**Tutorial title:** Robust estimation and detection schemes in non-standard conditions for radar, array processing and imaging.

**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.).

**Outline:** This tutorial is mainly a survey on:

- General Gaussian adaptive detection schemes for radar, array processing, Synthetic Aperture Radar, 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,
- Applications.

This tutorial is cut into three main parts:

- **The first part (2h)** 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 (2h)** 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 (2h**) 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 presenter:** Jean-Philippe Ovarlez (ONERA & CentraleSupélec, France) was born in Denain, France in 1963. He received jointly the engineering degree from Ecole Supérieure d'Electronique Automatique et Informatique (ESIEA), Paris, France and the Diplôme d'Etudes Approfondies degree in Signal Processing from University of Paris Saclay, France and the Ph.D. degree in Physics from the University of Paris 6, France, in 1987 and 1992, respectively. In 2011, he obtained a Research Directorship Habilitation (HDR) thesis in Signal Processing from the University of Paris Saclay and his qualification to the University Professor position. In 1992, he joined the Electromagnetic and Radar Division of the French Aerospace Lab (ONERA), Palaiseau, France, where he is currently Chief Scientist and member of the Scientific Committee of the ONERA Physics Branch. Since 2008, he is attached at a part time to CentraleSupélec SONDRA Lab, in charge of Signal Processing activities supervision. In 2015, he becomes member of Special Area Team (SAT) in Theoretical and Methodological Trends in Signal Processing (TMTSP), EURASIP and treasurer of the IEEE GRSS French Chapter in 2016. His research interests are centered in the topic of Statistical Signal Processing for radar and SAR applications such as Time-Frequency, imaging, detection and parameters estimation.