

## Tutorial : MIMO Radar

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MIMO (multiple-input multiple-output) radar refers to the use of multiple transmitters and receivers, for sensing the environment and the targets present in this environment. Basically MIMO radar uses multiple antennas that transmit correlated or uncorrelated waveforms. For the last ten years MIMO has led to extensive research and publications, both in communications and Radar domains. Why such interest for MIMO in radar? Beside the prolific amount of publications, how to assess the interest of MIMO to overcome the current limitations of conventional radar? The tutorial attempts to answer these questions, as well as to provide the fundamentals and tools to understand the link between theoretical considerations and radar system design. After a summary of the state of art – we may notice that MIMO was invented more than 25 years ago – the course will provide the fundamentals of MIMO radar, how to define a MIMO radar configuration, introduce the signal model, waveform design, signal processing, detection and localization. A particular emphasis will be put on the coherent MIMO in conjunction with the unique properties of the MIMO steering vector. A large part of the course will be focused on applications, including MIMO-STAP for GMTI, low frequency radar for coastal maritime surveillance.

Audience: the course is suitable for engineers, scientists and researchers involved in the design and study of new radar configurations. A basic knowledge of radar systems will be helpful.

### Course Outline

#### Introduction

State of art, MIMO system in navigation, communication and radar domain;  
Flashback to the first MIMO radar, RIAS (SIAR), its advantages and drawbacks.

#### MIMO configurations

Definition of MIMO; MIMO and radar diversity;  
Coherent, statistical and hybrid MIMO;  
Examples of application  
First assessment of benefit of MIMO over conventional radar systems.

#### Signal model and performances

Power budget of MIMO system, examples of codes,  
Fast or slow time coding, which code for which application?  
Properties of the transmitted pattern

#### MIMO waveform design for radar applications

Waveform schemes: fast time CDMA, FDMA, TDMA, DDMA,..  
Examples of codes: sub-carriers, OFDM codes, PN (pseudo-noise), Hadamard codes

#### Signal processing

MIMO signal chain; mathematic formulation  
Estimation of the steering vector  
Impact of the Doppler shift on signal processing  
Detection scheme (Gaussian / non Gaussian noise)

#### Properties of the MIMO steering vector

Benefit of the combined transmit and receive array directivity  
MIMO and high resolution techniques

#### Some relevant application of MIMO to radar

Bistatic / Multistatic GMTI/STAP  
Low frequency HF radar and application to maritime surveillance (HFSWR)



**Marc Lesturgie** obtained the Engineering degree in 1985 from ENSAE in France (Ecole Nationale Supérieure de l'Aéronautique et de l'Espace), and a Master degree in Electronic & Microwave from University of Toulouse in 1986. In 2005 he obtained a Research Directorship Habilitation thesis from the University of Paris VI. He joined the French Aerospace Lab (ONERA) in 1987 and worked in a wide range of low frequency and new radar concepts, covering bistatic, multistatic and distributed radars. From 1996 to 2000 he is the head of the "New radar concepts" team in ONERA. In 2006, Marc Lesturgie is appointed as Director of SONDRRA (*Supelec-ONERA-NUS-DSTA Research Alliance*) - a joint laboratory between France and Singapore. In 2007 he is the head of the Electromagnetics department in Supelec.

In 2008, still Director of the SONDRRA laboratory, Marc Lesturgie is also Deputy Director at the Electromagnetics and Radar Department of ONERA. Since 2005, he has been also an Adjunct Principle Research Scientist with the Temasek Laboratories, at the Nanyang Technological University in Singapore. Chairman of the SEE/Committee 23 (radio-location and navigation) between 2000 and 2006, he has organized several International conferences, acted as the Technical Chairman of the International Conference on Radar Systems in 2004 (Toulouse) and 2009(Bordeaux). Marc Lesturgie is senior member of the IEEE, Fellow and Emeritus member of SEE and lectures regularly on radar topics in French and overseas Universities.