Rain Fade Compensation Alternatives for Ka Band Communication Satellites

Roberto J. Acosta, Ph.D.
NASA Lewis Research Center
Cleveland, Ohio

3rd Ka Band Utilization Conference
Sorrento, Italy
September 15-18, 1997

MOTIVATION OF WORK

- Evaluate system and rain fade characteristics and their impact on future system design of Ka-band communication satellite systems.
- Evaluate alternative rain fade measurement and compensation techniques
- Design and develop technology verification experiments for validating techniques and approaches.

FADE CHARACTERISTICS

Rain Induced (random)

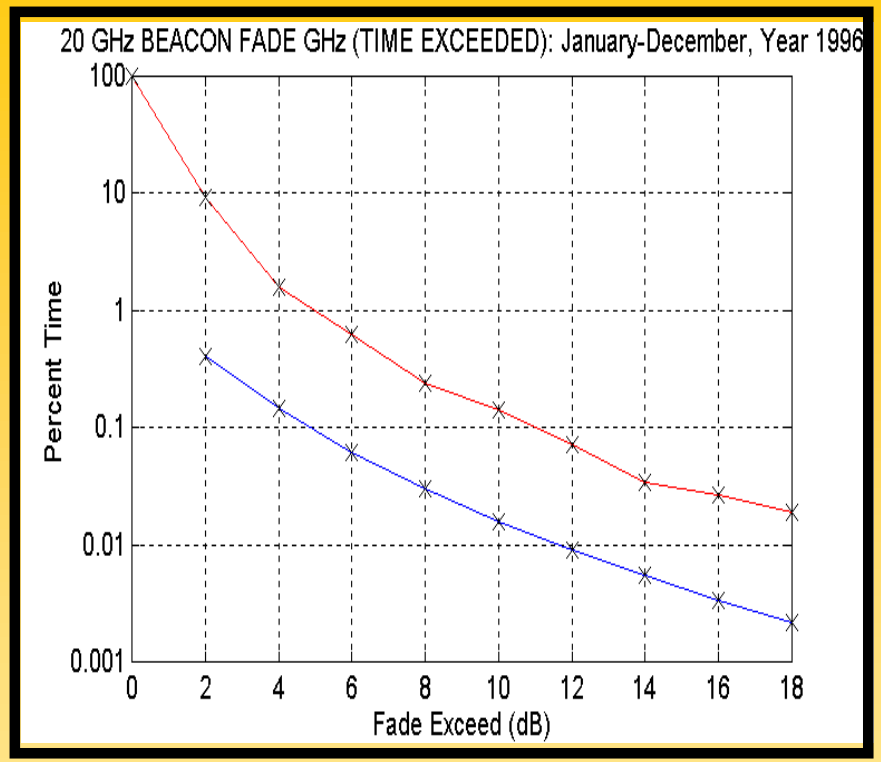
- Rain fade depth
  - Fade rate
  - Fade duration
  - Inter-fade interval
  - Frequency scaling
  - Correlation of fade within 1 GHz band
  - Correlation of rain events over extended areas
- Antenna wetting
- Depolarization
  - Rain
  - Ice

System Induced

- Ground Station
  - Pointing error in rain
  - Snow accumulation
  - LNA stability
  - De-Icers
- Spacecraft
  - Antenna Pointing Thermal
  - Attitude Control

THEORY VS. EXPERIMENT

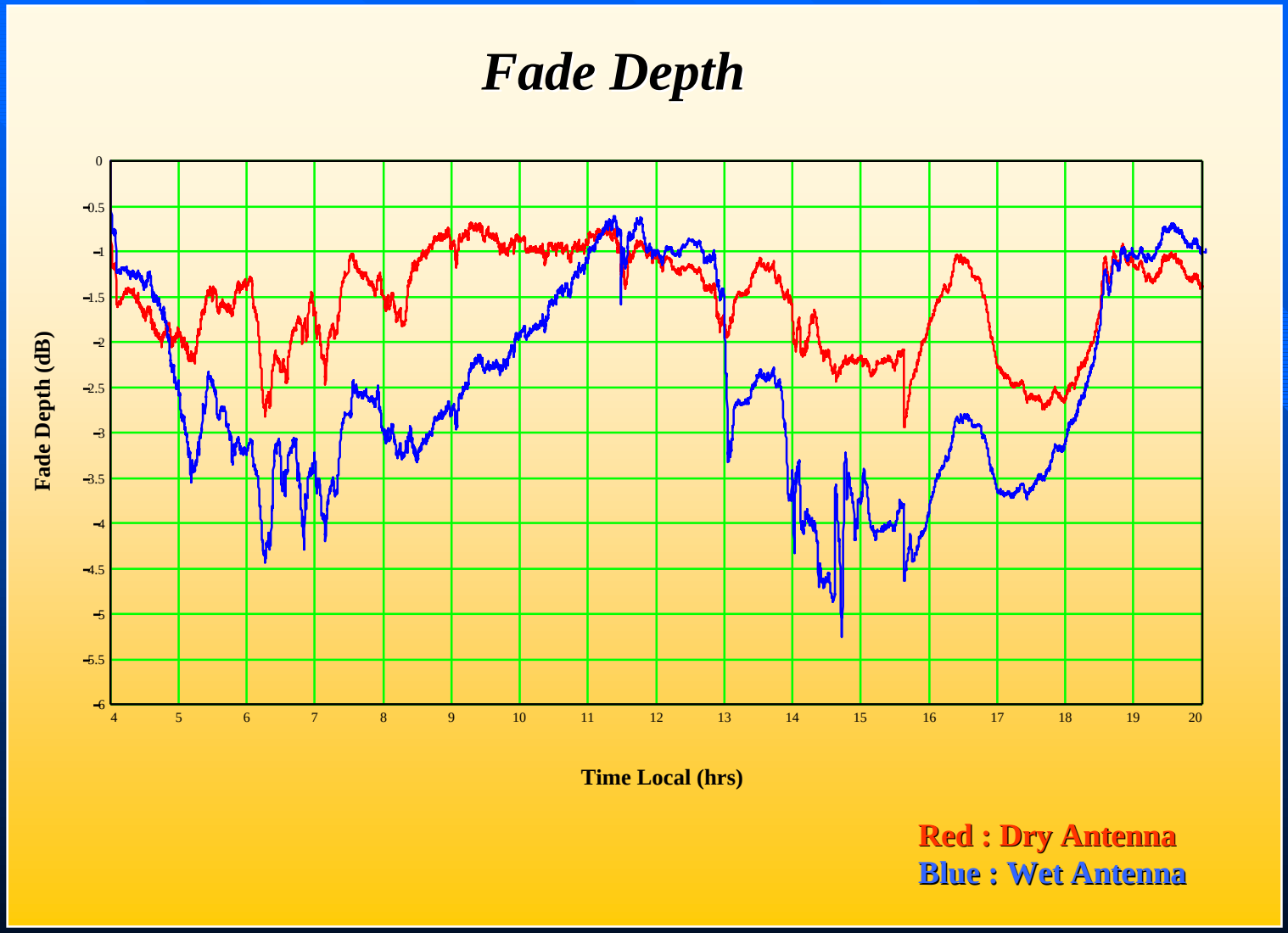
FADE AVAILABILITY FOR CLEVELAND - 1996



Ground Station System Degradation Effects

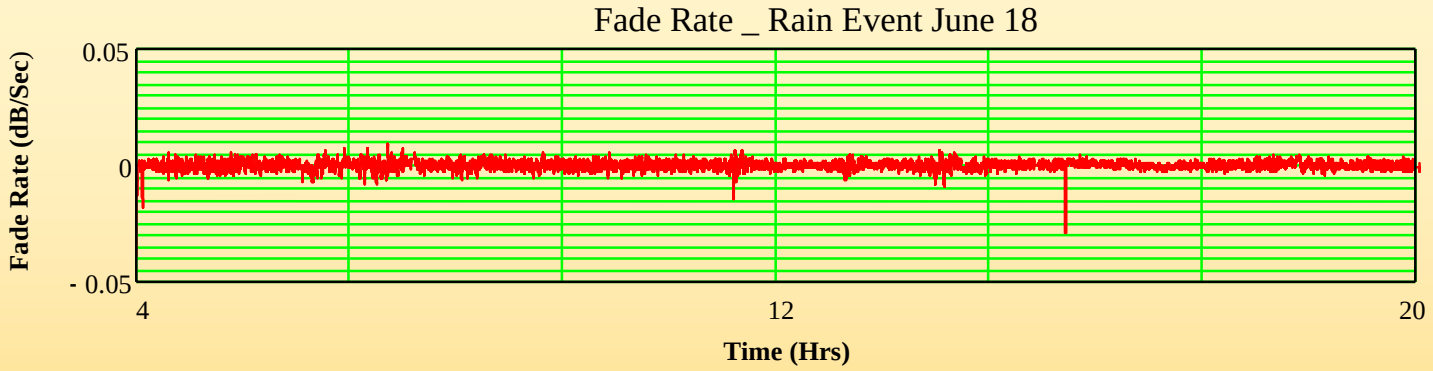
- **Antenna wetting**
- **Snow accumulation**
- **Antenna pointing errors - during rain**
- **De-Icers thermal effect**
- **Ground station thermal stability - LNA,LO, etc.**
- **Measurement error**

WET ANTENNA STUDIES

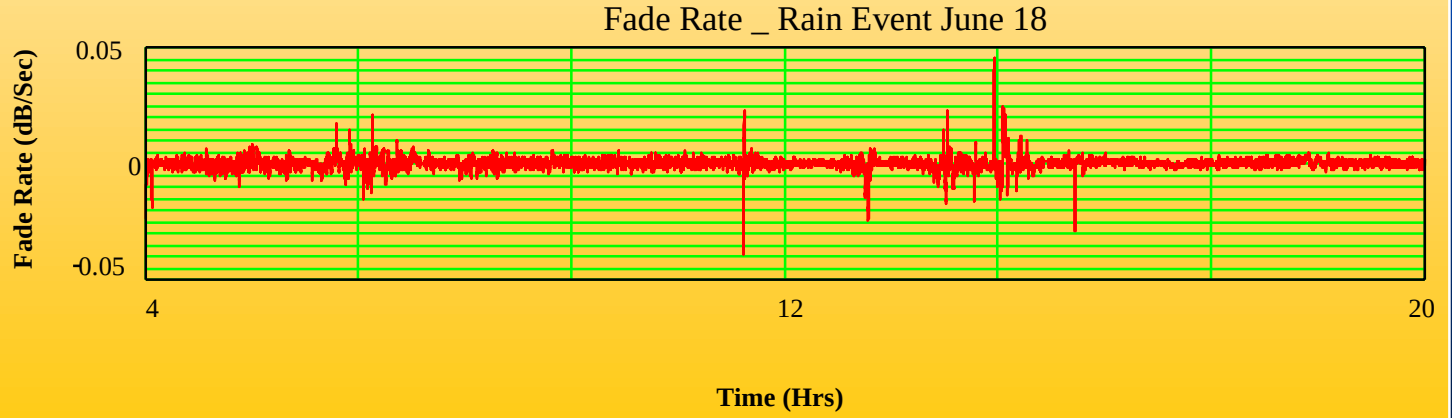


WET ANTENNA STUDIES

Dry Antenna Fade Rate

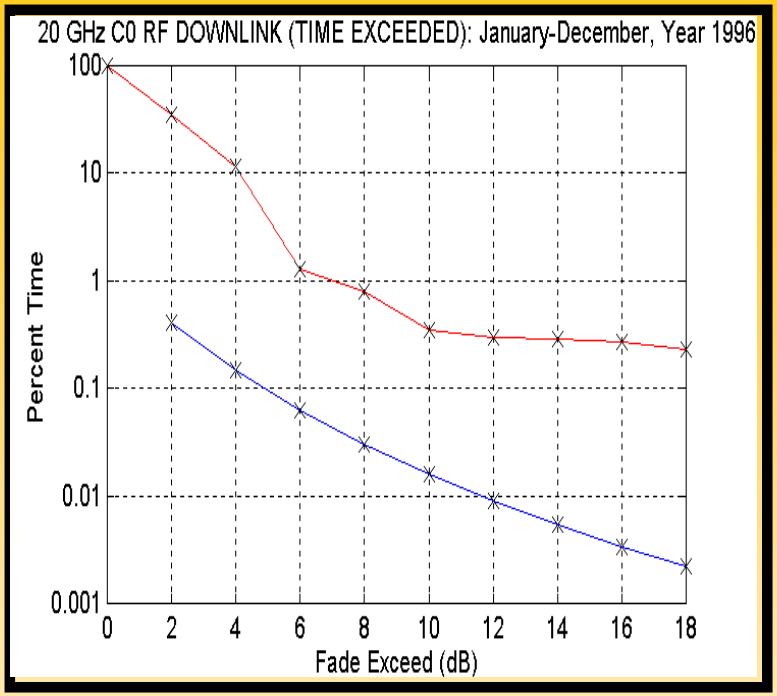


Wet Antenna Fade Rate



THEORY VS. EXPERIMENT

FADE AVAILABILITY FOR CLEVEAND - 1996



GROUND STATION AND SPACECRAFT DEGRADATION EFFECTS

- **Multibeam antenna pointing errors**
- **Attitude control errors**
- **Measurement errors**

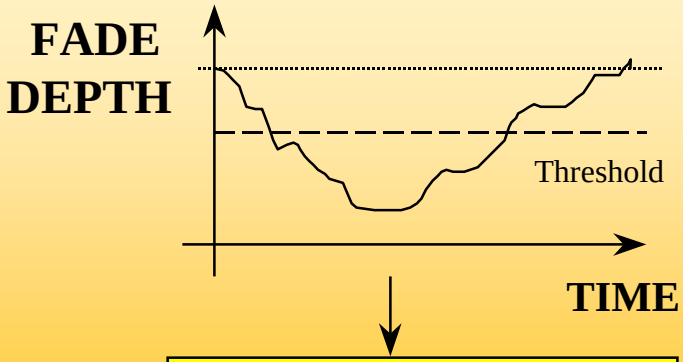
KEY SYSTEM MARGIN CONSIDERATIONS

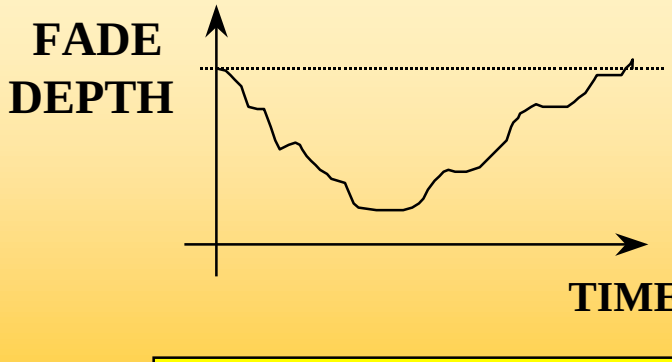
– **Clear Sky margin (fixed)**
  - **Clear sky attenuation (gaseous absorption) < 1 dB**
  - **Measurement errors < 1 dB**
  - **Frequency scaling error < 1 dB**
  - **Time delay in applying compensation < 1 dB**

  ~ Clear Sky Margin = 4 dB

– **Margin available through dynamic fade compensation**
  - **Avoid enabling compensation too frequently by applying wait time**
  - **Dynamically allocate margin on the basis of rain and other propagation impairments**

RAIN FADE COMPENSATION ALGORITHM



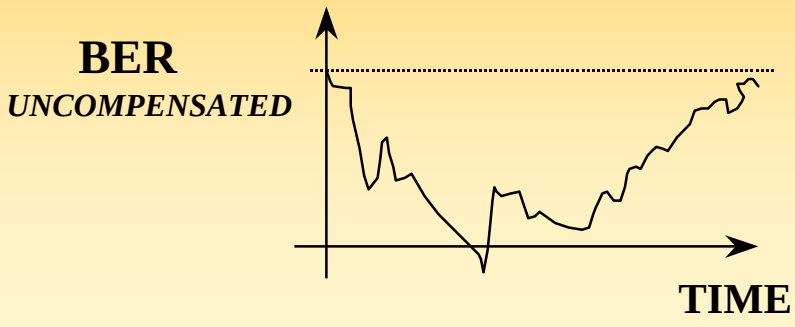


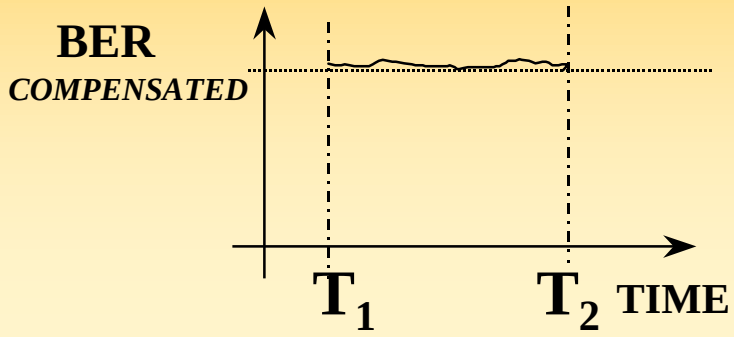
FADE SENSING ALGORITHM

- *Fade Depth*
- *Fade Rate*
- *Threshold Values*
- *Descision*

COMPENSATION ALGORITHM

- *Enable FEC*
- *Enable Burst Reduction*
- *Increase RF Power*
- *Enable Diversity Station*





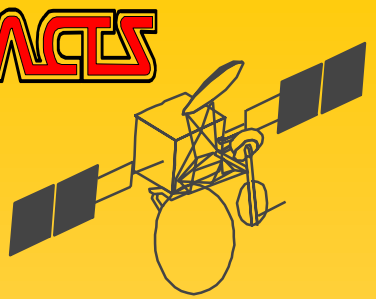
Rain Fade Sensing Techniques

- Satellite beacon
  - in-band or out-band
- Channel BER monitoring by a known data pattern
  - e.g., framing bits, unique words, etc.
- BER monitoring for channel coded data
  - comparing re-encoded bits
- Pseudo BER
  - count number of symbols within an interval
- Measuring signal-to-noise
  - estimation from mean and variance
- Fade estimate from receive AGC level

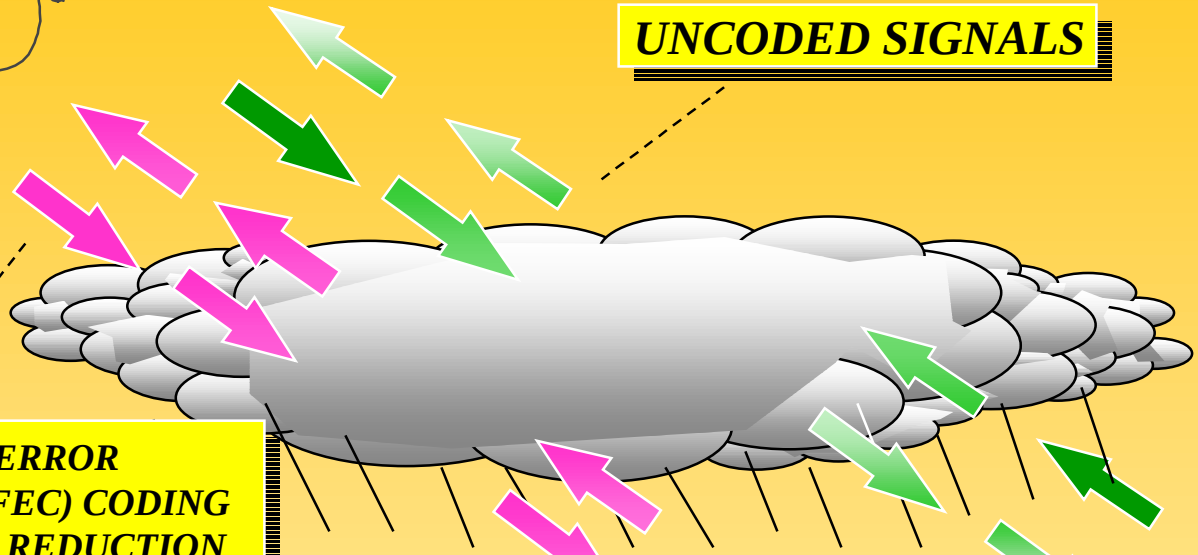
Rain Fade Compensation Techniques

- **Increase power**
  - **Uplink power in dynamically adjusted**
  - **Open-loop, closed-loop and feedback-loop**
- **Information rate and FEC code rate changes**
  - **FDMA,CDMA and TDMA**
- **Combination of above**
- **Diversity stations**

ACTS Rain Fade Compensation



UNCODED SIGNALS



FORWARD ERROR CORRECTION (FEC) CODING & BURST RATE REDUCTION

IMPACT ON SYSTEM
Adds 10 dB of Fade Margin

Station #1
LOST MESSAGE

Station #2
MESSAGE IS RECOVERED

SUMMARY

- **ACTS has successfully demonstrated at least two different rain fade compensation techniques.**
  - **VSAT dynamic rain fade compensation**
  - **Uplink power control**
- **ACTS has successfully modeled rain fade characteristics.**
  - **Dr. Manning's model seems to underestimate fade availability**
- **ACTS has experimentally characterized system and propagation effects affecting fade availability.**
  - **Antenna wetting**
  - **Narrow beam technology**
  - **Attitude and ground station effects**