Fade Mitigation Techniques At Ka-Band

Asoka Dissanayake

Introduction

- Rain fading is the dominant propagation impairment affecting Ka-band satellite links and rain fade mitigation is a key element in the design of Ka-band satellite networks, Some of the common fade mitigation techniques include:
  - power control
  - diversity
  - adaptive coding
  - resource sharing
- ACTS provides an excellent opportunity to develop and test Ka-band rain impairment amelioration techniques.
- Up-1ink power control and diversity are discussed.

UP-link Power Control

- Up-link power control is one of the fade mitigation techniques that can be implemented relatively easily. Power control at an earth station attempts to maintain a constant power flux density at the satellite irrespective of fading conditions along the propagation path.

- Types of up-link power control (ULPC):
  - open loop
  - closed loop
  - feedback loop

- Open loop is the easiest to implement and does not require system-wide considerations.

Open-loop ULPC

- Requires estimation of fading/enhancement on the up-link. One of the following methods may be used:
  - radiometry
  - beacon measurement
  - BER measurement

- Technique used determines accuracy and cost.

- In general, beacon measurement provides a higher accuracy at a modest cost.

Beacon Measurements

- Attenuation along the satellite path deduced from measured beacon level variations.

- In addition to propagation phenomena, beacon level variations are brought about by:
  - beacon EIRP changes
  - instability of measurement system
  - antenna pointing errors
  - spacecraft maneuvers
  - modulation on beacon signal

- Fade detection based on establishing a clear-sky level that has a dominant diurnal pattern.

Up-link Fade Estimation

- Most satellites carry a beacon sources in the down-link frequency band. When using a down-link beacon for power control, the estimated down-link fade must be frequency scaled to the up-link.

- Propagation factors contributing to fading:
  - gaseous absorption
  - rain attenuation
  - clouds and melting layer
  - tropospheric scintillation

- Each factor has a different average frequency scaling law. In addition, there are random variations around the average scaling ratio.

ULPC Implementation Issues

- Point of application of power control (RF or IF)
- Control accuracy, HPA non-linearities
- Fail safe operation to protect space segment
- Interference:
    - adjacent channel
    - orthogonally polarised channel
    - off axis emission
- Power control dynamic range

Power Control Algorithm

- Detect down-link fade after establishing the reference level; reference level based on long-term observations using an adaptive filter with a time constant of the order of 1 hour
- Down-link fade separated in to rain fade and scintillation components; an averaging time of 20 sec. used in estimating rain fade.
- Current level of rain fade predicted using an adaptive filter
- Frequency scaling of rain and scintillation fades to 29 GHz

Experiment Details

Power control carried out using a 29 GHz pilot carrier transmitted from the LET at Lewis Center in Cleveland; transponder carrier received at Clarksburg.

Power control based on down-link attenuation measurements at 20 GHz

- Beacon reception and pilot transmission are done on separate antennas; antenna separation -15 ft; little impact on measurements
- Control applied at IF; power control resolution: 0.2 dB; update rate 5 Hz
- Maximum power control range: 25 dB; however, investigation will be limited to a control range of 15 dB.
- Power controller was able to maintain control accuracy within ±2.5 dB

Site Diversity

- Site diversity is one of the fade mitigation methods that takes advantage of finite size of rain cells.
- Site diversity applied in the conventional sense involves two earth stations interconnected via a dedicated terrestrial line.
- Relatively high cost of conventional diversity makes it less attractive to network operators.

Factors Affecting Diversity

- Site separation
- Rain climate
- Frequency
- Elevation angle
- Baseline orientation

Wide-area Diversity

- Use of site diversity when interconnecting wide-area networks using satellites. Satellite link serving as a variable bandwidth backbone.
- Presence of more than one earth terminal within a wide-area network; adequate site separation to provide uncorrelated fading.
- Interconnection of earth terminals using an appropriate data service.

COMSAT

Networked Diversity

- Cost of implementing site diversity can be reduced using:
  - public switched network for interconnection
  - sharing of earth station resources.

- Rain fading is restricted to a small fraction of time in a year and the use of the switched network on as needed basis can bring significant cost advantages.

- Sharing of earth station resources implies that not all terminals are fully occupied at all times. This is especially true for VSAT type terminals

COMSAT

Diversity Implementation

- Link evaluation (beacon, radiometer, BER, AGC)

- Switching with minimum data loss (short-term prediction of fading conditions)

- avoidance of frequent switch operations (statistics of fade durations and inter-fade intervals)

- Central control or distributed control

Results

Result	COMSAT	MITRE
Down time due to fading (> 4 dB)	159 min	191 min
Unavailable time with full diversity	33 min	45 min
Networked unavailable time	43 min	54 min
Number of attempted switches	61	55
Number of failed switches	11	9

Conclusions

Power Control

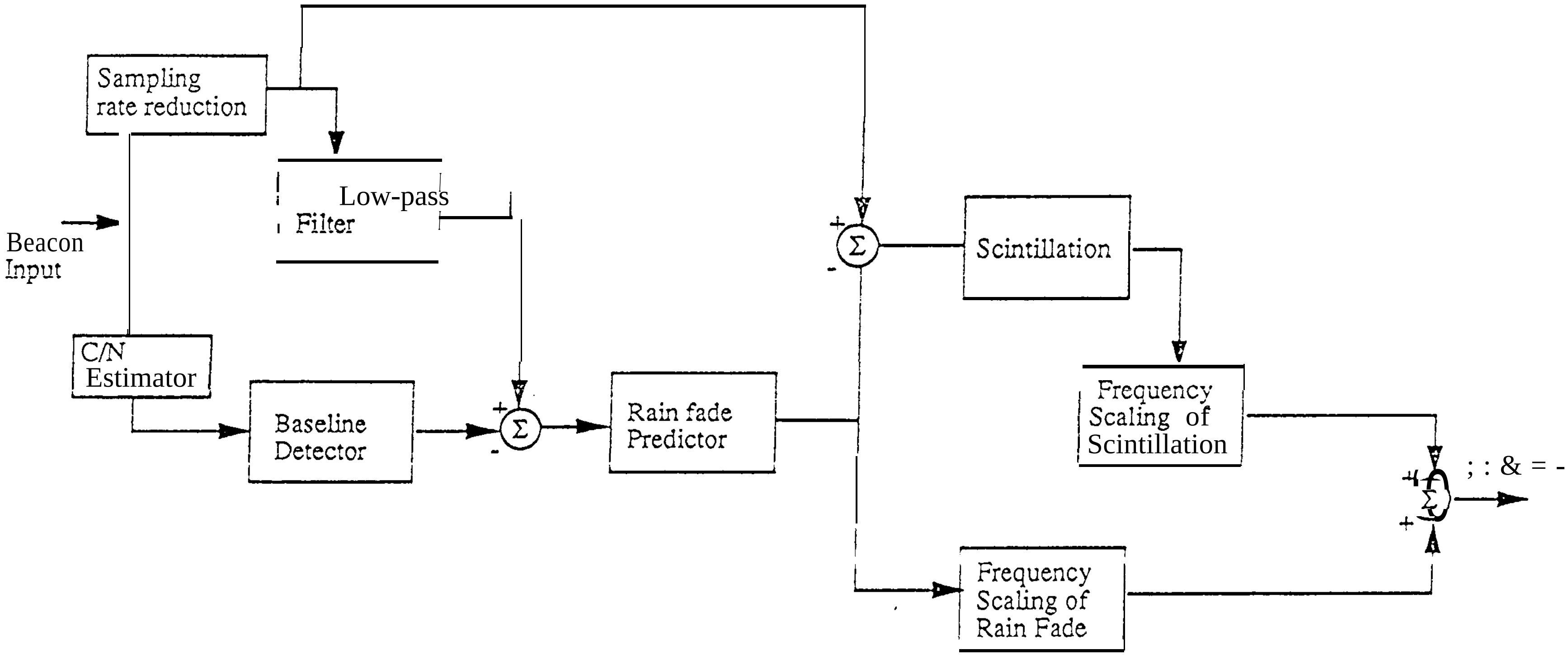
- Experiment demonstrated the usefulness of power control and helped establish design parameters for operational systems.

- When restricted to a power control range of 15 dB, the control accuracy can be maintained within ±2.5 dB.

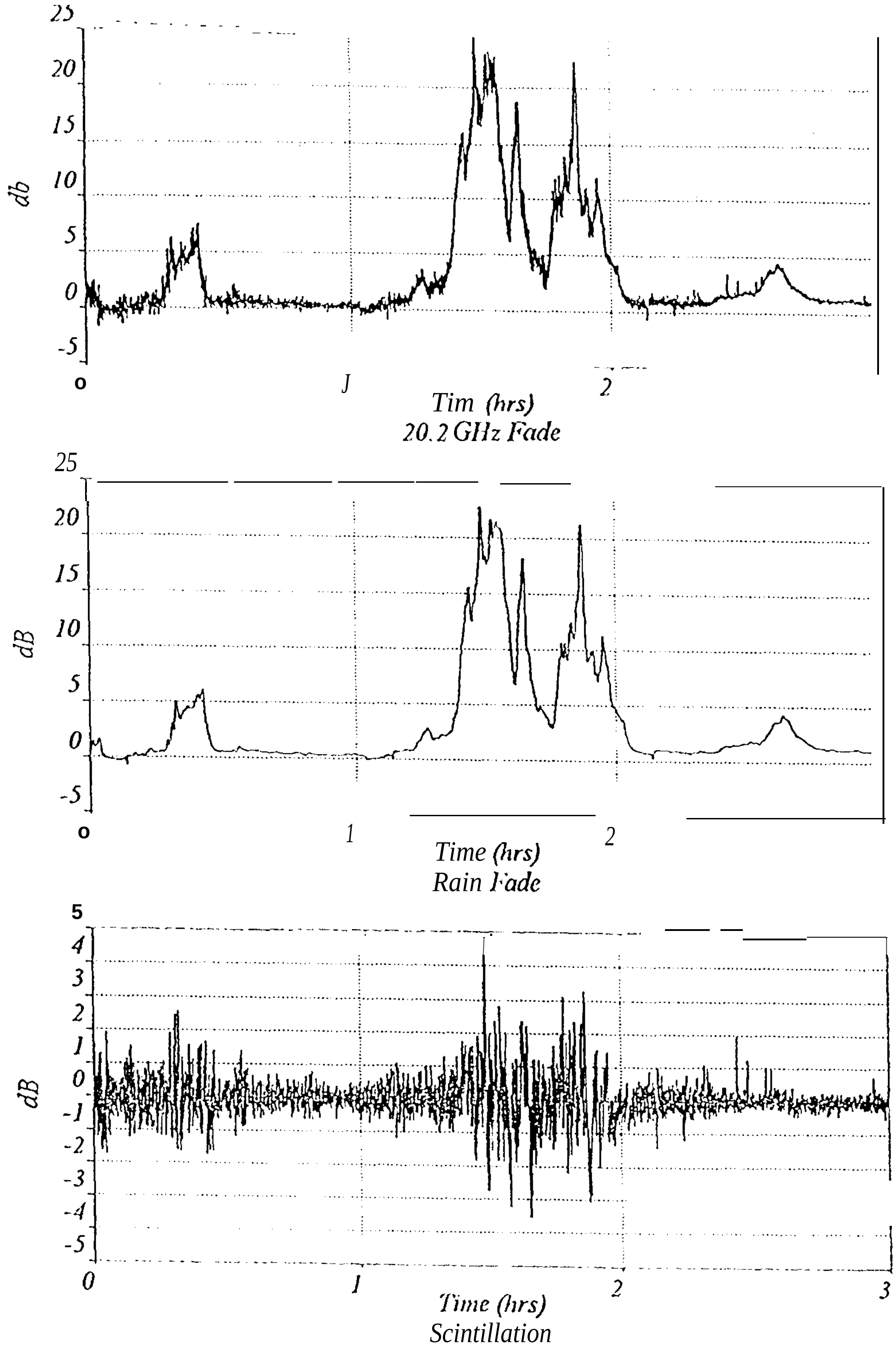
Diversity

- Wide-area diversity can be used to increase the availability of Ka-band VSAT terminals.

- It also allows for the increased utilization of both ground and space segment resources.



Up-link Fade Estimation Algorithm



Separation of Rain and Scintillation; Rain Event on 14 August, 1994

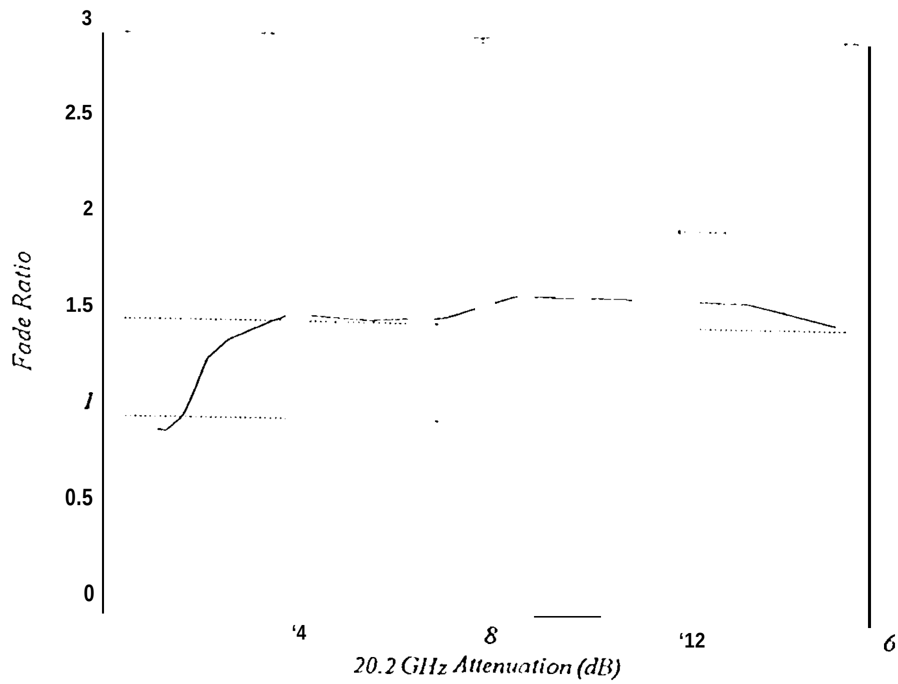
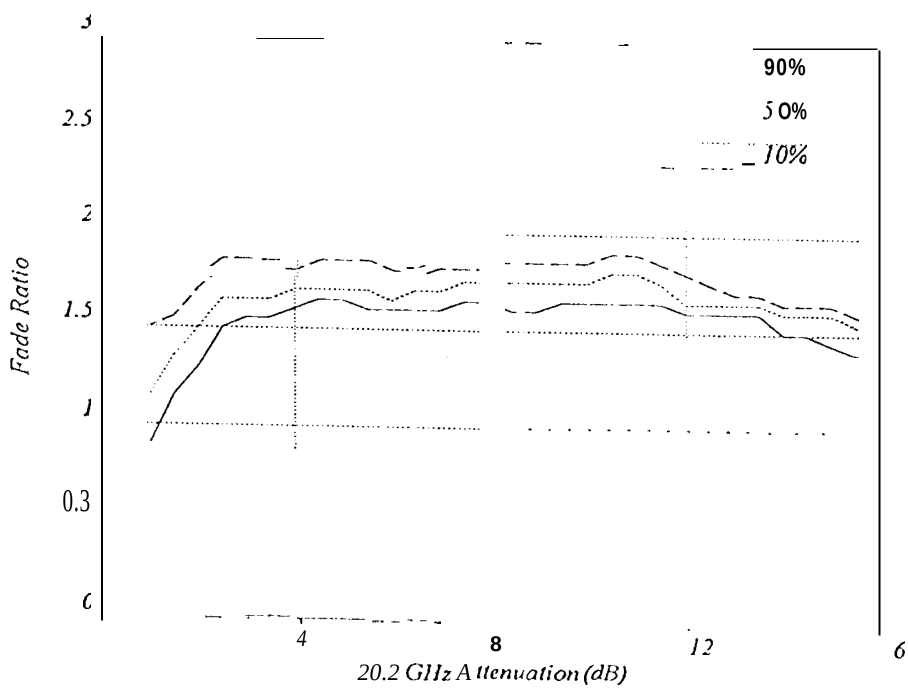
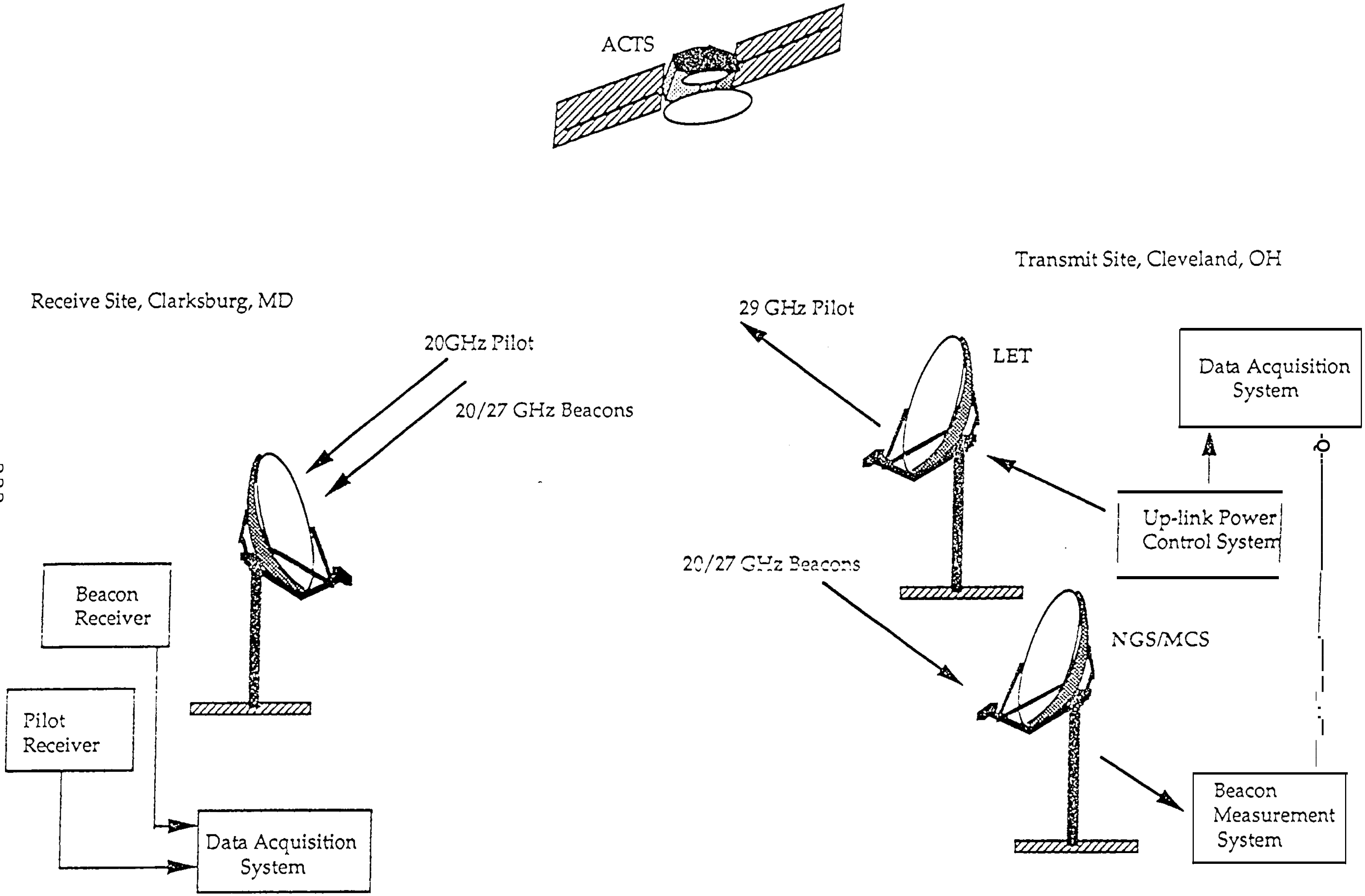


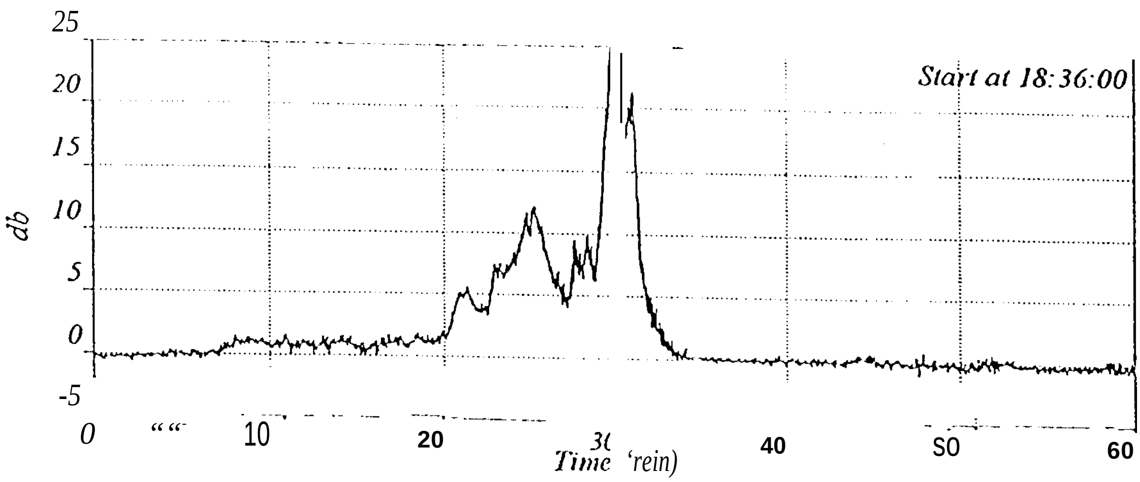
Figure 2.1 J Equiprobable Fade Ratio Between 27.5 and 20.2 GHz



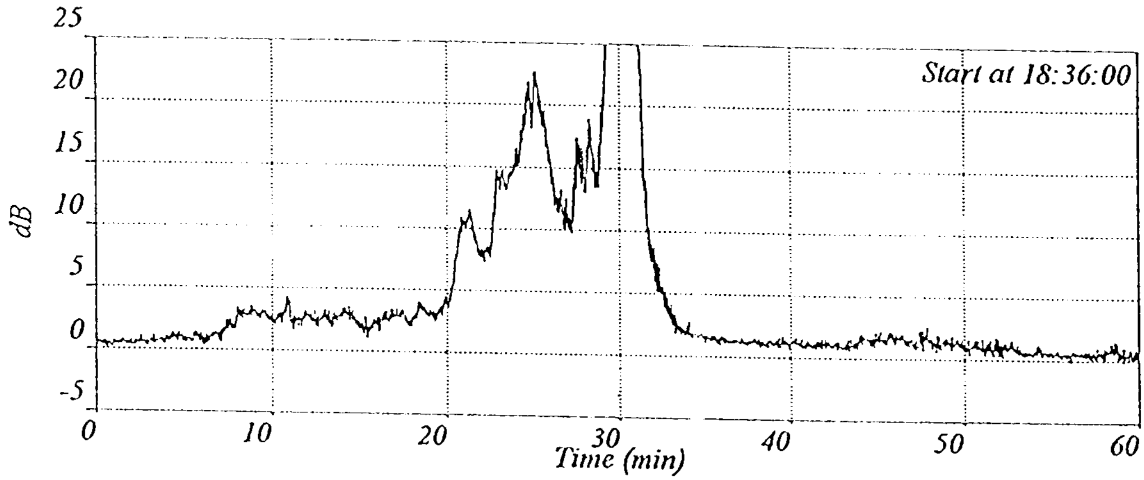
Distribution of Instantaneous Fade Ratio Between 27.5 and 20.2 GHz



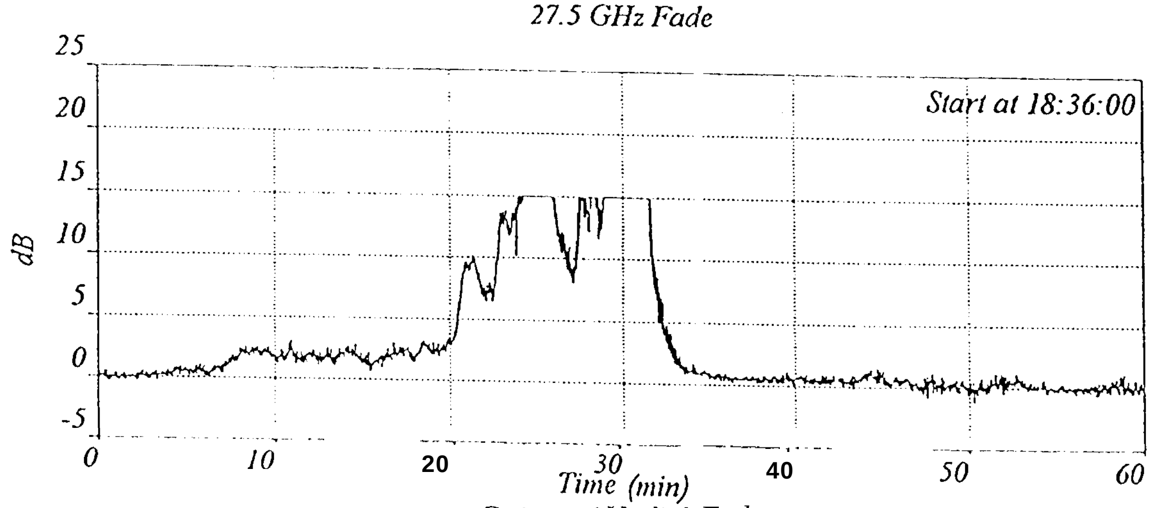
ACTS Up-link Power Control Experiment Configuration



20.2 GHz Fade

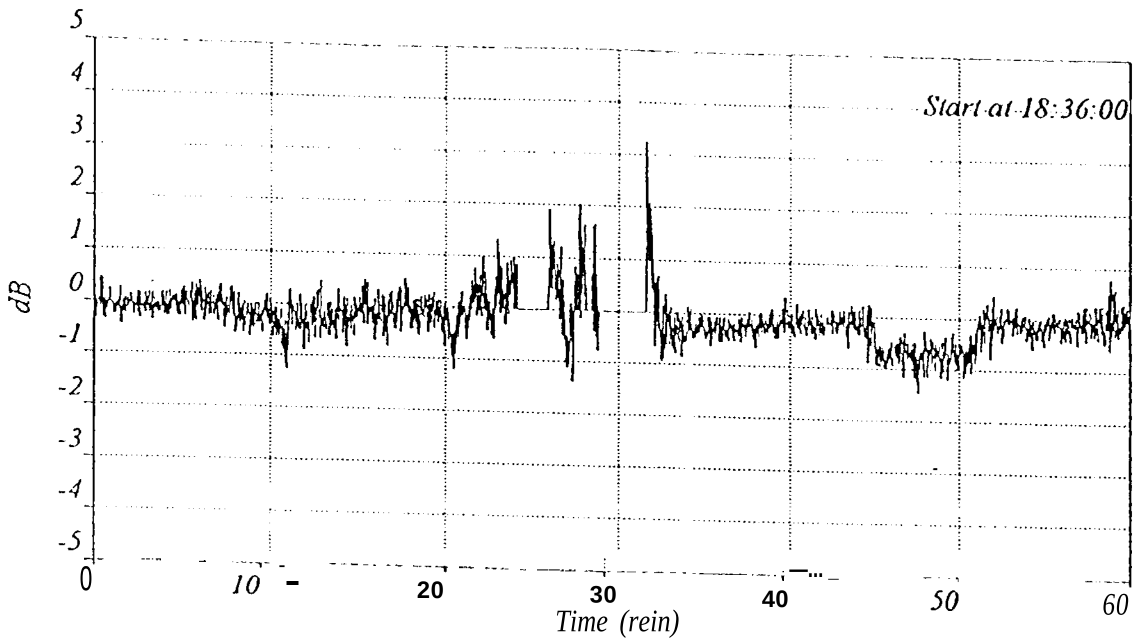


27.5 GHz Fade

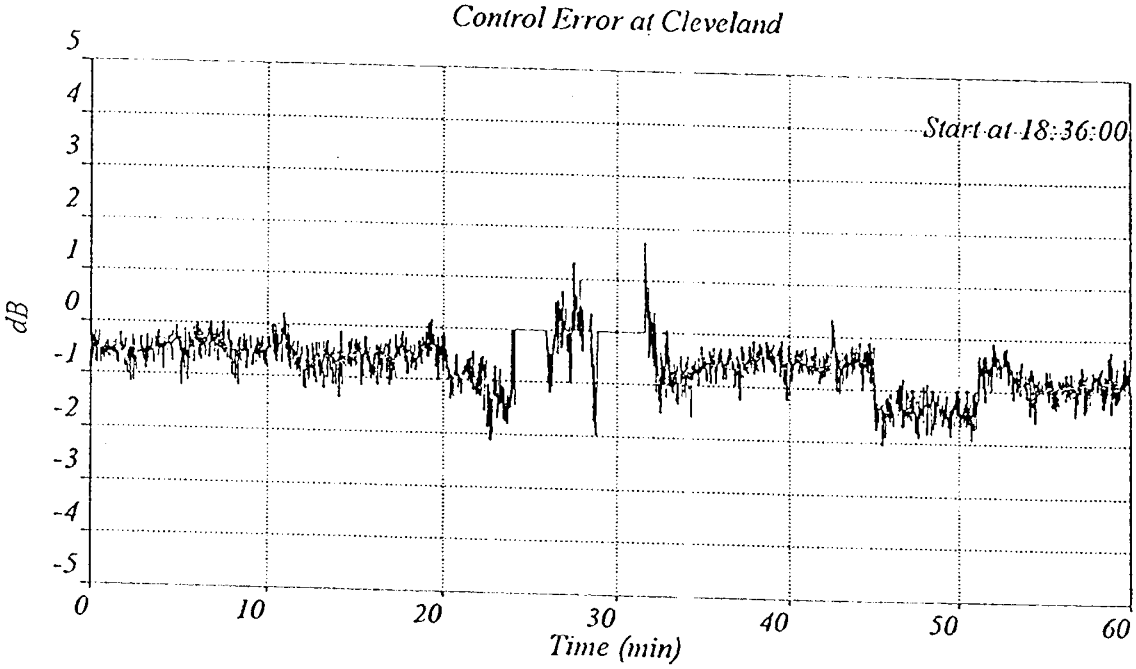


Estimated Up-link Fade

Rain Event 1 on 31 May, 1994

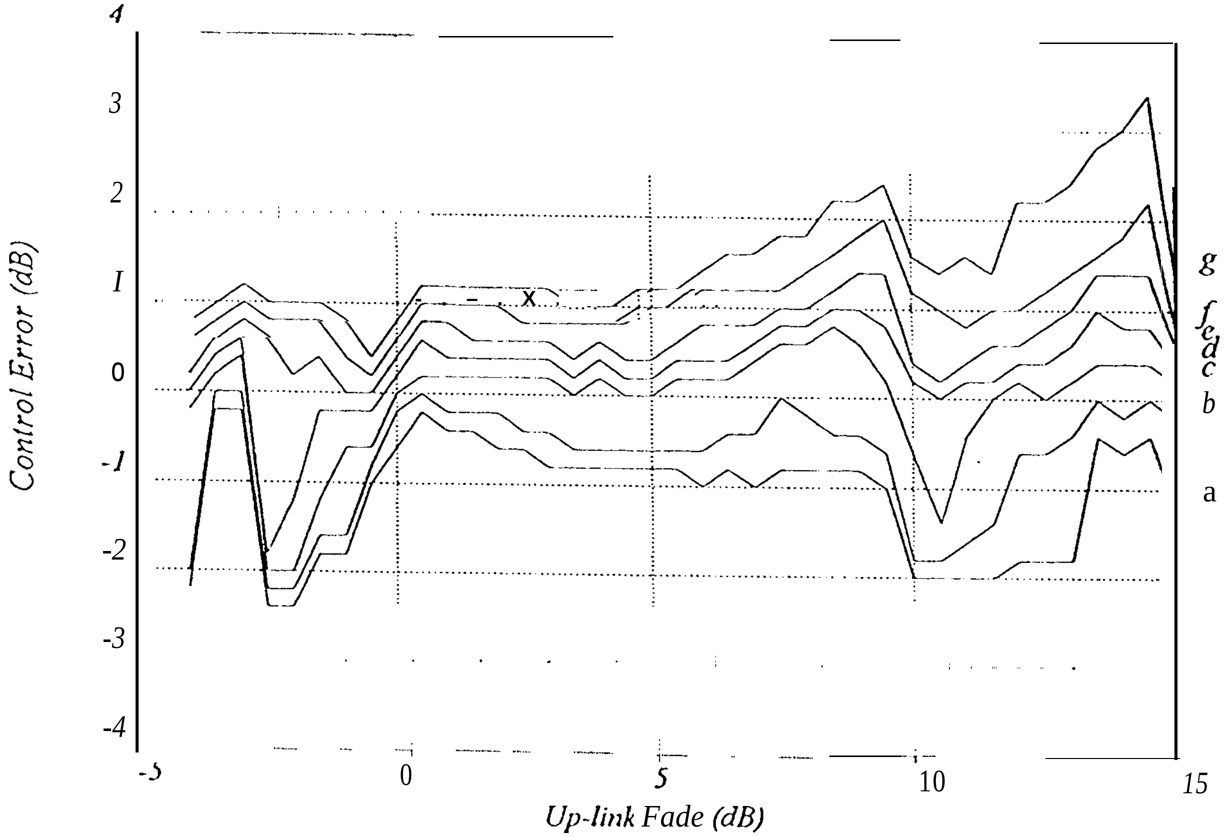


Control Error at Cleveland



Pilot Level at Clarksburg

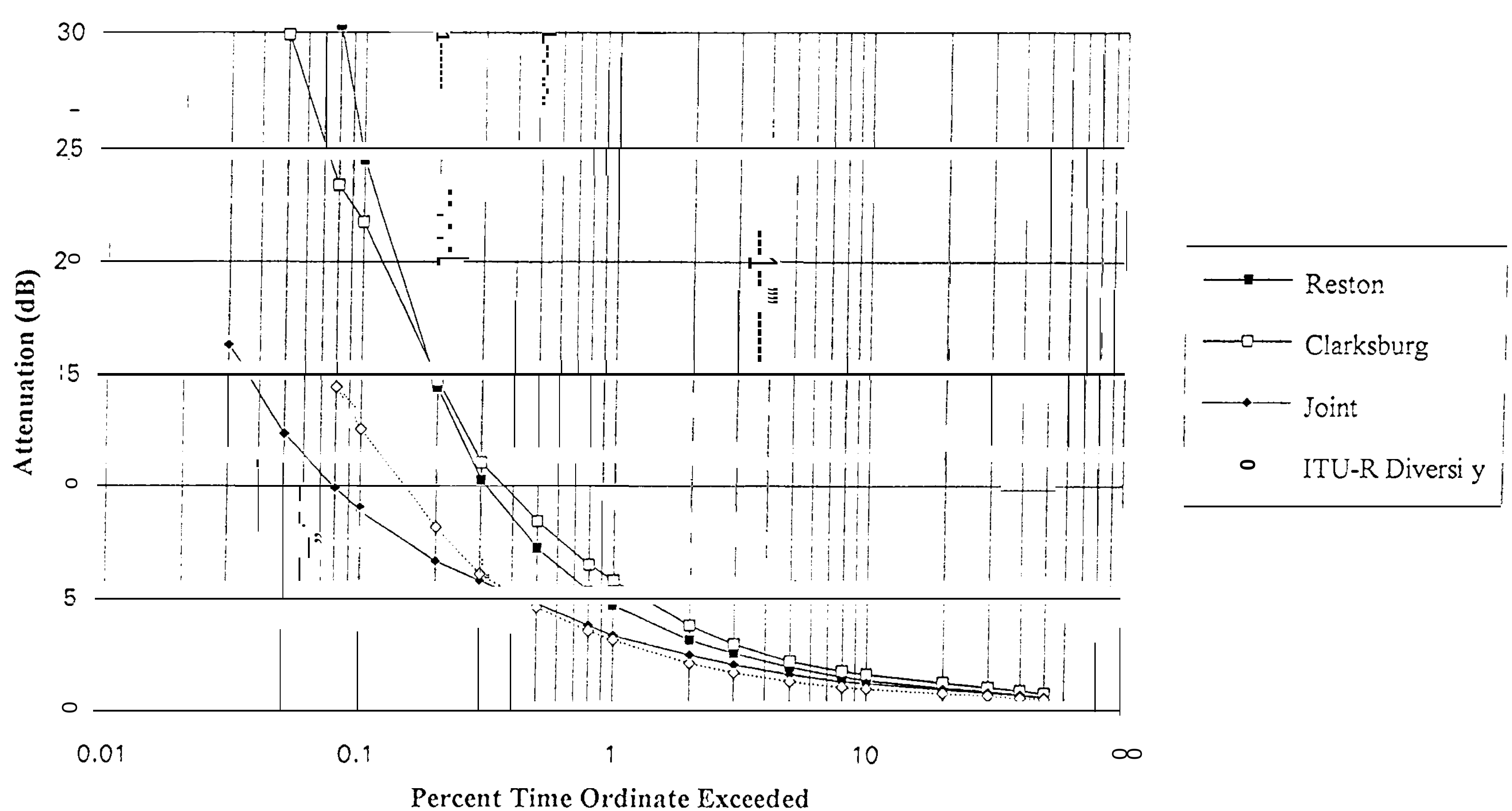
Control Error; Rein Event 1; May 31, 1994



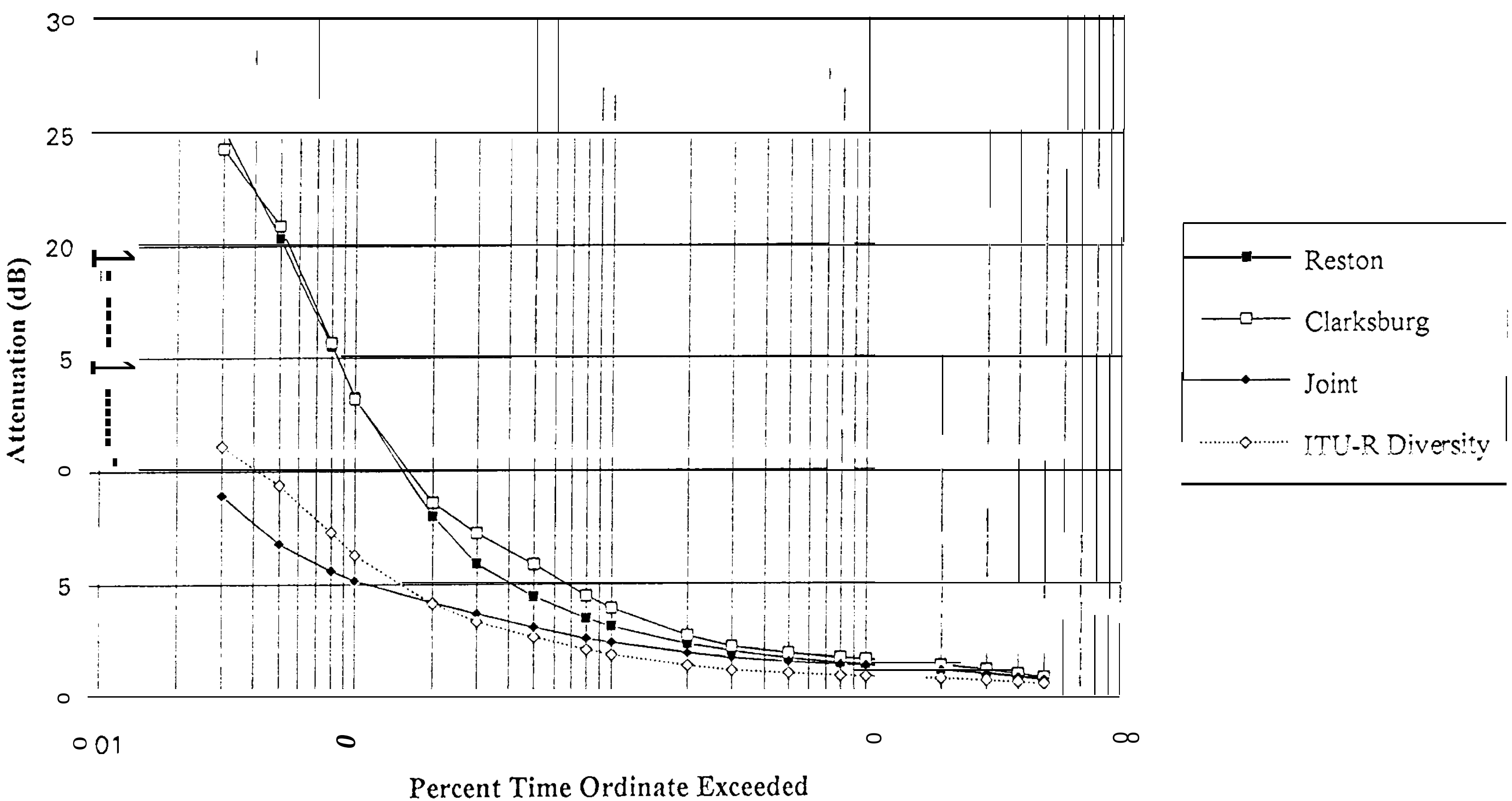
Distribution of Power Control Error;

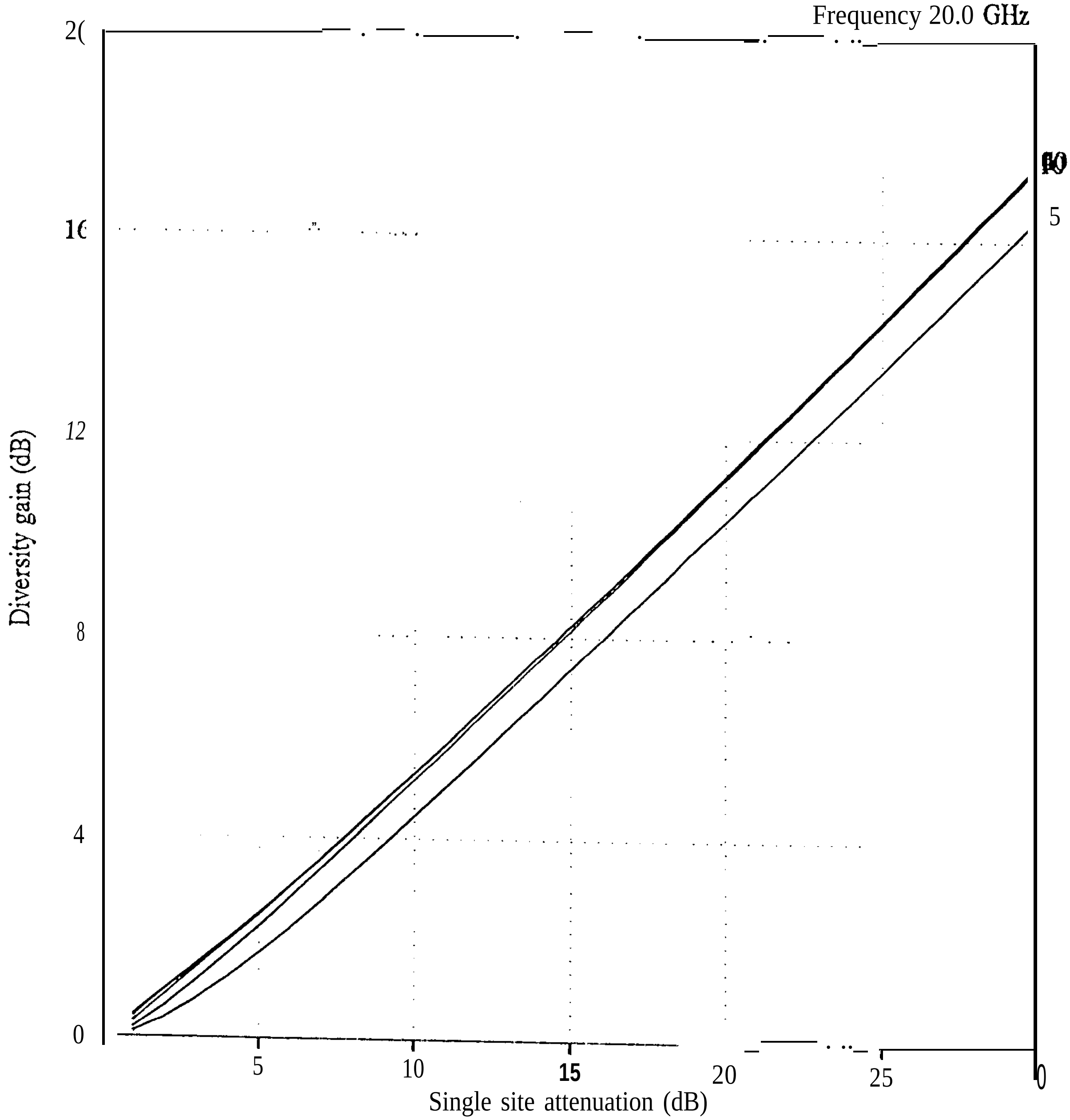
a: 99%, b: 950A, c.- 750A, *d: 50%, e: 25%, f: 5%, g: 1%*

27 GHz Attenuation

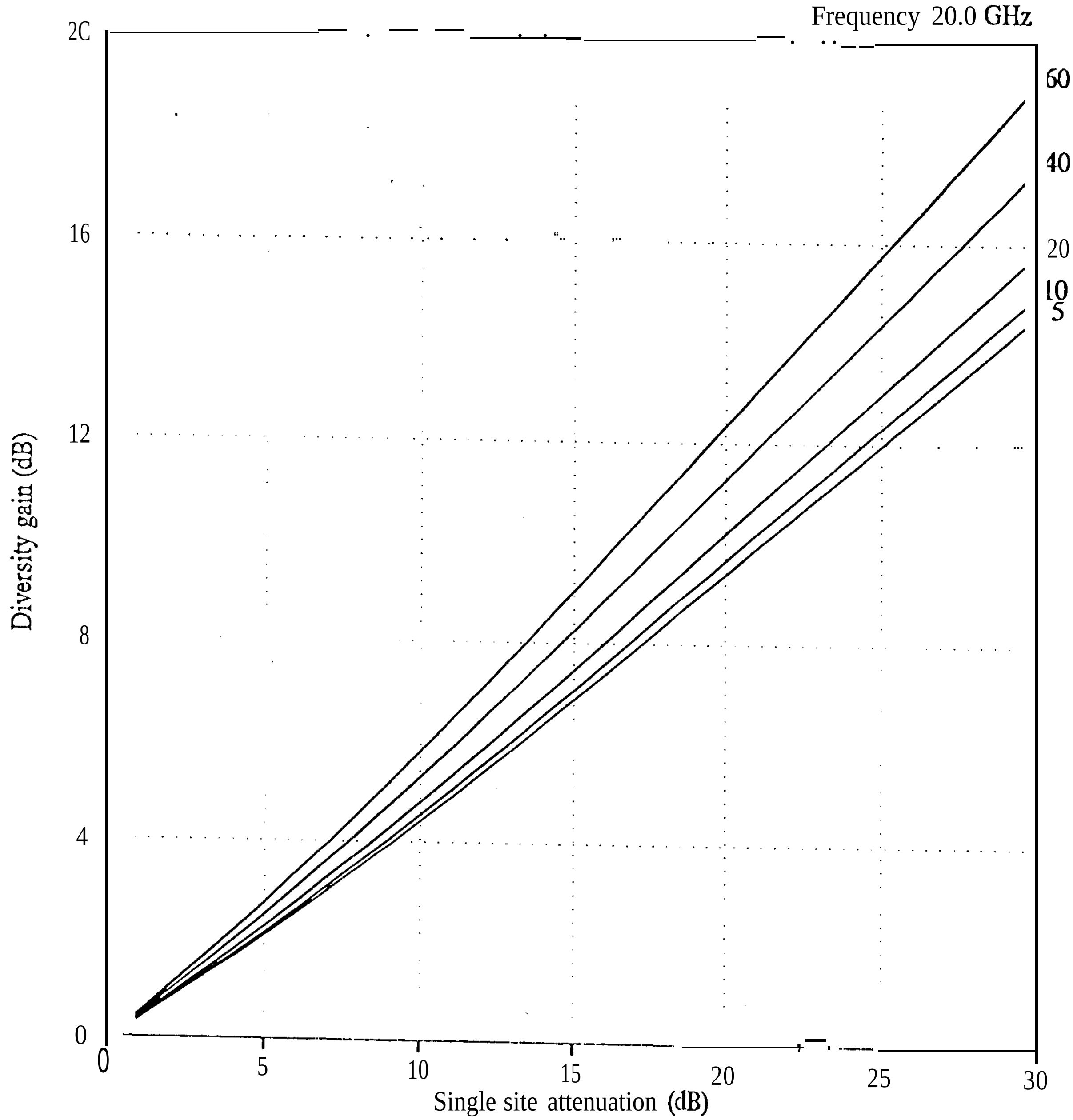


20 GHz Attenuation

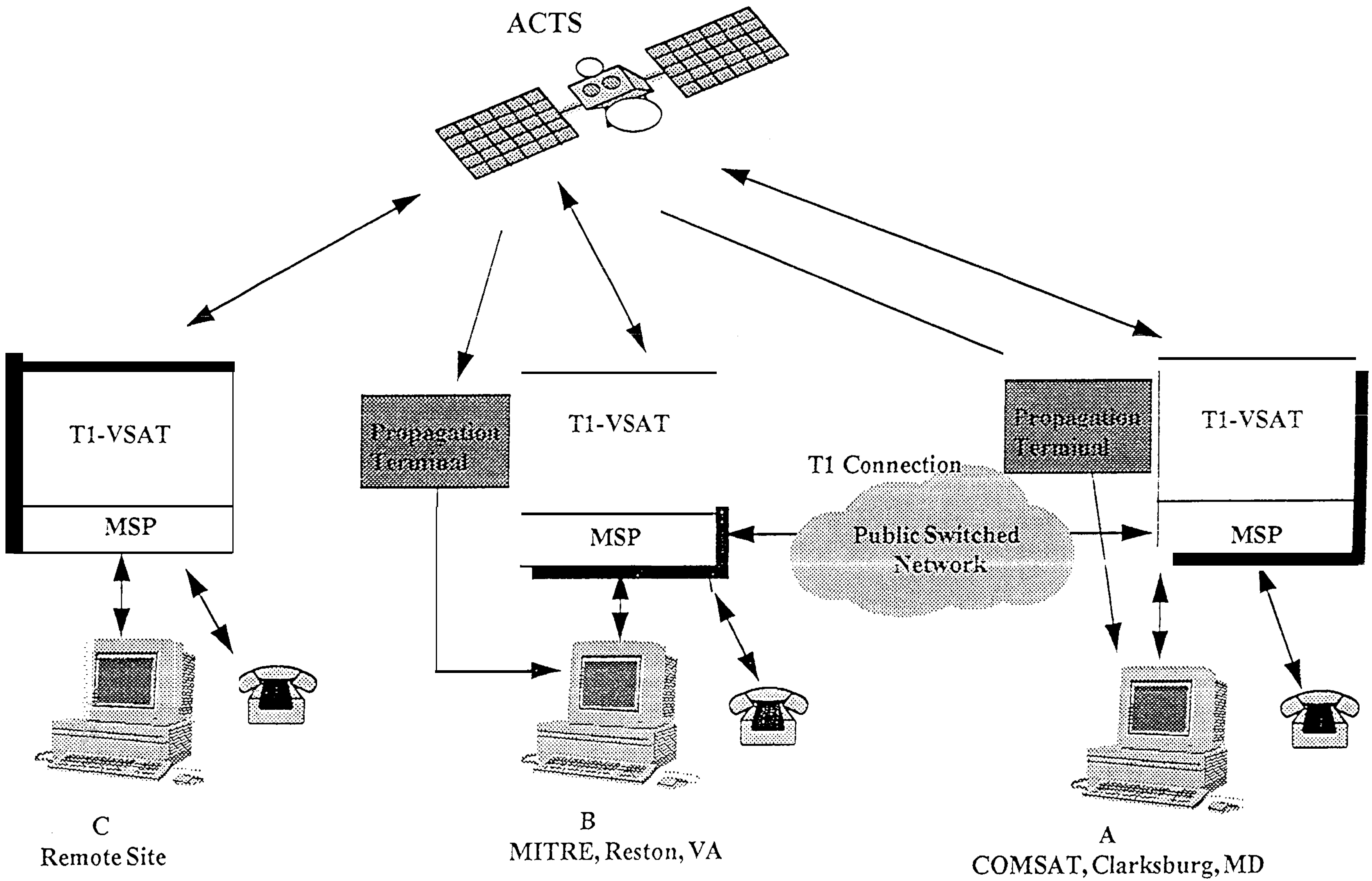




Diversity gain predictions for Clarksburg, MD.
Elevation angle: 40° Baseline orientation 45.0”
Site separations: 5, 10, 20,40, *60 km*



*Diversify **gain** predictions for **Clarksburg, MD.***
Site separation 40.0 km; ***Baseline orientation*** 45.0°
Elevation angles: 5°,100,200,400, and 60°



Wide-area Diversity Experiment Configuration