1) Title of the tutorial

Robust Estimation and Detection Schemes in non-Standard Conditions for Radar, Array Processing and Imaging.

2) Instructors name and affiliation

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3) a 300 word abstract describing the proposed topic and including an outline of the contents

Description of the tutorial: Since several decades, the Gaussian assumption has been widely used to deal with estimation and detection problems. More recently, some alternatives to this modeling, namely the *compound-Gaussian* model, the *Symmetric Invariant Random Vector* model or more general *Complex Elliptically Symmetric* (CES) process, have been studied, particularly for radar applications. Many works have shown for example the good agreement between such a model and real clutter radar data. Under these different statistical assumptions, several optimum and sub-optimum detectors, both designed for Gaussian or non-Gaussian disturbance, have been developed and analyzed, like for example, the well-known *Matched Filter* (MF) and the *Normalized Matched Filter* (NMF).

However, in practice, clutter and noise parameters are unknown and need to be estimated from a set of so- called secondary data. This leads to adaptive detection techniques. Their resulting performances strongly rely on the parameters estimation accuracy and particularly, on the clutter Covariance Matrix (CM) estimation. To tackle this challenging problem, recent works on Maximum Likelihood Estimation (MLE) and robust CM estimation have proposed different approaches such as the *Tyler Estimators* or the *M-estimators*. These estimators have been shown to perfectly handle the non-Gaussian nature, the spatial power heterogeneity, the non-stationarity of the clutter background. We will discuss about the required regularization procedure when the number of secondary data is less than the size of the observation vector or when some outliers or additional targets are present in the secondary data.

After briefly discussing the properties of the different statistical estimators (under Gaussian or non-Gaussian assumptions) used to describe the background data, different optimum and suboptimum adaptive detection schemes will be introduced. Finally, to deal with real applications, adaptive detection procedures as well as covariance matrix estimation schemes will be presented with the particular constraint of overall good regulation of false alarm strongly related to the detection performance. So, we propose to highlight these proposed estimation and detection schemes through some different applications on experimental data for example:

- Radar detection,
- Space-Time Adaptive Processing (STAP) and Array Processing,
- SAR Imaging (detection, change detection, classification, etc.),
- Hyperspectral Imaging (anomaly detection, target detection, etc.).

4) target audience and assumed knowledge

Tutorial Learning Objectives: This tutorial is mainly a survey on:

- General Gaussian adaptive detection schemes for radar, array processing, SAR, Hyperspectral imaging, etc.
- More recent statistical non-Gaussian modeling (compound Gaussian, SIRV, CES),
- Recent robust covariance matrix estimation schemes (Maximum Likelihood Estimators, M-estimators, regularization or shrinkage of covariance matrix estimates),
- Recent joint robust estimation and detection schemes (Adaptive Normalized Matched Filter with M- estimators) and their performance,

This tutorial is cut into three main parts:

- **The first part (1h)** is devoted to some reminders on adaptive processing (radar background, STAP, SAR, Hyperspectral imaging) as well as on estimation/detection theory. Particularly we present our motivations for defining more robust detection and estimation procedures,
- **The second part (1h30)** is more theoretical: we present general CES distributions, M-estimates, their properties and robustness, how to exploit *a priori* knowledge on the CM structure (Toeplitz, persymmetry, low-rank), shrinkage of CM. We will talk about the connections between robust CM estimators and Random Matrix Theory,
- **The last part (1h**) is to present performance (False Alarm regulation, Detection performance in terms of SNR) of the presented detection schemes compared to those of classical ones for experimental radar, STAP, SAR and hyperspectral target detection.

Tutorial Prerequisites: Statistical Signal Processing; radar; SAR imaging; hyperspectral imaging;