Application of Programmable Radios to Adaptive Communications

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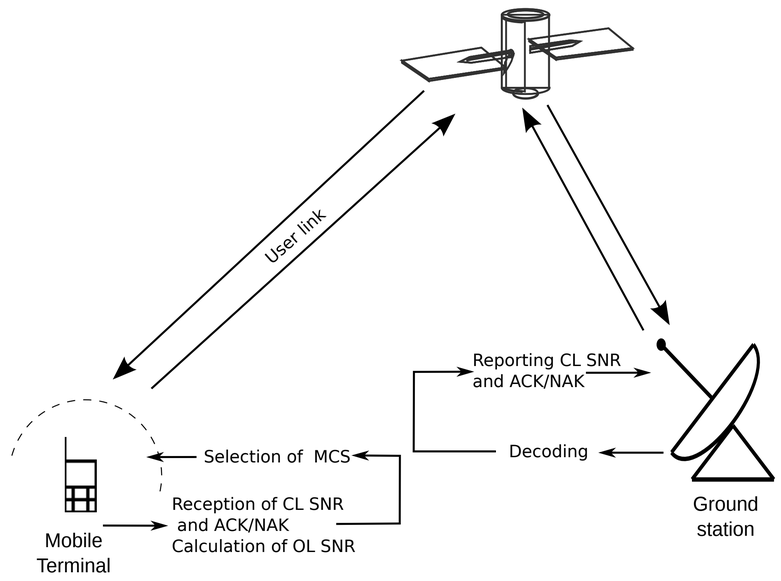
Motivation

The increasing demand of mobile data and the scarcity of spectrum in Satellite Communications (SatComs) force systems to be more efficient. Link adaptation techniques aim to increase the spectral efficiency adjusting modulation and channel coding dynamically. The consideration of mobile terminals and the long propagation delays makes link adaptation challenging in SatComs.



Software Defined Radio (SDR) technology makes possible to implement the physical layer in software. The flexibility it provides eases the implementation of adaptive systems and in this thesis SDR will be used to validate algorithms.

Thesis objectives

- **Main objective:** Advance the state-of-the-art in adaptive communications.
- **Specific objectives:**
  - Study of the convergence properties of previously developed algorithms.
  - Propose new link adaptation schemes for point-to-point communications with several users.
  - Propose new link adaptation schemes for satellite communications using double polarization.
  - Validation of the algorithms using SDR technology and thinking in mobile applications such as UAVs.

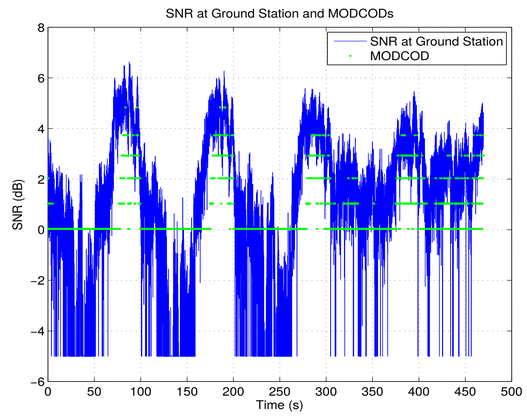
Research plan

- **Methodology**
  - Be in contact with other actors such as companies, standardisation organisations, technological centres and other universities.
  - Whenever possible, use real measurements and hardware to validate the algorithms developed.
  - Work flow for developing the new algorithms:
    1. Statement of an optimization problem
    2. Derivation of an easily implementable algorithm
    3. Convergence and robustness analysis
    4. Perform simulations comparing it with baseline solution.
  - Use of Matlab for performing simulations of the algorithms and comparing them using metrics such as the spectral efficiency or the Frame Error Ratio (FER).
  - Evaluation of the algorithms applied to satellite communications standards like S-UMTS or DVB-S2X.
- **Means**
  - Workstation at lab A-312 with laptop and software like Matlab, GNU Radio...
  - GPSC servers
  - Ettus and Nutaq SDR platforms
  - Spectrum analyser

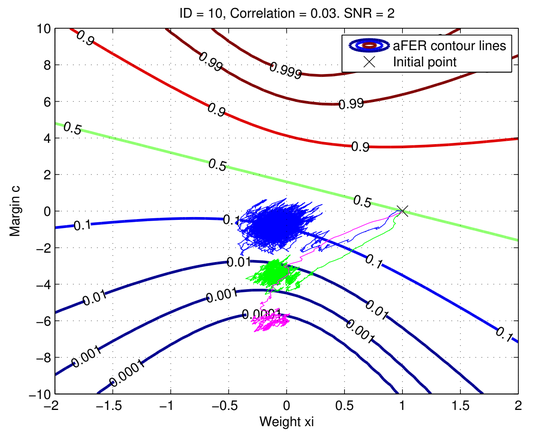
Next year planning

Task Description	2017 S1	2017 S2	2018 S1	2018 S2	2019 S1	2019 -
Analysis and modelling RSSI temporal series (Táctica)		■				
Prepare a journal with the results of the previous task		■				
Keep working on advanced capacity metrics; paper preparation.		■				
Teacher assistant in CDIX		■				
Take the course “Advanced Communications Systems”		■				
A few months stay in an international research centre			■			
Research algorithms for point to multipoint communications			■			
Collaboration in research projects about SatCom & SDR		■	■			

Results & Discussion

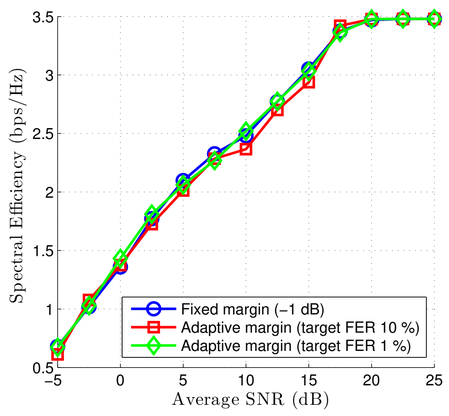


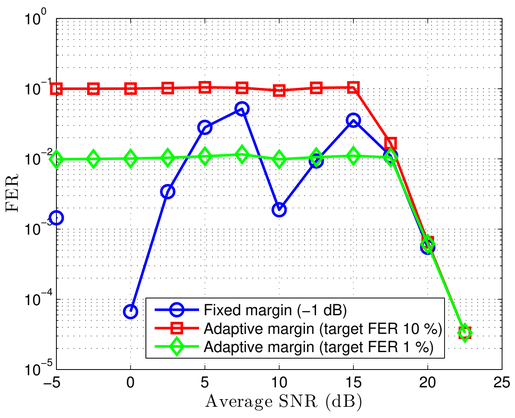
Experimental results of Tactica project. An UAV was communicated with a ground station by means of a MEO satellite. Link adaptation algorithm [1] follows channel variations adapting the rate accordingly. The periodic oscillation in the SNR is caused by the elliptical movement of the UAV. The algorithm also guarantees a preset Frame Error Rate (FER). [2]



Study of the algorithm convergence. SNR: $\rho \sim \mathcal{N}\left(\alpha\rho_{csi} + (1-\alpha)\bar{\rho},\ \sigma^2(1-\alpha^2)\right)$ Two adaptive parameters for MODCOD selection in the LUT: weight ξ_i and margin c_i. We calculate the theoretical values of $\xi - c$ which guarantee a specific FER, they lie in the level curves of the figure. Trajectory of the parameters in simulation is shown. For big and moderate FER they converge to a point in the respective level curve.

Link adaptation for dual polarization mobile satellite systems. [3]





The use of dual polarization simultaneously along with MIMO signal processing can provide remarkable throughput gains, up to 100 %, when compared with single polarization systems. There are available several MIMO transmission modes for use: Alamouti-like polarization-time coding, Polarization Modulation (analogous to Spatial Modulation) and V-BLAST. This new degree of freedom implies that the algorithm should select MIMO mode appart from MODCOD. The proposed adaptive algorithm satisfies the target FER when compared with the use of fixed margin. And the combination of dual polarization with adaptive MIMO provides throughput gains from 50 to 100 %, depending on the SNR, and extends the operation range at low SNR.

Average SNR	Selected modes	Efficiency (SISO)	Efficiency (MIMO)	Gain
-5 dB	OPTBC	0 bps/Hz	0.68 bps/Hz	Inf
-2.5 to 7.5 dB	PMod	0.68 - 1.50 bps/Hz	1.02 - 2.32 bps/Hz	50 - 55 %
10 dB	PMod (30 %), BLAST (70 %)	1.69 bps/Hz	2.47 bps/Hz	47 %
12.5 to 25 dB	BLAST	1.73 - 1.74 bps/Hz	2.77 - 3.48 bps/Hz	60 - 100 %

References

References

[1] A. Rico-Alvarino, A. Tato, and C. Mosquera. Robust adaptive coding and modulation scheme for the mobile satellite forward link. In *Signal Processing Advances in Wireless Communications (SPAWC), 2015 IEEE 15th International Workshop on*, June 2015.

[2] A. Tato, C. Mosquera, and I. Gomez. Link adaptation in mobile satellite links: field trials results. In *2016 8th Advanced Satellite Multimedia Systems Conference and the 14th Signal Processing for Space Communications Workshop (ASMS/SPSC)*, pages 1–8, Sept 2016.

[3] A. Tato, P. Henarejos, C. Mosquera, and Ana Perez-Neira. Link adaptation algorithms for dual polarization mobile satellite systems. In *2017 9th EAI International Conference on Wireless and Satellite Systems (acceptance pending)*, pages 1–10, Sept 2017.

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