Civil UAV monitoring techniques

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01 INTRODUCTION TO UAV

01 INTRODUCTION TO UAV

- UAV , commonly known as a **drone.**
- An aircraft without a human pilot aboard.
- The plane which utilizes remote radio control equipment and program control device to fly.

01 INTRODUCTION TO UAV

Main body

Remote control device

Aerial camera

Energy device

01 INTRODUCTION TO UAV

Interim Regulations on the management of unmanned aerial vehicles
The National Space Administration Committee

(1)Micro-UAVs

empty weight<0.25kg altitude<50m speed<40km/h

(2)Light-UAVs

empty weight<4kg takeoff weight<7kg altitude<120m speed<100km/h

(3)Small-size UAVs

empty weight<15kg takeoff weight<25kg

(4)Medium-sized UAVs

empty weight>15kg takeoff weight<150kg

(5)Large-sized UAVs

takeoff weight>150kg

01 INTRODUCTION TO UAV

Characteristics of drone

- **Low altitude**

About 2km in theory, less than 120m in general;

- **Low speed**

Nearly 15-100km/h for consumer use;

- **Small size**

Generally belong to Light UAV (<7kg);

Simple to operate; Easy to purchase;
Hard to discover; Difficult to administrate;

- Light housing material made of plastic and carbon fiber
- Wingspan ranges between 0.2m-1.3m
- Frequency bands 2.4GHz/5.8GHz/GPS
- FHSS/WIFI/Bluetooth/ Automatic Navigation / Remote Control etc.

01 INTRODUCTION TO UAV

Threaten national security

Engage in criminal acts

Threaten flight safety

It’s imperative to study the method of drone countermeasure.

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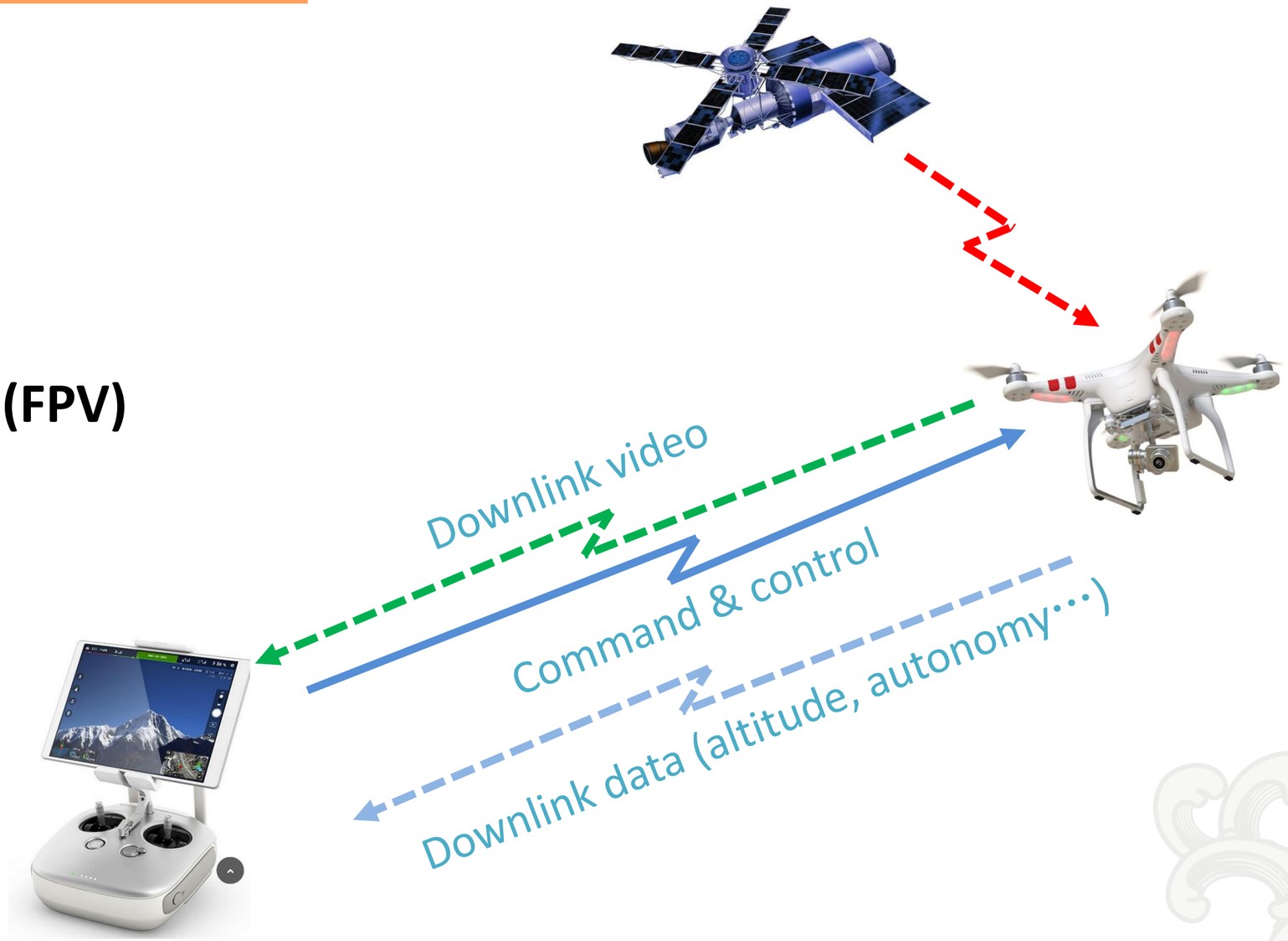
02 TECHNICAL CHARACTERISTICS

02 TECHNICAL CHARACTERUSTICS

Modes of operation

- ✓ **Signal control**
- ✓ **First person view (FPV)**
- ✓ **Autonomous**



02 TECHNICAL CHARACTERUSTICS

Technical Parameter

Signal	Frequency band	Modulation
Command & control	27MHz、35MHz、40MHz、72MHz、328～352MHz、400MHz、433MHz、560～760MHz、915MHz、933MHz、1.2GHz、2.4GHz、5.8GHz **（more than 90% use 2.4GHz and 5.8GHz）**	FHSS、DSSS、WiFi、Bluetooth
Downlink data (altitude, autonomy…)	Same with Command & control signal	Same with Command & control signal
Downlink Video	433MHz、328～334MHz、1.2GHz、2.4GHz、5.8GHz **（more than 90% use 2.4GHz and 5.8GHz）**	WiFi、analog PAL/NTSC、PSK、OFDM

02 TECHNICAL CHARACTERUSTICS

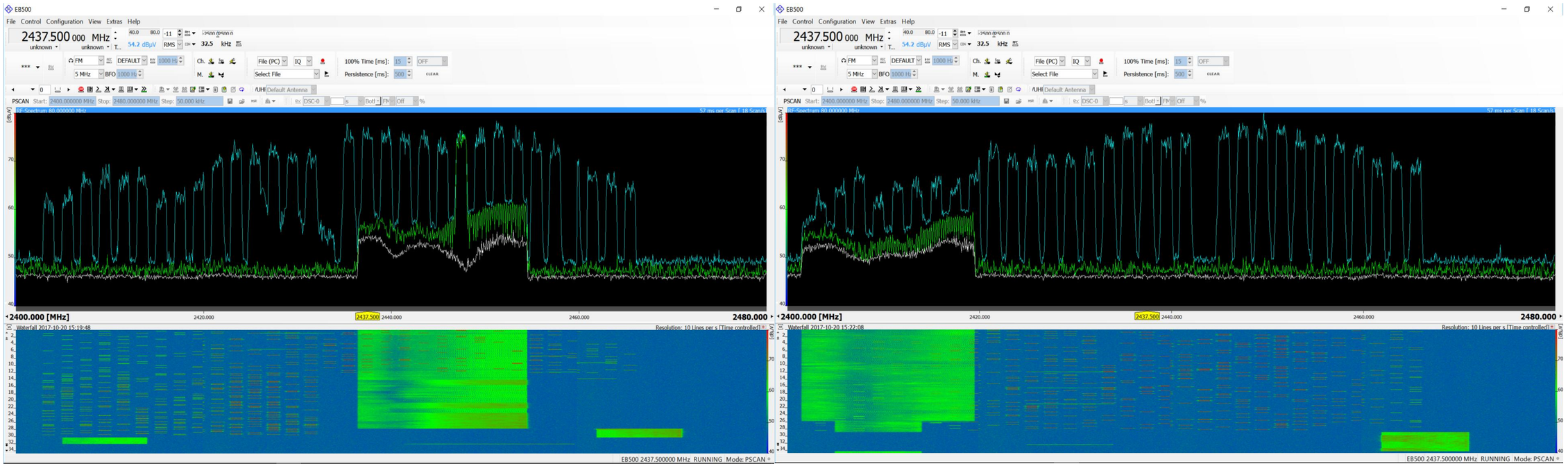
Technical Parameter

Satellite navigation	Band	Frequency
GPS	L1	1575.42MHz±12MHz
GPS	L2	1227.60MHz±12MHz
GPS	L5	1176.45MHz±12MHz
GLONASS	L1	1602MHz+k*0.5625MHz
GLONASS	L2	1246MHz+k*0.4375MHz
BeiDou-2	L1	1561.098MHz±2.046MHz
BeiDou-2	L2	1207.14MHz±10.23MHz
BeiDou-2	L3	1268.52MHz±10.23MHz

02 TECHNICAL CHARACTERUSTICS

Signal analysis

(1) DJI MAVIC

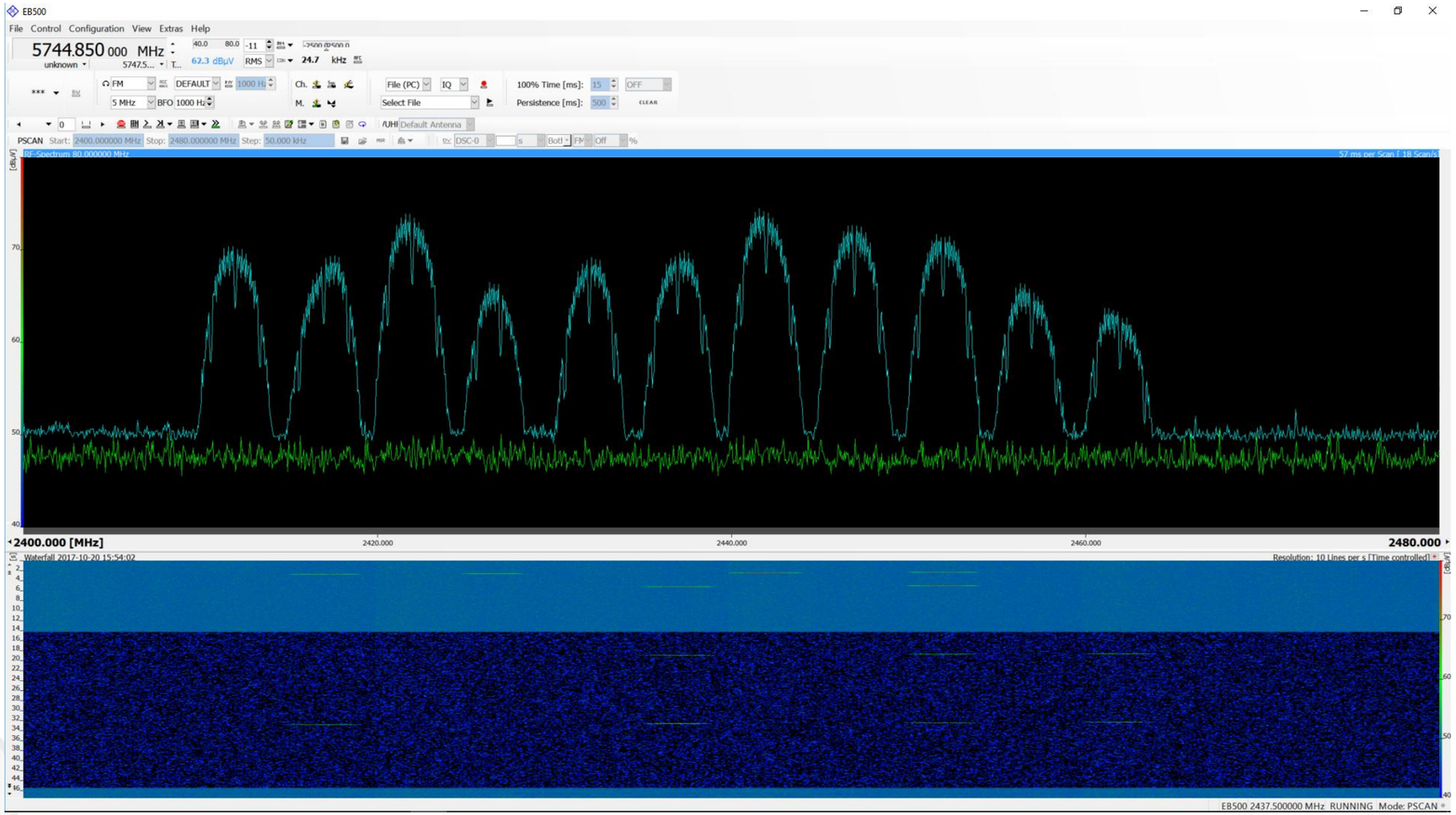


Frequency Band:2.4GHz ISM (Industrial, Scientific and Medical) Band
Command & control : FHSS/DSSS systems (1.4MHz, 2400MHz-2470MHz)
Downlink video: 20MHz, unfixed, QPSK/16QAM/64QAM

02 TECHNICAL CHARACTERUSTICS

Signal analysis

(2) DJI Phantom 3SE



When building a link between remote control and UAV

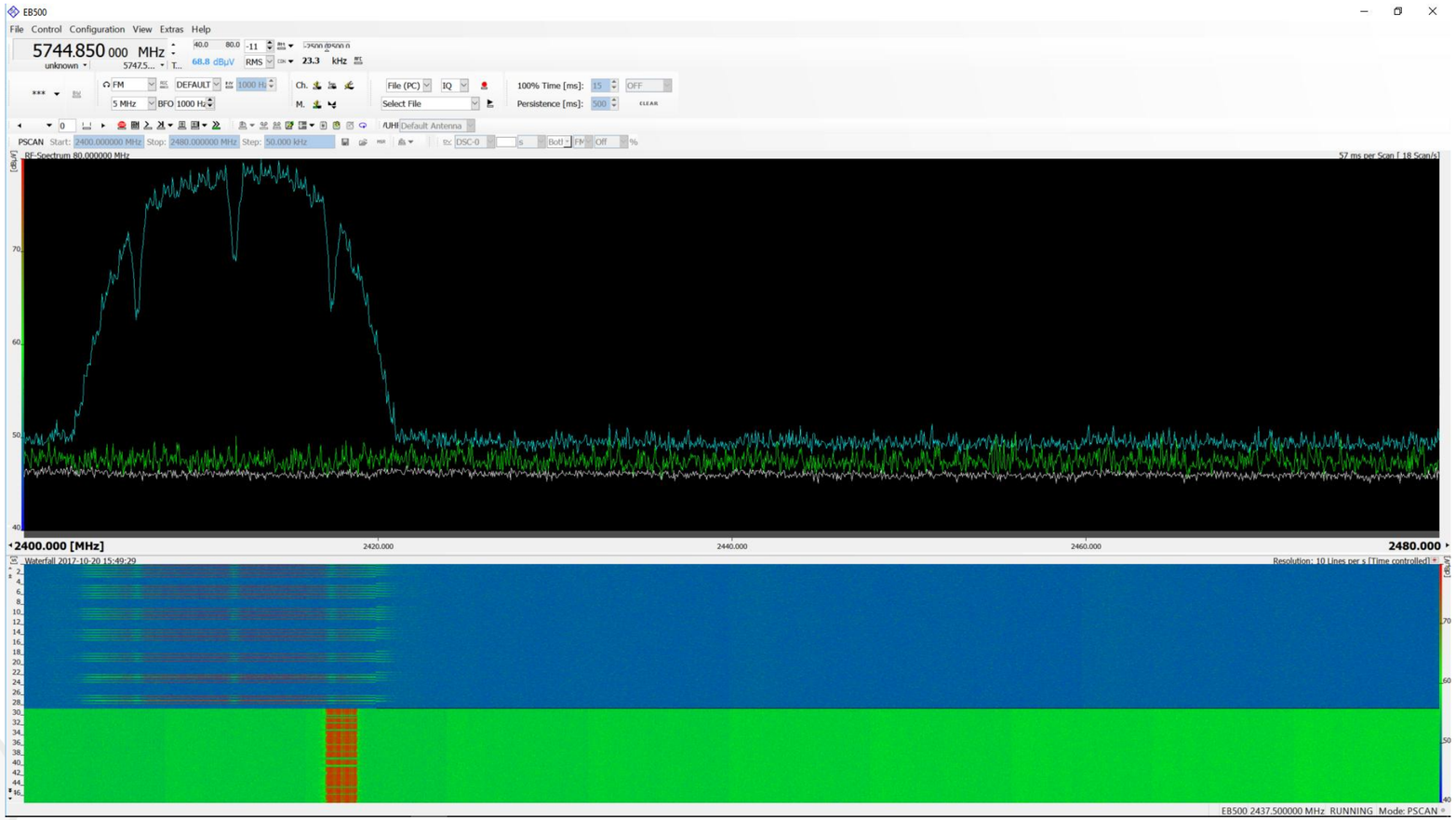
Frequency Band: 2.4GHz/5.8GHz Band

Command & control : FHSS/DSSS systems (5MHz)

02 TECHNICAL CHARACTERUSTICS

Signal analysis

(2) DJI Phantom 3SE



Flight phase

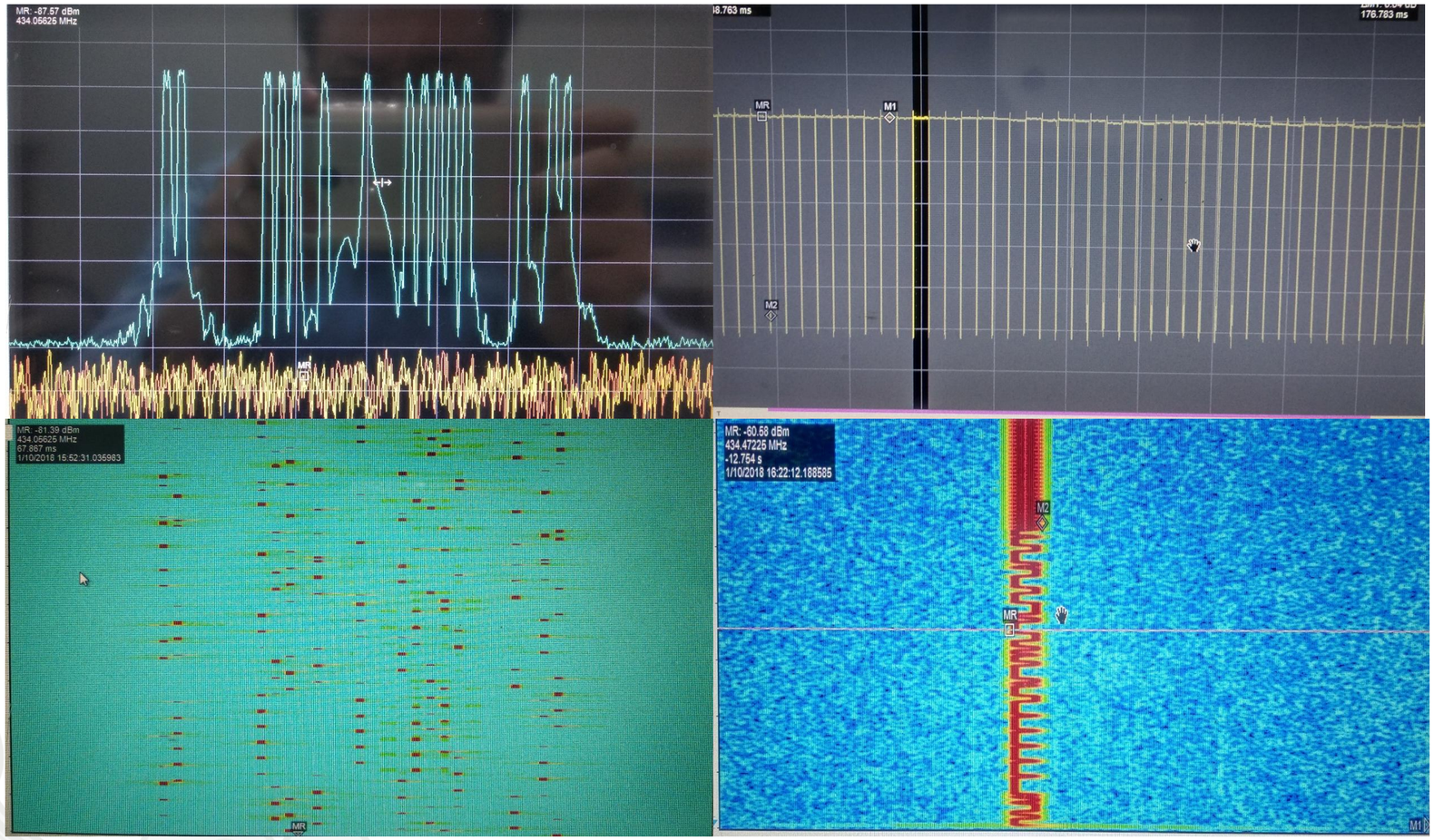
Frequency Band:
2.4GHz/5.8GHz Band

Command & control :
Wifi systems (20MHz)

02 TECHNICAL CHARACTERUSTICS

Signal analysis

(3) Futaba 433MHz



Center Frequency: 434.5MHz

Bandwidth: 3MHz

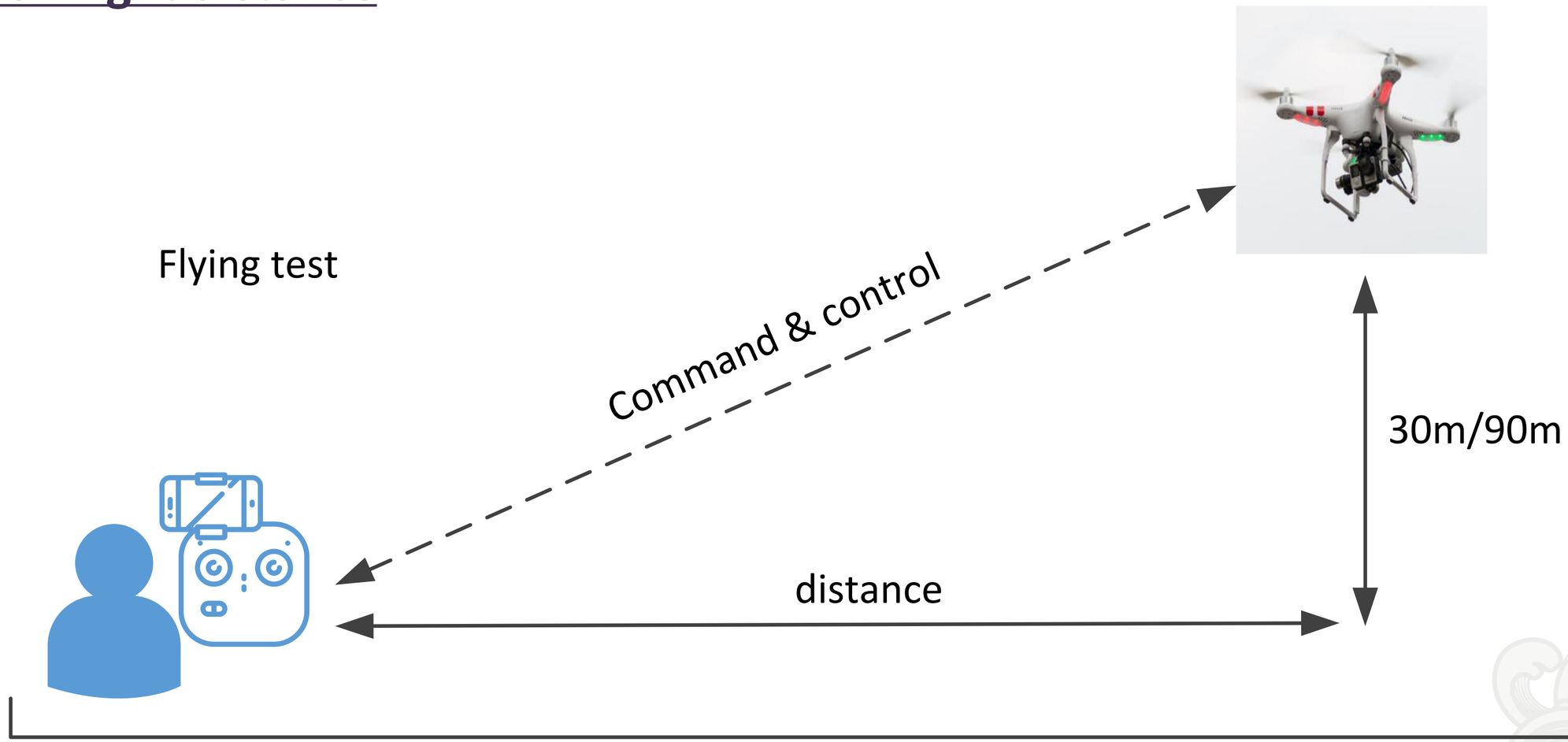
Modulation type: FSK (50KHz)

Number of carrier frequency: 15

Duration of one “hop”: 20ms

02 TECHNICAL CHARACTERUSTICS

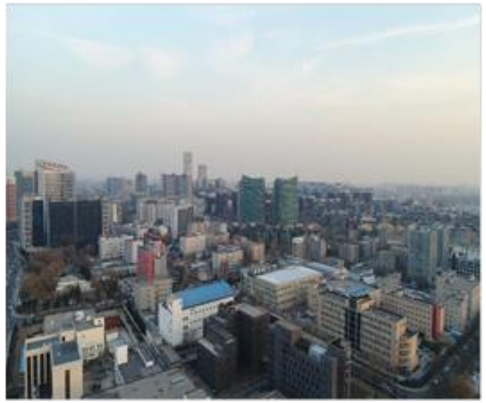
Test of flight distance



02 TECHNICAL CHARACTERUSTICS

Test of flight distance

实验场景
北京市丰台区世界公园



Urban

实验场景1
北京市大兴区生物医药基地

实验场景2
深圳市南山区大沙河道旁

Suburbs

实验场景1
北京市大兴区北京监测站

实验场景2
深圳市深圳湾婚庆公园

Open area

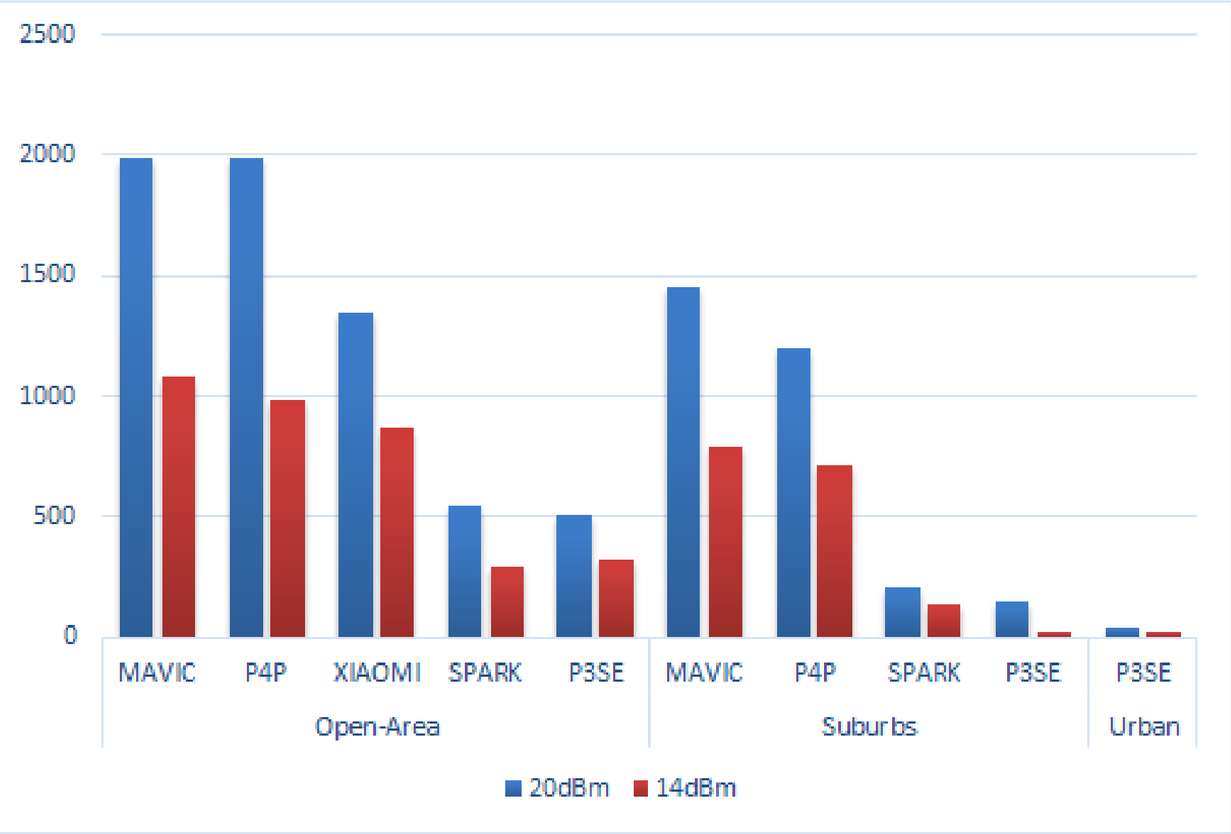
02 TECHNICAL CHARACTERUSTICS

Test of flight distance

	Model	Power(mW)	Frequency band	Modulation type
1	DJI MAVIC	100	2.4G	FHSS&DSSS
2	Mi 1080P	100	2.4G	FHSS&DSSS
3	Mi 4K	200	5.8G	FHSS&DSSS
4	DJI P4P	100	2.4G& 5.8G	FHSS&DSSS
5	DJI SPARK	100	2.4G & 5.8G	Wi-Fi
6	DJI P3S	100	2.4G	Wi-Fi
7	DJI P3SE	100	2.4G& 5.8G	Wi-Fi
8	XIRO Dobby	100	2.4G	Bluetooth

02 TECHNICAL CHARACTERUSTICS

Test of flight distance



- The greater power of the UAV, the farther the UAVs fly.
- $L_{FHSS/DSSS} > L_{WIFI}$
- The maximum flight distance will be double under ideal circumstance, if the power increase 6dB.
- The maximum flight distance in different scenarios is largely different.

02 TECHNICAL CHARACTERUSTICS

Radio Controlled via FHSS/DSSS

- **Wide spread (>80%)**
- Range: 1-3 km
- Wi-Fi is often used for the video downlink
- DJI MAVIC/DJI P4P/Mi 1080P/Mi 4K

Radio Controlled via Wi-Fi

- Range: 100m – 1km
- Some are equipped with a FPV
- DJI P3S/DJI P3SE/DJI SPARK

Radio Controlled via Bluetooth

- Low cost models
- Limited range with approx. 100 m
- XIRO Dobby

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03 DRONE COUNTERMEASURE

03 DRONE COUNTERMEASURE

Offline Countermeasure

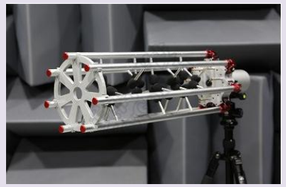
Detect the drone:
Sound/Optical/Low-altitude radar/Radio
Control the drone:
Radio Suppression/Laser Gun Attack/Physics Catch

Online Countermeasure

For connected drone, obtain the comprehensive situation and control them remotely.

03 DRONE COUNTERMEASURE

Offline Detection: No perfect method

Methods	Ranges	Advantages	Disadvantages	
Sound detection	≤300m	Simple, Low cost, Certain abilities of identification and location	Short detection range, Sensitive to meteorological condition and environmental noise	
Optical detection	≥3km	Low cost, Widely used, Less clutter impacts, Certain abilities of identification, Able to conduct with optic tracking	Less effective of visible light imaging device in night, Less angle of view, Weather-sensitive	
Low-altitude radar	≥4km	All-weather, Fast identification, Long detection range, Multi-target tracking	Existing blind zone at close range, Hard to discover the target with small RCS, Apply to flat site	
Radio detection	≥3km	All-weather, Capable of direction-finding location, Easy to install and deploy	Complex electromagnetic environment, Mediocre reliability, Unable to find inertial navigation drone	

03 DRONE COUNTERMEASURE

Offline Control: radio suppression is more popular

Technologies	Advantages	Disadvantages	
Radio Suppression	Convenience; Moderate cost; Significantly effective ；	Link suppression subject to usage mode; Navigation suppression and deceit subject to application scenarios;	
Laser Gun Attack	War industry use; Directly destroy;	More dangerous ; More secondary disaster;	
Physics Catch	Less secondary disaster;	Lack of operability;	

03 DRONE COUNTERMEASURE

Offline Control: radio suppression is more popular

Mode		Effect	Operating Range	Advantages / Disadvantage
Radio Suppression	Command & control	Autonomous Homing	<3km	Long usable distance Can not work under radio silence
	Satellite navigation signal	out of control	3-4km	Long usable distance application fields are limited
Deceptive Suppression	Satellite navigation signal	vertical landing	2-3km	No effect on other frequency band application fields are limited
		fly to opposite direction		
	Command & control	Take over the UAV	<2km	Control the UAV high technical difficulty

03 DRONE COUNTERMEASURE

Online Control

- Adopt the thought of ‘internet+’ to install communication modules on drone, back haul to the integrated control platform via public mobile network.
- Acquire the integrated flight condition in real time online
- Support remote control of drone in specific context

Multi-terminal synchronization

Manage and monitor drone via computer and phone whenever and wherever

Report flight data in real time

Automatically warning based on date in no-fly zone combined with electronic fence monitoring

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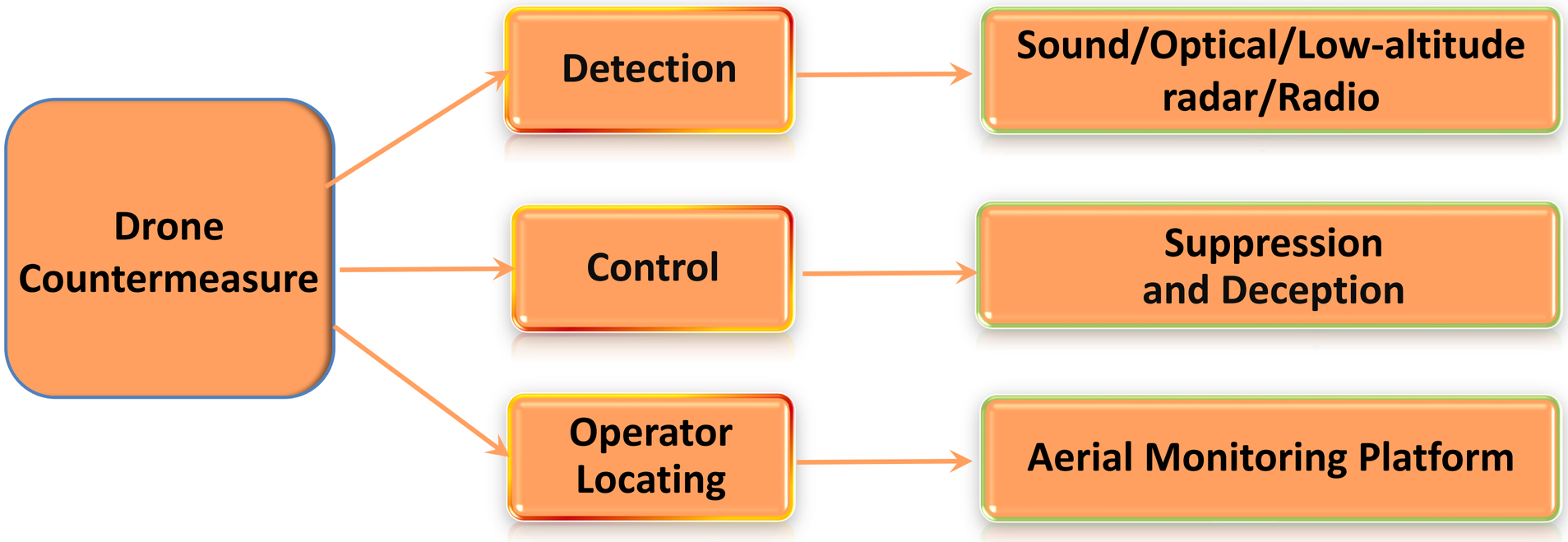
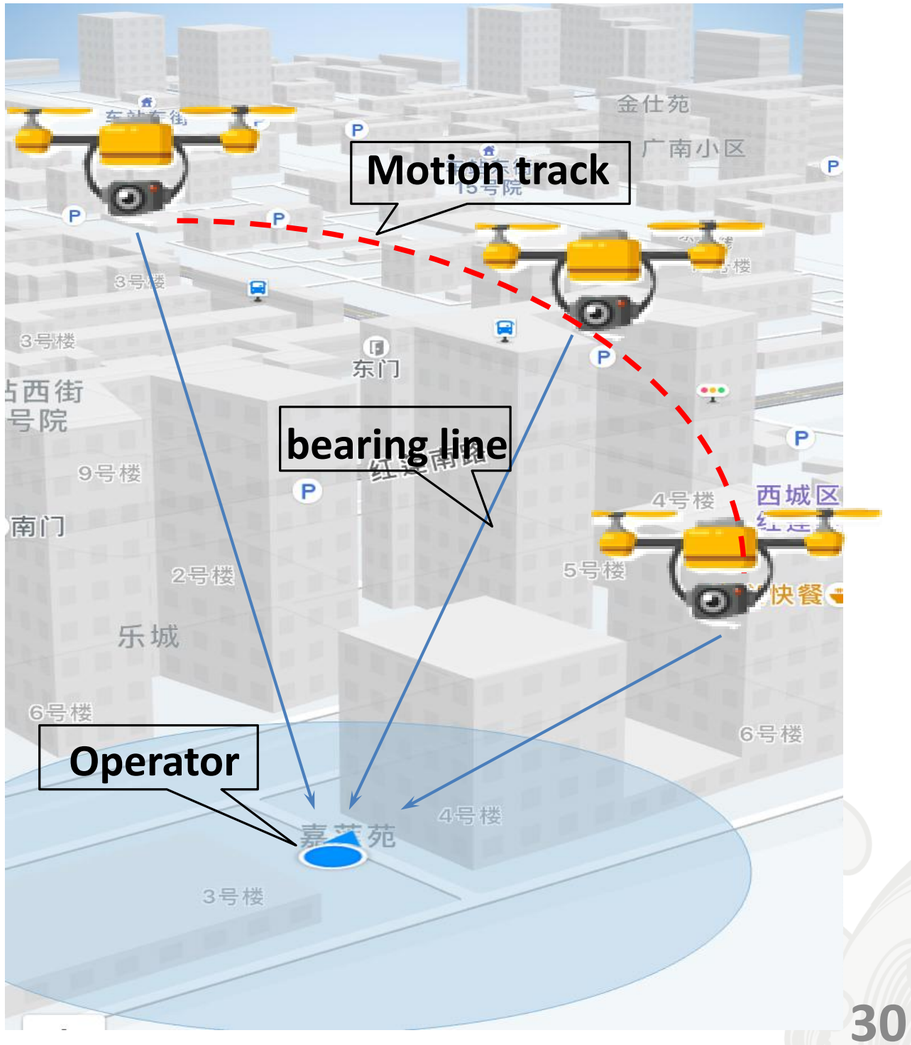
04 OPERATOR LOCATING BASED ON AERIAL MONITORING PLATFORM

04 OPERATOR LOCATING



04 OPERATOR LOCATING

- **Advantages:**
  - **Accurate Location**
    - Reducing impact of NLOS and Multipath for surficial device, do accurate location in complicated city situation.
  - **Highly Maneuverability**
    - Replace direction finding location by multi-stations to by just a set of monitoring system.
  - **Low Price**
    - The cost is far below existing monitoring devices.

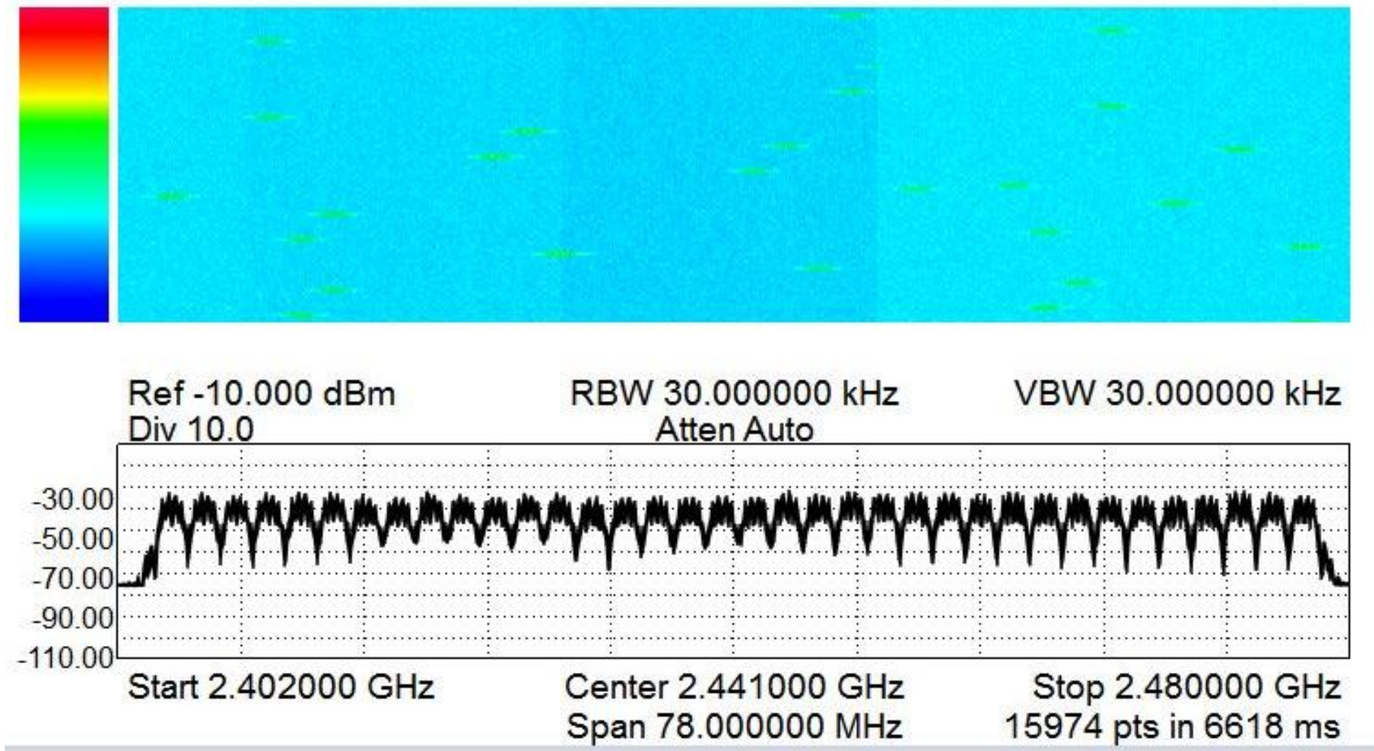


04 OPERATOR LOCATING

Innovation 1

Proposed a Fast Acquisition Algorithm of frequency hopping signals.

Improve the direction finding accuracy of frequency-hopping signal in low SNR and complex interference condition.



Frequency-hopping signal on remote control spectrogram

04 OPERATOR LOCATING

Innovation 2

Proposed an Nonlinear optimization location algorithm based on particle filter.

Improve the Location precision of frequency-hopping signal because of the DF error.

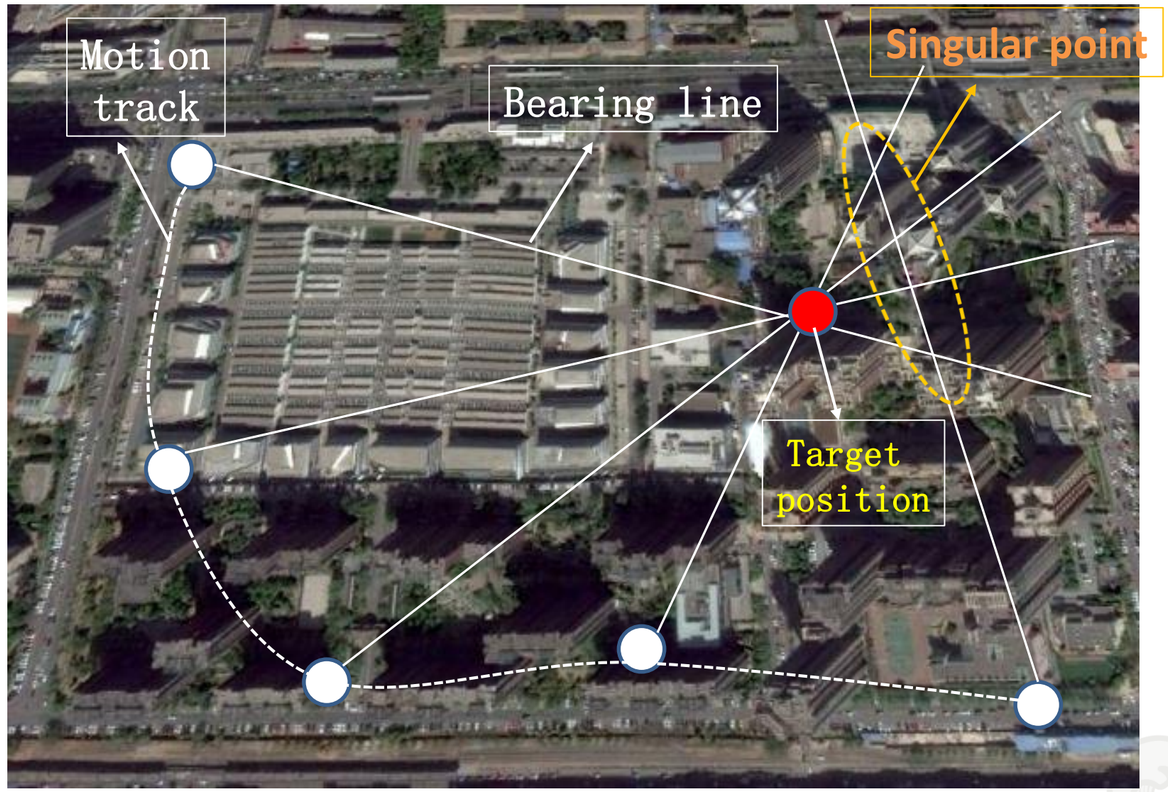


Diagram of location operator

04 OPERATOR LOCATING

Application Innovation

Developed an UAV operator locating system based on aerial monitoring platform.

Eliminated the influence of ground occlusion on the performance of traditional monitoring and locating system.

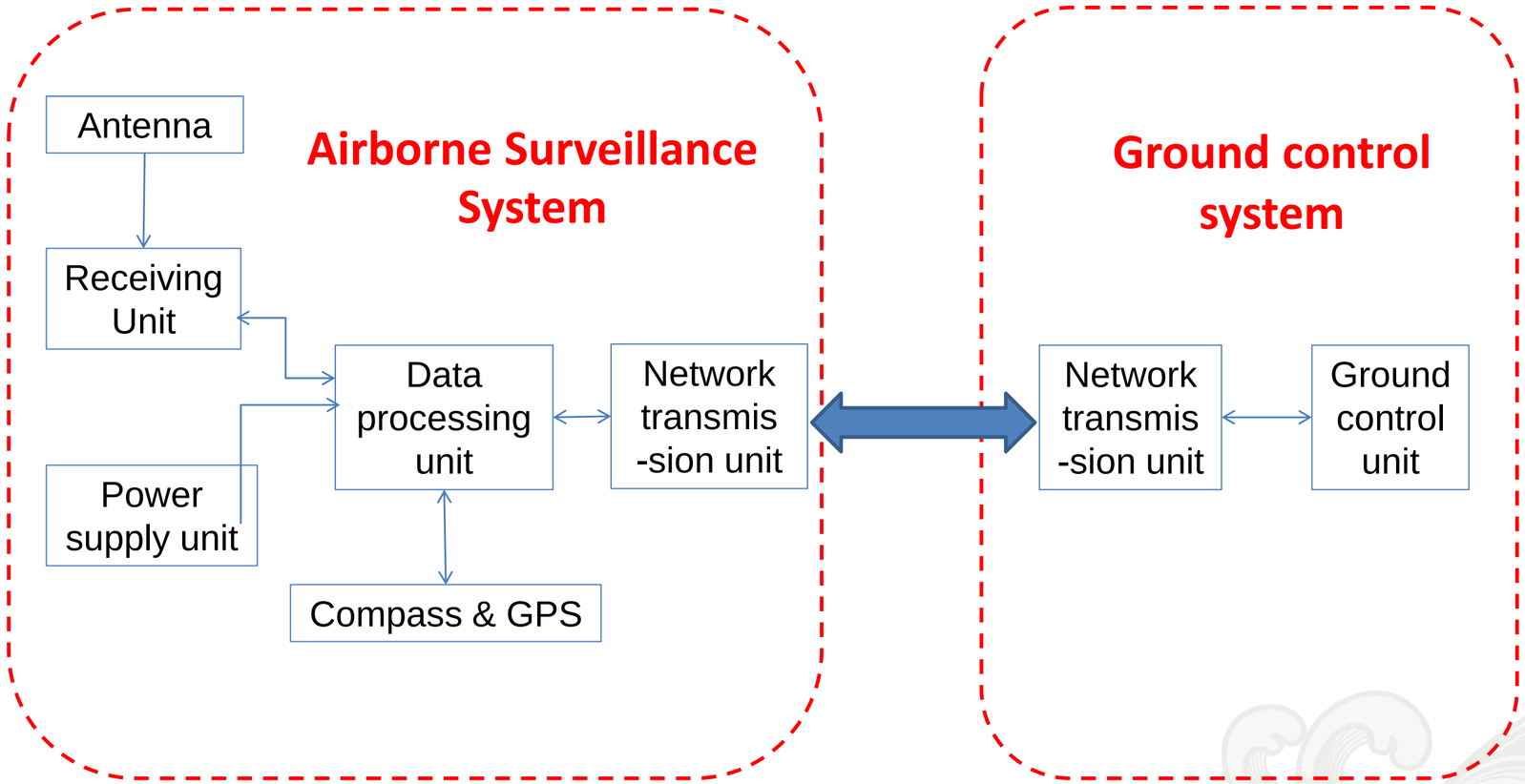


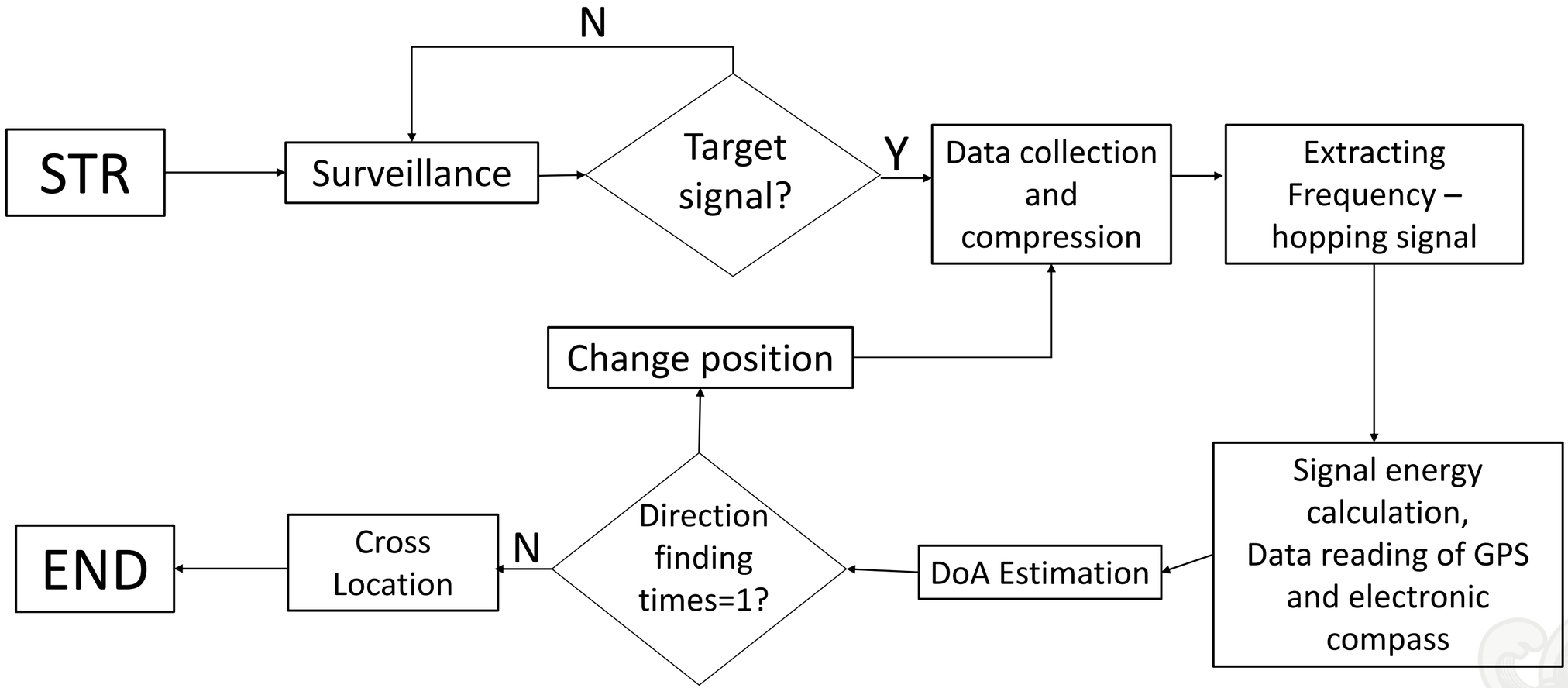
Diagram of platform structure frame

04 OPERATOR LOCATING

Key equipment of hardware system in aerial monitoring platform

1. **Using UAV as the main body of monitoring platform, remote control frequency 433MHz ;**
2. **Customized 2.4GHz high gain directional receiving antenna ;**
3. **Using miniaturized, high-performance receiving and computing modules to realize data acquisition and analysis processing functions;**
4. **Customized 3D electronic compass and high precision GPS to achieve high precision measurement of angle and position ;**
5. **Using 5.8GHz wireless transmission system to realize remote control.**

04 OPERATOR LOCATING



flow diagram of location

04 OPERATOR LOCATING

physical of UAV

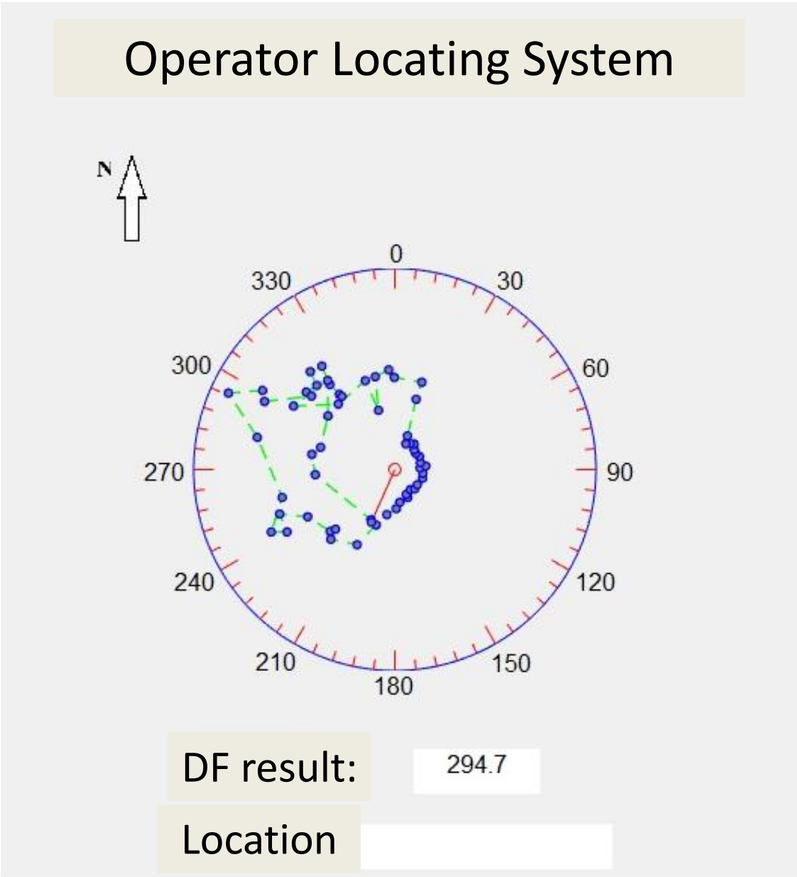
UVA in the sky

04 OPERATOR LOCATING

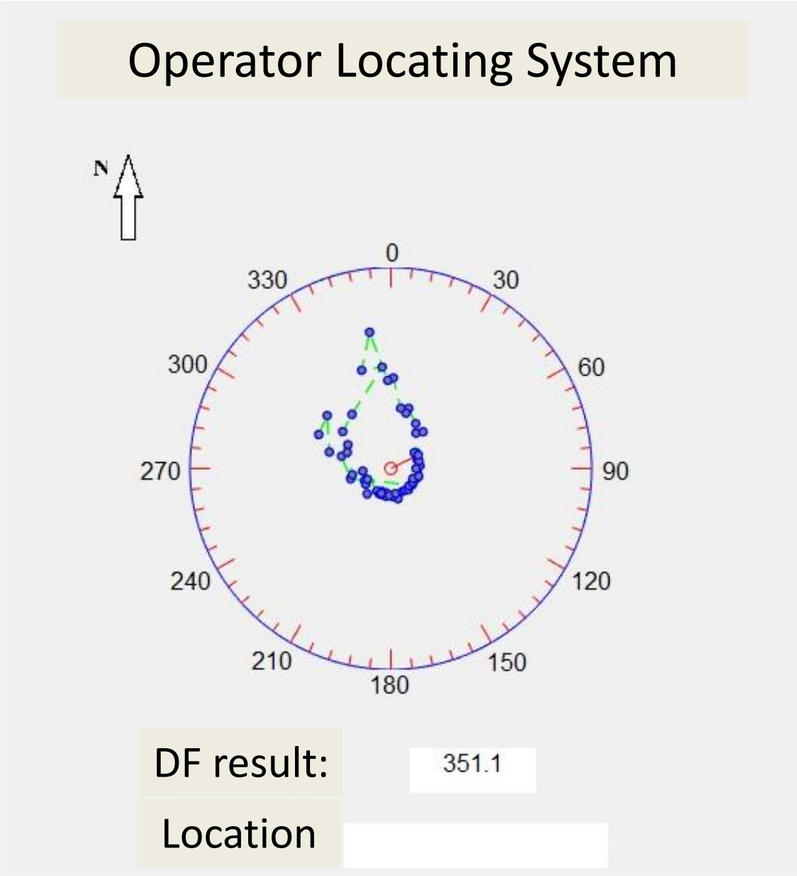
Civil UAV Monitoring Technology Seminar and Equipment Exhibition

04 OPERATOR LOCATING

Demonstration：The DF results of a "black flying" operator for a particular UAV



The DF result to Position 1



The DF result to Position 2

04 OPERATOR LOCATING

Location result

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05 SUMMARY

Summary

- It’s imperative to study the method of drone countermeasure, because UAVs can threaten airspace security, threaten national security, etc.
- > 90% are operating in the 2.4 GHz & 5.8 GHz ISM band using Bluetooth, FHSS/DSSS or Wi-Fi
- 433 MHz is a frequency still in use (rarely), helping to overcome longer distances compared to 2.4 GHz
- Video data are normally streamed on 2.4 GHz & 5.8 GHz (ISM)
- Detect the drone: Sound, Optical, Low-altitude radar, Radio
- Control the drone： Radio Suppression, Laser Gun Attack, Physics Catch
- For connected drone, obtain the comprehensive situation and control them remotely via online Platform.
- Operator locating system has three advantages, accurate location, highly maneuverability and low price

Thanks