Drone Detection

KEYSIGHT TECHNOLOGIES

Outline

- Introduction to Drones
- Keysight Tools for Signal Detection/Location
- Drone Detection/Location
- Field Trials

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, shipping, meteorology, 3D mapping, real estate, agriculture, search and rescue
- 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

- Sept 2013 A camera drone had a crashed in front of Chancellor Angela Merkel at an election campaign event in Germany
- Jan 2015 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
- Apr 2015 Drone carrying 28 lbs heroin from Mexico to US
- Dec 2015 A handgun was delivered into a Quebec prison
- April 2016 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"

Local Drone Attack

theguardian

Japan

Drone 'containing radiation' lands on roof of Japanese PM's office

Traces of radiation reportedly detected on drone carrying camera and bottle with unidentified contents

Associated Press in Tokyo

Wednesday 22 April 2015 07.00 EDT

This article is 1 year old

Shares 1,181 Comments 103

Save for later

Officials carry a blue box reportedly containing a drone from the rooftop of Shinzo Abe's offices in Tokyo. Photograph: Thomas Peter/Reuters

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

"Terrorist attacks using drones carrying explosives are a possibility," a senior member of the police department's security bureau told the Asahi Shimbun website.

What's a 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

http://www.droneflyers.com/2014/11/basics-radio-frequencies-fpv-quadcopter-drones/

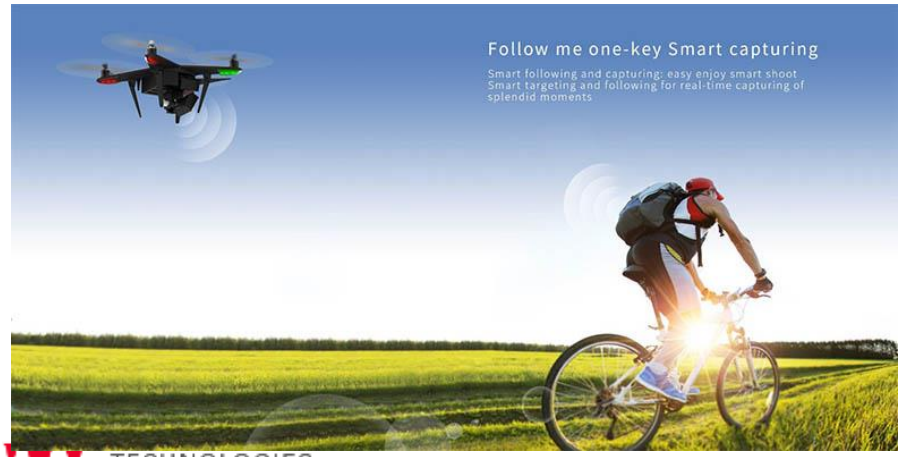
KEYSIGHT TECHNOLOGIES

Example Drones and their Specs

Manufa	Model	Wing span, m	Max Flight time, min	Payld Cap, kg	Max Speed, m/s	Max Alt, km	Max Oper Range, km	Controller Freq, GHz	Live Video Freq, GHz	
SteadiDrone	Vader X4	1.32	50	4.3	20	4	1.5	-	N/A	
Allied Drones	EF44	1.2	60	2	-	-	-	-	N/A	
Yuneec	Flying Eyes HX3	1.1	45	2.0	14.9	-	2.0	2.4	5.8	
Aerialtronics	Altura Zenith ATX8	0.6	45	2.9	20	-	1.0	2.4	5.8	
Microdrones	MD4-1000	1.03	88	1.2	12	1	0.5	2.4	N/A	
DJI	Spreading Wings S900	0.9	18	4.9	16	-	-	2.4	N/A	
DJI	Phantom 4		28	0.46	20	6	5.0	2.4	5.8	
Parrot	Bebop	0.248	22	0.02	13	0.15	2.0	2.4	5.8	

Types of Drones and Drone Operations

- Human operator with radio control of drone (hobby level drone)
- More expensive drones have GPS modules, and may have sonar for obstacle avoidance. These can be set on GPS waypoint missions. Several GPS waypoints can be programmed in.
- Train it to follow a target. (Hobbysists use it to follow a runner or a bicyclist)
- Return to home operation is optional
- Out of range behavior differs from drone-to-drone: fly away, descend to ground, return to home



http://www.buy-best-quadcopter.com/high-range/xiro-xplorer-aerial-uav-drone-quadcopter/

http://www.dronezon.com/learn-about-drones-quadcopters/drone-waypoint-gps-navigation-technology-explained/

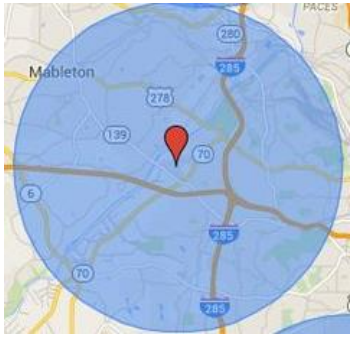
Video Signals

FPV = First Person View

Drones can record video, they can also transmit video live to an app

Technology	Video Quality	Range	HW
2.4 GHz Analog	Poor	Good	Specialized
2.4 GHz Wifi	Wifi Interference, Video latency	Good	Iphone or Android phone/tablet
5.8 GHz Wifi	Great (wider BW)	Not as good as 2.4	Newer Iphone or Android phone/tablet

3 Phases of Countering Drones



Detection → Location → Mitigation

Location task: Locate the controller or the drone or both, whatever transmits

Mitigation by jamming requires permission from the local frequency regulatory body.

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Brief Overview of the 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

N6841A Value Points:

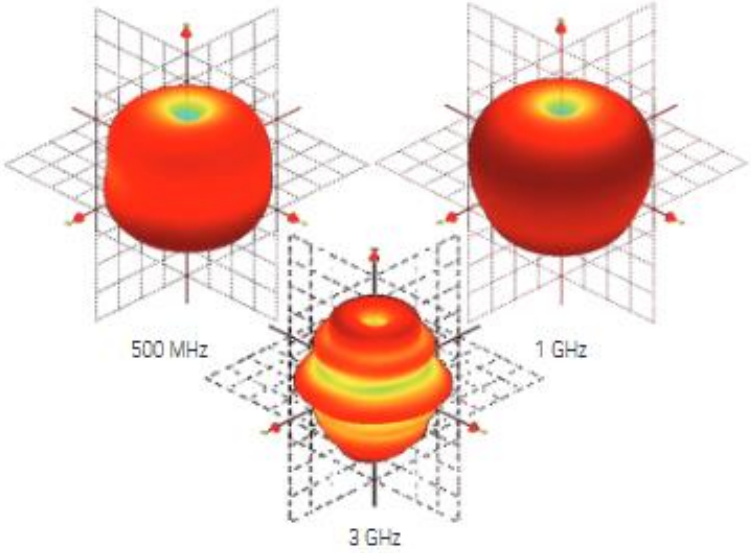
****Low-Cost
***Weatherproof: IP 67
**Synchronization < 20 nsec
*Proven Reliability (~2% CCAFR)

KEYSIGHT TECHNOLOGIES

Deployment: Keysight Broadband Omni Antenna

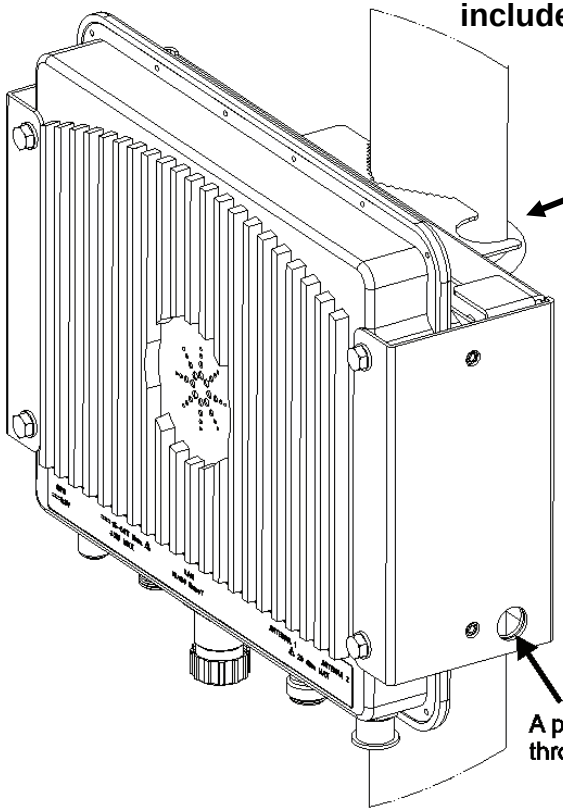
Model Number N6850A

- 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…



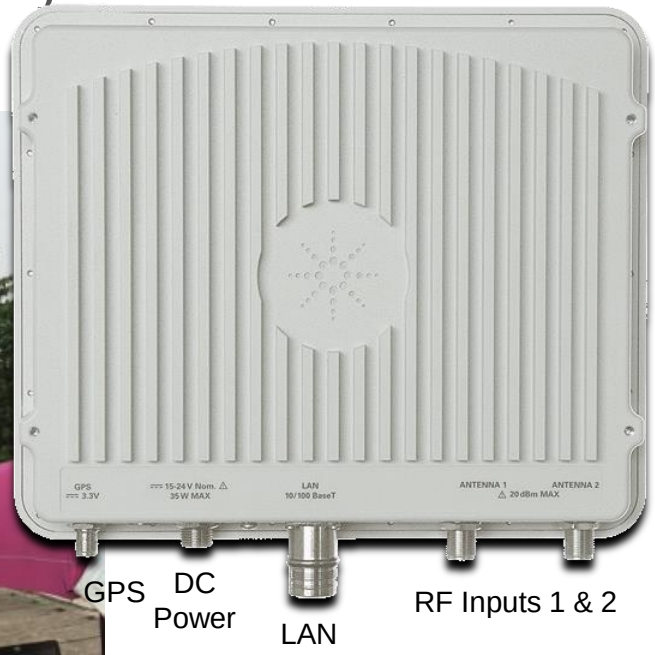
Pole / wall mount bracket included with Sensor

GPS Antenna mounting slot

One pole connection to mount RF Sensor plus GPS antenna.

Very easy to install.

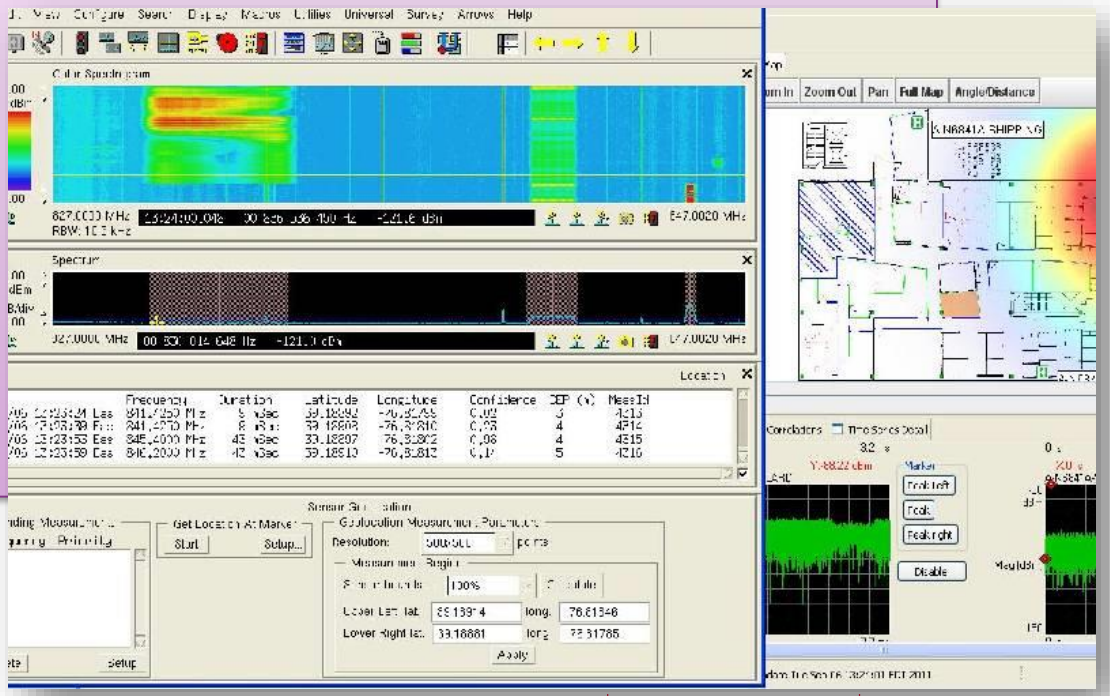
A padlock can be installed through the side holes



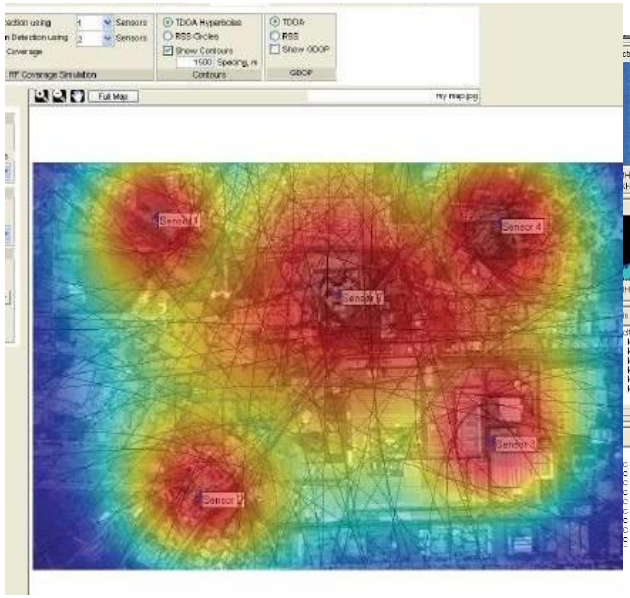
Size: 292 x 220 x 50 mm
Weight: 3.4 kg

Potential Applications for a Sensor Network

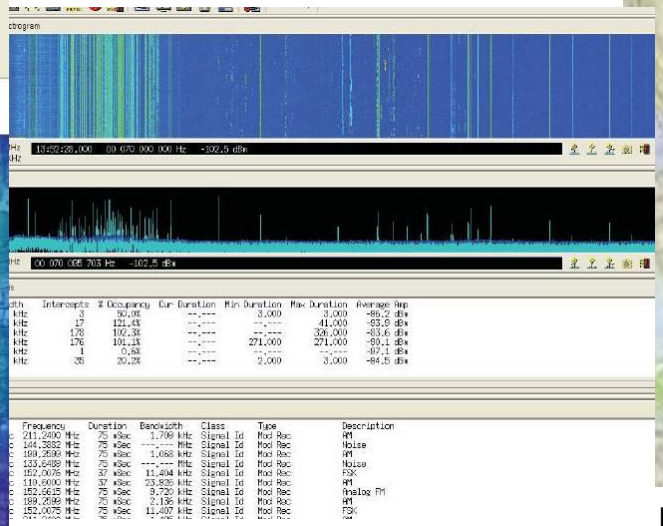
- Identify frequencies in use versus plan (military, event spectrum management)
- Locate interferers or violators (military, airports, aircraft, railway, frequency regulators)
- Identify/locate rogue emitters (e.g. secured areas, hospitals, venues needing radio silence)
- Identify/locate friendly emitters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

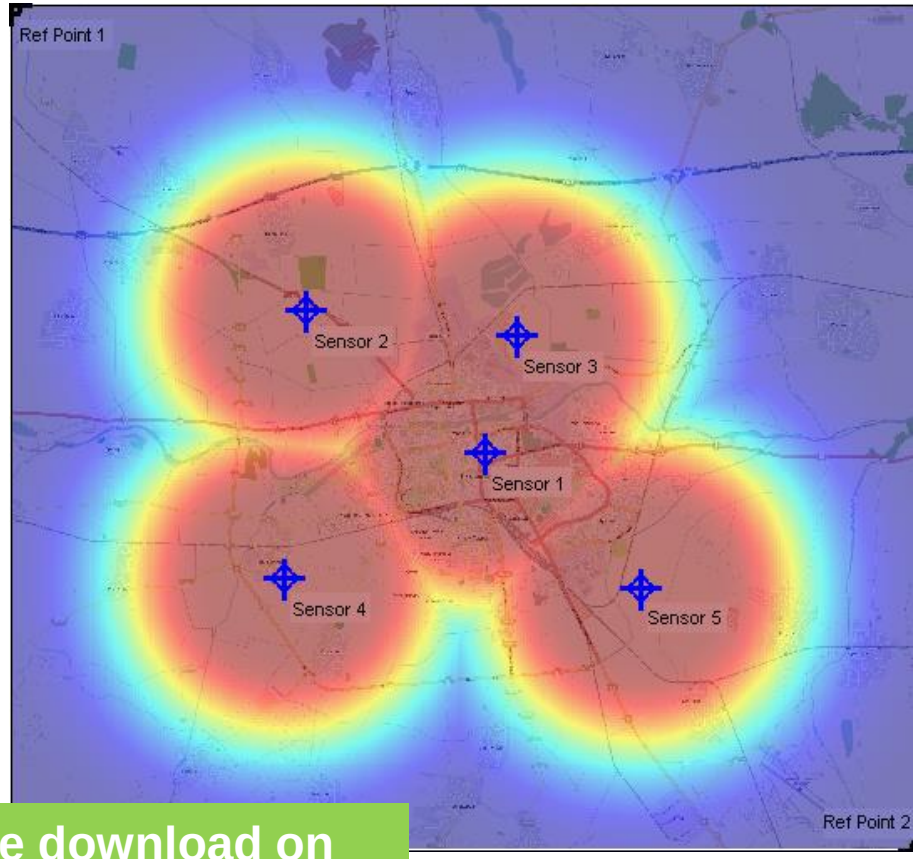
N6854A Geolocation Software: The cross correlations of signals received by each sensor provide the basis for the time-difference-of-arrival determination. Estimated position is shown in colors with the highest probability location in dark red.

Planning a Distributed Sensor Network

Sensor Placement and Optimization Tool (SPOT)

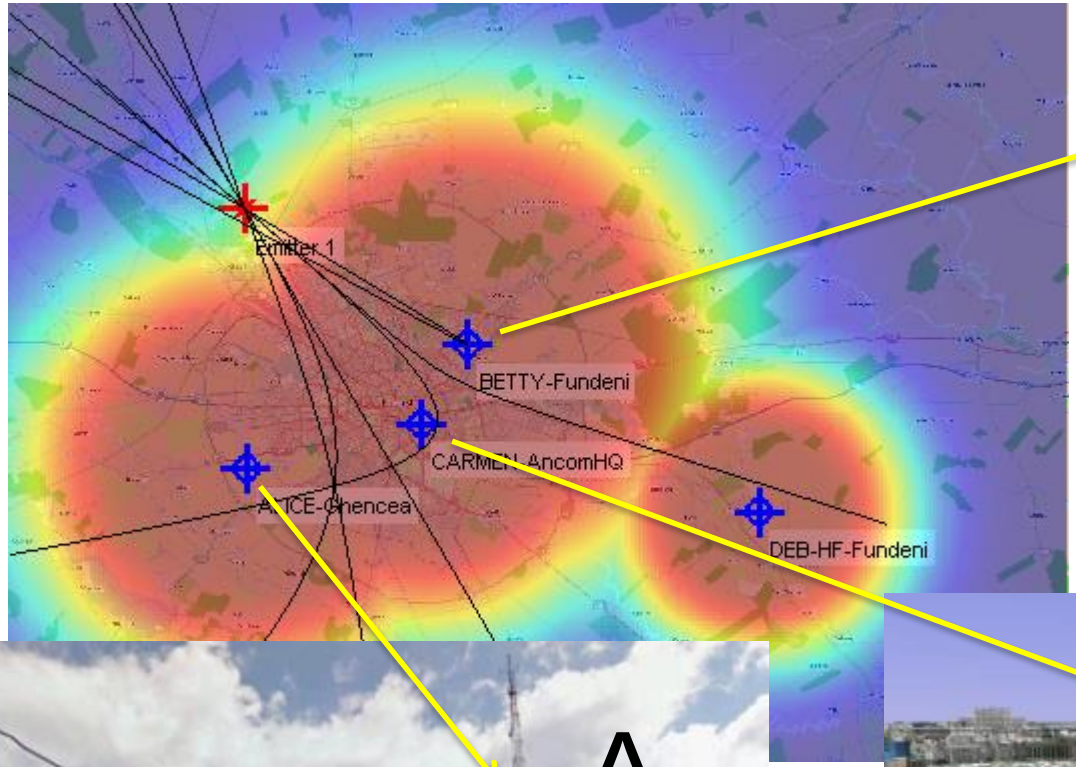
SPOT enables network planning and prediction of RF Detection Range and Geolocation Coverage Area.

- 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

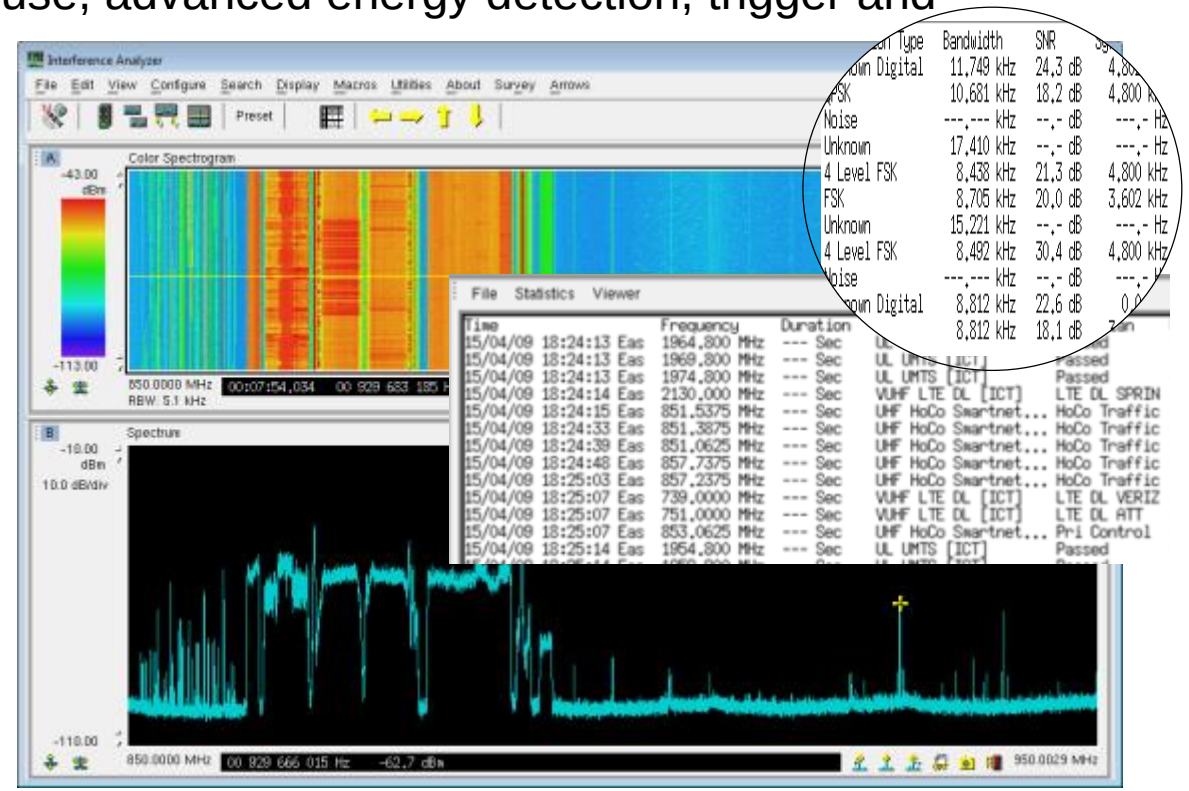
Planning: Example of SPOT Model



Automating RF Survey, Signal Classification

Software Enabler: N6820ES Signal Surveyor 4D

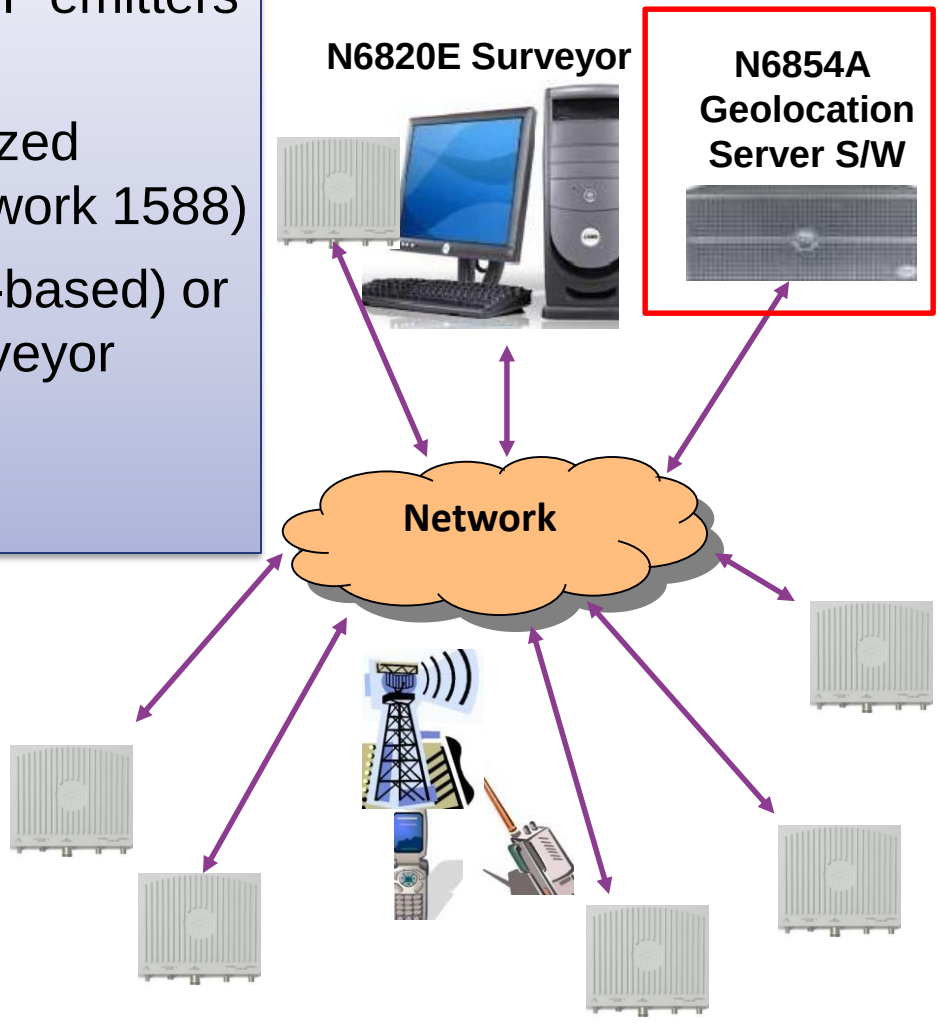
- Awareness of spectrum use, advanced energy detection, trigger and automatic alarm tasking
- Creates SQL database statistics collection including:
  - Externals/Internals
  - A Priori knowledge
- Modulation and Symbol rate classification
- Flexible Search modes (single or multi-band)



- Execute automatic or manual IQ or demodulated audio collection

N6854A RF Geolocation Server Software

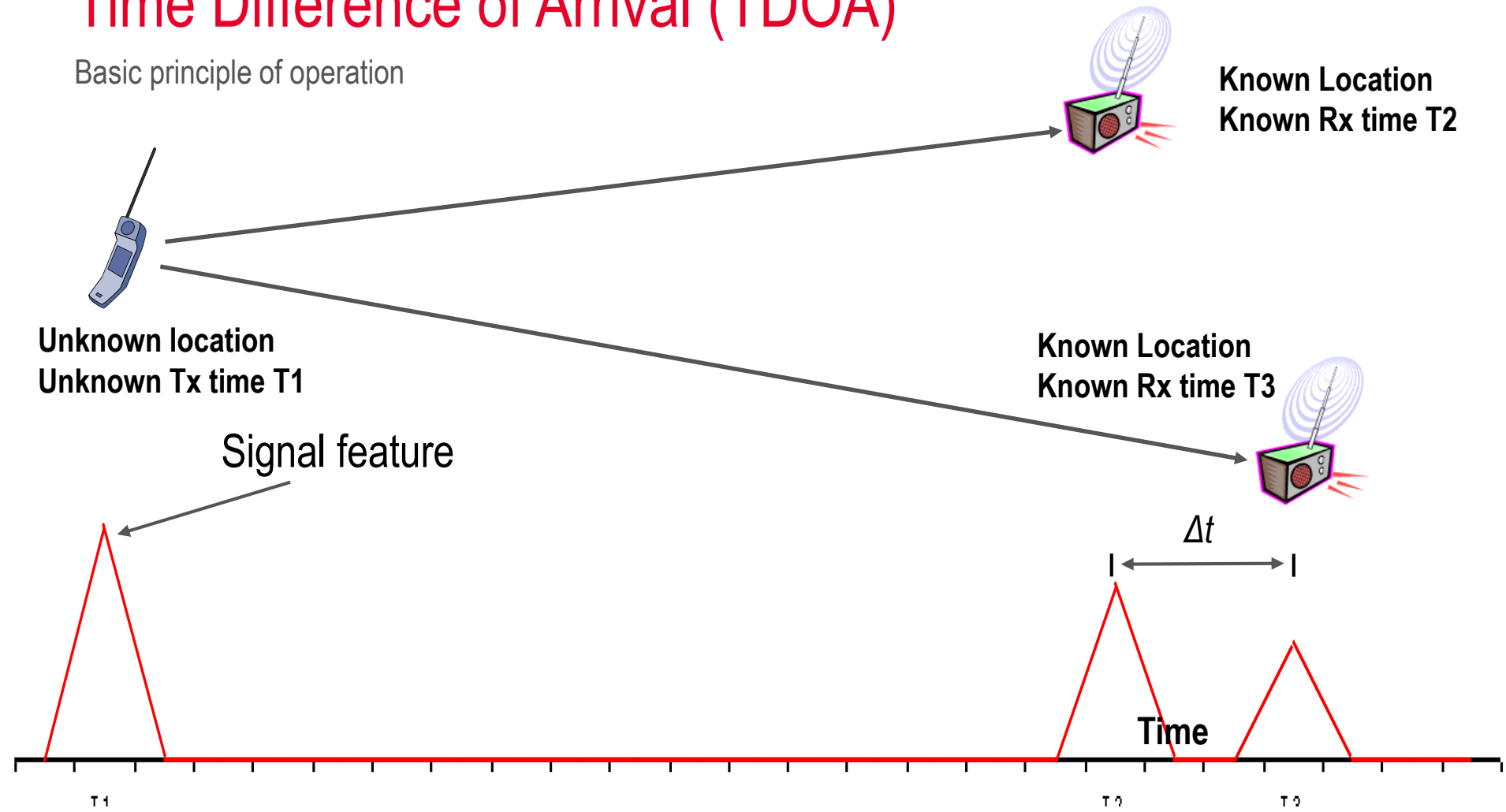
- Software that calculates location of RF emitters by TDOA , RSS, or Hybrid technique
- Employs a network of time synchronized N6841A RF Sensors (w/ GPS or Network 1588)
- Triggered manually (RF level or time-based) or from external application (Signal Surveyor N6820E or customer app.)



Geolocation Display

Time Difference of Arrival (TDOA)

Basic principle of operation

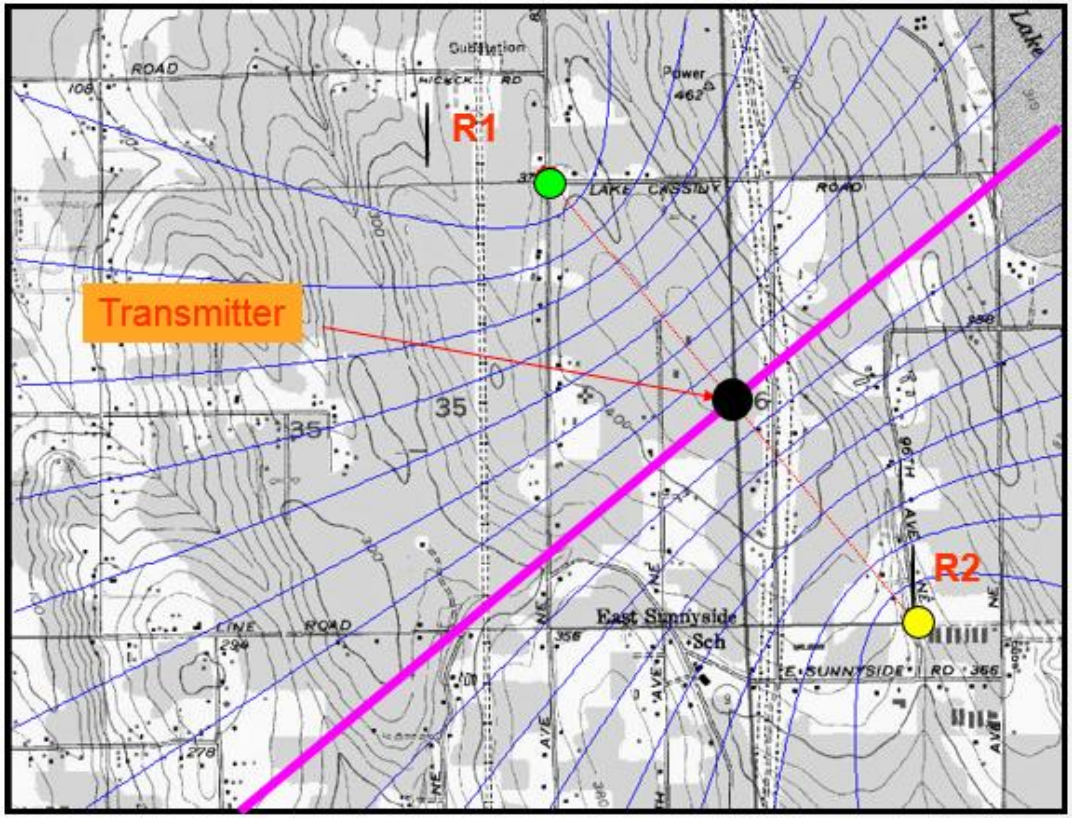


Measure time difference (Δt) between the arrival of the signal at each receiver

Time Difference of Arrival (TDOA)

Two-dimensional view of hyperbola

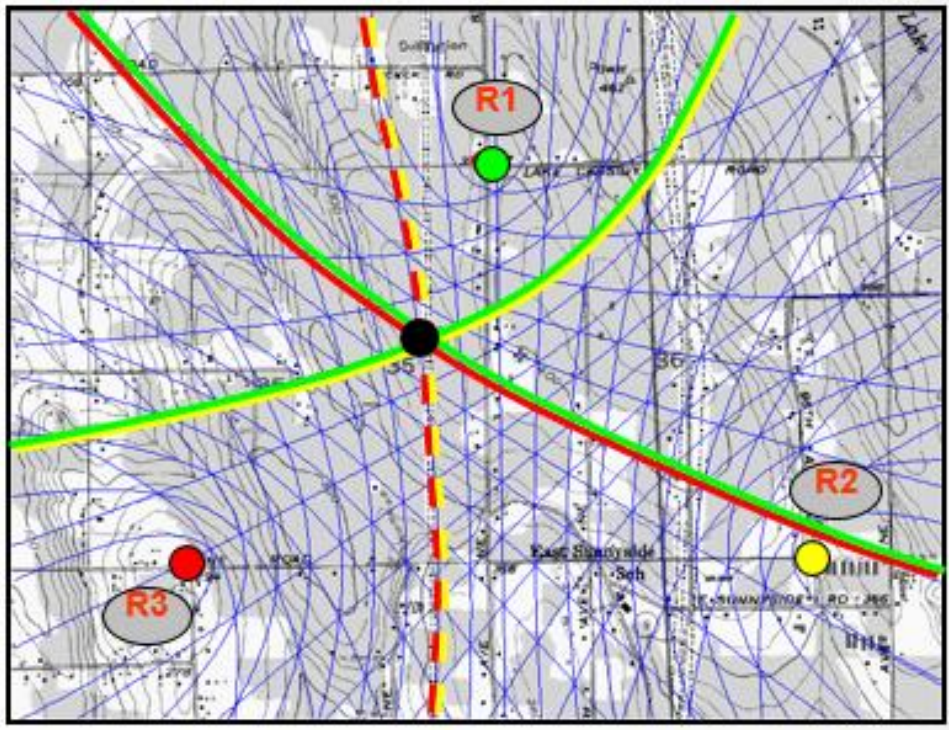
- Lines of constant time difference of arrival for a signal measured at two receivers form hyperbola, also known as isochrones.
- The two receiver locations are referred to as the foci of the hyperbola



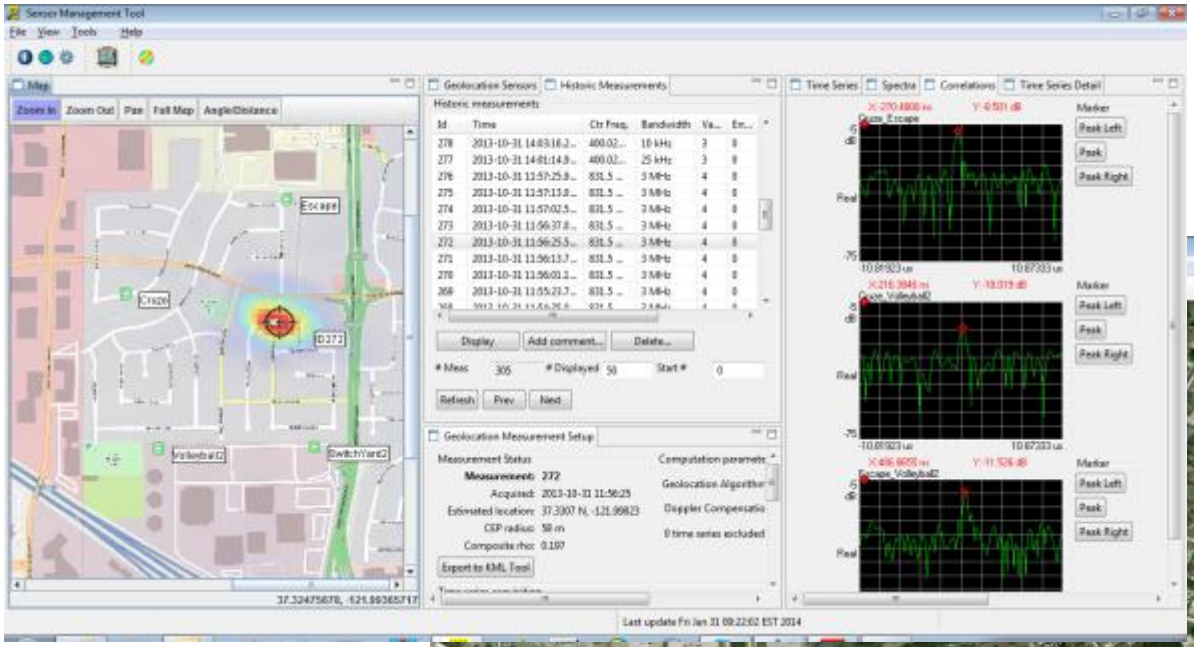
Time Difference of Arrival (TDOA)

Adding a third receiver

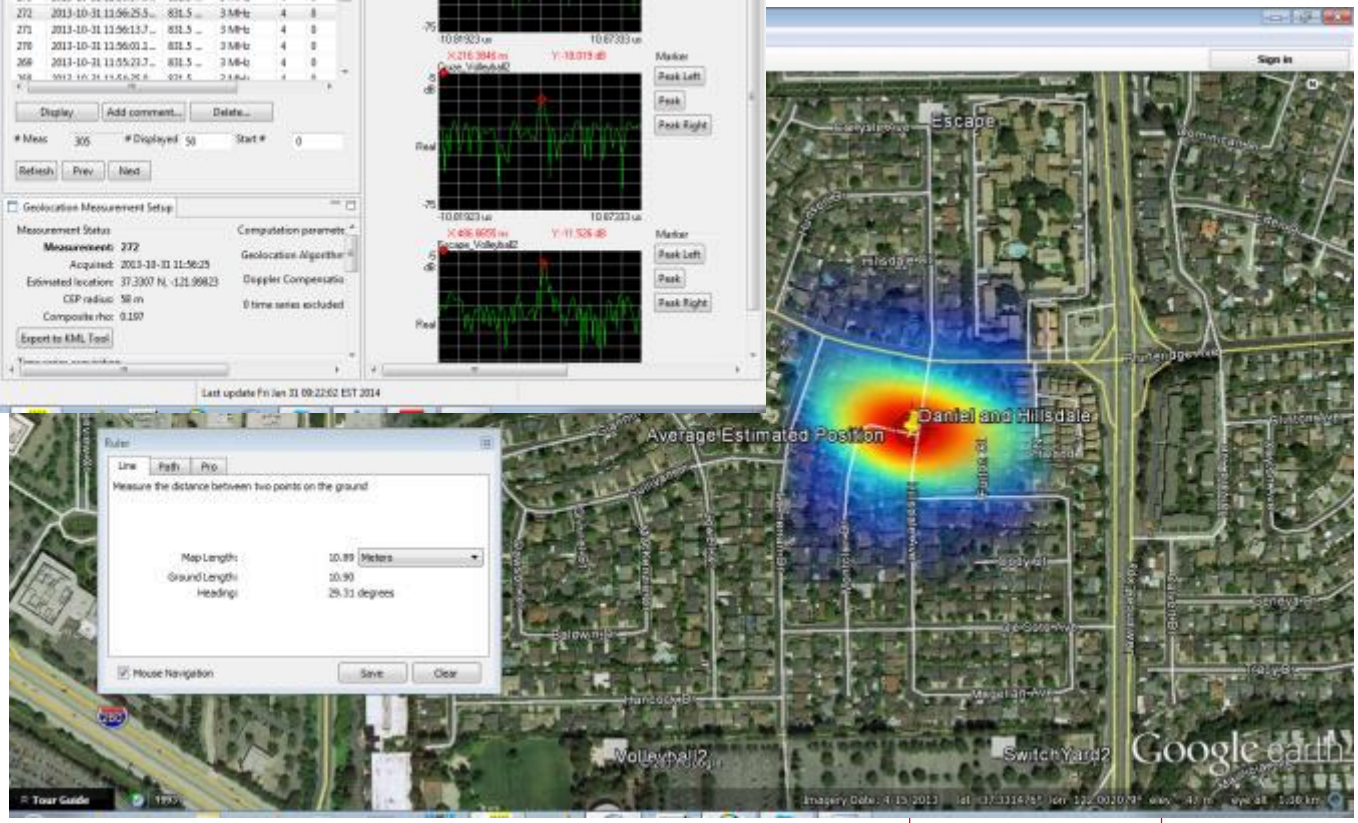
- 3rd receiver enables an estimated position (EP or "fix" of the transmitter to be calculated
- Three sensors produce three correlations from three sensor pairs.



Geolocation map



Exportable to Google Earth



Portable Tools - Fieldfox

Find Final Location

Frequency(GHz)
4/6.5/9/14/18/26.5/32/44/50

10 MHz BW / 12 us 100% POI Real Time Spectrum Analysis(RTSA)

Interference Signal Analysis

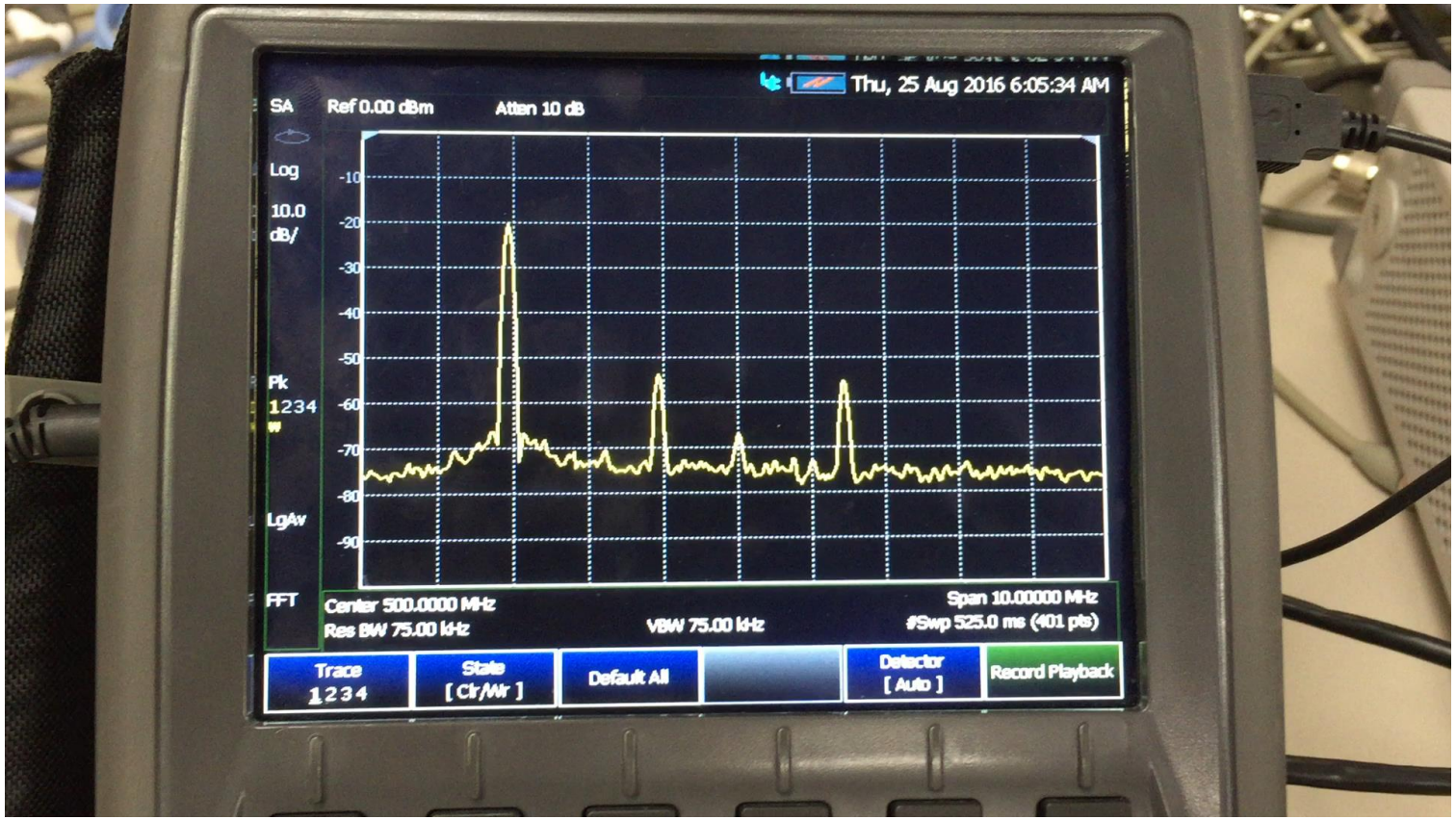
Internal GPS Receiver

CAT, NA, SA, PM, VVM, RTSA, TDR

KEYSIGHT TECHNOLOGIES

Interference Hunting Using Handheld Instruments

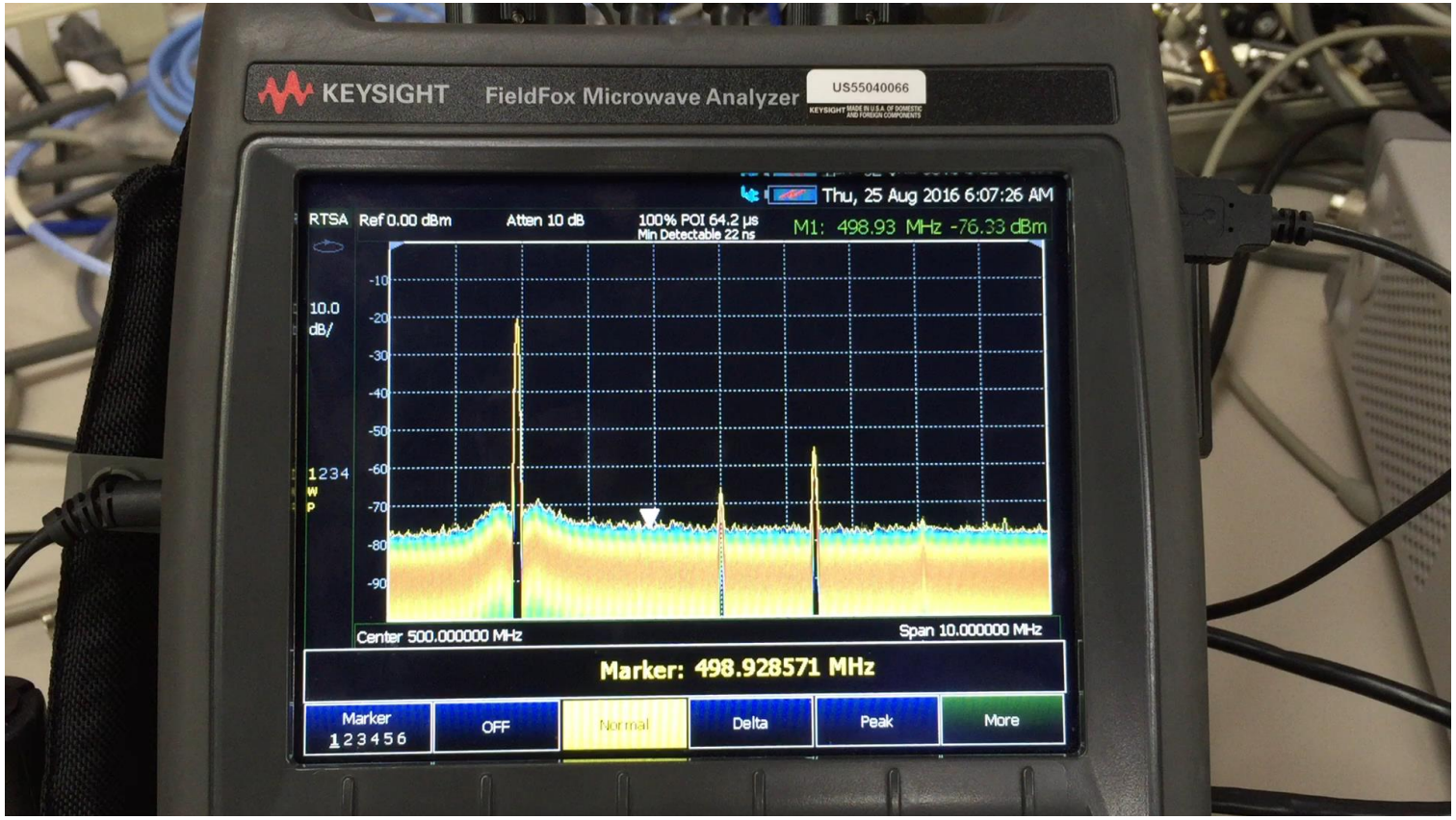
Using normal SA



Many signals are missed and measurement takes time

Interference Hunting Using Handheld Instruments

Using Real Time SA

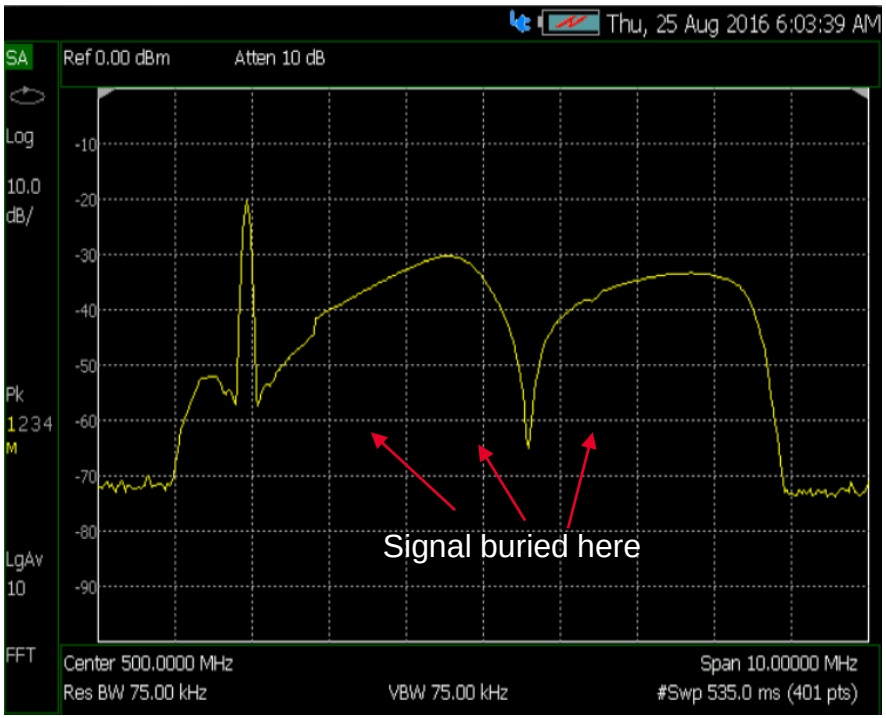


Able to observe fast signals

Interference Hunting Using Handheld Instruments

Comparison of normal SA vs RTSA

Normal SA using Max Hold



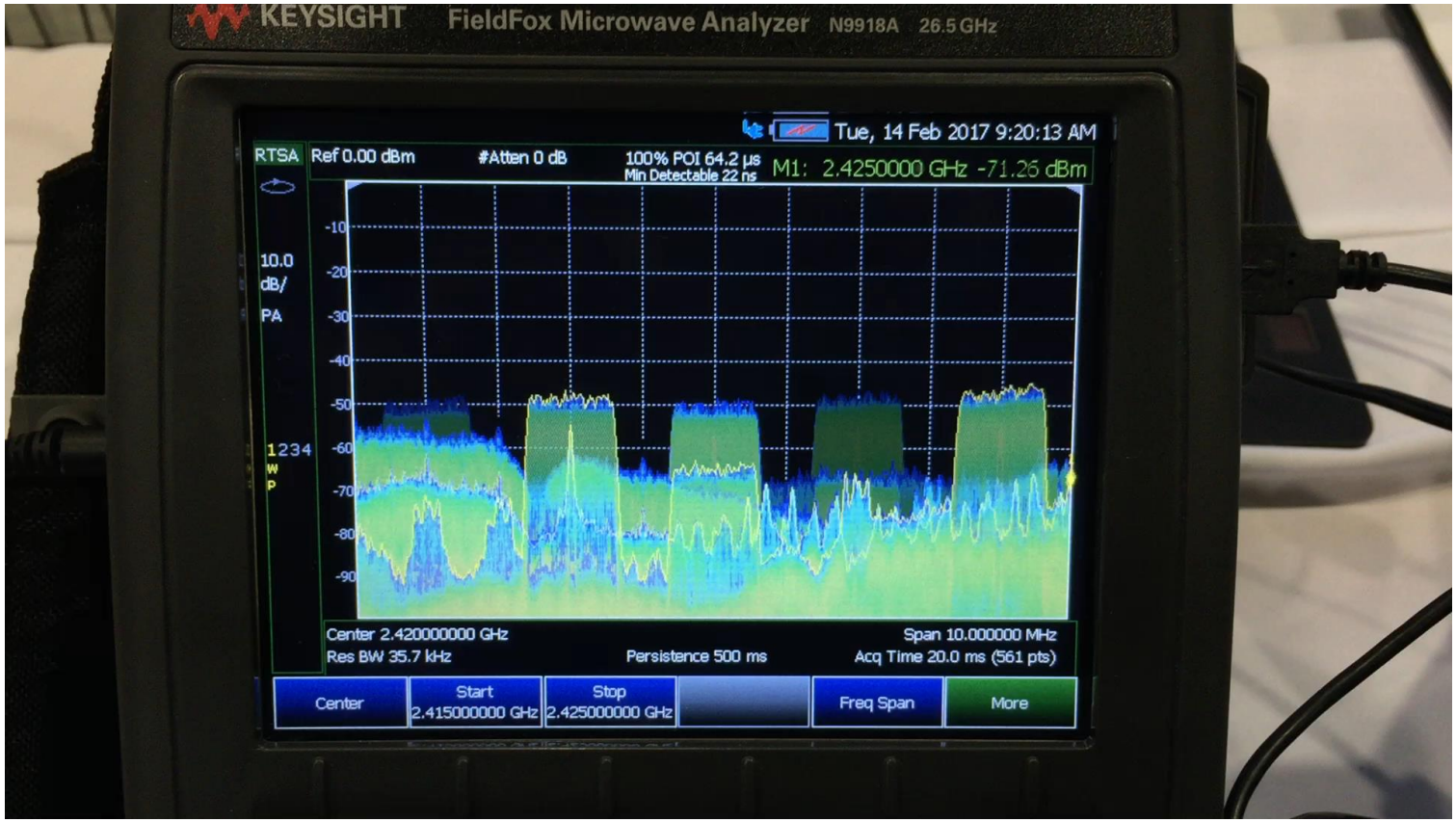
Narrow band signals are buried under wideband signals

RTSA

Signals can be observed

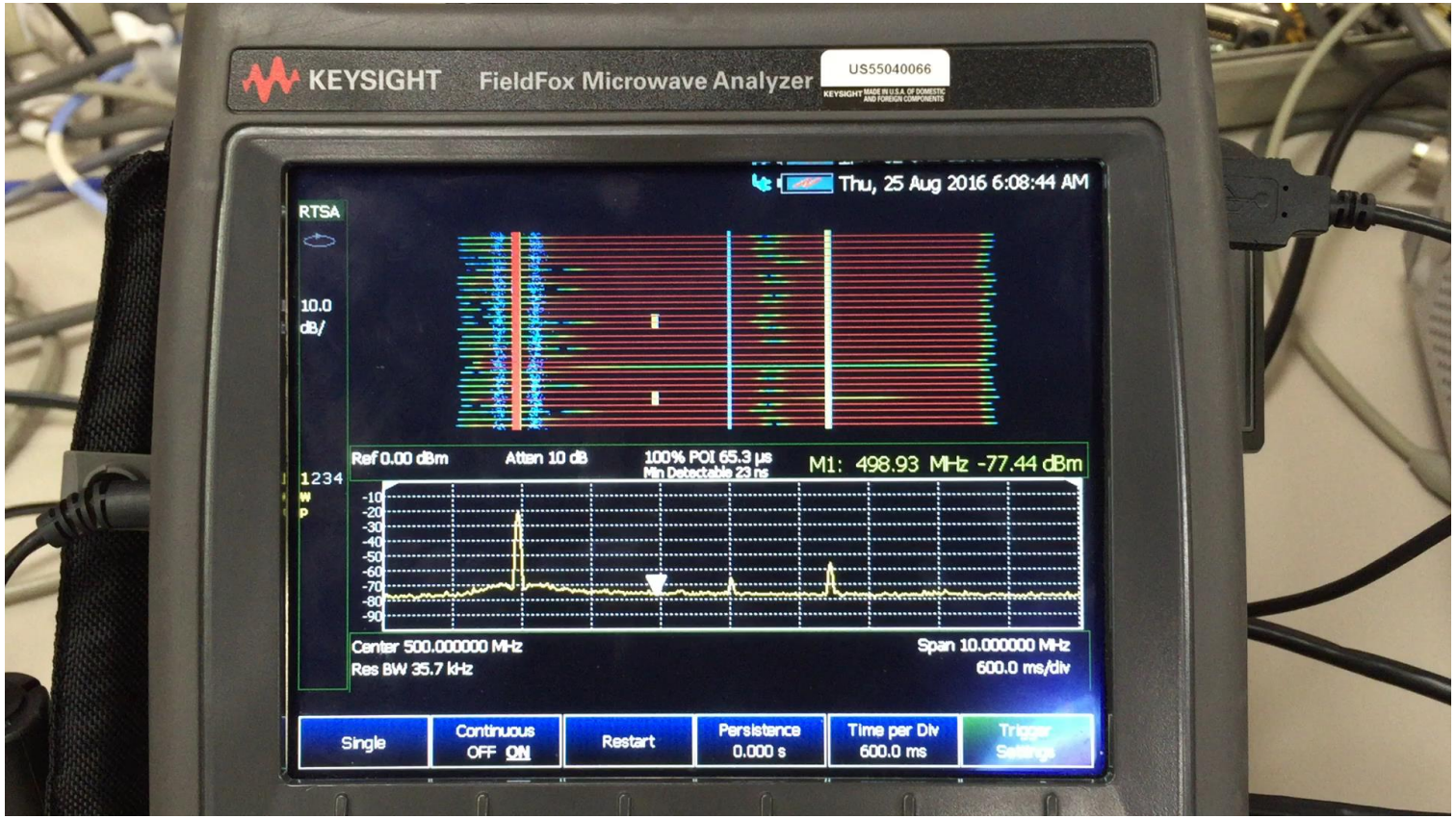
Drone Controller Signals

Using Real Time SA



Interference Hunting Using Handheld Instruments

Using Spectrogram with Real Time SA



Effective in observing intermittent signals

Find the Fieldfox that Meets Your Needs

N991xA

RF and microwave combination analyzer

Base : Cable and antenna tester

Key options:

- Spectrum analyser
- Vector network analyser
- Vector voltmeter
- Built-in power meter
- Pulse measurements

N992xA

RF and microwave vector network analyzer (VNA)

Base : Network analyzer

Key options:

- Full 2-port S-parameters
- Two-port QuickCal
- Time domain
- Cable and antenna analyser
- Vector voltmeter
- Built-in power meter
- -Pulse measurement

N993xA

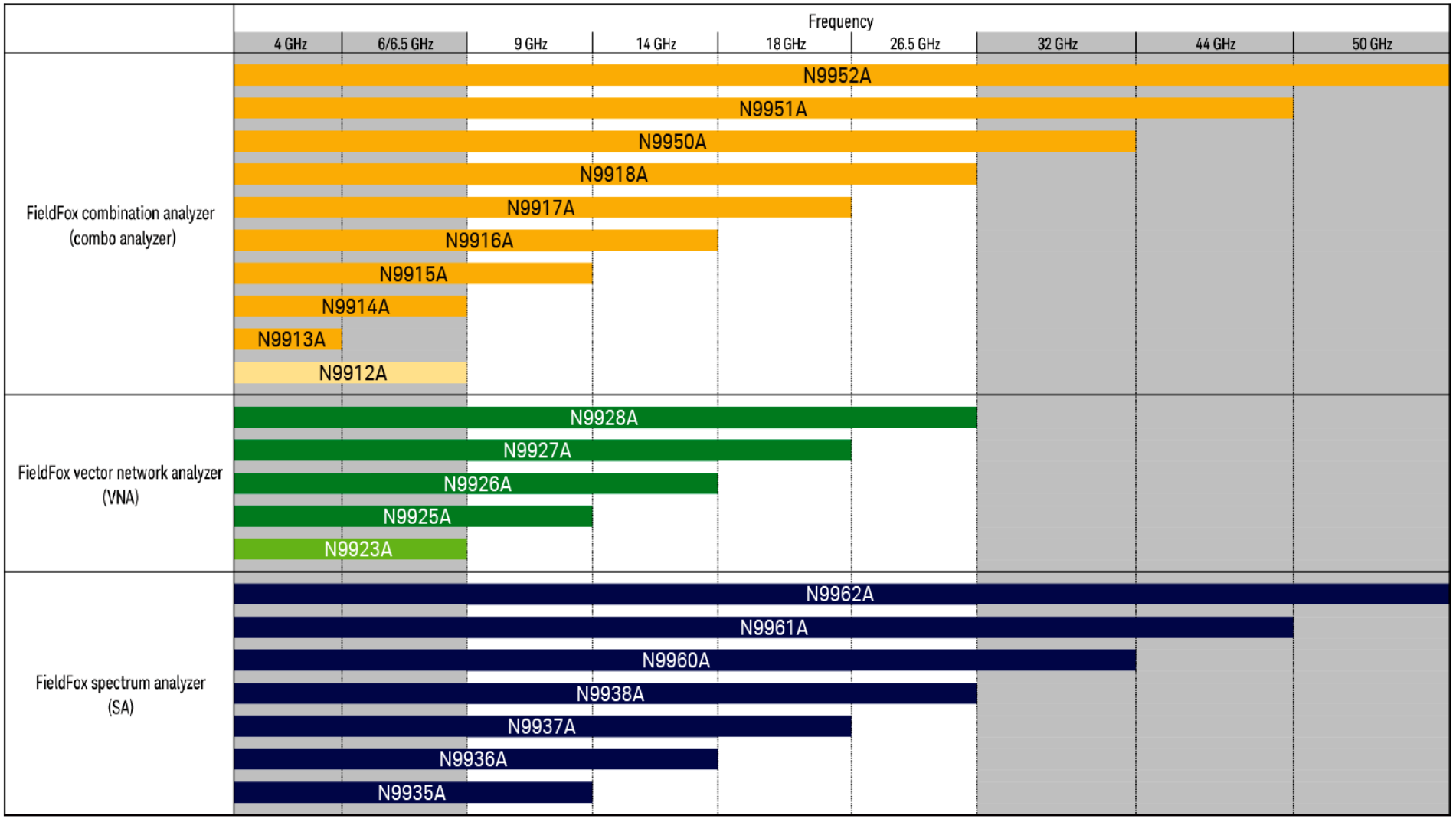
Microwave spectrum analyzer

Base : Spectrum Analyzer

Key options:

- Full-band tracking generator
- Full-band preamplifier
- Interference analyser and spectrogram
- Reflection measurement
- Built-in power meter
- Pulse measurement

Find the Fieldfox that Meets Your Needs



Fieldfox – Rugged, Reliable, and Weather Resistant

Fieldfox – Rugged, Reliable, and Weather Resistant

Fieldfox – Carry Precision With You

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ISM Bands

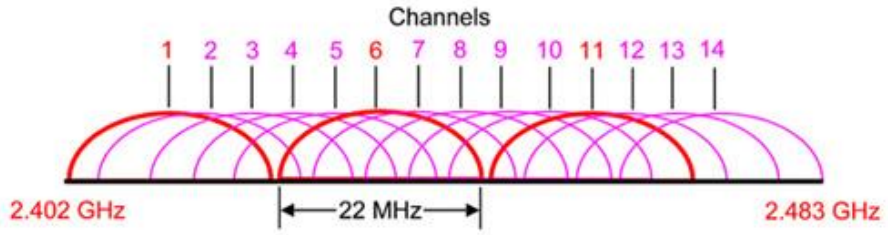
Spectrum where commercial drones are operated

Band Name	Start Frequency	Stop Frequency	Power Limitation
UHF Short Range Device	433.05 MHz	434.79 MHz	≤ 10 mW ERP
ISM 2.4 GHz	2.4 GHz	2.4835 GHz	≤ 100 mW EIRP
ISM 5.8 GHz	5.725 GHz	5.85 GHz	≤ 100 mW EIRP

Other Signals activity in ISM 2.4 GHz band:

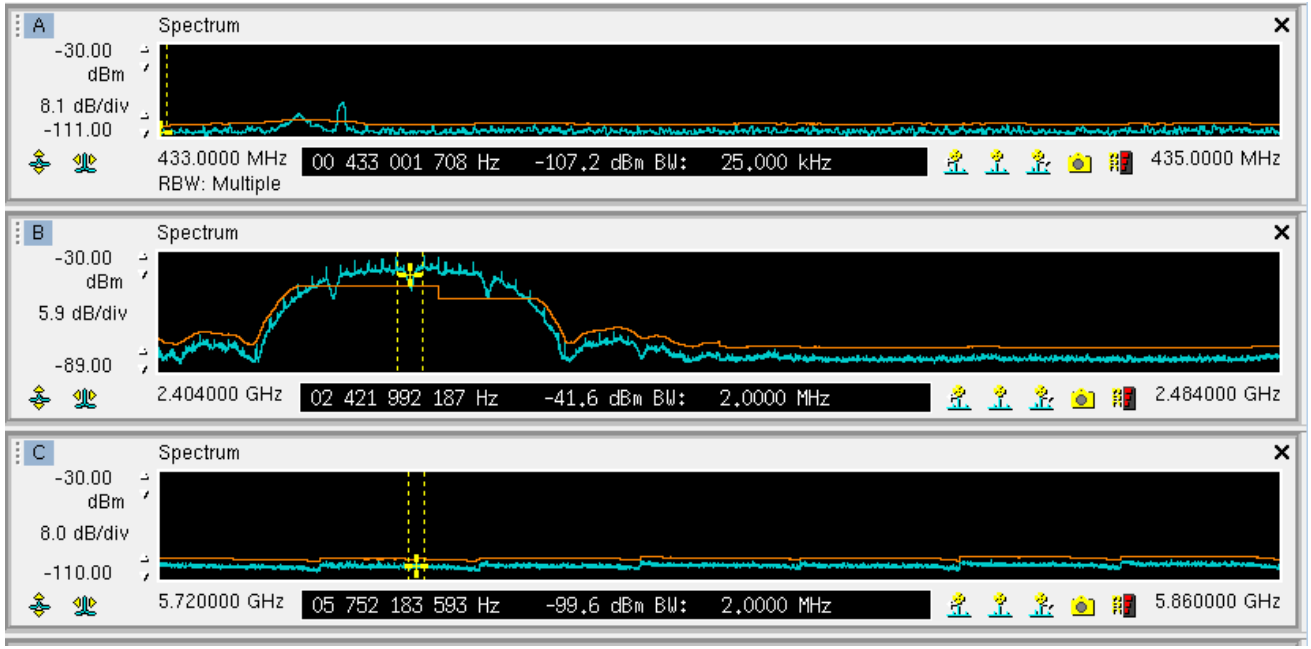
- Wi-Fi
- Bluetooth
- IoT Signals
  - ZigBee
  - Z-Wave
  - LoRa
- Microwave ovens

It's getting even busier…



Banded Search

- Commercial drones are controlled from any of 3 or 4 different frequency bands
- The receiver software should allow for a directed or banded search to improve POI.
- 400 MHz SRD >
- ISM 2.4 GHz >
- ISM 5.8 GHz >

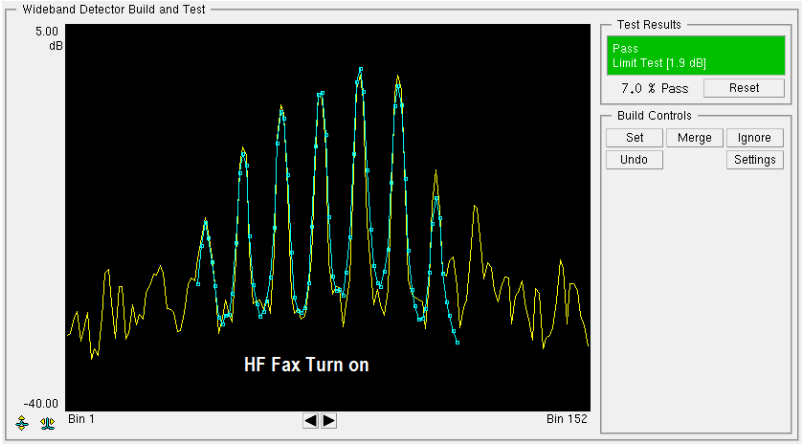


Noise Riding Energy Threshold

- In the busy ISM band, Wi-Fi signal activity creates a complex RF environment that can resemble a very active noise floor.
- Detecting and classifying signals is challenging in both situations
- Here we've set a noise-riding threshold; signals that go above the threshold trigger further processing

Spectral Shape Correlation

– After energy detection, classifying and isolating signals can be difficult.
  - Signals are very narrowband
  - They can be very low SNR riding on a moving noise floor

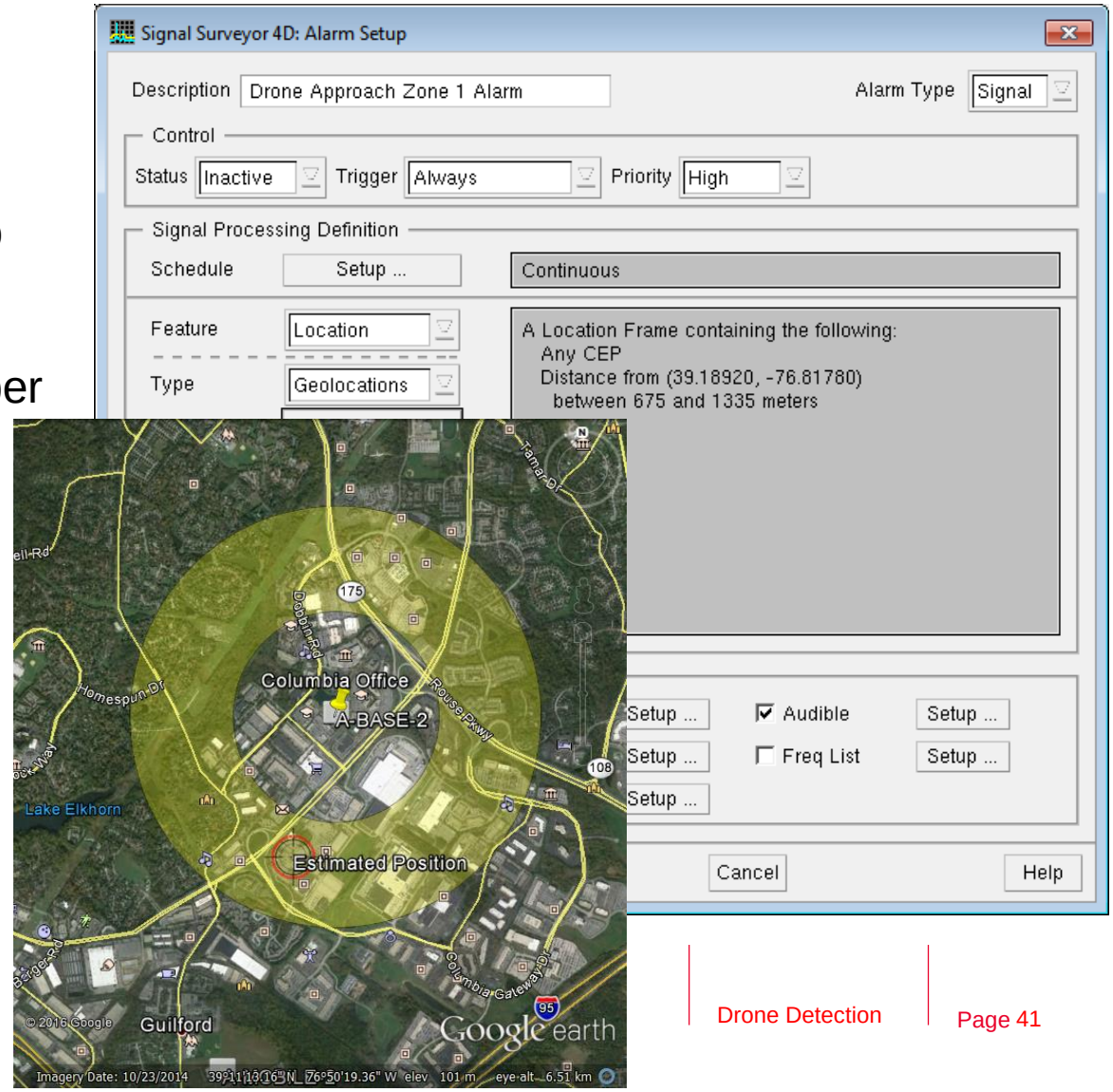


– Classifying and isolating in ISM can also be difficult
  - Signals can be masked by the ISM activity
  - Signals can be hopping across 80 MHz

– Spectral shape correlation can be used to isolate signals of interest in either band

Geo-Fencing

- Point on earth plus radius (in meters)
- Point on earth plus two radius “ring zone”
- Box off zone using upper left, lower right LAT, LONG pair



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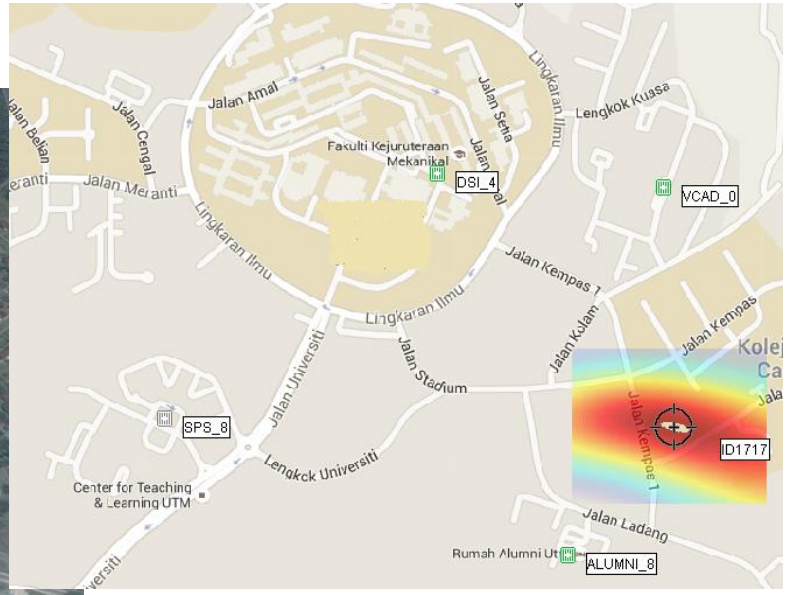
Locating drone controllers using TDOA network

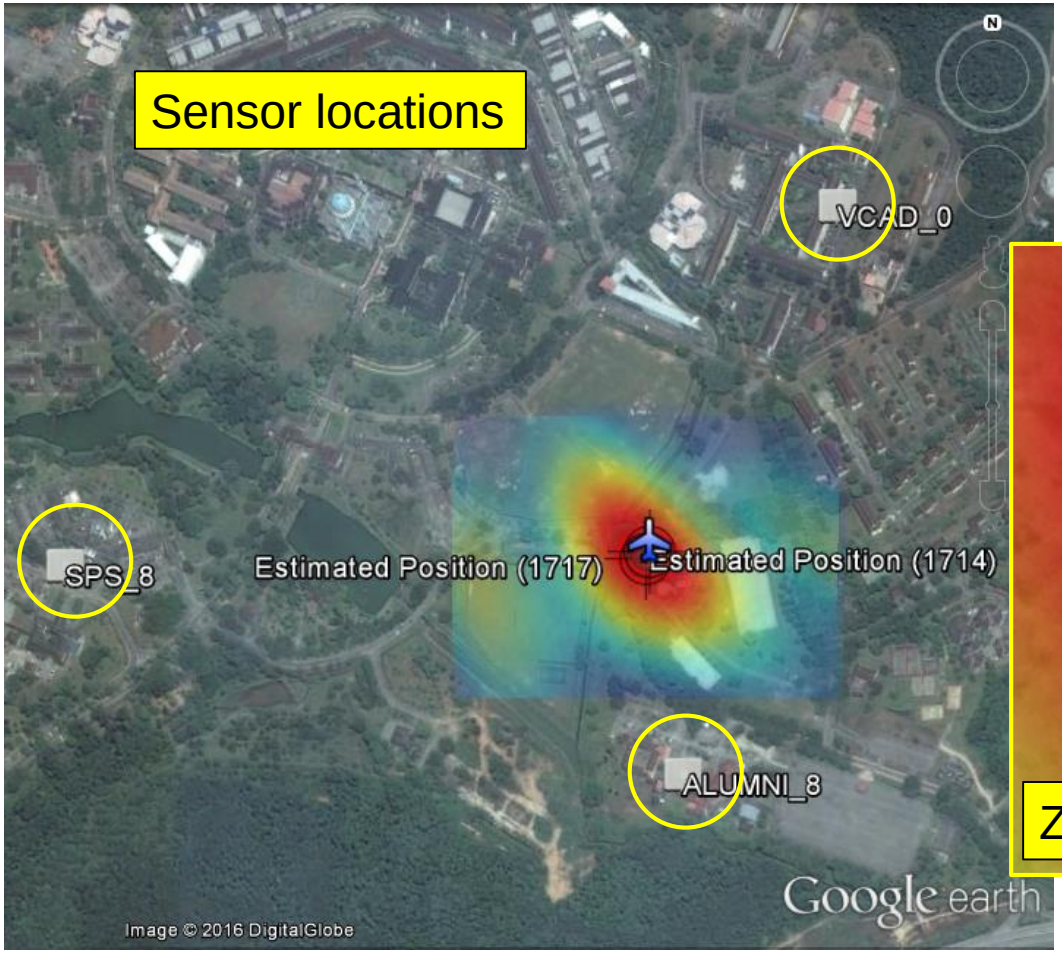
Field Trial data – January 2016

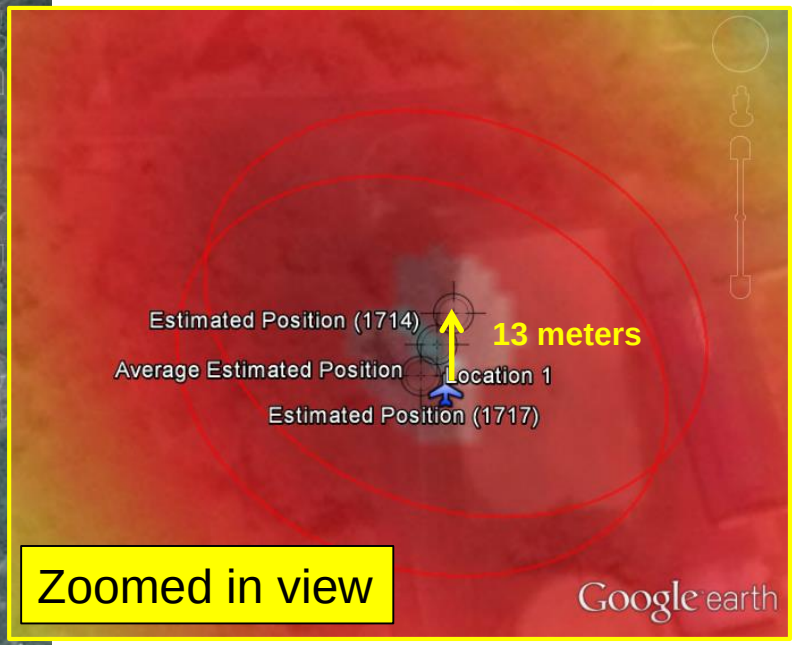
- Keysight conducted a trial with four RF Sensors in a campus setting using Time Difference of Arrival techniques to determine the emitter location (drone controller)
- Sensor separation was 900 meters E-W and 700 meters N-S
- Three test locations were selected.



Drone controller Geo trial – January 2016

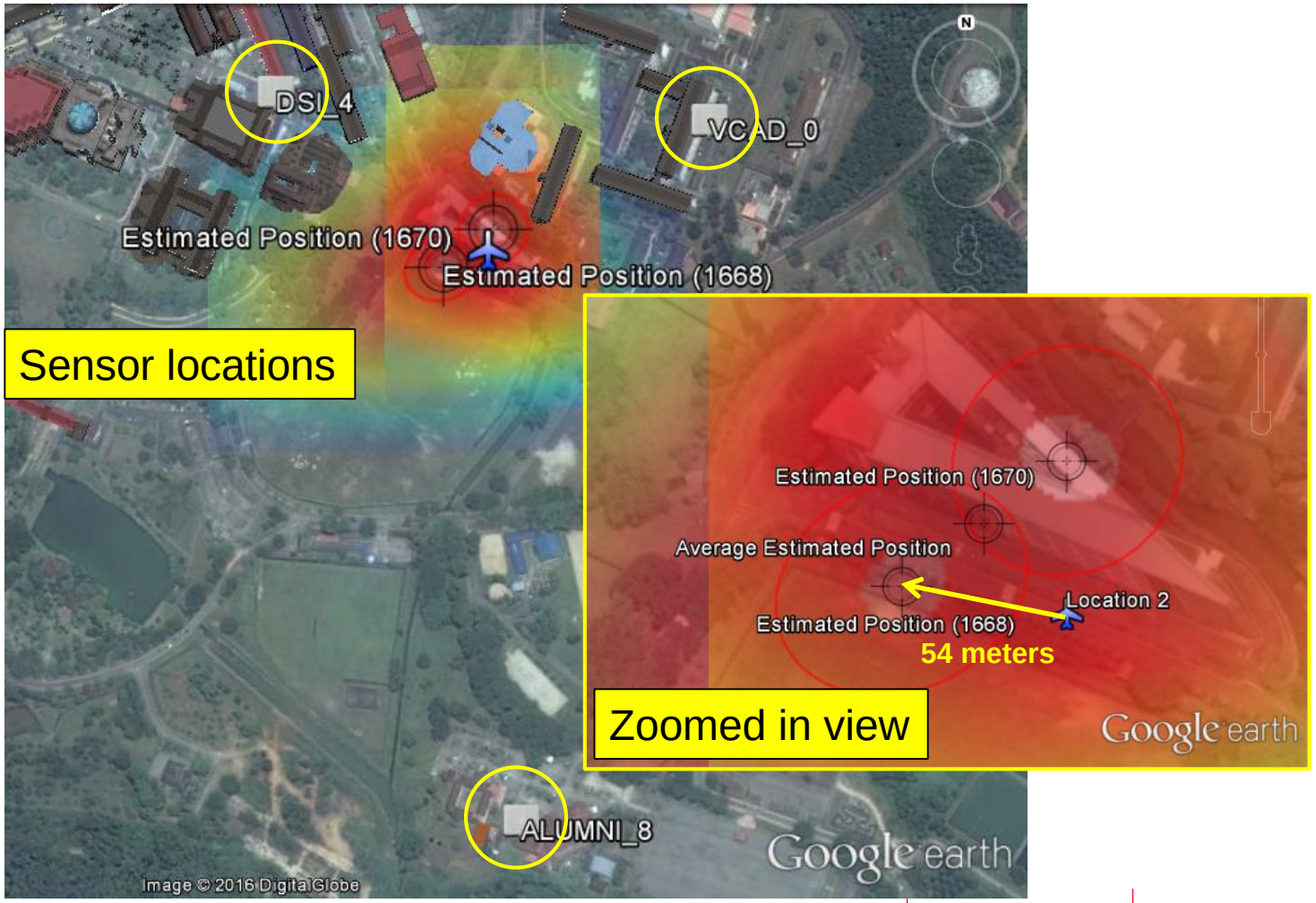
Spektrum *DX6i* Test Location #1





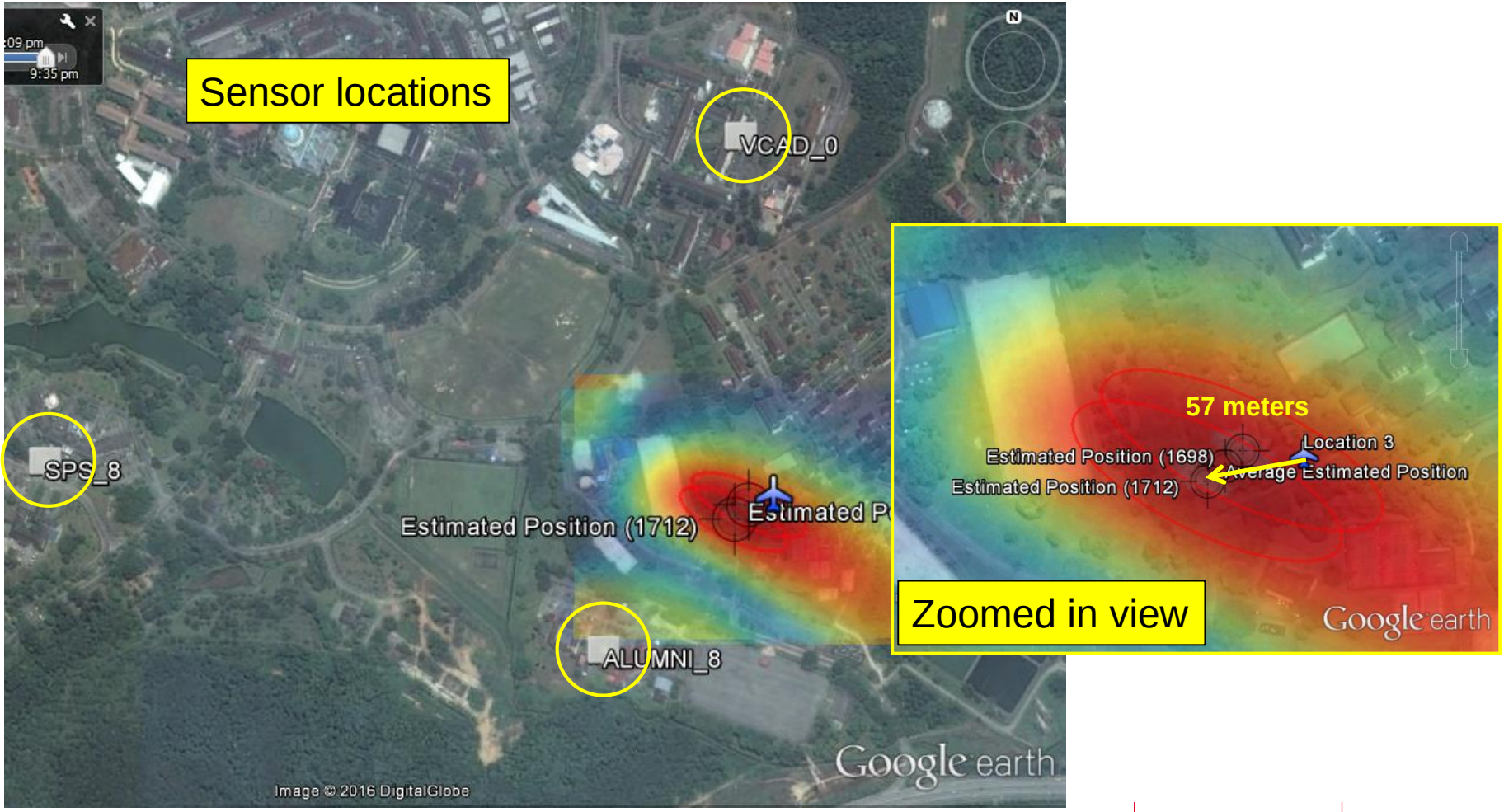
Drone controller Geo trial – January 2016

Spektrum *DX6i* Test Location #2



Drone controller Geo trial – January 2016

Spektrum *DX6i* Test Location #3



Summary

- The drone detection problem is tough, with so many new drones coming on the market
- Only need to focus on a certain set of drones, with enough payload capacity, operating range, and video live feed
- The drone detection problem is made more complicated by the myriad of signals in the 2.4 GHz ISM band
- Using the RF Sensor, you can create drone detection with as few as 3 sensors, to geolocate the drone
- FieldFox with RTSA and directional antenna can help detect drone signals and reach them
- Powerful Keysight software will help you to isolate the signal
- Once located, you can mitigate the drone

Thank you!