quasar Assessing **real life** benefits of Cognitive Radio

# The Commercial Sweetspot of Secondary Spectrum

- Preliminary findings of QUASAR

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ECC/COST-TERRA Workshop on CR and SDR, Mainz, Germany

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# QUASAR

## QUantitative Assessment of SecondARy spectrum

- Duration: 30 months (Jan 2010 – June 2012)

- Eleven partners
  KTH, Aalto, RWTH, UKIM, Yonsei
  Ericsson, BT
  PTS, BNetzA, Ofcom, Ficora

**QUASAR Objectives:**

- **Remove the "hype" from CR and DSA discussion**

- **Justified and quantified spectrum opportunity models**

- **Enable real business and deployment decisions**

# Key question

- **Is there secondary spectrum out there that lends itself for commercial use ?**
  - Can it be detected efficiently ?
  - Is there enough spectrum of “sufficient quality” .. Does it scale?
  - Can it be efficiently shared/distributed among users ?

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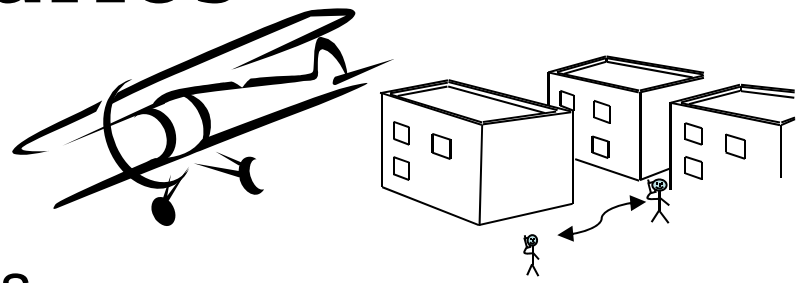
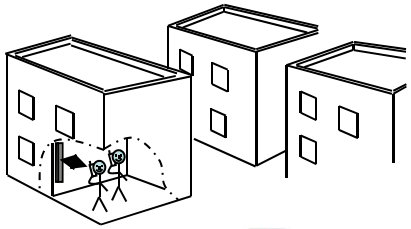
# QUASAR Methodology

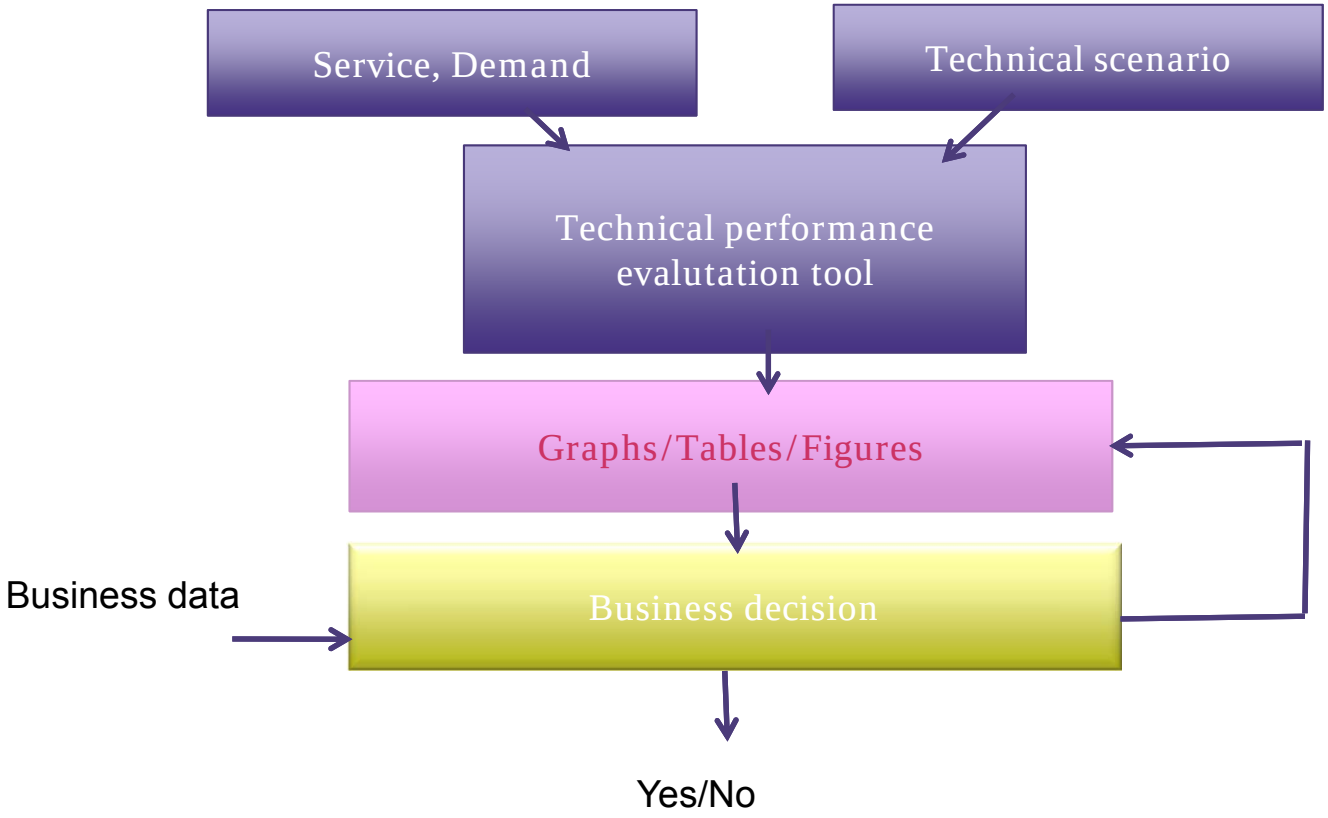
# Scenarios



1. Cellular use of white spaces
2. WiFi-like use of white spaces
3. Secondary wireless backhaul
4. Secondary spectrum commons in radar band
5. Indoor broadband in aeronautical spectrum
6. Cognitive machine-to-machine

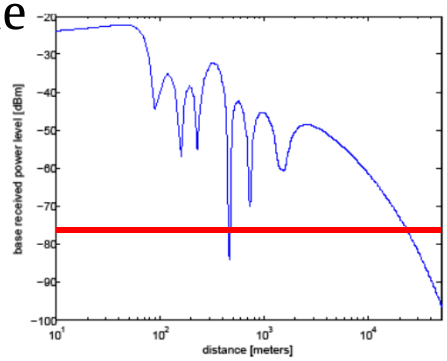


# Methodology for assessing Techno/Economics feasibility

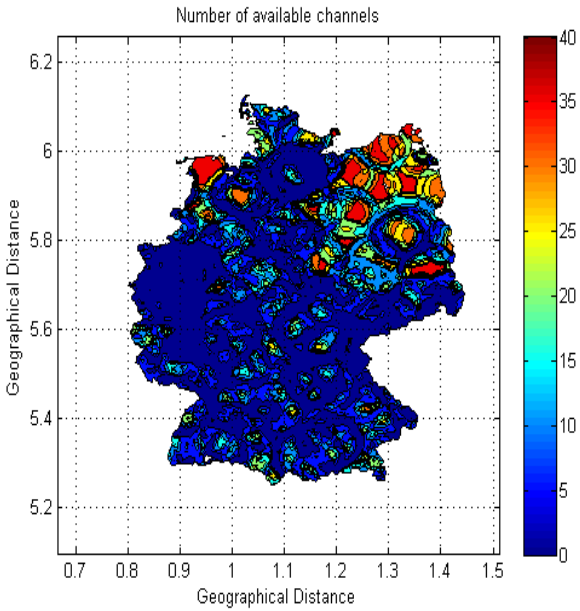


# Technical Assessment –

## Cellular in TVWS example




ITU-R P.1546.
Tx height 200m, $P_{Tx}$= 47dBW




### Evaluation methodology:

- Develop relevant definitions of white space (secondary system dependent)
- Simulations based on DTV Tx databases (locations, Tx power) & propagation models
- Measurements to verify models

### Expected output:

- Assessment of the usefulness of the white space for secondary usage
- Secondary system performance
- White space availability maps

# Business Analysis

- **Business requirements parameters**
  - Average spectrum availability
  - Spatial availability distribution
  - Correlation  Availability – Population density
- **Performance comparison parameter:**
  - ”Equivalent exclusive spectrum”

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# Important technical findings

# Key technical findings

- **Plenty of spectrum available – but very scenario & location specific - commercial success is where we can live with this**
- **Aggregate interference critical for the scalability – massive use of secondary spectrum**
  - Both co-channel & and adjacent channel interference has to be considered
- **”Cognitive” sensing is not very effective in most popular scenarios – geolocation based techniques are preferable**
  - Limited knowledge of victim receiver location
  - Difficult to assess aggregate interference
  - Sensing interesting to improve/calibrate database propagation models

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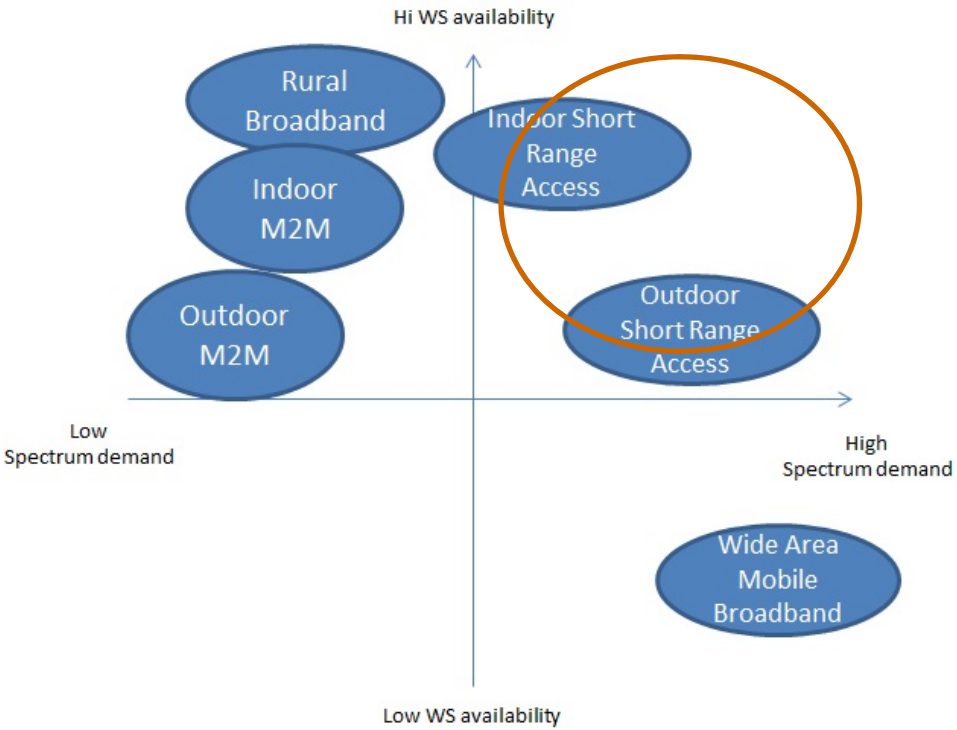
# The Commercial Sweetspot

**Key findings:** Which of the QUASAR scenarios are commercially promising?

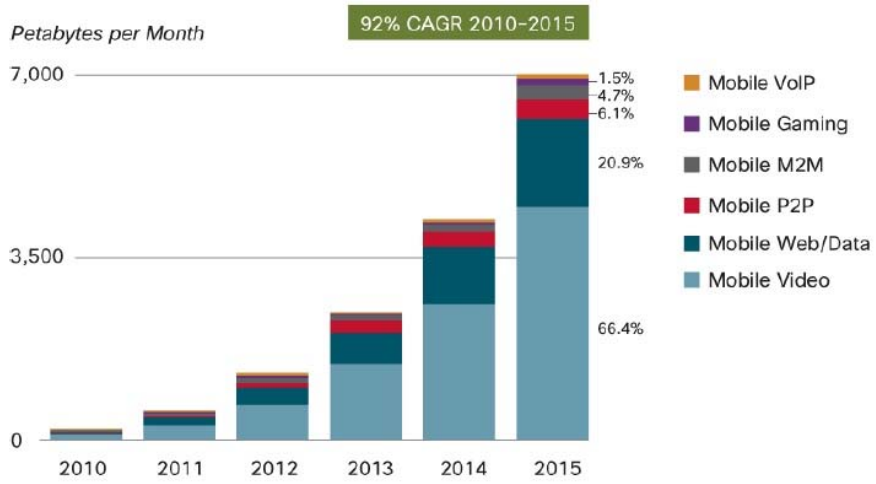



The **"Commercial Sweetspot"** of secondary spectrum

**Short range/indoor high capacity systems** = where large demand for and technical availability of spectrum meet

# ”White Space Offloading”

- More spectrum needed
  - More capacity, less energy
- Mostly short range deployment
  - Hot spot/Indoor capacity enhancement
  - Low cost equipment
  - Complement wide-area access services
- White Space Offloading
  - Low cost wireless equipment
  - Most investment in fixed infrastructure
  - Access to specific spectrum not critical




VoIP traffic forecasted to be 0.4% of all mobile data traffic in 2015.
Source: Cisco VNI Mobile, 2011

# Densification: Technology shift

- Industry grade eq
- High power/long range
- Carefully planned deployment – outdoor
- 24-7 availabilty
- Backhaul critical & expensive
- High **system** complexity
- **COST = equipment, site, spectrum, energy, maintenance**

- Consumer grade eq
- Low power/Short range
- Massive deployment – mainly indoor
- Reliability through redundancy
- Deploy where backhaul available
- Low **system** complexity (?)
- **COST = Deployment**

# Spectrum options for offloading

| | Exclusive <6 GHz | Shared < 6 GHz | Secondary <6 GHz | Exclusive > 10 GHz |
|---|---|---|---|---|
| Availability | Very Low | Low (100 MHz) | Good (>1 GHz) for indoor use | Very good |
| Advantages | • Guaranteed QoS<br>• Long-term investments<br>• NLOS propagation | • Spectrum available<br>• Low cost equipment<br>• ”Adhoc” deployment (NLOS) | • Spectrum available<br>• Low cost equipment<br>• ”Adhoc” deployment (NLOS) | Very high capacity<br>Low interference |
| Disadvantages | • High spectrum cost<br>• Low availability | • No QoS guarantees<br>• Low availability | • Limited QoS guarantees<br>• Regulatory uncertainty | LOS propagation<br>Small antennas<br>Planned deployment |

# Other scenarios

- **Rural Broadband & M2M based on secondary spectrum**
  - Technical feasible, opens market for new actors – but plenty of excess capacity in traditional licensed spectrum
- **Wide –area cellular based on secondary spectrum**
  - May work is some (rural)areas, but technical availability is too limited/erratic where the large demand is to motivate long-term investments

# Conclusions

- A **metodology** for assessing the technical availability of spectrum and the business requirements
- **Plenty of spectrum available – but very scenario & location specific**
- **”Cognitive” sensing not very effective in many popular scenarios – geolocation based techniques preferable**
- **The ”Commercial Sweetspot” of secondary spectrum**
  - **Short range / indoor high capacity systems** =where large demand for and technical availability of spectrum meet

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Thank You for Your attention!

http://quasarspectrum.eu

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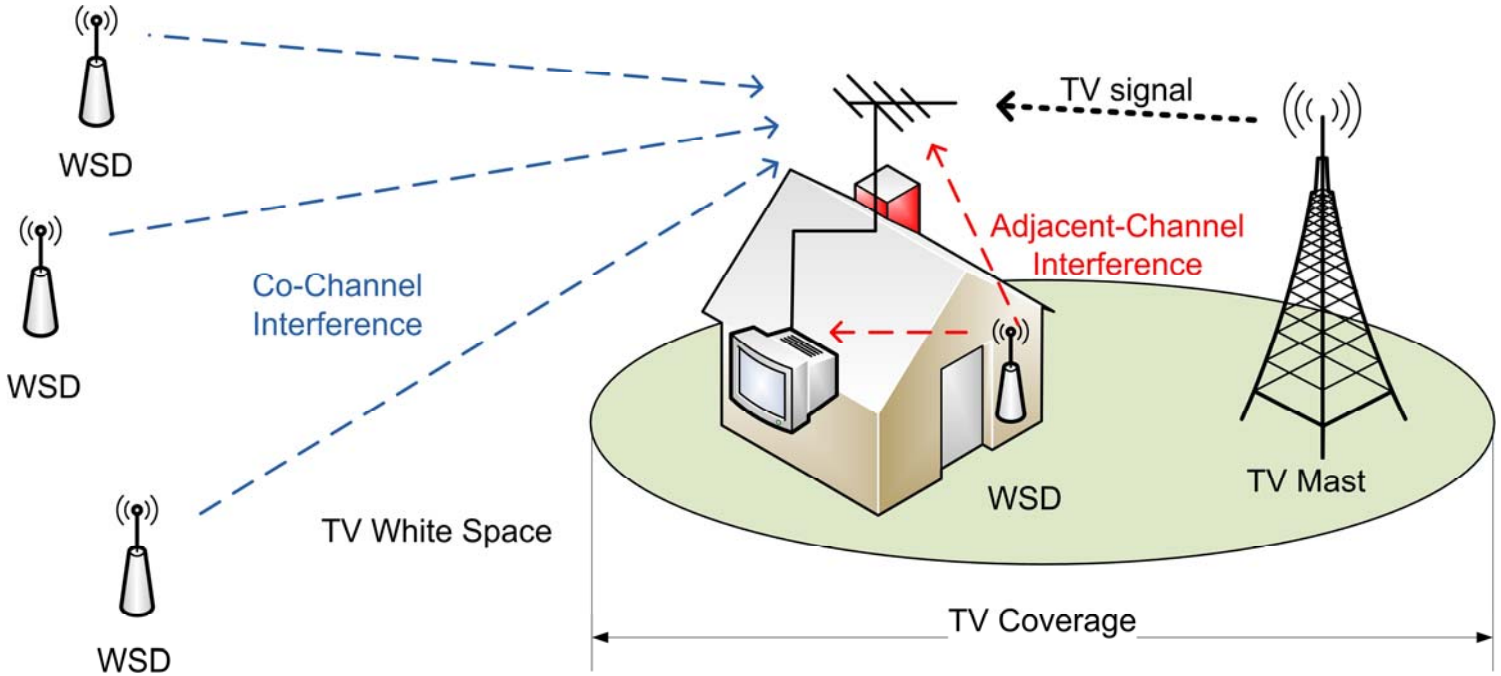
# Additional Slides

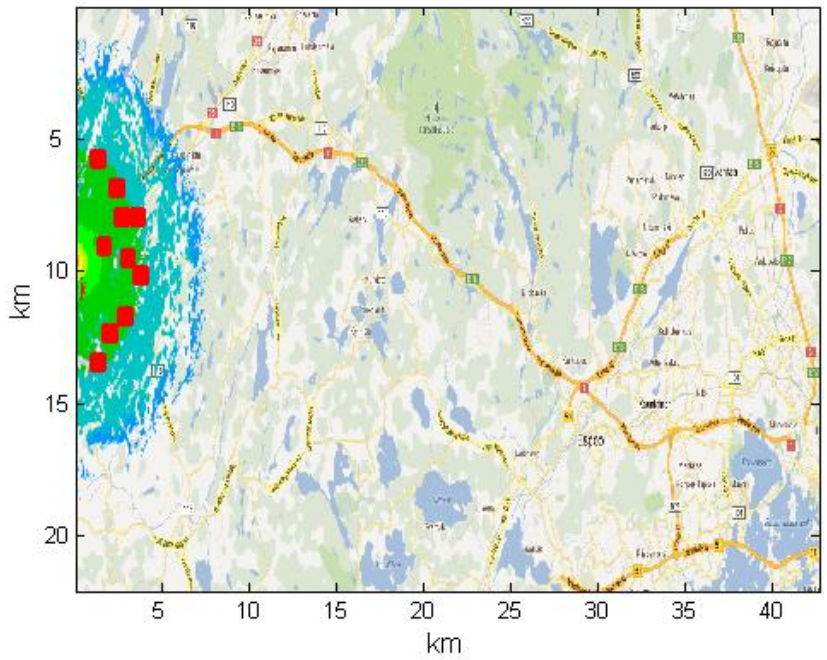
# Prerequisites for successful sharing

- **Exploit differences in utilization patterns between primary and secondary**
  - Temporal: Secondary system use spectrum when primary is not active
  - Spatial: Short range secondary system co-exists with long-range/wide-area system
- **Reliable information about primary transmitter/receivers**
  - Fixed primary system with known behavior
  - Reliable estimates/measurements or statistical information

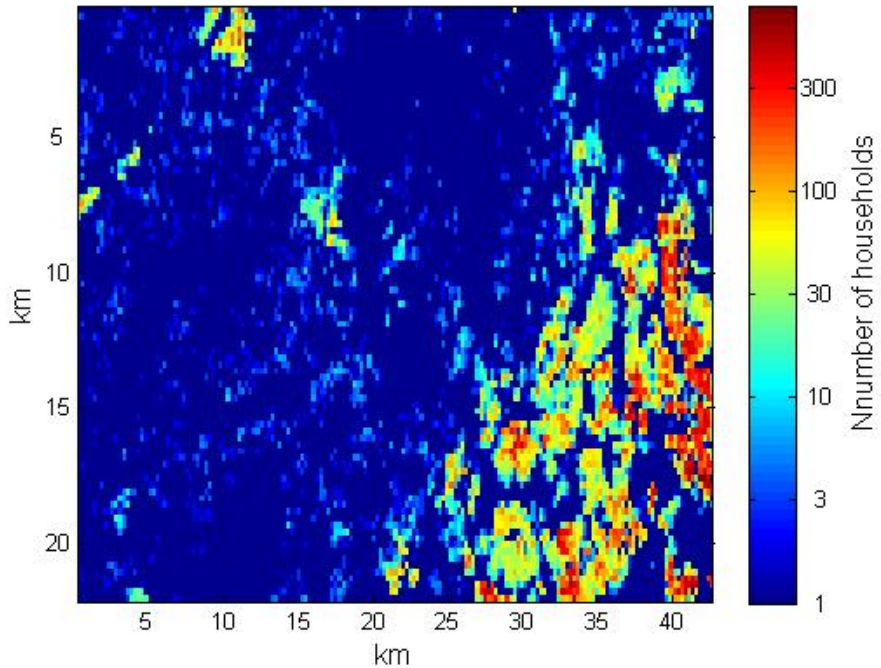
# Co-channel & Adjacent channel interference



# Aggregate interference due to “massive” use




TV coverage area, TV test points and secondary deployment area

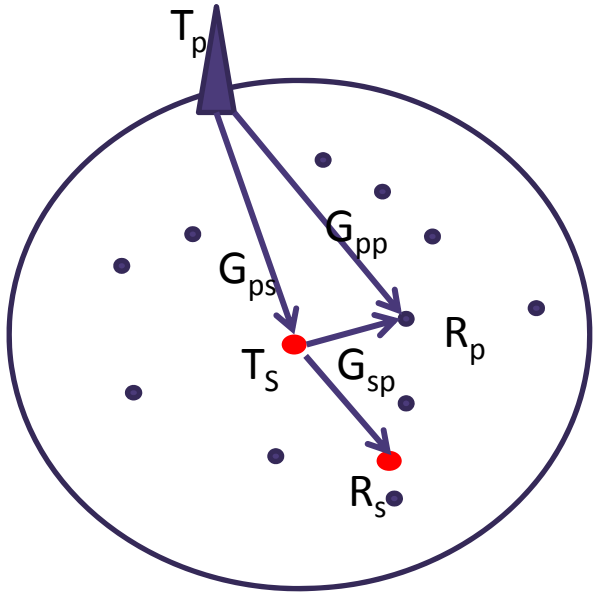



Density of the households
Each household → 1 transmitter

K Koufos, K Ruttik and R Jäntti, ”Aggregate interference from WLAN in the TV white space by using terrain-based channel model”
Submitted to CROWNCOM 2012

# Reliability of sensing

- Opportunity (not signal) Detection problem
- Even with “perfect” signal detection uncertainty remains about
  - Primary receiver location
  - Primary system path loss
  - Aggregate interference
- Maps into high interference margins




| Scenario | Standard deviation | *IM* (95%) | *IM* (99%) | Rate (*IM*=95%) | Rate (*IM*=99%) |
|---|---|---|---|---|---|
| Low detection correlation ( =0) | 23,0 | 37,8 | 53,5 | 1,66E-04 | 4,51E-06 |
| High detection correlation ( =1) | 21,5 | 35,4 | 50,1 | 2,86E-04 | 9,75E-06 |
| Known primary receiver position | 11,3 | 18,6 | 26,3 | 1,38E-02 | 2,33E-03 |
| Known path gain | 8,0 | 13,2 | 18,6 | 4,83E-02 | 1,38E-02 |
| Genie aided access (full knowledge) | 0 | 0 | 0 | 1 | 1 |