

Rain Fade Compensation Alternatives for Ka Band Communication Satellites

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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)

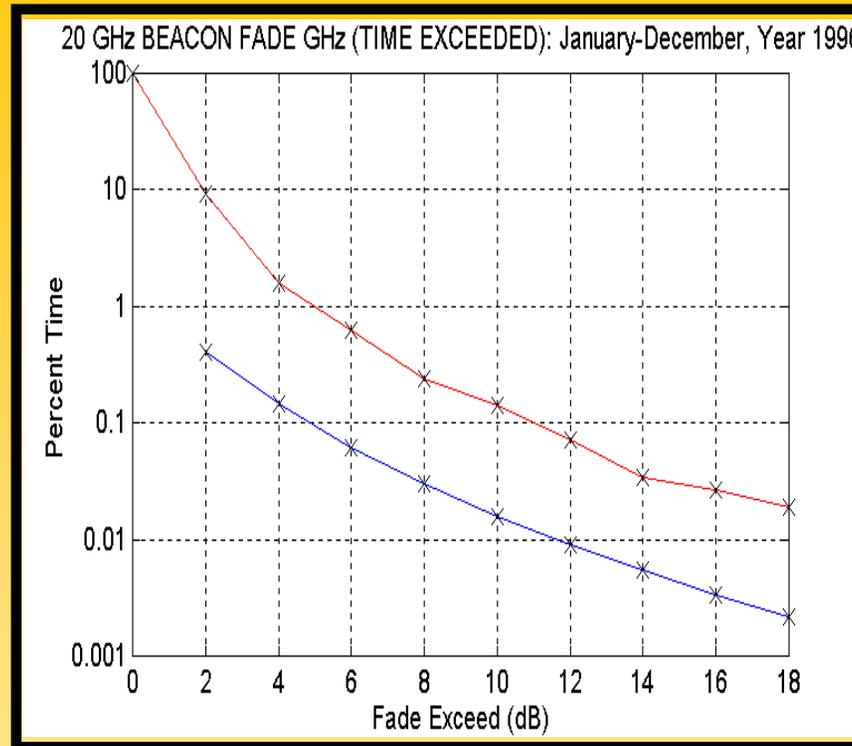
- Rain fade depth
 - Fade rate
 - Fade duration
 - Inter-fade interval
 - Frequency scaling
 - Correlation of fade within 1 GHz band
 - Correlation of rain events over extended areas
- Antenna wetting
- Depolarization
 - Rain
 - Ice

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

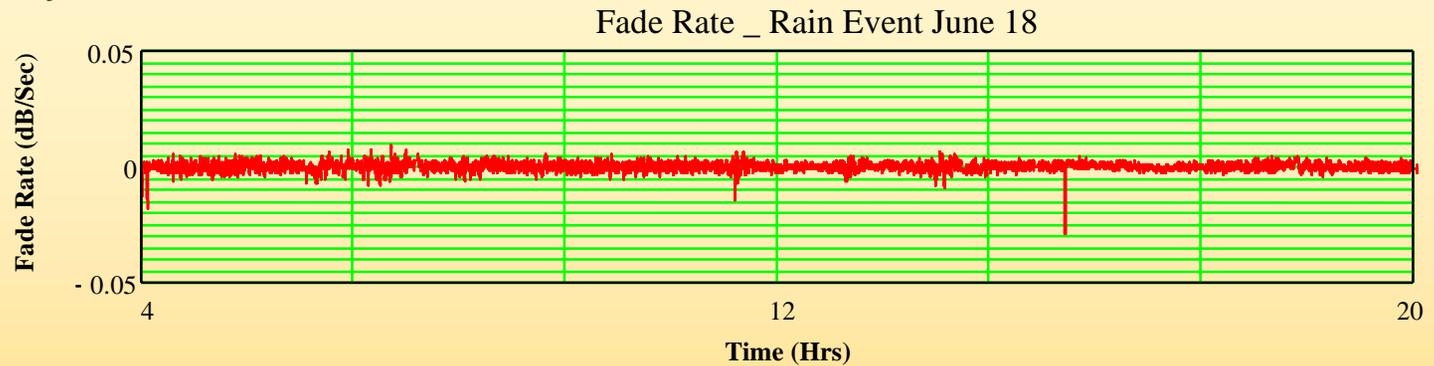
Fade Depth



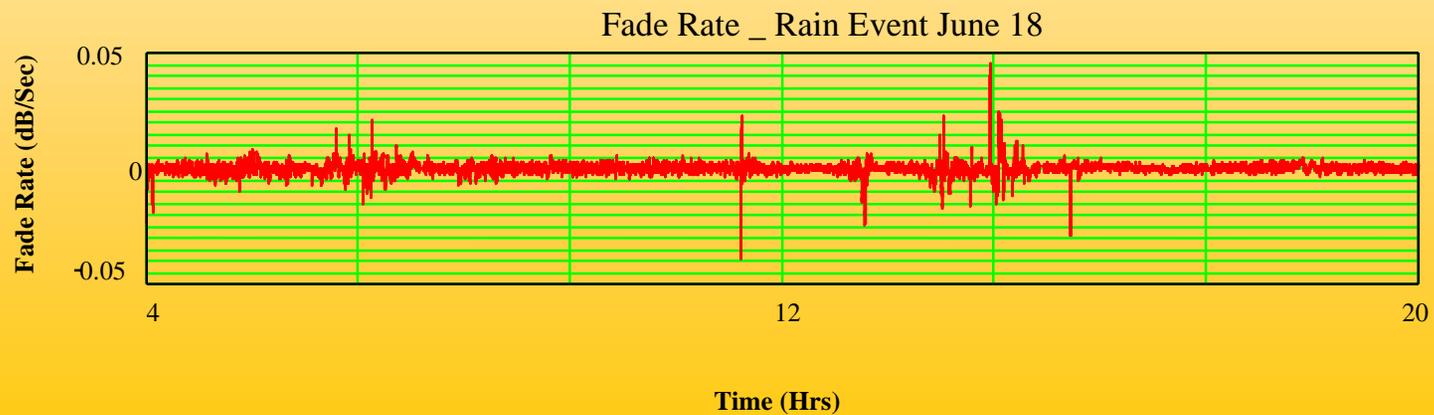
Red : Dry Antenna
Blue : Wet Antenna

WET ANTENNA STUDIES

Dry Antenna Fade Rate

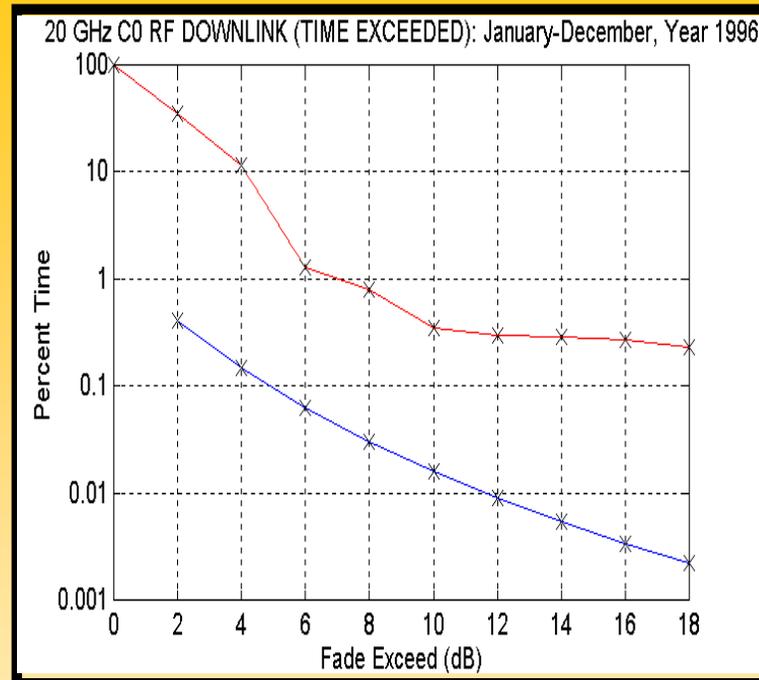


Wet Antenna Fade Rate



THEORY VS. EXPERIMENT

FADE AVAILABILITY FOR CLEVELAND - 1996



GROUND STATION AND SPACECRAFT DEGRADATION EFFECTS

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

KEY SYSTEM MARGIN CONSIDERATIONS

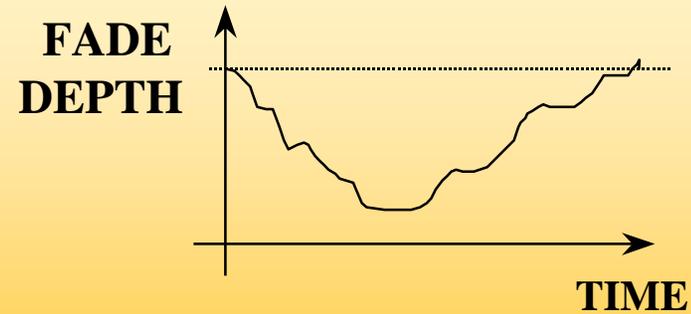
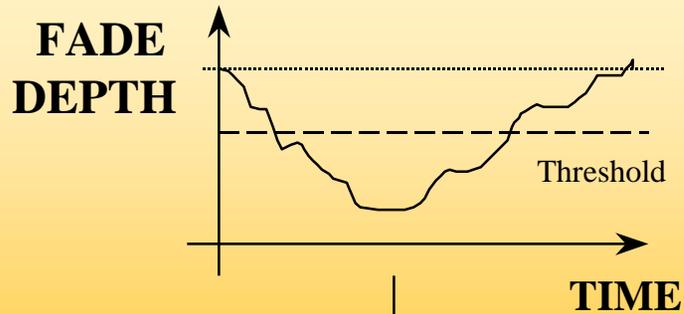
– Clear Sky margin (fixed)

- 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

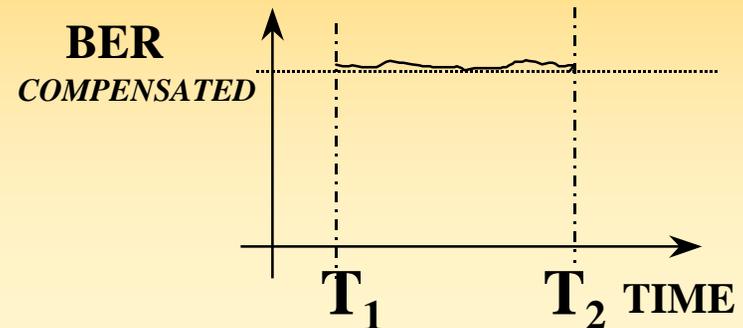
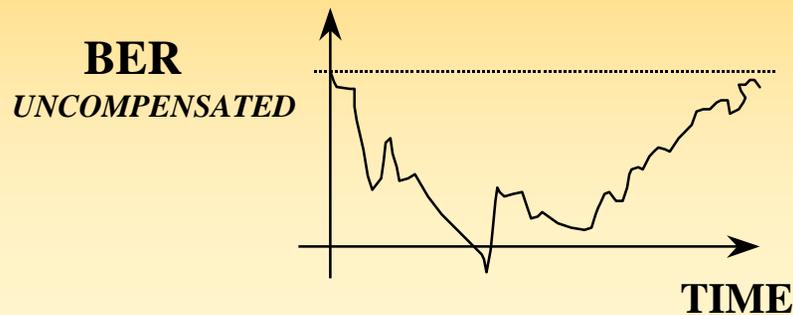


FADE SENSING ALGORITHM

- *Fade Depth*
- *Fade Rate*
- *Threshold Values*
- *Decision*

COMPENSATION ALGORITHM

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



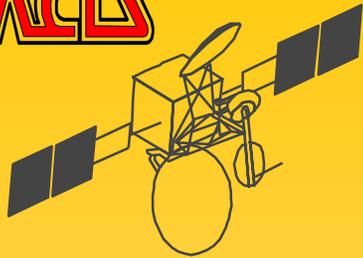
Rain Fade Sensing Techniques

- 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

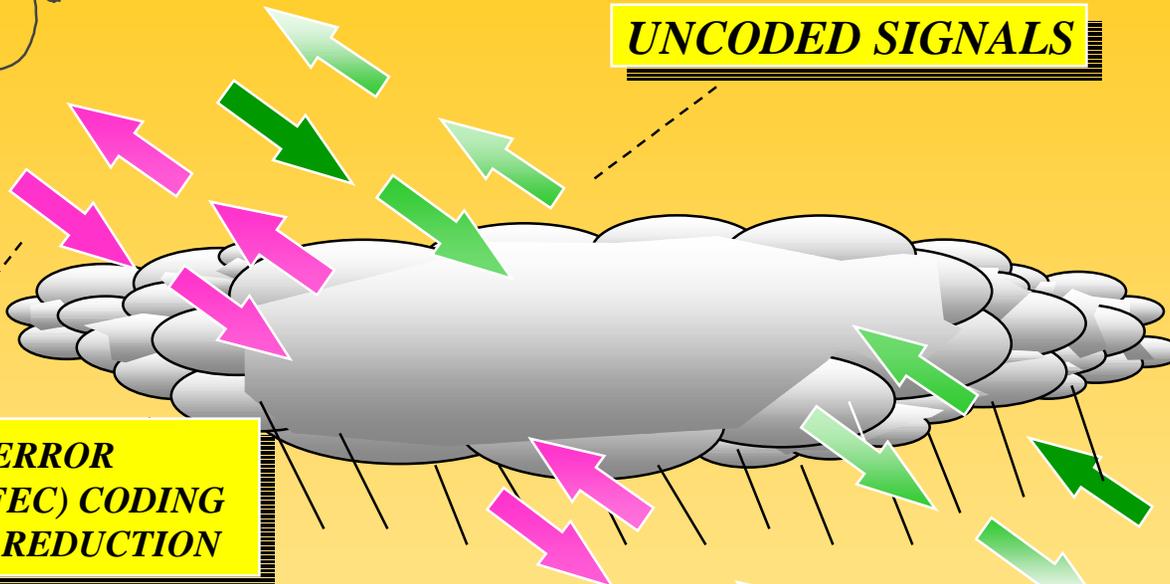
- Increase power
 - Uplink power is dynamically adjusted
 - Open-loop, closed-loop and feedback-loop
- Information rate and FEC code rate changes
 - FDMA, CDMA and TDMA
- Combination of above
- Diversity stations

ACTS



ACTS Rain Fade Compensation

UNCODED SIGNALS



**FORWARD ERROR
CORRECTION (FEC) CODING
& BURST RATE REDUCTION**

**IMPACT ON SYSTEM
Adds 10 dB of Fade Margin**



Station #2

MESSAGE IS RECOVERED



Station #1

LOST MESSAGE

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