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Strategies for Limiting Civil Interference Effects Inspired by Field Observations

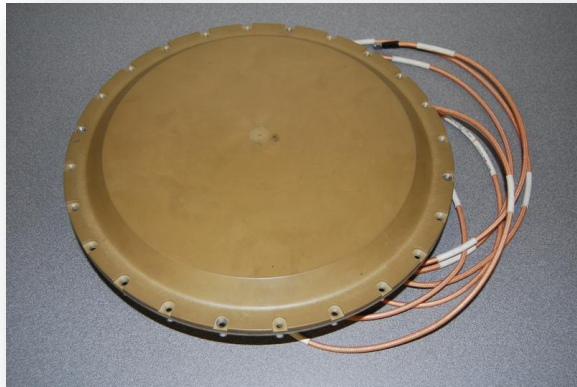
And Why Civil Receivers Need to Have Jamming Meters

Special Thanks to Darren McCarthy of R&S for
Sharing Portland International Airport Results



Logan Scott has 35 years of military and civil GPS systems engineering experience. He is a consultant specializing in radio frequency signal processing and waveform design. At Texas Instruments, he pioneered approaches for building high-performance, jamming-resistant digital receivers. At Omnipoint (now T-Mobile), he developed spectrum sharing techniques that led to a Pioneer's preference award from the FCC. He is a cofounder of Lonestar Aerospace, an advanced decision analytics company located in Texas. Logan has been an active advocate for improved civil GPS location assurance through test based GPS receiver certification, crowdsourced jammer detection and location, and, by adding robust signal authentication features to civil GPS signals. Logan is a Fellow of the Institute of Navigation and holds 36 US patents.

Classic Military Antijamming Strategies Will Not Be Effective in a Civil Environment



SIZE

**Absent These Technologies,
A Knowledgeable Jammer Will Win
(Against A GNSS Signal)**

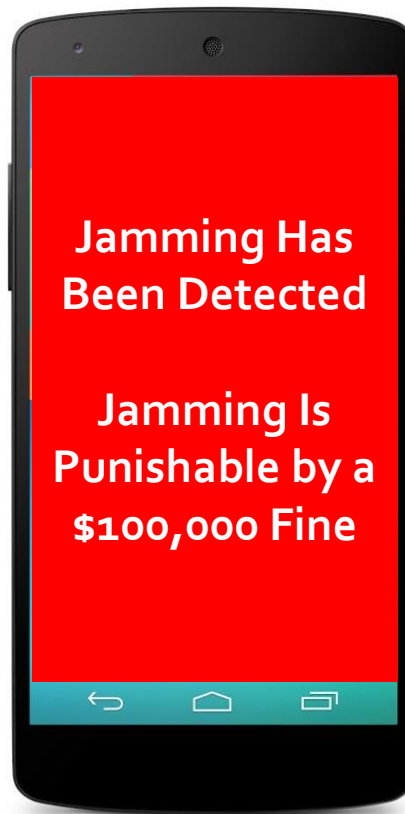


COST

CASUALTIES



How Would a Jammer React If His Phone Did This When He Turned ON?



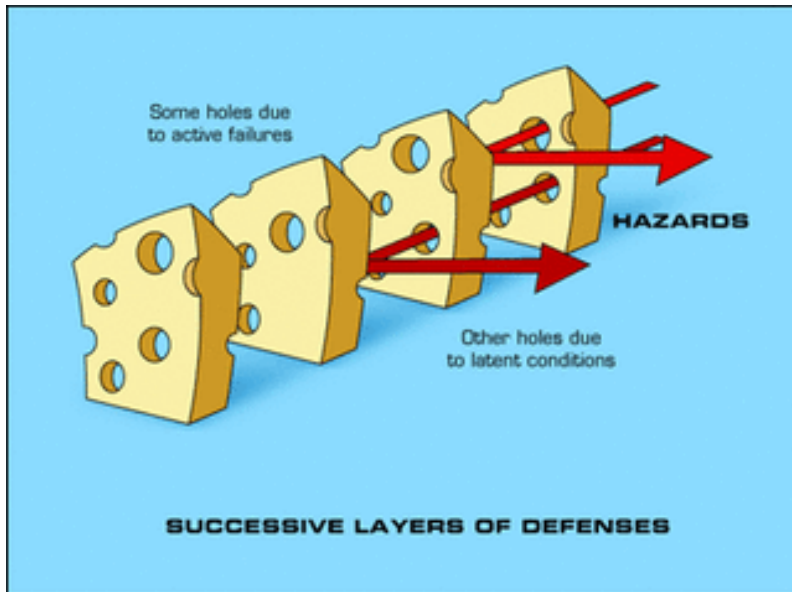
- **Triggering Factors**
 - Jamming Power
 - Jamming Duration
 - Channel Stability

Civil Policy Objective Should Be To Limit The Damage Caused By Jamming

This is Not The Same as “Catching Them” and Putting Them In Jail

1. Discourage People from Acquiring Jammers
2. Get Jammers to Turn OFF / Remain OFF
3. Get Jammers to Limit Their Effective Range
4. Continue to Operate If Jamming Happens

Defending Against Jamming Requires a Multi-Layered Approach



- Legal
 - Jammers are Like Guns
- Education
 - Jammers Are Dangerous
- Enforcement
 - Must Be Able to Detect & Find Jammers
- Resilience
 - Multisource Navigation Guided by Situational Awareness

Why Would Someone Do That?

Motivation Can Indicate Location, Method, and Mitigations

- GPS Jamming and Spoofing (Military)
 - Denial of Navigation to Opposing Forces
 - Create Confusion / Lessen Effectiveness
- GPS Jamming and Spoofing (Civil)
 - Accidental
 - Deliberate
 - Criminal Enterprise (More Likely Reason)
 - Privacy & Safety Concerns (Rising Motivation)
 - Terroristic Exploit (Less Likely Reason)

Civil GNSS Jammers Tend to Be Mobile

WAAS Reference Stations are Seeing Numerous RFI Events

Median Weekly RFI Events
(detected by AGC and longer than 30s)

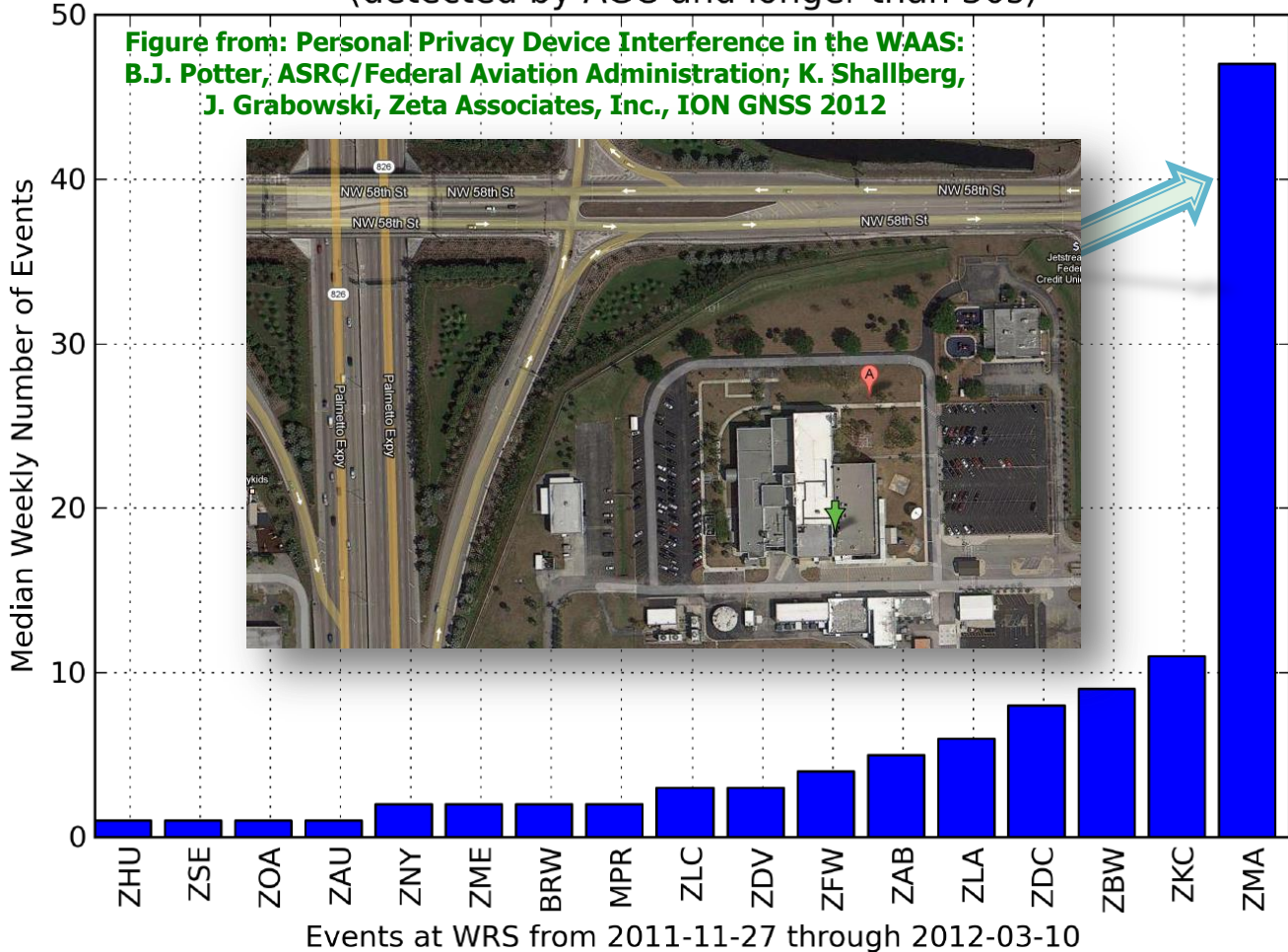


Figure from: Personal Privacy Device Interference in the WAAS: B.J. Potter, ASRC/Federal Aviation Administration; K. Shallberg, J. Grabowski, Zeta Associates, Inc., ION GNSS 2012

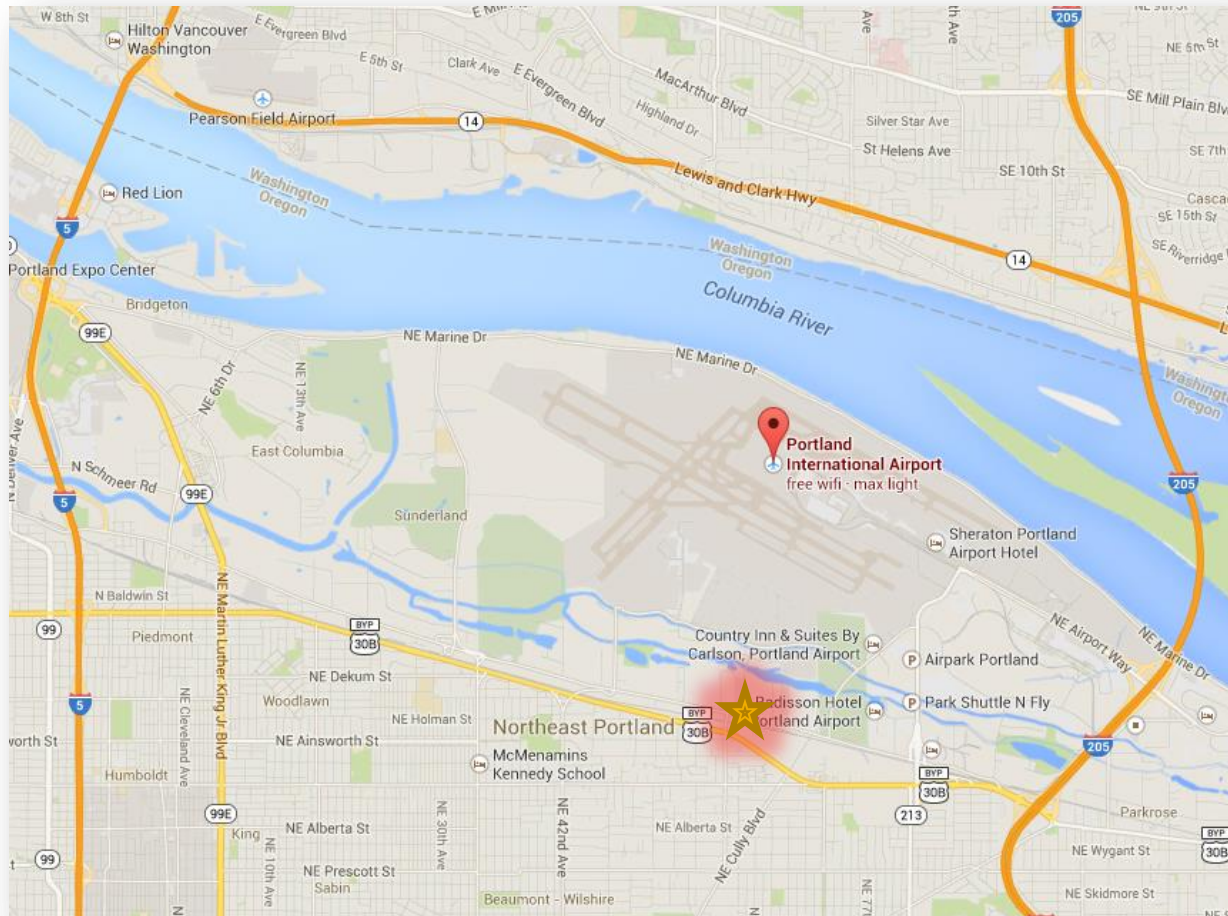


- Isoz et. al. report average of **117 events/day** at Kaohsiung International Airport - Taiwan

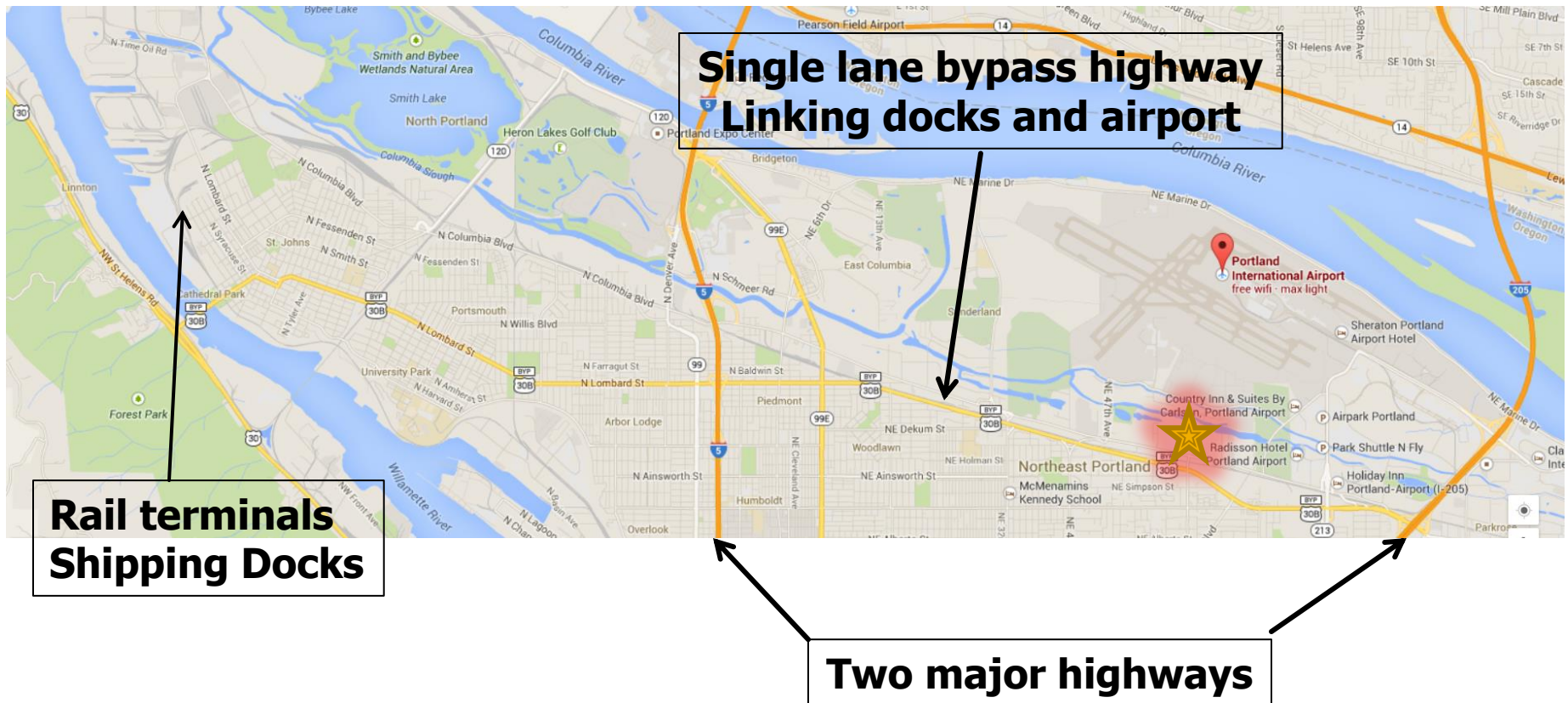
Isoz et al., Assessment of GPS L1/Galileo E1 Interference Monitoring System for the Airport Environment, ION GNSS 2011

Rohde & Schwarz Set Up a Van Based RF Monitor on Highway 30B Near Portland International Airport (PDX)

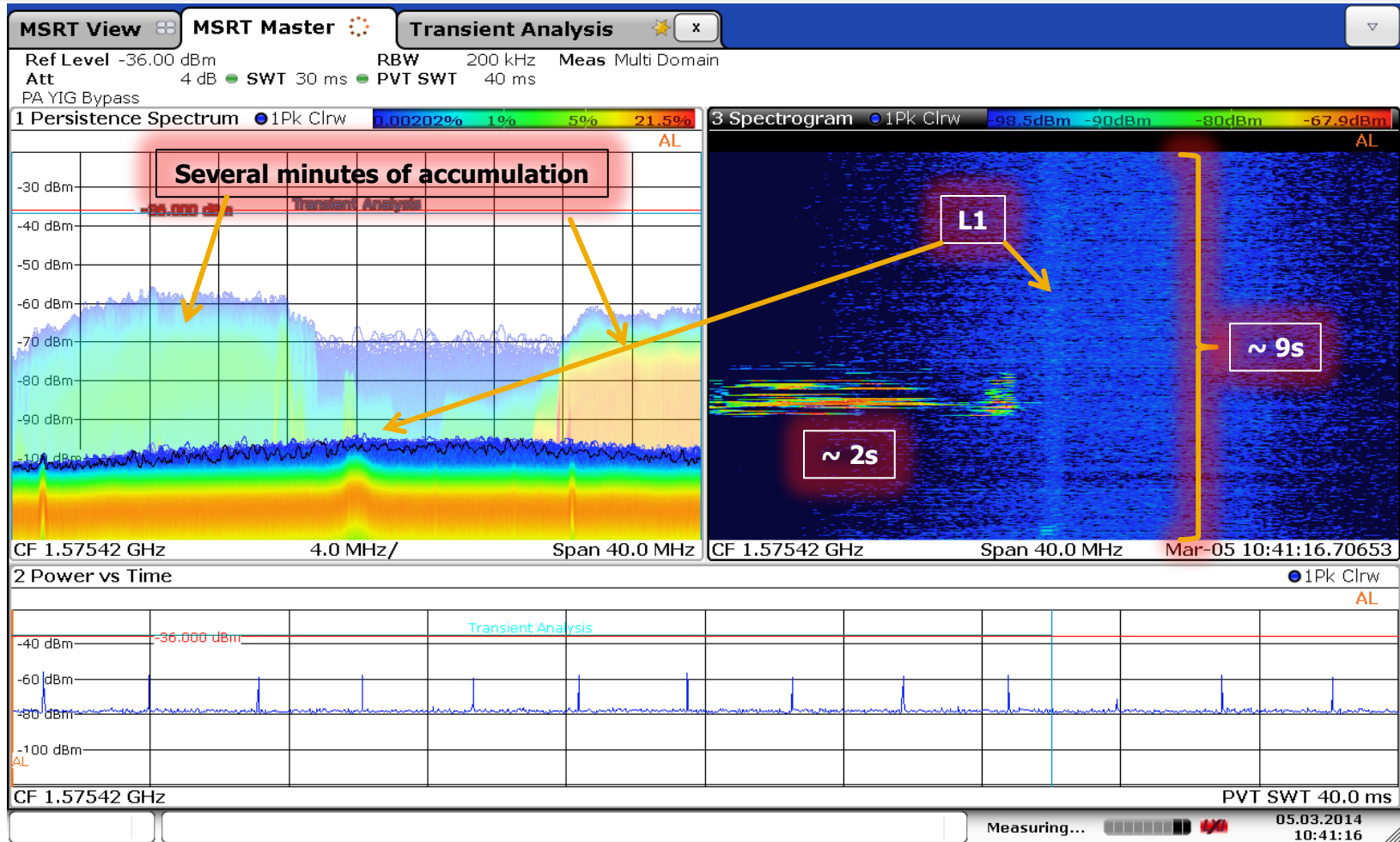
About Every 3rd or 4th Truck Was Radiating At or Near GPS L1



Another perspective



Example Signal of Interest During Parked Observation (40 MHz Span)



Date: 5.MAR.2014 10:41:15

Screen Shot Courtesy of Darren McCarthy of Rohde & Schwarz

Double Tandem Trash Hauler Jammed GPS



- Why?
 - Driver Continued to Jam Even After He Was “Caught”
 - Driver was Visibly Upset and Angry
- What Was He Hauling?



Photo Courtesy of Darren McCarthy of Rohde & Schwarz

Legitimate Hazardous Waste Disposal Is Extremely Expensive

Illegal Dumping is a Multi Billion Dollar Industry

These Are Just the Taxes / Ton



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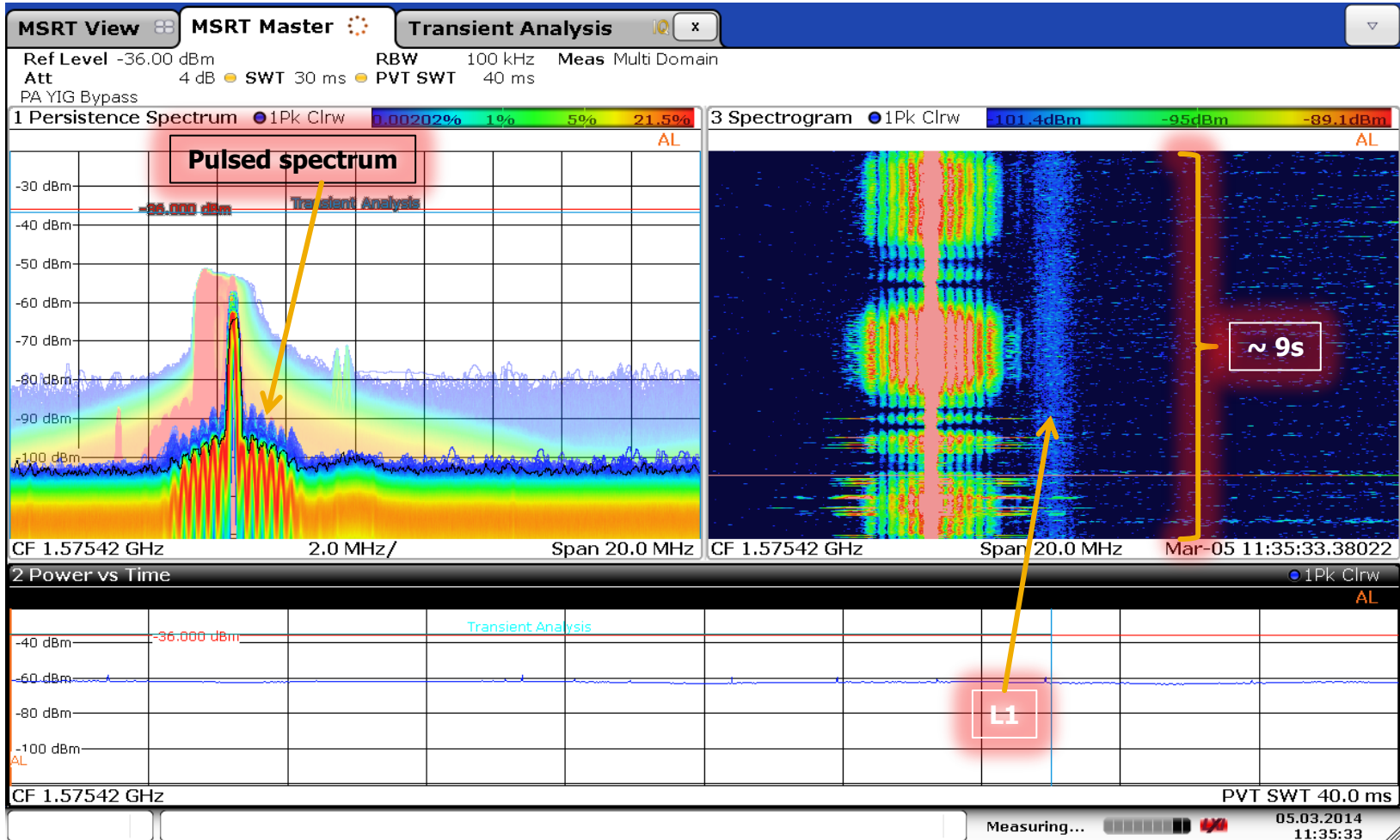
Historical Tax Rates - Special Taxes and Fees

11b. Disposal Fee

Waste Type	Disposal Fee						
	2008	2009	2010	2011	2012	2013	2014
Exempt waste	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Non-RCRA hazardous waste (including asbestos) *	\$19.30	\$20.27	\$19.98	\$20.16	\$20.71	\$21.11	\$21.48
Non-RCRA hazardous waste generated in a cleanup action (excluding asbestos) *	\$5.72	\$5.72	\$5.72	\$5.72	\$5.72	\$5.72	\$5.72
RCRA hazardous waste or hazardous waste not elsewhere classified	\$47.81	\$50.21	\$49.48	\$49.95	\$51.30	\$52.29	\$53.21
RCRA hazardous waste treated to be a non-RCRA or nonhazardous waste *	\$19.30	\$20.27	\$19.98	\$20.16	\$20.71	\$21.11	\$21.48
RCRA hazardous waste generated in a cleanup action and treated to be a non-RCRA or nonhazardous waste *	\$5.72	\$5.72	\$5.72	\$5.72	\$5.72	\$5.72	\$5.72
Mining waste *	\$15.39	\$16.16	\$15.92	\$16.07	\$16.51	\$16.83	\$17.12
Extremely/restricted hazardous waste	\$236.70	\$248.58	\$244.96	\$247.26	\$253.98	\$258.88	\$263.40
Incineration/dechlorination residue	\$5.92	\$6.21	\$6.12	\$6.18	\$6.35	\$6.47	\$6.59

Jammer Operating In Pulse Mode

Jammer Seen Near PDX
from a Tandem Trash Truck.
Why? Motivation?

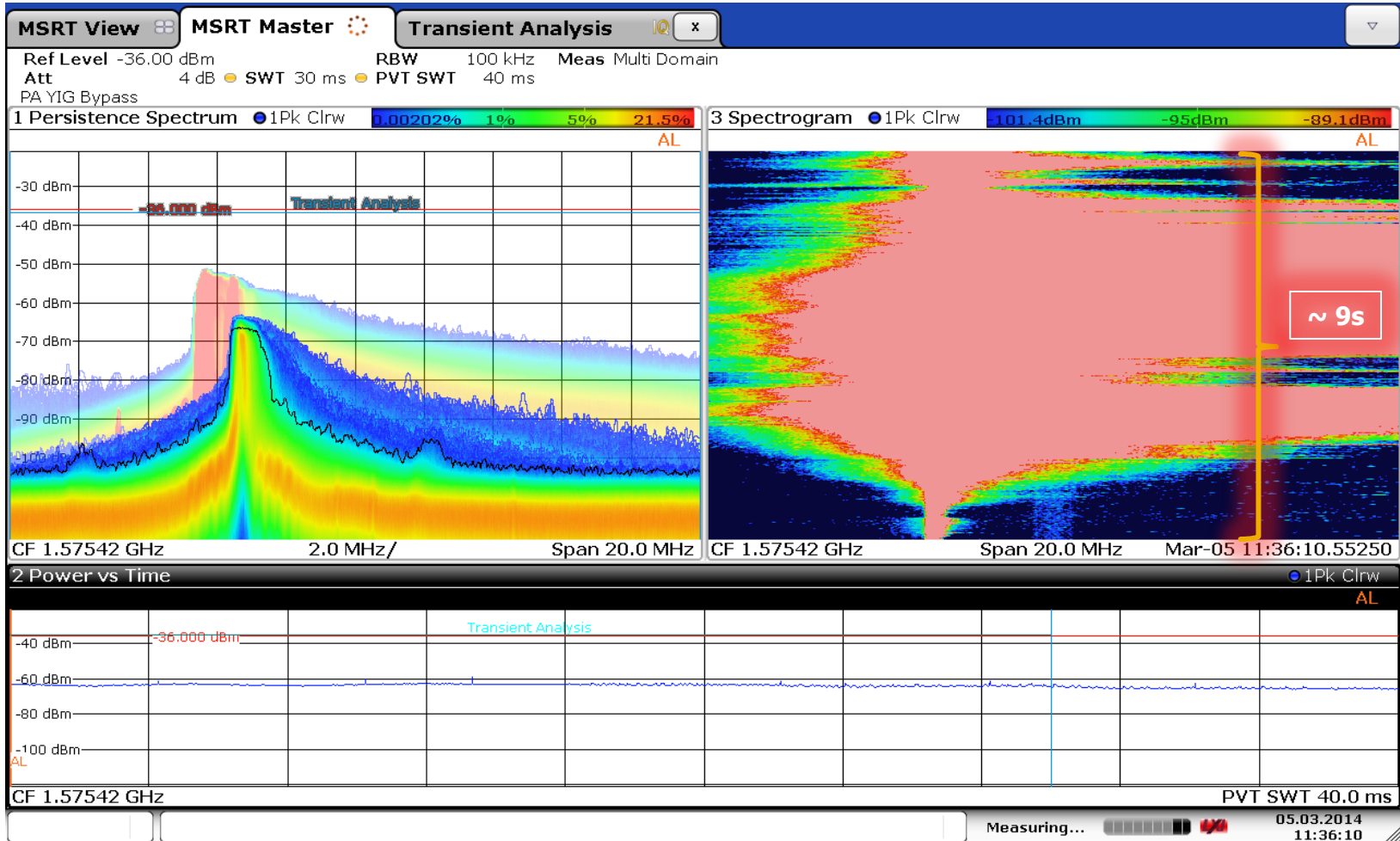


Date: 5.MAR.2014 11:35:31

Screen Shot Courtesy of Darren McCarthy of Rohde & Schwarz

Jammer Operating In Chirp Mode

Jammer Seen Near PDX
from a Tandem Trash Truck.
Why? Motivation?



Date: 5.MAR.2014 11:36:09

Screen Shot Courtesy of Darren McCarthy of Rohde & Schwarz

3 June 2014

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Newark 2012

- FBI Received Complaint
Aug 3 2012
- Using Direction Finding Equipment
FCC Found Parked Truck with Operating Jammer on
Aug 4 2012

Could This Jammer Have Been Found Without Direction Finding Equipment?

Truck driver has GPS jammer, accidentally jams Newark airport

An engineering firm worker in New Jersey has a GPS jammer so his bosses don't know where he is all the time. However, his route takes him close to Newark airport, and his jammer affects its satellite systems.

by Chris Matyszczyk [@ChrisMatyszczyk](#) / August 11, 2013 8:08 AM PDT



The company truck that was tracked.

Misappropriation of Resources Is a Common Jamming Motivation

Situational Awareness Can Mitigate Interference

Another
Motivation for
Receiver
Certification

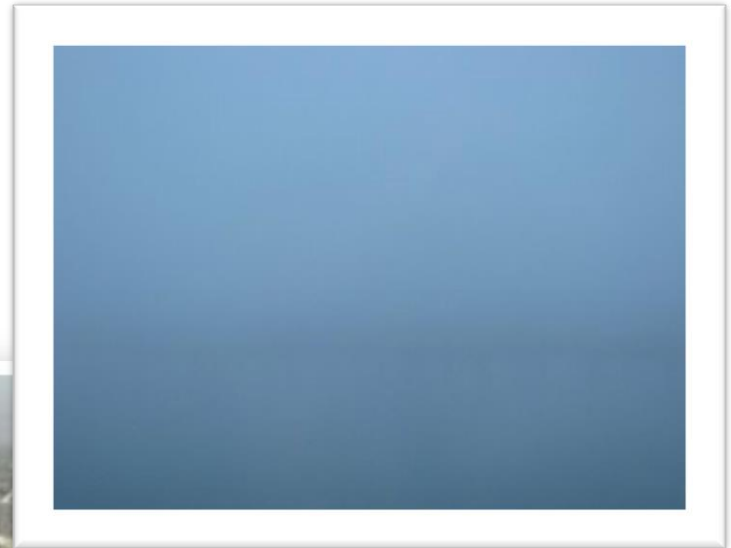
- Resources with Location Reporting Include:
 - **Garbage Trucks, Company Vehicles**, Taxis, Tractor Trailers, Construction Equipment, Emergency Services, Farm Equipment, Shipping Containers, White Vans etc.
- These Resources Are Usually Employee Operated
- **If** Interference/Signal Loss Is Detected for Extended Time:
 - This Should Raise Red Flags
 - Receiver on Asset should “Light Up” Warning Operator => **Jammer OFF**
 - Employer Can Take Enforcement Action => **Jammer OFF**

Aviation Is Not the Only Concern

The St. Lawrence Seaway Is Paralleled By Highways and Can Get Foggy



There Is a Ship In This Picture Too!



A Transport Quebec image of ice fog lifting off the St. Lawrence River onto Highway 20 near L'Île Perrot.

Road User Charging (RUC) Motivates Jamming (and Spoofing)



- Fraud Detection Is Essential
- Detected Jamming Should Raise Red Flags



California eyes \$3 billion RUC scheme to fund maintenance

Two of California's biggest transport coalitions have proposed a Road Repairs Fund, charging road users to create \$3 billion for highway maintenance.

Transport California and the California Alliance for jobs jointly submitted proposals to the California Attorney General, which they reckon if approved by voters, would raise \$3 billion annually to fix the Golden State's deteriorating roads, highways and bridges.

The proposed California Road Repairs Act of 2014 would impose a fee of 1 per cent of the market value of the vehicle.

Will Kempton, former head of Caltrans who leads the non-profit advocacy group Transport California, said the initiative would ask voters as early as November 2014 to

gradually increase vehicle registration fees over four years.

Pointing to California's impending financial crisis for road works, the proposal declared that poor road conditions cost Californian drivers more than \$600 each year in vehicle maintenance, and that worsening congestion costs motorists an estimated \$18.7bn every year in lost time and fuel – not to mention environmental pollution.

It presented the idea that every dollar of maintenance work that is put off, will end up costing \$50 in more expensive replacements and repairs later on. And it represented findings according to a recent report by the California Transport Commission, that 58 per cent of state roads need improvements.

Wider UAS Applications Could Motivate Jamming Targeting Airspace

- Particular Concerns
 - Targets Aviation
 - Jamming Navigation Signals Is Effective; It Grounds or Destabilizes UAS
- Jamming a UAS Is Anonymous
 - Hard to Assign Blame
 - Offender Is Unlikely to Be Caught

LAW & DISORDER / CIVILIZATION & DISCONTENT

High in the sky: Drones spot pot farms so criminals can rob them

Heat from grow lights gives away growers to surveillance by would-be Omars.

by Sean Gallagher - Apr 18 2014, 8:53am MDT

CYBERWAR PRIVACY 1



Microdrones GmbH

Fans of *The Wire* will remember how the fictional **Omar Little** made a livelihood off robbing drug dealers. Now imagine how much easier his job would have been if he had his own eye in the sky. While police departments in the US are now starting to adopt drone technology for surveillance, some criminals in England have been turning the technology to their advantage to target victims—specifically, marijuana growers.

Challenges In Locating GPS and Cellular Jammers



GPS + Cellular + WiFi Jamming Devices are Fairly Common

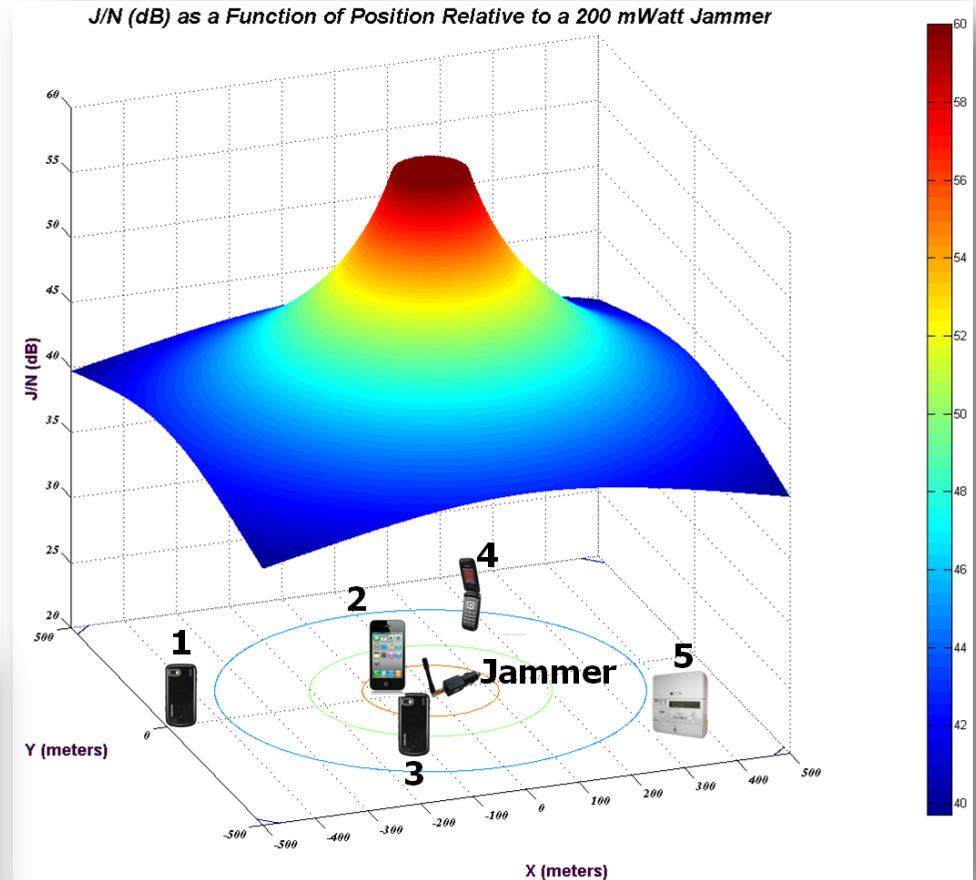


Crowdsourcing for Jammer Detection & Location (J911)

Geographic Coverage Is the Challenge for IDM Systems; Detectable Range May Only Be a Few Hundred Feet and Multipath Effects Can Be Severe

Collaborative Defense

- Devices Report Jamming Parameters & Own Position to J911
- Using Aggregate of Reports, J911 Can Determine Jammer *Position to ~ 40 meters in near real-time*
- J911 Can Report Interference Events to Networked Users (Like Traffic Reports)



from Logan Scott: J911: *The Case for Fast Jammer Detection and Location Using Crowdsourcing Approaches*, ION-GNSS-2011, September 20-23, 2011

Possible Outcomes of Improved Detection & Localization

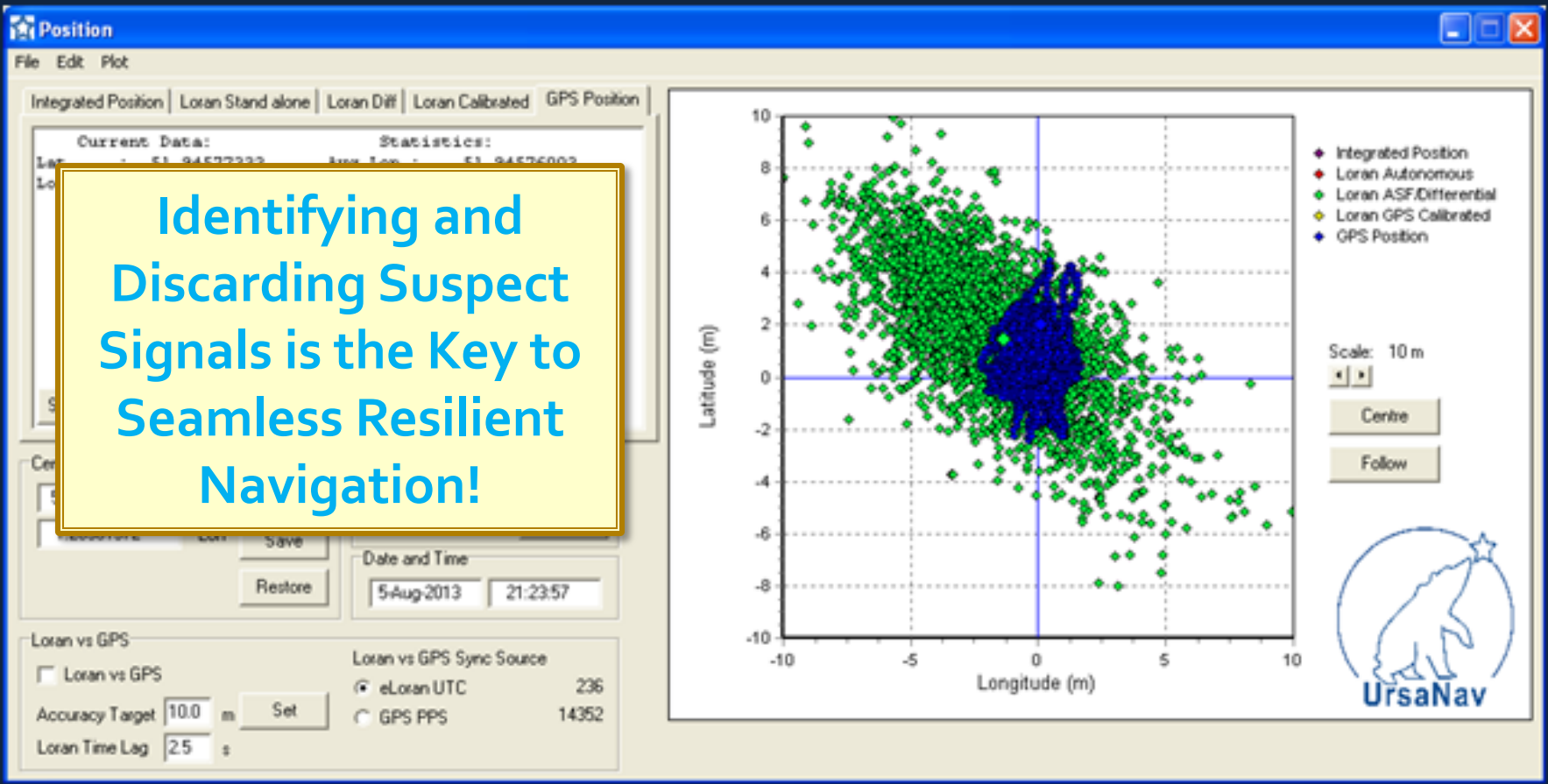
- Jammers Less Likely
- Jammers will move towards lower power but more effective waveforms
 - Reduces IDM Detection Range
 - Raises Cost for Fixed Infrastructure Approaches
 - Simple Receiver Based Antijamming techniques become less effective
 - Blankers, ADC Tricks etc.
- Becomes harder to prove an item is a jammer
 - Software Defined Radios



Jamming Meters Provide Situational Awareness

They Are Easy To Explain & Implement

1. Can Alert Asset Owners of Misappropriation
2. Provide Basis For Crowdsourced Detection
3. Alerts Users to Potential PNT Problems
 - Hazardously Misleading Information
 - Spoofing Detection
4. Identifies Suspect Signals for Resilience



➤ GPS offset 0.6 m, 2.2m (95%) from surveyed position

Used Courtesy of UrsaNav Inc

Situational Awareness Creates Herd Immunity

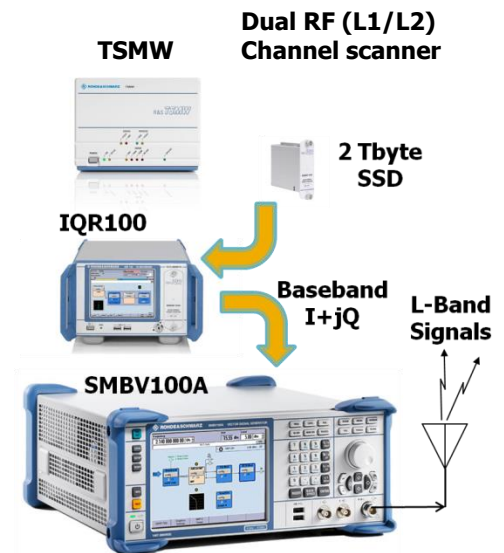
- If Jammers are Detected and Localized
 - Jammers are Less Likely to Be Purchased
 - Jammers Are Less Likely to Turn ON
 - Jammers are Less Likely to Cause Damage

**Civil GNSS Receivers Should Have
Jamming Detection as a Matter of
Good Policy**

Backup

J911 Proof of Concept Field Demonstration Program (1/2)

- Objectives
 - Demonstrate J911 jammer locating ability and determine jammer location accuracy statistics using field test data.
 - Characterize propagation channel and J/N (J/S) statistics as a function of range to the jammer in differing environments.
- Collection Method Does Not Jam GPS
 - Setup "Jammer(s)" somewhere in the **1710-1755 MHz band** and **record georeferenced I/Q data** in a variety of well described environments (e.g. Urban, Suburban, Airborne)
 - Good point space / materials maps desirable
 - Make meta-tagged recordings available to academia and industry



J911 Proof of Concept Field Demonstration Program (2/2)

- Database Applications
 - J911: Synthesize grid of cellphone reports with varying accuracy assumptions, reporting densities etc.
 - Apply various processing methodologies to geolocate jammer.
 - e.g. Corrected propagation based on pointspace database vs. generic propagation models
 - SA: Develop Improved Situational Awareness Algorithms based on Propagation Impaired View of Jammers
- Stimulate Collaborative Efforts Across Industry and Academia
- **Recruit People to The Problem**

ION is Pursuing Development of an XML Metadata Standard for Stored Recordings/Scenarios based on Response to:

A Universal GNSS Software Receiver MATLAB® Toolbox for Education and Research
Sanjeev Gunawardena
Ohio University

Possible Outcomes of Improved Detection & Localization

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Finding GPS / Cellular Jammers Blockers Is Highly Asymmetric From An Economic Perspective

You Are Looking for a \$25 Device

26, September, 2013

Google

Shopping About 1,180 results (0.30 seconds)

Web Your location: Fort Collins, CO - [Change](#) Sort by: **Default**

[Shopping](#) [Why these products?](#)

More

Show only

In stock nearby

New items

Any category

Knitting & Crocheting Patterns

Car Audio & Video

Any price

Up to \$50

\$50 - \$150

\$150 - \$400

Over \$400

\$ to \$

Any store

DHgate online store





AliExpress.com

Walmart

eBay - martinhod

eBay

More

	selling mini car gps blocker anti-gps tracker gps isolator block gp selling mini car gps blocker anti-gps tracker gps isolator block gps signal for car vehicle Add to Shortlist	\$27.17 Free shipping DHgate online store
	New Car Use Mini Gps Blocker/isolator Anti-gps Tracker New Car Use Mini Gps Blocker/isolator Anti-gps Tracker Add to Shortlist	\$16.09 Free shipping DHgate online store
	new car use mini gps blocker/isolator anti-gps tracker new car use mini gps blocker/isolator anti-gps tracker Add to Shortlist	\$12.86 Free shipping DHgate online store
	handheld devices car gps blocker anti-gps tracker gps isolator block handheld devices car gps blocker anti-gps tracker gps isolator block gps signal for car vehicle Add to Shortlist	\$41.30 Free shipping DHgate online store

In Principle: Finding A Jammer Is Easy

In Fact: Finding a Jammer Is Not Easy

- Angle of Arrival (AOA)
 - 2 Lines of Bearing
 - Large Array, Very Sensitive to Multipath
- Time Difference of Arrival (TDOA)
 - Well Known Cross Correlation Techniques
 - Precise Timing, Not Good with Narrowband Sources
- Frequency Difference of Arrival (FDOA)
 - Doppler Depends on Relative Velocity
 - Not Good with Wideband Sources
- Low Power Jammers => Short Detection Range
 - Portland OR, ~550 receivers

**And If He Is
Mode
Switching?**

Density of 1000 Phones/km² Is Common in Urban Areas

City	Population (thousands)	Geographic Area (km ²)	Phone Density (Phones/km ²)
Peoria, IL	112.9	115.0	687.4
Portland, ME	62.9	54.9	801.7
Fort Collins, CO	138.7	120.5	805.7
Dallas, TX	1299.5	887.2	1025.3
Portland, OR	582.1	347.9	1171.2
Washington, DC	599.7	159.0	2640.0
Newark, NJ	279.0	61.6	3170.2
New York, NY	8391.9	789.4	7441.5

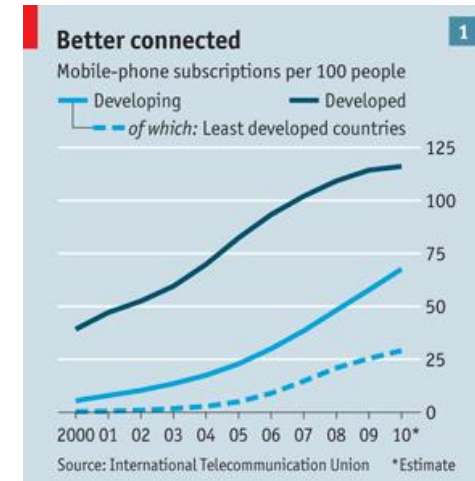


Figure from: The Economist, Jan 27th 2011

Assumes 70% of Population Carries A Cell Phone

User Community Needs, Pragmatic, Test Based Receiver Certification to Aid in the Selection Process

This Is Penetration Testing

- Start With Basic Situational Awareness Standard
 - RTCM Standard?
 - DHS Sponsor?

This Is
Emphatically
NOT 7 "9"s
Testing

- Level 1 Certification Tests For:
 - J/N Measurement
 - Jammer Type Identification
 - Basic Spoofing Detection
 - RAIM + Discontinuity Detection

**What is the value of a
silent smoke alarm?**

Must Report with Maximal
Effort
•Display/Alarm

- Higher Levels Certifications for Cryptographic & Physical Security
- Level 1 Draft Posted at My Website
 - <http://logan.scott.home.comcast.net/~logan.scott/Critical%20Infrastructure%20GPS%20Certification.pdf>

Civil Defenses Emphasize Situational Awareness, Uncorrelated Vulnerabilities, and Agility to Operate in Impaired Environments

The Whack a Mole Defense

Common Smart Phone Capabilities

- Sanity Checks and Signal Authentication to **Identify & Discard Suspect Signals**
- Global SatNav Systems
 - GPS L1/L2/L5 (31 SV)
 - GLONASS (23 SV)
 - BEIDOU (Compass) (14 SV)
 - GALILEO (4 SV)
- Regional SatNav Systems
- Some Other Navigation Sensors
 - WiFi
 - Cellular TOA/TDOA
 - IMU (\$3.35 in iPhone4)
 - Magnetic Field Sensor
 - Point Space Database
 - Atomic Clock or Equivalent
 - Localites
 - Barometric Altimeter
 - eLORAN
 - **Authenticatable Certified Systems**
- Size, Weight, Power, Cost & Export (ITAR) Considerations are Paramount



Look for Consistency Between Observables!