# LTE Measurements: What they mean and how they are used

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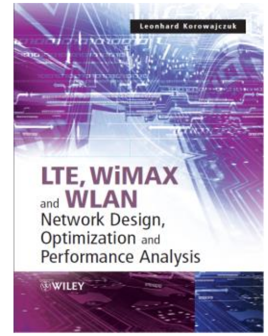
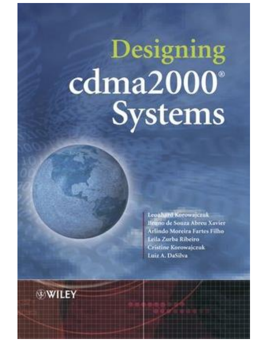
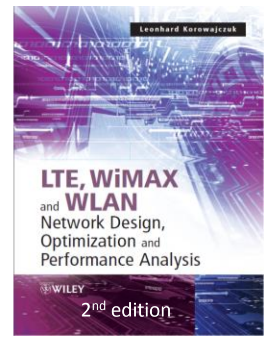
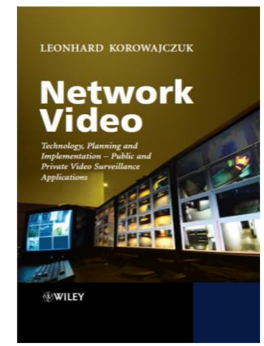
# Presenter

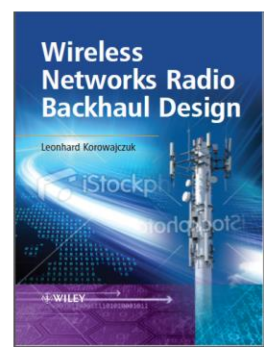
- **Leonhard Korowajczuk**
  - CEO/CTO CelPlan International
  - 45 years of experience in the telecom field (R&D, manufacturing and service areas)
  - Holds13 patents
  - Published books
    - "Designing cdma2000 Systems"
      - published by Wiley in 2006- 963 pages, available in hard cover, e-book and Kindle
    - "LTE , WiMAX and WLAN Network Design, Optimization and Performance Analysis "
      - published by Wiley in June 2011- 750 pages, available in hard cover, e-book and Kindle
  - Books in Preparation:
    - LTE , WiMAX and WLAN Network Design, Optimization and Performance Analysis
      - second edition (2014) LTE-A and WiMAX 2.1(1,000+ pages)
    - Network Video: Private and Public Safety Applications (2014)
    - Backhaul Network Design (2015)
    - Multi-Technology Networks: from GSM to LTE (2015)
    - Smart Grids Network Design (2016)

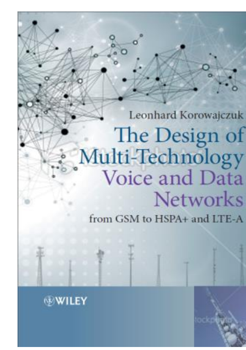












# CelPlan International

- Employee owned enterprise with international presence
  - Headquarters in USA
  - 450 plus employees
  - Twenty (20) years in business
- Subsidiaries in 6 countries with worldwide operation
- Vendor Independent
- Network Design Software (CelPlanner Suite/CellDesigner)
- Network Design Services
- Network Optimization Services
- Network Performance Evaluation
- Services are provided to equipment vendors, operators and consultants
- High Level Consulting
  - RFP preparation
  - Vendor interface
  - Technical Audit
  - Business Plan Preparation
  - Specialized (Smart Grids, Aeronautical, Windmill, ...)
- Network Managed Services
- 2G, 3G, 4G, 5G Technologies
- Multi-technology / Multi-band Networks
- Backhaul, Small cells, Indoor, HetNet, Wi-Fi offloading

# CelPlan Webinar Series

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  - May 7th 2014
- **How to Consider Overhead in LTE Dimensioning and what is the impact**
  - June 4th 2014
- **How to Take into Account Customer Experience when Designing a Wireless Network**
  - July 9th 2014
- **LTE Measurements what they mean and how they are used?**
  - August 6th2014
- **What LTE parameters need to be Dimensioned and Optimized? Can reuse of one be used? What is the best LTE configuration?**
  - September 3rd 2014
- **Spectrum Analysis for LTE Systems**
  - October 1st 2014
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- **Send suggestions and questions to: webinar@celplan.com**

# Webinar 1 (May 2014)
# How to Dimension User Traffic in 4G Networks

Participants from 44 countries

# Webinar 2 (June 2014)
# How to consider overhead in LTE dimensioning
# and what is the impact

Participants from 49 countries

# Webinar 3 (July 2014)
# How to consider Customer Experience when designing a wireless network

## Participants from 40 countries

| | | | |
|---|---|---|---|
| AT | CO | IR | PK |
| BB | DE | IT | PT |
| BH | DO | MX | RU |
| BJ | EG | MY | SA |
| BO | ES | NC | SR |
| BR | GB | NG | TH |
| BZ | GH | NL | TT |
| CA | GR | NZ | TW |
| CG | IE | PE | US |
| CH | IN | PH | ZA |

## Today's Webinar

# Webinar 4 (August 6$^{th}$, 2014)
# LTE Measurements
# What they mean?
# How are they used?

# LTE Measurements

- In LTE measurements are not just used to assess network quality, but are an integral part of the network operation
- Deployment data, as antenna orientation and location have to be informed to the eNB, so some of the features can perform correctly
- Broadband channels must be characterized in three dimensions (power, time and frequency)
  - Narrowband channels can be characterized just in two dimensions (power and time)
- Broadband channels require specialized field measurement equipment

# Measurements

1. Network Measurements
   1. UE Measurements
      - RSRP
      - RSSI and its variations
      - RSRQ and its variations
      - RSTD
      - RX-TX Time Difference
   2. Cell Measurements
      - Reference Signal TX Power
      - Received Interference Power
      - Thermal Noise Power
      - RX-TX Time Difference
      - Timing Advance
      - Angle of Arrival
   3. Measurement Reporting
      - Intra-LTE
      - Inter-RAT
      - Event triggered
      - Periodic
2. Field Measurements
   1. 1D Measurements
      - RF propagation model calibration
      - Receive Signal Strength Information
      - Reference Signal Received Power
      - Reference Signal Received Quality
      - Primary Synchronization Signal power
      - Signal power
      - Noise and Interference Power
      - Fade Mean
   2. 2D Measurements
      - Primary Synchronization Signal Power Delay Profile
   3. 3D measurements
      - Received Time Frequency Resource Elements
      - Channel Frequency response
      - Channel Impulse Response
      - Transmit Antenna Correlation
      - Traffic Load
   4. Measurement based predictions

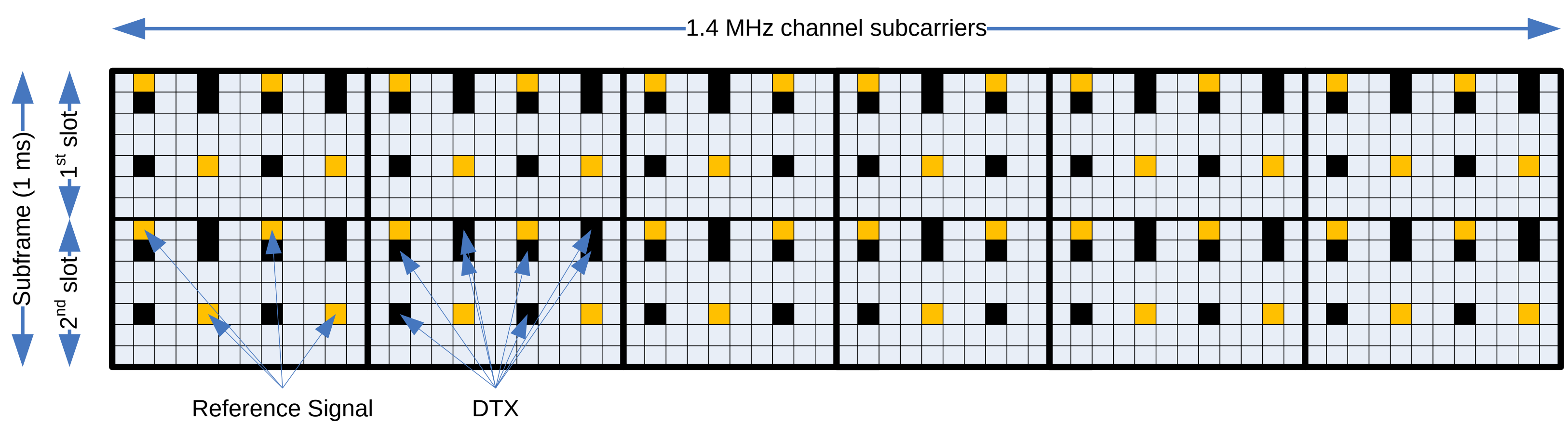
# 1. Network Measurements

# 1.1 UE Measurements

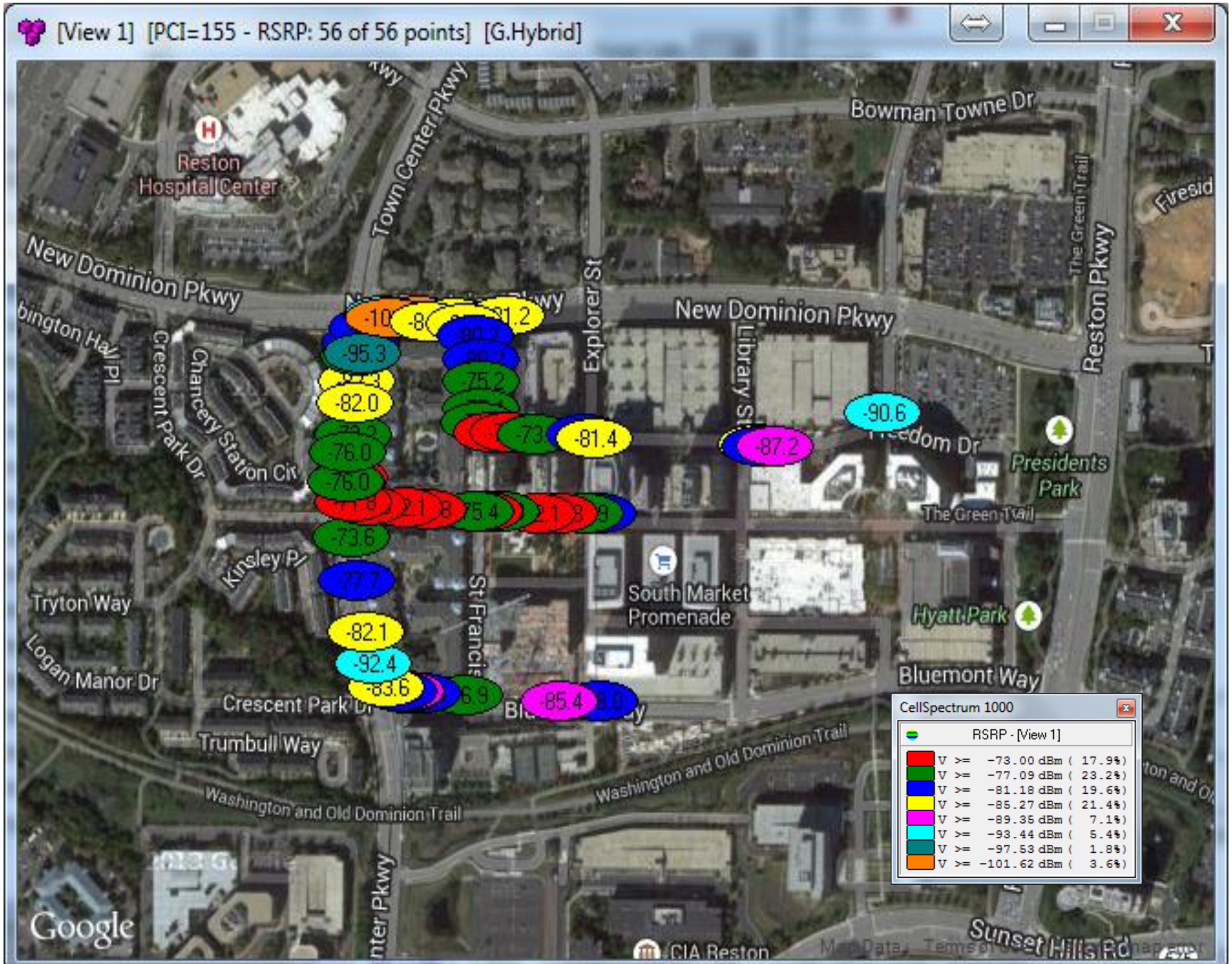
# Reference Signal Received Power (RSRP)

# Reference Signal Received Power (RSRP)

- Reference signal received power (RSRP), is defined as the linear average over the power contributions (in [W]) of the resource elements that carry cell-specific reference signals within the considered measurement frequency bandwidth
- For RSRP determination the cell-specific reference signals R0 according TS 36.211 shall be used. If the UE can reliably detect that R1 is available it may use R1 in addition to R0 to determine RSRP
- RSRP is the average power received from a single Cell Reference Signal Resource
  - This measurement excludes the energy of the cyclic prefix
- The reference point for the RSRP shall be the antenna connector of the UE. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding RSRP of any of the individual diversity branches



# RSRP


[View 1] [PCI=155 - RSRP: 56 of 56 points] [G.Hybrid]
CellSpectrum 1000
RSRP - [View 1]
V >= -73.00 dBm ( 17.9%)
V >= -77.09 dBm ( 23.2%)
V >= -81.18 dBm ( 19.6%)
V >= -85.27 dBm ( 21.4%)
V >= -89.35 dBm ( 7.1%)
V >= -93.44 dBm ( 5.4%)
V >= -97.53 dBm ( 1.8%)
V >= -101.62 dBm ( 3.6%)
Bowman Towne Dr
Reston Hospital Center
Town Center Pkwy
New Dominion Pkwy
Explorer St
Library St
Reston Pkwy
The Green Trail
Presidents Park
South Market Promenade
Hyatt Park
Bluemont Way
Tryton Way
Logan Manor Dr
Crescent Park Dr
Trumbull Way
Washington and Old Dominion Trail
Kinsley Pl
St Francis
CIA Reston
Sunset Hills Rd
-95.3
-82.0
-76.0
-73.6
-77.7
-82.1
-92.4
-83.6
-85.4
-81.4
-87.2
-90.6
-75.2
Google

# RSRP

- RS0 should be extracted using the pattern that is being transmitted, to minimize the influence of interference, although many detection algorithms used today do not do this analysis
- RSRP provides an approximate measurement of the signal power received (± 8 dB)
- RSRP provides better accuracy when comparing relative levels (± 3dB or ± 6dB )
- RSRP can be measured over one OFDM symbol carrying RSs, or over all carrying RSs symbols of an entire frame
  - Larger the number of symbols, more precise the measurement

# RSRP

- Used for:
  - Cell selection
  - Cell reselection
  - Handover
  - Path loss for power correction
- The maximum reportable RSRP considers
  - Maximum level that an UE can receive: -25 dBm
  - Bandwidth of 1.4 MHz bandwidth: 72 REs
    - $-25 - 10\log(72) = -44\ dBm$
- The minimum reportable RSRP considers
  - Maximum path loss of 152 dB
  - Transmit power of 43 dBm
  - Bandwidth of 20 MHz: 1200 REs
    - 43-152-10log(1200)= -139.72
- The absolute RSRP measurement accuracy specified by 3GPP is: ± 8 dB
  - Between two intra-frequency measurements is ± 3 dB
  - Between two inter-frequency measurements is ± 6 dB
- RSRP measurements are mapped onto integer values for reporting purposes

| Value Reported | Actual (dBm) |
|---|---|
| 0 | RSRP<-140 |
| 1 | -140 ≤ RSRP ≤ -139 |
| 2 | -139 ≤ RSRP ≤ -138 |
| 3 | -138 ≤ RSRP ≤ -137 |
| 4 | -137 ≤ RSRP ≤ -136 |
| .......... | .......... |
| n | n-139 ≤ RSRP ≤ n-140 |
| ........ | ........ |
| 87 | -54 ≤ RSRP ≤ -53 |
| 88 | -53 ≤ RSRP ≤ -52 |
| 89 | -52 ≤ RSRP ≤ -51 |
| 90 | -51 ≤ RSRP ≤ -50 |
| 91 | -50 ≤ RSRP ≤ -49 |
| 92 | -49 ≤ RSRP ≤ -48 |
| 93 | -48 ≤ RSRP ≤ -47 |
| 94 | -47 ≤ RSRP ≤ -46 |
| 95 | -46 ≤ RSRP ≤ -45 |
| 96 | -45 ≤ RSRP ≤ -44 |
| 97 | -44 ≤ RSRP |

# Received Signal Strength Indicator (RSSI)

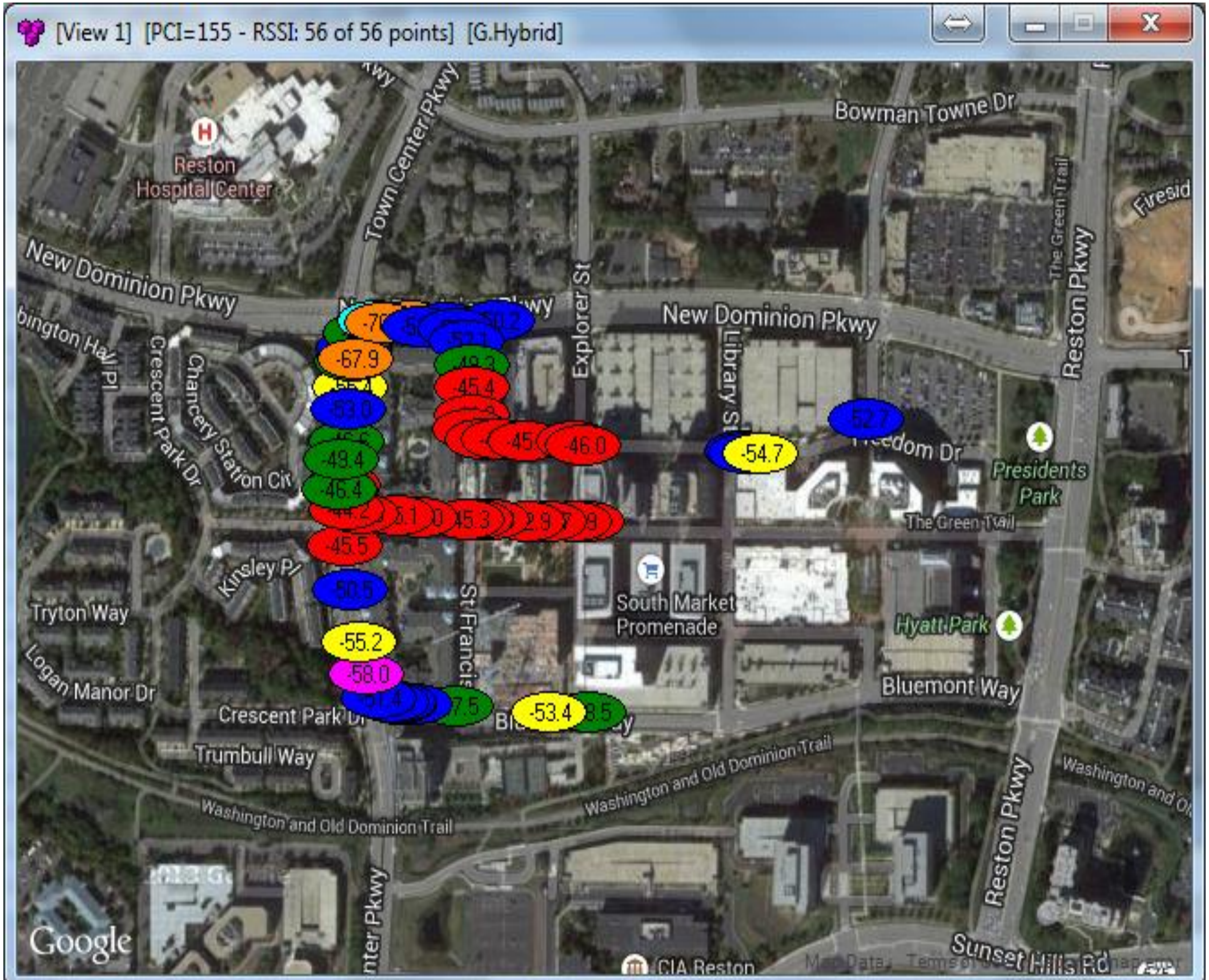
# Received Signal Strength Indicator (RSSI)

- E-UTRA Carrier Received Signal Strength Indicator (RSSI), comprises the linear average of the total received power (in [W]) observed only in OFDM symbols containing reference symbols for antenna port 0, in the measurement bandwidth, over N number of resource blocks by the UE from all sources, including co-channel serving and non-serving cells, adjacent channel interference, thermal noise etc…
- If higher-layer signalling indicates certain subframes for performing RSRQ measurements, then RSSI is measured over all OFDM symbols in the indicated subframes
- The reference point for the RSRQ shall be the antenna connector of the UE. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding RSRQ of any of the individual diversity branches
- It measures the average received power over the resource elements that carry cell-specific reference signals within the frequency bandwidth

# RSSI

- There are several interpretation of RSSI measurements and test equipment may present the measurement using different criteria
  - Criteria 1: measurement is done only on RE (Resource Elements) carrying RS, but without filtering it with the RS pattern
    - This is the most correct interpretation for RSSI, but is the least used
  - Criteria 2: measurement is done over all REs of an OFDM symbol carrying RSs
    - This is the most used interpretation for RSSI, but it is traffic dependent
  - Criteria 3: measurement is done over all REs of a subframe
    - This is an alternate measurement procedure, that is also influenced by traffic

# RSSI


[View 1] [PCI=155 - RSSI: 56 of 56 points] [G.Hybrid]
Bowman Towne Dr
Reston Hospital Center
Town Center Pkwy
New Dominion Pkwy
Explorer St
Library St
Reston Pkwy
Crescent Park Dr
Chancery Station Cir
Kinsley Pl
Tryton Way
Logan Manor Dr
Trumbull Way
St Francis
South Market Promenade
Presidents Park
Hyatt Park
The Green Trail
Bluemont Way
Washington and Old Dominion Trail
Sunset Hills Rd
CIA Reston
-67.9
-53.0
-49.4
-46.4
-45.5
-50.5
-55.2
-58.0
-53.4
-45.4
-46.0
-45.3
-54.7
-52.7
-50.2
Google

# Reference Signal Received Quality (RSRQ)

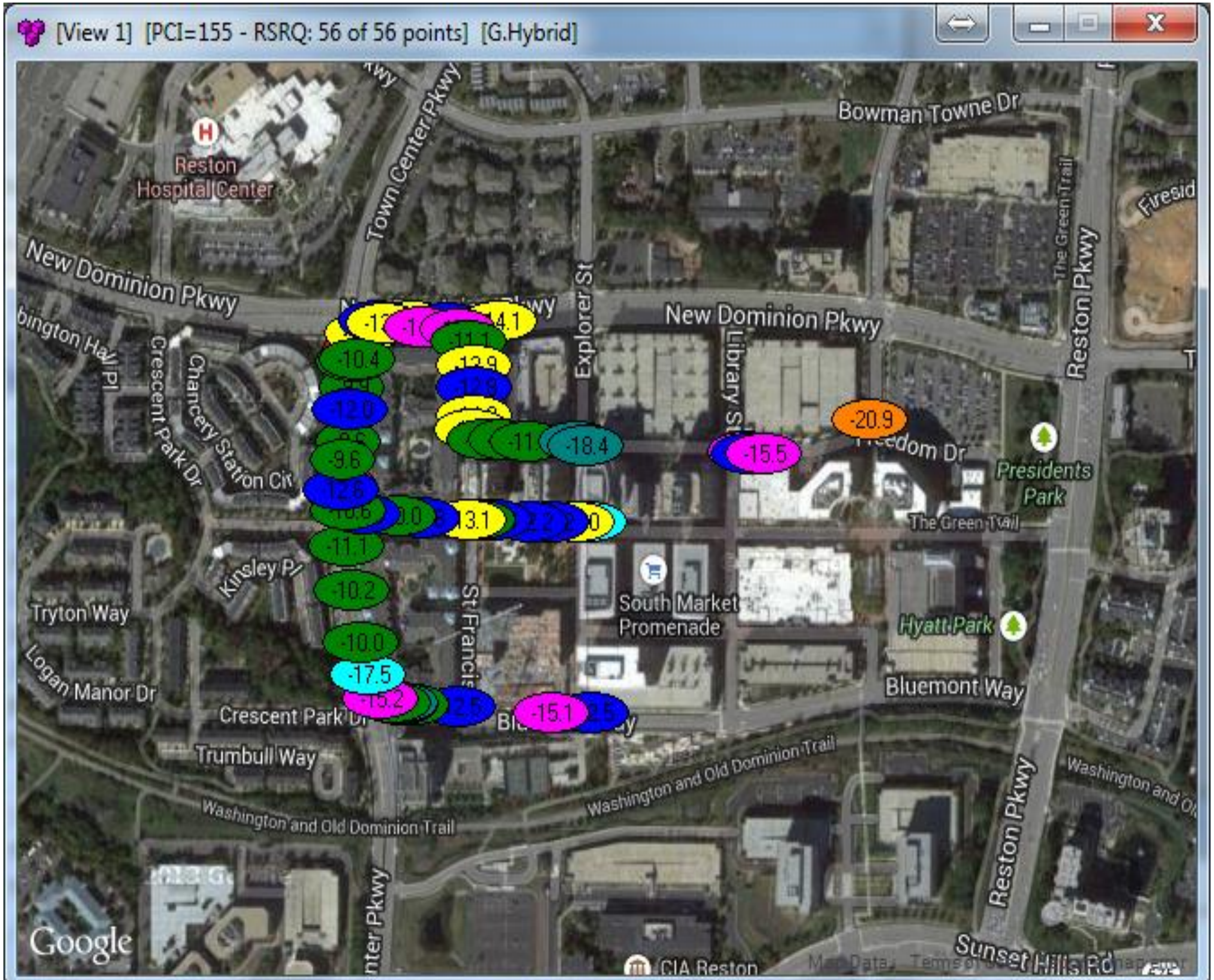
# Reference Signal Received Quality (RSRQ)

- RSRQ should reflect the quality of the connection, which is based on SINR
- RSRQ is defined as the ratio

$$RSRQ = N * RSRP/(EUTRA\ carrier\ RSSI)$$

  – where N is the number of RB's of the E-UTRA carrier RSSI measurement bandwidth
- The measurements in the numerator and denominator shall be made over the same set of resource blocks

# RSRQ


[View 1] [PCI=155 - RSRQ: 56 of 56 points] [G.Hybrid]
Reston Hospital Center
Town Center Pkwy
Bowman Towne Dr
New Dominion Pkwy
Explorer St
Library St
Reston Pkwy
The Green Trail
Presidents Park
Freedom Dr
South Market Promenade
Hyatt Park
Bluemont Way
Tryton Way
Logan Manor Dr
Crescent Park Dr
Trumbull Way
Kinsley Pl
Chancery Station Cir
Washington and Old Dominion Trail
Sunset Hills Rd
CIA Reston
-20.9
-15.5
-18.4
-10.4
-12.0
-9.6
-11.1
-10.2
-10.0
-17.5
-15.2
-15.1
Google

# RSQ

- The most prevalent interpretation of the 3GPP specification is the RSSI criteria 2
  - The specification gives lead to different interpretations
- The use of RSSI criteria 2 makes RSRQ vary with traffic, independently of the quality of the channel
- UE vendors may use any of the criteria to get better performance of its units
- The maximum reportable RSRQ considers
  - No Traffic being transferred, only RS
    - $RSRQ = N * RSRP/2 * RSRP = 0.5 = -3dB$
- The minimum reportable RSRQ considers
  - All symbols carrying traffic
  - An SIR (Signal to interference Ratio) of -9 dB
    - $RSRQ = N * RSRP/N * 12 * RSRP/8 = 1/96 = -19.82\ dB$
- The absolute RSRQ measurement accuracy specified by 3GPP for intra frequency is: ± 3.5 dB
- The absolute RSRQ measurement accuracy specified by 3GPP for measurements between intra and inter frequency is: ± 4 dB
- RSRP measurements are mapped onto integer values for reporting purposes

| Value Reported | RSRQ (dB) |
|---|---|
| 0 | RSRQ ≤ -19.5 |
| 1 | -19.5 ≤ RSRQ ≤ -19 |
| 2 | -19 ≤ RSRQ ≤ -18.5 |
| 3 | -18.5 ≤ RSRQ ≤ -18 |
| 4 | -18 ≤ RSRQ ≤ -17.5 |
| 5 | -17.5 ≤ RSRQ ≤ -17 |
| 6 | -17 ≤ RSRQ ≤ -16.5 |
| 7 | -16.5 ≤ RSRQ ≤ -16 |
| 8 | -16 ≤ RSRQ ≤ -15.5 |
| 9 | -15.5 ≤ RSRQ ≤ -15 |
| 10 | -15 ≤ RSRQ ≤ -14.5 |
| 11 | -14.5 ≤ RSRQ ≤ -14 |
| 12 | -14 ≤ RSRQ ≤ -13.5 |
| 13 | -13.5 ≤ RSRQ ≤ -13 |
| 14 | -13 ≤ RSRQ ≤ -12.5 |
| 15 | -12.5 ≤ RSRQ ≤ -12 |
| 16 | -12 ≤ RSRQ ≤ -11.5 |
| 17 | -11.5 ≤ RSRQ ≤ -11 |
| 18 | -11 ≤ RSRQ ≤ -10.5 |
| 19 | -10.5 ≤ RSRQ ≤ -10 |
| 20 | -10 ≤ RSRQ ≤ -9.5 |
| 21 | -9.5 ≤ RSRQ ≤ -9 |
| 22 | -9 ≤ RSRQ ≤ -8.5 |
| 23 | -8.5 ≤ RSRQ ≤ -8 |
| 24 | -8 ≤ RSRQ ≤ -7.5 |
| 25 | -7.5 ≤ RSRQ ≤ -7 |
| 26 | -7 ≤ RSRQ ≤ -6.5 |
| 27 | -6.5 ≤ RSRQ ≤ -6 |
| 28 | -6 ≤ RSRQ ≤ -5.5 |
| 29 | -5.5 ≤ RSRQ ≤ -5 |
| 30 | -5 ≤ RSRQ ≤ -4.5 |
| 31 | -4.5 ≤ RSRQ ≤ -4 |
| 32 | -4 ≤ RSRQ ≤ -3.5 |
| 33 | -3.5 ≤ RSRQ ≤ -3 |
| 34 | -3 ≤ RSRQ |

# Handset Positioning

Enhanced Cell ID

Assisted Global Navigation Satellite System

Observed Time Difference of Arrival

# Reference Signal Time Difference (RSTD)

# Reference Signal Time Difference (RSTD)

- Current LTE standards support three independent handset based positioning techniques
  - Enhanced Cell ID (ECID)
  - Assisted Global Navigation Satellite Systems (A-GNSS)
  - Observed Time Difference of Arrival (OTDOA)
- The E-SMLC (Enhanced Serving Mobile Location Center) is a network element in 3GPP Networks that calculates network-based location of UEs (User Equipment)
- The inter-connection between E-SMLC and UE is done using
  - LTE Positioning Protocol (LPP)
  - Secure User Plane Location (SUPL 2.0)

# Enhanced Cell ID (ECID)

- Cell ID (CID) positioning is a network based technique that can be used to estimate the position of the UE quickly, but with very low accuracy
- The position of the UE is estimated to be the position of the base station it is camped on
  - In ECID, the Round Trip Time (RTT) between the base station and the UE is used to estimate the distance to the UE
  - In addition, the network can use the Angle of Arrival (AoA) of signals from the UE to provide directional information
- The RTT is determined by analyzing Timing Advance (TA)measurements, either from the eNodeB or by directly querying the UE
- The eNodeB tracks two types of TA measurements
  - Type 1 is measured by summing the eNodeB and the UE receive-transmit time differences
  - Type 2 is measured by the eNodeB during a UE Random Access procedure

# Enhanced Cell ID (ECID)

- AoA (Angle of Arrival) is measured based on uplink transmissions from the UE and the known configuration of the eNodeB antenna array
  - The received UE signal between successive antenna elements is typically phase-shifted by a measurable value
  - The degree of this phase shift depends on
    - AoA
    - antenna element spacing
    - carrier frequency
- By measuring the phase shift and using known eNodeB characteristics, the AoA can be determined
  - Typical uplink signals used in this measurement are Sounding Reference Signals (SRS) or Demodulation Reference Signals (DM-RS)
- The main sources of error in ECID are receive timing uncertainty (which affects the RTT calculation) and multipath reflections
  - Typical accuracy is 150 m in LOS cases

# Assisted Global Navigation Satellite Systems (A-GNSS)

- GNSS refers collectively to multiple satellite systems, such as GPS and GLONASS
  - It is possible to use both satellite systems simultaneously, effectively increase the number of satellites available for signal acquisition
- The receiver needs to acquire satellite signals through a search process; it must lock onto at least four satellites in order to compute a 3-D position
- The performance of standalone GNSS can be significantly improved by a technique called Assisted GNSS
  - Standalone GNSS facilities of the phone are augmented by data provided by the network, termed "Assistance Data", which includes information the mobile GNSS receiver can use to accelerate the process of satellite signal acquisition
    - A-GNSS works well outdoors and in scenarios where a reasonably good view of the sky is available
    - Performance is generally poor in environments with high obscuration and multipath, such as indoors and in dense urban settings
- Typical accuracy is 10 to 50 m in outdoor environments

# Observed Time Difference of Arrival (OTDOA)

- UE measures time differences in downlink signals from two or more base stations
- Using the known position of the base stations and these time differences, it is then possible to calculate the position of the UE
  - Generally, the signals used for OTDOA are cell Reference Signals (RS)
- LTE OTDOA has to measure neighboring cell RSs accurately enough for positioning, but this is hard to achieve due to interference
- Release 9 defined special positioning Reference Signals called Positioning Reference Signals (PRS)
  - These special reference signals can assist in the measurement of neighboring cell signals by increasing RS energy
  - The PRS is periodically transmitted along with the cell specific RS in groups of consecutive downlink sub frames
  - PRSs are transmitted in port 6 and may be broadcast over part of the channel bandwidth
- In a fully synchronized network, the PRS patterns in two neighboring cells overlap
  - The network may mute the transmissions to improve neighbor signal acquisition
  - The network can also provide Assistance Data to the UE to aid its acquisition of the PRS
    - This data usually consists of
      - relative eNodeB transmit timing differences (in the case of a synchronous networks)
      - search window length
      - expected PRS patterns of surrounding cells
- In LTE, OTDOA and A-GNSS may be used together in a “hybrid” mode
- The accuracy is between 50 and 200 m

# Positioning Architecture in LTE Networks

- Positioning information exchange between the UE and the LTE network is enabled by the LTE Positioning Protocol (LPP)
- It can be used in the Control or User (traffic) planes
  - Signaling Plane implementations, most commonly used in emergency services, exchange messages between the network and the UE over the signaling connection
    - It is enabled by the Mobility Management Entity (MME), which routes LPP messages from the E-SMLC to the UE using NAS Downlink Transfer Messages
  - User Plane Positioning over LTE uses the data link to transmit positioning information, and is enabled by the SUPL protocol
    - SUPL 2.0 supports positioning over LTE, as well as, 2G and 3G networks, and provides a common user plane platform for all air interfaces
    - SUPL does not introduce a new method to package and transport Assistance Data, instead it uses existing control plane protocols, (such as RRLP (Radio Resource Location Service Protocol), IS-801 and LPP)

# Positioning Architecture in LTE Networks

- The E-SMLC (Enhanced Serving Mobile Location Center) is a network element in 3GPP Networks that calculates network-based location of UEs (User Equipment). The SMLC may control several LMUs (Location Measurement Units) which measure radio signals to help find mobile stations in the area served by the SMLC
  - It can calculate location using the TA (Timing Advance) method
- The E-SMLC communicates with the GMLC (Gateway Mobile Location Center), which is the interface to external LCS (Location Services) clients
- RSTD (Reference Signal Time Difference) is measured in units of $T_s$=1/30,720 ms= 0.3255 ns
- RSTD measurements are mapped onto integer values for reporting purposes

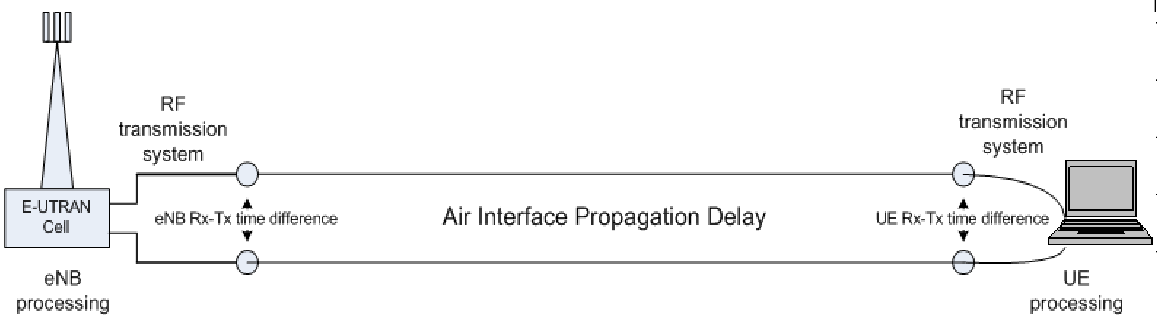
| Value Reported | Measurement (units of Ts) | Step Size (Ts) |
|---|---|---|
| 0 | -15391 > RSTD | 5 |
| 1 | -15391 ≤ RSTD ≤ -15386 | 5 |
| 2 | -15386 ≤ RSTD ≤ -15381 | 5 |
| ……. | ……. | ……. |
| 2258 | -4106 ≤ RSTD ≤ -4101 | 5 |
| 2259 | -4101 ≤ RSTD ≤ -4096 | 5 |
| 2260 | -4096 ≤ RSTD ≤ -4095 | 1 |
| 2261 | -4095 ≤ RSTD ≤ -4094 | 1 |
| ……. | ……. | ……. |
| 6353 | -3 ≤ RSTD ≤ -2 | 1 |
| 6354 | -2 ≤ RSTD ≤ -1 | 1 |
| 6355 | -1 ≤ RSTD ≤ 0 | 1 |
| 6356 | 0 ≤ RSTD ≤ 1 | 1 |
| 6357 | 1 ≤ RSTD ≤ 2 | 1 |
| 6358 | 2 ≤ RSTD ≤ 3 | 1 |
| ……. | ……. | ……. |
| 10450 | 4094 ≤ RSTD ≤ 4095 | 1 |
| 10451 | 4095 ≤ RSTD ≤ 4096 | 1 |
| 10452 | 4096 ≤ RSTD ≤ 4101 | 5 |
| 10453 | 4101 ≤ RSTD ≤ 4106 | 5 |
| ……. | ……. | ……. |
| 12709 | 15381 ≤ RSTD ≤ 15386 | 5 |
| 12710 | 15386 ≤ RSTD ≤ 15391 | 5 |
| 12711 | 15391 <RSTD | 5 |

# RX-TX Time Difference

# RX-TX Time Difference (RTTD)

- RTTD measurement was introduced in release 9 to support ECID (Enhanced Cell ID) location technique
- RTTD implements Type 1 measurements by calculating the Timing Advance
- RTSTD is measured in units of $T_s$=1/30,720 ms= 0.3255 ns
- RTTD step size is 2 $T_s$ for small time differences and 8 $T_s$ for large differences

| Value Reported | Measurement (units of Ts) | Step Size (Ts) |
|---|---|---|
| 0 | UE RX-TX < 2 | 2 |
| 1 | 2 ≤ RSRQ ≤ 4 | 2 |
| 2 | 4 ≤ RSRQ ≤ 6 | 2 |
| ……. | ……. | ……. |
| 2046 | 4092 ≤ RSRQ ≤ 4094 | 2 |
| 2047 | 4094 ≤ RSRQ ≤ 4096 | 2 |
| 2048 | 4096 ≤ RSRQ ≤ 4104 | 8 |
| 2049 | 4104 ≤ RSRQ ≤ 4112 | 8 |
| ……. | ……. | ……. |
| 4093 | 20456 ≤ RSRQ ≤ 20464 | 8 |
| 4094 | 20464 ≤ RSRQ ≤ 20472 | 8 |
| 4095 | 20472 ≤ UE RX-TX | 8 |




$$Type\ 1 = (eNB\ Rx - Tx\ Time\ Difference) + (UE\ Rx - Tx\ Time\ Difference)$$

# 1.2 Cell Measurements

# Cell Measurements

- Reference Signal TX Power
- Received Interference Power
- Thermal Noise Power
- RX-TX Difference
- Timing Advance
- Angle of Arrival

# Reference Signal TX Power

# Reference Signal TX Power

- Reference Signal TX Power (RSTX) is calculated as a linear average (in W) of Resource Elements assigned to Reference Signals
  - It is measured by the cell at the transmit antenna connector (port 0 and 1)
  - Introduced in release 8
- It's value is reported in SIB2 (PDSCH configuration) and has a range between -60 and -50 dBm

# Received Interference Power

# Received Interference Power

- Received Interference Power is defined as the uplink received interference power (including thermal noise) measured within the bandwidth of each Resource Block, over the entire bandwidth
  - It is measured at the receive antenna (when receive diversity is used, it is represented by the average of the receive ports
  - Introduced in release 8
- Measured values are reported in the Load Information (LI) message sent using the X2 protocol, to exchange uplink interference power between cells
  - LI is reported as high, medium or low
  - LI thresholds are defined by the O&M
  - A cell should avoid using at the cell edge RBs that create high interference levels at neighbor cells
- Mapping between measured and reported values is presented in the table

| Value Reported | Actual (dBm) | Step Size (dB) |
|---|---|---|
| 0 | RIP < -126 | 2 |
| 1 | -126 ≤ RIP ≤ -125.9 | 2 |
| 2 | -125.9 ≤ RIP ≤ -125.8 | 2 |
| | | |
| 2046 | -75.2 ≤ RIP ≤ -75.1 | 2 |
| 2047 | -75.1 ≤ RIP ≤ -75 | 2 |
| 2048 | -75.0 ≤ RIP | 2 |

# Thermal Noise Power

# Thermal Noise Power

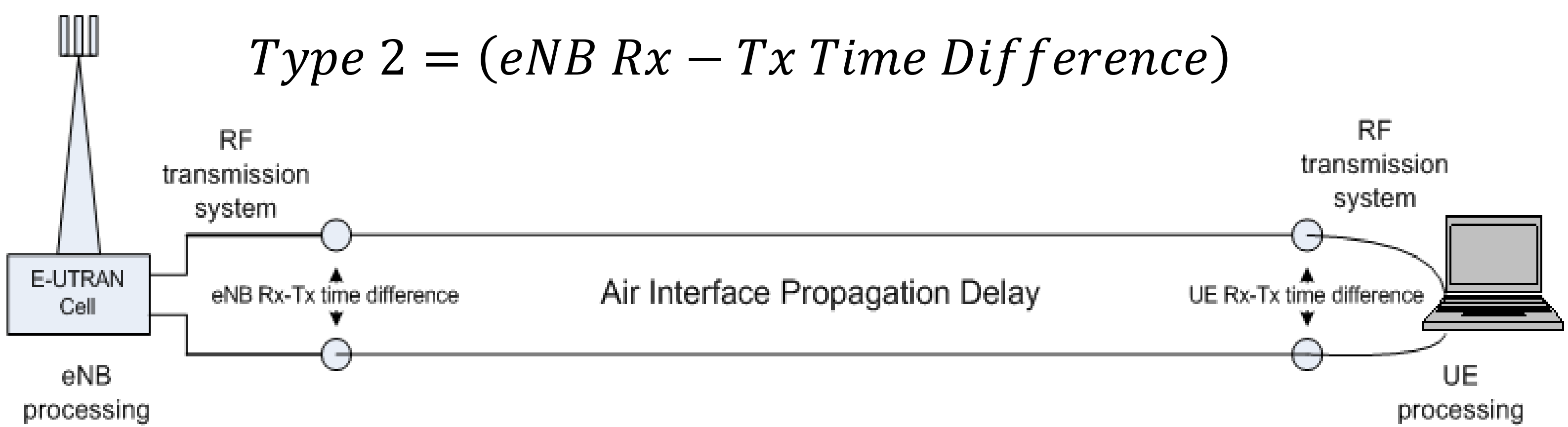
- Thermal Noise Power is defined as the uplink thermal noise power measured over the entire bandwidth
  - Allows to obtain a realistic measure of the uplink interference by subtracting the thermal power
  - It is measured at the receive antenna with the antenna disconnected
    - In case of diversity antennas, the average value is used
  - It was introduced in release 8

# RX-TX Time Difference

# RX-TX Time Difference

- The RX-TX measurement is required for location purposes, as distance calculations should consider only the air interface propagation delay
  - Release 8 measured only the cell Rx-TX time difference
  - Release 9 introduced the measurement at the UE side
  - The reference points are the respective antenna connectors

$$Type\ 2 = (eNB\ Rx - Tx\ Time\ Difference)$$



# Timing Advance

# Timing Advance

- Timing Advance reflects the delay caused at the cell and UE
  - Release 9 considers both delays

$$Type\ 1 = (eNB\ Rx - Tx\ Time\ Difference) + (UE\ Rx - Tx\ Time\ Difference)$$

  - Release 8 considers only the delay at the cell

$$Type\ 2 = (eNB\ Rx - Tx\ Time\ Difference)$$

- Timing Advance (TA) is expressed in $T_s$ units
  - $T_s = \frac{1}{30{,}720}\ ms = 32.55\ ns$
- The Round Trip Time (RTT) is calculated subtracting the Timing Advance measurement from the Timing Advance instruction provided by the Random Access process

| Value Reported | Measurement (units of Ts) | Step Size (Ts) |
|---|---|---|
| 0 | TA < 2 | 2 |
| 1 | 2 ≤ TA ≤ 4 | 2 |
| 2 | 4 ≤ TA ≤ 6 | 2 |
| ……. | ……. | ……. |
| 2046 | 4092 ≤ TA ≤ 4094 | 2 |
| 2047 | 4094 ≤ TA ≤ 4096 | 2 |
| 2048 | 4096 ≤ TA ≤ 4104 | 8 |
| 2049 | 4104 ≤ TA ≤ 4112 | 8 |
| ……. | ……. | ……. |
| 7688 | 49216 ≤ TA ≤ 49224 | 8 |
| 7689 | 49224 ≤ TA ≤ 49232 | 8 |
| 7690 | 49232 ≤ TA | 8 |

# Angle of Arrival

# Angle of Arrival

- The Angle of Arrival (AoA) measurement is defined as the estimated angle of the UE in relation to the geographical north direction
  - AoA measurements require an antenna array, as the angle is derived by computing the relative delays (phases) of the signal received by each antenna
    - Larger the number of antenna elements (antennas) more accurate is the calculation of the angle
    - This calculation is only valid if multipath is not prevalent as it will change the phases and consequently change the angle perception
  - AoA measurement is the reverse process of beamforming where each antenna element transmits the signal with a different phase, so to steer the combined signal to the desired direction
  - AoA was introduced in release 9
  - AoA can be used for UE location also
  - The Sounding Reference Signal (SRS) complement AoA measurements

| Value Reported | Measurement (degrees) |
|---|---|
| 0 | 0 ≤AoA ≤ 0.5 |
| 1 | 0.5 ≤AoA ≤ 1 |
| 2 | 1 ≤AoA ≤ 1.5 |
| ……. | ……. |
| 717 | 358.5 ≤AoA ≤ 359 |
| 718 | 359 ≤AoA ≤ 359.5 |
| 719 | 359.5 ≤AoA ≤ 360 |

# 1.3 Measurements Reporting

# Measurement Reporting

- Measurement Objects
- Reporting Configurations
- Measurements Identities
- Quantity Configurations
- Measurement Gaps
- Measurement Procedures

# Measurement Reporting

- eNodeB uses RRC messages (Connection Setup, Reconfiguration and Re-establishment) to request UE to do the following measurements
  - Intra-frequency measurements on the same RF carriers as used by the serving cell
  - Inter-frequency measurements on an LTE RF carrier that is not used by the serving cell
  - Inter-RAT GERAN
  - Inter-RAT UTRAN FDD and TDD
  - Inter-RAT cdma2000 HRPD (EVDO) or 1xRTT

# Measurement Objects

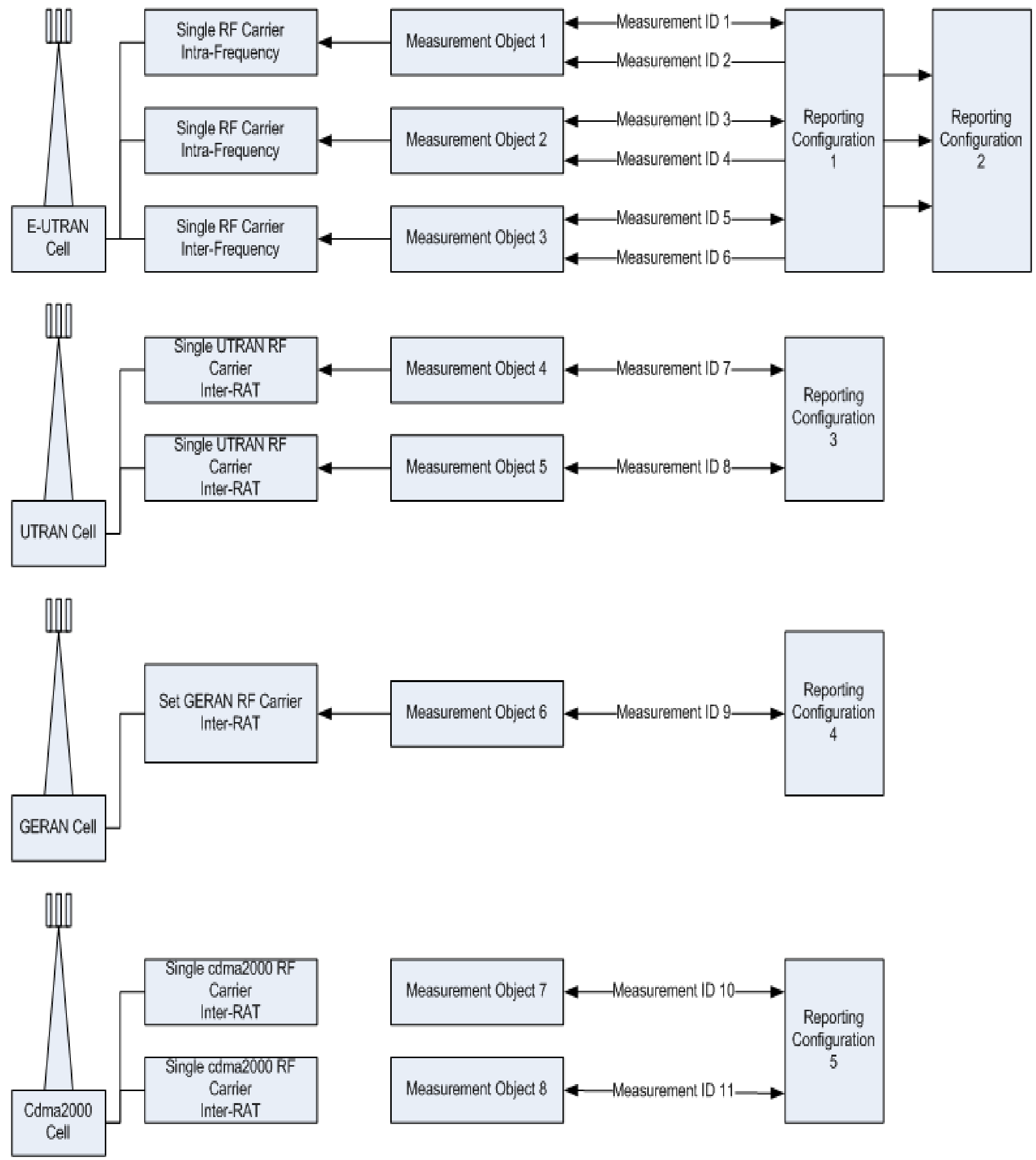
- Objects
  - Intra-frequency object defines a single LTE RF carrier
  - Inter-frequency object defines a single LTE RF carrier
  - Inter-RAT GERAN object defines a set of GERAN RF carriers
  - Inter-RAT UTRAN object defines a single UTRAN RF carrier
  - Inter-RAT object defines a single cdma2000 RF carrier
- Cells to be measured can be specified in a white list and cell to be excluded in a black list
- The following reports can be requested
  - CGI (Cell Global Identity) for specific PCI
  - CGI for a specific BSIC
  - CGI for a specific scrambling code
  - CGI for a specific PN offset

# Reporting Configurations

- LTE Reporting
  - Event triggered: based upon events A1, A2, A3, A4, A5, A6
    - Triggering quantity can be RSRP or RSRQ
    - Reported Quantity can be the triggering quantity or RSRP and RSRQ
  - Periodic: based upon a timer expiration
    - Reports the strongest cells or a CGI
- Inter-RAT Reporting
  - Event triggered: based upon events B1 and B2
    - Triggering quantity depends on the RAT
      - RSRP, RSRQ; UMTS CPICH RSCP, UMTS CPICH Ec/Io; GSM RSSI
    - Reports the strongest cells or a CGI

# Measurement Identities (MI)

- MI link measurement objects to reporting configurations
- Multiple measurement identities allow multiple measurement objects to be linked to the same reporting configuration
- Measurement identities are used as a reference when UE sends Measurement report messages



# Layer 3 Filtering

- Layer 3 Filtering filter events prior to event evaluation and reporting

$$F_n = \left(1 - {}^{1}\!/_{2}{}^{k/4}\right) F_{n-1} ({}^{1}\!/_{2}{}^{k/4}) Meas_n$$

  - $F_n$ is the updated filtered result
  - $F_{n-1}$is the previous measurement result
  - k is the filter coefficient (0,1,2,3,4,5,6,7,8,9,11,13,15,17,19)
  - $Meas_n$is the latest measurement received from PHY
- Filter coefficients assume that measurements arrive at a rate of one per 200 ms
  - Filter is adapted to maintain the same impulse response if they arrive at a different rate
- Filtering is applied in the same domain as the measurement
  - dBm for RSRP and dB for RSRQ

# Measurement Gap (MG)

- Measurement Gap defines when measurements inter-frequency and inter-RAT measurements should be made
  - Measurement gap duration is always 6 ms
  - UE is not permitted to transmit any data during measurement gaps
  - MG is configured by
    - Gap Pattern Identity (GPI), which can be 0 or 1
      - GPI=0 Measurement Gap Repetition (MGR) Period is 40 ms
      - GPI=1 Measurement Gap Repetition (MGR) Period is 80 ms
    - Gap Offset (GO)
      - GPI=0 GO can be configured with a value between 0 and 39
      - GPI=1 GO can be configured with a value between 0 and 79
  - An MG starts when

$$SFN\ mod(MGRP/10) = Floor\ (GO/10)$$

$$Subframe = GO\ mod\ (10)$$

  - Example: GPI=0, GO=12
    - SFN= 1,5,9,13,17,21
    - Subframe= 2

# Measurement Procedure

- Measurement procedures involve 3 types of cells
  - Serving cells: primary cell and secondary cell (if carrier aggregation is used)
  - Listed cells: cells that are specified within the measurement object
  - Detected cells: cell that are not specified within the measurement object but are detected by the UE
    - For Intra-frequency and Inter Frequency measurements UE measures all three types
    - For GERAN it measures detected cells
    - For UTRAN Inter-RAT it measures listed cells
    - For cdma2000 it measures listed cells

# A Events

- A Events are LTE events
- Event A1: serving cell becomes better than a threshold (R8)
  - Triggers when: $Meas_{serv} - Hyst > Threshold$
  - Cancels when: $Meas_{serv} + Hyst < Threshold$
- Event A2: serving cell becomes worse than a threshold (R8)
  - Triggers when: $Meas_{serv} + Hyst < Threshold$
  - Cancels when: $Meas_{serv} - Hyst > Threshold$
- Event A3: neighbor cell becomes better then the serving cell by an offset (R8)
  - Triggers when: $Meas_{neigh} + O_{neigh,freq} + O_{neigh,cell} - Hyst > Meas_{serv} + O_{serv,freq} + O_{serv,cell} + Offset$
  - Cancels when: $Meas_{neigh} + O_{neigh,freq} + O_{neigh,cell} + Hyst < Meas_{serv} + O_{serv,freq} + O_{serv,cell} + Offset$
- Event A4: neighbor cell becomes better than a threshold (R8)
  - Triggers when: $Meas_{neigh} + O_{neigh,freq} + O_{neigh,cell} - Hyst > Threshold$
  - Cancels when: $Meas_{neigh} + O_{neigh,freq} + O_{neigh,cell} + Hyst < Threshold$
- Event A5: serving cell becomes worse than threshold1 while neighbor cell becomes better than threshold2 (R8)
  - Triggers when:
    - $Meas_{serv} + Hyst < Threshold1$
    - $Meas_{neigh} + O_{neigh,freq} + O_{neigh,cell} - Hyst > Threshold2$
  - Cancels when:
    - $Meas_{serv} - Hyst > Threshold1$
    - $Meas_{neigh} + O_{neigh,freq} + O_{neigh,cell} + Hyst < Threshold2$
- Event A6: neighbor cell becomes better than a secondary cell by a threshold (R10)
  - Triggers when: $Meas_{neigh} + O_{neigh,cell} - Hyst > Meas_{sec} + O_{sec,cell} + Offset$
  - Cancels when: $Meas_{neigh} + O_{neigh,cell} + Hyst > Meas_{sec} + O_{sec,cell} + Offset$

# B Events

- B events are Inter-RAT events
- Event B1: inter-system neighbor cell becomes better than a threshold
  - Triggers when: $Meas_{neigh} + O_{neigh,freq} - Hyst > Threshold$
  - Cancels when: $Meas_{neigh} + O_{neigh,freq} + Hyst < Threshold$
- Event B2: serving cell becomes worse than threshold 1 while inter-system neighboring cell becomes better than threshold2
  - Triggers when:
    - $Meas_{serv} + Hyst < Threshold1$
    - $Meas_{neigh} + O_{neigh,freq} - Hyst > Threshold2$
  - Cancels when:
    - $Meas_{serv} - Hyst > Threshold1$
    - $Meas_{neigh} + O_{neigh,freq} + Hyst < Threshold2$

# 2. Field Measurements

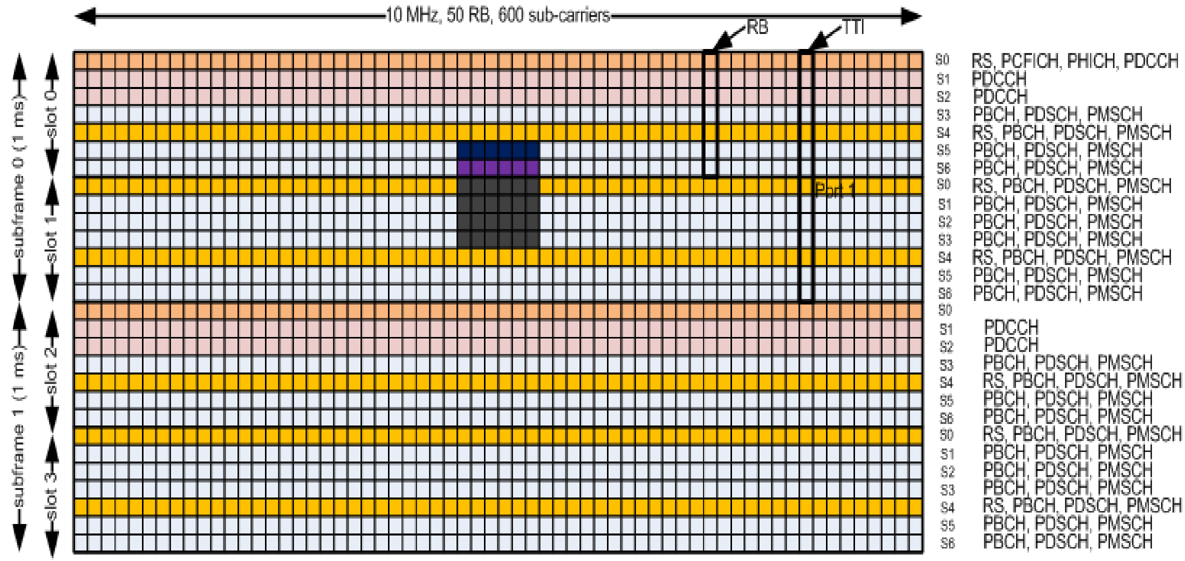

# LTE Frame Downlink

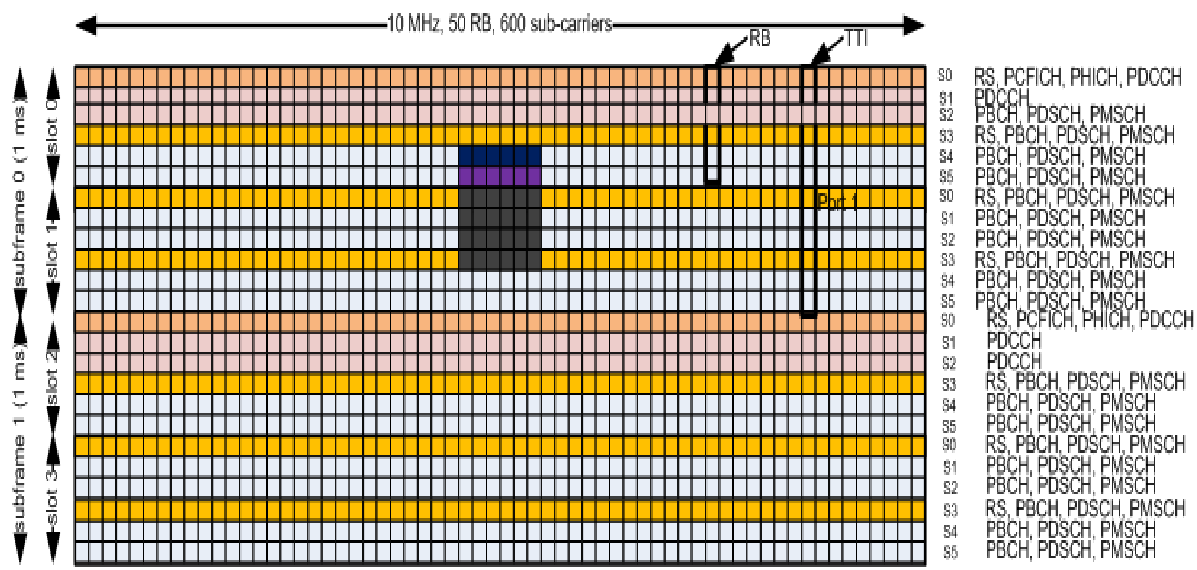
CelPlan
Wireless Solutions & Consulting

- Example on left: 5 MHz Bandwidth
- Subcarrier Width: 15 kHz
  - Central subcarrier
  - Null subcarriers
- Frame: 10 ms
  - Subframe: 1 ms
  - Slot: 0.5 ms
  - Symbol: 66.67 µs
  - Normal Cyclic Prefix: 5.2/ 4.7 µs (1.4 km)
  - Extended Cyclic Prefix: 16.7 µs (5 km)
- Resource Element
  - 1 subcarrier x 1 symbol
- Resource Block
  - 12 subcarriers x 1 slot
- Transmission Time Interval
  - 1 subframe
- Central Sub-carrier is not used
- Allocation
  - Green: Synchronization signals
  - Orange: Master Information Block
  - Yellow: Control/Signalling
  - Reference Signals: Blue
  - Light Blue: Traffic Data and Signalling

# LTE Frame Downlink

- Sub-Frame
- Slot
- Control Area
- Traffic Area
- Resource Element
- Resource Block
- PSS
- SSS
- CRS
- MIB
- PFCICH
- PHICH

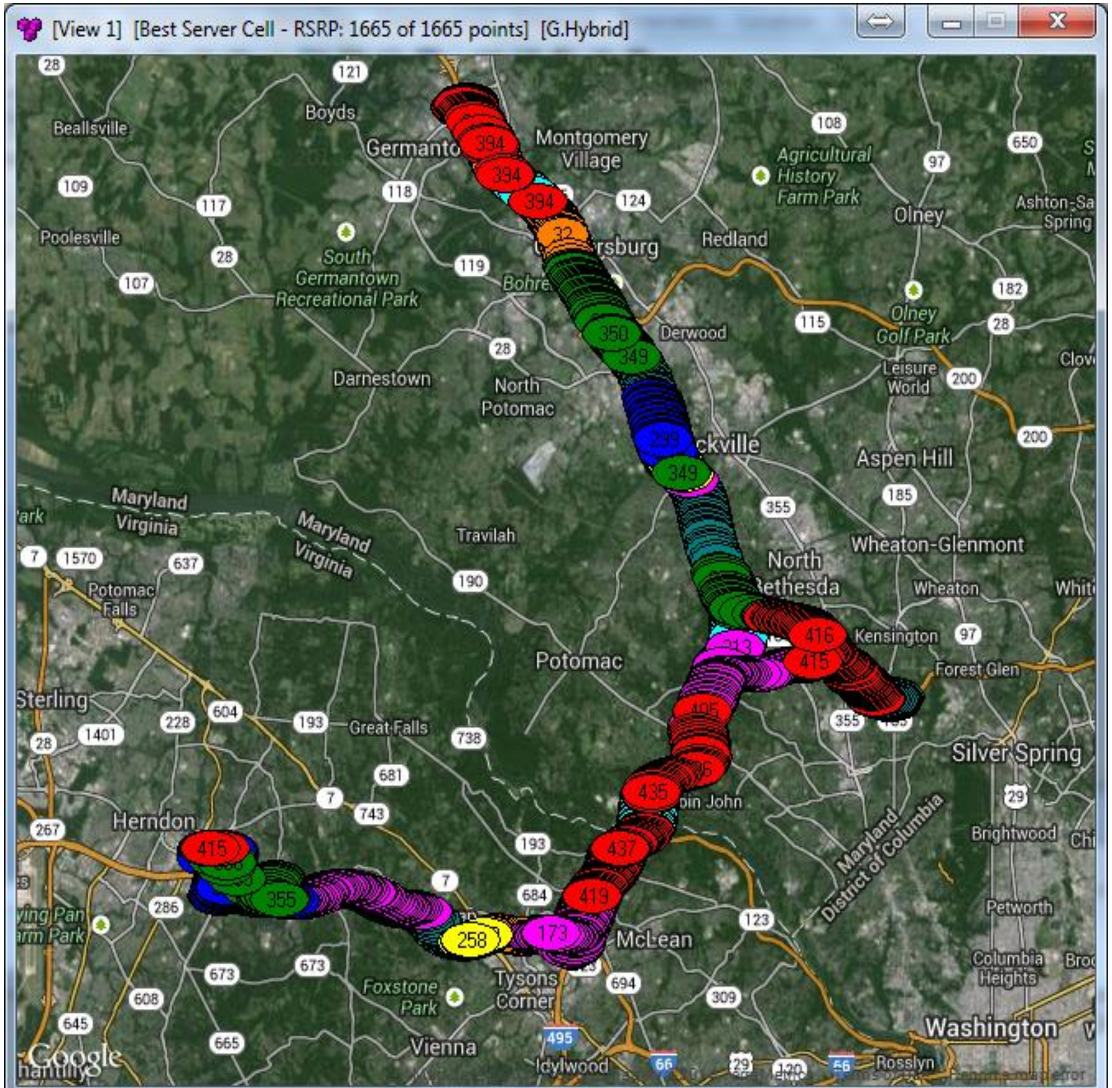


# CellSearch ™

- Cell Spectrum stores the entire bandwidth digital spectrum
  - 1.4 to 100 MHz
- This allows the retrieval of any information after the drive test
- CellSearch derives the main characteristics of each detected cell, by analyzing a 1.4 MHz bandwidth of each carrier
  - PCI (Physical Cell Identity): 1 to 504 (3*168)
  - Cyclic Prefix: normal, extended
  - Number Antennas: 1, 2, 3, 4
  - Bandwidth (MHz): 1.4, 3, 5 ,10, 15, 20
  - Physical Hybrid Indicator Channel (PHICH): duration (normal/ extended)
  - PHICH Group Scaling Factor: (1/6, 1/2, 1, 2)
  - Channel Format Indictor (CFI): 1, 2, 3

# CellSearch ™




Cell Parameters Visualization - CellSpectrum 1000

Configure | Visualize

Parameter: [1] Adjusted TFG

Antenna: 0

Total Cells: 84

Total Points: 2454

| Cell | PCI | Number of Points | Cyclic Prefix | Number of Antennas | Bandwidth (MHz) | Phich Duration | Phich Resource |
|---|---|---|---|---|---|---|---|
| 1 | 3 | 12 | Normal | 2 | 10 | Normal | 1 |
| 2 | 4 | 5 | Normal | 2 | 10 | Normal | 1 |
| 3 | 25 | 1 | Normal | 2 | 10 | Normal | 1 |
| 4 | 30 | 6 | Normal | 2 | 10 | Normal | 1 |
| 5 | 31 | 23 | Normal | 2 | 10 | Normal | 1 |
| 6 | 32 | 48 | Normal | 2 | 10 | Normal | 1 |
| 7 | 36 | 62 | Normal | 2 | 10 | Normal | 1 |
| 8 | 37 | 17 | Normal | 2 | 10 | Normal | 1 |
| 9 | 39 | 26 | Normal | 2 | 10 | Normal | 1 |
| 10 | 40 | 19 | Normal | 2 | 10 | Normal | 1 |
| 11 | 41 | 41 | Normal | 2 | 10 | Normal | 1 |
| 12 | 48 | 40 | Normal | 2 | 10 | Normal | 1 |
| 13 | 50 | 15 | Normal | 2 | 10 | Normal | 1 |
| 14 | 63 | 26 | Normal | 2 | 10 | Normal | 1 |
| 15 | 64 | 22 | Normal | 2 | 10 | Normal | 1 |
| 16 | 90 | 43 | Normal | 2 | 10 | Normal | 1 |
| 17 | 91 | 38 | Normal | 2 | 10 | Normal | 1 |
| 18 | 92 | 53 | Normal | 2 | 10 | Normal | 1 |
| 19 | 95 | 5 | Normal | 2 | 10 | Normal | 1 |
| 20 | 96 | 18 | Normal | 2 | 10 | Normal | 1 |
| 21 | 97 | 19 | Normal | 2 | 10 | Normal | 1 |
| 22 | 98 | 32 | Normal | 2 | 10 | Normal | 1 |
| 23 | 105 | 2 | Normal | 2 | 10 | Normal | 1 |
| 24 | 106 | 5 | Normal | 2 | 10 | Normal | 1 |
| 25 | 107 | 43 | Normal | 2 | 10 | Normal | 1 |
| 26 | 111 | 33 | Normal | 2 | 10 | Normal | 1 |
| 27 | 113 | 20 | Normal | 2 | 10 | Normal | 1 |
| 28 | 138 | 6 | Normal | 2 | 10 | Normal | 1 |

Visualize

Total Selected: 1

# Field Measurements

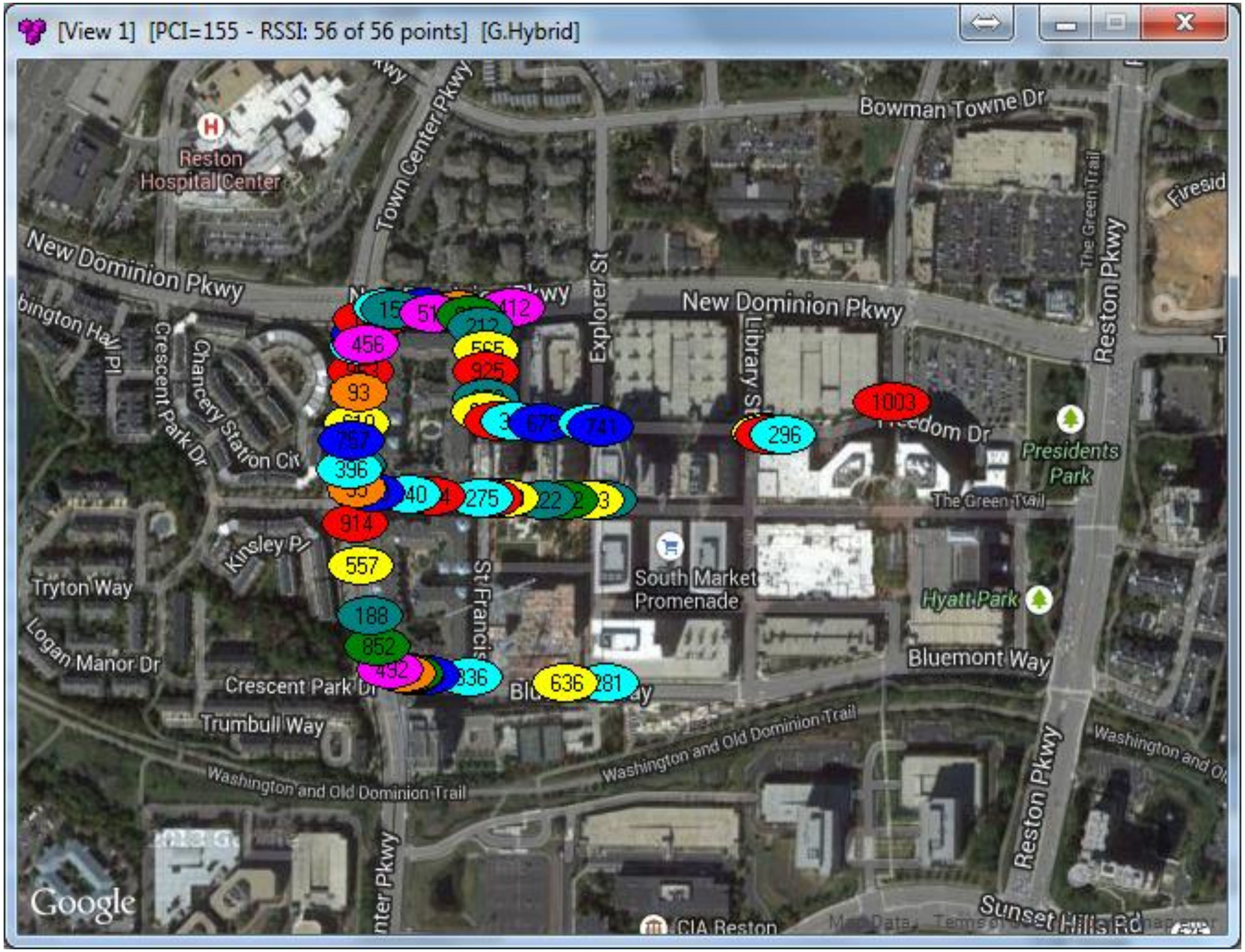
- 1D Measurements
  - RF propagation model calibration
  - Receive Signal Strength Information
  - Reference Signal Received Power
  - Reference Signal Received Quality
  - Primary Synchronization Signal power
  - Signal power
  - Noise and Interference Power
  - Fade Mean
- 2D Measurements
  - Primary Synchronization Signal Power Delay Profile
- 3D measurements
  - Received Time Frequency Resource Elements
  - Channel Frequency response
  - Channel Impulse Response
  - Transmit Antenna Correlation
  - Traffic Load
- Measurement Based Predictions

# 2.1 1D Measurements

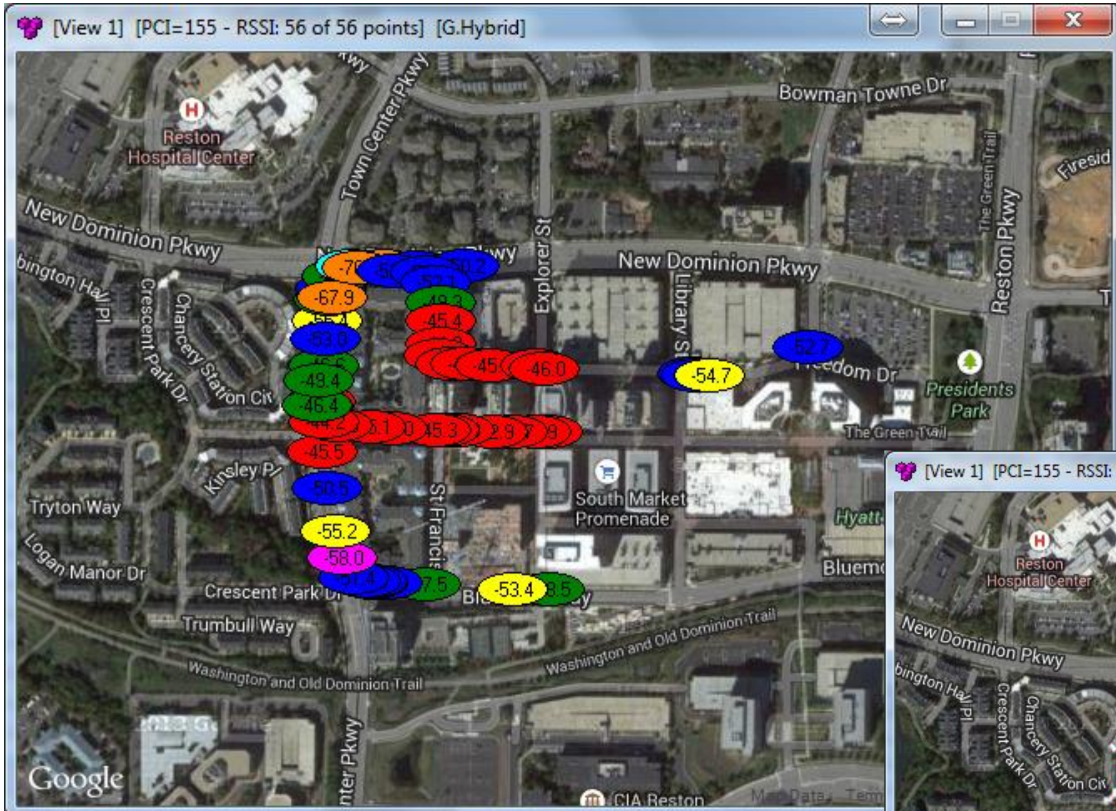
# 1D Measurements

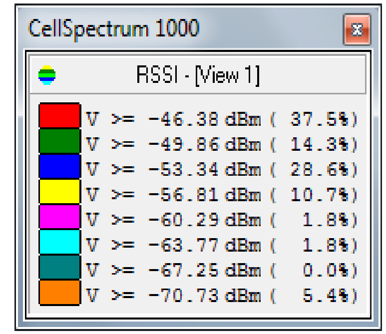
- System Frame Number (SFN)
- Receive Signal Strength Information (RSSI)
- Reference Signal Power (RSRP)
- Reference Signal Received Quality (RSRQ)
- Primary Synchronization Signal (PSS)
- Signal Power
- Noise and Interference Power
- Fade Mean

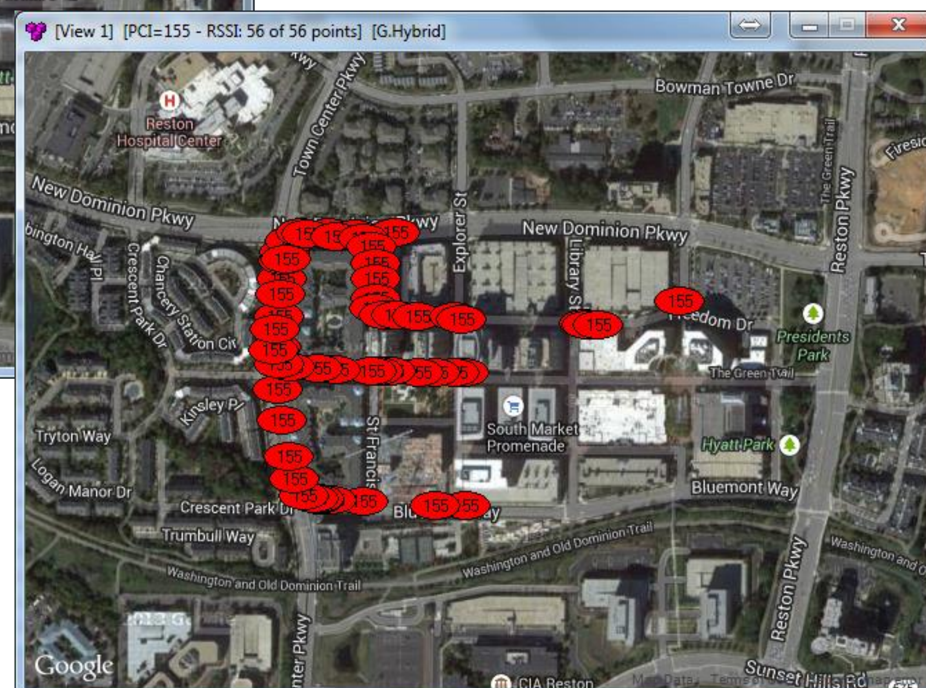
# System Frame Number (SFN)



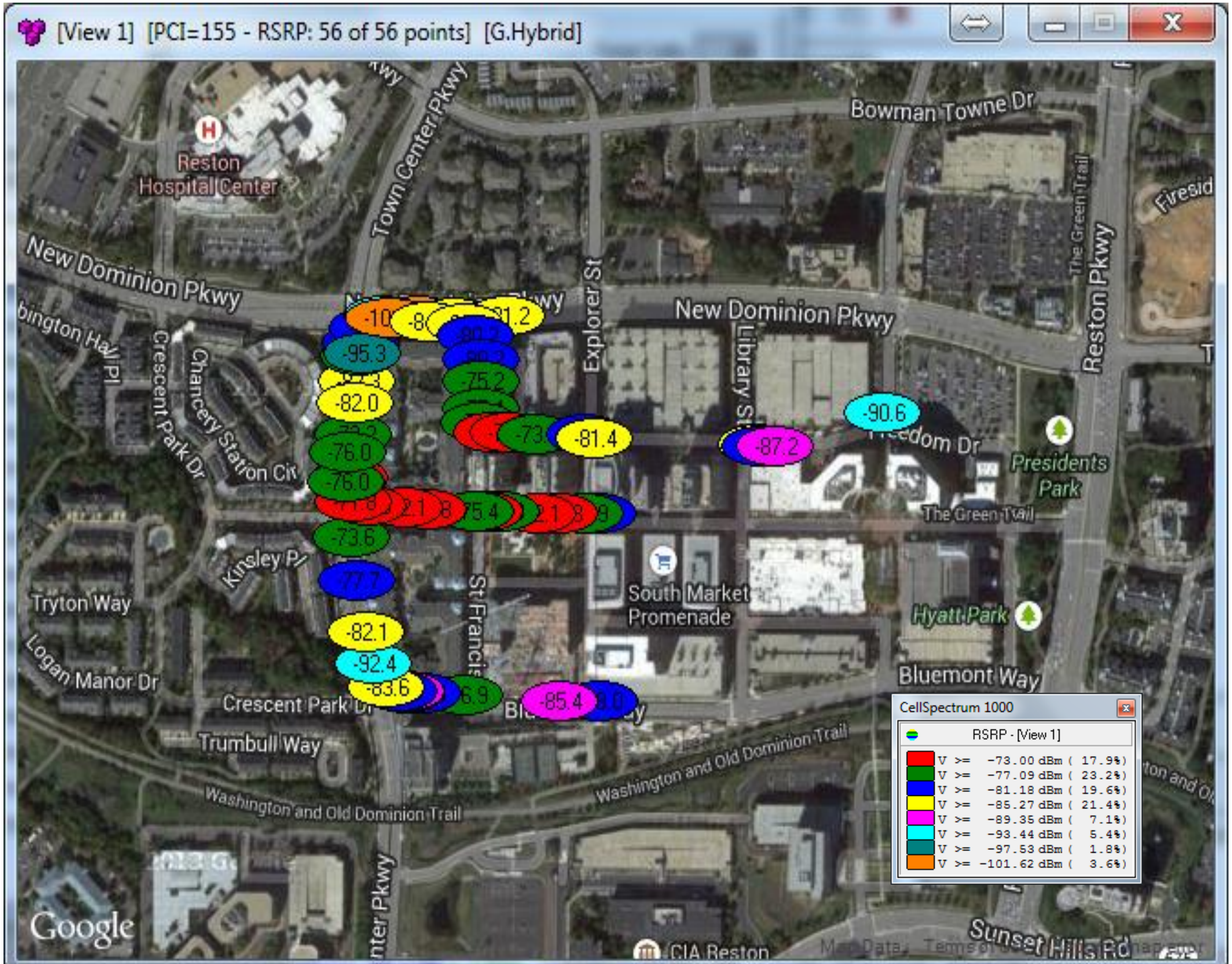
# Receive Signal Strength Information (RSSI)



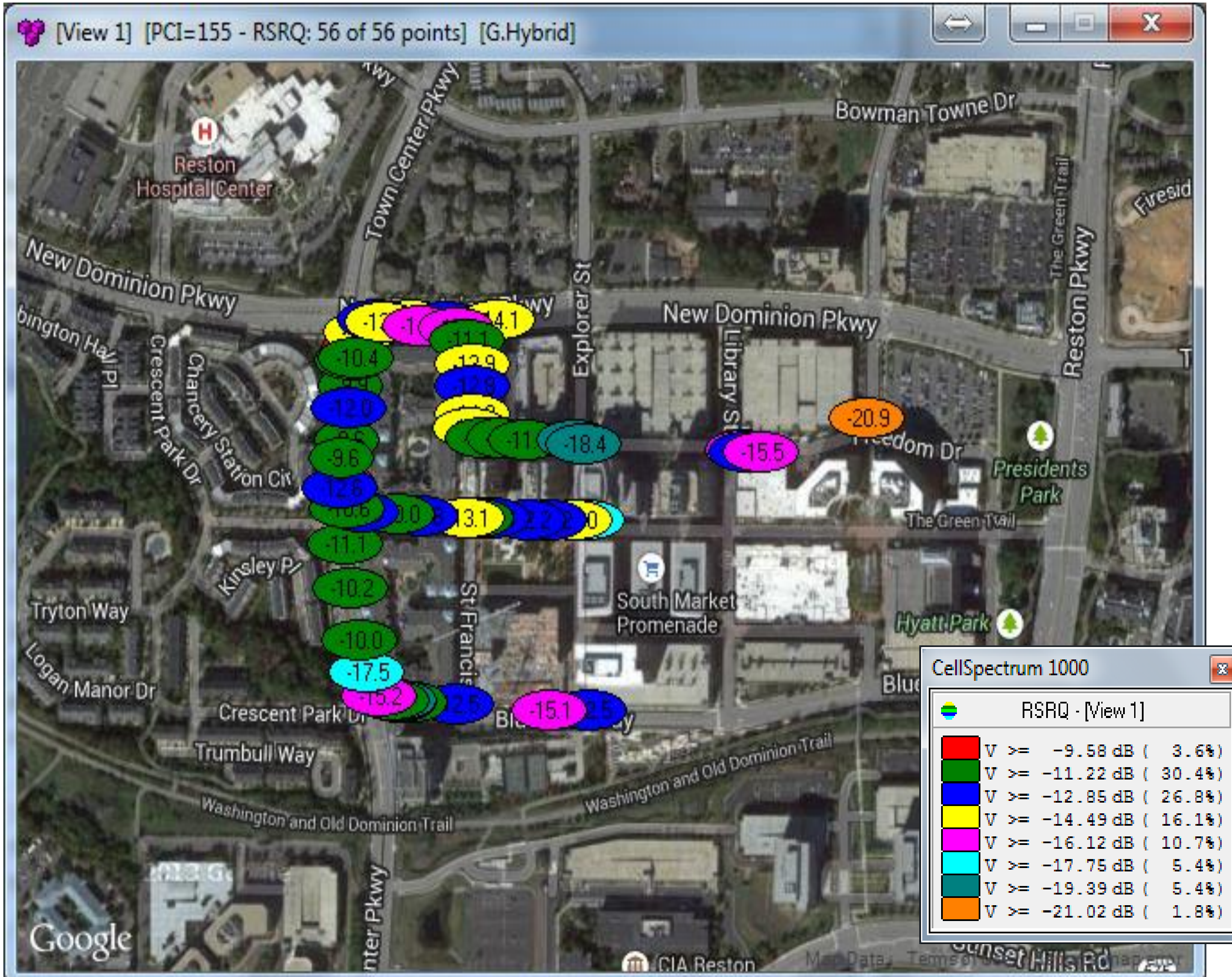



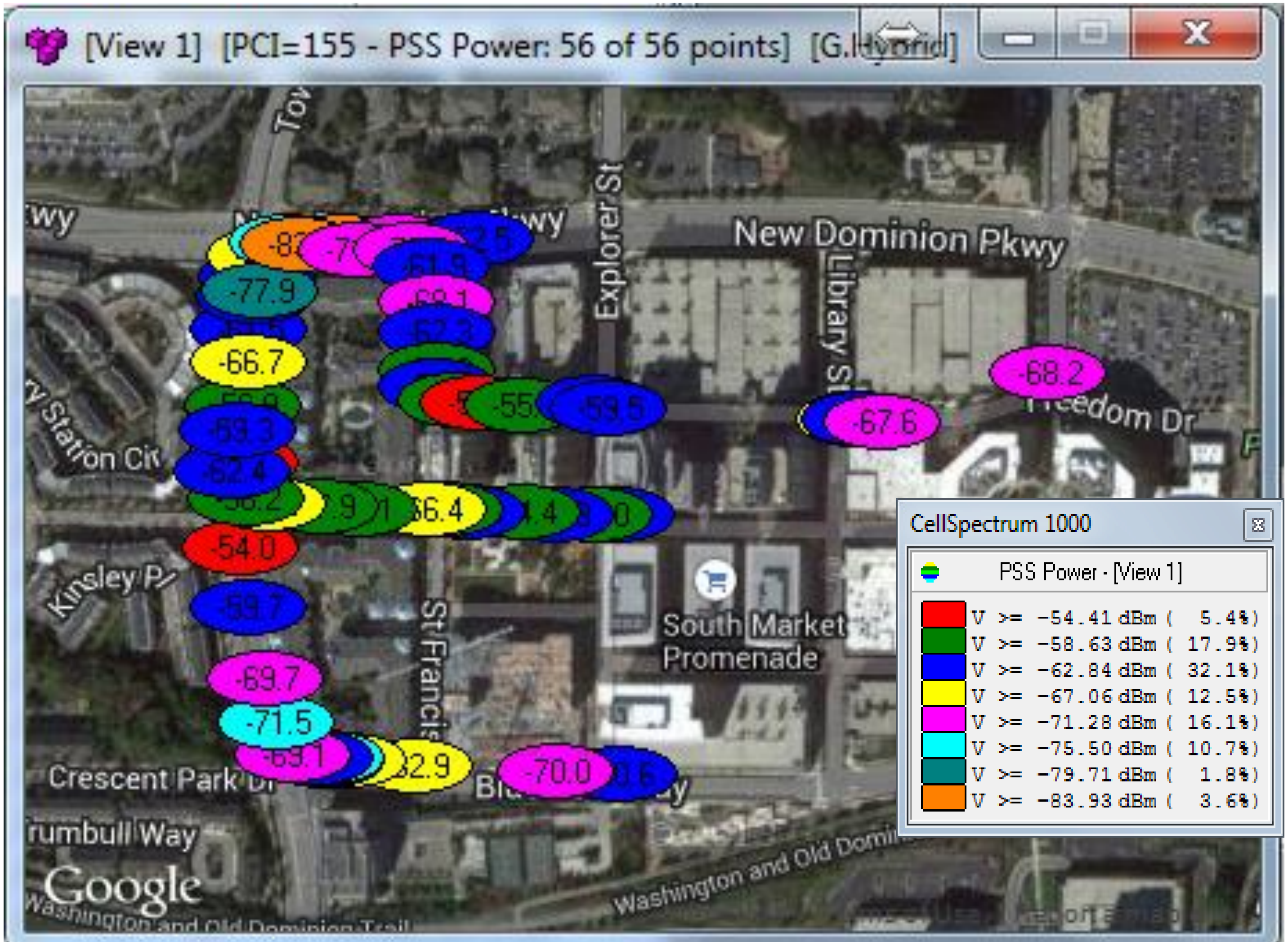
# Reference Signal Received Power (RSRP)



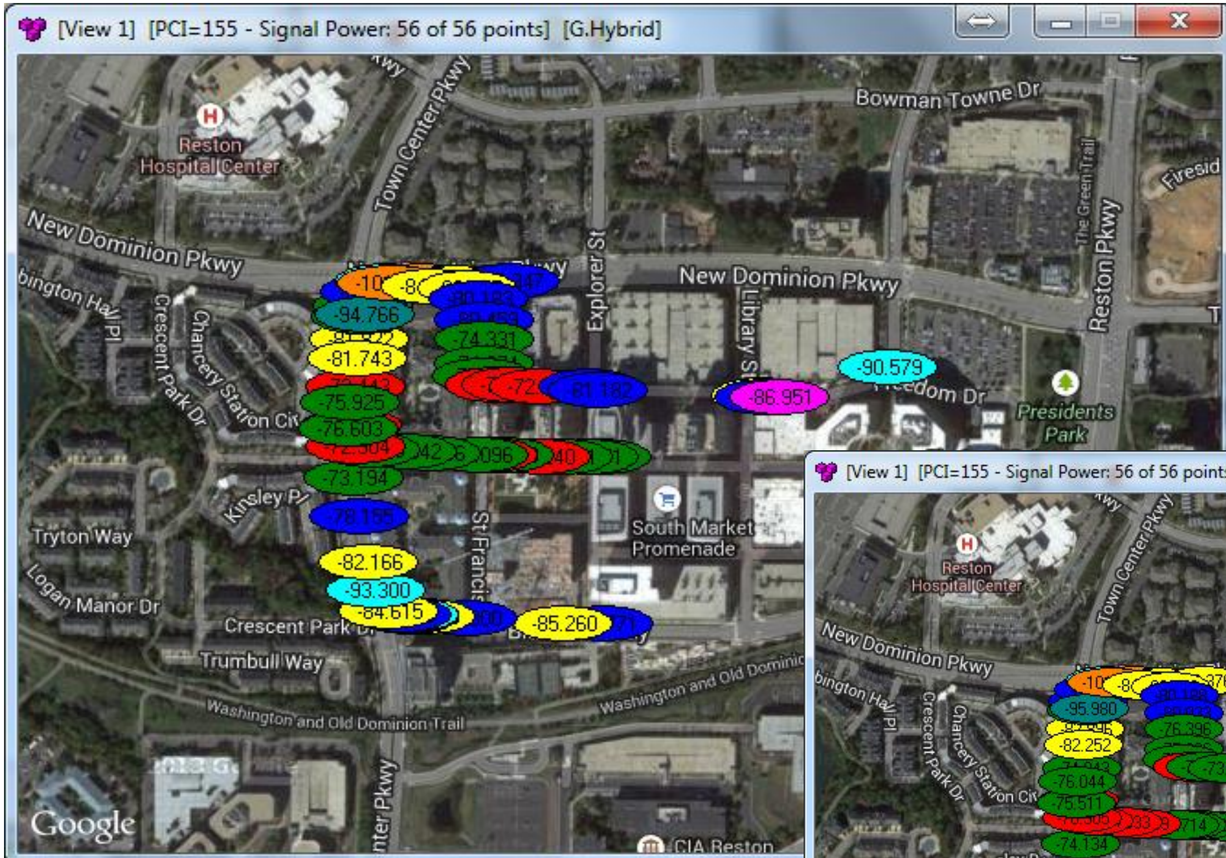
# Reference Signal Received Quality (RSRQ)

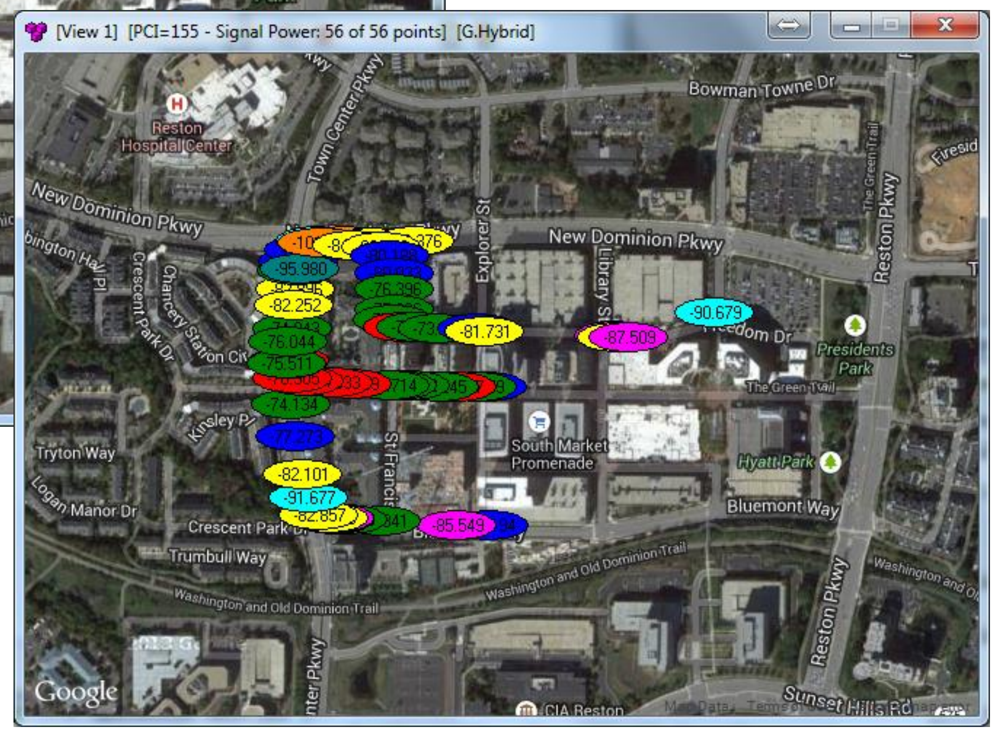


# Primary Synchronization Signal (PSS) Power

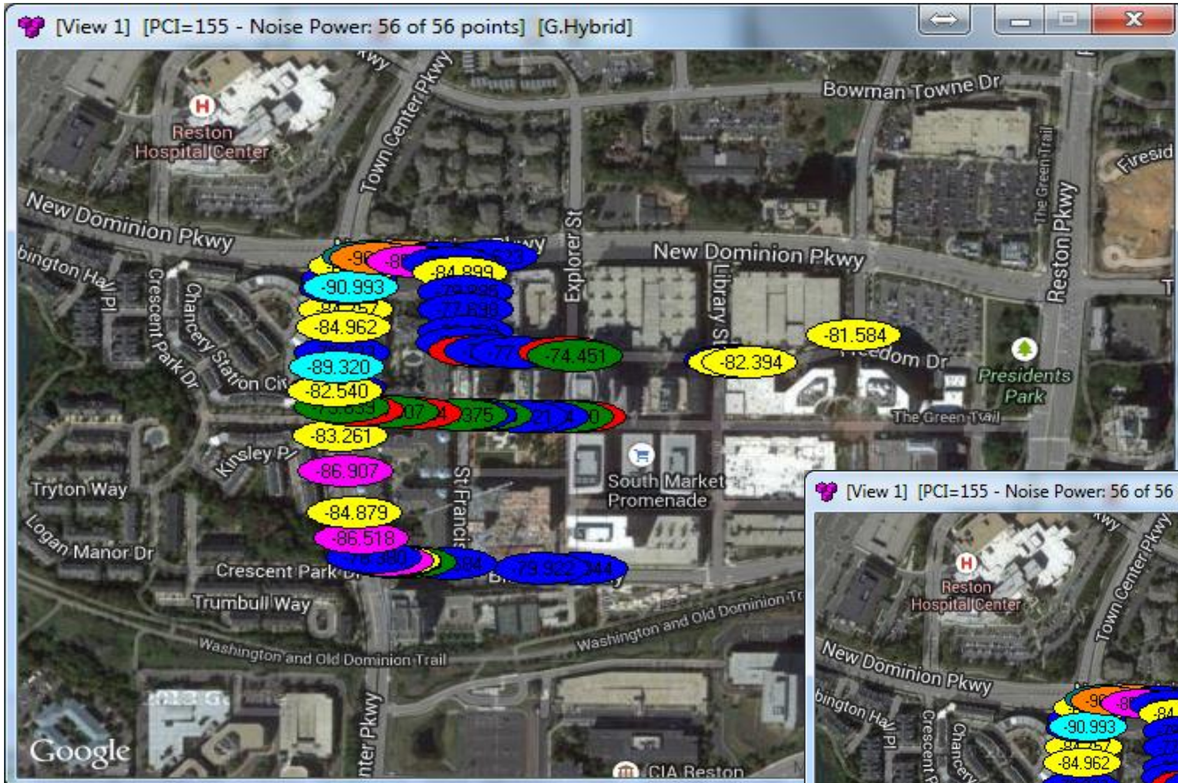


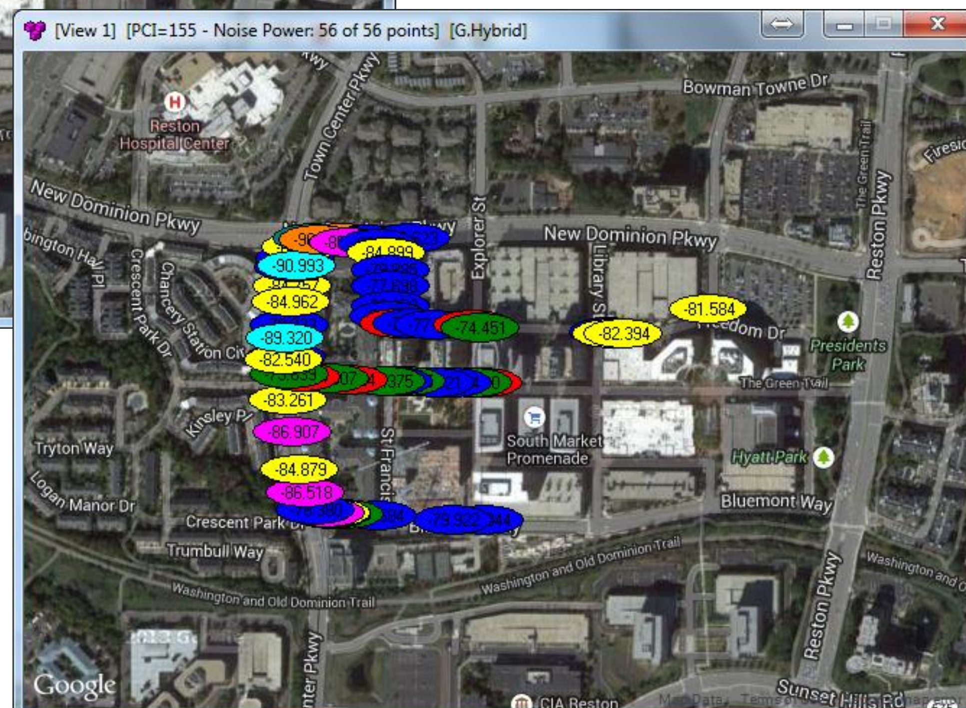
# Signal Power (SP)



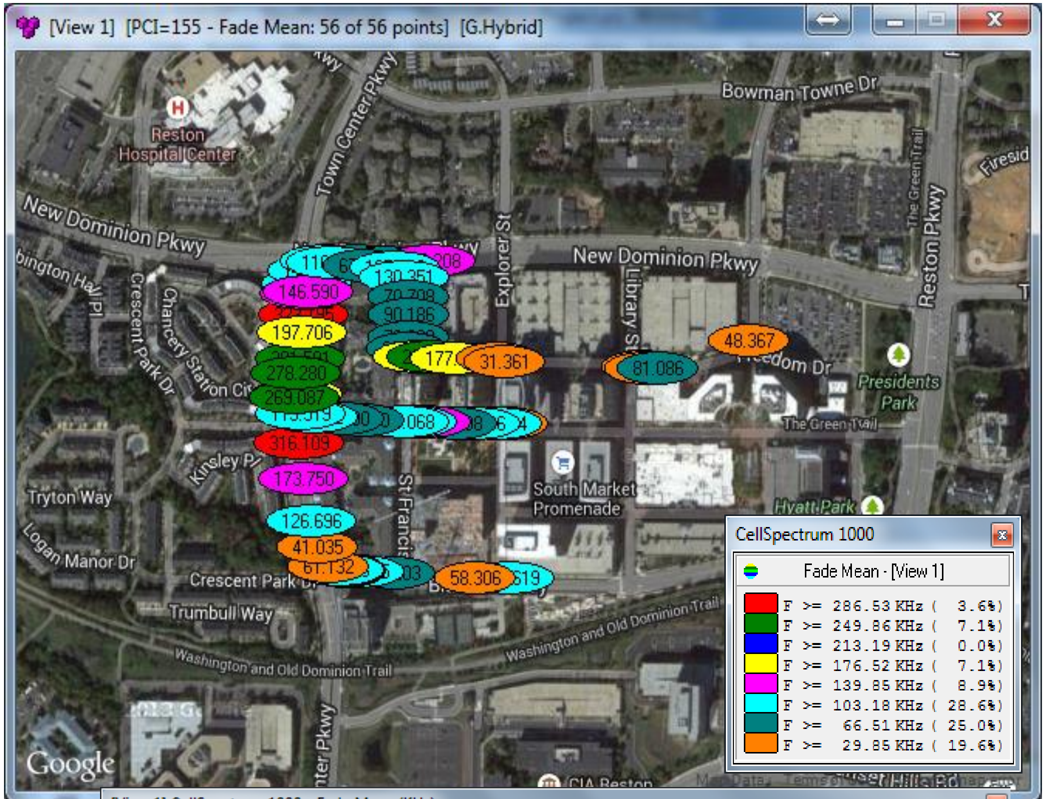



# Noise and Interference Power (NIP)

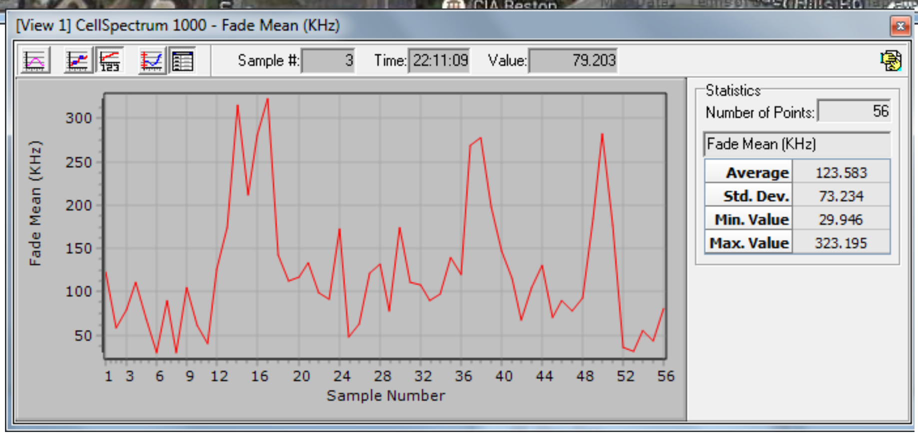


# Fade Mean



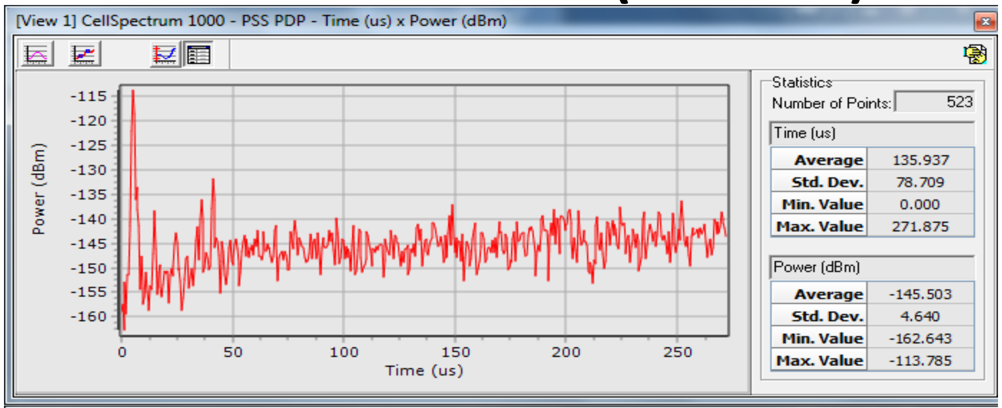
[View 1] [PCI=155 - Fade Mean: 56 of 56 points] [G.Hybrid]
CellSpectrum 1000
Fade Mean - [View 1]
F >= 286.53 KHz ( 3.6%)
F >= 249.86 KHz ( 7.1%)
F >= 213.19 KHz ( 0.0%)
F >= 176.52 KHz ( 7.1%)
F >= 139.85 KHz ( 8.9%)
F >= 103.18 KHz ( 28.6%)
F >= 66.51 KHz ( 25.0%)
F >= 29.85 KHz ( 19.6%)

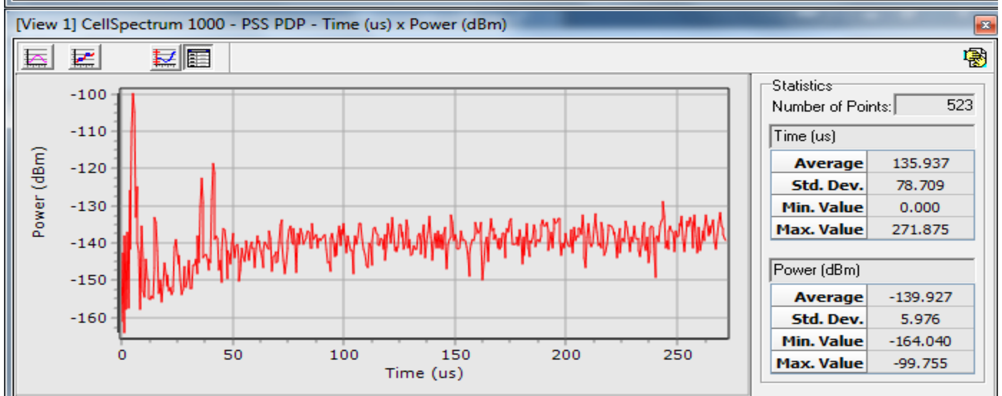



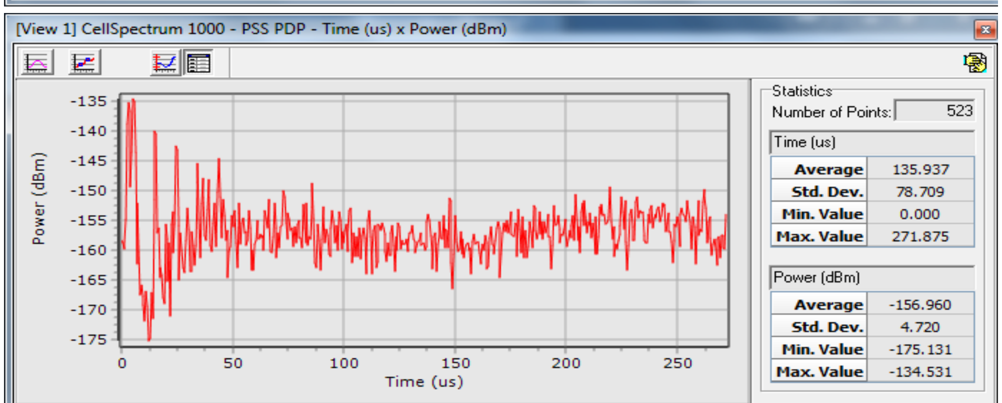
[View 1] CellSpectrum 1000 - Fade Mean (KHz)
Sample #: 3
Time: 22:11:09
Value: 79.203
Fade Mean (KHz)
Sample Number
Statistics
Number of Points: 56
Fade Mean (KHz)
Average 123.583
Std. Dev. 73.234
Min. Value 29.946
Max. Value 323.195

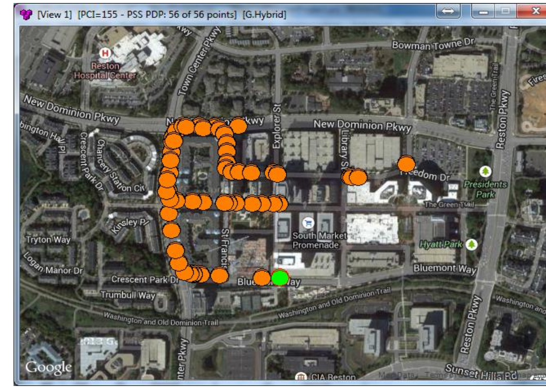
# 2.2 2D Measurements

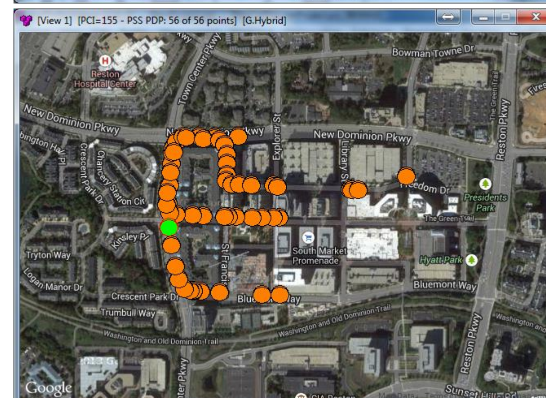
# Primary Synchronization Signal Power Delay Profile (PSS PDP)

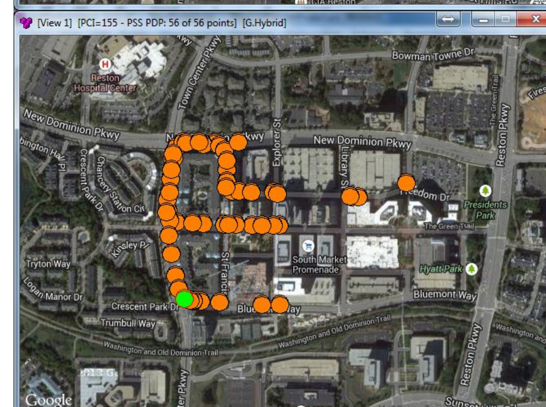


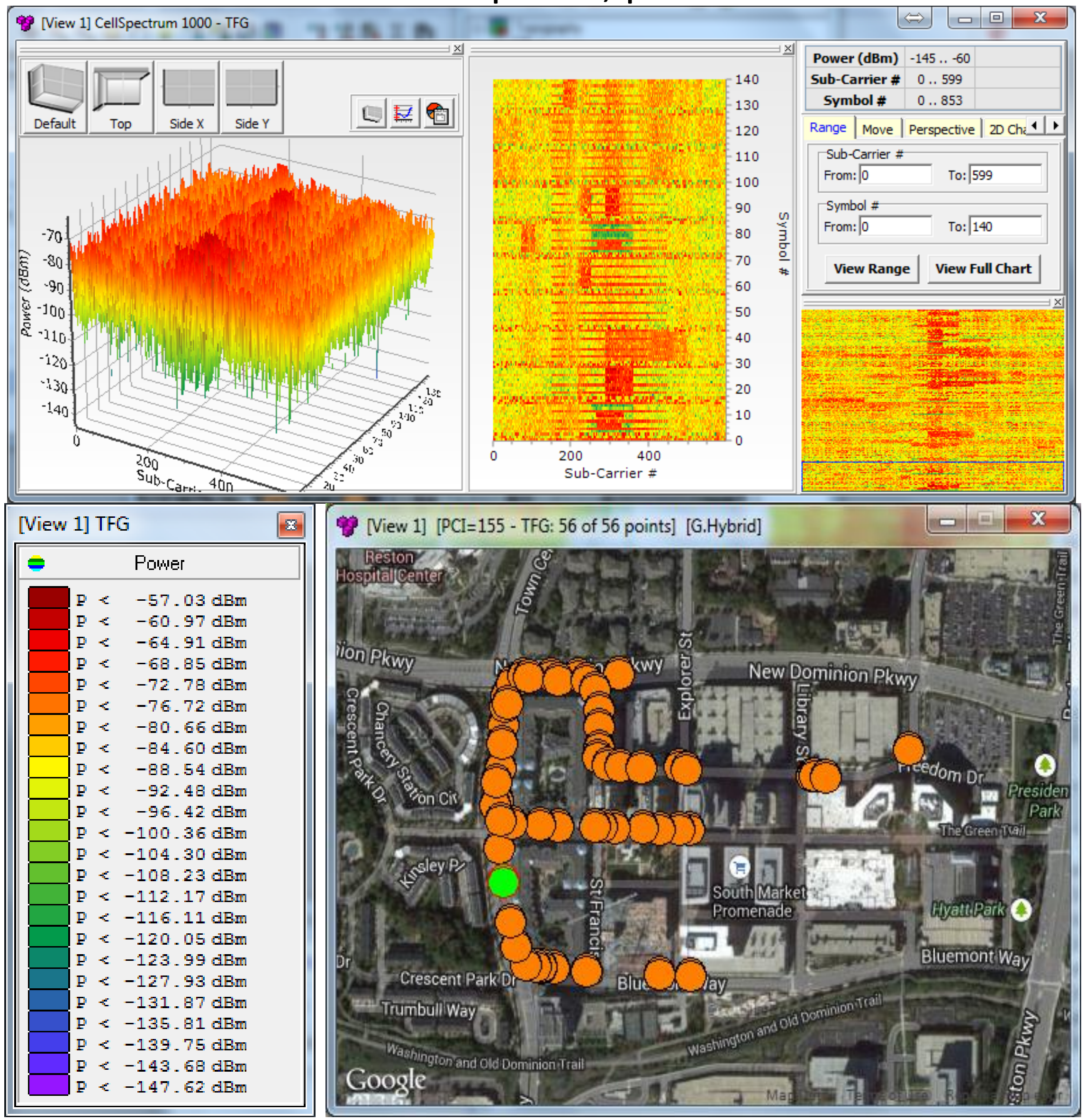
# 2.3 3D Measurements

# 3D Measurements

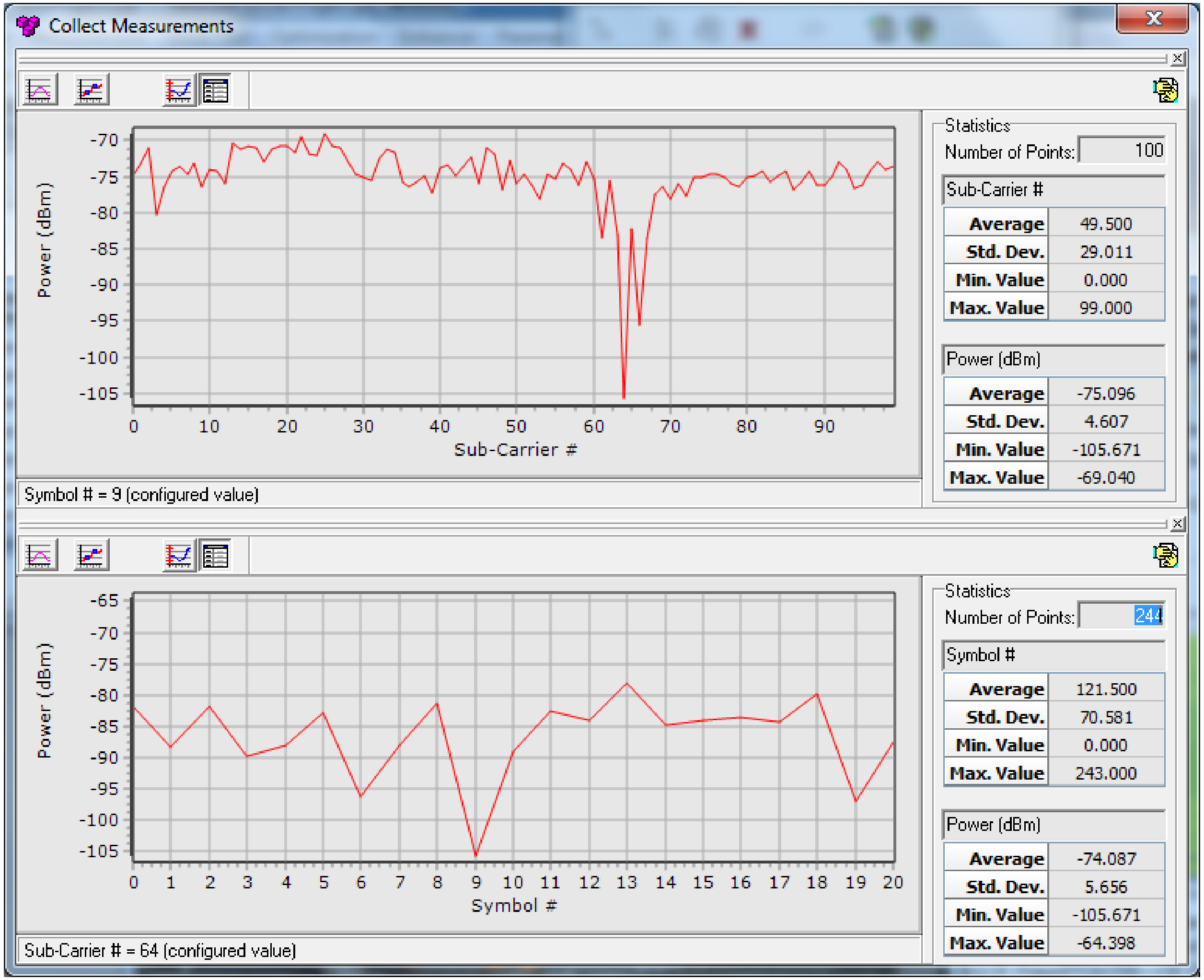
- Received Time Frequency Grid (TFG)
- Channel Frequency Response (CFR)
- Adjusted Time Frequency Grid (CFR)
- Channel Impulse Response (CIR)
- Transmit Antenna Correlation (TxAC)

# Received Time Frequency Grid (TFG)

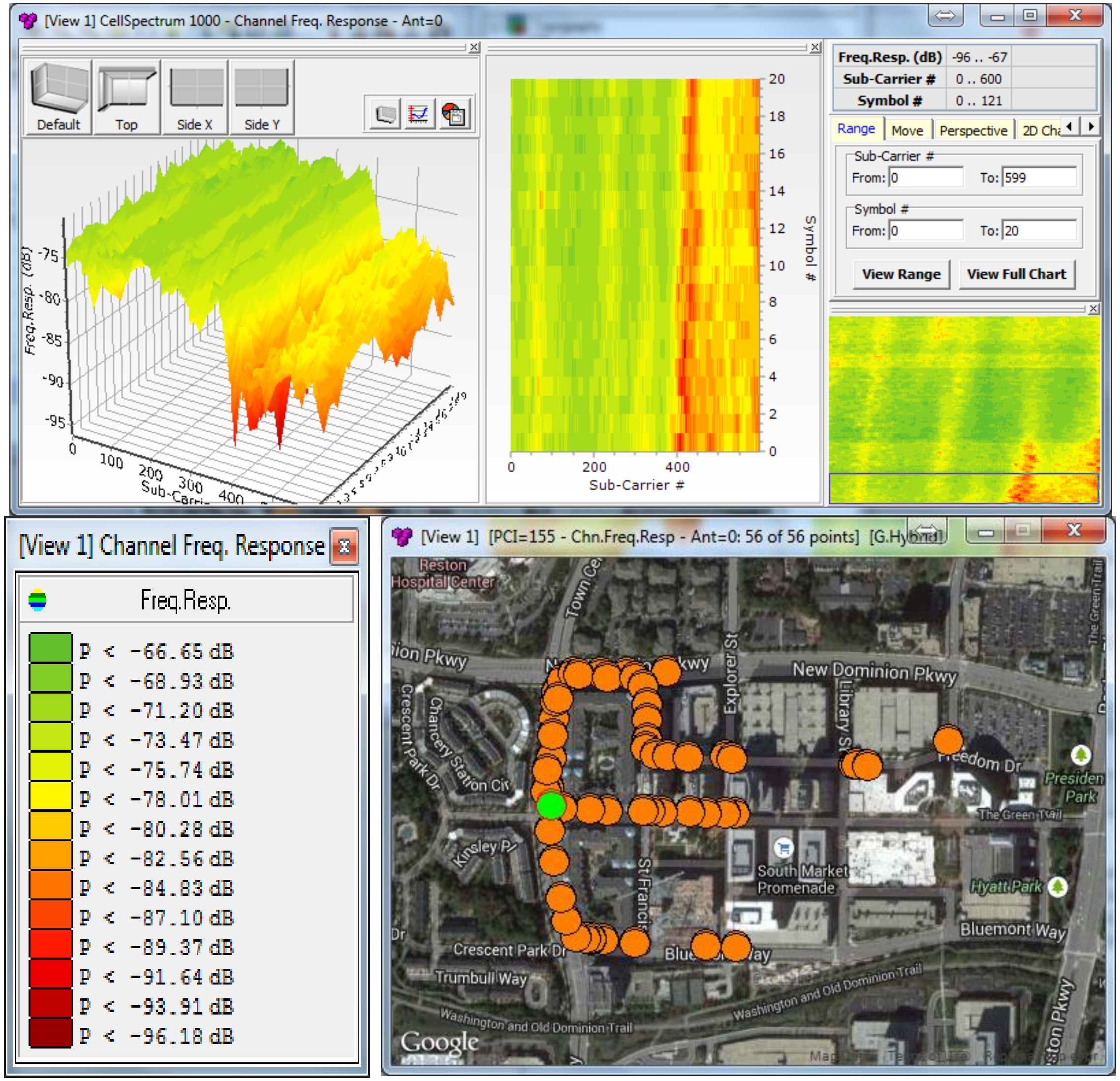
Antenna port 0, point 2



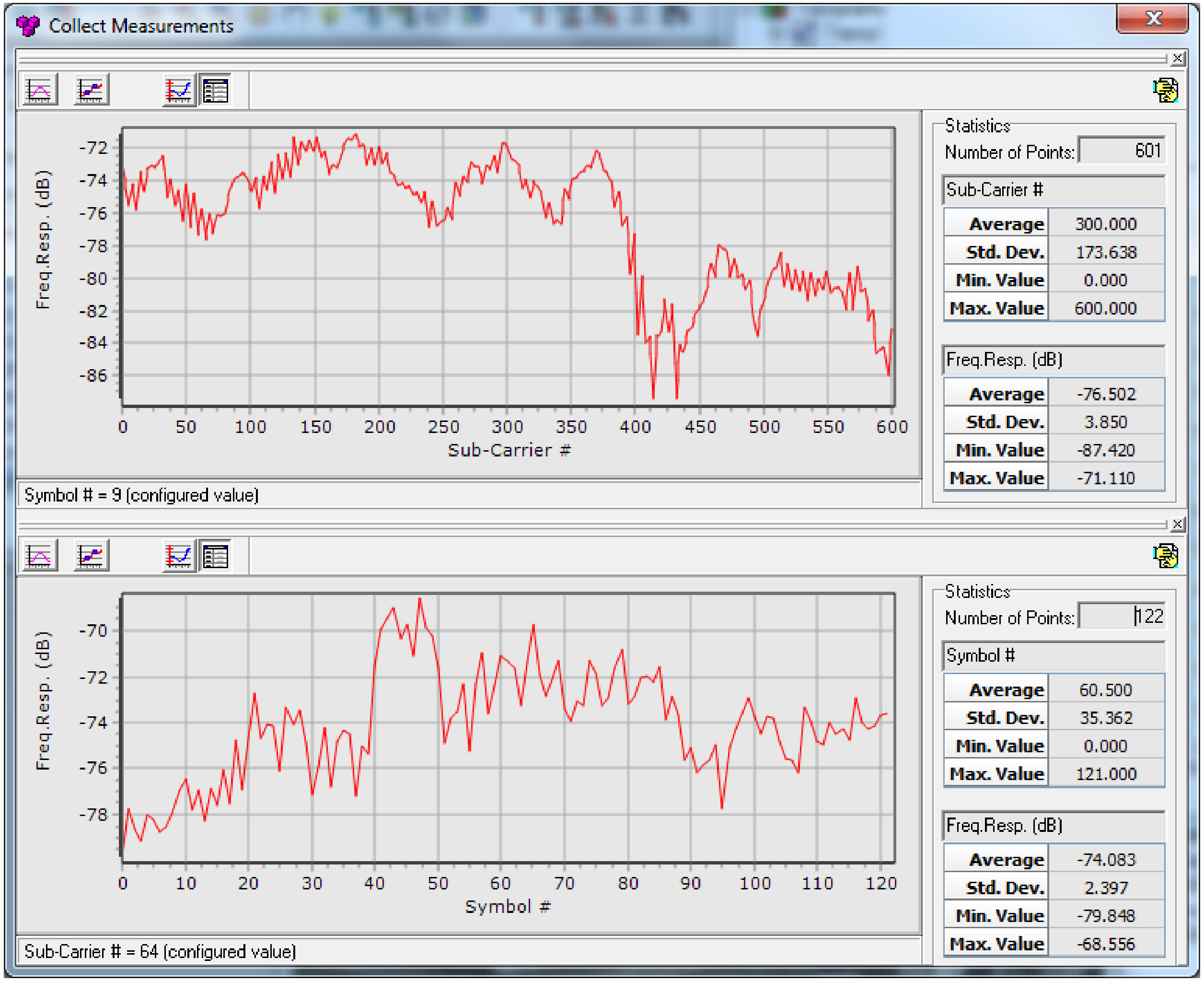
# Received Time Frequency Grid (TFG)



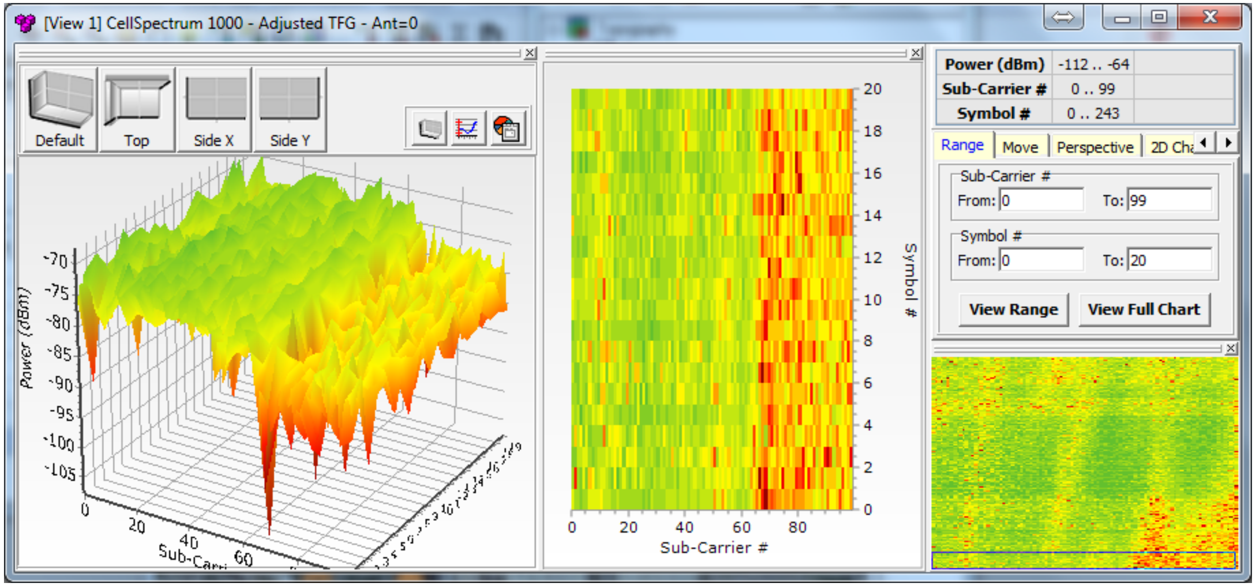
# Channel Frequency Response (CFR)

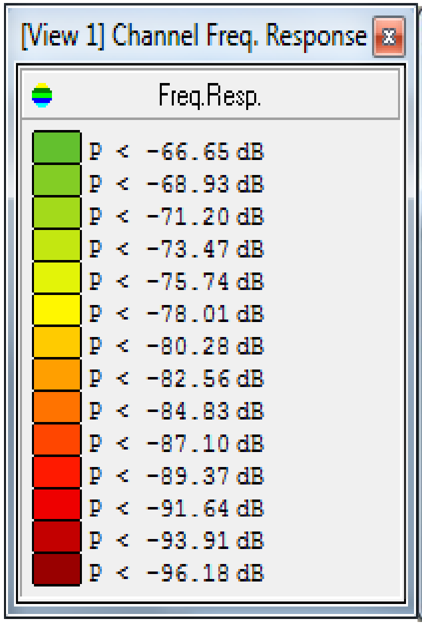


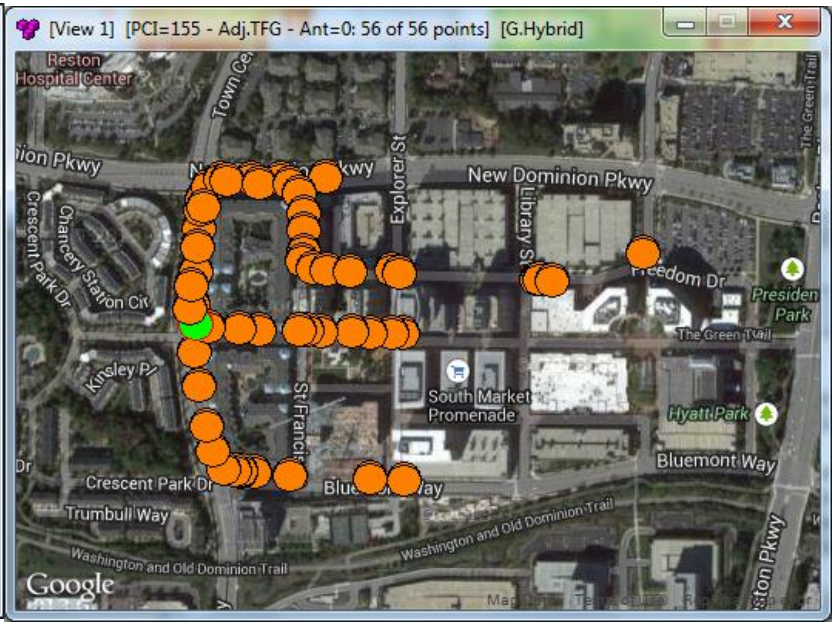
# Channel Frequency Response (CFR)



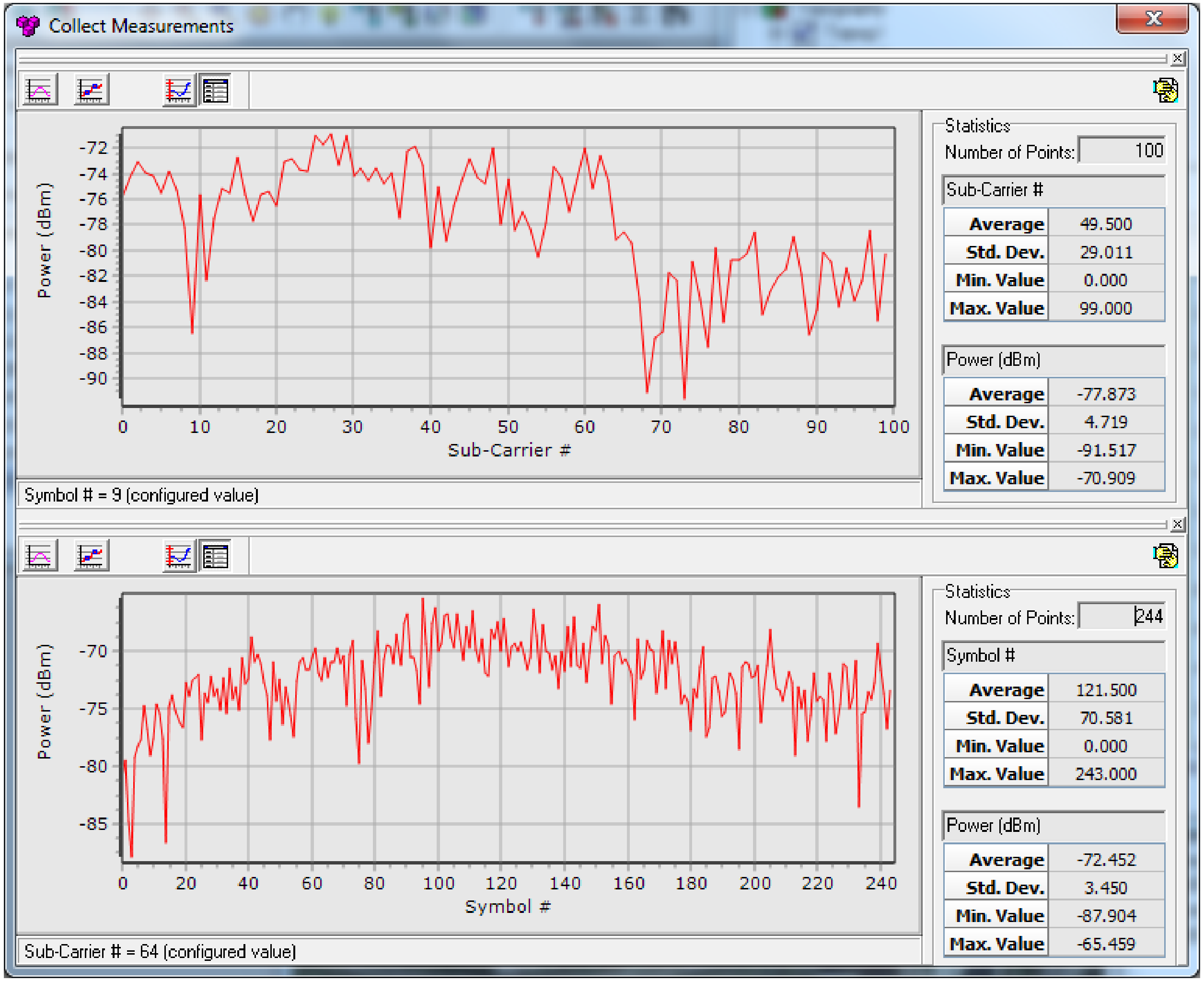
# Adjusted Time Frequency Grid (ATFG)



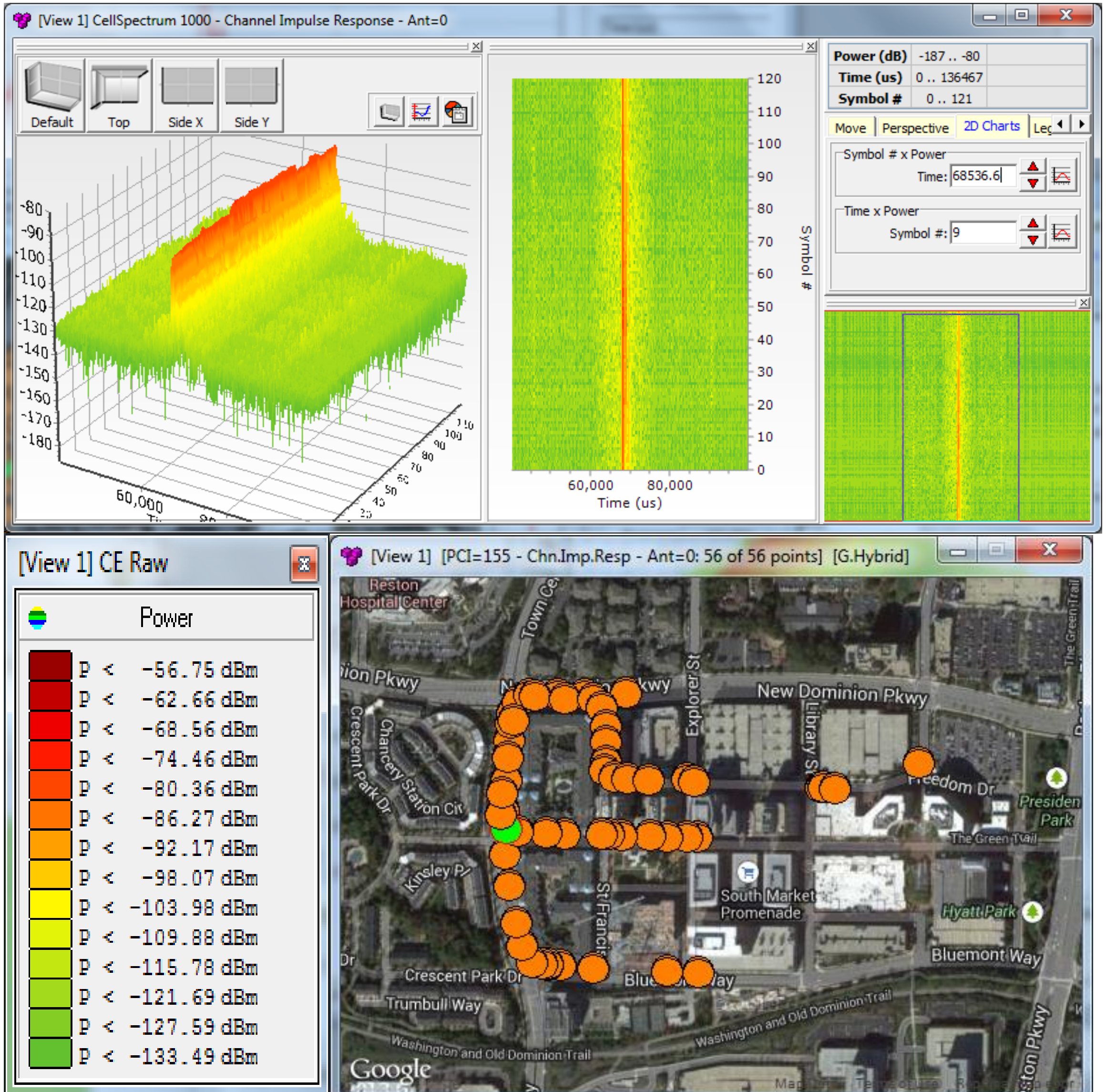



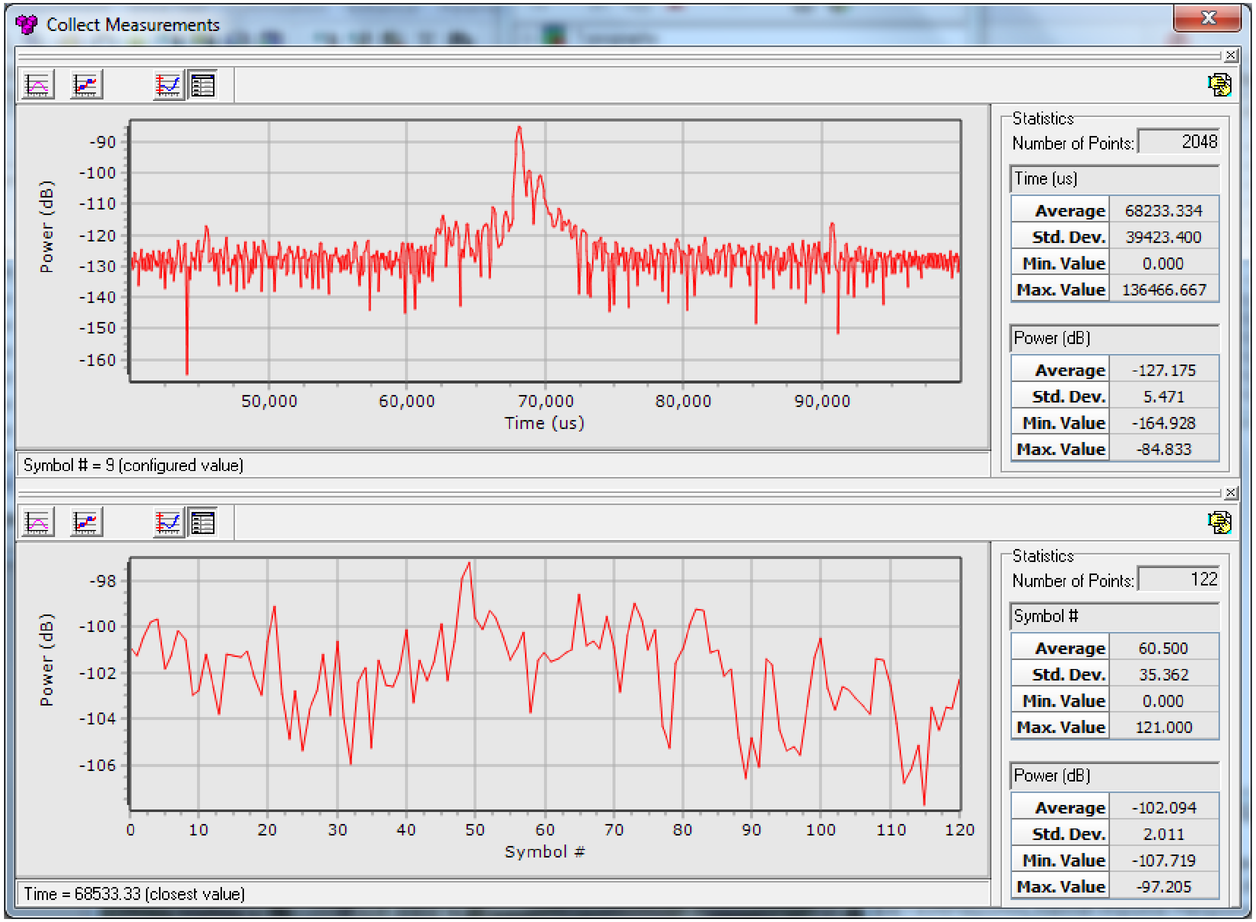
# Adjusted Time Frequency Grid (ATFG)



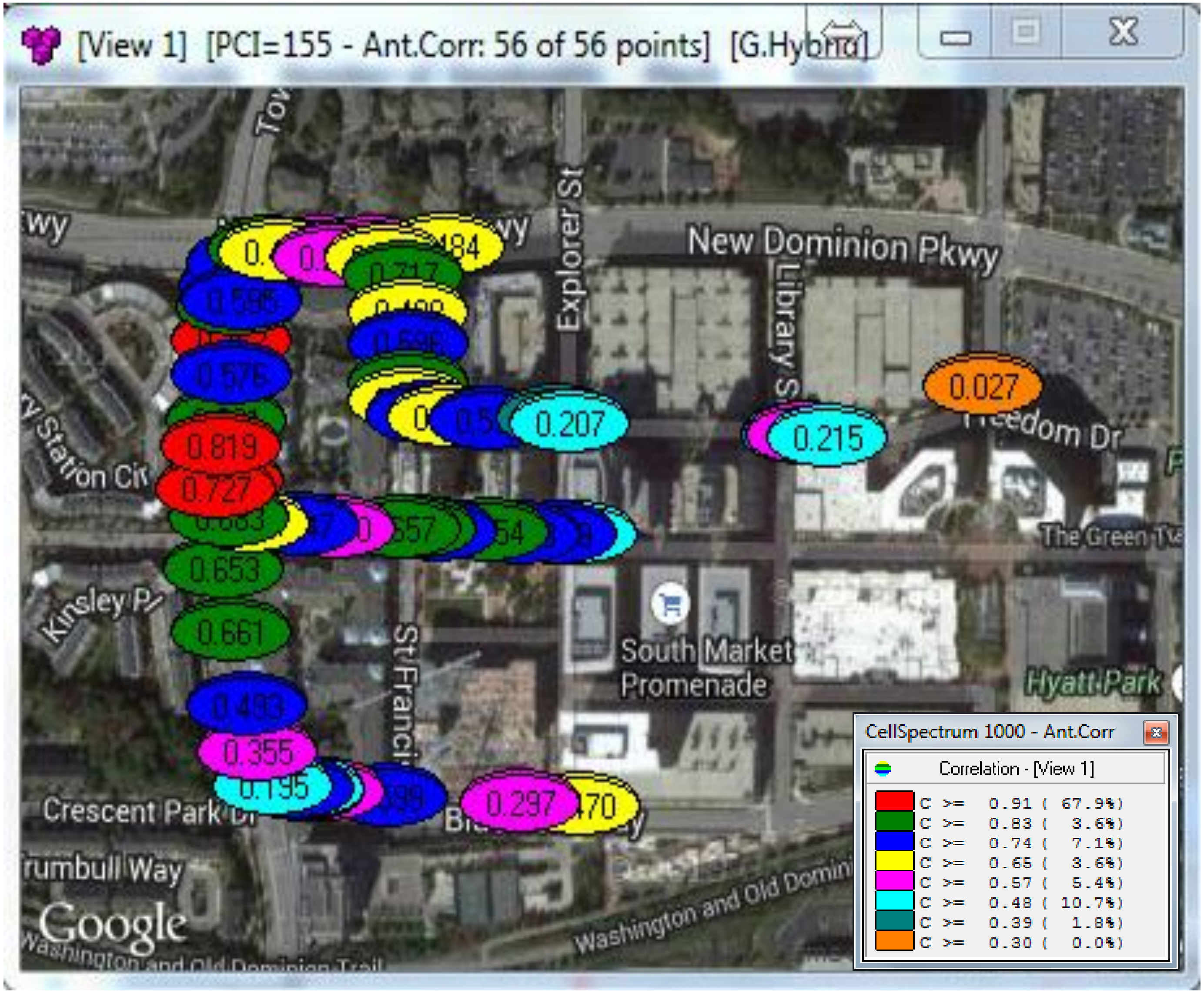
# Channel Impulse Response (IR)



# Channel Impulse Response (IR)



# Transmit Antenna Correlation (TxAC)



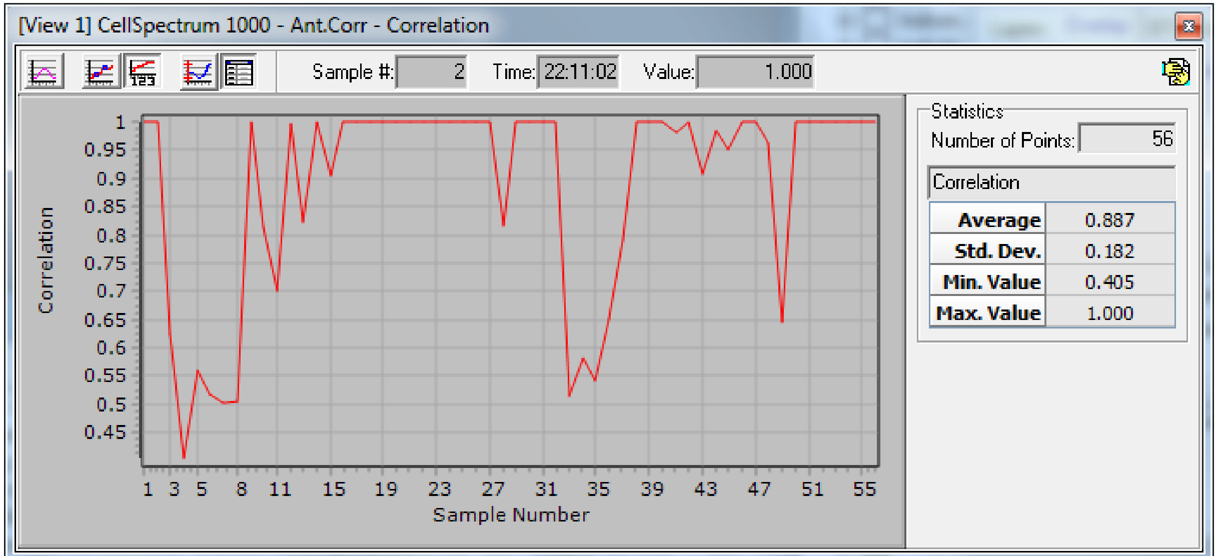
# Antenna Correlation

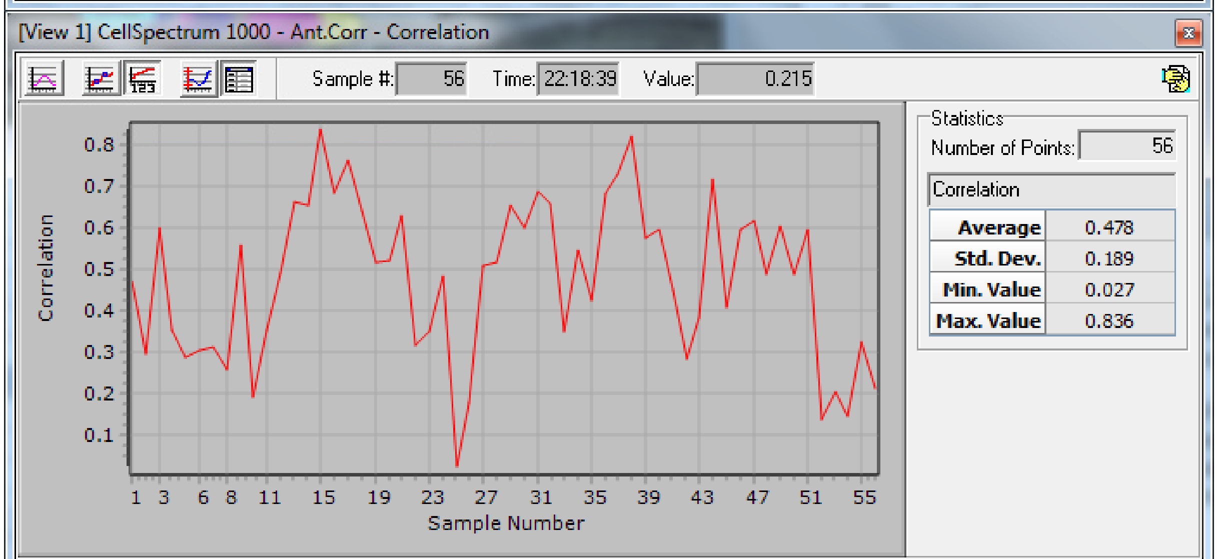
- Correlation is considered as the sympathetic movement of two or more variables
- Pearson's Product-Moment Correlation Coefficient

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{(n-1)s_x s_y} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}},$$

  – The correlation coefficient varies between +1 and -1
    - Positive Correlation: movement is in the same direction
    - Negative Correlation: movement is in the opposite direction
- Reference signals transmitted by two antennas can be used to establish the channel response
- The correlation coefficient for the two channel responses can then be calculated

# Transmit Antenna Correlation (TxAC)

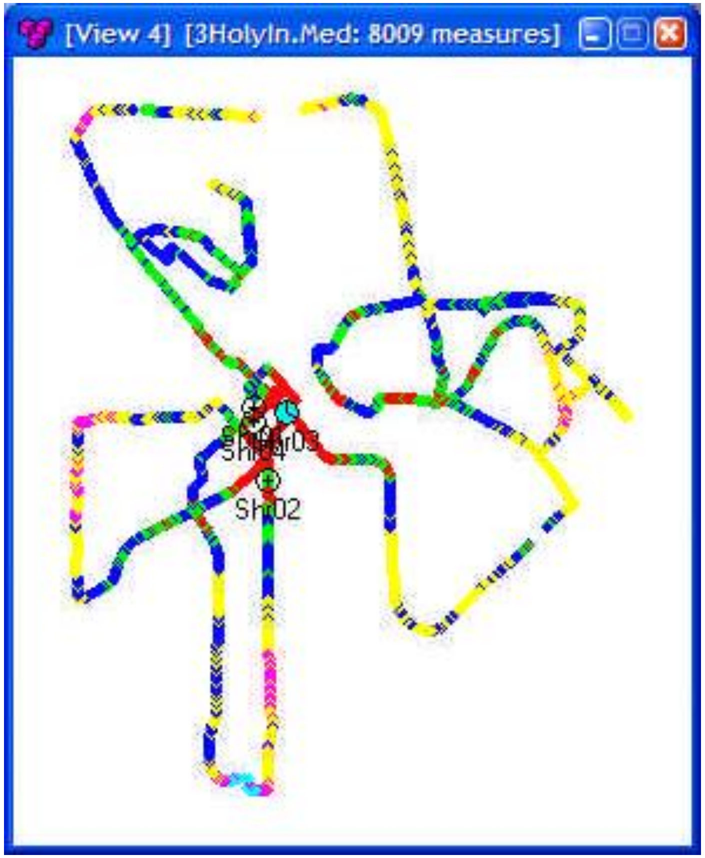


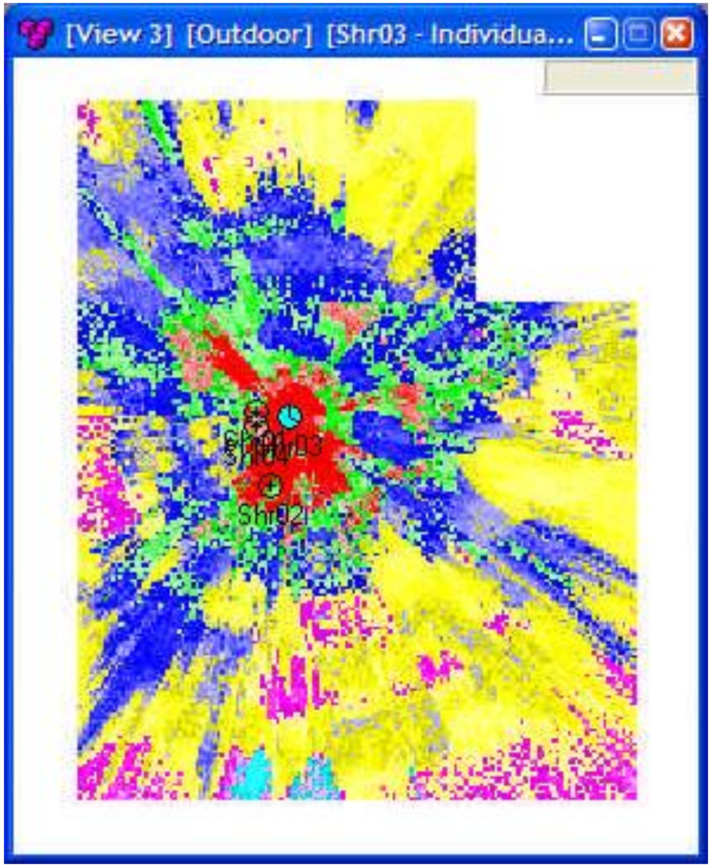



# 2.4 Measurement based Predictions

# CellPrediction™

- Collected measurements are interpolated by CellPrediction resulting in a continuous coverage plot



# 3. What LTE parameters need to be Dimensioned and Optimized

Next Webinar

September 3, 2014

# Next Webinar

## "What LTE parameters need to be Dimensioned and Optimized"

September 3, 2014

LTE has many parameters that have to be dimensioned or planned

- **Parameters to be dimensioned**
  - Cyclic Prefix
  - Control Format Indicator
  - PHICH duration
  - PHICH scaling factor
  - Other Reference Signals
- **Parameters to be planned (assigned)**
  - Physical Cell Identification (PCI)
  - PRACH parameter planning
    - Preamble format
    - PRACH configuration index
    - Zero correlation zone
    - Root Sequence Index
    - Frequency Offset
  - Uplink Reference Signal Sequence
  - Cell and BTS Identity Planning
  - Tracking Areas
  - Neighborhood Planning

LTE resources have to be optimized, as in any cellular network, with considerations for ICIC and other techniques

- **Resource Allocation in LTE**
  - Control, Traffic and Signalling
- **Interference Analysis**
  - SNR and SNIR, FEC, H-ARQ
- **Resource Reuse analysis in LTE**
  - Reuse of 1 x Reuse of n
- **Frequency Planning**
- **Traffic Resource Planning**
  - Allocation schedulers
  - Frequency segmentation
  - Time zoning
- **Control Resource Planning**
  - Can it be done?

# 4G Network Design and Optimization Boot Camp Online Edition – EMEA/APAC Region

August 19, 20 and 26, 27 2014

# 4G Technologies Boot Camp

## Online Edition - EMEA Region

- Designed to give CEOs, CTOs, managers, engineers, and technical staff the practical knowledge on 4G networks (America Region time)
- Modular Course – 2 days per module
  - **Module A: Wireless Communications Fundamentals**
    - July 22nd & 23rd, 2014
  - **Module B: 4G Technologies in-depth Analysis**
    - July 29th & 30th
- 4G Certification (Optional)
- Additional information, Pricing & Registration available at [www.celplan.com](http://www.celplan.com)

# 4. CelPlan New Products

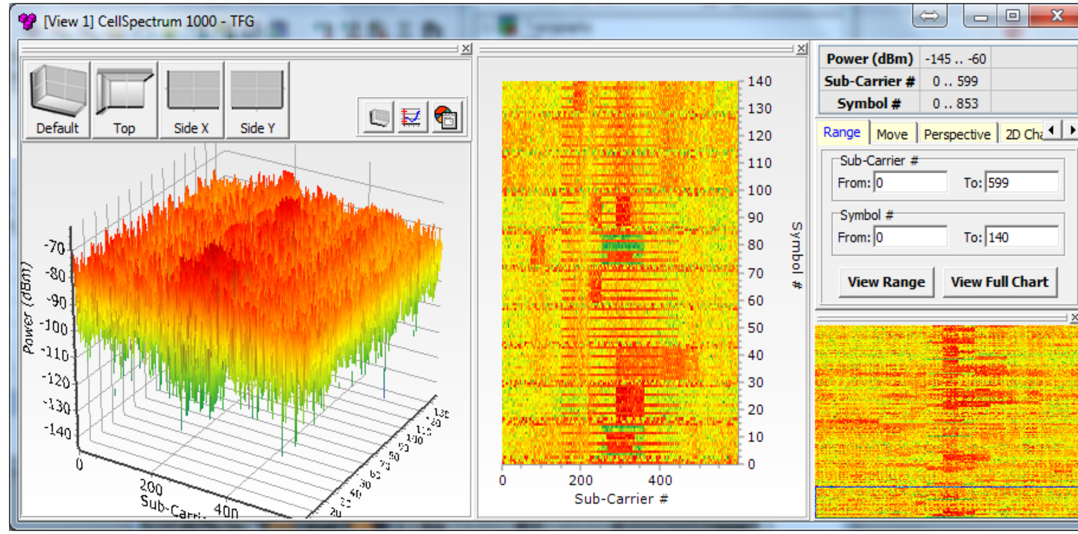
CellSpectrum

CellDesigner

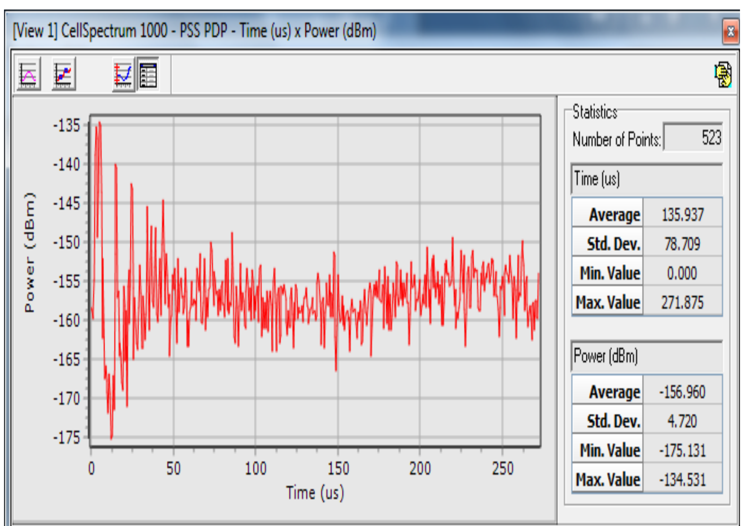
# CellSpectrum

- A unique spectrum scanner for LTE channels
- Presents measurements in 1D (dimension), 2D and 3D at RE (Resource Element) level

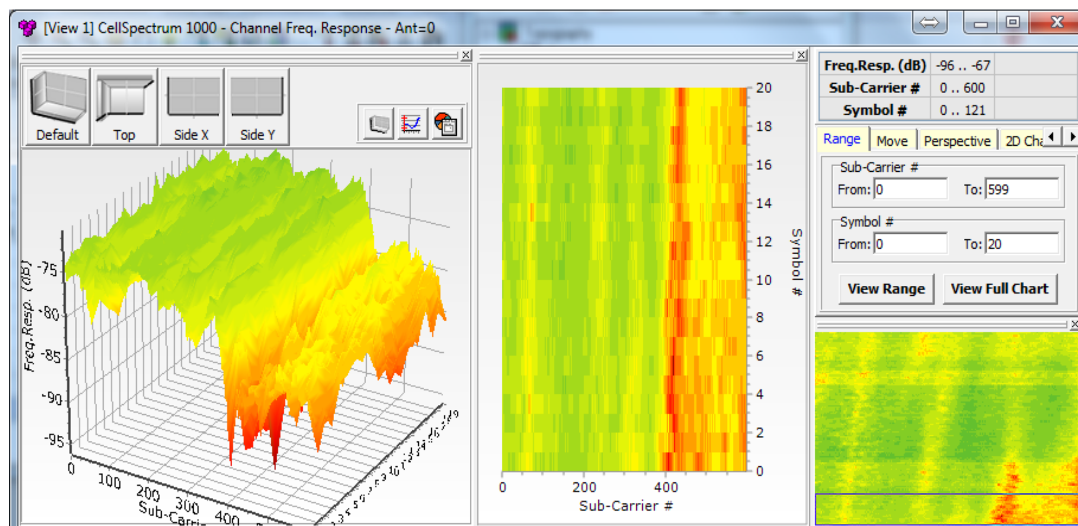
## Received Signal level




## Multipath



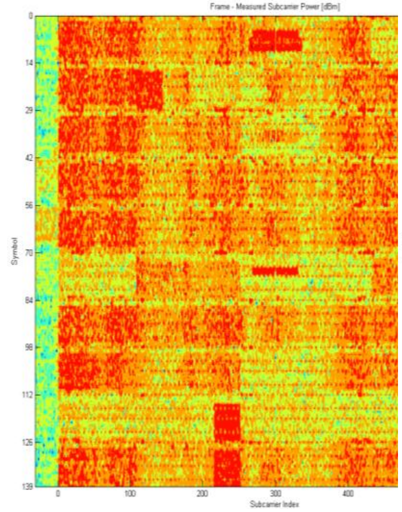

## RF Channel Response



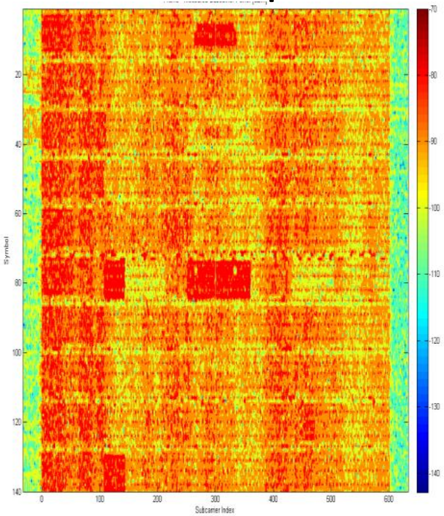
# CellSpectrum

- Provides a unique antenna correlation analysis for MIMO estimation and adjustment

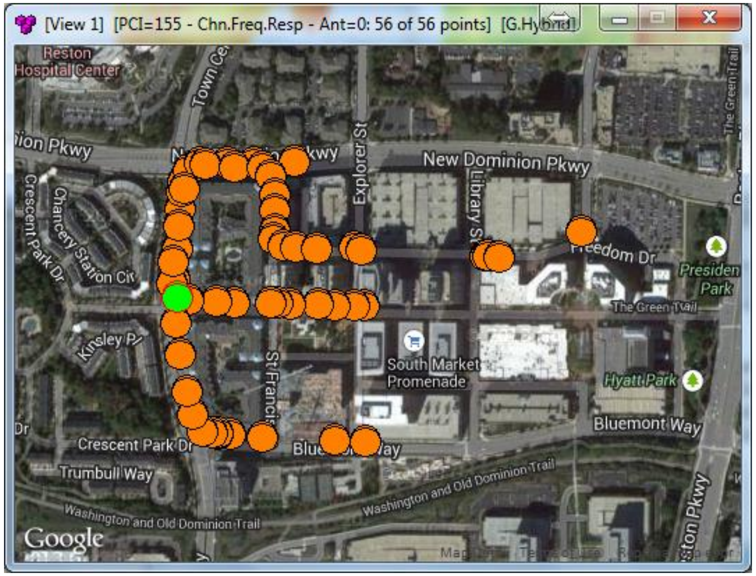
LTE frame port 0



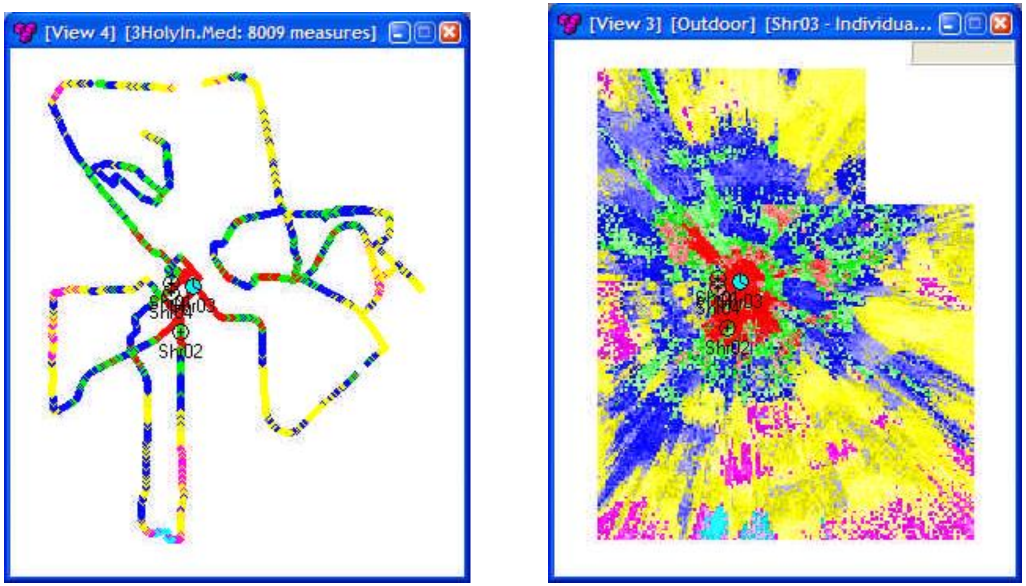

LTE frame port 1




Drive Test

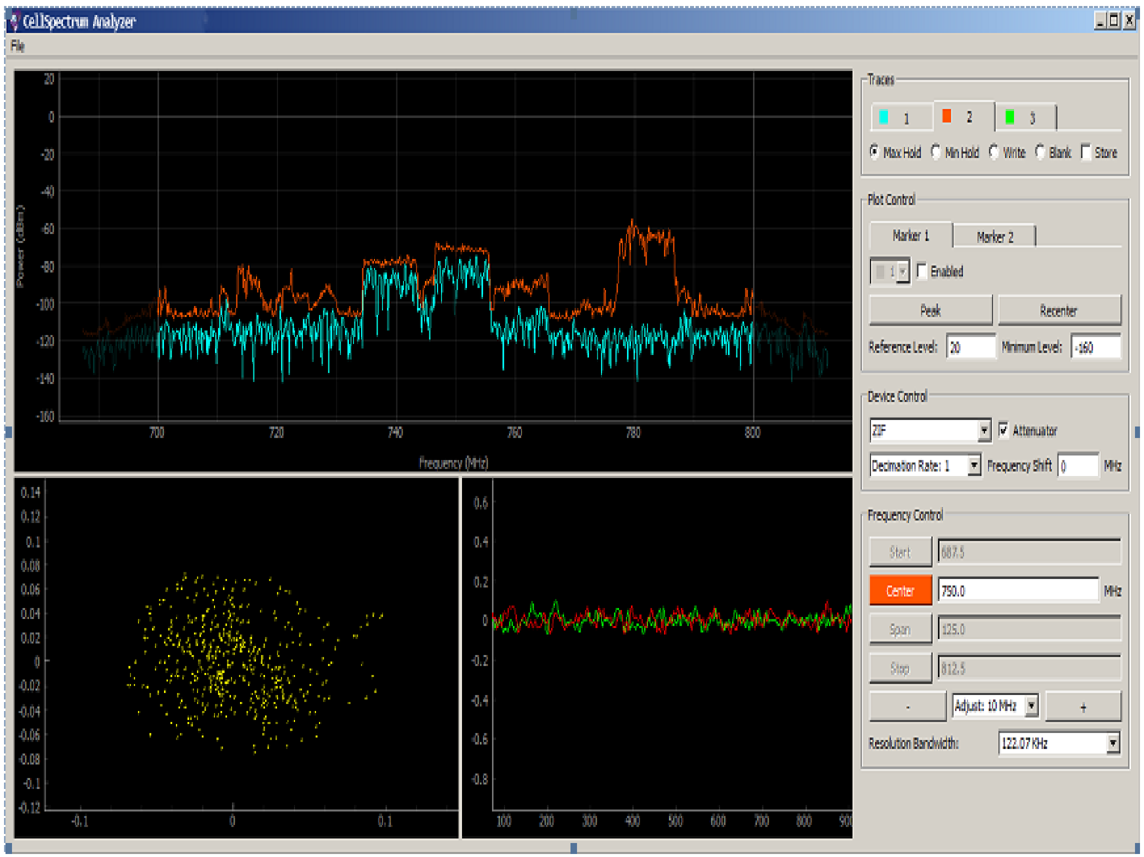



Measurement interpolation



# CelSpectrum™ Analyzer

- Range: 100 MHz to 18 GHz
- Bandwidth: 125 MHz (IBW: 100 MHz)
- Decimation: 1, 4, 8, 16, 32, 64, 128, 256, 512, 1024
- Resolution Bandwidth: 976.562 KHz, 488.281 KHz, 244.1141 KHz, 122.07 kHz, 61.035 kHz, 30.518 kHz, 15.259 kHz, 7.62939 kHz, 3.815 kHz
- Display: Max hold, Min hold, Write, Blank
- Capture modes:
  - Sweep and Block



# CellDesigner

A new Generation of Planning Tools

A collaborative work with operators

Your input is valuable

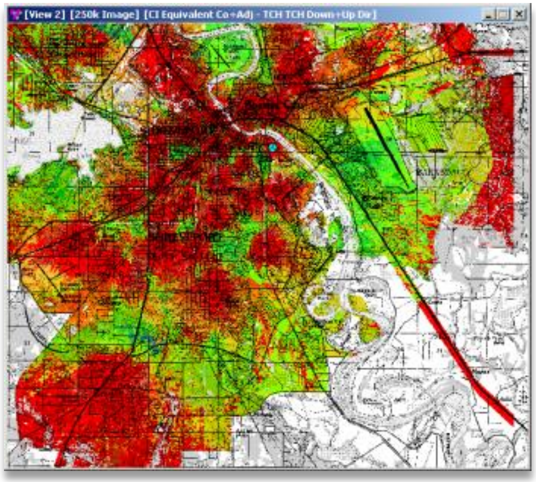
# CellDesigner

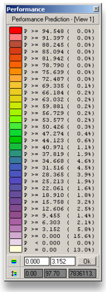
- CellDesigner is the new generation of Planning and Optimization tools
- Wireless networks became so complex that it requires a new generation of tools, capable of:
  - Documenting the physical deployments
  - Documenting network parameters for each technology
  - Flexible data traffic modelling (new services, new UE types)
  - Traffic allocation to different technologies
  - Fractional Resouce Planning
  - Performance evaluation
  - Integrated backhaul

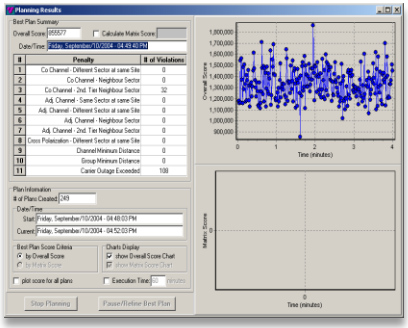
# CellDesigner™

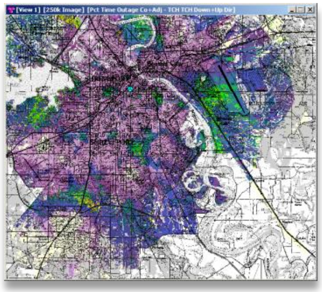
## Simultaneous Multi-Technology Support

- Supports all wireless technology standards:
  - LTE–A (TDD and FDD), WiMAX, WI-FI, WCDMA (UMTS), HSPA, HSPA+, IS2000 (1xRTT, EVDO), GSM (including Frequency Hoping), GPRS, EDGE, EDGE-E, CDMA One, PMR/LMR (Tetra and P25), MMDS/LMDS, DVB-T/H, and Wireless Backhaul
- Full network representation
  - Site, Tower, Antenna Housing, Antenna System, Sector, Cell, Radio
  - Full network parameter integration
  - KPI integration
- Full implementation of the Korowajczuk 3D model, capable of performing simultaneously outdoor and indoor multi-floor predictions
- Multi-technology dynamic traffic simulation









# CellDesigner™

CelPlan
Wireless Solutions & Consulting

## Automatic Resource Planning (ARP)

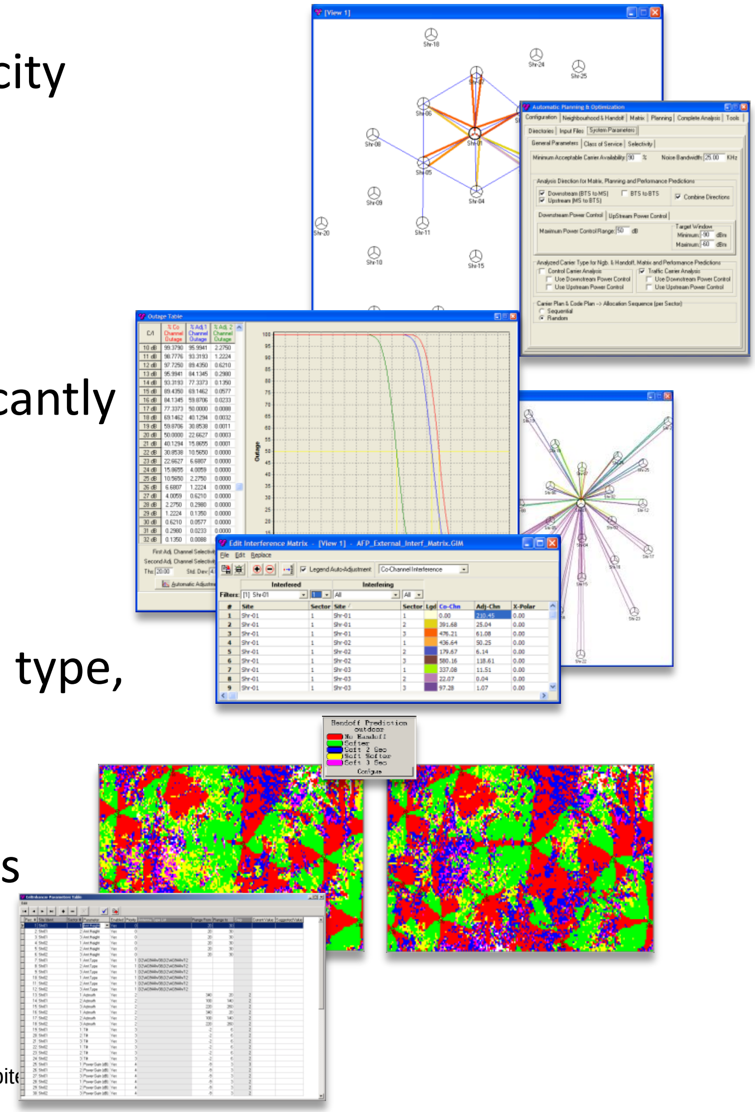
- Enables the dramatic increase of network capacity and performance
- Handover, Frequency and Code Optimization
- Automatically and efficiently optimizes handoff thresholds, neighbor lists, and frequency plans
- Patent-pending methodology capable of significantly increasing cell capacity (SON & ICIC)

## Automatic Cell Planning (ACP)

- Footprint and interference enhancement
- Allows optimization of radiated power, antenna type, tilt, azimuth, and height

## Performance Predictions

- Overall performance prediction per service class (bearer)



# CellDesigner™

**Google Earth Integration**

- Capable of presenting predictions and measurements live in Google Earth’s 3D environment

**Network Master Plan (NMP)**

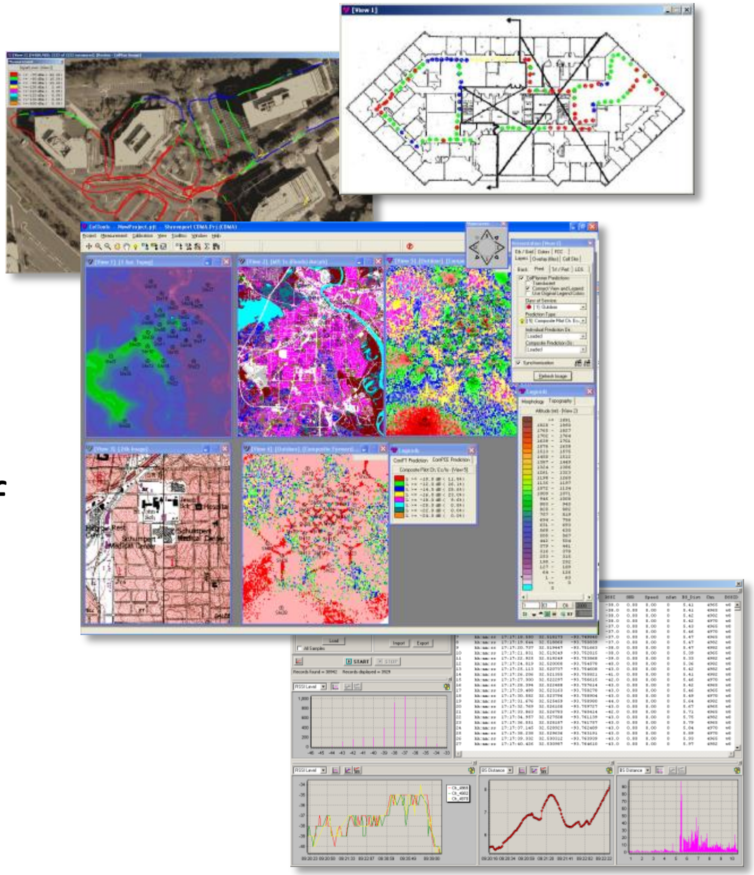
- Patent-pending methodology that simplifies SON and ICIC

**Integration of Field Measurement Data**

- Collection of data from virtually any type of measurement equipment and any format
- Automatic extraction of propagation parameters

**Integration of KPIs**

- Comparison reports between reported and calculated KPIS



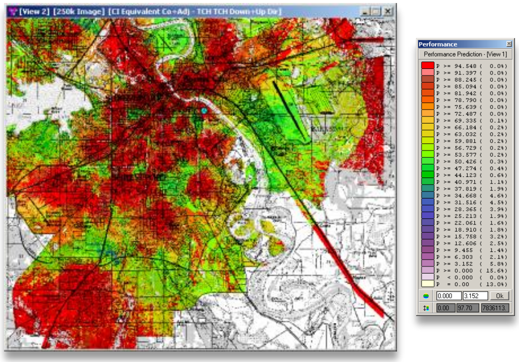
# CellDesigner™

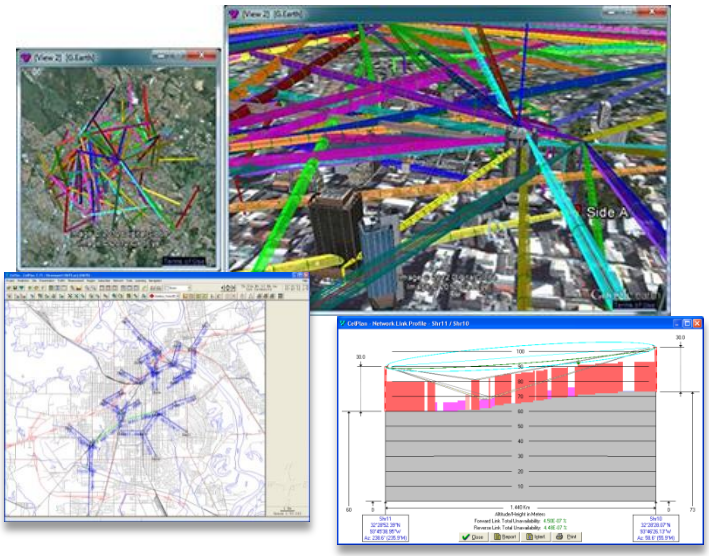
**GIS Database Editor**

- Allows the editing and processing of geographical databases

**Backhaul Planning**

- Calculates network interconnections, interference analysis & reporting for point-to-point, microwave transmission links
- Can display obstruction in Fresnel zones as well as the path loss
- Calculates attenuation caused by diffraction.
- Calculates rain attenuation for each link
- Provides link performance and compares against the requirements established by ITU-R





# Thank You!

Leonhard Korowajczuk

webinar@celplan.com

www.celplan.com

# Questions?