CONTINUOUS PHASE MODULATION FOR UAV CONTROL AND DATA LINK

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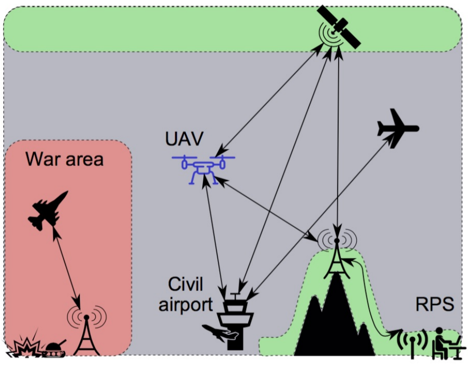
1. Context

- Unmanned Aerial Vehicle (*UAV*)

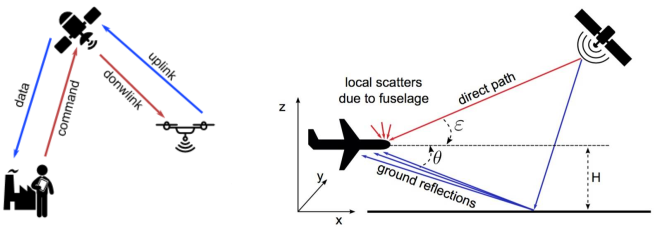
A lot of use: military use, forest surveillance, emergency situations, pipelines inspection, entertainment, communication, observation ...

- Typical UAV environment



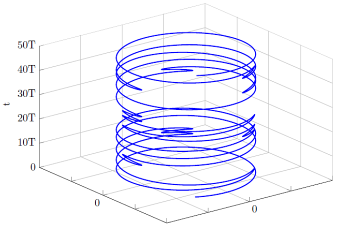
Need for a complete and safe integration in the existing air traffic aircraft system

- Communication link for UAV by satellite.



Ensure the control of the UAV in all situation

- Choice of Continuous Phase Modulation (*CPM*)
  - Robustness to non-linearities (due to its constant complex envelope)
  - Good Spectral occupancy
  - Already in use in satellite communication standard (as DVB-RCS2) and for tactical communication
  - Increased complexity at the receiver side



2. Continuous Phase Modulation

$\boldsymbol{\alpha} = \{\alpha_i\}$ block of N coded symbols taken in the M-ary alphabet $\{\pm1, \pm3, \ldots, \pm M-1\}$
Equivalent baseband complex envelope transmitted of CPM signal is

$$s_b(t) = e^{j\phi(t,\boldsymbol{\alpha})} \tag{1}$$

where $\phi(t,\boldsymbol{\alpha})$ is the information phase.
The received signal is:

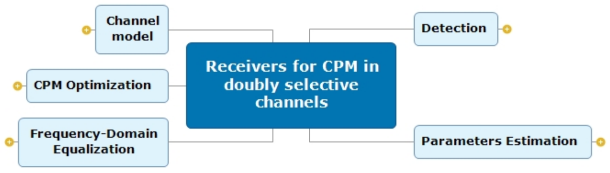
$$r(t) = e^{j2\pi f t+\theta} \sum_l h_l s_b(t-\tau_l) + w(t) \tag{2}$$

where

- $w(t)$ is a white Gaussian noise
- f is a carrier frequency offset
- θ is a phase offset
- $h_c(t) = \sum_{l=0}^{L_c-1} h_l \delta(t-\tau_l)$ is a frequency-selective channel

3. Thesis Goals and Contributions

- **Key points**:



Channel model
CPM Optimization
Frequency-Domain Equalization
Receivers for CPM in doubly selective channels
Detection
Parameters Estimation

- **Parameters Estimation**:
  Unknown parameters at the receiver side to estimate: f,θ, $\{h_l\}$; $\{\tau_l\}$ and L_c
  Most of other work done for AWGN channels, i.e. $h_c(t) = \delta(t)$

  Contribution (ICASSP 2017 and GRETSI 2017):

  - Joint Maximum Likelihood Estimation of carrier-frequency f and channel $h_c(t)$
  - Least Squares Channel Estimation with or without use of *a priori* on path delays $\{\tau_l\}$
- **Equalization**:
  Joint detection and equalization:
  - Optimal approach
  - Prohibitive complexity (exponentially scaling with both channel and CPM memories)

  Separation of channel equalization and CPM detection.

  Contribution (GRETSI and MILCOM 2017):

  - Study of the State of Art (similitudes and differences)
  - Generalization of those equalizers
  - Performance with channel estimation

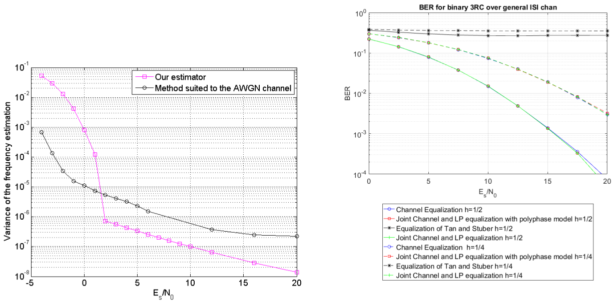


FIG. 1: Carrier-recovery and BER over general ISI channel

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