz2006
31	Inproceedings	Spinnler et al.	Chromatic dispersion tolerance of coherent optical communications syste...	2006		lpessoa	2009.08.03	Spinnler2006
32	Inproceedings	Taylor	Accurate digital phase estimation process for coherent detection using a p...	2005		lpessoa	2009.08.03	Taylor2005
33	Article	Taylor	Coherent detection method using DSP for demodulation of signal and sub...	2004	#IEEE_J_PTL#	lpessoa	2009.08.03	Taylor2004
34	Article	Treichler et al.	Practical blind demodulators for high-order QAM signals	1998	#IEEE_J_PROC#	lpessoa	2009.08.03	Treichler1998
35	Article	Xie	{Interchannel Nonlinearities in Coherent Polarization-Division-Multiplexed ...	2009	IEEE Photonics Tech...			xie2009interchannel
36	Article	Xie	{WDM coherent PDM-QPSK systems with and without inline optical dispers...	2009	Optics express			xie2009wdm
37	Inproceedings	Xie et al.	Nonlinear polarization scattering impairments and mitigation in 10-Gbaud ...	2009		lpessoa	2009.08.04	xie2009ofc
38	Article	Zhao and Namgoong	A novel phase-noise compensation scheme for communication receivers	2006	#IEEE_J_COM#	lpessoa	2009.08.03	Zhao2006

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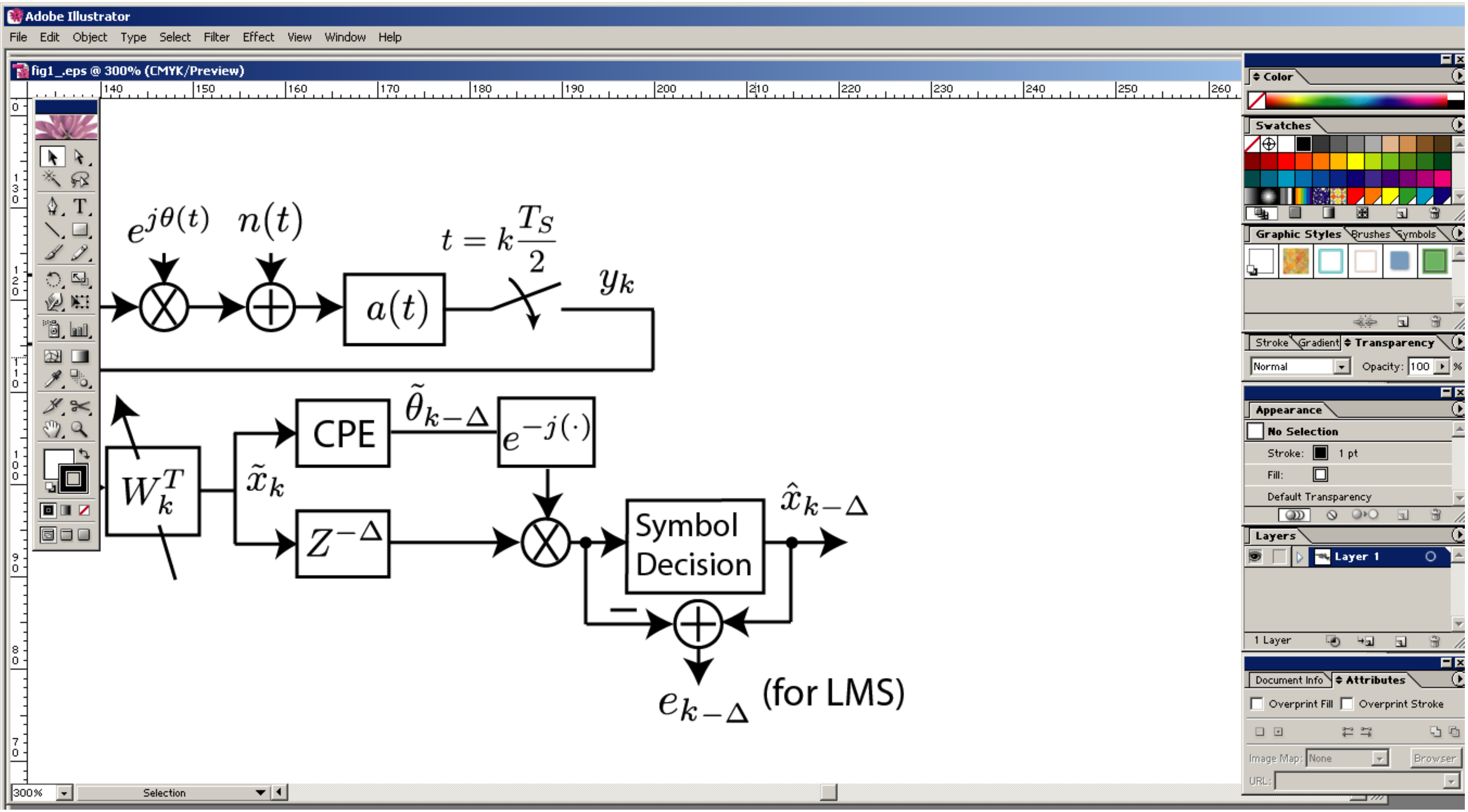

Conclusion

- Bottom-up approach for problem solving
- Publication oriented research
- Making the work always as comprehensive and complete as possible (later it will be usefull 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!