RF Sensor for Interference Detection
An RF Signal-Based Drone Detection System

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N6841A
RF Sensor

DJI Phantom 4
https://www.dji.com/product/phantom-4
Introduction

• Commercial Drones Market Worth $4+ Billion by 2021 and Growing at 109% CAGR to 2020 (reference PRNnewswire.com on 6.29.15)

• Defense applications including surveillance and drone strikes

• Commercial applications include aerial photography (空中摄影), shipping (運輸), meteorology (氣象), 3D mapping (3D映射), real estate (房地產), agriculture (農業), search and rescue (搜尋及救援)

• Hobbyists just like to fly them and take videos for fun

Courtesy of Amazon Prime Air

http://www.makeuseof.com/tag/5-amazing-uses-drones-future/

http://www.eyeondrones.com/drones-in-agriculture-to-be-or-not-to-be/
Concerns of Drones

• 2013.09 A camera drone had a crashed in front of Chancellor Angela Merkel at an election campaign event in Germany

• 2015.01 A White House radar system designed to detect flying objects like planes, missiles and large drones failed to pick up a small drone that crashed into a tree on the South Lawn

• 2015.04 Drone carrying 28 lbs heroin from Mexico to US

• 2015.12 A handgun was delivered into a Quebec prison

• 2016.04 Drone hits a British Midways airplane in flight

Terrorism, video surveillance, eavesdropping, paparazzi, unintentional disruption

“Law-enforcement officials have discovered criminals smuggling drugs and other contraband across the U.S. border and into prisons using the types of consumer drones increasingly popular with entrepreneurs and hobbyists. And authorities in the U.S., Germany, Spain and Egypt have foiled at least six potential terrorist attacks with drones since 2011.” – Wall Street Journal, “Criminals, Terrorists Find Uses for Drones, Raising Concerns”
"Terrorist attacks using drones carrying explosives are a possibility," a senior member of the police department's security bureau told the Asahi Shimbun website.

Japanese authorities have launched an investigation after a small drone reportedly containing traces of radiation was found on the roof of the prime minister's office, sparking concerns about drones and their possible use for...
What is Drone?

There are many different types, but we are concerned about commonly accessible hobby drones

- May have 4 – 8 rotors
- May be controlled by remote and/or mobile app
- May have GPS module and programmable GPS waypoints
- May carry a payload
- May have a video camera
- Video camera may have live view to phone

DJI Phantom 4
https://www.dji.com/product/phantom-4
~ US $1400
# Example Drones and Specifications

<table>
<thead>
<tr>
<th>Brand</th>
<th>Model</th>
<th>Wing Span (m)</th>
<th>Max Flight time (mins)</th>
<th>Payload Capacity (kg)</th>
<th>Max Speed (m/s)</th>
<th>Max Alt (Km)</th>
<th>Max Oper Range (km)</th>
<th>Controller Frequency (GHz)</th>
<th>Live Video Freq (GHz)</th>
<th>Price (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SteadiDrone</td>
<td>Vader X4</td>
<td>1.32</td>
<td>50</td>
<td>4.3</td>
<td>20</td>
<td>4</td>
<td>1.5</td>
<td>-</td>
<td>N/A</td>
<td>20K</td>
</tr>
<tr>
<td>Allied Drones</td>
<td>EF44</td>
<td>1.2</td>
<td>60</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>N/A</td>
<td>19K</td>
</tr>
<tr>
<td>Yuneec</td>
<td>Flying Eyes HX3</td>
<td>1.1</td>
<td>45</td>
<td>2.0</td>
<td>14.9</td>
<td>-</td>
<td>2.0</td>
<td>2.4</td>
<td>5.8</td>
<td>3K</td>
</tr>
<tr>
<td>Aerialtronics</td>
<td>Altura Zenith ATX 8</td>
<td>0.6</td>
<td>45</td>
<td>2.9</td>
<td>20</td>
<td>-</td>
<td>1.0</td>
<td>2.4</td>
<td>5.8</td>
<td>2K</td>
</tr>
<tr>
<td>Microdrones</td>
<td>MD4-1000</td>
<td>1.03</td>
<td>88</td>
<td>1.2</td>
<td>12</td>
<td>1</td>
<td>0.5</td>
<td>2.4</td>
<td>N/A</td>
<td>2K</td>
</tr>
<tr>
<td>DJI</td>
<td>Spreading Wings S900</td>
<td>0.9</td>
<td>18</td>
<td>4.9</td>
<td>16</td>
<td>-</td>
<td>-</td>
<td>2.4</td>
<td>N/A</td>
<td>1.4K</td>
</tr>
<tr>
<td>DJI</td>
<td>Phantom 4</td>
<td>28</td>
<td>20</td>
<td>0.46</td>
<td>20</td>
<td>6</td>
<td>5.0</td>
<td>2.4</td>
<td>5.8</td>
<td>1.4K</td>
</tr>
<tr>
<td>Parrot</td>
<td>Bebop</td>
<td>0.248</td>
<td>22</td>
<td>0.02</td>
<td>13</td>
<td>0.15</td>
<td>2.0</td>
<td>2.4</td>
<td>5.8</td>
<td>0.5K</td>
</tr>
</tbody>
</table>
Drone Signals to Identify (Controller to Drone)

Bands
- Band 1: 433 MHz ISM Band: 433.05-434.7
- Band 2: 2.4 GHz – WiFi g/b/n: ≈ 2.4 – 2.5 GHz
- Band 3: 5.8 GHz - Video downlink 10 MHz wideband signal

Signals
- **DSSS** (Direct sequence spread spectrum) using Cypress chips like CYWUSB6953.
  - The spectrum of this will be about 800 kHz wide.
  - Not hopping, but might alternate between two frequencies.
  - They may select a different frequency at the very beginning of the controller being turned on,

- **FHSS** (Frequency hopping spread spectrum).
  Possibly using a custom IC developed by Futaba.
  This signal will hop around in the spectrum.

- **FASST** is spread spectrum using 36 hopping frequencies spread across the entire 2.4 ISM band, GFSK modulation
Drone Signals to Identify (Video Signal)

- FPV = First Person View
- Drones can record video, they can also transmit video live to an app

<table>
<thead>
<tr>
<th>Technology</th>
<th>Video Quality</th>
<th>Range</th>
<th>HW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4 GHz Analog</td>
<td>Poor</td>
<td>Good</td>
<td>Specialized</td>
</tr>
<tr>
<td>2.4 GHz WiFi</td>
<td>WiFi Interference, Video latency</td>
<td>Good</td>
<td>iPhone or Android phone/tablet</td>
</tr>
<tr>
<td>5.8 GHz WiFi</td>
<td>Great (wider BW)</td>
<td>Not as good as 2.4</td>
<td>Newer iPhone or Android phone/tablet</td>
</tr>
</tbody>
</table>
3 Phases of Countering Drones

1. Detection
2. Location
3. Mitigation

• Location task: Locate the controller or the drone or both, whatever transmits
• Mitigation by jamming requires permission from the local frequency regulatory body
Keysight N6841A RF Sensor

Basic specifications

Key Features

• Indoor and outdoor spectrum monitoring and geolocation
• 20 MHz to 6 GHz
• 20 MHz of information BW
• Integrated GPS for time synchronization and location (outdoor)
• Network synchronization < 20 nS accuracy (indoor)
• Sealed Weatherproof Enclosure (rated IP67) inc mounting kit
• Low cost, for deploying sensor networks

GPS antenna

N6841A Value Points

**** Low-Cost
*** Weatherproof: IP 67
** Synchronization < 20 nsec
Keysight N6850A Broadband Omni Antenna

- Consistent pattern in both azimuth & elevation. Improves potential for effective power-based geolocation
- Compact, Simple to mount (~42 cm high)
- Operating range 20 MHz to 6 GHz
- Best performance 300 MHz to 6 GHz
- Creative mounting bracket suitable for:
  - Tripod, Pole/Rail or Mobile (magnetic)
Mounting and Deployment

Remote spectrum monitor and signal analyzer

Pole/wall mount bracket included with Sensor

GPS Antenna mounting slot

One pole connection to mount RF Sensor plus GPS antenna.

Very easy to install.

Size: 292 x 220 x 50 mm
Weight: 3.4 kg
Networking Sensors Together

VSA | SSR | SMT
---|---|---
Analysis

Central Server

SMT | S4D | GEO

Operations

Fixed or Mobile

SMS

> SQL Data
> IQ recordings
> Reports
> Spectral Data

Drone Detection
Potential Applications of a Sensor Network

- Identify frequencies in use versus plan (military, event spectrum management)
- Locate interferers or violators (military, airports, aircraft, railway, frequency regulators)
- Identify/locate rogue emitters (e.g. secured areas, hospitals, venues needing radio silence)
- Identify/locate friendly emitters (military, first responder)
Keysight Spectrum Monitoring and Geolocation Tools

**System Planning and Optimization Tool (SPOT)**
Used to explore RF signal propagation and predict signal detection coverage for sensor placement (included with SMT).

**N6820ES Signal Surveyor Software**
Easily integrates with the N6841A to detect signals of interest and pass them to the N6854A automatically.

**N6841A RF Sensor**

**N6854A Geolocation Software**
The cross correlations of signals received by each sensor provide the basis for the time-difference-of-arrival determination. Estimated position is shown in colors with the highest probability location in dark red.

[Images of software interfaces and RF sensor]
Planning a Distributed Sensor Network

Sensor Placement and Optimization Tool (SPOT)

SPOT enables network planning and prediction of RF Detection Range and Geolocation Coverage Area

- Density of sensors required for coverage
- Effectiveness of geometry to detect and locate emitters (GDOP)
- Model sensor installations:
  - Antennas, pre-amps,
  - RF cable runs, Elevation
- Propagation models for terrain and line of sight
- Reference Report ITU SM.2211, Annex 1 for more discussion.

Free download on www.keysight.com
Automating RF Survey, Signal Classification

Software Enabler: N6820ES Signal Surveyor 4D(S4D)

- Awareness of spectrum use, advanced energy detection, trigger and automatic alarm tasking
- Creates SQL database statistics collection including:
  - Externals/Internals
  - A Priori knowledge
- Modulation and Symbol rate classification
- Flexible Search modes (single or multi-band)
- Execute automatic or manual IQ or demodulated audio collection

[Image: Spectrum analysis and signal classification software interface]

Licensed SW
www.keysight.com
N6854A RF Geolocation Server Software

- Software that calculates location of RF emitters by TDOA, RSS, or Hybrid technique
- Employs a network of time synchronized N6841A RF Sensors (with GPS or Network 1588)
- Triggered manually (RF level or time-based) or from external application (Signal Surveyor N6820E or customer app.)
Drone Controller
Outdoor Geo Trial – January 2016

Spektrum DX6i – Test Location #1

Sensor locations

Estimated Position (1717)

Average Estimated Position

Estimated Position (1714)

13 meters

Zoomed in view
Drone Detection Life Demo

KOOME  DJI P3

- Direction, Multi Band Search
- Noise Riding Detection Threshold
- USD, Signal Classification

Intercept
Sound/Video Alarm