Session VI. Airborne Doppler Radar / NASA

Ground Clutter Measurements Using the NASA Airborne Doppler Radar: Description of Clutter at the Denver and Philadelphia Airports

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GROUND CLUTTER MEASUREMENTS USING THE NASA AIRBORNE DOPPLER RADAR:
A DESCRIPTION OF CLUTTER AT DENVER AND PHILADELPHIA AIRPORTS

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Detection of hazardous wind shears from an airborne platform, using commercial sized radar hardware, has been debated and researched for several years. The primary concern has been the requirement for "look-down" capability in a Doppler radar during the approach & landing phases of flight. During "look-down" operation, the received signal (weather signature) will be corrupted by ground clutter returns. Ground clutter at and around urban airports can have large values of Normalized Radar Cross Section (NRCS) producing clutter returns which could saturate the radar's receiver, thus disabling the radar entirely, or at least from its intended function.

The purpose of this research was to investigate the NRCS levels in an airport environment (scene), and to characterize the NRCS distribution across a variety of radar parameters. These results are also compared to results of a similar study[1,2] using Synthetic Aperture Radar (SAR) images of the same scenes. This was necessary in order to quantify and characterize the differences and similarities between results derived from the real-aperture system flown on the NASA 737 aircraft and parametric studies which have previously been performed using the NASA airborne radar simulation program.

This presentation describes the research and results obtained to date. These results were derived from data collected during the 1991 NASA Wind Shear Flight Experiment and include: the collection of data, analysis of incidence angle effects and polarization sensitivity, a comparison of NRCS statistics derived from the NASA radar and the ERIM SAR, an examination of intra-image features and inter-image repeatability, and an engineering summary of these results.

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1 D. Gineris, S. Harrah, and V. Delnore, "Analysis of Synthetic Aperture Radar (SAR) Data for Wind Shear Radar Clutter Modelling," *Proceedings of the Airborne Wind Shear Detection and Warning Systems: Second Combined Manufacturers' and Technologists' Conference*, Williamsburg, VA, October 18-20, 1988, pp. 225-244.

2 S. Harrah, V. Delnore, and R. Onstott, "Clutter Modelling of the Denver Airport and Surrounding Areas," *Proceedings of the Airborne Wind Shear Detection and Warning Systems: Third Combined Manufacturers' and Technologists' Conference*, Hampton, VA, October 16-18, 1990, pp. 785-836.

- Summary of Ground Clutter Flights
  - Locations & Measurements
  - Research Objectives
- Landing Scene NRCS Statistics
  - Measurement Repeatability
  - Incidence Angle Effects
  - Polarization Sensitivity
- Specific Terrain NRCS Statistics
  - Measurement Repeatability
  - Correlation to SAR Images
  - Incidence Angle Effects
- Dynamic Range of Clutter Returns
  - Antenna Pointing
  - Incidence Angle Effects
  - Polarization Sensitivity
- Conclusions
  - Application for Radar Design
  - FY' 92 Flight Plans

Summary of Ground Clutter Flights

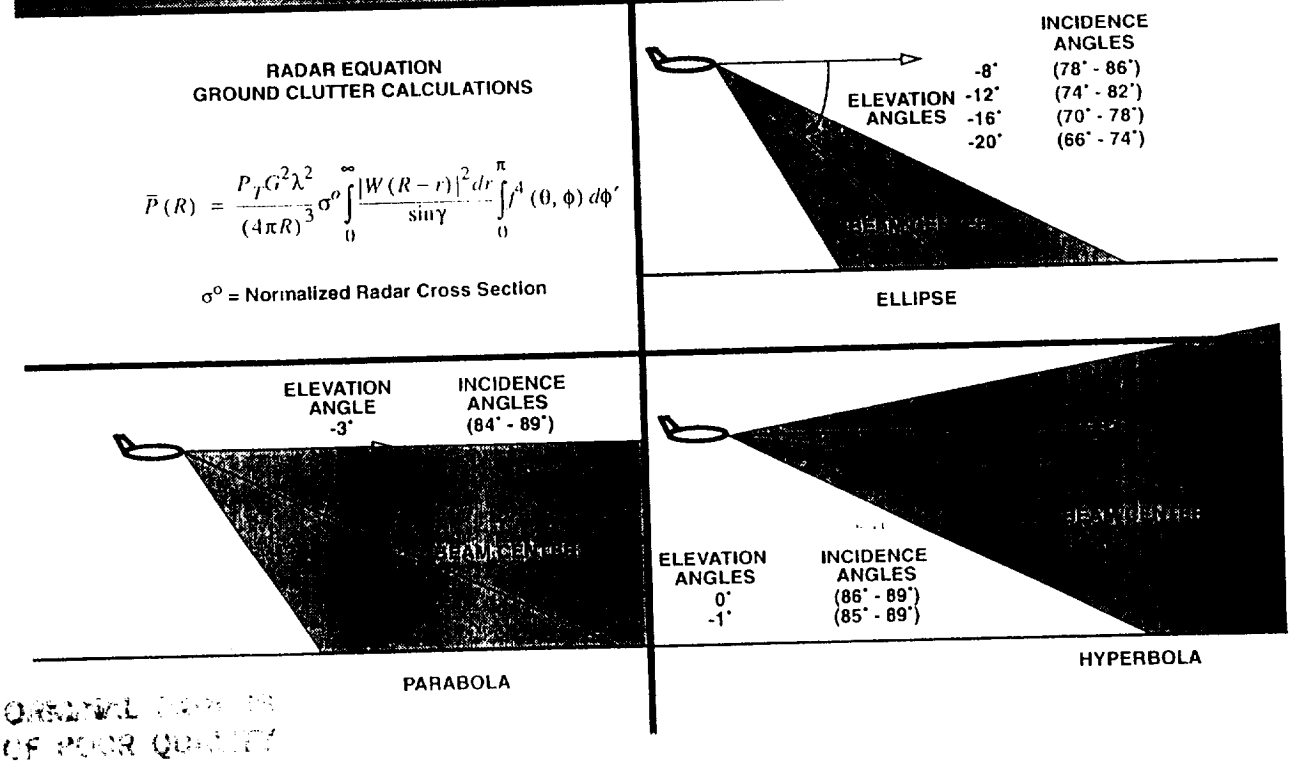
- Denver
  - 22 Approach/Landings (Runway 26 & 35)
  - Over 1 Hour of Recorded Final Approach Time
  - 22 Level Flights (~1000' AGL) (Runway 26 & 35)
  - Approx. 2,000,000,000 I&Q Samples
- Philadelphia
  - 31 Approach/Landings (Runway 27)
  - Over 1 Hour of Recorded Final Approach Time
  - Approx. 1,500,000,000 I&Q Samples
- Research Objectives
  - Evaluate Ground Clutter NRCS
  - Evalutate AGC Performance
  - Polarization & Antenna Tilt Management

GROUND CLUTTER MEASUREMENTS USING
THE NASA AIRBORNE DOPPLER RADAR
A DESCRIPTION OF CLUTTER AT DENVER AND PHILADELPHIA AIRPORTS

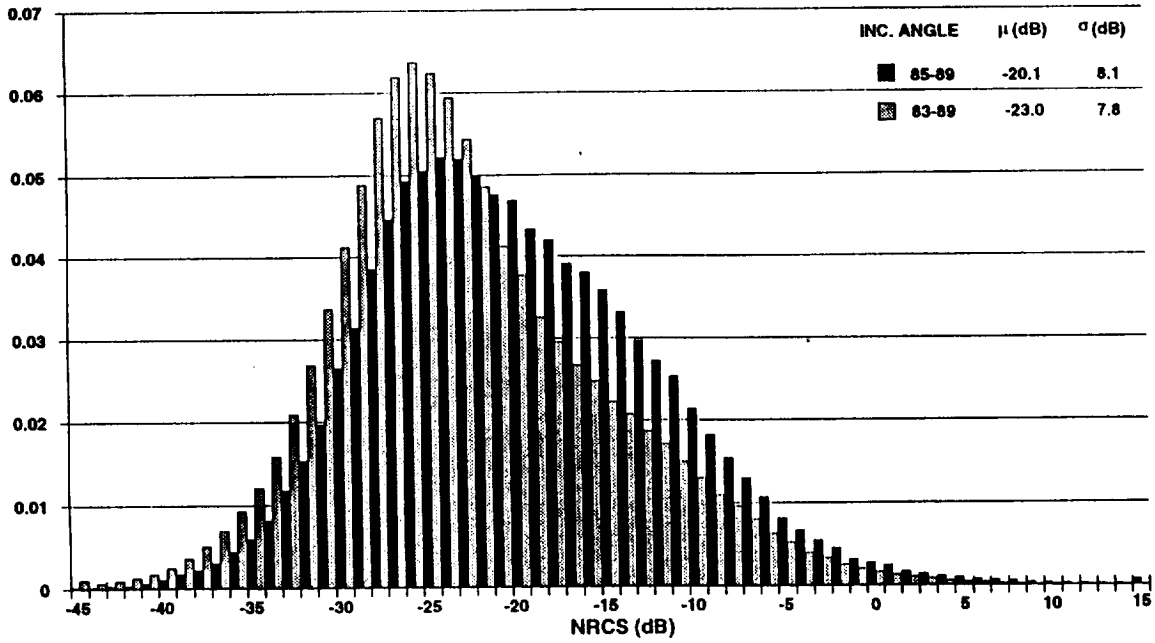
RADAR EQUATION
GROUND CLUTTER CALCULATIONS

$$\bar{P}(R) = \frac{P_T G^2 \lambda^2}{(4\pi R)^3} \sigma^o \int_0^\infty \frac{|W(R-r)|^2 dr}{\sin\gamma} \int_0^\pi f^4(\theta, \phi)\, d\phi'$$

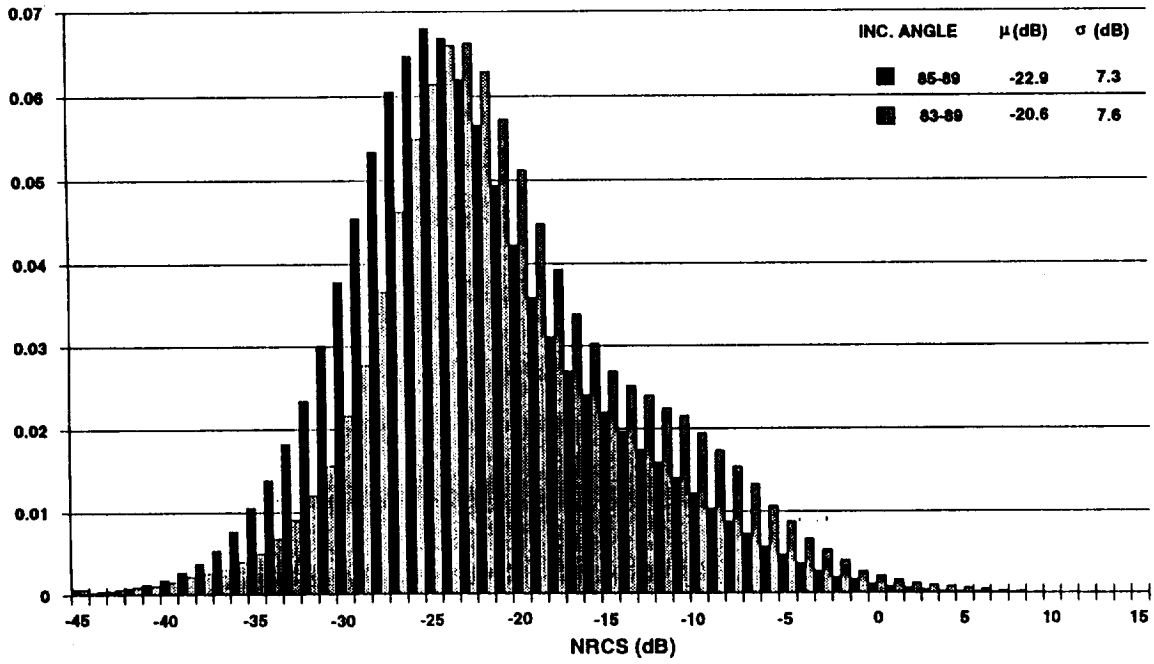
σ^o = Normalized Radar Cross Section



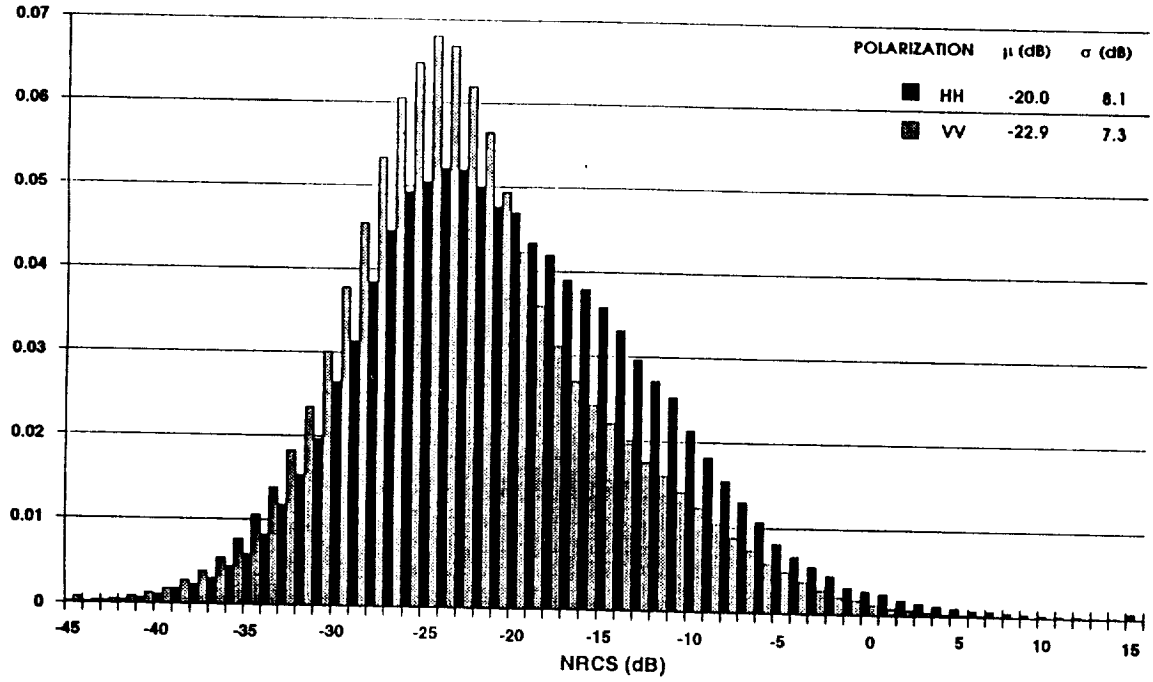
FINAL APPROACH GROUND CLUTTER NRCS (DENVER)
INCIDENCE ANGLE EFFECTS : HH POLARIZATION



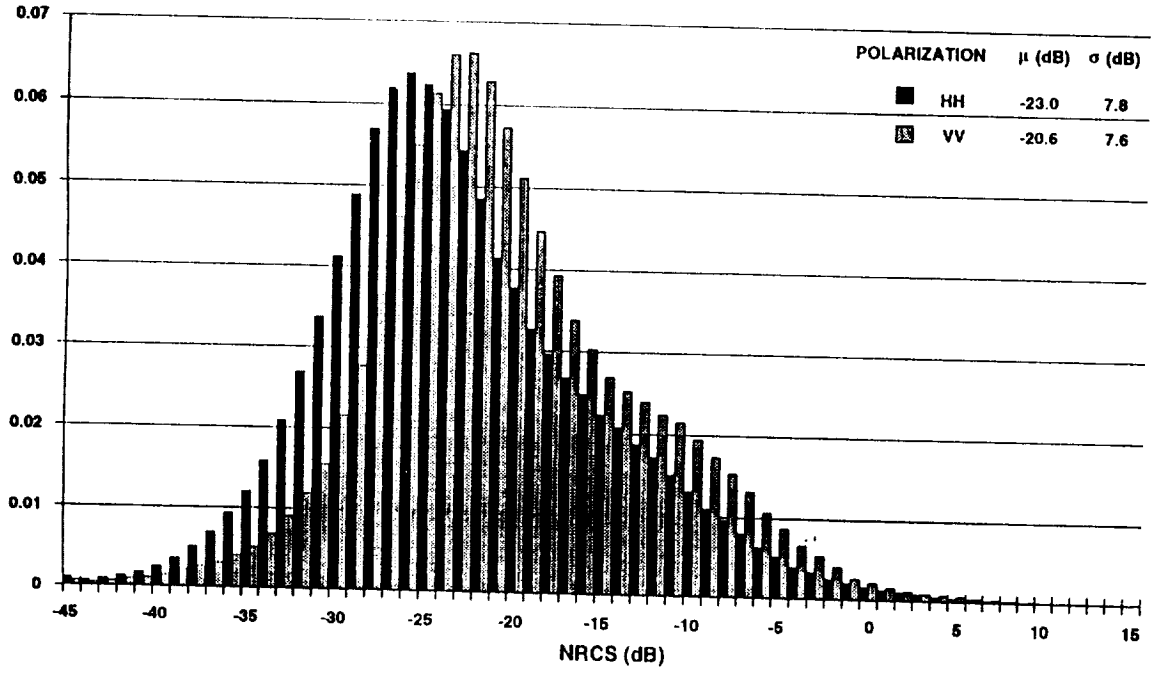
FINAL APPROACH GROUND CLUTTER NRCS (DENVER)
INCIDENCE ANGLE EFFECTS : VV POLARIZATION



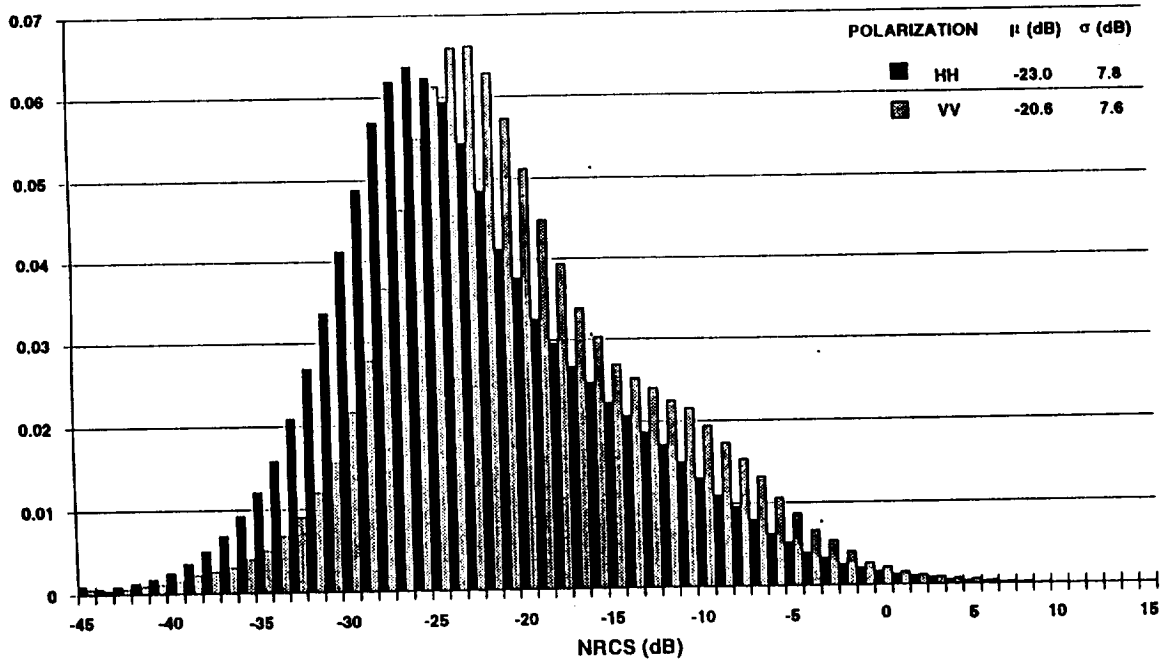
FINAL APPROACH GROUND CLUTTER NRCS (DENVER)
POLARIZATION SENSITIVITY : -1 ELEVATION



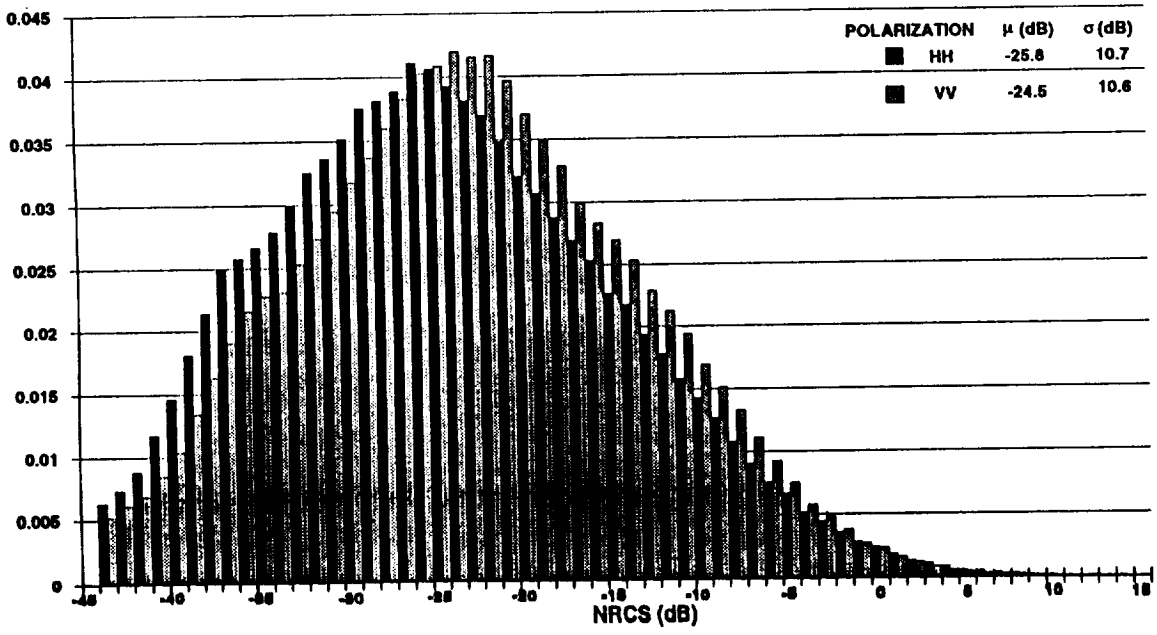
FINAL APPROACH GROUND CLUTTER NRCS (DENVER)
POLARIZATION SENSITIVITY : -3 ELEVATION

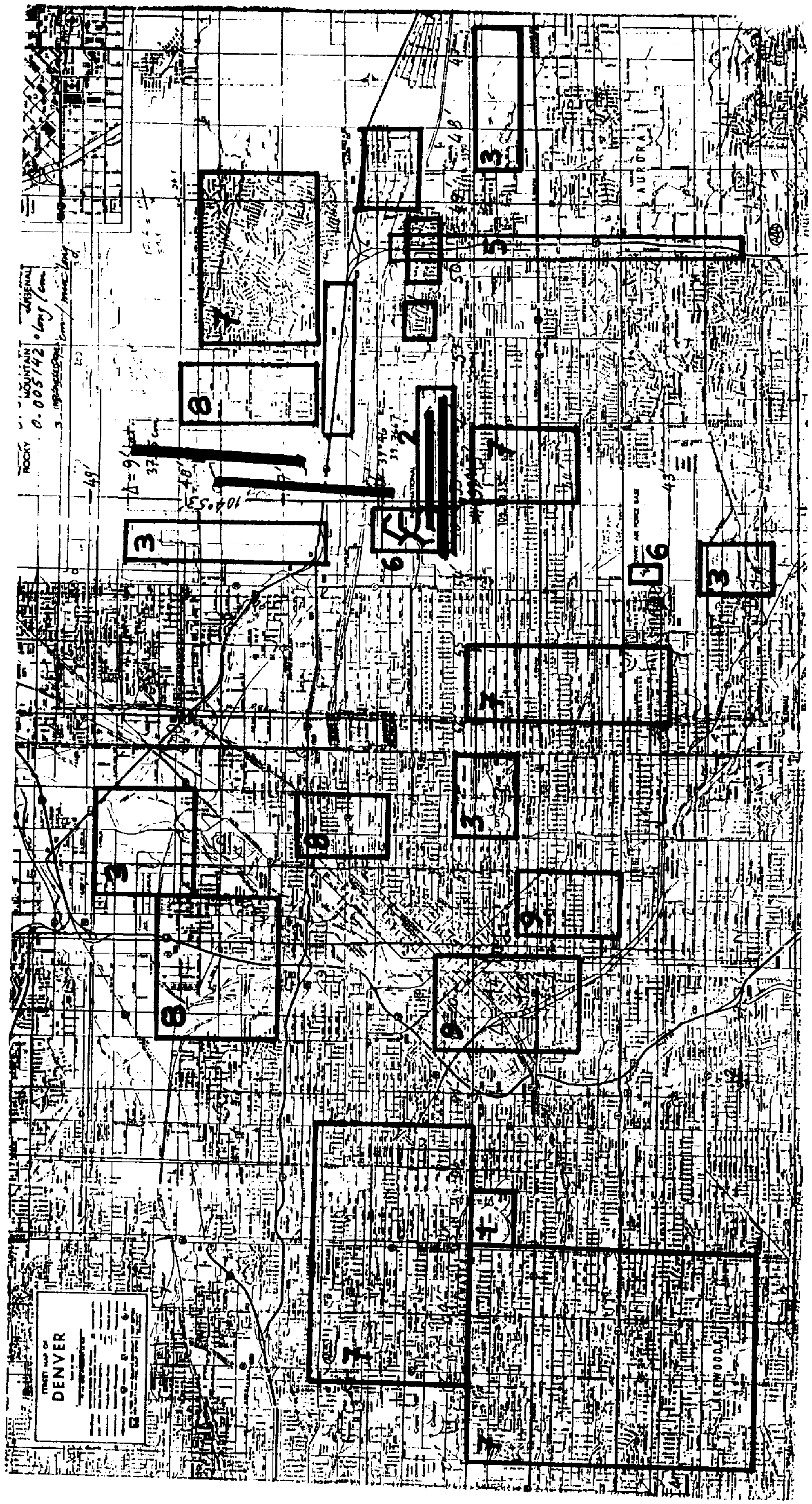


FINAL APPROACH GROUND CLUTTER NRCS (DENVER)
POLARIZATION SENSITIVITY : -3 ELEVATION

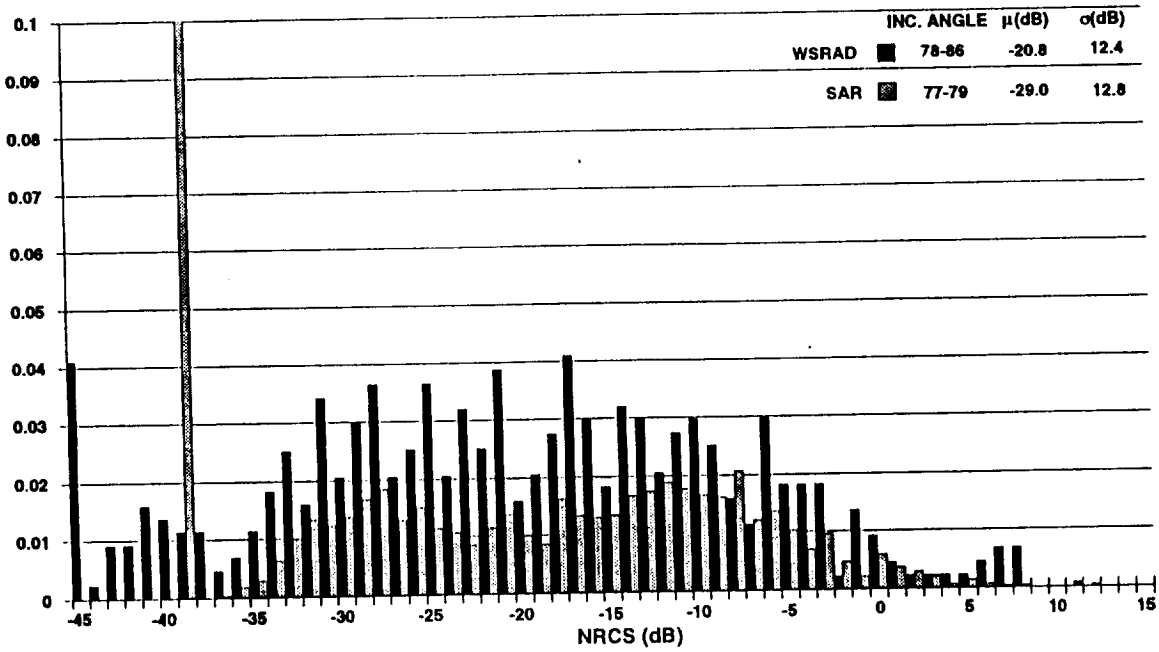


FINAL APPROACH GROUND CLUTTER NRCS (PHILADELPHIA)
POLARIZATION SENSITIVITY : -3 ELEVATION

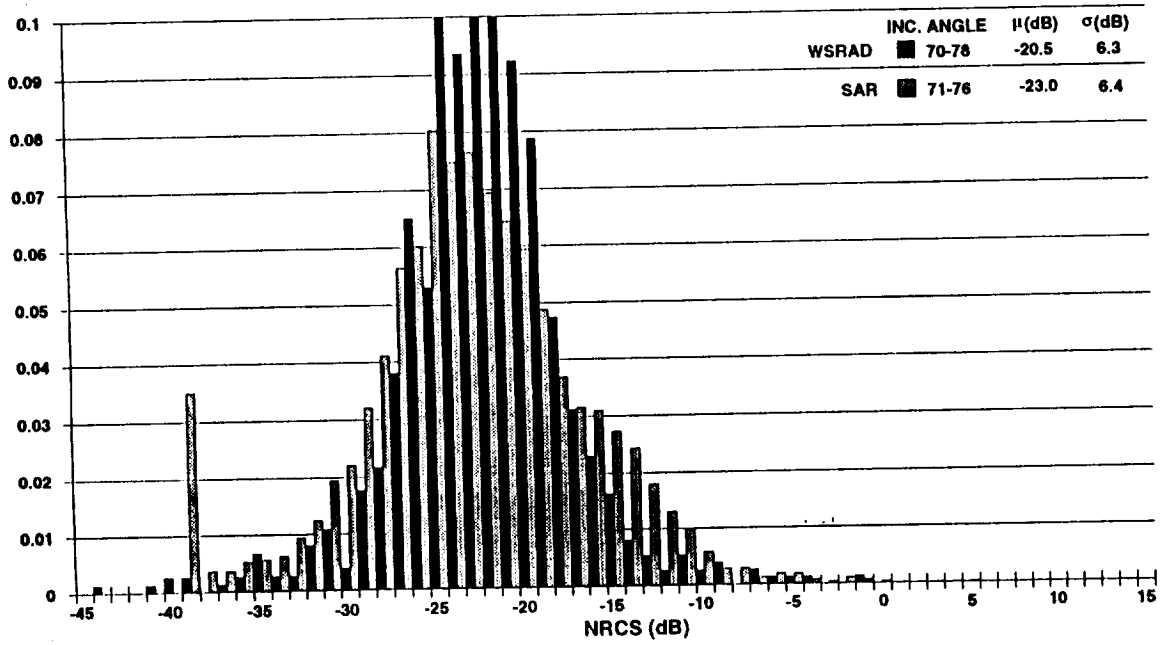




NRCS HISTOGRAM (DENVER TERMINAL)
WSRAD & SAR COMPARISON

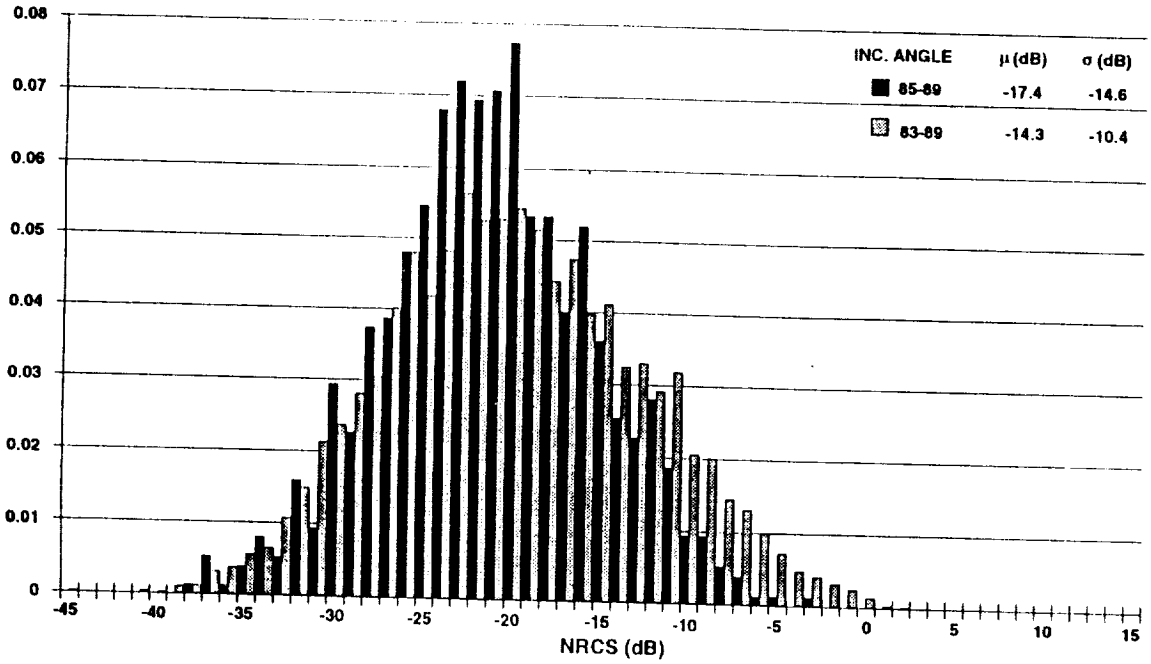


NRCS HISTOGRAM (DENVER PARKS)
WSRAD & SAR COMPARISON

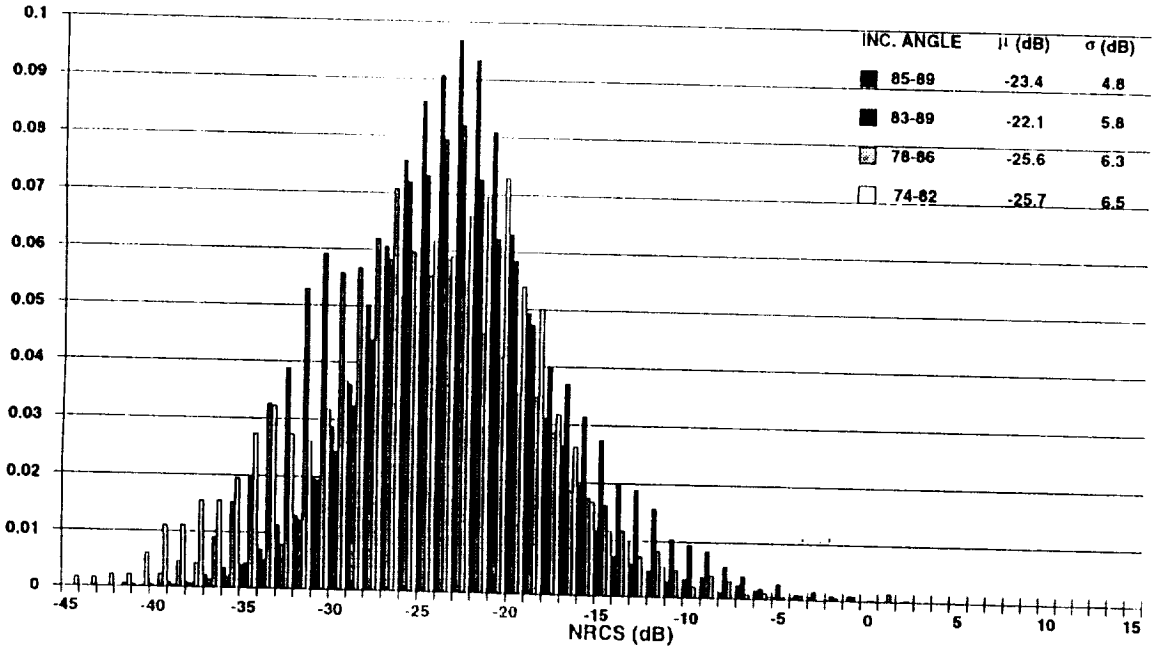


NASA WINDSHEAR RADAR
1991 FLIGHT EXPERIMENT

NRCS HISTOGRAM (DENVER URBAN)
MEASUREMENT REPEATABILITY

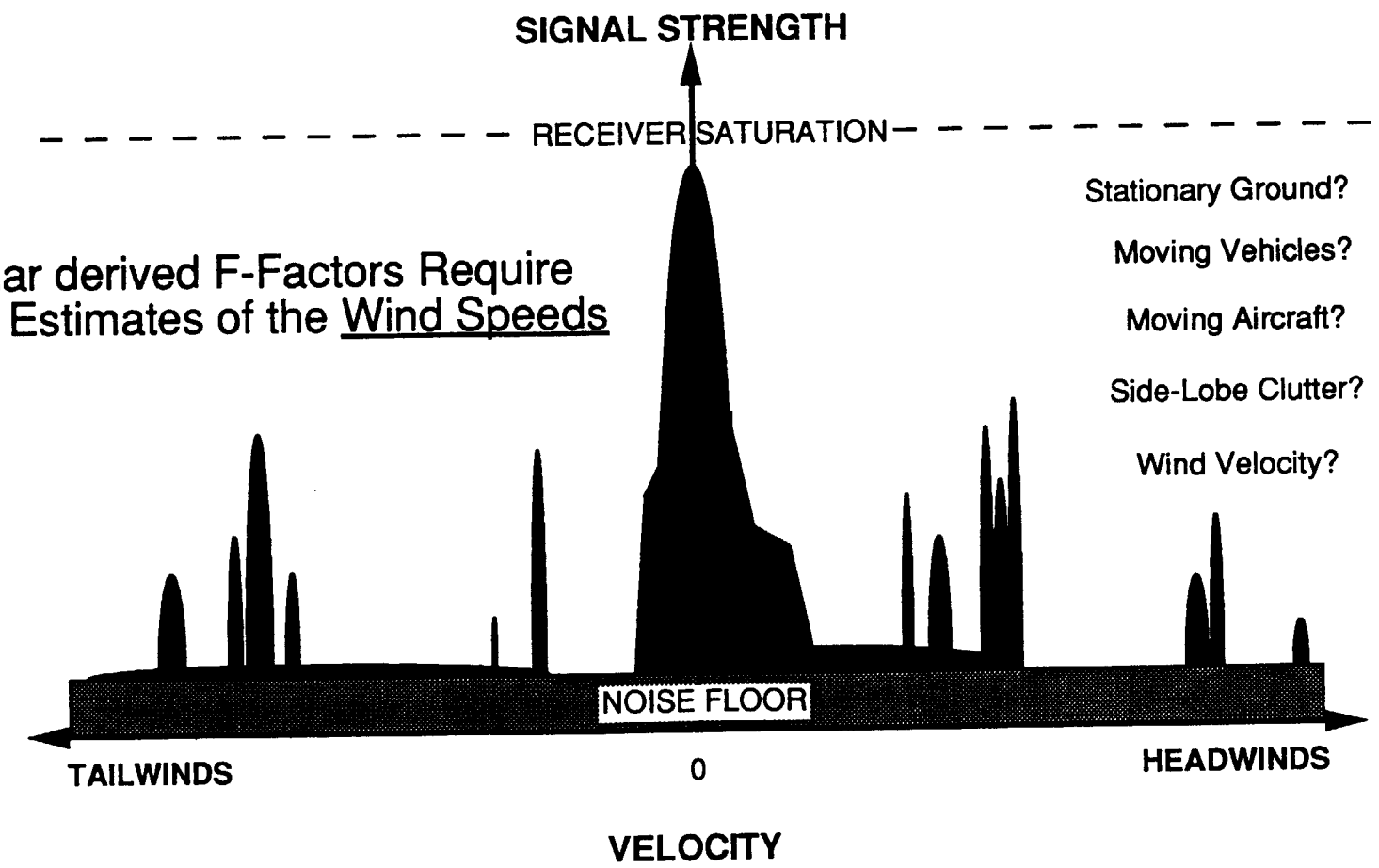


NRCS HISTOGRAM (DENVER RESIDENTIAL)
INCIDENCE ANGLE INSENSITIVITY



AIRBORNE WIND SHEAR DOPPLER RADAR SIGNAL

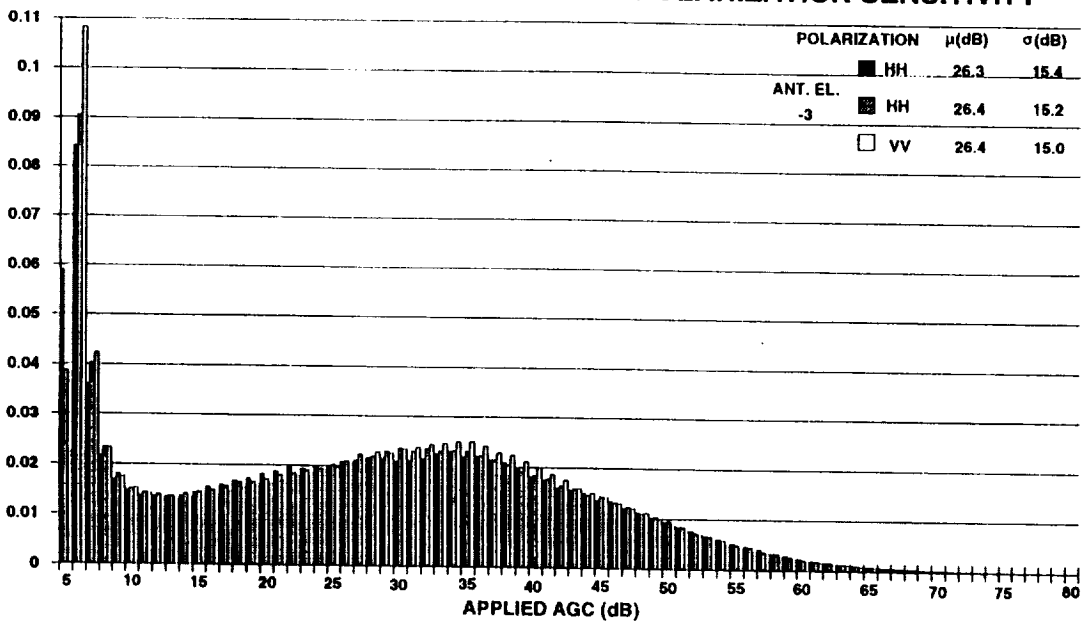
Proper Antenna Tilt Management
Allows The Radar Signal to be
Processed to give Velocity Information



Radar derived F-Factors Require
Good Estimates of the Wind Speeds

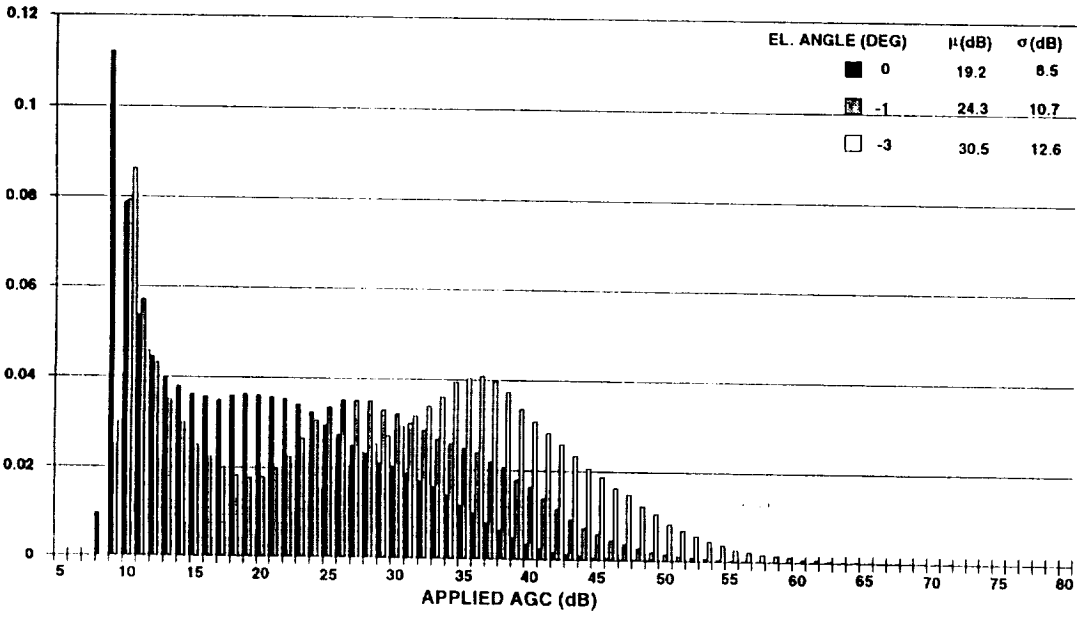
AGC HISTOGRAM (PHILADELPHIA - APPROACH 27)

MEASUREMENT REPEATABILITY & POLARIZATION SENSITIVITY



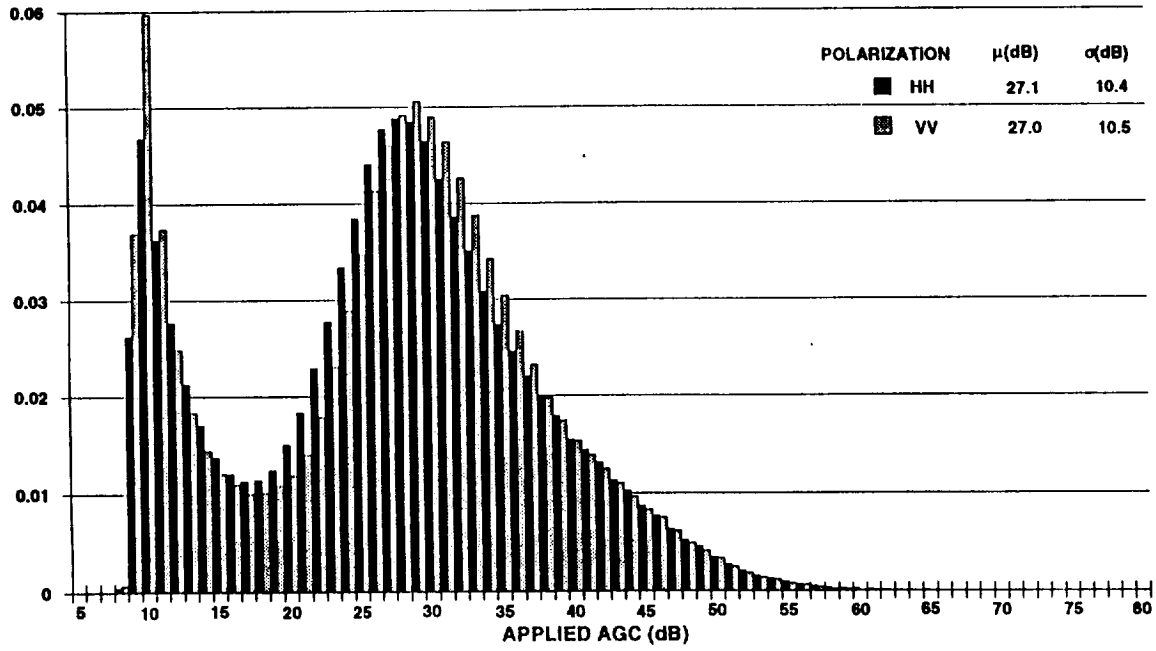
AGC HISTOGRAM (DENVER - APPROACH 26)

ANTENNA TILT MANAGEMENT : HH POLARIZATION

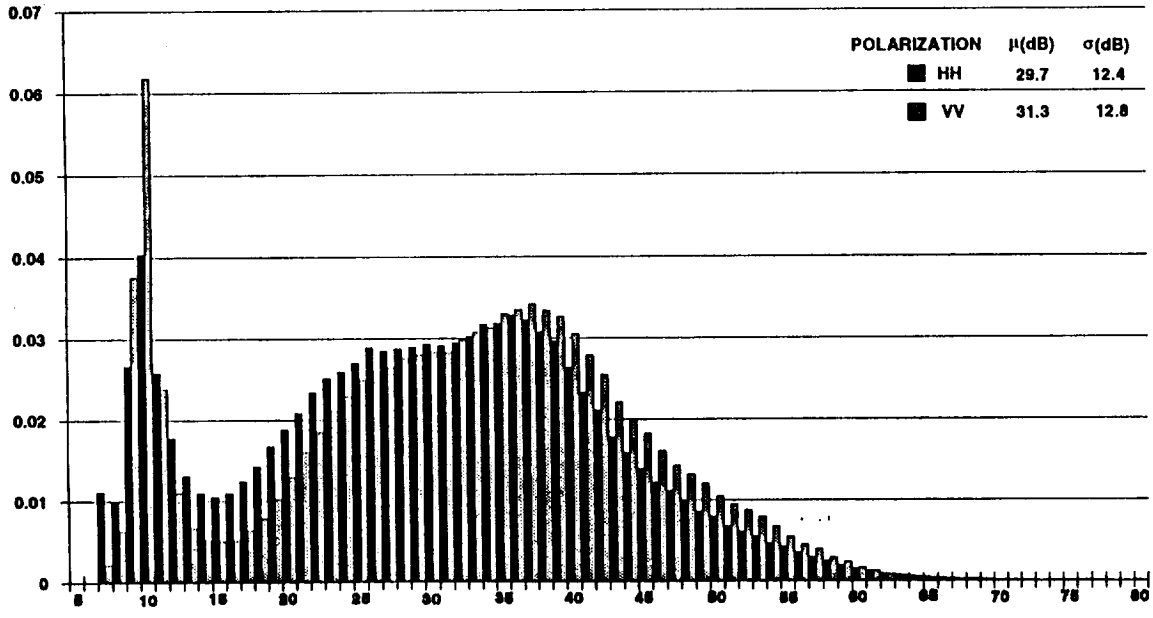


NASA WINDSHEAR RADAR
1991 FLIGHT EXPERIMENT

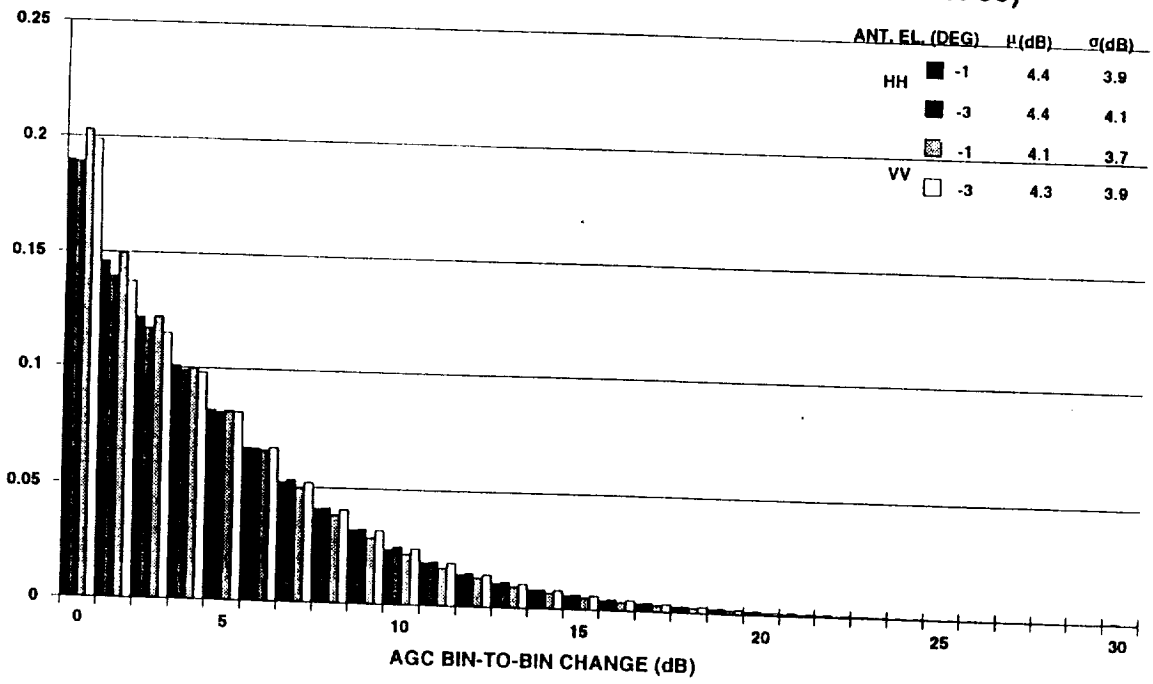
AGC HISTOGRAM (DENVER - APPROACH 35)
POLARIZATION SENSITIVITY : -1 ELEVATION



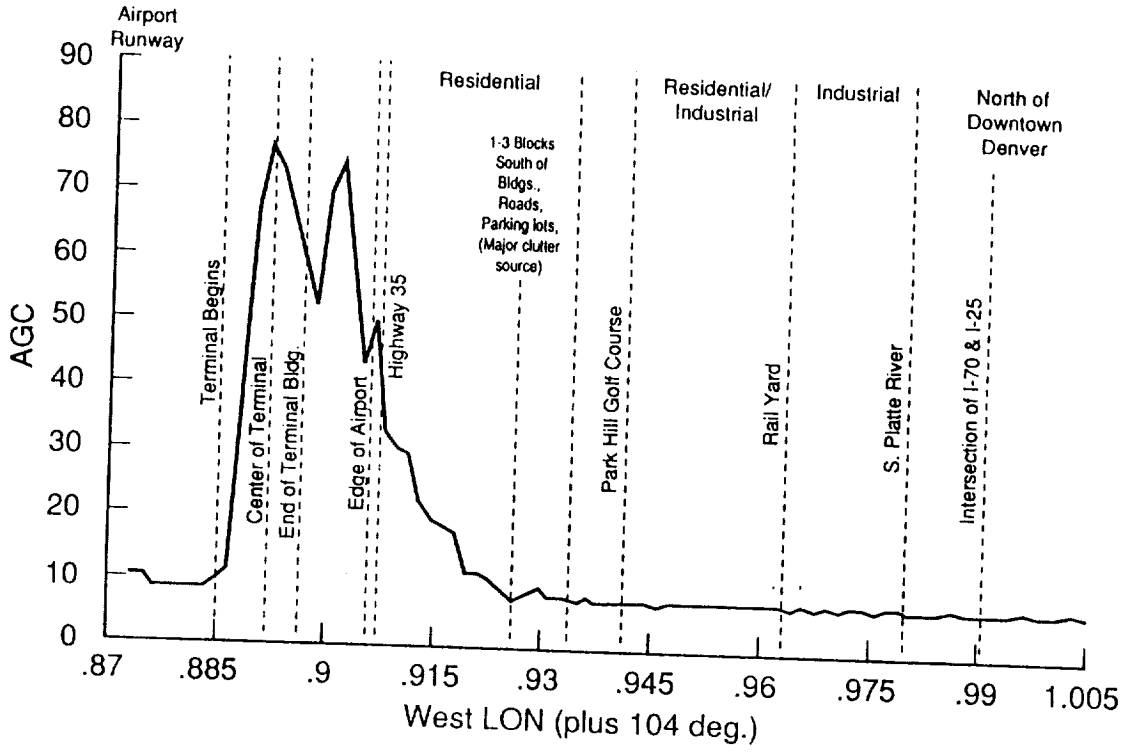
AGC HISTOGRAM (DENVER - APPROACH 35)
POLARIZATION SENSITIVITY : -3 ELEVATION



BIN-TO-BIN d(AGC) HISTOGRAM (DENVER - APPROACH 35)



STAPLETON TERMINAL



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Conclusions 1991 Flight Experiment

- NRCS Incidence Angle Effects

  Use Uncorrected NRCS from SAR Maps in Simulation
  Man-Made Clutter Insensitive to Incidence Angle

- NRCS Polarization Sensitivity

  Angular Dependency to Polarization Sensitivity
  6 dB or Less of Seperation HH - VV

- Comparison with SAR Derived NRCS Statistics

  Natural Targets Show Good Agreement with SAR
  SAR Maps Should Produce Realistic Clutter in Simulation
  Reasonable Fidelity (Dynamic & Spatial Variations)

- AGC Incidence Angle Dependency

  6 dB/1° Lower AGC Mean at Angles of Interest
  2 dB/1° Lower AGC Std. Dev. at Angles of Interest

- AGC Polarization Dependency

  1-3 dB Reduction Using VV (@ -1°)
  1-3 dB Reduction Using HH (@ -3°)

- Bin-To-Bin AGC Independent of Tilt & Polarization

- Implications for 1992 Flight Experiment

  Re-Investigate a Few Key Terrain Features
  Increase Database for Polarization Study
  Continue to Examine Moving Clutter

Ground Clutter Measurements Using the NASA Airborne Doppler Radar: Description of Clutter at the Denver and Philadelphia Airports

Questions and Answers

Q: Jim Evans (MIT) - What is the instability residue of the radar transmitter? What is the signal wave form which has been used to obtain data? What are the antenna side lobes, in elevation, with the radome on? How is the data below the receiver sensitivity represented in the clutter histograms?

A: Steve Harrah (NASA Langley) - After talking to Collins, we would prefer not to openly disclose the instability residue values. If you would like to talk to Collins they are more than willing to share that information with you. The wave form is basically a simple rectangular pulse. The antenna side lobes are basically a half of a dB below what they are with the radome off. Those levels are typically 30-35 dB down for the first side lobe. In my clutter analysis I made sure, through the equations that were implemented, that we only looked at ground clutter targets which fell within four degrees of the center of the beam. In that respect, I don't believe we saw anything that did not have a significant amount of AGC applied to them. By that, it tells me that they weren't down in the noise.

Q: Jim Evans (MIT) - Will clutter measurements be conducted with realistic profiles at ugly clutter locations?

A: Steve Harrah (NASA Langley) - We are planning on making some additional measurements this year as I stated in my conclusions and future work statement. We are going to try and look at the urban clutter in Denver. As you suggest further on down in your comments to use runway 8. We will try and work that into the schedule and as long as we can get ATC to agree with it. In addition to that, we are going to make a trip to Washington this year we think, and maybe some other uglier clutter sites.