# 信号与系统实验

主讲人：吴光 博士

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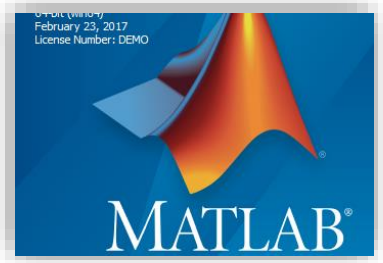
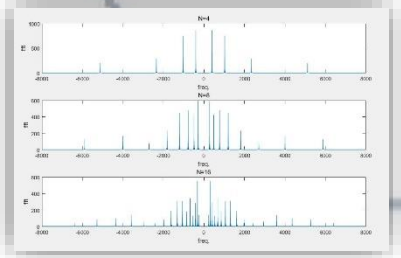
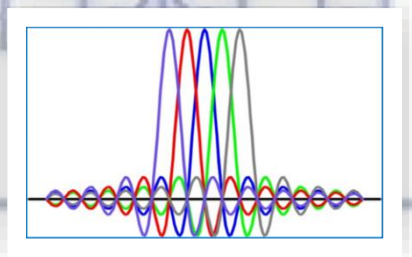
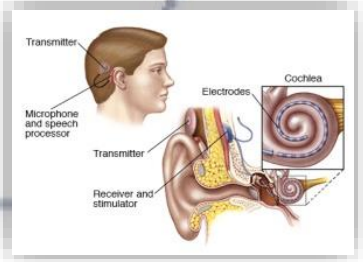







南方科技大学
SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

# Signals and Systems (Lab)

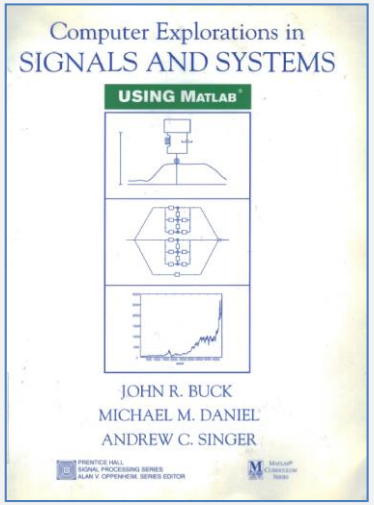
## Project2: Motion detection via communication signals

Dr. Wu Guang
wug@sustech.edu.cn
Electrical & Electronic Engineering
Southern University of Science and Technology

# Labs in this course

## 📖 5 Lab assignments+2 Projects

- Lab 1: MATLAB Programming (3 Weeks)
- Lab 2: Linear Time-Invariant Systems (2 Weeks)
- Lab 3: Fourier Series Representation of Periodic Signals (2 Weeks)
- Lab 4: The Continuous-Time Fourier Transform (2 Weeks)
- Lab 5: Coding Test & System, Transform, Convolution and Filter (1 Week)
- Project 1: Speech synthesis and perception with envelope cue (3 Weeks)
- **Project 2: Motion detection via communication signals (3 Weeks)**

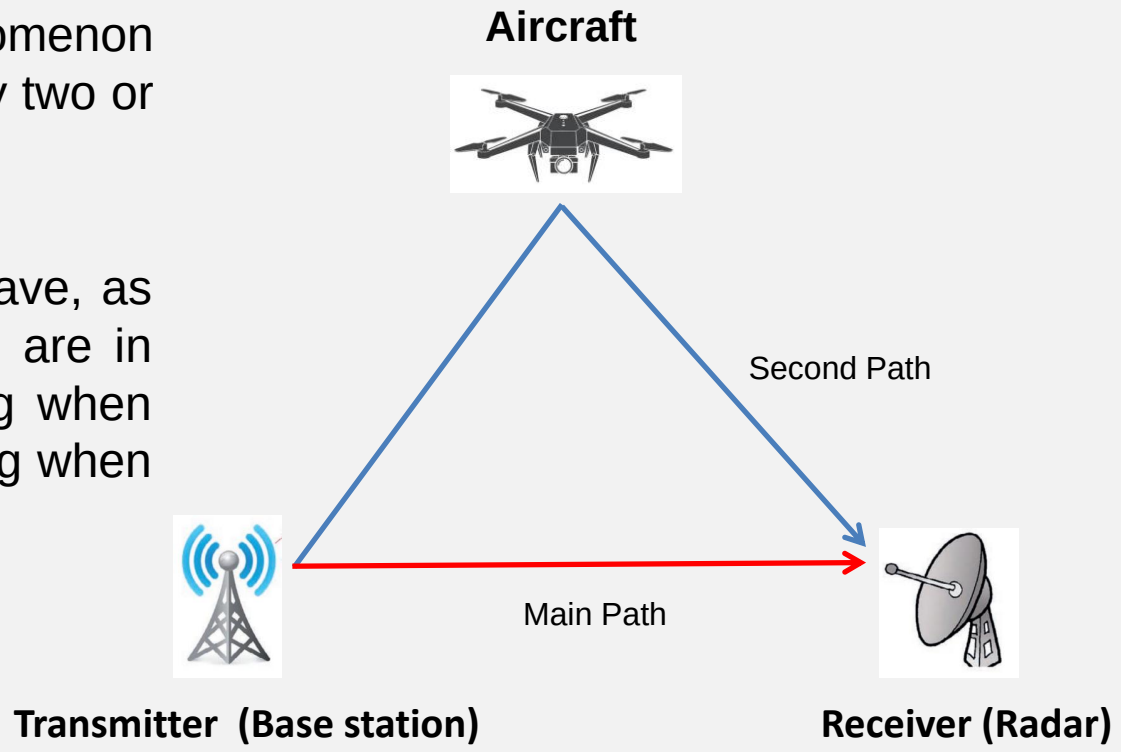


# Multipath propagation

**Multipath propagation:** Multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. (Wikipedia)

**Doppler shift:** A change in the observed frequency of a wave, as of sound or light, occurring when the source and observer are in motion relative to each other, with the frequency increasing when the source and observer approach each other and decreasing when they move apart. (Wikipedia)

**Radar :** A method of detecting distant objects and determining their position, velocity, or other characteristics by analysis of very high frequency radio waves reflected from their surfaces. (Wikipedia)




Multipath effect

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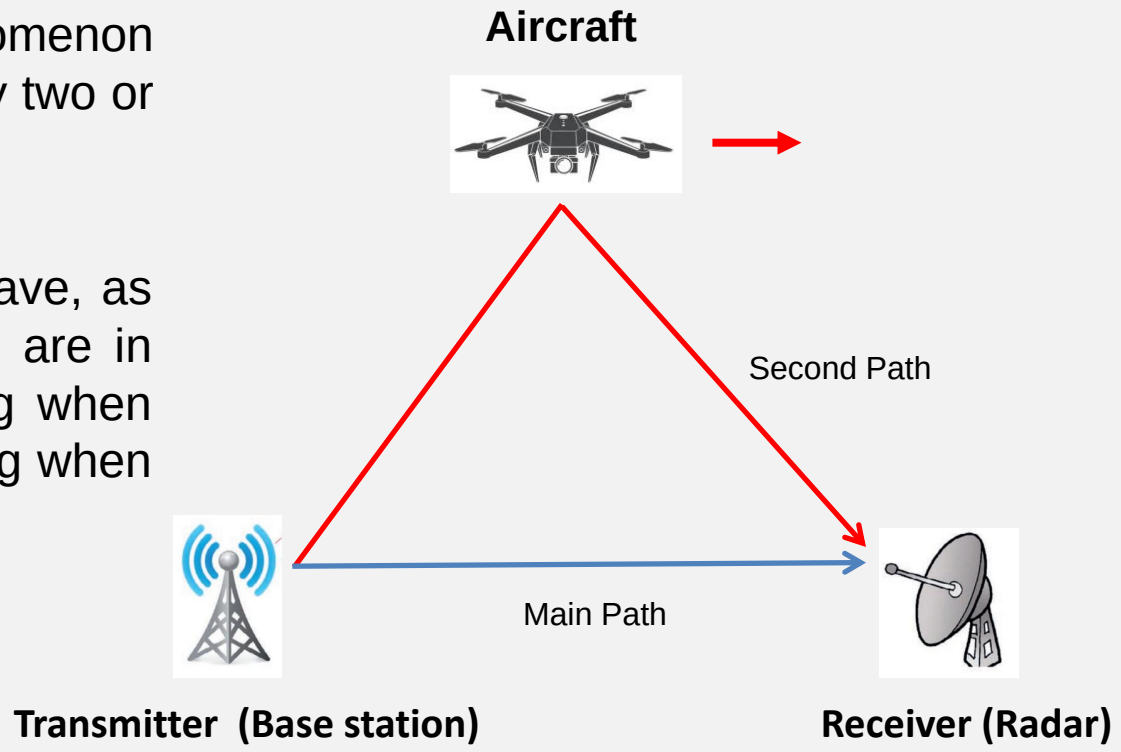
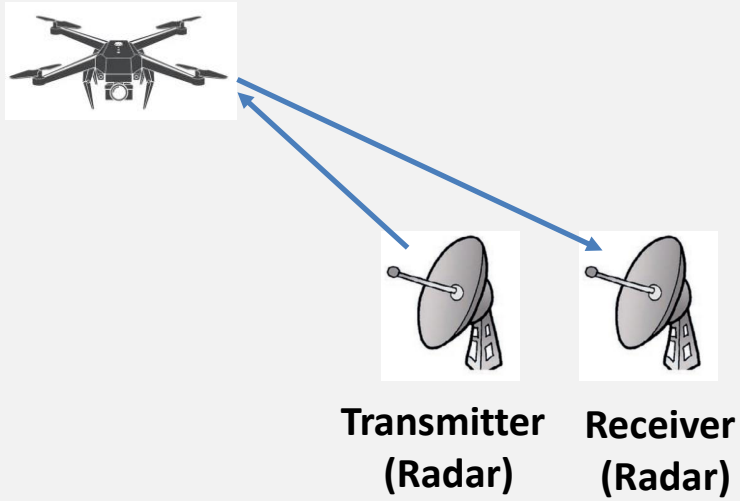
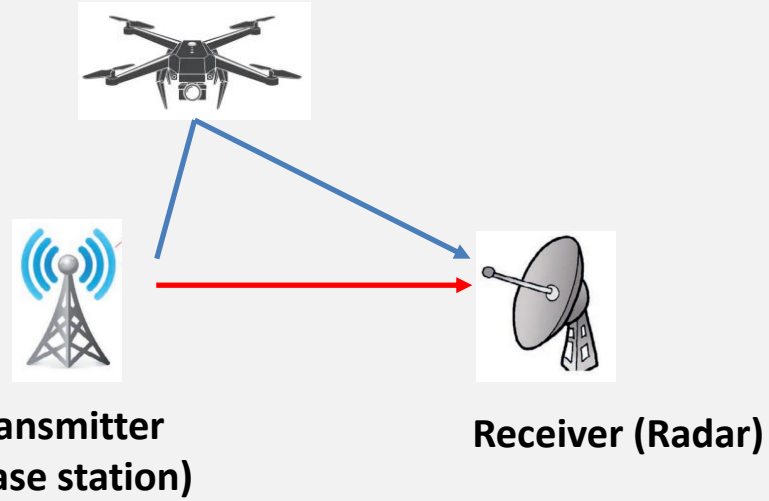



Multipath effect

# Active radar or Passive radar




**Active radar**



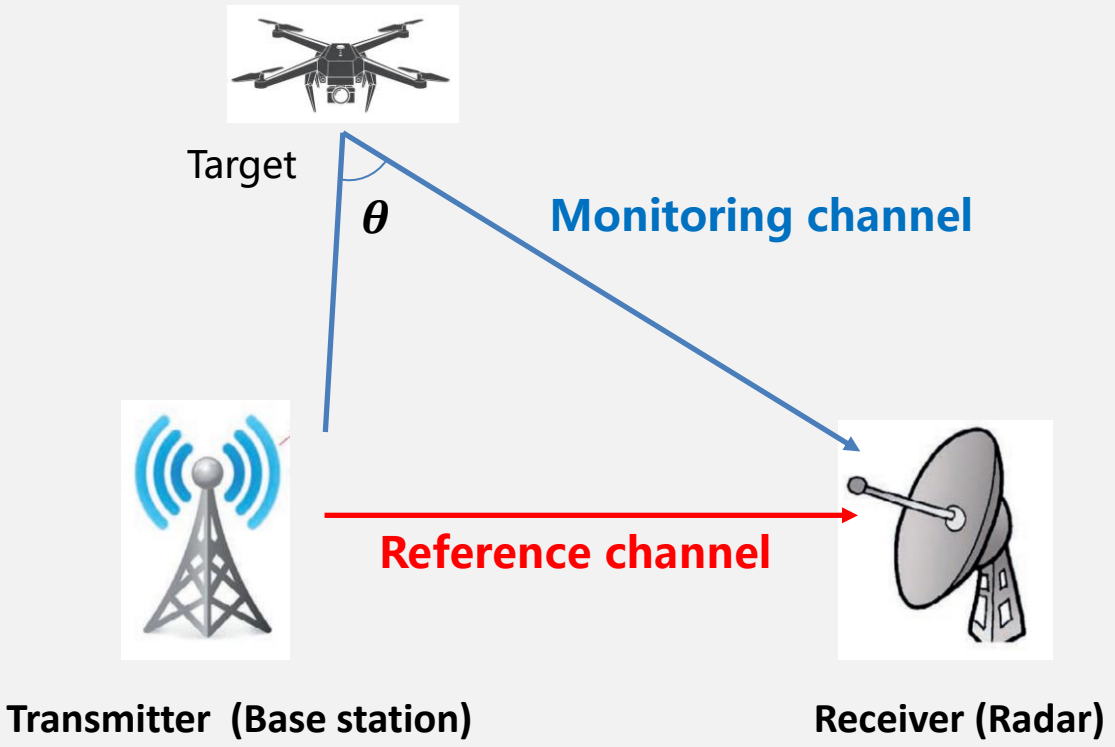

**Passive radar**

In military applications,

- Passive radar keeps radio silence during target detection, which is difficult to locate or be interfered, so it is very suitable for scenes with high requirements for concealment.
- No additional time / frequency resources are required, which makes its cost and complexity much lower than that of traditional active radar equipment.

# Basic principle of passive radar

- Passive radar first receives a reference signal sent from a transmitter.
- Then , the transmitted signals through a direct path (commonly referred to as "reference channel").
- At the same time, the receiver will receive the reflected signal scattered by the target.
- The target range and Doppler shift can be estimated by calculating the time difference and frequency difference between the signals sampled from the two channels.




$$\text{路径长度差} = \text{信道时延差} \times \text{光速}$$

$$\text{目标速度} = \frac{\text{波长} \times \text{多普勒频移}}{2cos(\theta/2)}, \theta = 90$$

# Basic principle of passive radar

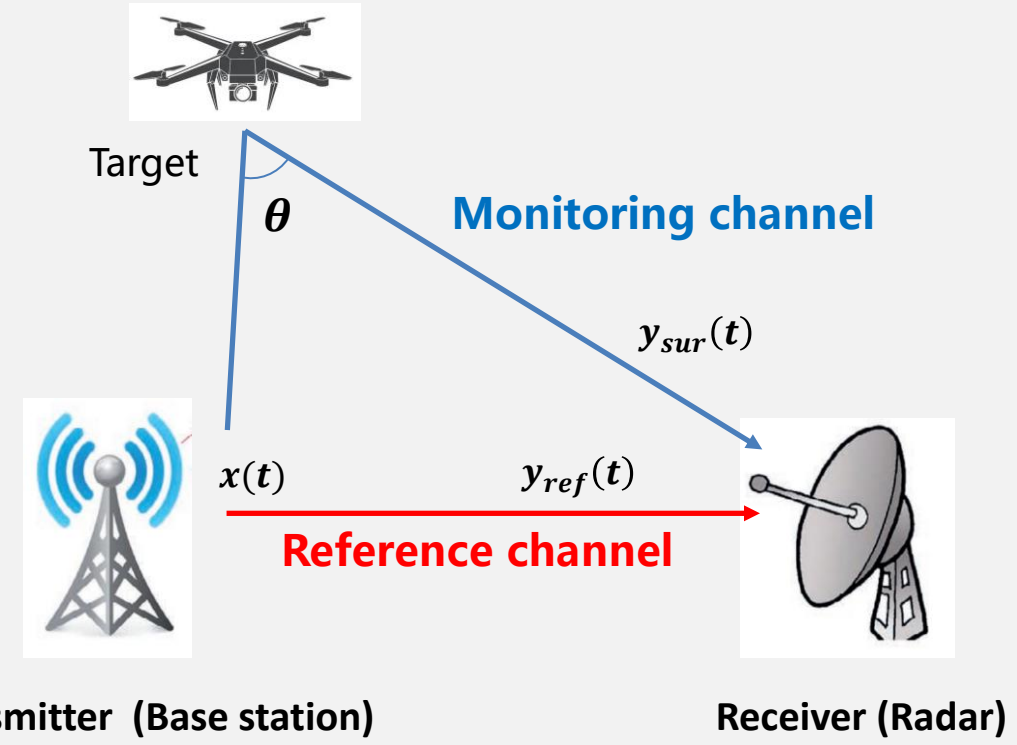
- 假设 $x(t)$ 为发射信号，
- 参考信号$y_{ref}(t) = \alpha x(t - \tau_r)$ 为时延和衰减后的发射信号
- 监视信号$y_{sur}(t) = \beta x(t - \tau_s)e^{j2\pi ft}$ 为衰减、时延和多普勒频偏后的信号。

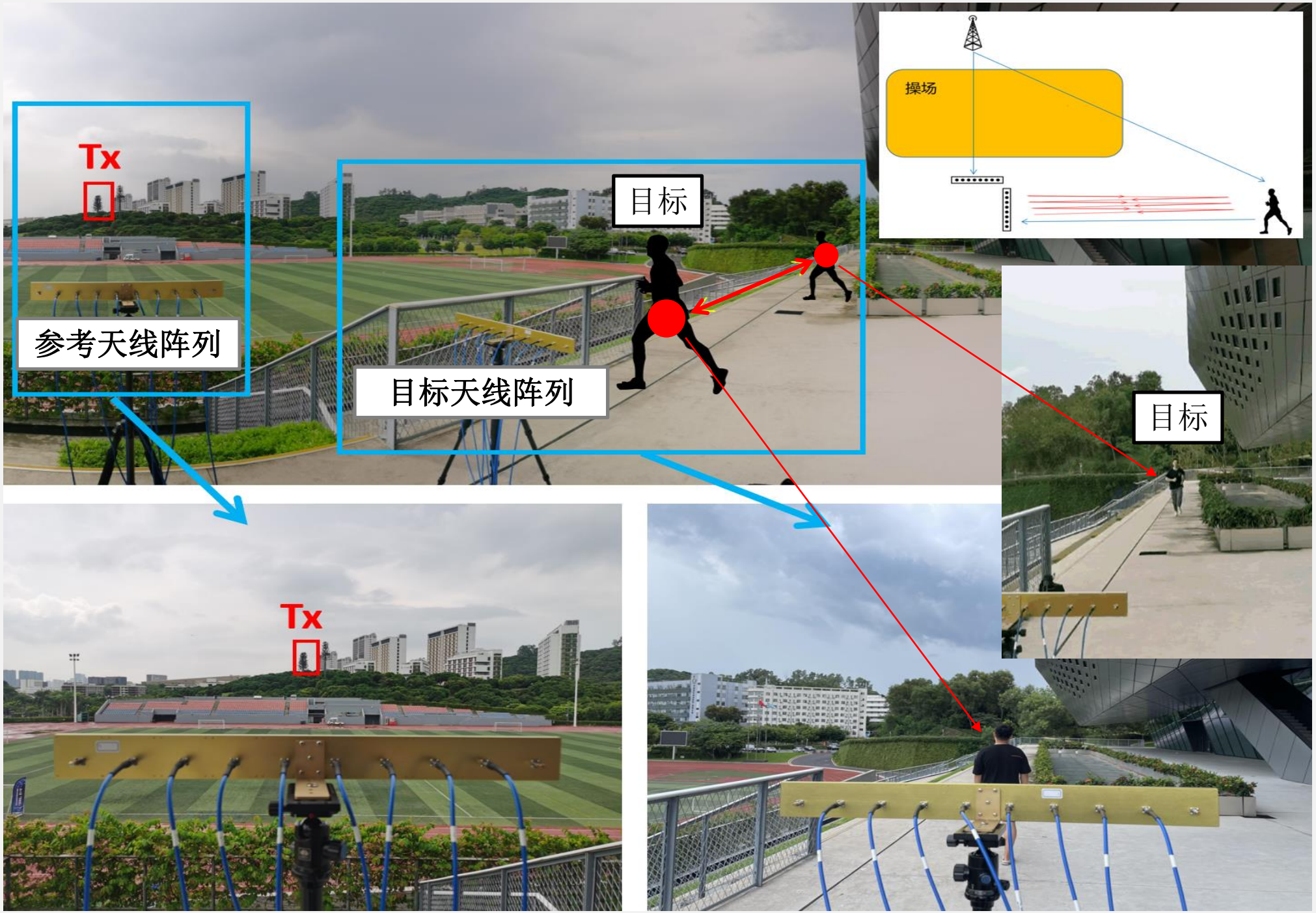
- 定义模糊函数，

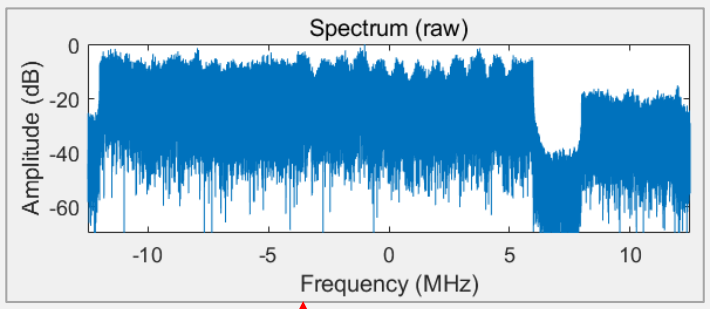
$$Cor(c,d) = \int_t^{t+T} y_{sur}(t+c)y_{ref}^*(t)e^{-j2\pi dt}\,dt$$

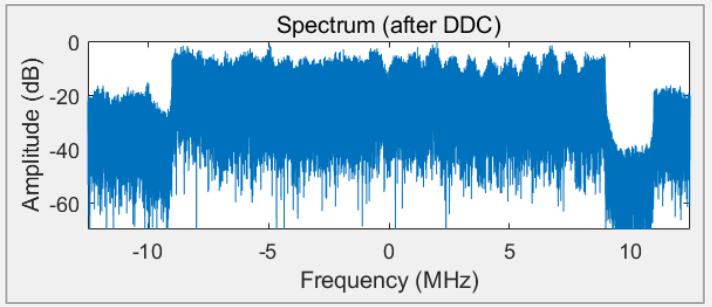
- 估计时延差和多普勒频移 $(\tau, f)$:

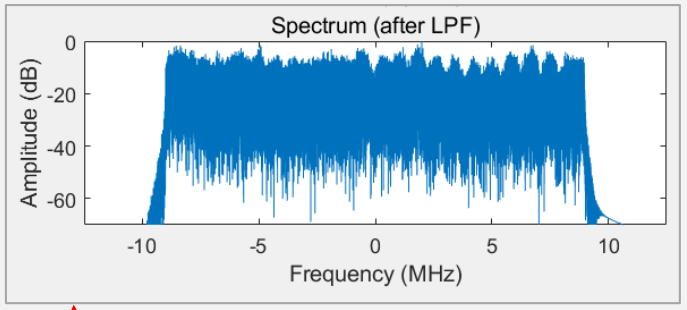
$$(\hat{\tau}, \hat{f}) = \arg\max_{c,d} Cor(c,d)$$




Tx
参考天线阵列
目标
目标天线阵列
操场
目标
Tx




Read data

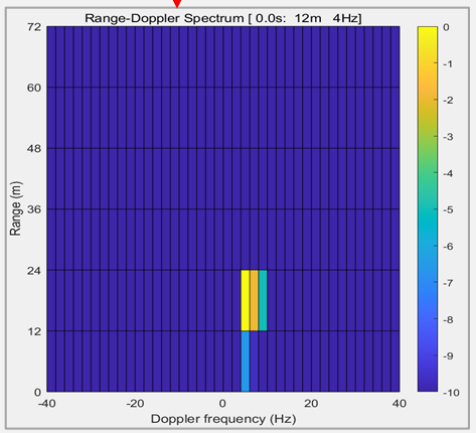
Digital Down Convert

Low-Pass Filtering

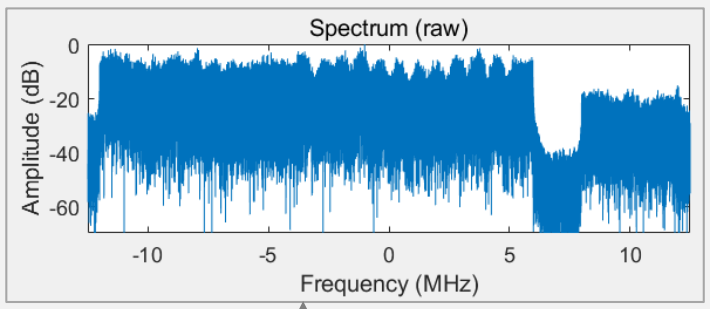
Ambiguity Function Process

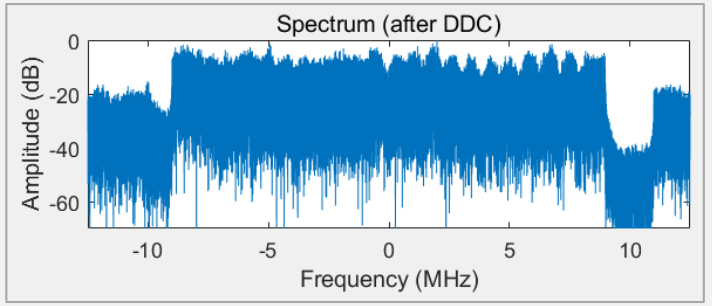
Plot Spectrum

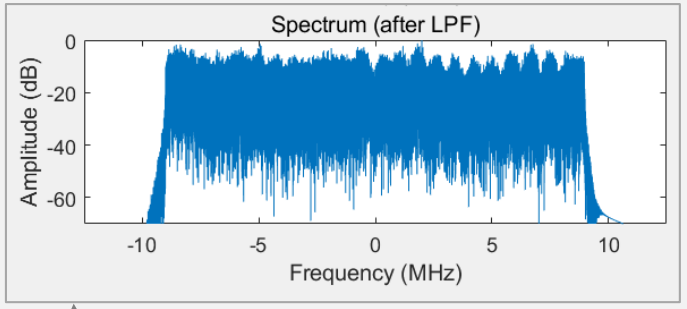
Sliding window




① 接收2110-2130MHz和2130-2135MHz两个频段的基带信号。
② 在信号处理前，需要滤除2130-2135MHz(5M带宽)的基站信号，保留2110-2130MHz(20M带宽)的信号。
③ 将2110-2130MHz(20M带宽)信号变频到零中频，再通过低通滤波器滤掉高频信号。

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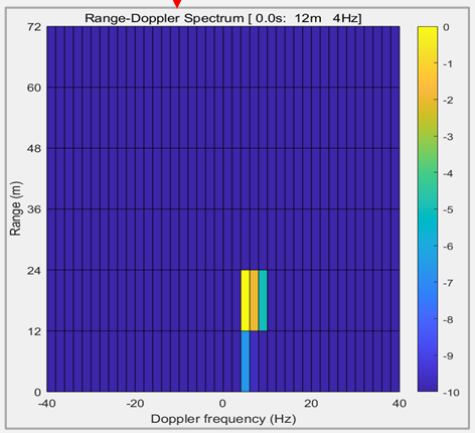


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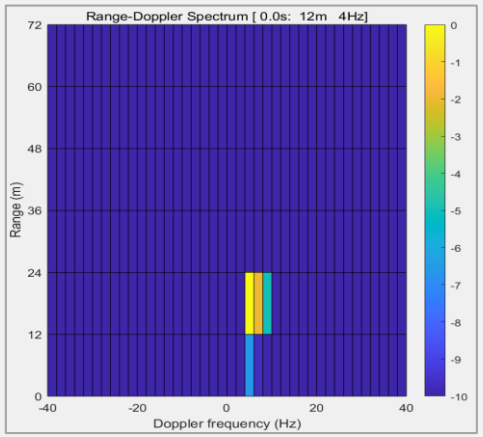
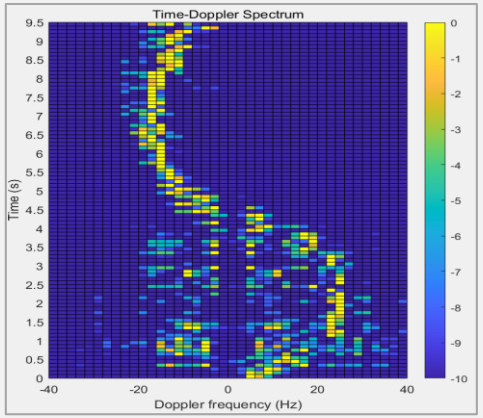
- 在两路接受信号中取$[t, t+T]$时间内的片段进行模糊函数计算，通过遍历所有可能的$(c, d)$求模糊函数值，选取最大值对应的$(c, d)$作为估计值。

$$\boldsymbol{Cor(c,d,}\mathrm{t}\boldsymbol{)} = \int_{\boldsymbol{t}}^{\boldsymbol{t+T}} \boldsymbol{y}_{\mathrm{sur}}(\boldsymbol{t}+\boldsymbol{c})\boldsymbol{y}_{\mathrm{ref}}^{*}(\boldsymbol{t})\boldsymbol{e}^{-\boldsymbol{j2\pi d t}}\boldsymbol{dt}$$

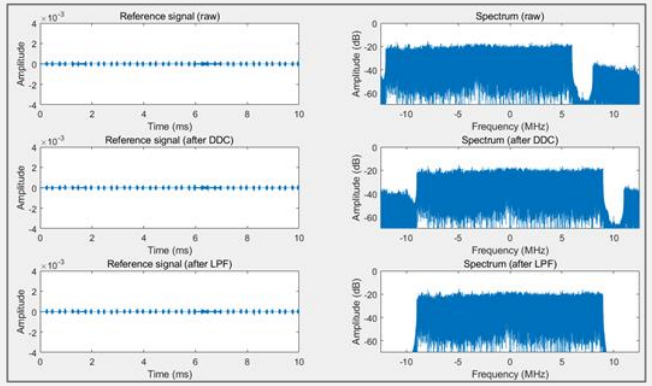
$$\boldsymbol{g(d,t)} = \max_{c} |Cor(c,d,\boldsymbol{t})|$$

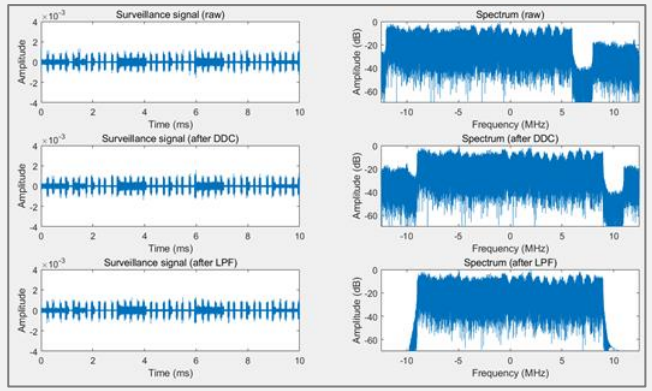



- 将$\boldsymbol{g(d,t)}$向量化为$\hat{\boldsymbol{g}}(\boldsymbol{t})$，绘制出$\hat{\boldsymbol{g}}(\boldsymbol{t})$随时间的变化关系

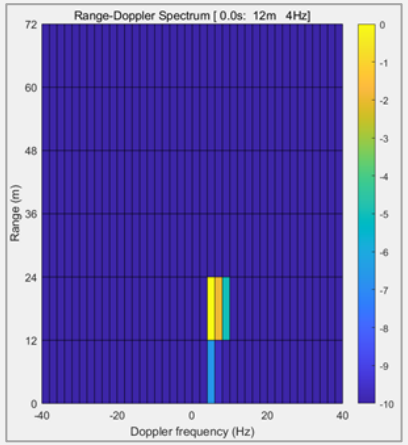


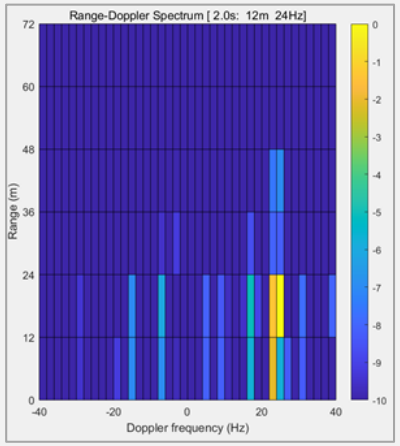
（1）参考信号和监测信号的原始、变频后、低通滤波后的信号时域波形和频谱：

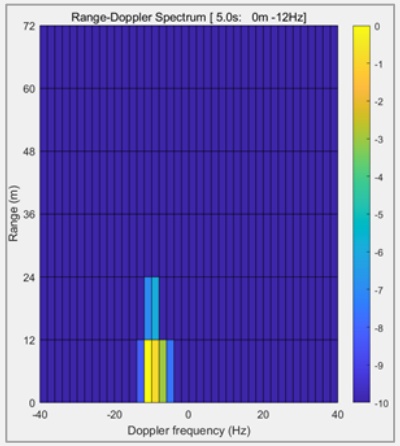


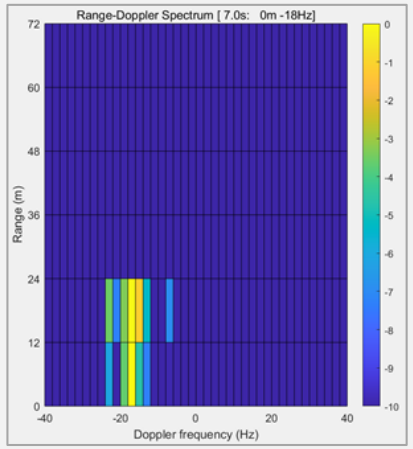




（2）0-0.5s、2-2.5s、5-5.5s、7-7.5s信号处理后得到的距离-多普勒谱：

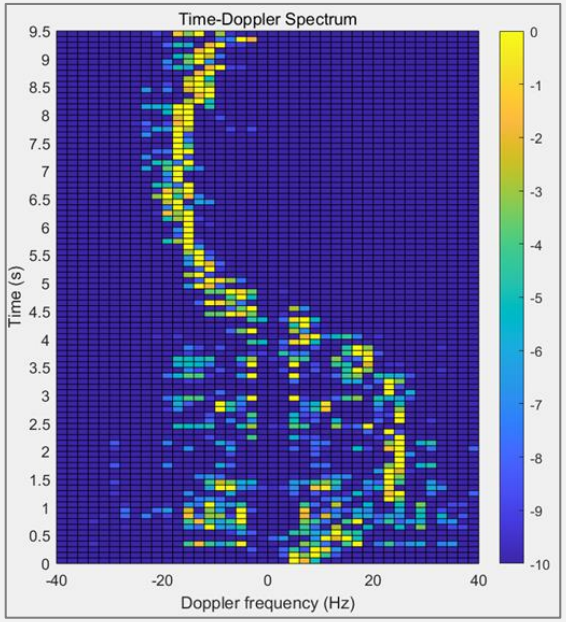



（3）以CIT=0.5s为滑动窗口每次滑动0.5s处理得到的10s数据的多普勒-时间谱：



# Passive Radar Tutorial

Heiner Kuschel, Diego Cristallini, Fraunhofer, Germany
Karl Erik Olsen, Norwegian Defence Research Establishment, Norway

**Passive Radar signifying the localisation of a target by radar measurements without using own controlled emissions has been discussed, tried, reinvented, and matured within the last 80 years. Its advantages, like covert operation and saving the costs of a transmitter, are obvious. Military as well as civilian interests combined with the advances in technological developments have recently boosted research on passive radar and passive radar systems are currently approaching the market. This tutorial shall give an overview of the history, development, and processing in passive radar and enable the interested reader to further investigate the subject exploiting the presented material together with the cited references.**

## I. INTRODUCTION

Passive Coherent Location (PCL) systems have received significant interest in the academic and military communities. Since the end of World War II the interest in bistatic radars has been cyclic, with a periodicity of 15 to 20 years [1, Preface]. The most successful bistatic radar application since the mid-40s is the semiactive homing missiles. Interest in PCL is currently at a lasting peak, mainly due to rapidly emerging technology which has matured enough for the military to see PCL as a potential sensor for surveillance.

The attractive features of passive radar from a military point

ted waveforms of such transmitters of opportunity are normally not optimised for radar purposes, the receiver structure and receiver processing have to be specifically tailored to exploit such waveforms. Omnidirectional surveillance often requires multichannel array antennas of circular geometry spanning a relatively large bandwidth. Receiver channels in the in the UHF-region and below allow digitization of the received signals close to the antenna elements and features software defined radar where all the processing happens in the digital domain. This leaves the Analog-Digital (AD) converter as the decisive element. Powerful Central Processing Units (CPUs) and even Graphics Processing Units (GPUs) are available today to support the required radar processing (e.g., cross-correlation, beam forming, direct signal suppression, and direct signal reconstruction in the case of digital waveforms).

Such advanced signal processing approaches have been reported in the literature and at conferences in increasing numbers in recent years, and indicate that the main driver for most research and development has been the military air surveillance application. However, niche applications have also been addressed in the civilian world, taking advantage of the already available illuminations and thus avoiding further cluttering of the spectrum.

### A. STRUCTURE OF THE TUTORIAL

# Organization

- **Each group consists of four students.**
- **Each group need present the two Lab projects (submit reports for both projects):**
  - The presentation date
  - **Each presentation is 10 minutes (including Q & A)**
  - All team members need to contribute to the presentation.
  - Presentation in English (recommended) or Chinese.

# The presentation should...

- **Introduce**
  - team
  - objective of the project
  - background review (search more additional information)
  - methodology
- **Discuss**
  - what you have learned from this study?
  - problems during this project and your solution
  - investigation beyond project tasks
  - critical thinking
- **Present**
  - relevant data, figure, etc.
  - the results for project tasks (e.g., with demo, Figure, etc.)
  - interpretation of project findings
- Appendix (if any)
- Team effort (e.g., individual contribution)
- Reference
- Q & A (answer questions raised from audience)

- Question ?