Power Control for Commercial Satellites Using Radar Data

March 1-3, 2005

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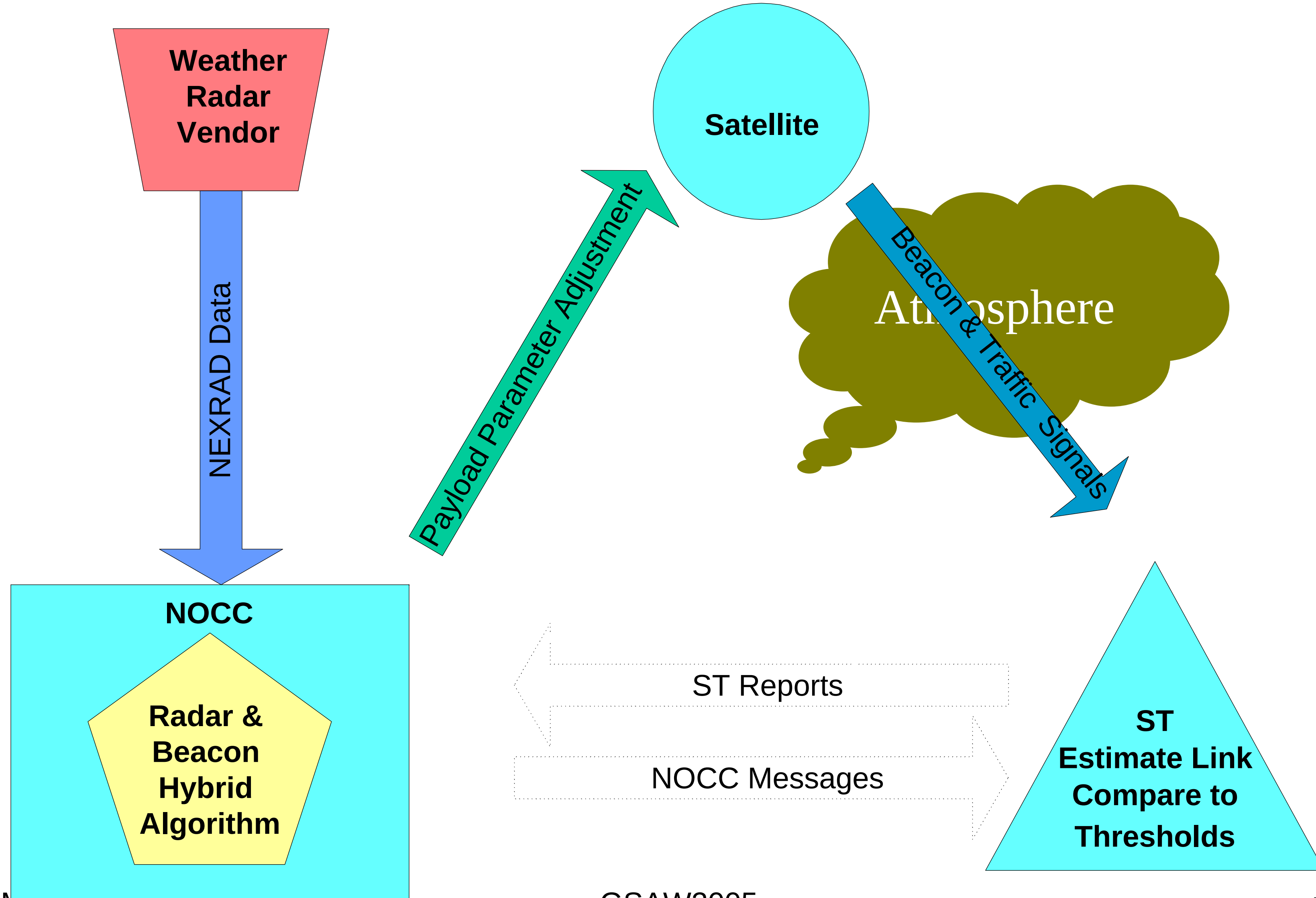
Purpose of Power Control

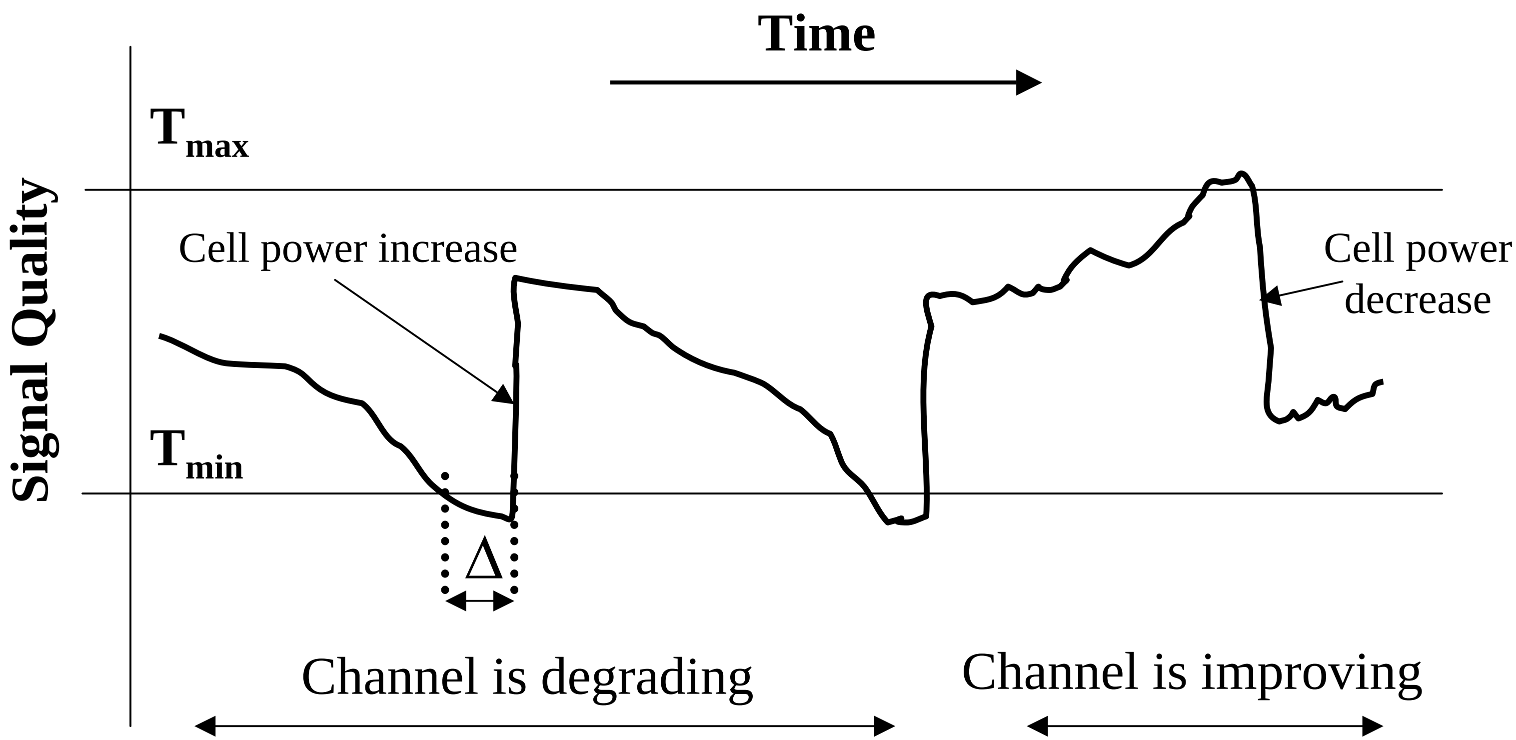
- **Compensate for up- and down- link margin losses due to rain fades, particularly at Ka- and/or Ku- band**
- **Minimize the required total aggregate satellite RF power (EIRP) to achieve the downlink availability for terminals in each beam, by dynamically distributing satellite EIRP in response to changes of weather condition in each beam**
- **Mitigate impairments caused by co-channel, cross-pol, and adjacent channel interference in a multi-beam Ka-/Ku- band system**

Downlink Power Control

Downlink Power Control Concept

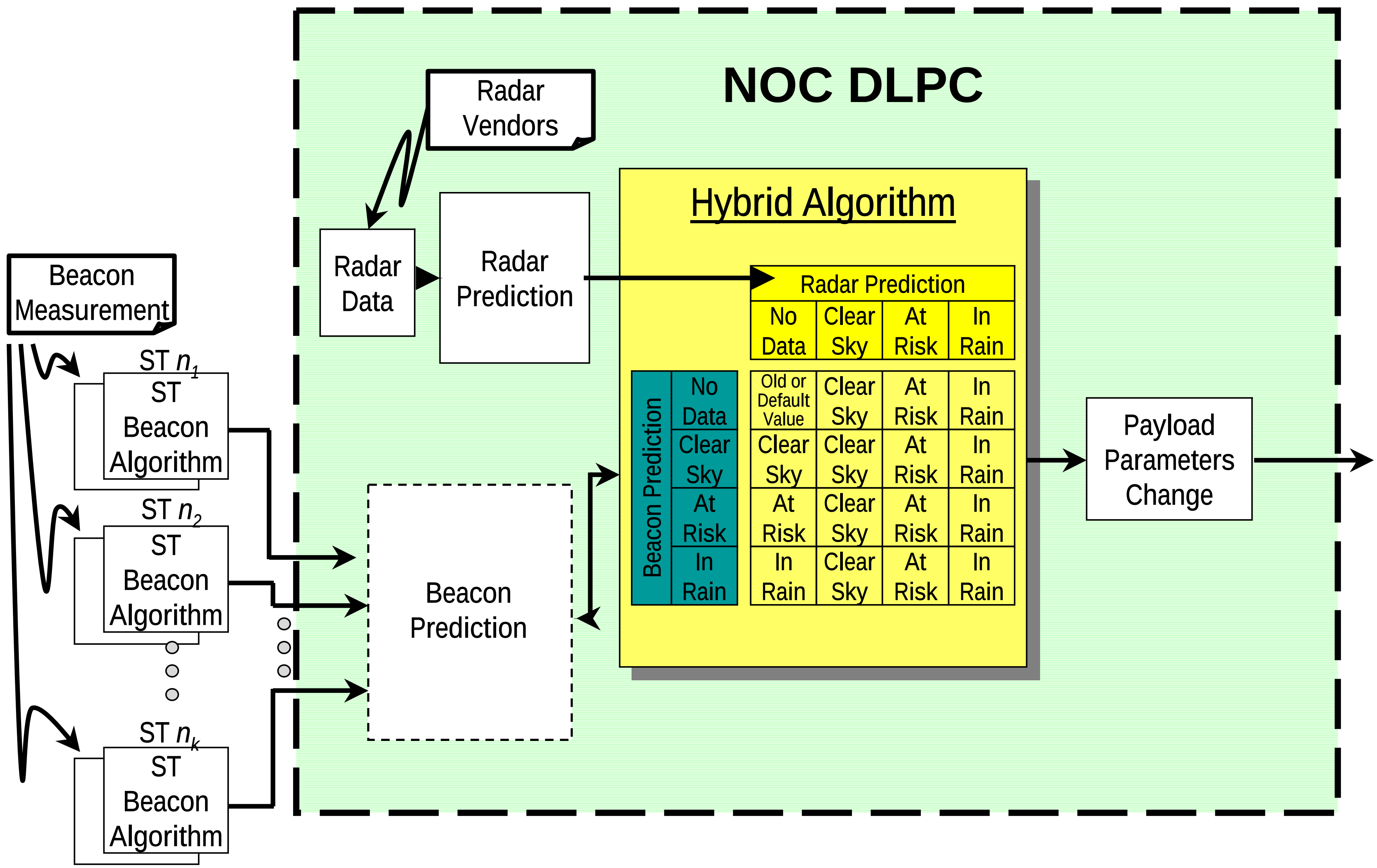


Downlink Channel Condition as a Function of Time



Δ: response time, a function of round trip propagation delay and processing time

Hybrid Downlink Power Control



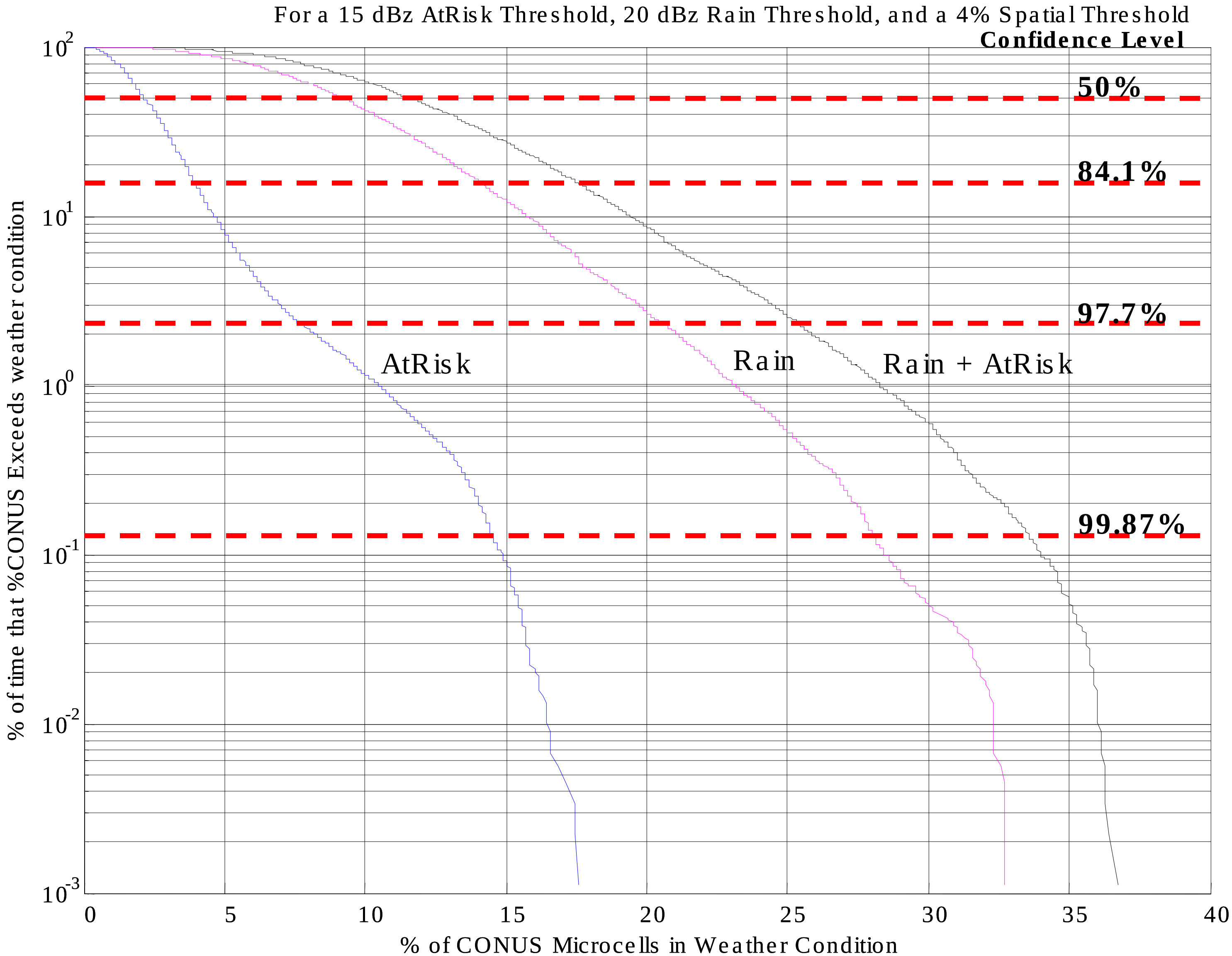
Radar Pixel Classification Rules

$$WeatherState(MG_n): \begin{cases} \text{Clear Sky}, & dBz(MG_n) < 15 \\ \text{At Risk}, & 15 \le dBz(MG_n) < 20 \\ \text{Rain}, & dBz(MG_n) \ge 20 \end{cases}$$

Cell Weather Classification Rules

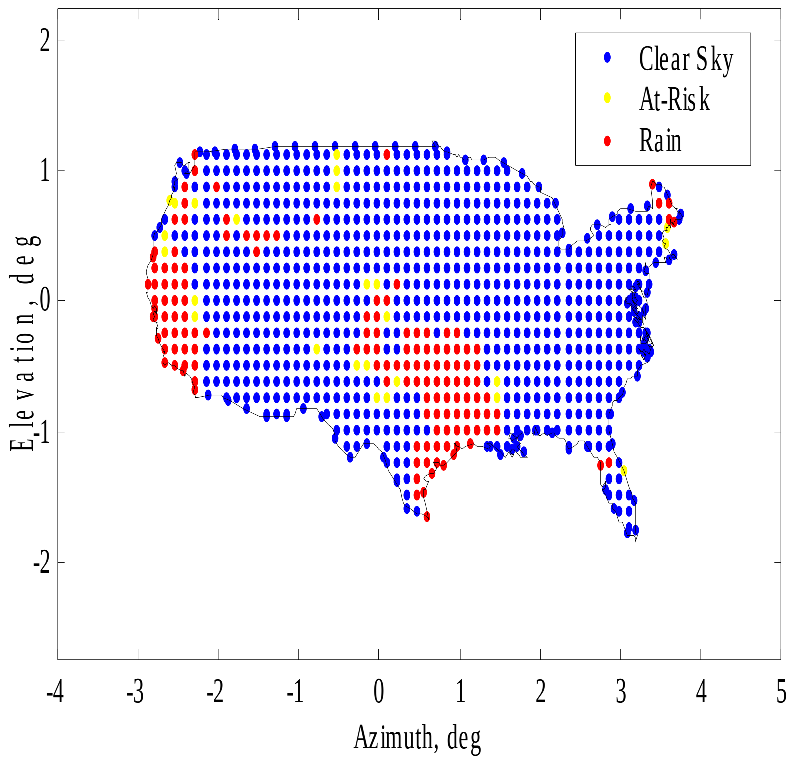
If (ClearSky)% > (100% - (AreaThreshold)%)	**Clear**
Else If (Rain)% > (AreaThreshold)%	**Rain**
Else If ((Rain)% + (AtRisk)%) > (AreaThreshold)%) **& ((Rain)% + (NoData)% < (AreaThreshold)%)**	**At Risk**
Otherwise	**Insufficient Data**

CONUS Rain Statistics

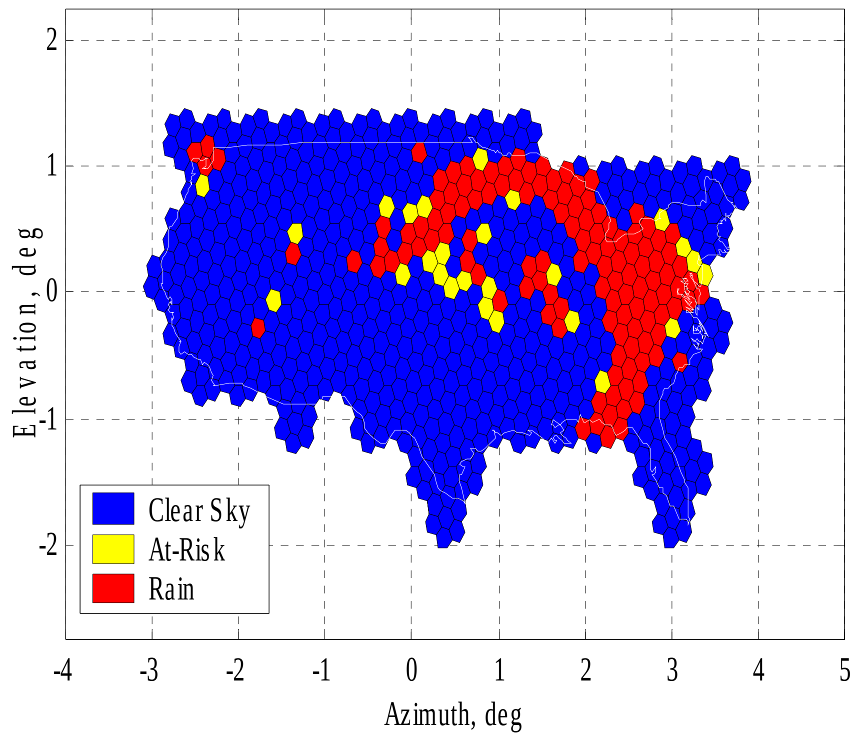


A Snapshot of Classified CONUS Weather

Classified Weather at Each PSA

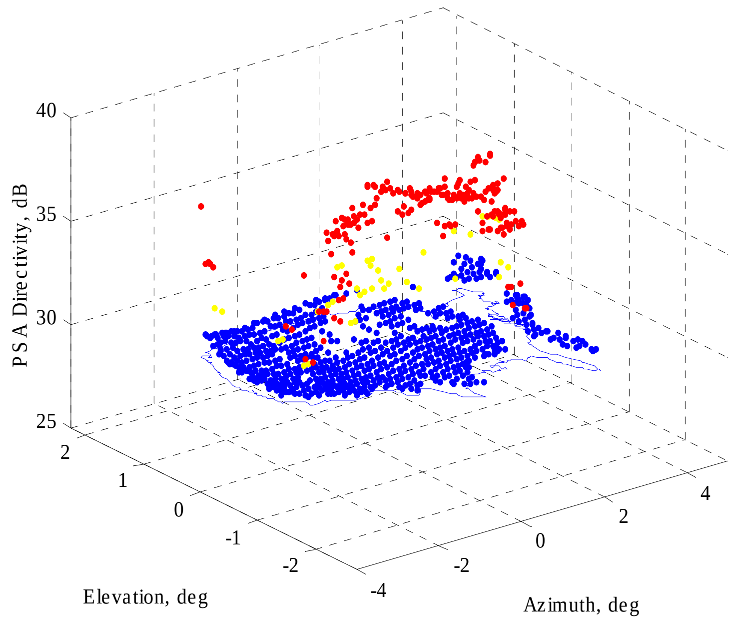


Classified Weather at Each Cell

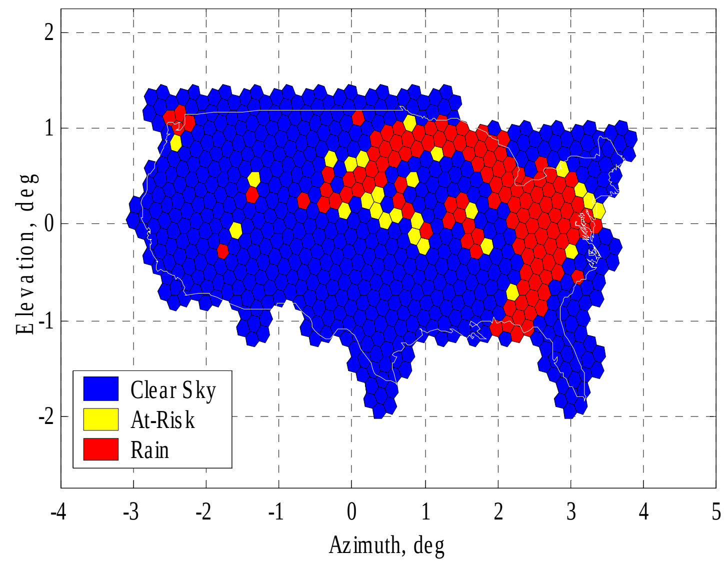


CONUS Weather Map & Desired Directivity Profile

Weather Map

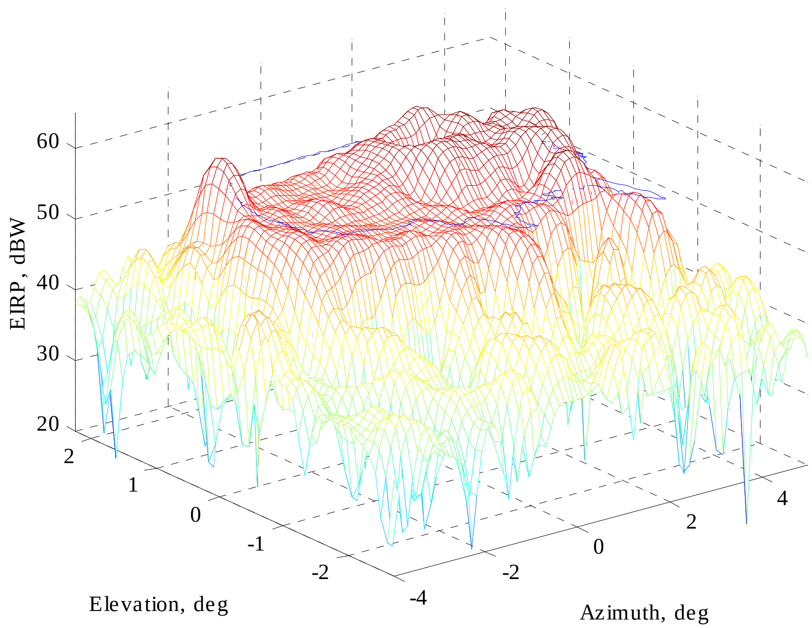


Desired Directivity Profile

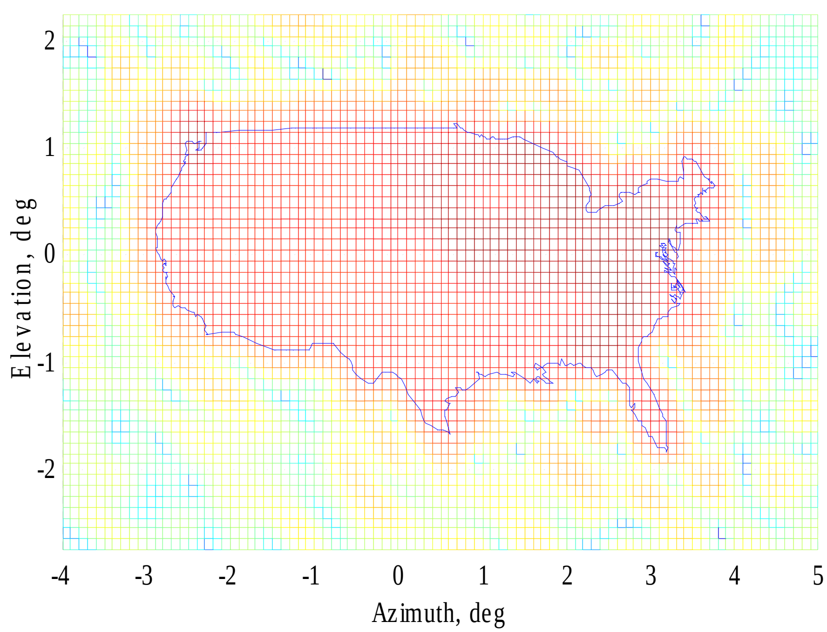


Resultant Downlink EIRP Plots for a CONUS Shaped Beam

3-D View

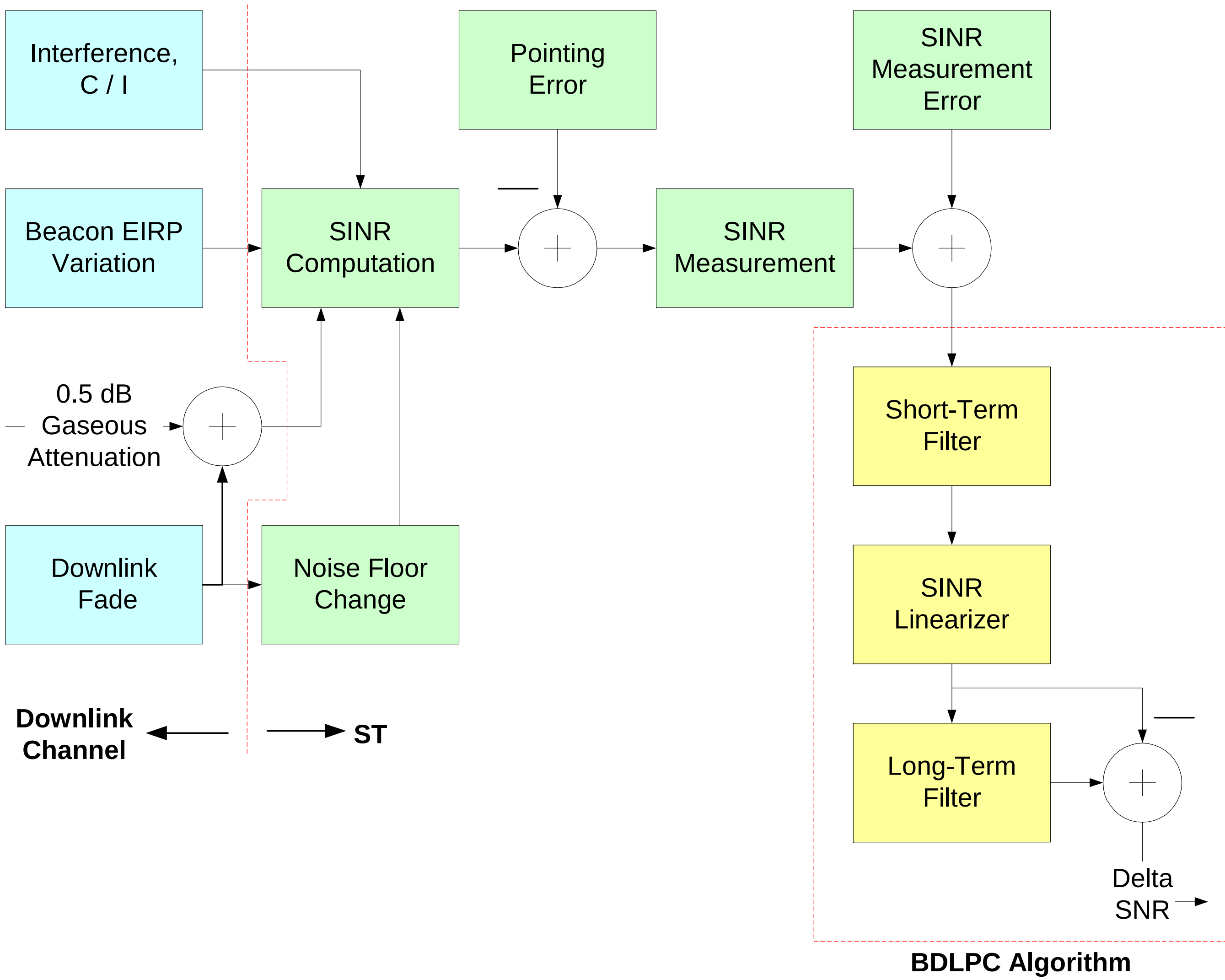


Top View



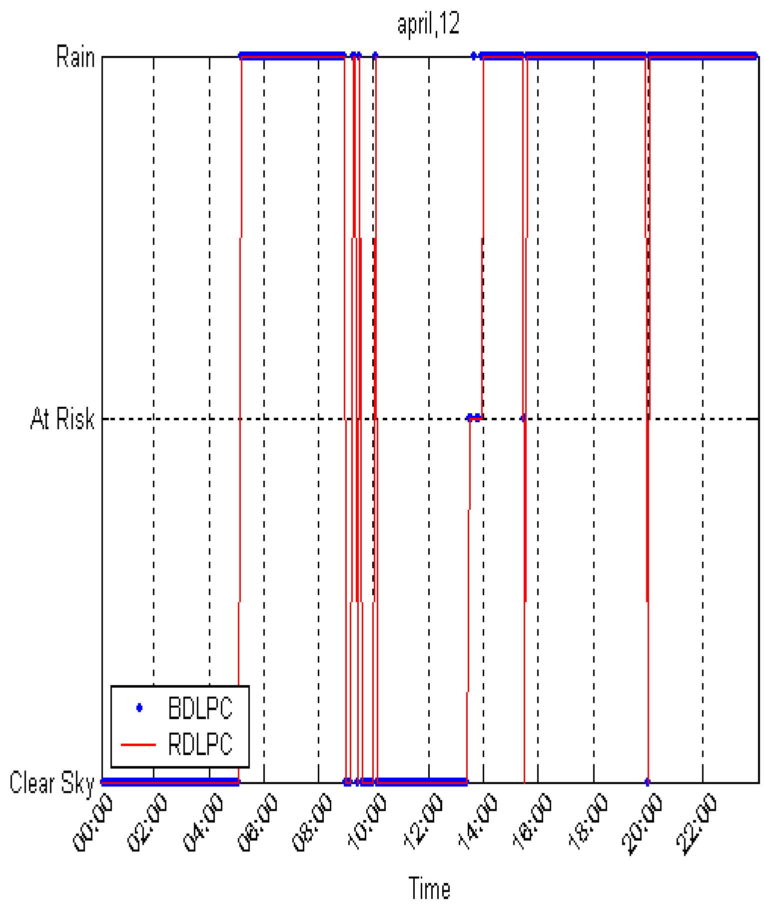
Pencil Beam DLPC Simulation

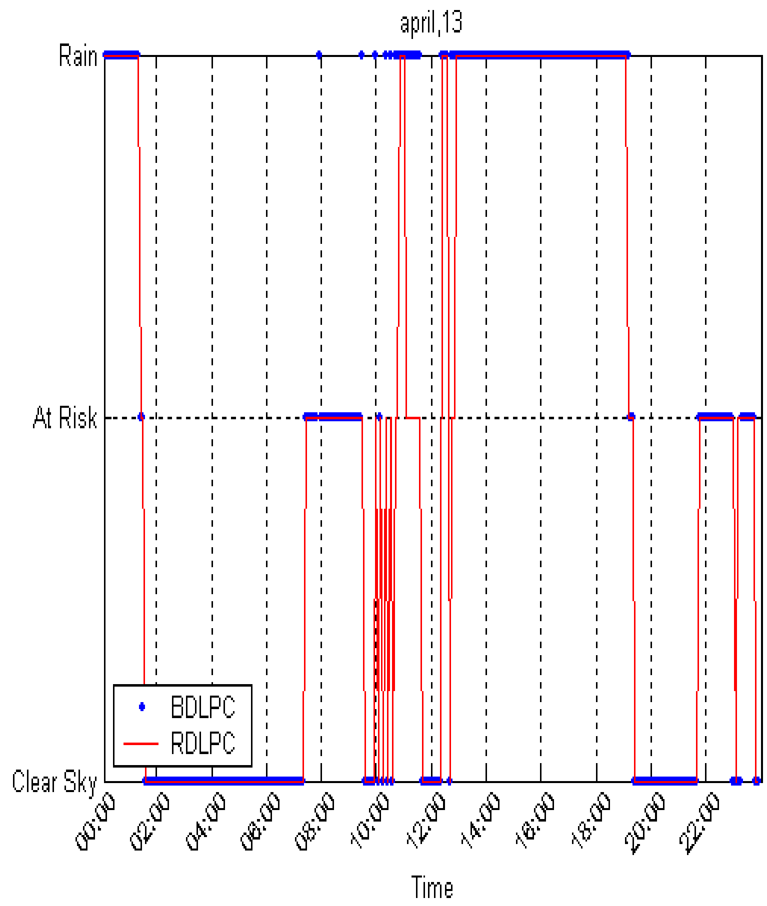
ST Simulation Model



Radar & Beacon DLPC Simulation Results (1)

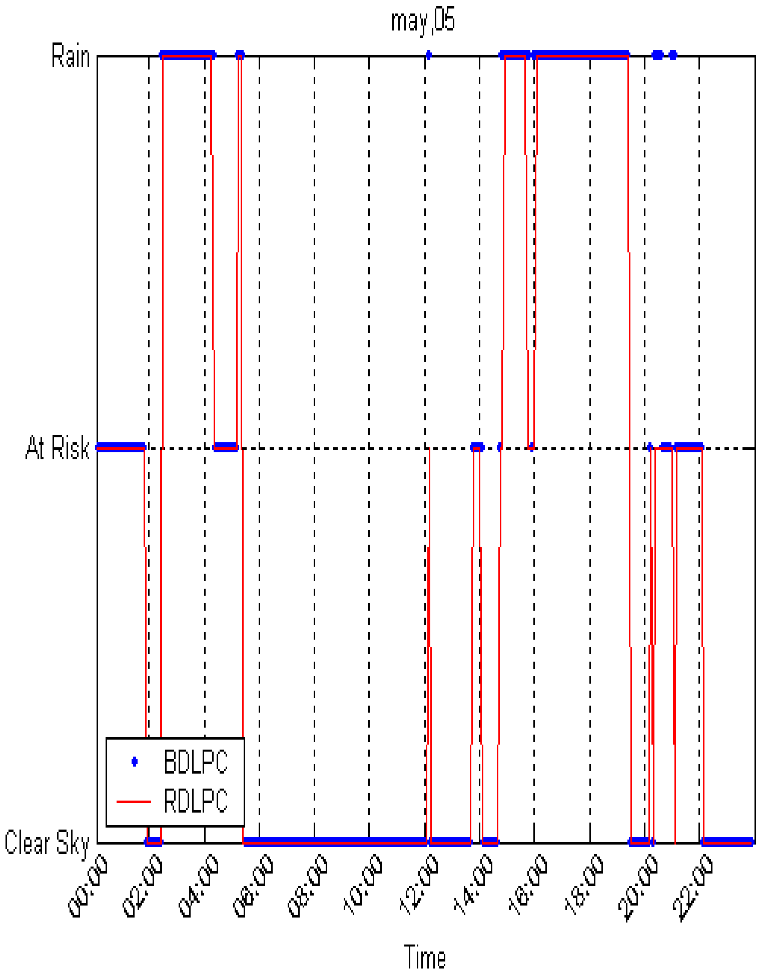
Year : 2002, Microcell : 263, Clusters : 1000, STs / Cluster : 1

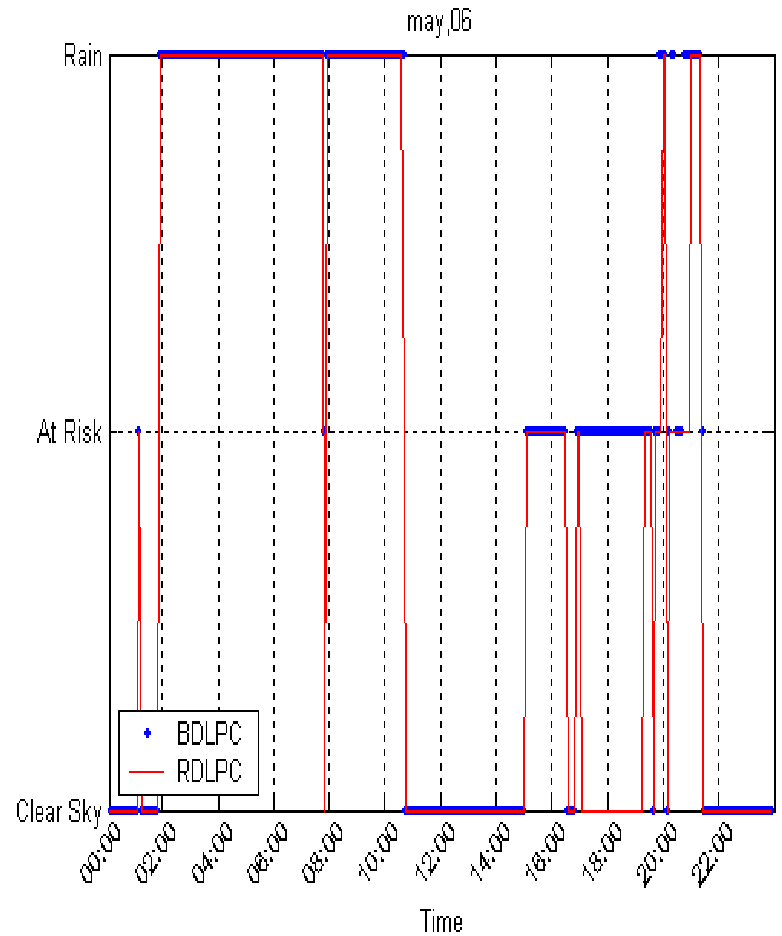




Radar & Beacon DLPC Simulation Results (2)

Year : 2002, Microcell : 263, Clusters : 1000, STs / Cluster : 1



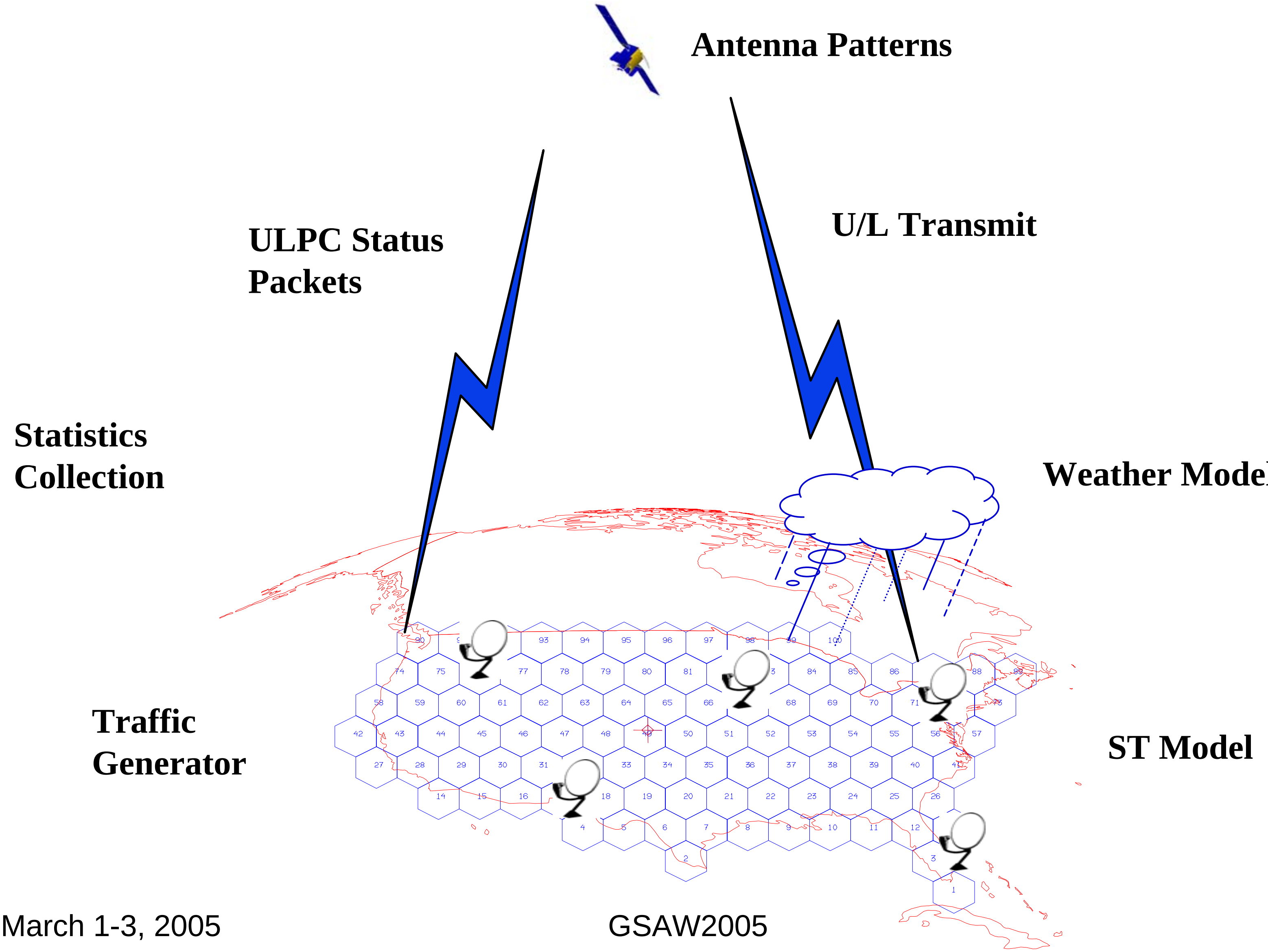


Uplink Power Control

ULPC - Objective

- **Set ST's uplink transmit power above the noise and interference level to achieve the target PLR, without overpowering other (faded) STs, in an environment where**
  - **The downlink (D/L) fade cannot perfectly predict the uplink (U/L) fade.**
  - **The ST transmitter power varies with frequency and from unit to unit.**
  - **The interference may vary much more rapidly than the round trip control loop delay.**
  - **The satellite antenna C/N varies with time.**
  - **The downlink beacon C/N varies with time.**

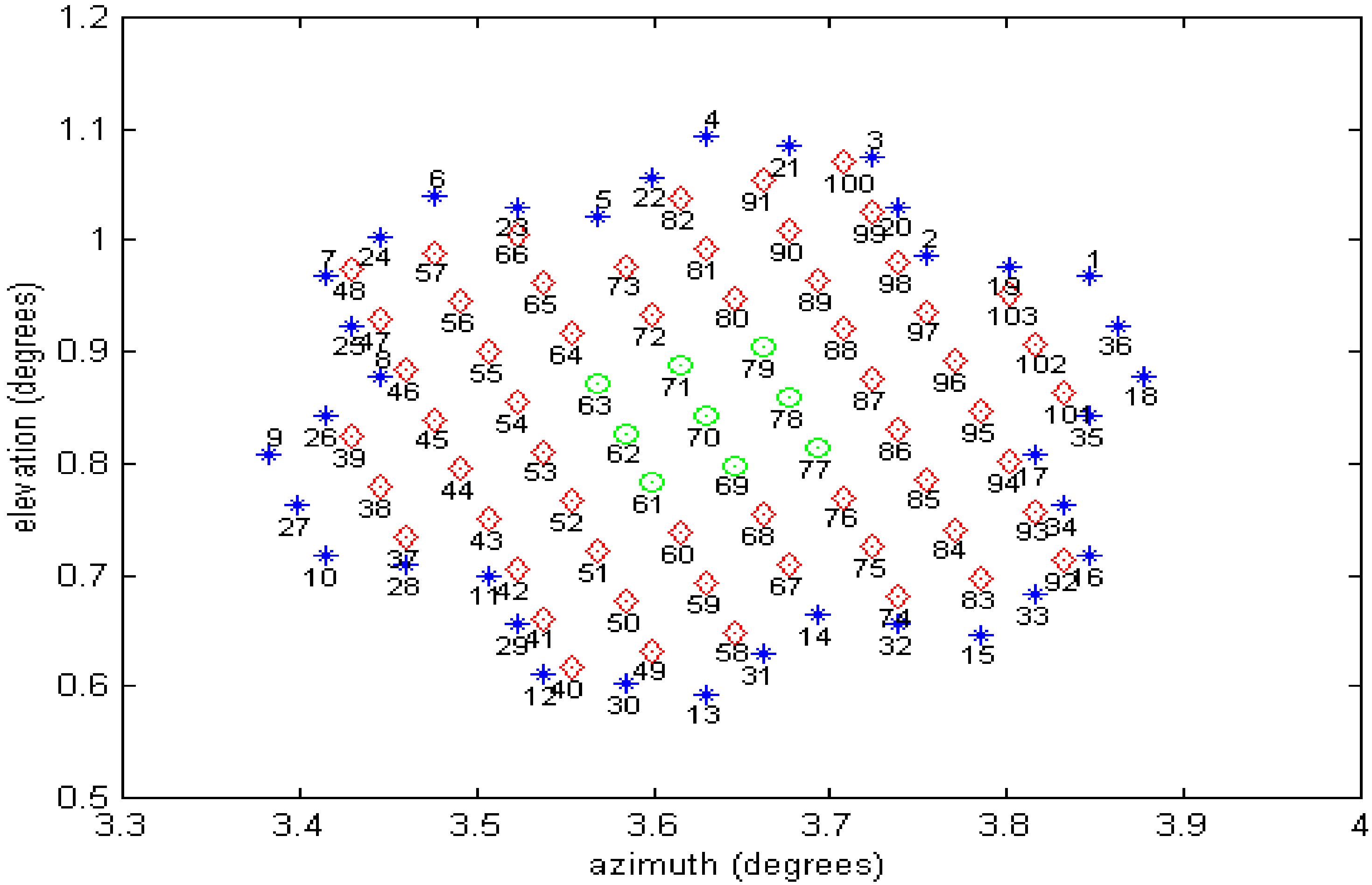
ULPC Simulation Environment (1)



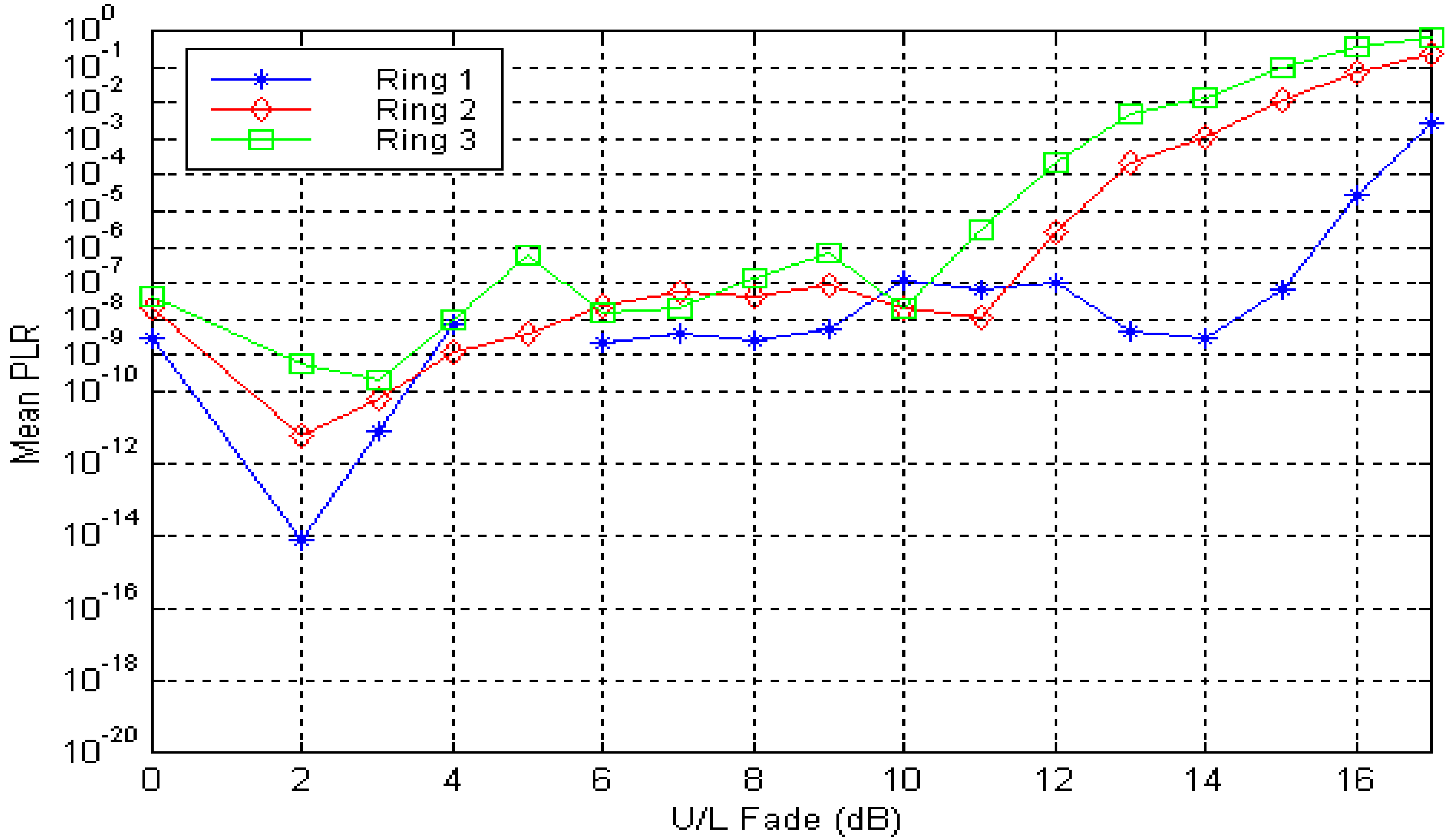
ULPC Simulation Environment (2)

- **All STs assumed to be operated in 512K mode only**
- **The following parameters are modeled**
  - **ST transmit chain (PA, power setting error, pointing error, etc).**
  - **Beacon variation, beacon measurement error and beacon noise floor variation**
  - **Satellite received C/N variation and C/N measurement error**
  - **ULPC status packet loss and delays and RS failures**
  - **External interference**
- **Assumed traffic model**
- **Severe CONUS weather mix with clear-sky/mix/rain condition ratio of 50/25/25%**

Ring Definition of UL Cells



Mean PLR versus U/L Fade



PLR threshold = 10^{-5}

Concluding Remarks

- The hybrid radar- and beacon- mode DLPC offers a reliable means to dynamically deliver satellite power to users in accordance to weather condition
- Radar- mode DLPC method can be readily applied to some bent-pipe satellites for one-way broadcast transmission
- Beacon- based closed- loop ULPC can be effectively used not only to compensate for UL fades, but also to mitigate the effects of CCI, XPI and ACI. This method can be readily adapted for VSAT applications as well.