Civil UAV monitoring techniques

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01 INTRODUCTION TO UAV
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.
INTRODUCTION TO UAV

Main body

Remote control device

Aerial camera

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

1. **Micro-UAVs**
   - Empty weight: < 0.25 kg
   - Altitude: < 50 m
   - Speed: < 40 km/h

2. **Light-UAVs**
   - Empty weight: < 4 kg
   - Takeoff weight: < 7 kg
   - Altitude: < 120 m
   - Speed: < 100 km/h

3. **Small-size UAVs**
   - Empty weight: < 15 kg
   - Takeoff weight: < 25 kg

4. **Medium-sized UAVs**
   - Empty weight: > 15 kg
   - Takeoff weight: < 150 kg

5. **Large-sized UAVs**
   - Takeoff weight: > 150 kg
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.
It’s imperative to study the method of drone countermeasure.
02 TECHNICAL CHARACTERISTICS
Modes of operation

✓ Signal control
✓ First person view (FPV)
✓ Autonomous
## Technical Parameter

<table>
<thead>
<tr>
<th>Signal</th>
<th>Frequency band</th>
<th>Modulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command &amp; control</td>
<td>27MHz, 35MHz, 40MHz, 72MHz, 328 ~ 352MHz, 400MHz, 433MHz, 560 ~ 760MHz, 915MHz, 933MHz, 1.2GHz, 2.4GHz, 5.8GHz</td>
<td>FHSS, DSSS, WiFi, Bluetooth</td>
</tr>
<tr>
<td>( more than 90% use 2.4GHz and 5.8GHz )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Downlink data (altitude, autonomy...)</td>
<td>Same with Command &amp; control signal</td>
<td>Same with Command &amp; control signal</td>
</tr>
<tr>
<td>Downlink Video</td>
<td>433MHz, 328 ~ 334MHz, 1.2GHz, 2.4GHz, 5.8GHz</td>
<td>WiFi, analog PAL/NTSC, PSK, OFDM</td>
</tr>
<tr>
<td>( more than 90% use 2.4GHz and 5.8GHz )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Technical Parameter

<table>
<thead>
<tr>
<th>Satellite navigation</th>
<th>Band</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
<td>L1</td>
<td>1575.42MHz ± 12MHz</td>
</tr>
<tr>
<td>GPS</td>
<td>L2</td>
<td>1227.60MHz ± 12MHz</td>
</tr>
<tr>
<td>GPS</td>
<td>L5</td>
<td>1176.45MHz ± 12MHz</td>
</tr>
<tr>
<td>GLONASS</td>
<td>L1</td>
<td>1602MHz + k*0.5625MHz</td>
</tr>
<tr>
<td>GLONASS</td>
<td>L2</td>
<td>1246MHz + k*0.4375MHz</td>
</tr>
<tr>
<td>BeiDou-2</td>
<td>L1</td>
<td>1561.098MHz ± 2.046MHz</td>
</tr>
<tr>
<td>BeiDou-2</td>
<td>L2</td>
<td>1207.14MHz ± 10.23MHz</td>
</tr>
<tr>
<td>BeiDou-2</td>
<td>L3</td>
<td>1268.52MHz ± 10.23MHz</td>
</tr>
</tbody>
</table>
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
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)
Signal analysis

(2) DJI Phantom 3SE

Flight phase

Frequency Band: 2.4GHz/5.8GHz Band

Command & control: Wifi systems (20MHz)
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
Test of flight distance

Flying test

Command & control

Distance

30m/90m
Test of flight distance

Urban

Suburbs

Open area
# Test of flight distance

<table>
<thead>
<tr>
<th>Model</th>
<th>Power(mW)</th>
<th>Frequency band</th>
<th>Modulation type</th>
</tr>
</thead>
<tbody>
<tr>
<td>DJI MAVIC</td>
<td>100</td>
<td>2.4G</td>
<td>FHSS&amp;DSSS</td>
</tr>
<tr>
<td>Mi 1080P</td>
<td>100</td>
<td>2.4G</td>
<td>FHSS&amp;DSSS</td>
</tr>
<tr>
<td>Mi 4K</td>
<td>200</td>
<td>5.8G</td>
<td>FHSS&amp;DSSS</td>
</tr>
<tr>
<td>DJI P4P</td>
<td>100</td>
<td>2.4G &amp; 5.8G</td>
<td>FHSS&amp;DSSS</td>
</tr>
<tr>
<td>DJI SPARK</td>
<td>100</td>
<td>2.4G &amp; 5.8G</td>
<td>Wi-Fi</td>
</tr>
<tr>
<td>DJI P3S</td>
<td>100</td>
<td>2.4G</td>
<td>Wi-Fi</td>
</tr>
<tr>
<td>DJI P3SE</td>
<td>100</td>
<td>2.4G &amp; 5.8G</td>
<td>Wi-Fi</td>
</tr>
<tr>
<td>XIRO Dobby</td>
<td>100</td>
<td>2.4G</td>
<td>Bluetooth</td>
</tr>
</tbody>
</table>
The greater power of the UAV, the farther the UAVs fly.

$L_{\text{FHSS/DSSS}} > L_{\text{WIFI}}$

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.
## TECHNICAL CHARACTERISTICS

<table>
<thead>
<tr>
<th>Radio Controlled via FHSS/DSSS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wide spread (&gt;80%)</strong></td>
</tr>
<tr>
<td><strong>Range: 1-3 km</strong></td>
</tr>
<tr>
<td><strong>Wi-Fi is often used for the video downlink</strong></td>
</tr>
<tr>
<td><strong>DJI MAVIC/DJI P4P/Mi 1080P/Mi 4K</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Radio Controlled via Wi-Fi</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Range: 100m – 1km</strong></td>
</tr>
<tr>
<td><strong>Some are equipped with a FPV</strong></td>
</tr>
<tr>
<td><strong>DJI P3S/DJI P3SE/DJI SPARK</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Radio Controlled via Bluetooth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low cost models</strong></td>
</tr>
<tr>
<td><strong>Limited range with approx. 100 m</strong></td>
</tr>
<tr>
<td><strong>XIRO Dobby</strong></td>
</tr>
</tbody>
</table>
Content

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.
## Offline Detection: No perfect method

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

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radio Suppression</strong></td>
<td>Convenience; Moderate cost; Significantly effective;</td>
<td>Link suppression subject to usage mode; Navigation suppression and deceit subject to application scenarios;</td>
</tr>
<tr>
<td><strong>Laser Gun Attack</strong></td>
<td>War industry use; Directly destroy;</td>
<td>More dangerous; More secondary disaster;</td>
</tr>
<tr>
<td><strong>Physics Catch</strong></td>
<td>Less secondary disaster;</td>
<td>Lack of operability;</td>
</tr>
</tbody>
</table>
### Offline Control: radio suppression is more popular

<table>
<thead>
<tr>
<th>Mode</th>
<th>Effect</th>
<th>Operating Range</th>
<th>Advantages / Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radio Suppression</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Command &amp; control</td>
<td>Autonomous Homing</td>
<td>&lt;3km</td>
<td>Long usable distance  Can not work under radio silence</td>
</tr>
<tr>
<td>Satellite navigation signal</td>
<td>out of control</td>
<td>3-4km</td>
<td>Long usable distance  application fields are limited</td>
</tr>
<tr>
<td><strong>Deceptive Suppression</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satellite navigation signal</td>
<td>vertical landing</td>
<td>2-3km</td>
<td>No effect on other frequency band  application fields are limited</td>
</tr>
<tr>
<td>Command &amp; control</td>
<td>Take over the UAV</td>
<td>&lt;2km</td>
<td>Control the UAV  high technical difficulty</td>
</tr>
</tbody>
</table>
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.
04 OPERATOR LOCATING BASED ON AERIAL MONITORING PLATFORM
Drone Countermeasure

Detection

Sound/Optical/Low-altitude radar/Radio

Control

Suppression and Deception

Operator Locating

Aerial Monitoring Platform
• 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.
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
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
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.
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.
Spectrum inventory and utilization evaluation

Flow diagram of location

STR → Surveillance → Target signal? Y → Data collection and compression → Extracting Frequency-hopping signal

N → Change position

END → Cross Location → Direction finding times=1? Y → DoA Estimation → Signal energy calculation, Data reading of GPS and electronic compass

N → Change position
04 OPERATOR LOCATING

physical of UAV

UVA in the sky
Civil UAV Monitoring Technology Seminar and Equipment Exhibition
Demonstration: The DF results of a "black flying" operator for a particular UAV

The DF result to Position 1:
- Location: 294.7

The DF result to Position 2:
- Location: 351.1
Location result
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