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nasa pers. only

NASA Contractor Report 4305
DOT/FAA/DS-89/16

Synthetic Aperture Radar Imagery of Airports and Surrounding Areas

Denver Stapleton International Airport

Robert G. Onstott and Denise J. Gineris

CONTRACT NAS1-18465
JULY 1990

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Prepared for
Langley Research Center
under Contract NAS1-18465

NASA
National Aeronautics and
Space Administration
Office of Management
Scientific and Technical
Information Division

1990

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FOREWORD

This is the final report of Phase III for Contract NAS1-18465, Processed Synthetic Aperture Radar (SAR) Data, sponsored by National Aeronautics and Space Administration (NASA) Langley Research Center (LaRC). This report is the last in a three report series. The overall effort has, as its thrust, the statistical description of ground clutter at airports and in the surrounding areas. In Phase I of this activity, SAR data of airports which existed in the Environmental Research Institute of Michigan (ERIM) SAR data archive were examined for utility to this program. Eight digital scattering coefficient images at high resolution and coarse resolution were created. The coarse resolution images were provided to NASA LaRC for use in their Microburst/Clutter/ Radar Simulation programs, whereas, the high resolution images underwent a statistical clutter analysis at ERIM. In Phase II of this program, SAR data were collected on an opportunity basis at the Philadelphia Airport using a set of radar parameters which more closely matched those which are anticipated to be encountered by an aircraft on its approach to an airport. One digital scattering coefficient image, each at high resolution and coarse resolution, was created. During Phase III, a dedicated SAR mission was flown of the Denver Stapleton International Airport and surrounding area. A wide variety of geometries and scene contents were acquired. These data and study results are to be presented in this report.

The work reported here was performed by members of the Radar Science Laboratory, Advanced Concepts Division, Environmental Research Institute of Michigan, under the direction of Dr. S.R. Robinson. The principal investigator for this project was Dr. R.G. Onstott. The contract was monitored by E.M. Bracalente, NASA Langley Research Center, Hampton, Virginia.

The authors gratefully acknowledge the support of the Radar Science Laboratory Staff during this project, in particular, Mr. Christopher Wackerman, Mr. Steven Lerman, Ms. Rita Woods, Mrs. Janice Anquetil, Ms. Marsha Allen, Mr. James Schipp, Mr. Scott Gaboury, and Mr. Charles Harkness.

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I. INTRODUCTION

Low altitude microburst windshear represents a significant hazard to aircraft, particularly during take-off and landing; the intense down drafts and the resultant divergent outflow can have a significant effect on the lift characteristics of the endangered aircraft. When encountered at low altitude, the pilot has little time to react correctly to maintian safe flight. The Federal Aviation Administration (FAA), jointly with the National Aeronautics and Space Administration (NASA), has sponsored an investigation into the development of airborne sensors to detect microburst windshear. One sensor of interest is a microwave Doppler radar operating at X-band or higher frequencies. Critical to the analysis of the capability of such a sensor to perform this detection is the microwave backscatter description of both the microburst event and the clutter background, especially during the approach and departure from an airport.

NASA Langley Research Center (LaRC) has developed a Microburst/ Clutter/Radar simulation program to assess the performance of Doppler radars for this application and to test potential signal processing techniques. The simulation program models the output of an airborne Doppler radar as it views a low-level microburst along the approach to an airport. Inputs to this simulator include the airport ground clutter data base, a simulated microburst data base, the operating parameters of the proposed weather radar, and candidate signal processing software for use in detection. In the operation of the simulation program the received signal amplitude level for each range bin is calculated. Each range bin may include contributions from both the microburst and the ground clutter.

Many questions arose during this study. What is the general description of the airport clutter environment? How does this environment change from airport to airport? How complex does an airport scene have to become before it degrades detection? In general, the limits of detectability of microburst events must be established for an airborne Doppler radar to be an effective tool in the prevention of aircraft windshear catastrophes. The Environmental Research Institute of Michigan (ERIM) has provided NASA LaRC with calibrated high-resolution synthetic aperture radar (SAR) images of selected airport scenes from the ERIM SAR data archive for use in their Microburst/Clutter/Radar Simulator and to characterize the ground clutter at surrounding airports. In addition, statistical analyses of these airport environments have been performed by ERIM to describe the range of scattering conditions encountered. ERIM has also performed a clutter analysis of the Philadelphia Airport to extend the work done in Phase I in order to assist in establishing these limits. Clutter types, mean backscatter intensities, probability distributions, and areal extent of the clutter types in the image were determined. With the analysis of the characteristics of clutter in the scene, the effects of scene composition were studied.

The analysis of the eight images from ERIM's archives in Phase I of this three phase program has provided important information concerning clutter returns from airport scenes. Clutter backscatter responses for the same clutter type were found very similar. Differences in their means were attributable to differences in incidence angle. Probability density functions which describe the scattering of a particular clutter type were nearly identical from image to image. This is an important result because it indicates a high degree of stability in the returns which would be expected from clutter around an airport. A Doppler radar designed to detect microburst windshear at one particular airport may not have to compensate for different clutter scenes as the plane travels from airport to airport. Through the analysis of these eight images and the Philadelphia Airport image we gained information about the types and characteristics of radar clutter surrounding airports. However, further analysis of strongly backscattering clutter regions was needed. The data analyzed in Phase I and Phase II indicated that although only a fraction of the clutter surrounding the airport is of an intensity to be of concern, almost all of it is located on the airport grounds. It was concluded that detailed analysis of the clutter from specific types of buildings, planes, and other airport vehicles should be performed, and that the motion of vehicles and planes should be examined.

As anticipated, the data in the SAR archive and that of the Philadelphia Airport, by itself, did not have the breadth to fully describe the range of airport clutter scenes possible. This was, of course, the impetus behind Phase III, in which a dedicated SAR data collection was conducted. The SAR archive allowed us to begin to survey the clutter environment at a few selected airports. This information was enriched in Phase II by gathering data at smaller depression angles. In Phase III, small depression angle data were collected at an airport which has a history of frequent windshear hazards. This report presents the results of this dedicated collection.

The Denver Stapleton International Airport was chosen by NASA LaRC as the focus of the dedicated data collection. This airport has had a history of windshear events, many of which have been documented by the National Oceanographic and Atmospheric Administration (NOAA). Additionally, it is located near the center of Denver, a large metropolitan area, and experiences heavy air traffic. As a clutter scene it is therefore representative of other airports which serve large urban areas. Finally, the airport is located near the Rocky Mountains, which allows the examination of ambiguity effects of mountain clutter which have the potential to mask microburst targets. For these reasons this site selection represents a good case study for use in the NASA simulation program. It must be determined if highly urbanized areas such as this represent a critical radar clutter environment which can effect the ability of incoming aircraft to detect microburst events.

The NASA Denver collection consisted of one mission flown on 16 November 1988. Twenty seven data passes were made with the purpose of collecting SAR data which would represent the radar clutter field which an airplane would experience when landing at this airport. In simulating this flight geometry, a series of low altitude passes were utilized to image the ground scene at very large incidence angles. This configuration is illustrated in Figures 1a through 1d.

Numerous flight lines were developed so that the airport was imaged with portions of the city of Denver either positioned in the background or the foreground of the image. This coverage was achieved with flight lines which formed boxes which focused on the center of the airport, and with a series of north-south flight lines which were incrementally displaced to the west. These flight lines provide data in which aspect and incidence angle variation may be studied for the various clutter scenes of which the airport and the city are composed. As an example, in the 'step west' collection of data the airport is in both the near and far range, hence include variation in incidence angle ranging from 85° to 50°. The location of these flight lines and pass identification are provided in Table 1 and ground area coverage in Figure 2.

II. DATA COLLECTION

The radar used during this data collection operates at frequencies of 1.25, 5.26, and 9.375 GHz. It is fully polarimetric, able to record 4 complex images, operates in the strip map mode, and is capable of producing 1.6 meter range by 2.2 meter azimuth resolution images. Four channels of high density data tapes are available, each capable of recording 4096 range elements. The operator is able to select wavelength, transmit polarization, receive polarization, fine or coarse (1.6 to 3.2 m), range resolution and slant range for each channel. It is possible to operate in a wide swath mode such that a 32 km strip map is made at one wavelength and one polarization or the four channels can be used to record the scattering matrix of a scene at one frequency and fine resolution over a 6 km range interval. The goal of the data collection plan was to provide SAR data which is collected to closely match an aircraft on its landing approach. The preferred SAR configuration is detailed in Table 2. The various radar parameters and geometries are addressed individually below and recommendations are made. These recommendations are shown in Table 3 and figures illustrating imaging geometries are provided in Figure 3 and 4. A more detailed description of the SAR may be found in Appendix B of the second report.

Frequency

The P-3 SAR operates at 1.25, 5.25, and 9.38 GHz. The frequency of 9.38 GHz (X-band) was selected because it corresponds with existing X-band weather radars which have proven useful in detecting weather related features.

Polarization

The P-3 SAR facility is fully polarimetric. This means that up to four complex images at VV, VH, HV, and HH polarizations may be recorded at the selected frequency of operation. With the recording of these four complex images additional images at arbitrary transmit and receive polarizations may be synthesized (i.e., circular polarization). Recording the four complex images also allows for the complete description of the scattering properties of the various elements within the clutter scene. Such information is critical to the understanding of the scattering mechanisms at play, and potentially to the determination as to whether troublesome scattering scenes may be suppressed. During the proposed data collections, priority was to be given to recording four complex 12 km x 12 km images (VV, VH, HV, and HH) since these may be produced in one pass when using coarse resolution.

Depression Angle

An aircraft during its final approach is typically flying on a 3° glide slope. During the SAR data collection, it would have been considered to be optimum if images were centered about a 3° depression angle.

Resolution

For any swath modes recorded, the P-3 SAR can operate either in high resolution, with an azimuth resolution of 2.8 m, and a range resolution of 1.6 m, or in low resolution, with an azimuth resolution of 2.8 m and a range resolution of 3.0 m. Using low resolution, the range coverage of each channel is 9830 m, and using high resolution, the range coverage of each channel is 4915 m. Since the goal here was to produce about a 13 km x 13 km image about the airport, coarse resolution was chosen so that four complex 12 km x 12 km images (VV, VH, HV, and HH) may be produced in one pass. Operation in this mode was recommended since the final images would be digitally processed to a resolution of 20 m.

Image Size

An image about 13 km x 13 km with the airport touch down point near the center of the image was considered optimum by NASA LaRC personnel. The system can operate in three different swath modes. The configuration of these swath modes are illustrated in Figure 5. In single-swath mode (Figure 5a), the radar collects the same range coverage in each channel using four different frequency and polarization combinations. In double-swath mode (Figure 5b), twice the range coverage of single-swath mode is recorded but only two frequency and polarization combinations can be used. In quad-swath mode (Figure 5c), four times the range coverage of single swath mode is recorded but only one frequency and polarization combination can be used. In double- and quad-swath mode there is no range overlap between channels that are contiguous in range. Images of 12 km x 12 km may be formed in 1 pass using the double swath-mode and were recommended.

Airport/SAR Orientation

To simulate the needed image geometry, the SAR had to be oriented such that the path of the aircraft was perpendicular to the main runways of the airport. If additional passes were possible then alignment with secondary runways was proposed to provide complementary views of the airport from which aspect angle dependence would be studied and the composition (i.e., grass, forest, urban, etc.) of the airport scene may be supplemented.

Airport Selection

Denver Stapleton International Airport was selected by NASA to be the airport of choice. There is a dense urban area surrounding the airport and the airport has experienced a large number of windshear events in the past.

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III. IMAGE DESCRIPTION

In this Phase III effort eight images were selected for analysis. Four were from the set of passes which stepped incrementally west across the Denver area, with the images made looking west. The remaining four images were from a fully polarimetric set of data in which the airport was imaged from the south. These images are presented in Figures 6 through 13.

Figures 6 through 9 represent a fully polarimetric set of data. The airport subtends incidence angles from 77° to 82°. The image subtends incidence angles from 43° to 82° and ground range from 1593 m to 12047 m. The orientation of these images differs from that of the four westward stepping images. Where the 'step' images are west looking, this set is north looking. The image covers an area which extends from just south of Lowry Air Force Base (AFB) to almost north of the Denver airport and from the east of the warehouse district to the east of the airport to just west of Lowry AFB. This particular image coverage has provided a scene of complex composition. Starting from the south, which is in the image near range, is the Lowry AFB which is flanked on either side by residential areas. The residential area just to the east of the base is part of the city of Aurora, and is centered on the Aurora Municipal Golf Course. The streets in this area are generally curvilinear, a characteristic of suburban developments. To the east of this residential area is a more rural section of Aurora and part of the Buckley Air National Guard Base. North of Lowry, and extending in a band which crosses half the image is an urban community. This community is centered on Colfax Avenue, a main thru-way through Denver, and extends up to the airport on the north side and down to Lowry AFB on the south side. This community is made up of blocks of smaller, closely spaced ranch style homes. Most homes in this area are made of brick. To the east of this community is a mixed usage area. Interstate 225 runs down the center of this area, which includes the Fitzsimmons Army Medical Center, the Fitzsimmons Golf Course, several shopping areas (including a large mall), small businesses, and a small residential area. Going further north, is the Denver airport. All terminals, associated buildings, and parking lots west of the runways are distinguishable. East of the airport are additional airport buildings and an area composed of large warehouses. Interstate 70 separates the airport buildings from the warehouse district, goes under the north/south runways, and cuts through part of the city just west of the airport. The city area just to the west of the airport is a conglomeration of office buildings, hotels, and other related facilities. In the most northerly parts of the image is the highly industrialized suburb of Denver called Commerce City, airport runways, warehouses, a residential area, and a rural area. The Commerce City area is separated from the business park by Interstate 270.

An interesting phenomenon occurs in the northern residential area east of the warehouse district. In this area, we can observe the effects of changing aspect angle. As this is a suburban area, the streets are generally curvilinear. Most houses are built so that the front (the longest side) of the house is parallel to the street on which it is located. At such high incidence angles (the residential area subtends incidence angles from 80° to 83°) the house fronts act as planar reflectors and when oriented perpendicular to the look direction of the radar they act as specular scatterers and produce large returns. As the orientation of the houses change, more energy is reflected away from the radar and a lower backscatter return.

Figures 10 through 13 represent radiometrically corrected versions of the four westward stepping images collected at HH polarization. In this image set, the airport first appears in far range, Figure 10, with west Denver and Aurora, appearing in near range. North is to the right of the image. Much of the area to the east of the airport appears to be a combination of fallow farmland and scrub. Two residential developments are present in the extreme near range of the image. As one proceeds westward, the Rocky Mountain Arsenal occupies the northern portion of the image. A military complex on the arsenal shows up as a collection of bright returns partially surrounded by three lakes. A few individual trees can be identified in this area. The Arsenal's boundary runs along the airport grounds. South of the Arsenal are, a residential area, a warehouse district, Interstate 70, a mixed area which includes the Fitzsimmons Army Medical Center, and another residential area. West of this lies the airport; the terminals of the airport and several airport buildings are very distinct. A warehouse district lies directly east of the airport. South of the airport is a small urban/residential area and Lowry AFB. Westward beyond the airport in the extreme far range of the image lies the city of Denver. At these incidence angles (83° to 85°), very little can be seen except for those bright returns from buildings. The airport is approximately located at an incidence angle of 82° in the image. The image subtends incidence angle from nadir to 85° and a ground range of 19586 m.

Figure 11 represents the second westward step in the series of west stepping images. The Denver airport and Lowry AFB are close to the center of this image; more of the Denver area west of the airport is revealed. Several warehouses can be distinguished directly east of the airport. A prominent feature in the far range north of the image is a large dark 'X'. This 'X' is the intersection of Interstate 270 and Highway 265. The area slightly southeast of this feature is Commerce City. It extends from the highway intersection to the airport boundary. The dark rectangle just south of the intersection is the Park Hill Golf Course. Downtown Denver begins to appear as the brightest area in far range directly west of the airport. An urban pocket west of Lowry AFB is also apparent. Bright returns are visible even at the farthest ranges. The airport is located at an incidence angle of approximately 77° and downtown Denver appears to be at 84°. The image subtends incidence angles from prenadir to 85° and a ground range of 19585 m.

Figure 12 represents the third westward step in this image set. Here the airport is located in near range at an incidence angle of 63°. Features at the airport and Lowry AFB are very distinct. Individual buildings at both sites can be distinguished as well as different surface conditions at each of the airports. Most noticeable is a striped feature at the north end of the airport. Several different surface conditions are characterized by areas of brighter and darker returns. Airplanes around the terminal and around a cargo hangar just west of the airport runways can be distinguished. Commerce City is completely recognizable. Much more of the urban area between the airport and downtown is illuminated. Bright returns from the west side of Denver begin to appear in far range. Several of the rectangular areas of low return located in the mid-range of the airport are parks. Individual trees and fairway areas are recognizable at the Park Hill Golf Course. The square area almost directly in the center of the image (at an incidence angle of 80°) is the Denver City Park. Downtown Denver is located directly west of this park at an angle of 82°. This image subtends angles from nadir to 85° and has a ground range of 19586 m.

Figure 13 is the last of this image set. In this case the airport is almost completely out of the image. The only remaining airport features which are discernable are the cargo hangars west of the north-south runways. The airport was imaged at approximately 24°. Traveling westward through the image we first pass through Commerce City and then through the residential areas to the north and south of Commerce City. Beyond this, the intersection of Interstate 270 and Highway 265 lies to the north, while urban communities, Park Hill Golf Course, and City Park lie to the south. Further west, the Commerce City area becomes more residential. The area directly north of downtown appears to be a stockyard and railroad junction. In the downtown area, individual buildings and their shadows are visible. The downtown area is located at approximately a 79° incidence angle. Beyond the downtown area, all that is visible in the far range of the image are a few bright returns. This image subtends incidence angle of nadir to 85° and has a ground range of 19583 m.

IV. PROCESSING AND CALIBRATION

Processing and calibration of the image proceeded in much the same manner as the images processed from the SAR archive, the object of the work done during Phase I. Refer to the first report of this series and to Appendix B of the second report for a description of this calibration procedure. The procedure deviated slightly due to recent modifications in the processor which enabled us to produce an image with the full ground coverage desired, instead of an image produced from the mosaicking of multiple images. The resultant phase history tape used for the Denver images represents a 8192 element by 4096 element file. With a pixel spacing of 3.24 m in azimuth and 2.4 m to 4.8 m in range, the Denver images are produced from a reflectivity map of a 13,271 m by 9830 m or 13,271 m by 19660 m area.

As with the archival images, the phase histories of the Denver images were focused in azimuth and range. This was achieved by convolving the data with a match filter of the transmitted radar chirp in azimuth and range. The data were processed to remove the effects of system noise and were then radiometrically corrected to compensate for the effects of range fall-off, the antenna gain pattern, and resolution cell power. The radiometrically corrected image was then converted to normalized radar scattering coefficients (NRCS) by normalizing the magnitude of the radar cross section by the resolution area. The terms scattering coefficients and NRCS will be used interchangeably.

The absolute calibration of the Denver images were performed based on data obtained from a calibration array positioned at the Denver and Lowry AFB airports. This array is described in Appendix A. For a radar operating in its linear region, a linear relationship will exist between the measured intensity of a point target in an image and the expected value of the backscattering cross-section of the target. The slope of the function is unity and the y-intercept of the function is a measure of the system gain function. The system gain function determined from the calibration data was then applied to the Denver data.

Once calibrated, an image was downsampled to a resolution of 19.44 m in azimuth and 19.2 m in slant range. The data were then weighted with a cosine function and converted to the ground range by upsampling. The purpose of the cosine weighting was to compensate for a "ringing" effect which arises due to the upsampling process. The image was then oriented to the desired configuration and then written to tape along with a vector file containing incidence angle information.

V. CLUTTER ANALYSIS PROCEDURES

In establishing the criteria for which microburst events can be detected, a careful characterization of airport clutter is required. The questions that arose immediately were: what are the types of clutter which commonly occur at an airport, how does the clutter environment change with incidence angle and polarization, and what is the density and location of strong returns at an airport? A clutter analysis of a subject of the Denver data has been performed to address these questions. This analysis was performed on 4096 element x 4096 element, slant range images of radar scattering coefficients σ^{o} with the finest resolution possible to allow precise sampling of both distributed and point targets. These images have one independent sample per resolution cell.

The first step in our analysis was to characterize the area surrounding the Denver Stapleton International Airport. The area surrounding the airport is a mixture of industrial, suburban, and urban communities. Two analyses were performed to quantify the amount and characteristic clutter return of each type of community in the image. The first analysis performed was the differentiation of the image into its various constituent communities. The results of this areal analysis were tabulated and the percentage of each community within the image calculated. The second analysis performed was a threshold analysis in which the images thresholded into 5 dB intervals to enable us to locate and quantify sources which produced similar absolute backscatter levels.

Using statistical techniques, we also performed an analysis of each major clutter group in the image as well as a few unique clutter areas. Regions of critical clutter types were located and extracted. The mean, standard deviation, and coefficient of variation for each of these subregions were then calculated using techniques described in Appendix C of the second report. Coefficients of variation were determined to examine the uniformity of these subregions. Most distributed targets have a low coefficient of variation. The few pixels of very high returns are often times embedded in a background of low returns. The coefficient of variation also provides textural information about distributed targets. For example, a field of grass (a very uniform distributed target) is expected to have a lower coefficient of variation than a forest because forest returns may arise from dissimilar scatters such as trunks, crowns and the soil surface. During Phase I, probability density functions were determined indicating that most clutter types were well described using a gamma density function. These calculations were not further duplicated in Phase III.

Regions of similar clutter properties were then employed in general clutter characterization and in the examination of their response with incidence angle. Areas of similar clutter type and incidence angle were merged. Five degree incidence angle bins were used in the range of 60 degrees and beyond, since backscatter returns from distributed targets generally changes rapidly in this region. Ten degree incidence angle bins were used in the range from 30 to 60 degrees, where backscatter values are relatively constant. Histograms, means, standard deviations, and coefficients of variation were calculated. The general shape and tail characteristics of the histograms were also examined. The tails of a histogram represent that portion of the plot where the histogram decays into values of zero percent occurance. The leading tail of the histogram represents the front, or large NRCS value area, of the plot while the trailing tail represents the rear, or small NRCS value area, of the plot. It should be noted that in order to compare the expected scattering cross-sections from point and man-made targets to normalized radar cross-sections the area extent of the target must be taken into account.

Incidence angle effects in the data were examined by plotting the mean return of each clutter sub-region as a function of the mean incidence angle and are important in the analysis of both distributed and man-made targets.

When the clutter analyses were performed for each of the eight Denver images, an inter-image analysis was performed to examine the dependence of the backscatter response on incidence angle, aspect angle, and antenna transmit-receive polarization.

VI. CLUTTER ANALYSIS RESULTS

The Denver Polarimetric Set

The first set of images, whose results will be discussed, is a set of four linearly polarized complex images which were collected during Pass 37. The image composition areal analysis of this scene is provided in Table 4. The airport grounds occupy a significant portion of this image, about 15%. About 42% of the image is composed of man-made targets and another 40% by cultural/distributed targets (i.e., residential and urban areas). Only 9% of the image consists of low backscatter producing distributed targets such as rural grasslands. The strong point and distributed man-made scatterers are concentrated in the area immediately surrounding the airport and are attributed to the warehouses which lie to the east of the airport and the industrial business parks located to the west. Mean scattering coefficients, minimums, maximums, and standard deviations have been determined as a function of polarization for each of the major clutter groups and are presented in Tables 5 to 8 and Figures 14 to 17. In general, the backscatter of grass, water, and runways is significantly weaker than for any other clutter scene with values at or below -25 dB. For like polarization the residential, urban, and parking lot clutter normalized radar scattering cross-section cluster between -17 dB to -4 dB. The point-like, man-made targets have mean values greater than about -5 dB at like polarization. In the cross-pol image, mean NRCS values for all clutter groups other than natural distributed targets cluster between -35 dB and -17 dB, about 15 dB weaker than that at like polarizations. The location and detailed statistics for each of the individual clutter areas are given in Appendix B.

The difference between the NRCS distributions at like- and cross-polarization is a function of the polarization properties of the clutter scenes. Dielectric distributed targets such as water, grassy fields, and runways produce weak cross-polarized backscatter since their backscatter is dominated by surface scatter. Energy which falls on such targets which have randomly oriented scattering elements may produce strong returns at both like- and cross-polarization. Forest areas with well developed canopies represent such a scene. Targets which are dominated by dihedral-like features, or facets, such as urban areas, warehouses, and industrial facilities, are seen to not depolarize or repolarize the incident wave and return the scatter field with the polarization of the incident wave. These trends are observed in these data with cross-polarized returns for these targets are weak while like-polarized returns are high.

The tripartite nature of the NRCS values of like-polarization (distributed terrain, distributed cultural scenes, and point and distributed man-made targets) differ from the bimodal trends observed in previous data. In the Philadelphia and archival data, discussed in Reports 1 and 2 (Onstott et al., February & March 1990) the distributed terrain produced NRCS with values of less than -20 dB, while the hard target clutter groups had values of -8 dB and above. The Denver data discussed in this report may differ because of the nature of the residential and urban clutter groups. A significant difference between the Denver area data and the data from the other sites is the lack of trees. Residential and urban areas in the previous images had high tree densities, and produced backscatter statistics very similar to those of forest. Without the contributions due to trees, Denver residential and urban clutter statistics are more similar to industrial and city clutter than to grass and forest clutter. The mean, minimum, and maximum NRCS and coefficient of variation for each of the four images in the polarimetric set are:

	Mean (dB)	Minimum (dB)	Maximum (dB)	Coefficient of Variation
X-HH	-6.47	-44.08	36.50	32.64
X-VV	-11.21	-43.57	35.53	37.78
X-VH	-28.69	-47.09	13.88	17.84
X-HV	-27.55	-45.26	15.54	18.76

The mean of the X-HH Denver image is significantly higher than that of the Philadelphia image, about 8 dB. This is attributed to the difference in the composition of the images. The Philadelphia Airport image included natural terrain and the contribution of trees worked to reduce the NRCS for residential and urban areas, hence, one would anticipate its mean to be lower.

With the clutter returns separating into three major categories the data were thresholded to further determine the location and percentage of specific types of clutter. This analysis was performed on the contracted 293 element x 293 element images for efficiency. In the contraction process averaging is performed and the return distributions adjust accordingly. The minimum and maximum return values move closer to the mean and the NRCS distribution narrows somewhat but otherwise shows the same trends as those obtained from the high resolution images. The bar charts of the mean and standard deviation for a number of clutter types are provided in Figures 14 through 17 and show that, in general, the different clutter types at each of the different polarization clustered in a similar fashion but with different means. For this reason only one set of thresholded images, for HH-polarization will be presented. In the histogram of NRCS values shown in Figure 18 we see that approximately 7% of the image has values of -30 dB or less. Figures 19 through 23 illustrate the thresholded images. These low return areas are located mostly at the airport in the form of runways and in the small lakes that dot the image. Some of the grassy areas, especially at far range, also produce very weak returns. Approximately twenty-five per cent of the image has values between -20 dB and -30 dB and consist mostly of grassy areas and other distributed terrain targets. Forty-two per cent of the image has NRCS values between -10 dB and -20 dB, and are indicative of the urban nature of the scene. These sources of moderate returns are primarily due to the urban areas between the airport and Lowry AFB. Eighteen per cent of the image has NRCS values between -10 dB and 0 dB. These areas are located primarily in the warehouse and industrial complex on either side of the airport and in the residential area south of the airport. Approximately 4% of the image has values between 0 dB and 10 dB. These areas are located almost exclusively in the warehouse, airport, city areas in the far range, as well as along the major thoroughfares in the city. Approximately 1% of the image has values greater than 10 dB. These areas are located to the east and west of the airport. They consist of industrial complexes, warehouses, and airport buildings.

Since these four images were acquired simultaneously, a critical attribute of a polarimetric radar, the histograms provide the ideal means to study the effect of polarization diversity. The study of the linear polarization properties has been performed and included in this report. A more extensive study which would include determining the optimum polarization for clutter suppression and simulation of various circular and elliptical polarization has been reserved and proposed as a future effort.

Because of the large quantity of data and similarity between VV and HH clutter statistics, we will examine the trends of the incidence angle plots and histograms for the HH-polarized images. These will then compare with the results for the other polarizations when differences occur. The results of the statistical analysis at the three polarizations are presented in Appendix B. Histograms which were calculated for similar clutter categories as well as for the entire image are presented in Figures 24 through 43. In Figure 24, the histogram of the NRCS for the entire image is presented. The scattering cross-sections do not vary as rapidly as in the Philadelphia image. This is illustrated by a coefficient of variation which is smaller in the case of the Denver polarimetric images than the Philadelphia image by a factor of two. This would indicate that the Denver area does not have as diverse a collection of clutter groups as that of the Philadelphia areas.

Figures 25 through 30 present histograms of scattering coefficients for residential clutter at HH-polarization for selected incidence angle ranges. Over the range from 50° to 74° the shape changes little and there is a couple dB changes about the overall mean response. The histogram for residential clutter in the incidence angle range of 75° to

79°, Figure 29, has a very unusual shape. The residential clutter area which contributed to this histogram is located directly east of the airport in a subdivision with curvilinear street patterns. The apparent aspect angle dependence of its backscatter is evident in the distant shape of histogram. At the largest angles of 80° to 84°, Figure 30, many of the residential clutter returns are at the system noise level and are not shown in the histograms. This is seen in a reduction of the magnitude of the histogram shown. However, the strong returns, as illustrated by those shown in Figure 30, dominate the backscatter of the region as illustrated by a mean NRCS of about -15 dB. In further comparing the histogram at 80° to 84° with that at 70° to 74°, the leading tail experienced about a 3 dB reduction in the NRCS at the 0% of occurrence point. This suggests that there is a possible population of scatter that is relatively insensitive to elevation angle. However, the reduction by a factor of about 6 in the percent occurrence suggests that these scatterers are relatively sparse.

The urban clutter is presented in Figures 31 through 34. In all incidence angle regions, the urban clutter appears to have a distribution very similar to that of the residential clutter but with about a 4 dB higher cross-section level. Interestingly, the histogram for the 75° to 79° incidence angle range is broader than in the other cases and the maximum cross-sections are 7 dB higher with only a small reduction in the percentage of occurrence. In summary, the density of man-made targets in urban areas is usually higher than that of residential areas. For example, the houses are closer together and the areal extent of distributed natural targets such as trees and grasslands is less.

The histograms for city and industrial clutter are presented in Figures 35 through 38. These clutter groups are treated together since they represent collections of man-made targets with little contribution of other types of clutter. All three clutter histograms share the same general shape, a rapidly decaying trailing tail and a slowly decaying leading tail. This shape was also seen in some of the man-made target histograms obtained from the Philadelphia image. The mean of the city clutter is several dB higher than that of the industrial areas, but are up to 17 dB greater than residential and urban clutter. The characterization of the angular response trends of city and industrial clutter is at best, limited.

The grass clutter is presented in Figures 39 through 41. Because of the orientation of the image we were limited to the examination of the grassy areas at the nearest and farthest incidence angle ranges. The grassy areas in the Denver images produced approximately the same NRCS as those obtained from the Philadelphia image. In addition, they also show the characteristics at high incidence angles of essentially all returns at or below the system noise level except for a very small population of moderate returns well separated from the noise values.

Histograms of water and runway clutter at about 77° in this are presented in Figures 42 and 43. Returns for both areas were largely at or below the system receiver with an additional distribution noise of weak returns, about 15 dB above this level (about -30 dB). About 87% of the runway clutter and 94% of the water clutter are at or below the system noise level. Mean NRCS for these clutter types were about -39 and -37 dB, respectively.

Figures 44 through 48 present plots of mean scattering coefficient versus mean incidence angle for each of the distributed clutter groups examined in this image. The residential was the only clutter group with a diverse range of incidence angles. These data exhibit trends similar to those seen in the Philadelphia data. The angular response remains flat from 50° to 75° and then drops off sharply. Grass clutter returns also decrease at large incidence angles as anticipated.

Man-made targets in the vicinity of the airport and elsewhere were examined and their RCS are presented in Table 9. The hard targets examined were all large in size and, like those large targets in the Philadelphia image, have RCS of 35 dB to 50 dB. It is important to note that the airline terminals are the source of the largest RCS in the 13 km region about the airport. The distributions of NRCS for these targets are presented in Figures 49 through 54. The non-vehicular man-made targets, with the exception of the building clutter in Figure 51, have distributions which are generally the same. This is attributed to the similar nature of the geometrical structures of these targets. The parking lot has a distribution which is broad and has a large variance. Automobiles oriented at a variety of aspect angles would produce a wide distribution.

Full image histograms at VV, VH, and HV polarizations are presented in Figures 55 through 57 for comparison to the image histogram at HH-polarization in Figure 24. In general, HH-polarized returns appear to be larger than those at VV, (about 5 dB) which are in-turn larger (about 17 dB) than VH and HV returns. The histograms of the single swath images are larger in size than those of the double swath images because the single swath images, by virtue of their smaller incidence angle range, have far fewer pixels at or below the system noise value. They also show a slight skew to the right, a long leading tail and have almost identical coefficients of variation. The clutter for the cross-polarization images produced smaller coefficients of variation. The histograms and statistics at VH and HV are virtually identical, as is expected based on reciprocity.

In comparing the shapes of the distributions for different clutter groups of each polarization we will examine one incidence angle group from each clutter group. Additional histograms are presented in Appendix C. In comparing the histograms of urban clutter in the 60° to 64° incidence angle range, (see Figure 58), we see that the urban clutter at HH-polarization is narrower than that at VV, VH, or HV. Interestingly, the VV and HH distributions are almost symmetric. The VH and HV distributions show the skew typical of homogenous clutter scenes. These trends exist at all incidence angles. In general, the VH and HV returns are at least 10 dB less than the VV and HH returns. RCS at HH and VV are well separated (about 12 dB), the largest separation of any of the clutter scenes and with HH returns larger than those at VV. Returns at VV appear to be suppressed. For residential clutter, the trends in histogram shape, (see Figure 59), are similar to those of urban clutter, except VH and VV are separated by only 3 dB. In the 75° to 79° incidence angle region, (see Figure 60), the distribution of returns are multimodal data. Returns at or below the receiver noise floor comprise a large number of the returns but are not shown in these figures. The industrial clutter, (see Figure 61), is similar to the urban clutter in that separation between HH and VV is 6 dB which is twice that for residential clutter but half that of urban clutter. This suggests that VV returns are also suppressed, as was also true for urban clutter. For the grass clutter, (see Figure 62), the histograms at the four polarizations are very similar in shape. NRCS at HH are higher than at VV by about 4 dB and HV by 12 dB. This is a reversal in the expected polarization response and requires further consideration. Like the industrial returns, the city clutter distributions share the same histogram shape, but the VH and HV polarizations have a much lower mean, (about 30 dB). Since the city is composed of shapes which may produce many single and double-bounce type reflectors oriented vertically and horizontally to the radar, the returns at like-polarization RCS would be expected to be high and low at cross-polarization. NRCS for the water and runway areas in all four images are very low at and/or below the SAR system noise level.

In general, a man-made target is large compared to the radar wavelength in the dimensions perpendicular to the radar, we would expect the HH and VV returns to be similar, and the cross-pol NRCS to be smaller by 15 dB or more. Since HH NRCS are larger than those of VV for urban, industrial, and city clutter, and the difference between like and cross-polarizations are large, this argues that there may be an enhancement at HH polarization due to sensing horizontal features such as edges formed at roof lines etc. Brewster angle effects are not expected to contribute here. Complex targets composed of trihedrals, vertical corner dihedrals, and horizontal corner dihedrals do not cause significant repolarization, so very low cross-polarization returns are produced. This effect can be observed in the terminal and parking lot histograms shown in Figures 63 and 64 and in Tables 9 through 12. In the histograms, we see that the distributions at co-polarization and cross-polarization are dissimilar, and the NRCS at cross-polarization are 20 to 27 dB lower than at like-polarization.

In comparing the incidence angle plots of scattering coefficients at the different polarizations we can see the differences in the mean values as well as differences in the response trend at each of the four polarizations.

The angle and polarization response for grass clutter is presented in Figure 65. All four polarizations suggest the trend in which NRCS decreases with increasing incidence angle as has been measured using scatterometers. There is also a very steep but small rise in NRCS at about 82°. The slope of NRCS angle response for VV polarization appears to be the shallowest of the four. The exact cause of these two responses had not been determined at the time of the writing of this report but are under consideration. In general, the cross-polarization responses are approximately 11 dB below those at like-polarization. For residential clutter, (see Figure 66), the two like-pol and cross-pol responses produce different trends. The angular response at cross-pol decreases slightly at high incidence angles, flattens in the 55° to 75° range, and decreases again at the largest incidence angles. The two like-pol trends are somewhat similar through 75° but then diverge. The HH-pol response drops from about -10 dB to -26 dB as angles approach 82° while the VV-pol response remains between -12 dB and -20 dB. At both polarizations the residential clutter at large angles varies widely which is attributed to aspect angle sensitivity. Urban clutter, (see Figure 67), is somewhat similar to the residential clutter in that each polarization produces trends which differ, i.e., the like-pol responses differ and the like and cross-pol responses differ. The NRCS VV-pol are tightly clustered and increase at 80° angle where as the NRCS at HH-pol are less tightly clustered and increase at 80°. The cross-pol responses is tightly clustered about a trend which is relatively flat to about 76° and decreases slightly as the angle is increased to 80°. For the city and industrial clutter, (see Figures 68 and 69), the data is limited to angles between 78° and 80° so their angular response trends may not be defined. For the city returns, the NRCS cluster at different values for each polarization; 4 dB for HH-pol, -1 dB for VV-pol, -24 dB for VH-pol and -23 dB for HV-pol. The industrial clutter repeats this type of clustering although the HH-pol data is more spread. In general, the NRCS for HH and VV polarizations trend in similar ways with respect to incidence angle and the HH-pol values are about 4 dB higher than at VV-pol. The VH-pol and HV-pol values are virtually identical but the HV-pol returns are consistently higher than the VH-pol returns by about 1 dB. The difference in the cross-pol returns is probably due to radar effects which cannot be removed from the data without full polarimetric calibration. The RCS of the 60 cm trihedral reflectors measured from each of the like-pol images are presented in Table 13 and are virtually identical. Differences in the two like-pol channels seem to become more pronounced as the clutter targets become more hard target like. The difference in polarization responses may be due to Brewster angle effects on the dihedral responses formed between the ground and buildings, but there is no conclusive evidence to support this. More effort should be made in the examination of expected returns from mixed dielectric and man-made targets at large incidence angles. In comparing the NRCS at these returns from the polarimetric set of data we see that HH-polarization yields the highest values, while at VV-polarization NRCS are slightly lower, ranging from 0.5 dB to 9.3 dB less than at HH. The NRCS at cross-polarization are significantly less (about 20 dB), than at like polarization. The NRCS at VH-polarization are 1 dB to 2 dB greater than at HV-polarization.

Using the residential clutter at the far range of the polarimetric images, we can qualitatively study the effects of aspect angle on clutter return. The returns from a few residential areas and their orientations with respect to the radar, are presented in Table 14. As would be expected, when the primary face of the buildings in the area are parallel to the line of flight of the radar, the residential area produces a strong backscatter due to specular returns. When the primary faces of the buildings are oriented perpendicular to the line of flight, strong specular returns originate from the sides of the building. Since the sides are usually smaller in size than at the primary faces, their backscatter responses are somewhat less. The lowest RCS produced arose from those buildings whose primary faces are oriented at some angle other than parallel or perpendicular to the line of flight. Energy hitting the surfaces of the buildings at these angles is generally reflected away from the radar. This was seen to be especially true at large incidence angles.

The Denver 'STEP WEST' Set

The First 'Step West'

The clutter content of the First 'Step West' image is presented in Table 15. One third of the image is occupied by the grasslands located to the east of the airport. Forty percent of the image is occupied by residential and urban areas to the south and west of the airport. Only a small portion of this image is occupied by the city of Denver proper, about 22%, and by Lowry Air Force Base, about 2.4%. The Lowry facility contains an assortment of targets. Approximately 4% of the image is composed of warehouses, located to the east of the airport, and 14% is composed of the airport grounds and facilities.

Table 16 and Figure 70 present the NRCS means, minimums, maximums, and standard deviations for each of the major clutter groups. The location and statistics of individual clutter area are given in Appendix B. From the bar chart in Figure 70 we observe the dichotomy which was present in previous SAR images. Distributed man-made targets clutter apart from natural distributed targets, but the separation between them is narrower than was found in the previous images. The mean, minimum, and maximum NRCS of the image are -8.61 dB, -38.71 dB and 35.54 dB, respectively. The mean value of this image is somewhat higher than that of the Philadelphia Airport image, and is attributed to the more culturally developed character of the Denver area. A coefficient of variation of 37 is similar to that of the like-polarization single swath Denver images discussed previously.

Given that the scattering coefficients of the image tended to separate into either man-made or natural distributed-target, the thresholding of the image allowed us to further determine the location and percentage of specific types of clutter. A histogram of radar scattering coefficients for the entire image and for 5 dB bins is provided in Figure 71. The images shown in Figures 72 through 76 were produced by setting individual pixels whose values are below the stated threshold are set to zero while pixel values greater than the threshold are set to 255. It should be noted that this operation has been performed on the contracted version of the calibrated image. Because image contraction involves averaging the distribution of coefficients that result are more narrow, as expected, and the lowest and highest coefficients measured will differ from those presented elsewhere.

Based upon the bar chart shown in Figure 71, we see that fifty-three percent of the image has a value of -28 dB or less. Figure 72 reveals that these low return areas arise primarily due to smooth grass fields and scattering at small grazing angles. Low returns also exist in the residential and parking lot areas. Twenty-nine percent of the image has NRCS values between -18 db and -28 dB. These areas include almost all of the distributed targets. Figure 73 shows all returns which are greater than -20 dB. The natural targets which produce NRCS values greater than -20 dB appear to be limited to treelines and shorelines. All other returns appear to be man-made in origin. This behavior was also suggested in the bar chart shown in Figure 70. The -15 dB to -20 dB NRCS value range appears to demarcate natural distributed returns from hard-target returns. At the -10 dB threshold, Figure 74, most of the returns which are visible come from sources which are man-made. Most prominent are the returns from the warehouse, industrial areas, and the airport terminal facilities. The urban areas which include very few trees, are also an important source of backscatter at these levels. Only 1.2% of the image has values of 0 dB or above and the majority of these returns are associated with the airport, the industrial areas, or the warehouses. This was the same fraction of strong returns present in the Philadelphia image. About 0.1% of the NRCS exceed 10 dB. These returns appear to be almost solely associated with a special case of scattering from a dihedral. The cases of very strong backscatter arises when the buildings are large and are oriented broadside to the radar, and the surface adjacent to the building is very smooth and unobstructed. This geometry allows the specular component of the scattered field to be directed back to the radar. Strong returns of this type are particularly characteristic of the airport environment where there are large unobstructed expanses of very smooth tarmacs.

Now let us look at the histograms which were derived from the composite clutter groups of this image. The Denver first 'step west' image is unique in the broad range of incidence angles with which the grassy areas to the east of the airport were imaged. This large amount of data enables us to describe trends in this clutter group for a wide range of incidence angles, Figures 77 through 96. On the whole, the distributions which represents grass clutter, Figures 76 through 83, remain similar in shape for all incidence angles, but decrease in size and mean. The decrease in size is due to the increase of grass clutter values which are at or below the noise floor of the data at increasing angles. The decrease in mean is a phenomena which is typical for grass, as well as other natural surfaces, and has been observed in experimental data. This image also has a large range of residential clutter. Like the grass clutter, the residential clutter, Figures 84 through 89, maintains a characteristic distribution shape at all incidence angles. The mean NRCS of the residential clutter seems to decrease at approximately 70° to 74°. The 50° to 59° residential clutter plot seem to have an abnormally low mean value which may be caused by aspect angle effects. Urban, industrial, and city clutter occur only in far range, Figures 90 through 94. The majority of the clutter in these groups comes from areas in the image where returns are nearly binary, either having very high values or values at or below the system noise level. At all incidence angles NRCS of water, Figures 95 through 9,7 is at or below the system noise level.

Figures 98 through 102 present plots of the mean NRCS versus mean incidence angle for each of the distributed clutter groups examined in this image. The plots which have a wide range of incidence angle, residential and grass, both exhibit a decrease in NRCS with increasing incidence angle. The grass clutter values range from around -17 dB at incidence angles close to 40° to around -36 dB at 82° incidence angle.

This range of values is similar to that observed in the Philadelphia image and in the Denver single swath image. The residential clutter starts with a high around -10 dB and decreases to around -22 dB at 80°. Both curves exhibit a generally flat profile at smaller incidence angles, but neither curve has the sharp drop off of values that was seen in the Philadelphia data. As for urban, city, and industrial clutter, incidence angle variation is limited and angular response trends may not be predicted. For the most part, urban, industrial, and city clutter appear to have NRCS which cluster between -3 dB and -18 dB. The industrial sites are represented at the high end of this cluster and the urban areas at the low end. This may be due to the changing density of man-made targets in each of these groups. The industrial areas would tend to have the largest quantity of hard targets and the urban areas the least, per unit area. The difference in the values for the man-made target clutter when compared to those obtained from the single swath images, is probably not significant.

A series of man-made targets were selected throughout the image and their RCS values were calculated by including their areal extent. These values are presented in Table 17. In general, the RCS values of these targets are less than those for similar targets in the Denver X-HH single swath image. The difference is attributed to incidence angle effects. In addition, these hard targets in this image appear to have a greater range of values than those of the previous Denver X-HH image, and range from 47 dB for sections of the airport terminal to 10 dB for a plane. Histograms of selected targets are presented in Figures 103 through 107. Like the non-vehicular hard targets in the Philadelphia image and those in the Denver single swath image, the terminal, building, and warehouse distributions all have a rapidly decreasing trailing tail, hence, a gradually decaying leading tail skewed to the right. The warehouse distribution is unique in that its leading tail decays even more slowly. There is nothing conclusive which can be derived from the distribution of planes or the parking lot as surveyed in this image other than there are a number of pixels that have NRCS which range from -10 dB to +8 dB, with values of about -5 typical.

The Second 'Step West'

The second 'step west' Denver X-HH image differs from the previous Denver image in that it contains less rural area and more of the urban area which surrounds the airport. Bright returns originating from the downtown Denver area can be seen at the far range of the image. The difference is evident in the areal analysis presented in Table 18. Only 6.2% of this image is rural, compared to 30% for the first step, and approximately one half of the image is cultural-type clutter. The one third of the image at far range was not classified, but is composed of urban areas. Like the previous image, the two airports in the scene occupy approximately 15% of the image.

Table 19 and Figure 108 present the NRCS means, minimums, maximums and standard deviations for each of the major component clutter groups in this image. The locations and statistics of each individual clutter area are given in Appendix B. Unlike the previous 'step west' image, this image does seem to separate itself into a low set of values and a high set of values with the exception of the grass clutter in the 70° to 74° incidence angle bin and the residential clutter in the 50° to 59° incidence angle bin. In general, the distributed targets in the scene have NRCS of around -25 dB and less, while the man-made target areas have NRCS of -15 dB or above. The mean, minimum, and maximum NRCS of the image are -6.8 dB, -39.89 dB, and 37.17 dB respectively, and the coefficient of variation is 24. The mean of this image is approximately 1.8 dB greater than the first 'step west', an increase attributed to the reduction in the areal extent of rural areas.

A histogram of radar scattering coefficients for the entire image and for 5 dB bins is provided in Figure 109. The images shown in Figures 110 through 114 were produced by setting individual pixels whose values are below the stated threshold are set to zero while pixel values greater than the threshold are set to 255.

Based upon the bar chart shown in Figure 109, we see that fifty-four percent of the image has a value of -28 dB or less. Figure 111 reveals that these low return areas arise primarily due to grass fields and the unclassified areas of the image which are observed at large incidence angles. Low returns also exist in the residential and parking lot areas. Twenty-one percent of the image has NRCS values between -18 db and -28 dB. These areas include almost all of the distributed targets. Figure 111 shows all returns which are greater than -20 dB. The natural targets which produce NRCS values greater than -20 dB are shorelines and treelines. All other returns appear to be man-made in origin. This behavior was also suggested in the bar chart shown in Figure 108. At the -10 dB threshold, Figure 112, most of the returns which are visible come from man-made sources. Most prominent are the returns from the airport facilities, warehouses, industry, urban areas, and residential areas. Approximately 2.6% of the image has NRCS of 0 dB or above, almost double that of the previous images. Sources of these returns are concentrated in the immediate vicinity of the airport and arise due to the airport buildings, terminals, warehouses, and industrial areas.

Histograms for composite clutter groups are presented in Figures 115 through 135. The distributed targets for this image have histograms which are similar in shape and trend to those of the Denver 'first step' west image. The grass clutter, Figures 115 through 120, is almost identical in distribution shape to that of the previous image although the angular response trend is not exactly the same. For residential clutter, Figures 121 through 126, we observe a relatively constant mean for all incidence angle groups. The shape of the histograms remain fairly similar from 40° to 65° but then a broadening of the distributions becomes apparent as angles increase from 65° to 74°. The histogram at 80° to 84° is somewhat odd because the scattering coefficients broke into two families, those which produce strong returns (about -10 dB) and those which are weak and at or below the system noise floor. The histogram for water, Figure 127, also shows a small population of moderately sized NRCS, but with a majority of its cross-sections at or below the system noise level of -40 dB. As in the previous image, the industrial, city, and urban clutter occur at higher incidence angles. The histograms of these features, Figures 128 through

135, are similar in shape to those of the previous image, have large NRCS and produce a very wide distribution of values, greater than 60 dB.

The incidence angle plots of the clutter for this image are similar to those of the previous Denver images. Urban and city clutter, Figures 136 and 137, are almost identical to that of the first 'step west' image. The urban clutter shows the trend where NRCS decreases rapidly after 80°, and the city clutter produces a tight cluster of values (about +4 dB) at incidence angle values from 80° to 82°. The industrial clutter, Figure 138, shows an angular response centered about -9 dB which increased slightly at 82°. Residential clutter, Figures 139, shows a trend where NRCS increases from 40° to 65° and then remains flat to 82°. These data did not drop off at the higher incidence angles as in the other cases. The grass clutter response is essentially flat from 40° to 80°. However, the mean values of the residential and grass clutter, are essentially similar to that of the other images. Residential clutter has a mean value of about -15 dB and a grass mean of approximately -25 dB.

Man-made target clutter is presented in Table 20 and Figures 141 through 143. This data is similar to that of the first 'step west' image. The values of RCS from each image compare favorably. The airport terminals in the first 'step west' image produced values between 32 dB and 47 dB. The values produced in the second 'step west' image lie between 36 dB and 44 dB. Warehouses in the first 'step west' image produced values of 27 dB to 33 dB compared to those in the second 'step west' image of 24 dB to 34 dB. Histograms of man-made target clutter are also similar in both shape and mean value to those of the first 'step west' image. Overall, these data suggest that small changes in aspect and elevation angle produce small changes in overall RCS levels, even though individual scatterers may scintillate wildly.

The Third 'Step West'

As these double swath images progress west, more and more of the city of Denver is revealed to the radar. Only 1.0% of the image is rural (Table 21). Fifty-five percent of the image is occupied by man-made clutter and 30% is unclassifiable, but is known to be part of the city of Denver. Eleven and a half percent of the image is occupied by airport facilities, and 2.3% by parks and other recreational areas within the city.

The statistical values of clutter groups in the image are presented in the bar chart in Figure 144 and in Table 22. In the bar chart we see that once again, the distributed targets tend to have values of -25 dB or less, and the man-made targets appear to have values of -15 dB or more. The industrial clutter in the 40° to 49° range and urban clutter at 50° to 59° range produced weaker backscatter than anticipated. The areas used for the clutter analysis of this image and the statistics of individual clutter areas are given in Appendix B. The mean, minimum, and maximum NRCS of the image are -7.64 dB, -39.69 dB, and 42.08 dB respectively. These values correlate well to values obtained from the other Denver images. However, the coefficient of variation at a value of 60 is significantly higher than that of the other Denver images, by a factor of about 1.6. This is attributed to the increasingly urban nature of the clutter scene as it moves westward. The composition of the image is such that almost one-half of the intensity values for this image are at or below the system noise level. Almost all of the other half of the image is composed of urban areas and produce large NRCS. Since there are very few in between values, the variance and the coefficient of variation are large in this case.

A histogram of radar scattering coefficients for the entire image and for 5 dB bins is provided in Figure 145. The images shown in Figures 146 through 150 were produced by setting individual pixels whose values are below the stated threshold are set to zero while pixel values greater than the threshold are set to 255. Based upon the bar chart shown in Figure 145, we see that fifty percent of the image has a value of -28 dB or less. Figure 146 reveals that these low return areas arise primarily due to homogeneous grass fields, street, runways, parking lots, and unclassified areas of the image. Twenty-one percent of the image has NRCS values between -18 db and -28 dB. These areas include almost all of the distributed targets. Figure 147 shows all returns which are greater than -20 dB. The natural targets in this image which produce NRCS values greater than -20 dB are limited to treelines and tree returns. All other returns are man-made in origin. This behavior is also suggested in the bar chart shown in Figure 144. The -23 dB NRCS value range appears to demarcate natural distributed returns from man-made target returns. Most of the returns above the -10 dB threshold (see Figure 148) come from hard-target sources. Most prominent are the returns from the Centre City, the airport terminals, other tall urban buildings, grain elevators, and warehouses. A noticeably smaller percentage of the total number of returns with values above -10 dB are produced by residential and urban areas. Only 1.3% of the image has values of 0 dB or above. In this case, the sources of large NRCS are spread throughout the image but are primarily associated with the airport buildings, the Centre City, and large structures which face the radar. The composition of the image is highly cultural and is visualized in Figure 149 by populations of strong returns throughout the image and even at the extreme incidence angles. There are very few NRCS above 10 dB, about 0.06%,and a significant portion of these were associated with Centre City.

The histograms for the distributed target clutter are presented in Figures 151 through 177. Starting with the grass clutter, Figures 151 through 157, we see trends similar to the other Denver images. The histogram shapes are generally symmetric and the centroid of the NRCS histogram varies little from 35° to 79°, ranges from about -25 to -27 dB. Probably the most pronounced feature is that the leading tail has increased in size at the largest incidence angles (75° to 79°) and the largest NRCS were produced. The residential clutter, Figures 158 through 162, produced NRCS distribution which are broad, more than double those of grass clutter, and are especially broad at the small incidence angles (30° to 40°). The maximum NRCS were also produced at these angles and were approximately 20 dB larger in cross-section than those produced at the larger angles. The shape of the histograms is quite similar to that of the previous Denver images and the residential clutter drops approximately 2 to 3 dB over the range of 40° to 79° which is an intermediate decrease when compared to the other Denver double swath images. The urban clutter presented in Figures 163 through 169 show trends similar to those of the residential clutter. One important addition is that at 80° to 84° the largest NRCS was at least 15 dB greater than that obtained at the angles from 50° to 79° and was about the same size as that obtained at 30° to 40°. In general, the histograms have very similar shapes except at the smallest incidence angles (30° to 34°). The mean NRCS of the urban clutter also drops by approximately 4 dB over this angle range. The clutter data at 50° to 59° produced a much narrower angle distribution and has a lower mean. The histogram for urban clutter at 80° to 84° is smaller in amplitude because most returns produced were below the system noise floor but has a mean which is larger than that obtained at the middle angles. City and industrial clutter histograms are presented in Figures 170 through 177. Both groups of clutter yield generally the same returns. Their histogram shapes and means are similar. Exceptions to this are industrial clutter at 40° to 49° and at 75° to 79°. The industrial clutter in the 40° to 49° bin has a different distribution than other clutter in this group and a mean that is exceptionally low. Industrial clutter in the 75° to 79° range has a consistent mean value, but bimodal shape. In summary, the largest NRCS are produced at the smallest and largest angles, and the angular response trend will show an increase in NRCS at the largest incidence angle. The lack of water areas in the images, as well as in all of the Denver images, makes it difficult to categorize water returns. Generally, they are extremely low and appear to be somewhat contaminated by shoreline values (Figures 178 and 179). Runway clutter, Figure 180, produces very weak backscatter.

Scattering coefficients versus incidence angle for different clutter groups are plotted in Figures 181 through 185. Once again, lack of diversity in the incidence angles subtended by the data makes it somewhat difficult to characterize trends in the data. The mean grass clutter NRCS is generally about -26 dB and decreases a few dB at the largest angles (80° to 84°). At angles from 76° to 82°, urban, industrial, residential, and city clutter cluster at -16 dB, -12 dB, -18 dB and -10 dB respectively. City, industrial, and urban areas show a trend where NRCS increases from 78° to 82°.

The RCS of selected man-made targets observed in this image are presented in Table 23, and histograms of the scattering coefficients (NRCS) are presented in Figures 186 through 189. The RCS values calculated for these targets correlate well with those obtained from the other double swath images. Backscatter from buildings, terminals, parking lots, and planes shows a range of possible NRCS is from -40 dB to +17 dB. Their histograms are correspondingly broad. The mean NRCS for these four cases are also very similar, ranging from -10 dB to -14 dB. RCS values for these targets range from 11 dB to 38 dB for effective areas ranging from 760 m^2 to 41,000 m^2. The airport terminals were the largest man-made targets observed. The magnitude of target RCS appear to be directly proportional to the effective ground area. Regressing these data yields a relationship where RCS = 12.59 * effective area. The RCS response of these data with area was examined and the receiver was, in general, not saturated.

The Fourth 'Step West'

The last of the four double swath images analyzed covers the city of Denver to the west of the airport. This image contains clutter which is almost totally dominated by cultural targets. From Table 24, we see that only 1% of the image is composed of natural distributed clutter. In this case it is in the form of recreational areas. The unclassifiable portion of the image is from the west side of Denver.

The statistics of major clutter categories are presented in Table 25 and Figure 190. The full statistics and locations of areas which were included in this analysis are provided in Appendix B. In general, most of the distributed man-made targets have mean NRCS of -15 dB and more, while natural distributed targets have NRCS values of -15 dB or less. The exception is residential clutter, whose values seem to be low. The mean, minimum, and maximum NRCS of the image are -5.14, -39.53, and 49.09. The higher mean of this image is easily attributed to the increase of man-made targets in the scene. The coefficient of variation of the image is 110, much higher than for any image analyzed previously.

A histogram of radar scattering coefficients for the entire image and for 5 dB bins is provided in Figure 191. The images shown in Figures 192 through 196 were produced by setting individual pixels, whose values are below the stated threshold, to zero while pixel values greater than the threshold are set to 255. Based upon the bar chart shown in Figure 191, we see that sixty percent of the image has a value of -28 dB or less. Figure 192 reveals that these low return areas arise primarily within the unclassified area of the image which is primarily residential. About seventeen percent of the image has NRCS values between -18 db and -28 dB. Figure 193 shows all returns which are greater than -20 dB. All returns appear to be from man-made targets. In Figure 13, two features are well-defined in the upper left half of the image. They are the Denver Mile High Stadium which has a shape of an ellipse, (located 1/4 right and 4/7 up from lower left hand corner), and the AMC Cancer Research and Hospital, (located 1/4 right and 5/7 up from the lower left hand corner), directly above the stadium and is seen as a cluster of horizontal and vertical segments. These large cultural features suggest what is required physically to produce a significant return at small angles. At the -10 dB threshold, Figure 194, a major portion of the returns are absent but the ones that remain are mainly from the urban areas observed at the medium incidence angles. The previously mentioned hospital is still easily recognizable and a large number of its scatterers are still present. The leading edge of the stadium is still strongly scattering, but the number of scatterers defining the outer edge is reduced and the ellipse is no longer defined. Only 0.9% of the image has values of 0 dB or above and the majority of these returns are generated at the smallest incidence angles, there are very few NRCS of this size at the middle or large angles. The number of scatterers with NRCS of 10 dB or larger is exceedingly small, about 0.03%, as illustrated in Figure 196.

The histograms for the clutter subsections are presented in Figures 197 through 221. The grass clutter, Figures 197 and 198, for this image is almost identical to that of previous distributions; the only difference being a large leading tail. This may be caused by some contamination from other types of clutter. The mean of the grass clutter in this image is also consistent with that of other Denver images and with the Philadelphia image. The residential clutter histograms, Figures 199 through 202, show means which are high at 65° to 74° but an order of magnitude lower at 50° to 59° and 75° to 79°. However, the shapes of the histograms for angles from 50° to 70° are essentially identical. Histograms of urban clutter shown in Figures 203 through 207, have essentially the same shapes and are similar to those of the residential clutter. This may be due to the similarity of the different types of clutter areas. Both consist primarily of single family and multiple family dwellings with the only difference being the density of the houses per unit area. The similarities between residential and urban clutter can also be observed in other Denver images as well.

The distributions for city and industrial clutter are presented in Figures 208 through 218. In general, the industrial and city clutter, have histograms which show similar shapes, and are skewed, and have a leading tail. These two clutter types produce very similar clutter levels. In the case of the city clutter, NRCS ranged from -9 to -15 for angles from 40° to 79°. The industrial clutter produces NRCS which are about 1.4 dB larger. Water clutter, Figure 219, produced NRCS which are slightly above to below the receiver noise floor. A mean of -35 dB was obtained at 70° to 74°.

Incidence angle plots for these data are presented in Figures 220 through 224. The city clutter produced a response which may be independent and fluctuate within a 6 dB interval about a mean of -12 dB. Urban and industrial clutter show responses which are more dynamic (about 15 dB). They show large NRCS at 45° and much smaller NRCS at 78° to 80°. The urban clutter response between 54° to 72° is reasonably flat and centered about a mean of about -14 dB. The residential clutter data is sporadic which may be due to aspect angle dependencies. There is not a wide enough range of grass clutter to support incidence angle analysis, but the values do cluster around -25 dB -- similar to the grass clutter in previous images. The grass clutter appears to have a rapidly decreasing trend over the range of incidence angles it subtends, (68° to 76°) and produces reasonably weak backscatter (about -25 dB).

Since this image covers an area which does not include the airport, the man-made targets are limited to selected buildings in the Denver area. The RCS values calculated for these buildings are presented in Table 26. The buildings have RCS values that range from 18 dB to 37 dB, and areas which range from 140 m^2 to 9700 m^2. Although little forested land exists in the Denver area, we were able to acquire enough spatial samples to produce the histograms shown in Figures 226 and 227. Mean NRCS range from -16 dB to -19 dB for angles from 65° to 74°.

VII. IMAGE COMPARISON

With the wide range of incidence angles, aspect angles, and polarizations afforded to us by the Denver data we can intercompare results of the images for certain clutter areas. The histograms of the HH-polarized images and a table of their representative statistical values are presented in Figures 228 through 232 and Table 27. The mean value of the HH-polarized single-swath image correlates with those of the double swath images. It is not surprising that the mean of the single-swath Denver image is closest to that of the second 'step west' double swath image; these two images essentially image the same area. Comparing the four double swath images statistics we observe some interesting trends. First, all histograms are skewed to the right. This behavior was also observed in the city and industrial clutter groups of the images. Skew in the total image statistics may be indicative of image content. The means of the NRCS in the images are reasonably similar. They vary within a 3.5 dB interval positioned about a mean of -6.9 dB. The lowest image mean (by 1.7 dB) occurs with the Denver first 'step west' image, which contains a considerable area of naturally distributed clutter, and the highest image mean (1.8 dB) occurs with the Denver fourth 'step west' image, which contains the largest percentage of man-made clutter. In general, the variances and coefficient of variations of the images increase as the image content becomes more cultural, i.e., as one, moves in a westwardly direction.

Table 28 presents a list of common areas analyzed. Using the HH polarimetric data in combination with the double swath data we can analyze aspect angle differences between the images. The double swath data by itself provides information about the changes in clutter return with respect to changes of incidence angle for any specific area of the image. Table 29 presents a comparison of values from the Denver single swath image with those of the double swath series at similar incidence angles. In general, the NRCS values from the westward looking image are lower (by about 5.5 dB) than those of the northward looking image. The exceptions to this trend are some of the residential clutter at 79° and the grass clutter. It was anticipated that grass clutter would be insensitive to aspect angle. The NRCS for the grass clutter of the polarimetric image is lower (by 4.4 dB), which is opposite the general trend. However, the grass clutter values on average are consistent with each other. Differences in residential clutter have the potential to be very aspect angle dependent, based on the orientation of the residential areas to the radar. In general, the mean difference in NRCS of the residential clutter looking north versus west is only 1.1 dB. Individual residential areas showed variations from 1.4 to 4.9 dB. This variation is attributed to the gridded street structure where blocks are larger in one dimension and when this dimension is oriented broadside to the radar larger NRCS are produced. The greatest reduction is seen when residential areas are oriented at angles which are not orthogonal to the radar look direction. The airport terminals produce much smaller NRCS (by 10.3 dB) in the west looking images because they are oriented along an east-west axis, because the primary faces of the terminals are oriented north and south. Industrial, urban, and city areas also showed strong aspect angle dependence.

The set of 'step west' images also provided some tests of NRCS dependency with incidence angle. Table 30 presents some selected clutter areas which have been analyzed in each of the 'step west' images. The data is somewhat limited since only 3 or 4 incidence angles could be tested for any particular clutter. Grass produced NRCS which were constant at the middle incidence angles and then decreased slightly (4 dB) at the largest angle (79°). This is similar to trends found in the Philadelphia data, the Denver data when based on various fields, and is the anticipated response. The two airport terminal responses, provided in Table 30, increased NRCS when going from 68° to 78°, but produced opposite response when going from 78° to 83°. The conclusion is that enhanced NRCS may be produced, but this is not deterministic. Similar results were produced by the industrial and city clutter. Significantly enhanced NRCS may be produced at the large angles but do not necessarily become larger as the angle exceeds 82.5°. Residential clutter produced a trend where there was a 7 dB fluctuation in going from 81° to 83°. In general, the response shown here suggest that the NRCS response is reasonably flat from 58° to 83°, with the possibility of enhancement or reduction at any particular angle. In the case of this example both were experienced over a 2° change at the largest angles. The urban areas suggest a trend where there is an enhancement at the largest incidence angles which is followed by a reduction as the angle is made larger.

To further intercompare the various major clutter categories, data acquired from the Philadelphia and Denver data collections have been summarized in Table 31. In this table mean NRCS (in dB), variances (in magnitude), and coefficients of variation (ratio between variance and mean and expressed in dB) are provided. Averages of the values shown in this table are presented here in summary. When comparing the average backscatter coefficients, the clutter types cluster according to the following groups in order of largest to smallest cross-sections: (a) terminals (-3 dB), (b) city and industrial (-7 dB), (c) warehouse (-10 dB), (d) urban and residential (-14 dB), and (e) grass (-24 dB). The standard deviation produced by the samples of the various clutter categories acquired from the different images cluster accordingly: (a) residential, urban, and grass (3 dB), (b) industrial, city, and terminals (7 dB), and (c) warehouse (10 dB). These data show that the more homogeneous the distribution of scatters within a clutter scene the less variation is observed between different scenes. On the other hand, the man-made clutter scenes composed of large geometrical shapes produces widely variable backscatter levels and are very scene-orientation angle dependent, the warehouse case being the most extreme example. The average of the coefficients of variation determined for individual clutter scenes for these major clutter categories clustered accordingly: (a) industrial and city (11 dB), residential, urban, warehouse, and terminal (5 dB), and (c) grass (1 dB). This shows that the inter-scene variability is the greatest for the most physically diverse areas (industrial and city) and the least for the natural, uniformly distributed targets (i.e. grass).

In summary, the overall trend for residential, terminal, industrial, and city clutter appears to include enhanced NRCS at the small incidence angles (i.e., from 30° to 45°), a region where NRCS varies little with angle (i.e., from 45° to 75°), and a region where NRCS may be enhanced.

For cross reference purposes, Table 32 presents each image number with the figure and table numbers corresponding to it.

VIII. CONCLUSIONS AND RECOMMENDATIONS

The Denver data collection provides an important source of clutter data for the analysis of scattering in highly urbanized areas. Clutter categories mainly included Centre City, urban, industrial, residential, airport facilities, and grasslands. The percentage of large normalized radar cross-sections in these data is much greater than in any of the previously analyzed data. The variety of clutter types is also large. A set of data was also collected which allowed for a study of polarization effects. It was determined that the largest NRCS were produced at HH-polarization. NRCS at VV polarization were, on average, about 6 dB lower. This was of course, dependent on clutter type. The calibrated reflectors purposely positioned within these images, were virtually identical. The cross-polarized clutter produced NRCS which were approximately 22 dB less than those obtained at HH-polarization.

A series of four images, called 'step west,' were constructed at HH-polarization which were positioned repeatedly further west, while maintaining a large percentage of overlap. These data yield results which are consistent within themselves and consistent with the polarimetric set. Their means vary by only 3.5 dB over all the images although their variances increase as the images step further to the west into the more urban portion of Denver.

The incidence angle analysis produced some interesting results. Most NRCS for distributed targets in the Denver set of images decreased in value as incidence angle increased, a trend which has been measured experimentally using scatterometers. The man-made or cultural clutter did not show the same consistency in incidence angle trends. For these high density man-made targets the largest cross-sections were produced at smallest and largest incidence angles, however, increasing the incidence angle further did not guarantee larger cross-sections would be produced. In numerous cases, the cross-sections at the largest angles were an order of magnitude smaller that at angles 2° smaller. This suggests that NRCS at large angles will be highly variable.

The most striking conclusion of the Denver data analysis (and the Philadelphia data as well) is the consistency of the statistics and distributions of specific clutter groups. This consistency may allow for the development of classification schemes which may be used to identify areas of the clutter field which may present a particular clutter problem and more easily mask or produce a false wind shear hazard. If the clutter can be characterized, a radar system may use this added information in improving the delineation of backscatter arising from large amplitude ground clutter areas.

As part of the Phase III (Option 2) activity a dedicated SAR mission was flown of the Denver Stapleton Airport with the purpose of providing a clutter data base which included a wide variety of image geometries and clutter types. During this collection, 27 data passes of about 20 nautical miles each were collected. This included a series of low altitude passes in which scenes were imaged at very small depression angles. Data were acquired of the Centre City of Denver, the many urban areas, the industrial centers, and the mountains immediately adjacent to this area. These images included a wide variety of clutter scenes.

There were four important aspects to this data collection. These include acquiring data of as diverse a variety of clutter scenes possible such that aspect and depression angle dependence may be studied. In addition, the complete scattered field on a select number of these passes was made with which the polarization properties of the various clutter scenes would be documented and allow for polarization synthesis to be used to support polarization-based clutter suppression techniques.

The Denver airport and surrounding area provided the following scene composition:

(a) Airport grounds, buildings, vehicles, obstacles, and terminals,

(b) Centre City,

(c) Industrial and warehouse,

(d) Urban,

(e) Residential and suburban subdivision developments,

(f) Shopping centers with parked cars,

(g) Grassland and cropland,

(h) Forest, and

(i) Mountain.

In the work reported here, two sets of images were targeted for analysis. These included the 'Step West' and the Fully Polarimetric Airport Set. Examination of aspect angle requires that multiple views of the same clutter region be studied. The SAR data were collected such that four views were aligned with the 4 cardinal directions (north, south, east and west). With the present analysis, only two views have been exploited, those obtained by comparing the 'Step West' data and the north-looking Full Pol Set. Two of the most important clutter scenes, Centre City and industrial, were observed at only one aspect angle.

The depression angle response of most of the clutter scenes is in reasonable shape, except that we have not derived benefit from the data with the smallest depression angles. This would extend the angular responses to about 2.5 degrees from grazing, a region were an improved description is very important. The clutter scenes of grass, forest and croplands have been characterized with very few observations. It may be argued that the grassland and cropland data are not critical because they produce weak backscatter and are not "show stoppers". The areal extent of forest was very limited in the data examined to date. A complete characterization is important; because it is a clutter scene that has considerable areal extent in a large number of American airports and it produces a moderate backscatter intensity, on a level similar to that of residential and urban areas and may act, in a number of cases, to dominate the urban and residential backscatter. To more comprehensively address the angular response of forest clutter in the Denver image scenario, data collected of a range of mountains, either in full pol or VV- and HH-pol, needs to be studied.

The polarization property description of the Centre City and industrial areas is presently limited to one polarization (HH). The Centre City and industrial areas were observed only in the 'Step West' and not in the Full-Pol image. In addition, the multiple observations for the forest, croplands, and grasslands is limited. The polarization descriptions of the Centre City and industrial areas are particularly important; these scenes represent two critical sources of the largest cross-sections which may be observed by a radar and determining ways to suppress the clutter which originates from them may mean the difference between a sensor that is feasible and one that is not.

These data contained in the Denver Stapleton data collection may be summarized as follows:

1) Fully Polarimetric (Pass 37)

These data were exploited in the analysis performed here for use to determine the difference in amplitudes due to polarization, to incidence angle variations, and to the differences in the distribution in the returns from the various clutter scenes. The radar was pointed to the north when this scene was imaged.

What has yet to be done with these data is a polarimetric analysis where the scattering properties are fully studied. The data were collected which completely characterize the scattered field and allow the ability to synthesize arbitrary polarizations in the study of clutter suppression. Circular and elliptical polarized imagery may be synthesized to contrast them with the results obtained in the clutter analysis of the linear polarized data. This should prove to be particularly important in the suppression of the strong returns that arise due to the terminals and buildings located on the airport grounds and the industrial areas. Polarizations that maximize the microburst returns, which minimize the clutter returns, and which optimize the microburst-to-clutter ratio would be selected for this study.

2) 'Step West' 4 Pass Set (Passes 12, 2, 25, and 29)

These data were used in the study reported here. A statistical analysis was based on these 4 images. Angle of incidence effects was a key element of this study. These data provided a good assortment of different clutter types and there is a good description of these clutter distributions.

These data could be exploited further by combining with (1) and studying the north/west look angle dependence. Efforts resulted in examination of about 3 to 5 clutter samples within each clutter category for common incidence angles. The clutter scenes composed of the airport terminals, the city, and the residential areas were most sensitive to aspect angle. For angles from 40° to 65° the acceptable deviation for common angles was 5°, and for the angle region from 65° to 82° a deviation of 3° was used. It is felt that the number of comparisons made here was limited. Results of the angular analysis for these data which resulted from this study show that the decay of the backscatter intensity with angle is very slow or flat in the middle angle region and suggests that the angle bins may be widened further and the number of intercomparisons that can be made can be increased.

3) Single and Double Swath Imagery of Agricultural Lands (Passes 27, 12, and 25)

These data were not utilized, but may be used to more fully characterize the statistics at the smaller incidence angles of these distributed clutter. There are 6 images available for this study.

4) East, North, and South Double Swath Box Set (Passes 27, 31, and 39)

These three images are important in making a much more comprehensive study of the aspect angle dependence of clutter. The information contained in these scenes that was not contained in the images processed to date include downtown Denver (Centre City), the front range of the Rockies, and all of the metropolitan area surrounding Denver.

5) Very-Low Altitude Passes (Pass 43)

The purpose of the collection of these data was to obtain measurements at as small a grazing angle as was possible given SAR system constraints. This was accomplished in a special collection geometry in which the aircraft was operated at an altitude of 1500 m above ground level, rather than at 3000 m. Angles ranged from nadir to 87.5° in these images whereas the range of angles which was typical in the data reported here was from 40° to 84°. This was accomplished in this data set which includes both VV and HH polarizations. A statistical analysis should be made of these data at these extreme angles and the two polarizations, and then combined and compared with the existing results. Two images would be processed, analyzed, and reported.

6) Full-Pol Middle-Angle Set (Passes 8 and 35)

These data provide a good link to the data utilized in the SAR archive analysis previously performed. In addition, these data may be used to further extend and contribute to the description of the incidence angle response of the scattering cross-sections. There are from 2 to 8 scenes that could be used for this effort.

(7) Mountain Data (Passes 18-23 and 14-16)

A calibrated high resolution and contracted image has been created for one mountain scene (Pass 14). A contracted image has been provided to NASA for use in the Simulation Program. There was a predominant feature which was long in the along-track extent and produced a very strong backscatter response. Additional scenes exist that present different scene compositions. To date only one polarization (HH) has been processed, and this image has not been statistically analyzed. The analysis that should be performed here would address the incidence angle response of mountain forest clutter, the impact of local slope on the backscatter response, and the polarization properties of forest clutter. In addition, these data could be further supplemented by a fully polarimetric data set which was collected.

The justification for further work with these data is based on completing the comprehensive study of aspect angle, depression angle, and adequate descriptions of the various clutter scenes. The aspect angle study has been limited -- at present only 2 of the possible 4 (orthogonal) aspect angles have been exploited -- and needs to be expanded. The depression angle study is in reasonable shape, except that it is polarization limited and has not been extended to the smallest grazing angles. The statistical description of the Centre City and industrial areas, two key large cross-section sources, is limited in all aspects (grazing angle, aspect angle, and polarization). Forest characterization is also limited. The polarization study has been limited to linear polarizations and the area centered about the airport. This can be expanded by including the description of the clutter scenes that have been characterized at one linear polarization (HH), by examining circular polarization, and by examining the polarizations that maximize the microburst signatures (i.e. a particular elliptical polarization), and by examining the polarizations that minimize the ground clutter.

REFERENCES

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Table 1. NASA LaRC Denver Flight Summary

Pass	Beg Lat	Beg Lon	End Lat	End Lon	Comments
2*	39:56.51	104:44.43	39:36.49	104:44.43	1st Step West, West-Look
4	39:56.51	104:45.52	39:36.49	104:45.42	Full Pol Airport, West-Look
6	39:36.49	104:59.28	39:56.51	104:59.28	Full Pol Airport, East-Look
8	39:56.51	104:50.35	39:36.49	104:50.35	Full Pol Airpot Mid Angle, West-Look
10	39:36.49	105:03.77	39:56.51	105:03.77	Double Swath Airport, East-Look
12*	39:56.51	104:47.43	39:36.49	104:47.43	2nd Step West, West-Look
14	39:32.48	105:06.82	40:14.52	105:06.82	Rocky Mountains, Double Swath
15	39:32.48	105:06.82	40:14.52	105:06.82	Rocky Mountains, Double Swath
16	39:32.48	105:06.82	40:14.52	105:06.82	Rocky Mountains, Double Swath
18	40:14.52	105:08.63	39:32.48	105:08.63	Rocky Mountains, Full Pol
19	40:14.52	105:08.63	39:32.48	105:08.63	Rocky Mountains, Full Pol
20	40:14.52	105:08.63	39:32.48	105:08.63	Rocky Mountains, Full Pol
21	40:14.52	105:08.63	39:32.48	105:08.63	Rocky Mountains, Full Pol
22	40:14.52	105:08.63	39:32.48	105:08.63	Rocky Mountains, Full Pol
23	40:14.52	105:08.63	39:32.48	105:08.63	Rocky Mountains, Full Pol

Table 1. Cont.

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NASA LaRC Denver Flight Summary

Pass	Beg Lat	Beg Lon	End Lat	End Lon	Comments
25*	39:36.49	104:50.43	39:56.51	104:50.43	3rd Step West, West-Look
27	39:56.51	104:41.03	39:36.49	104:41.03	Double Swath Airport, West-Look
29*	39:36.49	104:53.43	39:56.51	104:53.43	4th Step West, West-Look
30*	39:36.49	104:53.43	39:56.51	104:53.43	4th Step West, West-Look
31	39:55.36	104:44.63	39:55.36	105:11.88	Double Swath Airport, South-Look
33	39:51.79	104:44.23	39:51.79	105:11.47	Full Pol Airport, South-Look
35	39:44.89	104:44.23	39:44.89	105:11.47	Full Pol Airport Mid Angle North-Look
37*	39:41.17	104:44.24	39:41.17	105:11.46	Full Pol Airport, North-Look
39	39:37.60	104:44.64	39:37.60	105:11.86	Double Swath Airport, North-Look
41	39:36.49	104:53.43	39:56.51	104:53.43	4th Step West, West-Look
42	39:36.49	104:53.43	39:56.51	104:53.43	4th Step West, West-Look
43	39:40.49	104:53.31	39:52.50	104:53.31	Low Altitude, West-Look
44	39:40.49	104:53.31	39:52.50	104:53.31	Low Altitude, West-Look

* = Analyzed in this Study

Table 2. Comparison of Preferred and Actual Configurations

Parameter	NASA Ideal Scenario	Denver Data
Depression Angle Range	3° to Nadir	2.5° to Nadir
Swath		
Along - Track	12 km	13.3 km
Across - Track	14 km	19.7 km
Altitude	1738 m (5700')	1738 m (5700'), 854 (2800')
Airport Position	4 km from far range edge	2 km from far range edge
Polarization	HH	VV, VH, HV, HH
Resolution	<20 m x 20 m	2.4 m x 3.24 m 4.8 m x 3.24 m

Table 3. P-3 SAR Operating Parameters

Specification	Value
Frequency	X,L,C
Polarization	VV, HH, VH, HV
Viewing Direction	Left or Right
Processing	Real-Time, Optical , Digital

Swath Width in Range Direction	Single	Double	Quad
Narrow Band (High-Res)	4915 m	9830 m	19660 m
Wide Band (Low-Res)	9830 m	19660 m	39320 m

Resolution	Azimuth x Range
High	2.8 m x 1.6 m
Low	2.8 m x 3.2 m

Center Frequency Beamwidth	Vert. Pol	Hori. Pol
X-Band	1.7°	1.6°
C-Band	3.6°	3.45°
L-Band	8.55°	9.75°

Table 4. Image Composition Areal Analysis, Denver Polarmetric Set

Clutter Scene	Percent of Total Image Area
Residential	19.0
Rural	18.6
Warehouses	7.0
Mixed	8.0
Industrial	3.0
City	2.8
Airport Grounds and Terminal	14.6
Lowry AFB	6.2
Urban	20.8

Table 5. Clutter Returns for Targets at Denver Stapleton Airport Polarimetric Set, X-HH

	Mean (dB)	MIN (dB)	Max (dB)	SDev (MAG)	$\frac{\text{Mean + SDev}}{\text{Mean}}$ (dB)
Grass (50-59)*	-21.00	-44.08	-6.64	.10441 x 10^{-1}	3.64
Grass (75-79)*	-30.22	-44.08	-13.09	.21119 x 10^{-2}	5.08
Residential (50-59)*	-11.68	-44.08	19.12	.59200 x 10^{0}	9.87
Residential (75-79)*	-12.30	-44.08	18.95	.82514 x 10^{0}	11.76
Urban (60-64)*	-5.66	-44.08	23.59	.25927 x 10^{1}	10.23
Urban (75-79)*	-7.50	-44.08	29.92	.45779 x 10^{1}	14.27
Water (75-79)*	-38.65	-44.08	-23.10	.50215 x 10^{-3}	6.70
City (75-79)*	5.15	-44.08	34.63	.37365 x 10^{2}	10.94
Industrial (75-79)*	3.38	-44.08	29.28	.19002 x 10^{2}	9.88
Parking Lot	-4.12	-44.08	13.12	.12100 x 10^{1}	6.15
Runway	-36.68	-44.08	-12.92	.10065 x 10^{-2}	7.55
Terminal	6.48	-44.08	25.61	.17051 x 10^{2}	6.84
Warehouse	-0.24	-44.08	20.53	.44717 x 10^{1}	7.58

* = Number Incidence Angle Range

Table 6. Clutter Returns for Targets at Denver Stapleton Airport Polarimetric Set, X-VV

	Mean (dB)	MIN (dB)	Max (dB)	SDev (MAG)	$\frac{\text{Mean + SDev}}{\text{Mean}}$ (dB)
Grass (50-59)*	-25.80	-43.57	-10.03	$.34159 \times 10^{-2}$	3.61
Grass (75-79)*	-31.44	-43.57	-13.23	$.13072 \times 10^{-2}$	4.50
Residential (50-59)*	-14.97	-43.57	17.15	$.34861 \times 10^{0}$	10.77
Residential (75-79)*	-15.04	-43.57	13.94	$.30263 \times 10^{0}$	10.28
Urban (60-64)*	-16.85	-43.57	13.65	$.17979 \times 10^{0}$	9.87
Urban (75-79)*	-12.15	-43.57	25.70	$.13591 \times 10^{1}$	13.67
Water (75-79)*	-40.81	-43.57	-27.20	$.20740 \times 10^{-3}$	5.44
City (75-79)*	-1.10	-43.57	28.37	$.80474 \times 10^{1}$	10.56
Industrial (75-79)*	-3.34	-43.57	23.39	$.40105 \times 10^{1}$	9.85
Parking Lot	-9.68	-43.57	8.60	$.33556 \times 10^{0}$	6.15
Runway	-37.37	-43.57	-15.51	$.55439 \times 10^{-3}$	6.05
Terminal	-1.28	-43.57	18.69	$.46972 \times 10^{1}$	6.53
Warehouse	-4.72	-43.57	16.91	$.16342 \times 10^{1}$	7.67

* = Numbers Incidence Angle Range

Table 7. Clutter Returns for Targets at Denver Stapleton Airport Polarimetric Set, X-VH

	Mean (dB)	MIN (dB)	Max (dB)	SDev (MAG)	$\frac{\text{Mean + SDev}}{\text{Mean}}$ (dB)
Grass (50-59)*	-33.92	-47.09	-14.27	$.66402 \times 10^{-3}$	4.21
Grass (75-79)*	-42.44	-47.09	-24.30	$.14458 \times 10^{-3}$	5.48
Residential (50-59)*	-24.50	-47.09	11.73	$.53663 \times 10^{-1}$	12.07
Residential (75-79)*	-33.80	-47.09	-5.41	$.31217 \times 10^{-2}$	9.29
Urban (60-64)*	-27.13	-47.09	2.90	$.14319 \times 10^{-1}$	9.24
Urban (75-79)*	-30.18	-47.09	5.07	$.85834 \times 10^{-2}$	9.98
Water (75-79)*	-45.06	-47.09	-32.65	$.65201 \times 10^{-4}$	4.90
City (75-79)*	-24.30	-47.09	3.28	$.28775 \times 10^{-1}$	9.42
Industrial (75-79)*	-23.80	-47.09	2.78	$.33097 \times 10^{-1}$	9.51
Parking Lot	-29.27	-47.09	-13.98	$.28976 \times 10^{-2}$	5.38
Runway	-45.84	-47.09	-19.68	$.19722 \times 10^{-3}$	9.33
Terminal	-18.28	-47.09	0.30	$.58057 \times 10^{-1}$	6.91
Warehouse	-27.27	-47.09	-6.87	$.79704 \times 10^{-2}$	7.20

* = Numbers Incidence Angle Range

Table 8. Clutter Returns for Targets at Denver Stapleton Airport Polarimetric Set, X-HV

	Mean (dB)	MIN (dB)	Max (dB)	SDev (MAG)	$\frac{\text{Mean + SDev}}{\text{Mean}}$ (dB)
Grass (50-59)*	-32.53	-45.26	-12.73	$.91835 \times 10^{-3}$	4.032
Grass (75-79)*	-41.36	-45.26	-22.69	$.17296 \times 10^{-3}$	5.27
Residential (50-59)*	-24.14	-45.26	7.30	$.31966 \times 10^{-1}$	9.64
Residential (75-79)*	-32.17	-45.26	-3.86	$.45922 \times 10^{-2}$	9.372
Urban (60-64)*	-25.98	-45.26	3.96	$.17698 \times 10^{-1}$	9.07
Urban (75-79)*	-28.64	-45.26	6.77	$.12393 \times 10^{-1}$	9.94
Water (75-79)*	-43.99	-45.26	-30.04	$.80419 \times 10^{-4}$	4.79
City (75-79)*	-22.67	-45.26	4.98	$.42302 \times 10^{-1}$	9.46
Industrial (75-79)*	-45.26	-45.26	4.42	$.48488 \times 10^{-1}$	9.58
Parking Lot	-27.61	-45.26	-12.00	$.43188 \times 10^{-2}$	5.49
Runway	-45.84	-45.26	-17.95	$.22859 \times 10^{-3}$	8.71
Terminal	-16.89	-45.26	1.83	$.78860 \times 10^{-1}$	6.96
Warehouse	-25.47	-45.26	-5.11	$.11989 \times 10^{-1}$	7.23

* = Numbers Incidence Angle Range

Table 9. Man-Made Targets Represented as σ Polarimetric Set, HH

Identifier	Region	Θ	σ (dB)	Effective Area (m^2)
H1	Building	64.51	40.45	13296.96
H2	Terminal	77.65	49.69	18662.40
H3	Terminal	78.04	48.54	18631.30
H4	Building	80.23	44.90	8849.09
H5	Building	80.37	44.34	11290.75
H6	Building	78.29	39.52	4665.60
H7	Warehouse	78.38	39.73	6384.10
H8	Warehouse	78.47	35.57	6283.01
H9	Warehouse	78.53	37.24	3849.12
H10	Warehouse	78.60	35.97	6407.42

Table 10. Man-Made Targets Represented as σ
Polarimetric Set, VV

Identifier	Region	Θ	σ (dB)	Effective Area (m^2)
H1	Building	64.57	31.16	13296.96
H2	Terminal	77.65	44.63	18662.40
H3	Terminal	78.04	43.16	18639.07
H4	Building	80.23	41.09	8654.69
H5	Building	80.37	39.05	12433.82
H6	Building	78.29	37.89	4665.60
H7	Warehouse	78.38	34.81	6422.98
H8	Warehouse	78.47	32.02	6197.47
H9	Warehouse	78.53	33.68	3802.46
H10	Warehouse	78.60	29.92	6143.04

Table 11. Man-Made Targets Represented as σ Polarimetric Set, VH

Identifier	Region	Θ	σ (dB)	Effective Area (m^2)
H1	Building	64.51	14.19	13071.46
H2	Terminal	77.65	25.81	16057.44
H3	Terminal	78.04	22.30	14206.75
H4	Building	80.23	12.62	1741.82
H5	Building	80.37	14.85	1726.27
H6	Building	78.29	15.95	4269.02
H7	Warehouse	78.38	12.73	3289.25
H8	Warehouse	78.47	8.69	2099.52
H9	Warehouse	78.53	10.64	1889.57
H10	Warehouse	78.60	7.94	2472.77

Table 12. Man-Made Targets Represented σ

Polarimetric Set, HV

Identifier	Region	Θ	σ (dB)	Effective Area (m^2)
H1	Building	64.51	15.04	12908.16
H2	Terminal	77.65	27.14	16492.90
H3	Terminal	78.04	23.80	14253.41
H4	Building	80.23	14.34	1586.30
H5	Building	80.37	16.12	1640.74
H6	Building	78.29	17.62	4206.82
H7	Warehouse	78.38	14.44	3413.66
H8	Warehouse	78.47	10.66	2169.50
H9	Warehouse	78.53	12.51	2013.98
H10	Warehouse	78.60	9.63	2449.44

Table 13. Comparison of Sigma Returns of 60 cm Trihedral Reflectors

Reflector ID	Incidence Angle	σ (dB) X-HH	σ (dB) X-VV	σ Theoretical
60.12	56.8	27.30	26.24	26.81
60.14	76.1	26.85	25.05	26.34
60.16	77.9	25.52	26.86	26.01
60.02	78.0	24.96	26.53	25.74
60.22	80.8	24.48	26.46	25.32
60.08	81.3	26.60	27.16	25.17

Table 14. Aspect Angle Comparison Using the Polarimetric Set, Re Indicates Residential Clutter Areas

Area	θ	Orientation of Primary Face wrt Line Of Flight	X-VV	X-HH	X-VH	X-HV
Re12	79.6°	Parallel	-6.8	-1.94	-29.0	-27.6
Re13	79.7°	60°	-19.7	-19.5	-36.3	-34.7
Re14	79.8°	60°	-16.2	-14.9	-35.0	-33.3
Re16	80.7°	70°	-14.6	-22.1	-32.8	-32.2
Re21	81.5°	Parallel	-14.4	-16.1	-34.8	-33.2
Re22	81.6°	Parallel	-13.4	-13.8	-35.1	-34.3

Table 15. Image Composition Areal Analysis: Denver First 'Step West'

Clutter Scene	Percent of Total Image Area
Rural	31.8
Residential	10.2
Urban	30.1
Mixed	5.3
City	2.2
Warehouses	4.0
Airport Grounds and Terminals	14.0
Lowry AFB	2.4

Table 16. Clutter Returns for Targets at Denver Stapleton Airport, First 'Step West'

	Mean (dB)	MIN (dB)	Max (dB)	SDev (MAG)	$\frac{\text{Mean + SDev}}{\text{Mean}}$ (dB)
Grass (50-59)*	-24.64	-38.71	-6.60	$.32668 \times 10^{-2}$	2.90
Grass (75-79)*	-26.42	-38.71	-4.33	$.38398 \times 10^{-2}$	4.29
Residential (50-59)*	-18.24	-38.71	3.58	$.60453 \times 10^{-1}$	7.02
Residential (75-79)*	-17.00	-38.71	19.34	$.21828 \times 10^{0}$	10.77
Urban (75-79)*	-14.65	-38.71	11.42	$.19197 \times 10^{0}$	8.20
Water (65-69)*	-38.50	-38.71	-27.90	$.98888 \times 10^{-4}$	2.30
Water (75-79)*	-38.22	-38.71	-17.26	$.39668 \times 10^{-3}$	5.60
City (80-84)*	-9.53	-38.71	24.06	$.20831 \times 10^{1}$	12.94
Industrial (75-79)*	-10.78	-38.71	17.33	$.67768 \times 10^{0}$	9.60
Buildings	-14.50	-38.71	3.61	$.12622 \times 10^{0}$	6.59
Parking Lot	-13.49	-38.71	8.15	$.31819 \times 10^{0}$	9.09
Plane	-16.82	-38.71	-4.13	$.67021 \times 10^{-1}$	6.26
Terminal	-3.50	-38.71	21.97	$.45529 \times 10^{1}$	10.49
Warehouse	-10.46	-38.71	16.43	$.76626 \times 10^{0}$	9.79

* = Number Incidence Angle Range

Table 17. Man-Made Target RCS

Denver Airport, First 'Step West', HH

Identifier	Region	Θ	σ (dB)	Effective Area (m^2)
H1	Terminal	82.51	47.02	8164.80
H2	Terminal	82.49	37.92	6500.74
H3	Terminal	82.54	32.54	2581.63
H4	Warehouse	79.56	33.19	2659.39
H5	Warehouse	79.56	31.05	2892.67
H6	Warehouse	79.56	28.75	2550.53
H7	Warehouse	79.56	27.60	2581.63
H8	Building	70.10	28.90	22348.22
H9	Building	76.12	24.87	9673.34
H10	Building	76.12	23.80	10559.81
H11	Building	76.55	20.82	10777.54
H12	Building	78.42	30.48	4665.60
H13	Warehouse	80.44	32.66	8071.49
H14	Warehouse	80.48	33.42	5723.14
H15	Plane	82.35	10.06	77.76
H16	Plane	82.36	12.33	77.76
H17	Plane	82.45	17.42	248.83

Table 18. Image Composition Areal Analysis: Denver Second 'Step West'

Clutter Scene	Percent of Total Image Area
Rural	6.2
City	3.6
Industrial	3.2
Residential	10.9
Urban	30.0
Warehouses	3.5
Mixed	3.1
Airport Grounds and Terminals	11.6
Lowry AFB	3.8
Areas Unclassified	33.4

Table 19. Clutter Returns for Targets at Denver Stapleton Airport, Second 'Step West'

	Mean (dB)	MIN (dB)	Max (dB)	SDev (MAG)	Mean + SDev (dB) / Mean
Grass (50-59)	-27.82	-39.89	10.94	$.18182 \times 10^{-2}$	3.22
Grass (70-74)	-23.68	-39.89	-8.16	$.43218 \times 10^{-2}$	3.03
Residential (50-59)	-21.42	-39.89	1.80	$.23816 \times 10^{-1}$	6.34
Residential (70-74)	-16.70	-39.89	8.22	$.68150 \times 10^{-1}$	6.22
Urban (70-74)	-13.80	-39.89	16.36	$.26352 \times 10^{0}$	8.65
Water (65-69)	-36.28	-39.89	-16.76	$.92841 \times 10^{-3}$	6.94
City (80-84)	-2.91	-39.89	31.08	$.84665 \times 10^{1}$	12.44
Industrial (70-74)	-8.80	-39.89	22.28	$.19420 \times 10^{1}$	11.97
Warehouses	-11.14	-39.89	12.40	$.41337 \times 10^{0}$	8.04
Terminal	-4.74	-39.89	21.98	$.30517 \times 10^{1}$	10.04
Parking Lot	-8.95	-39.89	12.59	$.50041 \times 10^{0}$	6.93

Table 20. Hard Targets Represented as σ
Denver Airport, Second 'Step West', HH

Identifier	Region	Θ	σ (dB)	Effective Area (m^2)
H1	Warehouse	72.46	34.34	36671.61
H2	Warehouse	69.62	24.70	4354.56
H3	Warehouse	69.62	28.15	4587.84
H4	Warehouse	69.62	23.10	4276.80
H5	Warehouse	69.62	23.54	4059.07
H6	Terminal	78.39	44.60	34292.16
H7	Terminal	78.36	40.35	34121.09
H8	Terminal	78.51	36.05	24043.39
H9	Warehouse	74.67	32.08	16282.94

Table 21. Image Composition Areal Analysis: Denver Third 'Step West'

Clutter Scene	Percent of Total Image Area
Residential	3.0
Lowry AFB	3.0
Airport Grounds and Terminal	8.4
Warehouse	1.5
Rural	1.0
Urban	34.0
Parks	2.3
City	6.5
Industrial	10.3
Areas Unclassified	30.0

Table 22. Clutter Returns for Targets at Denver Stapleton Airport, Third 'Step West'

	Mean (dB)	MIN (dB)	Max (dB)	SDev (MAG)	Mean + SDev (dB) / Mean
Grass (40-49)	-25.26	-39.69	-14.74	$.30500 \times 10^{-2}$	3.06
Residential (40-49)	-16.44	-39.69	8.87	$.15151 \times 10^{0}$	8.85
Urban (50-59)	-21.72	-39.69	5.64	$.44291 \times 10^{-1}$	8.80
City (75-79)	-13.98	-39.69	16.47	$.38371 \times 10^{0}$	10.25
Industrial (40-49)	-29.02	-39.69	-18.57	$.11345 \times 10^{-2}$	2.80
Parking Lot	-13.48	-39.69	1.91	$.78172 \times 10^{-1}$	4.38
Planes	-12.80	-39.69	2.40	16549×10^{0}	6.18
Terminal	-9.56	-39.69	12.61	$.56524 \times 10^{0}$	7.86
Runway	-37.38	-39.69	-21.49	$.24541 \times 10^{-3}$	3.70
Buildings	-11.45	-39.69	16.97	$.69836 \times 10^{0}$	10.31

Table 23. Man-Made Represented at σ

Denver Airport, Third 'Step West', HH

Identifier	Region	Θ	σ (dB)	Effective Area (m^2)
H1	Terminal	67.90	37.51	40824.00
H2	Terminal	67.82	37.47	42674.69
H3	Terminal	68.33	32.63	30995.14
H4	Plane	66.23	23.01	762.05
H5	Building	70.22	31.15	13934.59
H6	Building	70.77	30.98	15847.49
H7	Building	70.88	33.28	9222.34
H8	Building	66.54	28.94	14727.74
H9	Building	68.40	26.22	4650.05
H10	Building	67.99	24.57	4650.05
H11	Building	67.87	30.33	12192.77
H12	Building	65.10	25.70	7387.20
H13	Warehouse	62.60	25.07	26313.98
H14	Building	76.61	27.67	6936.19
H15	Plane	66.51	11.25	1368.58
H16	Plane	66.46	12.40	1570.75
H17	Plane	67.21	18.59	1632.96
H18	Plane	67.87	18.51	777.60
H19	Plane	67.72	15.13	1135.30
H20	Plane	66.76	15.29	1026.43
H21	Plane	68.26	15.63	762.05
H22	Plane	68.04	20.53	777.60
H23	Plane	67.37	18.03	777.60

Table 24. Image Composition Areal Analysis: Denver Fourth 'Step West'

Clutter Scene	Percent of Total Image Area
Urban	22.4
Mixed	2.1
Industrial	15.6
City	5.6
Parks	1.0
Residential	0.6
Areas Unclassified	52.7

Table 25. Clutter Returns for Targets at Denver Stapleton Airport, Fourth 'Step West'

	Mean (dB)	MIN (dB)	Max (dB)	SDev (MAG)	$\frac{\text{Mean + SDev (dB)}}{\text{Mean}}$
Grass (65-69)	-19.01	-39.53	0.14	$.30053 \times 10^{-1}$	5.31
Residential (50-59)	-19.67	-39.53	9.47	$.85470 \times 10^{-1}$	9.50
Urban (50-59)	-15.27	-39.53	14.80	$.16302 \times 10^{0}$	8.12
Water (70-74)	-35.19	-39.53	-19.90	$.69052 \times 10^{-3}$	5.16
City (50-59)	-14.48	-39.53	12.58	$.24981 \times 10^{0}$	9.04
Industrial (50-59)	-13.76	-39.53	16.88	$.56079 \times 10^{0}$	11.56
Buildings	-9.48	-39.53	17.18	$.10622 \times 10^{1}$	10.18
Trees (65-69)	-16.16	-39.53	-0.07	$.68691 \times 10^{-1}$	5.84

Table 26. Hard Targets Represented as σ
Denver Airport, Fourth 'Step West', HH

Identifier	Region	Θ	σ (dB)	Effective Area (m^2)
H1	Building	80.28	29.58	2799.36
H2	Building	80.12	28.01	1228.61
H3	Building	80.12	20.61	559.87
H4	Building	81.92	18.86	419.90
H5	Building	82.54	29.47	730.94
H6	Building	82.80	30.38	435.46
H7	Building	81.68	22.33	388.80
H8	Building	82.00	28.16	637.63
H9	Building	81.80	20.55	497.66
H10	Building	82.05	22.73	233.28
H11	Building	82.09	19.53	326.59
H12	Building	81.23	18.03	466.56
H13	Building	82.42	18.29	248.83
H14	Building	82.23	20.70	419.90
H15	Building	81.55	36.13	9657.79
H16	Building	81.94	29.62	995.33
H17	Building	81.48	30.88	870.91
H18	Building	81.47	34.76	1601.86
H19	Building	83.21	28.26	388.80
H20	Building	83.18	28.98	559.87
H21	Building	83.87	33.49	295.49
H22	Building	83.87	26.39	139.97
H23	Building	83.93	27.76	186.62
H24	Building	84.03	35.43	357.70
H25	Building	84.83	35.00	279.94
H26	Building	84.08	36.75	762.05
H27	Building	84.58	32.50	155.52

Table 27. Comparison of Image Statistics at HH-Polarization

Image	Min (dB)	Max (dB)	Mean (dB)	Variance	Coefficient of Variation
Full Pol Set	-44.08	36.50	-6.47	54.04	32.64
1st Step West	-38.71	35.54	-8.61	25.48	36.69
2nd Step West	-39.89	37.17	-6.80	25.94	24.35
3rd Step West	-39.69	42.08	-7.64	106.99	60.10
4th Step West	-39.53	49.09	-5.14	1127.10	109.70

Table 28a. Common Clutter Areas, HH

Region \ Image	Second 'Step West'	Third 'Step West'	Pol. Set, X-HH	First 'Step West'	Fourth 'Step West'
Grass	G4	G2	X	X	X
	G5	G3	G18	X	X
	G12	G5	X	G54	X
	G13	G6	X	X	X
	G14,G15	G7	X	G53	X
	G16	G8	X	X	X
	G17	G10	X	G55	X
	G21	G16	X	X	G1
	G19	X	X	G56	X
	G1	X	X	G7	X
	X	X	G1	G59	X
	X	X	G2	G46	X
	X	X	G3	G45	X
Hard Targets	H2	X	H7	X	X
	H3	X	H8	X	X
	H4	X	H9	X	X
	H5	X	H10	X	X
	H1	X	X	H13	X
	H6	H1	H2	H1	X
	H7	H2	H3	H2	X
	H8	H3	X	H3	X
Miscellaneous	M1	M1	M5	M1	X
	X	X	M4	M2	X
Industrial	I10	I3	X	I13	I1
	I11	X	X	I14	I2
	I12	I4	X	X	I3
	I13	I5	X	X	I4

Table 28b. Common Clutter Areas, HH

Region \ Image	Second 'Step West'	Third 'Step West'	Pol. Set, X-HH	First 'Step West'	Fourth 'Step West'
Industrial	I14	I6	X	X	I5
	I5	X	I1	X	X
	I7	X	I2	X	X
	X	X	I3	I2	X
	X	I14	X	X	I12
	I1,I2	I1	X	I7,I8	X
	I3,I4	I2	X	I9,I10	X
	I15	I7	X	X	I6
	X	X	I13,I14	I5	X
	X	X	I5	I10	X
Residential	Re17	X	X	X	Re1
	Re18	X	X	X	Re2
	Re19	X	Re24	Re7	Re4
	Re10,11,12	X	Re1	X	X
	Re8	X	Re5	Re23	X
	Re6,Re7	X	Re8	Re24,25	X
	Re5	X	Re25	X	X
	X	Re5	X	X	Re6
	X	Re7	X	X	Re7
	X	Re2	X	X	Re4
	Re4	X	Re20,21,22	X	X
	Re13	X	X	Re22	X
	Re14	X	X	Re26	X
	X	X	Re7	Re3	X
	X	X	Re9	Re4	X
	X	X	Re11	Re6	X
	X	X	Re14	Re16	X

Table 28c. Common Clutter Areas, HH

Region \ Image	Second 'Step West'	Third 'Step West'	Pol. Set, X-HH	First 'Step West'	Fourth 'Step West'
Residential	X	X	Re15	Re15	X
	X	X	Re17,18,19	Re11	X
	X	X	Re21,22	Re8	X
	Re15	Re1	Re23	X	X
	Re9	Re13	Re4	X	X
Urban	U2	U2	U17	X	X
	U5	U3	U19	U7	X
	U6	U4	X	U8	X
	U7	U5	X	U9	X
	U10	U9	U13,U14	X	U1
	U11	U10	U12,U13	X	U2
	U12	U11	U10,U11	X	U3
	U13	U13	U9,U10	X	U4
	U14	U8	U20	U6	X
	U8	X	X	X	U6
	U9	X	U5,U6,U7	X	U5
	U1	X	U16	U1	X
	U3	X	U18	U2	X
	X	U3	X	U3	X
	X	U13	U15	X	X
	X	X	U3,U4	X	U14
	X	X	U1	X	U15
City	C4	X	C8,C9	C3	C6
	C5	X	C8,C9	C4	C7
	C9	M6	X	X	X
	C10	M5	X	X	X
	C12	M3	X	X	X

Table 28d. Common Clutter Areas, HH

Region \ Image	Second 'Step West'	Third 'Step West'	Pol. Set, X-HH	First 'Step West'	Fourth 'Step West'
City	C13	M2	X	C1	C1
	C6	C7	X	X	C8
	X	C2	C1,2,3,4,5	X	X
	X	C3	C6,C7	X	X
	C7	C8	X	X	C9
	C8	C10	X	X	C10
	C1	C4	X	C5	C3
	C2	C5	X	C6	C4
	C3	C6	X	X	C5
Runway	Ru1	X	Ru1	X	X
	Ru2	X	Ru5	X	X
Water	W1	X	X	W1	X
	W2,W3	X	X	W2	X

Table 29. Aspect Angle Comparison

Feature	Incidence Angle	σ°, X-HH Polarmetric Return North Look	σ°, X-HH Double Swath Return West Look
Grass	77.3°	-31.86	-27.45
Terminal	78.5°	6.98	-1.78
Terminal	78.2°	5.83	-6.04
Parking lot	78.7°	-4.20	-8.95
Industrial	78.9°	2.32	-12.03
Industrial	81°	0.23	-10.72
Residential	67.2°	-13.02	-14.48
Residential	79.5°	-16.08	-17.48
Residential	79.5°	-13.78	-17.48
Residential	79°	-22.12	-18.46
Residential	79°	-23.00	-18.46
Residential	79.5°	-23.23	-18.46
Urban	77.2°	-8.76	-17.88
Urban	77°	-10.17	-17.88
Urban	75°	-10.71	-14.54
Urban	77.7°	-0.85	-17.88
Urban	64.6°	-5.66	-12.67
City	80.4°	2.73	-5.16
City	80.5°	4.61	-4.63

Table 30. Common Areas Observed With Different Incidence Angles, HH Polarization

Feature	Incidence Angle (deg)	NRCS Value (dB)
	39.8	-23.07
Grass	68.3	-23.67
	79.1	-27.67
	58.2	-19.66
Residential	81.0	-18.18
	83.2	-24.60
	67.9	-8.60
Terminal 1	78.4	-1.78
	82.5	0.63
	67.8	-8.92
Terminal 2	78.4	-6.04
	82.5	-8.47
	66.6	-13.50
Parking Lot	78.0	-8.95
	82.4	-13.14
	38.9	-1.90
	71.7	-10.16
Industrial 1	72.5	-12.38
	80.0	-10.31
	80.3	-7.60
	45.1	-6.26
	73.4	-13.76
Industrial 2	80.0	-3.80
	83.2	-12.63

Table 30. (Cont'd)

Feature	Incidence Angle (deg)	NRCS Value (dB)
	70.8	-10.56
	79.1	-9.35
City 1	82.5	-2.43
	84.5	-15.05
	46.7	-11.78
	73.9	-13.20
City 2	80.2	-5.95
	83.4	-10.23
	51.3	-14.50
	74.5	-13.08
City 3	80.5	-2.99
	83.5	-10.34
	64.1	-14.00
Urban 1	77.9	-13.65
	82.3	-16.78
	73.0	-15.07
Urban 2	79.0	-12.98
	83.1	-19.19
	68.7	-12.94
Urban 3	78.2	-10.94
	82.9	-11.22

Table 31. Comparison of Clutter Statistics

Residential

Image	Mean (dB)	Variance	Coefficient of Variation
Third 'SW', HH	-17.19	0.5053×10^{-2}	3.72
Second 'SW', HH	-16.70	0.464×10^{-2}	3.19
First 'SW', HH	-15.62	0.116×10^{-1}	3.93
Pol. Set, HH	-8.79	$0.109 \times 10^{+1}$	7.88
Fourth 'SW', HH	-11.76	0.636×10^{-1}	3.79
Philadelphia, HH	-19.61	0.150×10^{-1}	11.21
Pol. Set, VV	-15.26	0.484×10^{-1}	7.38

Urban

Image	Mean (dB)	Variance	Coefficient of Variation
Pol. Set, VV	-15.31	0.385×10^{-1}	6.66
Fourth 'SW', HH	-12.45	0.527×10^{-1}	4.04
Pol. Set, HH	-7.96	$0.228 \times 10^{+1}$	9.43
First 'SW', HH	-14.65	0.369×10^{-1}	5.61
Second 'SW', HH	-13.80	0.694×10^{-1}	6.32
Third 'SW', HH	-15.70	0.103×10^{-1}	3.77

City

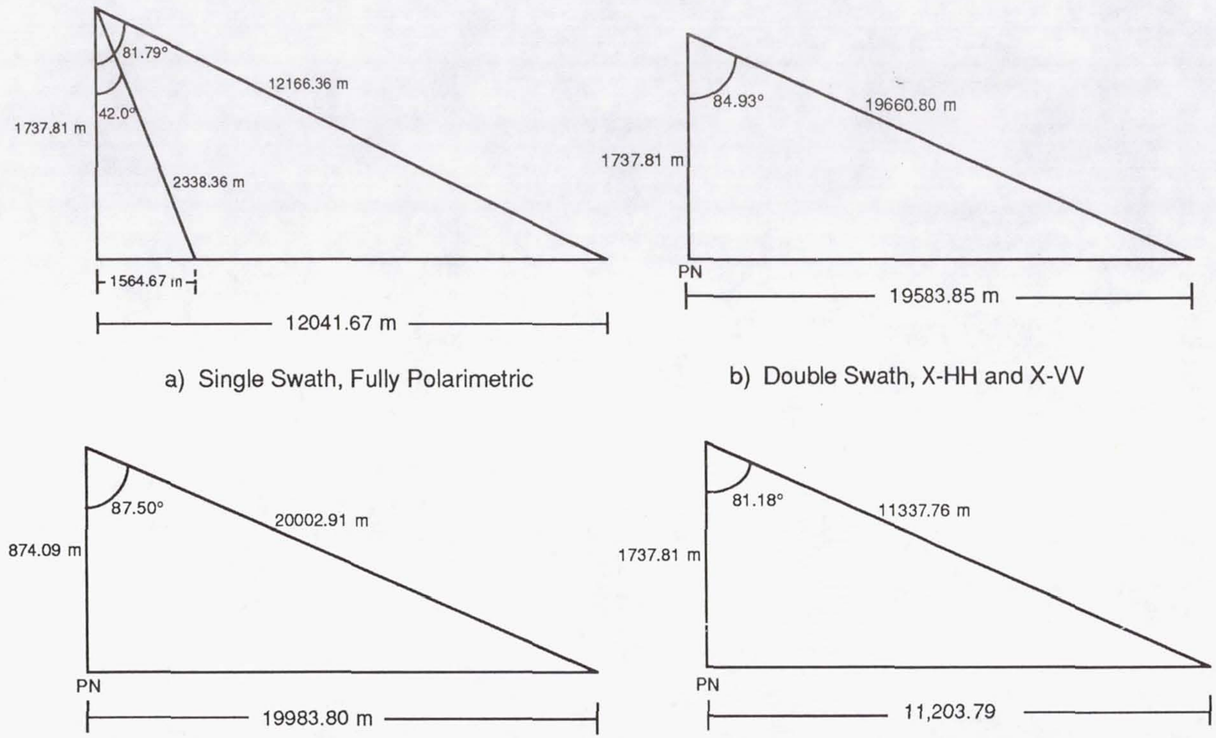
Image	Mean (dB)	Variance	Coefficient of Variation
Pol. Set, VV	-1.10	0.648×10^{2}	10.36
Third 'SW', HH	-13.11	0.320	11.58
Second 'SW', HH	-2.91	71.680	16.55
First 'SW', HH	-9.53	4.339	18.71
Pol. Set, HH	5.15	$1.395 \times 10^{+4}$	11.42
Fourth 'SW', HH	-12.93	0.100	6.22

Table 31. (Cont.)

		Industrial	
Philadelphia, HH	-7.35	1.223×10^{1}	18.98
Fourth 'SW', HH	-5.54	5.768×10^{1}	8.61
Pol. Set, HH	3.38	3.61×10^{3}	8.72
First 'SW', HH	-10.78	.4582	8.11
Second 'SW', HH	-8.80	3.771×10^{1}	14.72
Third 'SW', HH	-13.76	0.416×10^{-1}	4.85
Pol. Set, HV	-3.34	0.161×10^{2}	8.65
		Grass	
Pol. Set, VV	-31.33	0.171×10^{-5}	1.82
Third 'SW', HH	-24.29	0.144×10^{-4}	1.02
Second 'SW', HH	-23.67	0.194×10^{-4}	1.02
First 'SW', HH	-21.35	0.731×10^{-4}	1.17
Pol. Set, HH	-21.00	0.109×10^{-3}	1.31
Fourth 'SW', HH	-24.63	0.156×10^{-4}	1.14
Philadelphia, HH	-23.64	0.314×10^{-4}	1.30
		Terminal	
Philadelphia, HH	3.99	$.317 \times 10^{3}$	7.11
Pol. Set, VV	1.28	$.221 \times 10^{2}$	3.56
Pol. Set, HV	-16.89	$.621 \times 10^{-2}$	3.85
Pol. Set, HH	6.48	$.291 \times 10^{3}$	3.84
First 'SW', HH	-3.50	$.207 \times 10^{2}$	10.18
Second 'SW', HH	-4.74	$.931 \times 10^{1}$	9.08
Third 'SW', HH	-9.56	.320	5.11
		Warehouse	
Pol. Set, VV	-4.72	$.267 \times 10^{1}$	4.85
Pol. Set, HH	-0.24	$.200 \times 10^{2}$	4.73
First 'SW', HH	-10.46	.587	8.52
Second 'SW', HH	-11.14	.171	5.37
Pol. Set, HV	-25.47	$.144 \times 10^{-3}$	4.23

Table 32.
Cross Reference Table

Image Name	SAR Image	Clutter Returns Table #	Bar Chart Figure #	Histogram Figure #	σ^o Step Figure #	PDF Figure #	Areal Analysis	Man-Made Targets	Incidence Angle Plots	Appendix Figure #	Appendix Table #
Den. Pol. Set, X-HH	P3T625	5	14	18	19-23	24-54, 228	4	9	44-48 65-69	B-1	B-1
Den. Pol Set, X-VV	P3T638	6	15	NA	NA	55, 58-64	4	10	65-69	NA	B-6
Den. Pol. Set, X-VH	P3T639	7	16	NA	NA	56, 58-64	4	11	65-69	NA	B-7
Den. Pol. Set, X-HV	P3T640	8	17	NA	NA	57, 58-64	4	12	65-69	NA	B-8
Den. 1st Step West	P3T629	16	70	71	72-76	77-97, 103-107, 229	15	17	98-102	B-2	B-2
Den. 2nd Step West	P3T583	19	108	109	110-114	115-135,141-143, 230	18	20	136-140	B-3	B-3
Den. 3rd Step West	P3T587	22	144	145	146-150	151-180, 186-189, 231	21	23	181-185	B-4	B-4
Den. 4th Step West	P3T647	25	190	191	192-196	197-219, 225-227, 232	24	26	220-224	B-5	B-5



a) Single Swath, Fully Polarimetric

b) Double Swath, X-HH and X-VV

c) Low Altitude Double Swath, X-HH and X-VV

d) Mid-Angle Single Swath, Fully Polarimetric

Figure 1. Image Geometries Used in the Denver Collection
a) Single Swath
b) Double Swath
c) Low Altitude
d) Mid-Angle

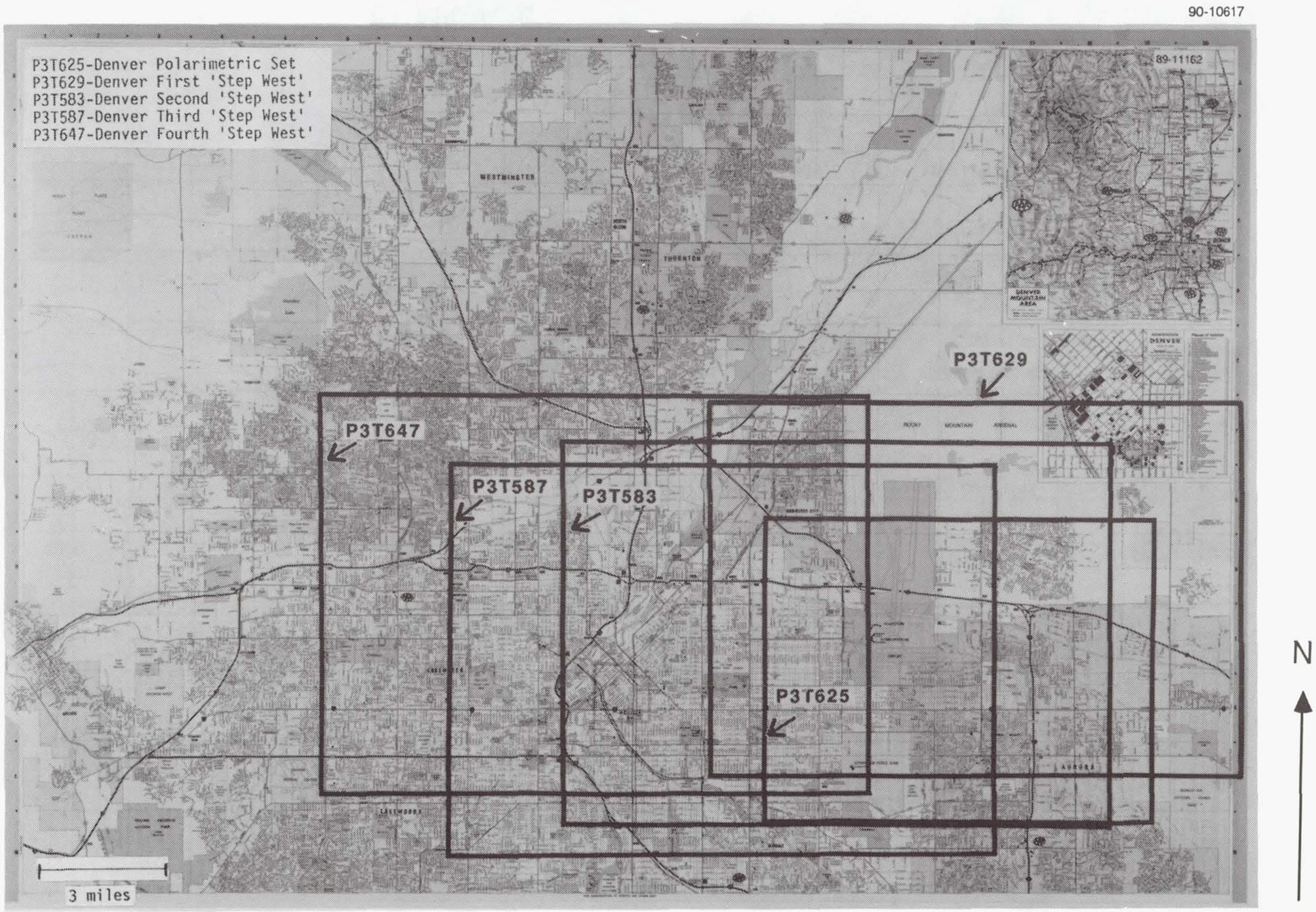


Figure 2. Ground Coverage of the Processed Denver Images

Parameter	Value
Altitude	1524 m
Depression Angle	8°
Distance to Touchdown Point	10844 m
Resolution	2.7 m * 3.0 m
Pixel Spacing	1.62 m * 2.4 m
Image Size	12 km * 9.8 m
Polarizations	VV, VH, HH, HV
Frequency	X, L, C

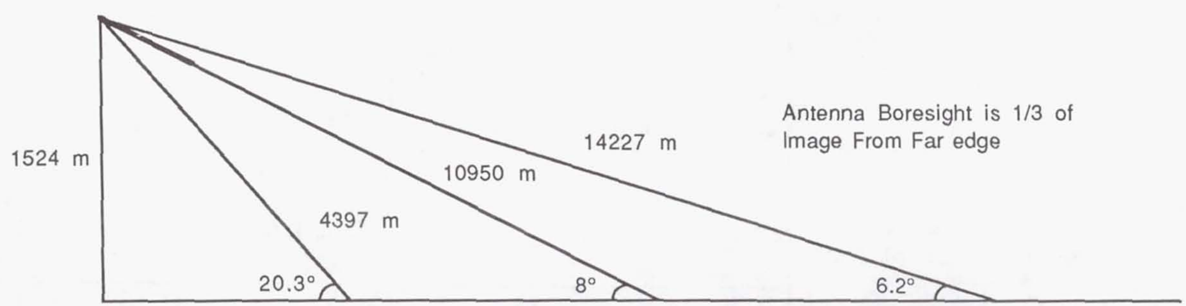


Figure 3. Proposed SAR Imaging Geometry.

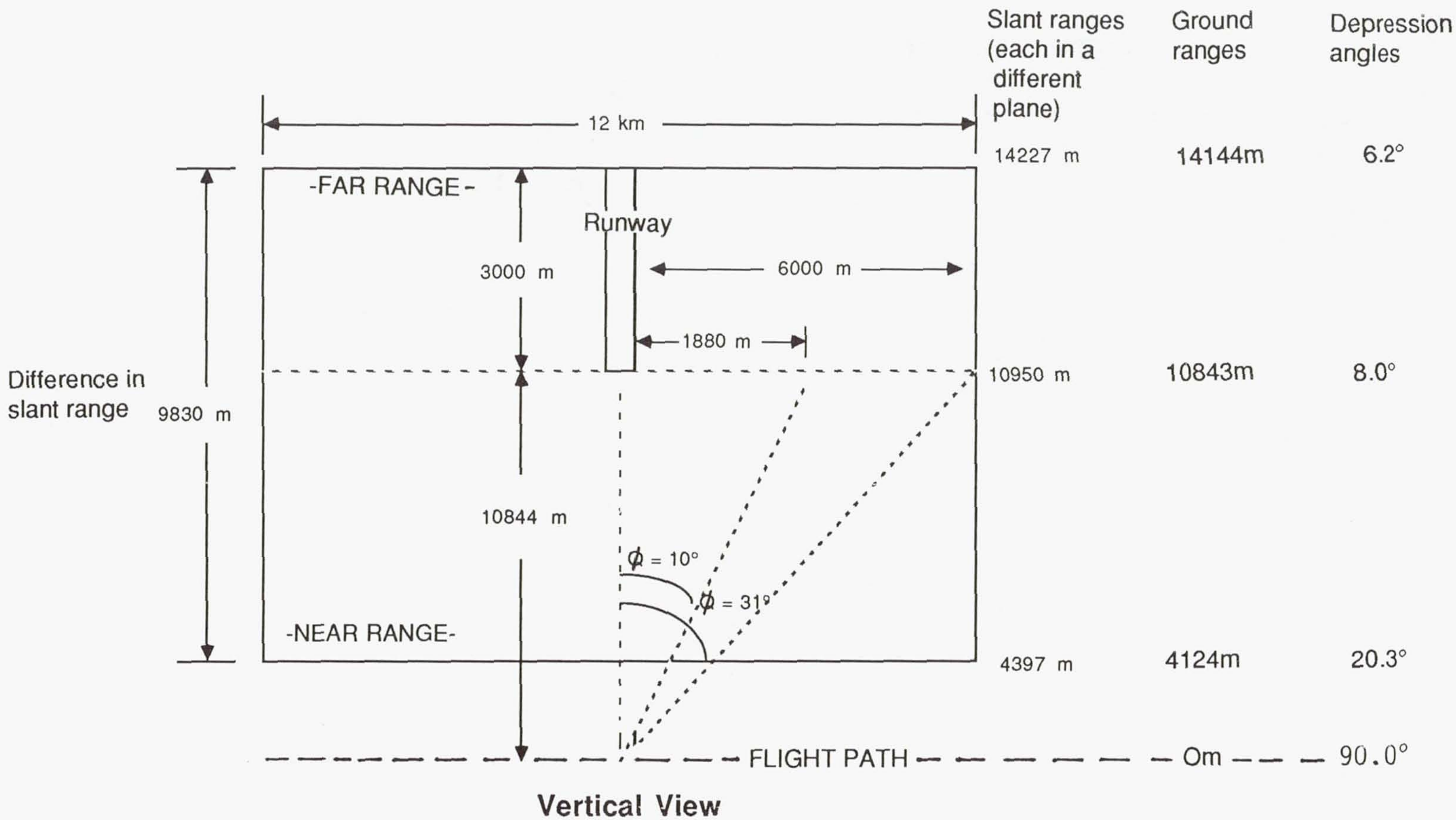


Figure 4. Proposed SAR Imaging Geometry.

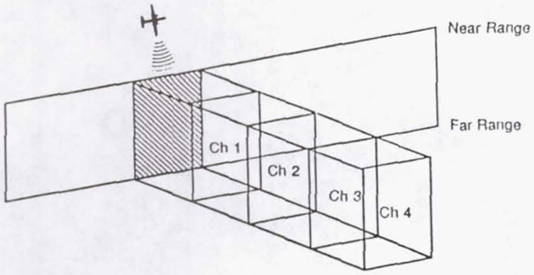


Figure 5a. Single-Swath Mode

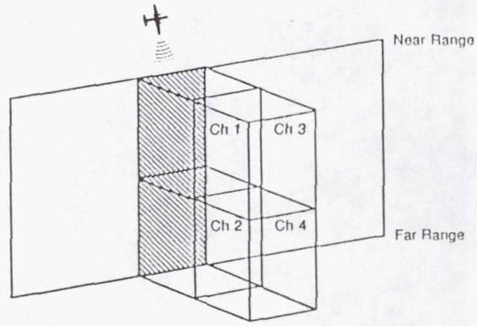


Figure 5b. Double-Swath

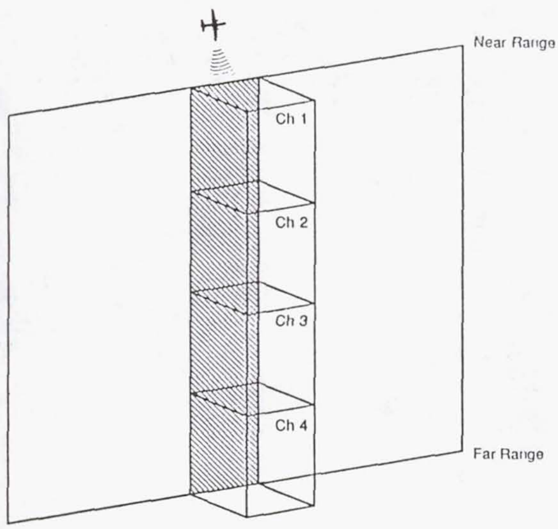


Figure 5c. Quad-Swath Mode

Figure 5. P-3 SAR Swath Modes

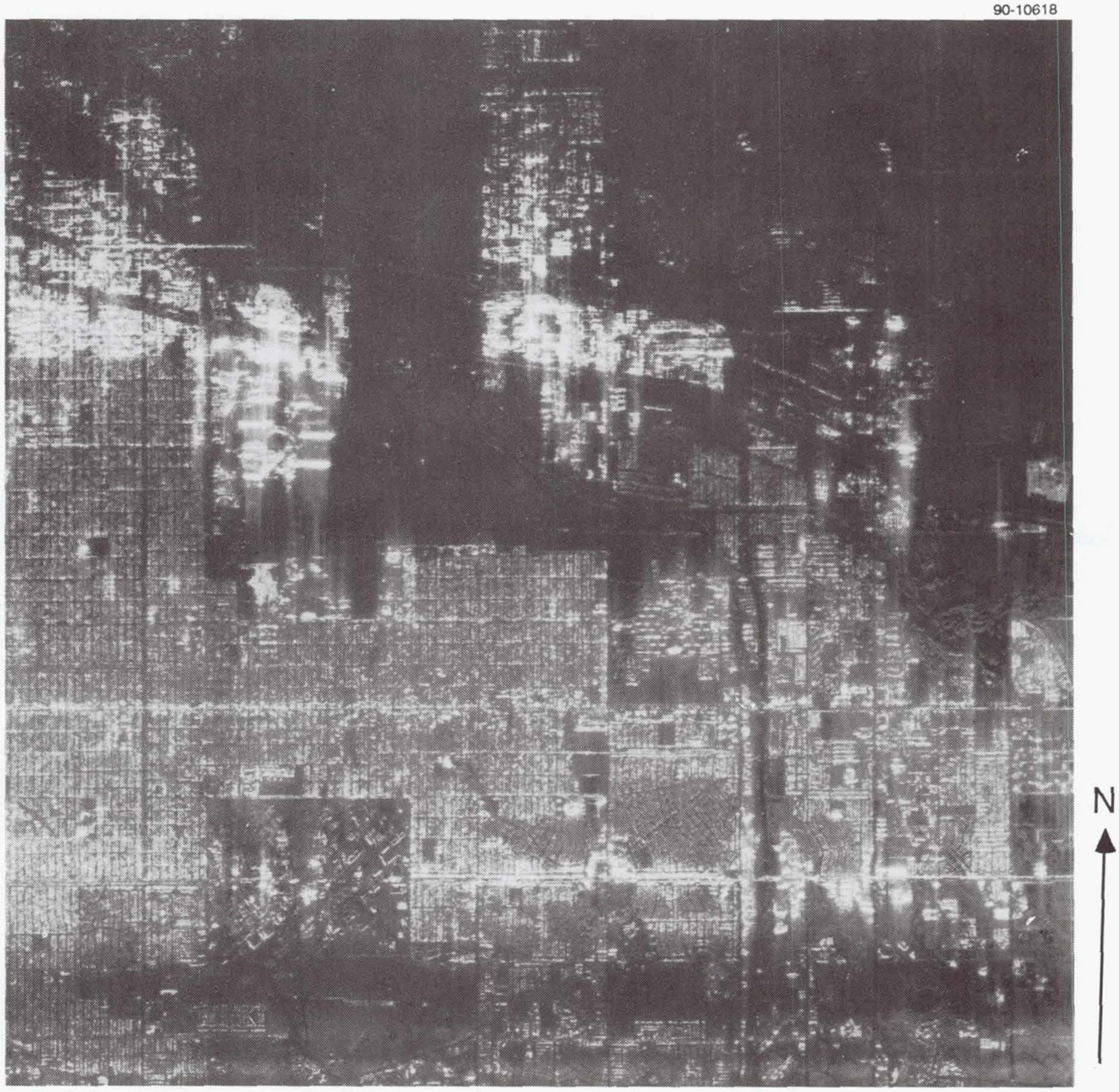


Figure 6. Denver Stapleton International Airport Polarimetric Set, HH

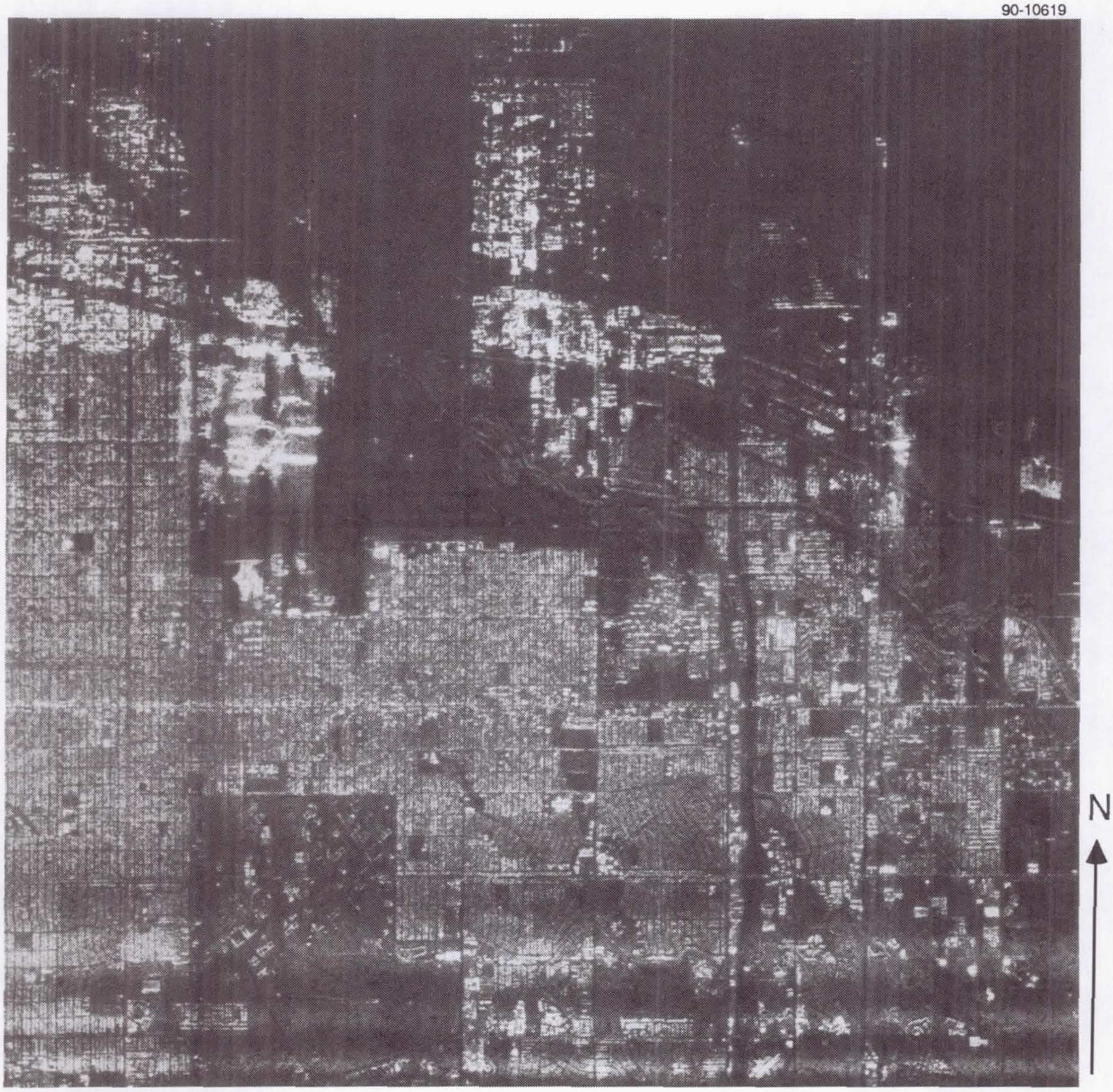


Figure 7. Denver Stapleton International Airport Polarimetric Set, VV

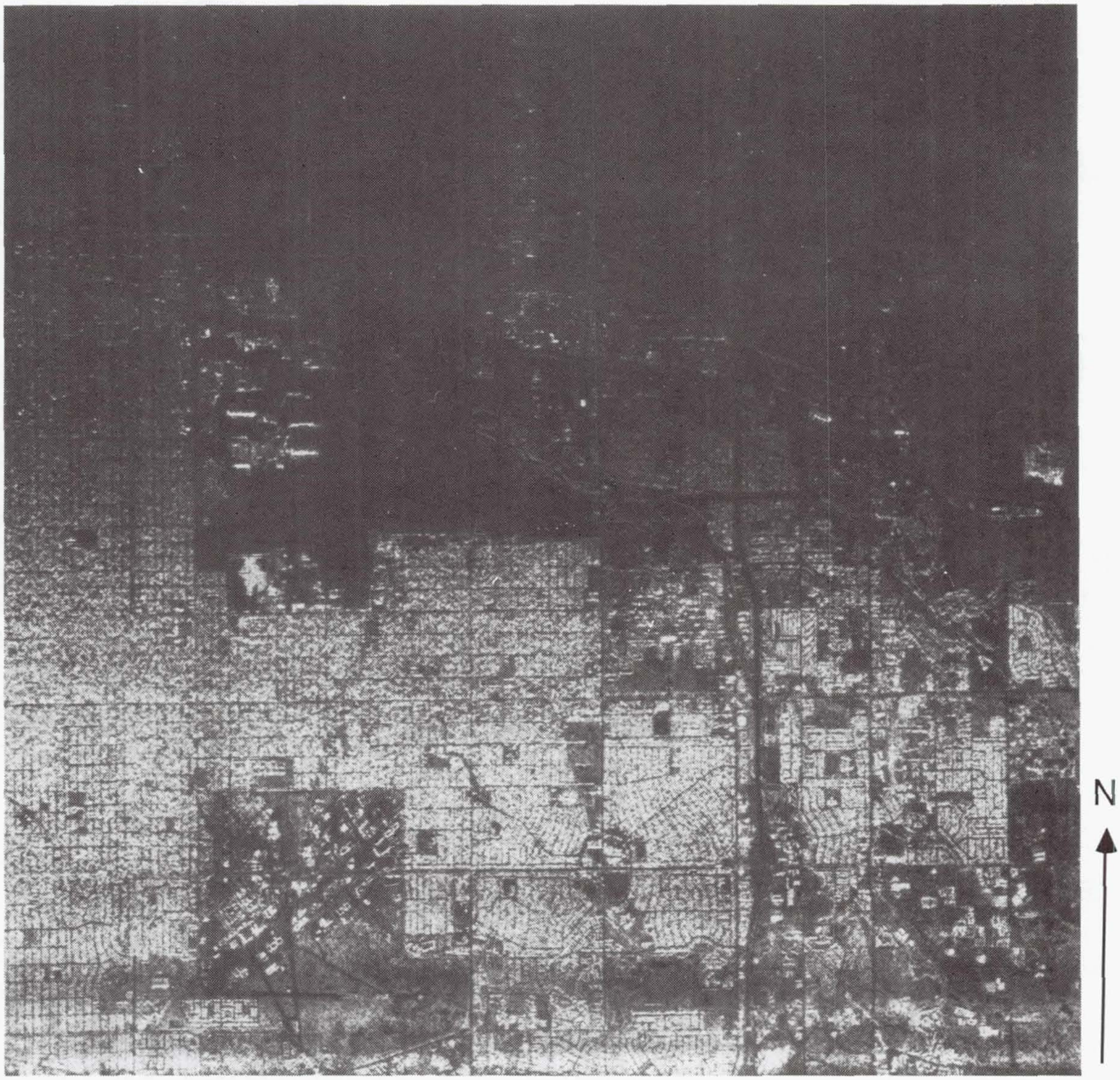


Figure 8. Denver Stapleton International Airport Polarimetric Set, VH

90-10621

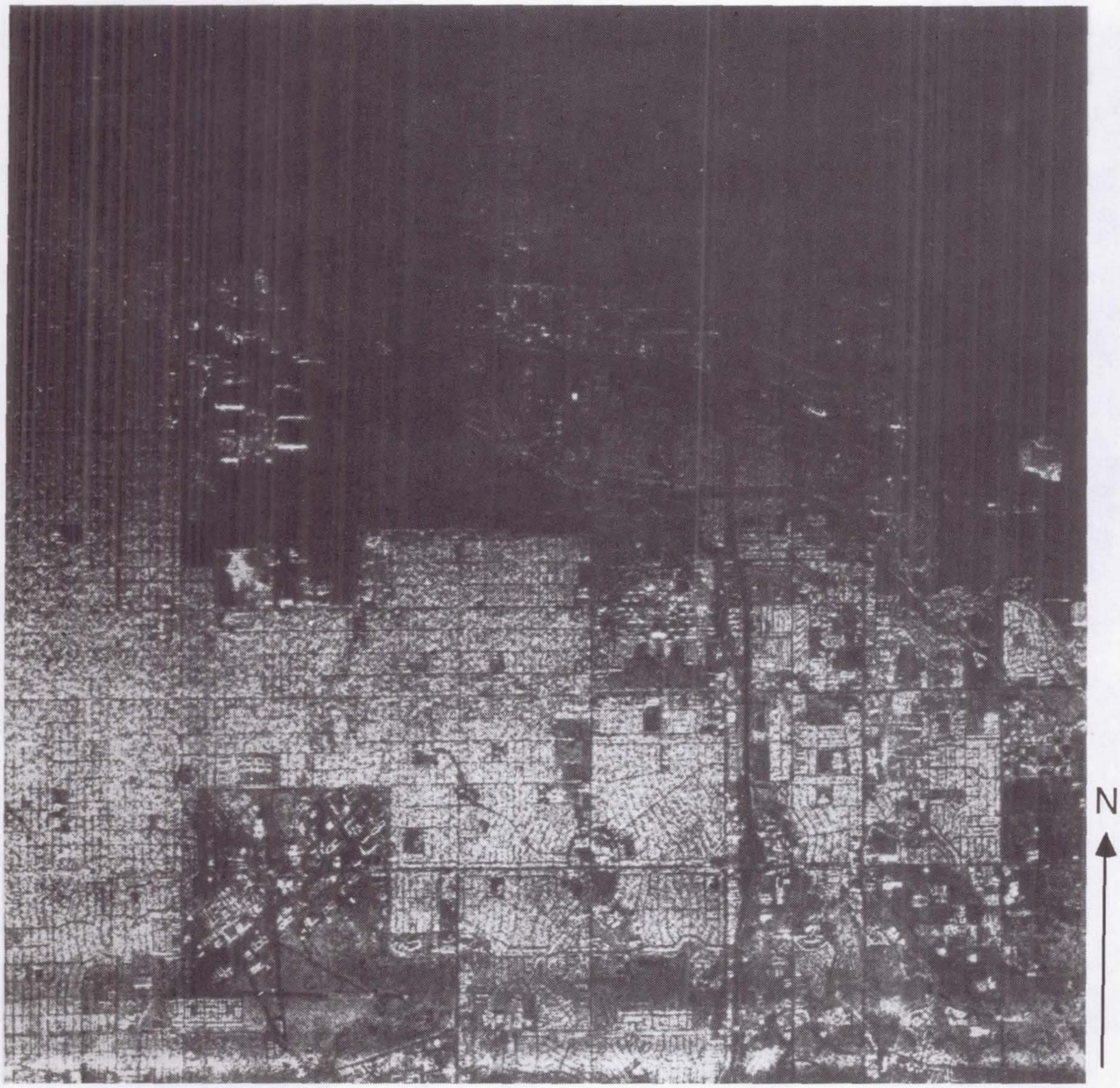


Figure 9. Denver Stapleton International Airport Polarimetric Set, HV

90-10622

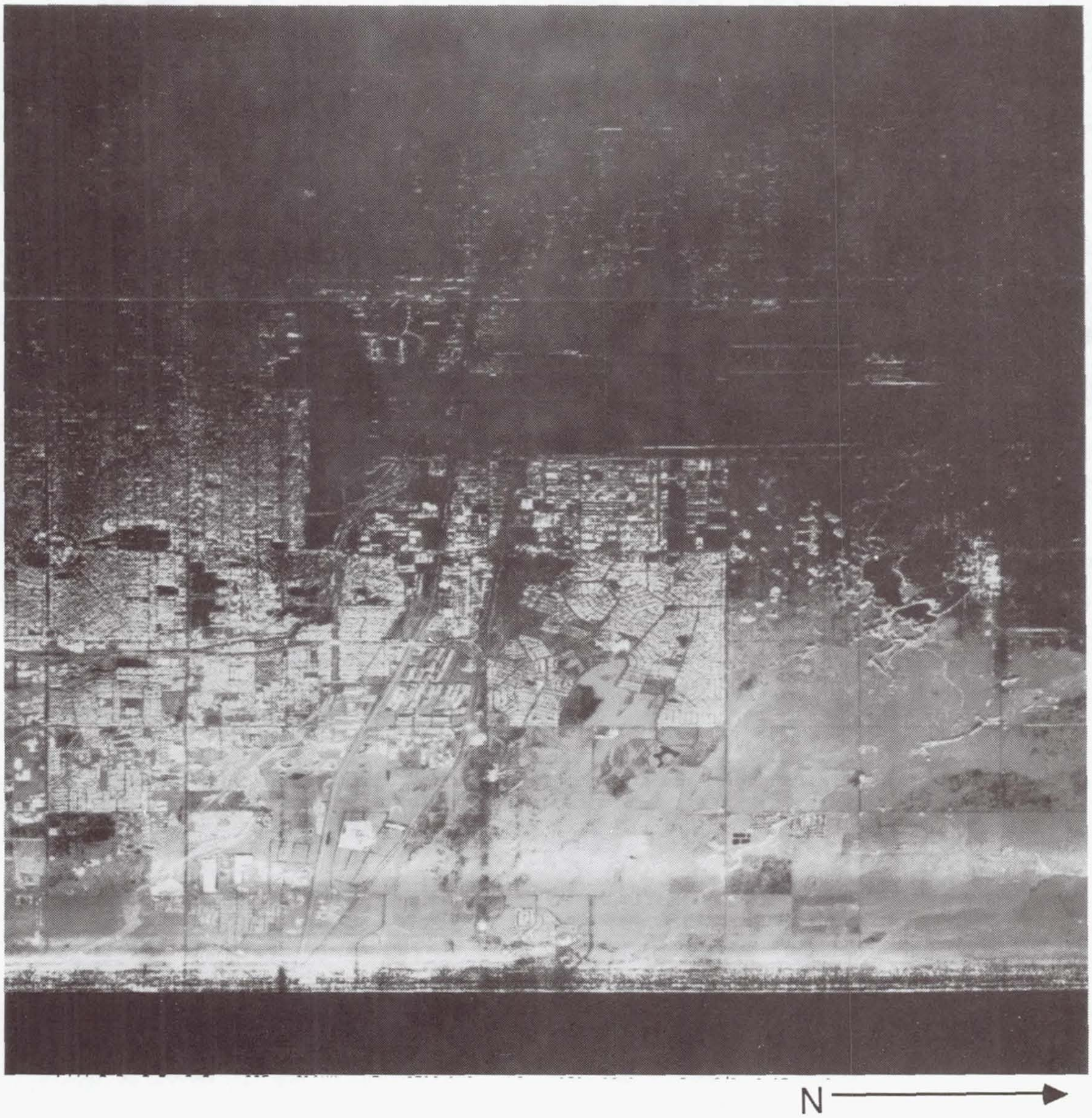


Figure 10. Denver Area, First Step West, X-HH

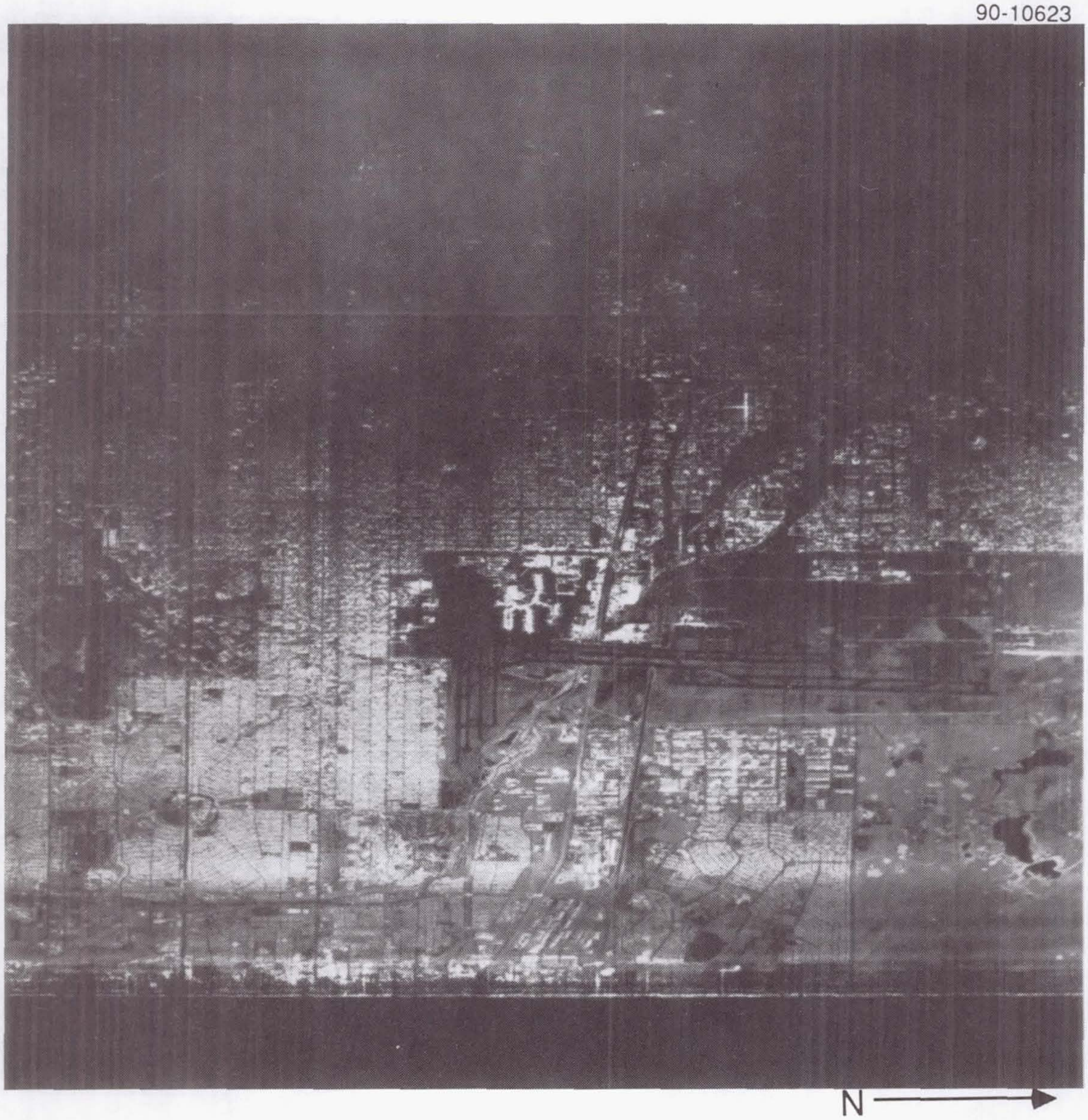


Figure 11. Denver Area, Second Step west, X-HH

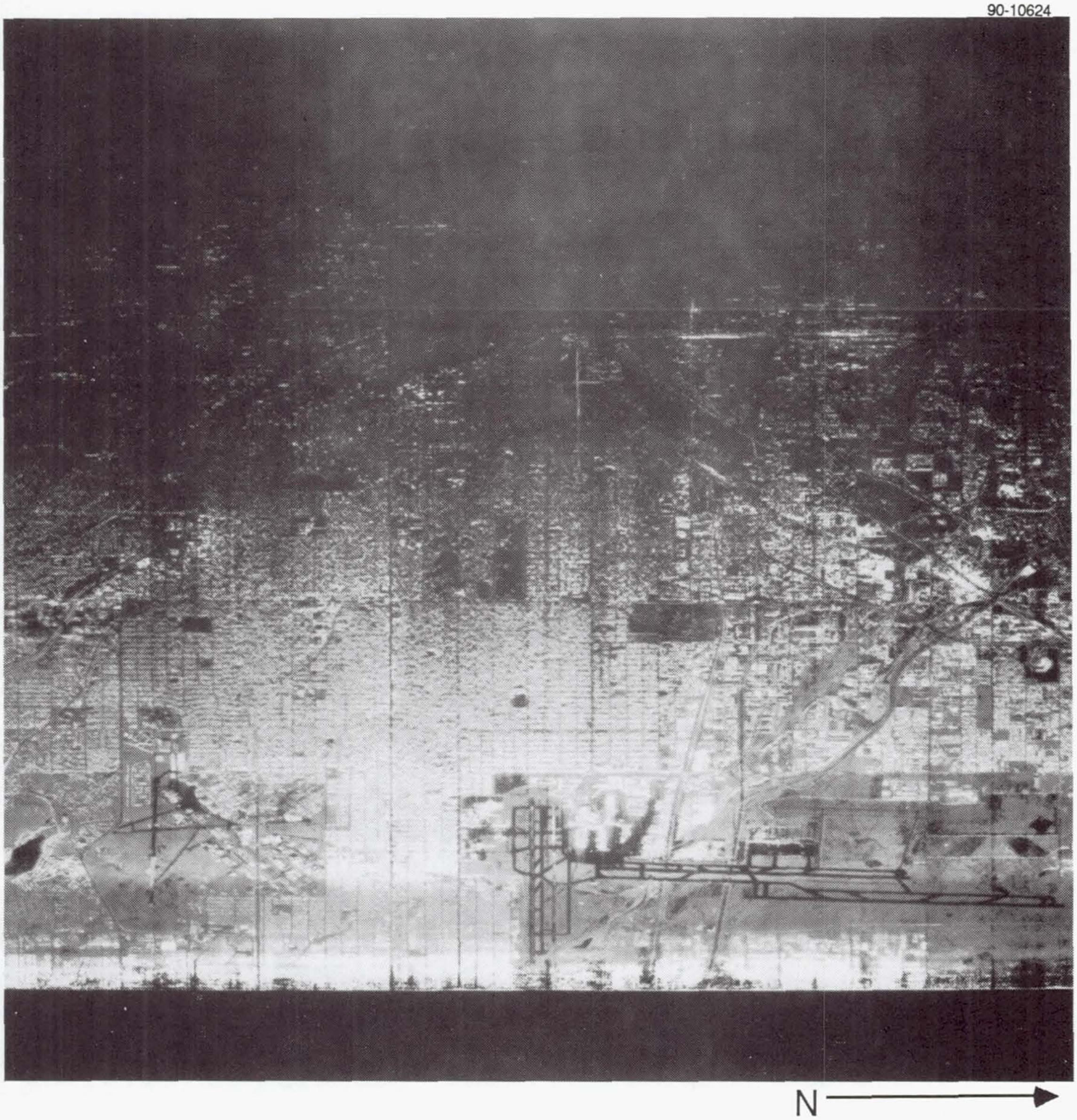


Figure 12. Denver Area, Third Step West, X-HH

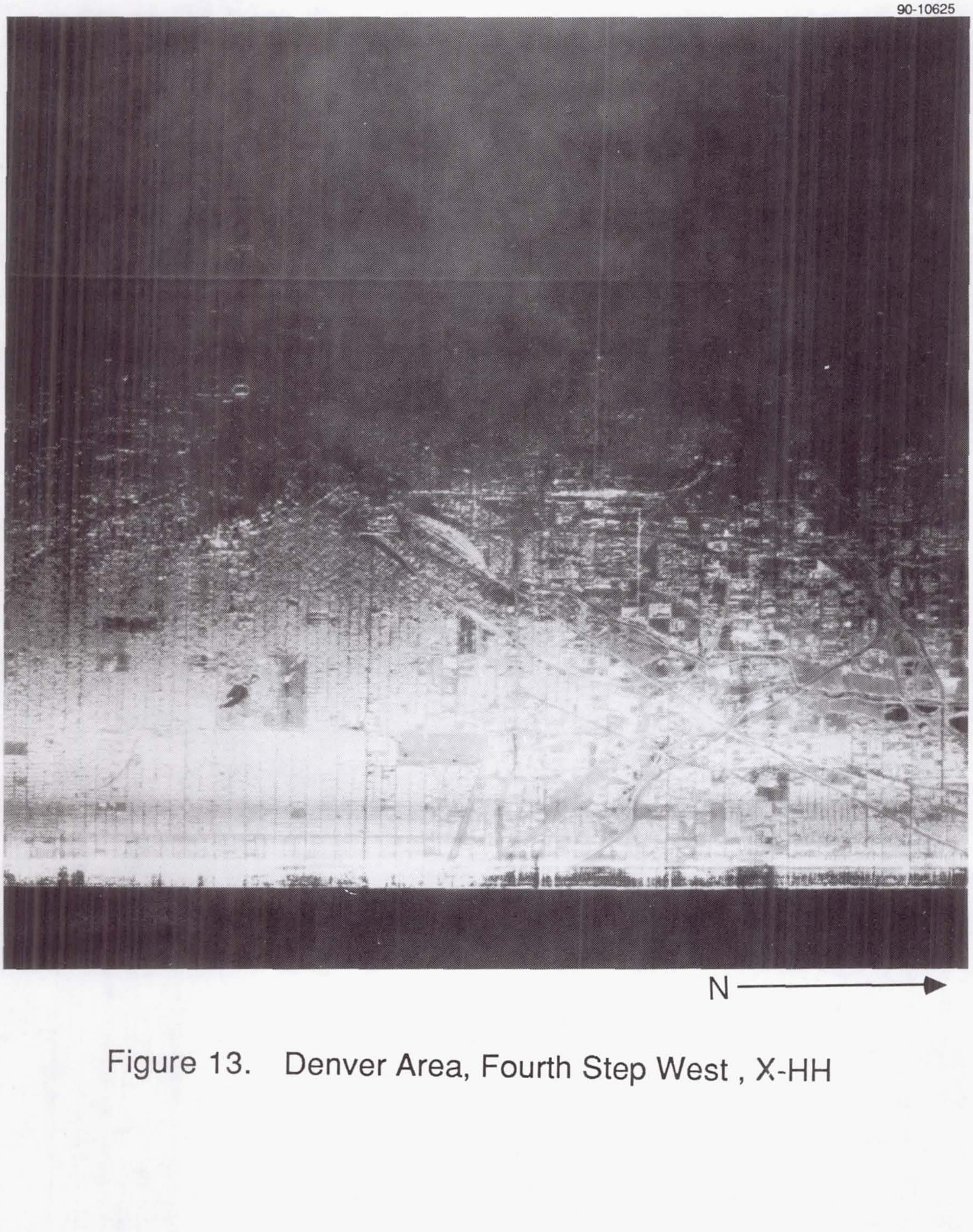


Figure 13. Denver Area, Fourth Step West , X-HH

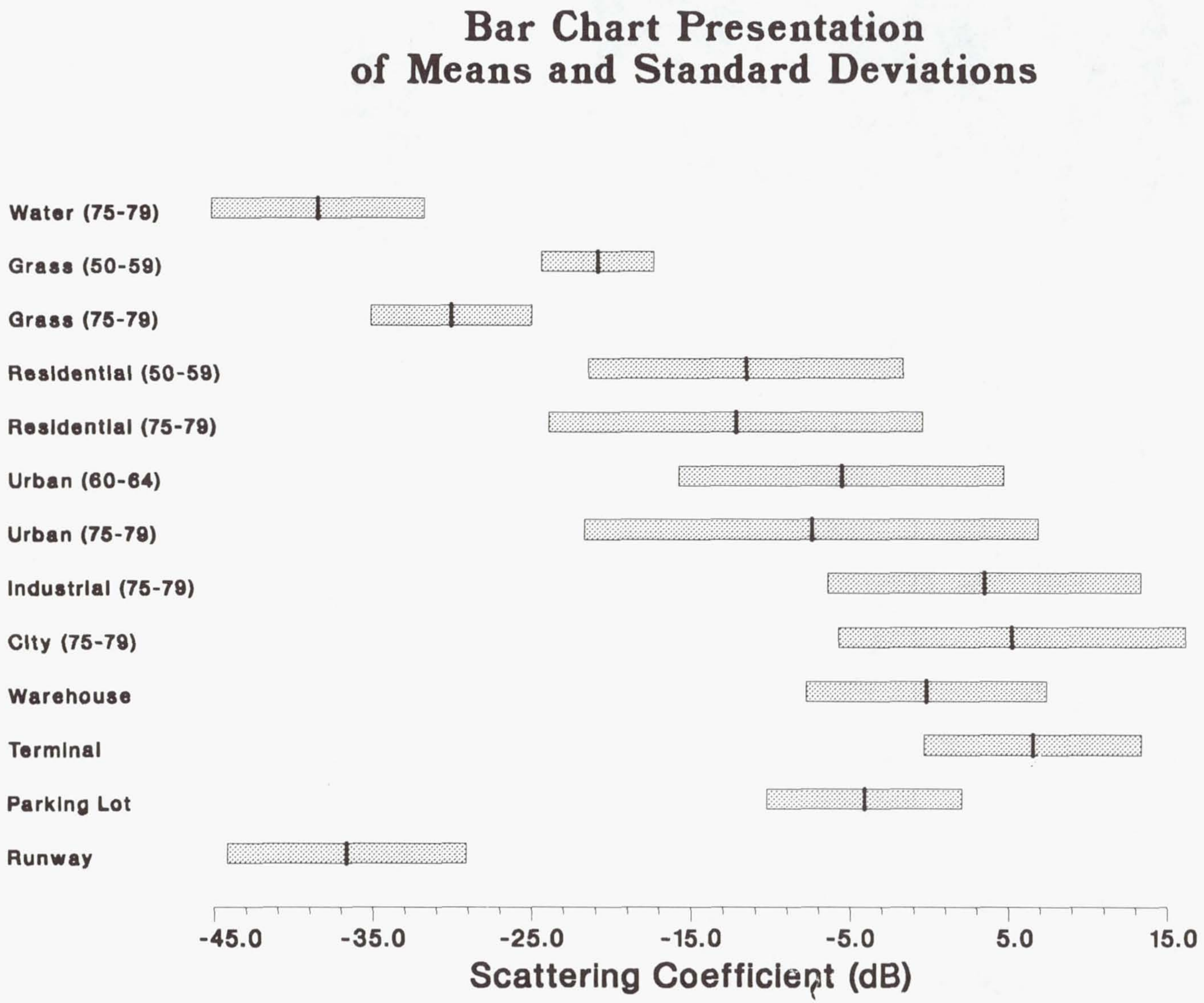


Figure 14. Mean Scattering Coefficient Values, Denver Polarimetric Set, X-HH

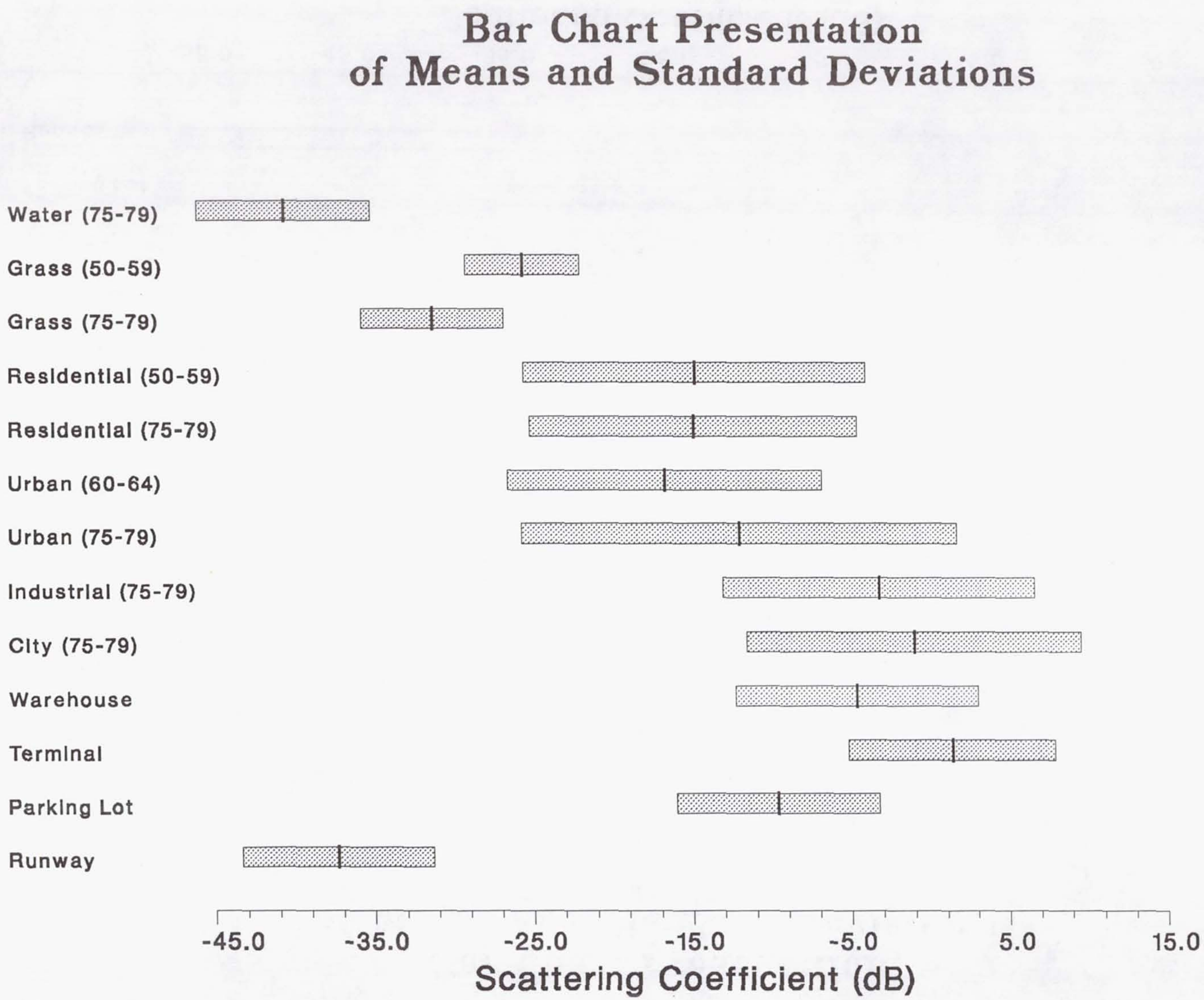


Figure 15. Mean Scattering Coefficient Values, Denver Polarimetric Set, X-VV

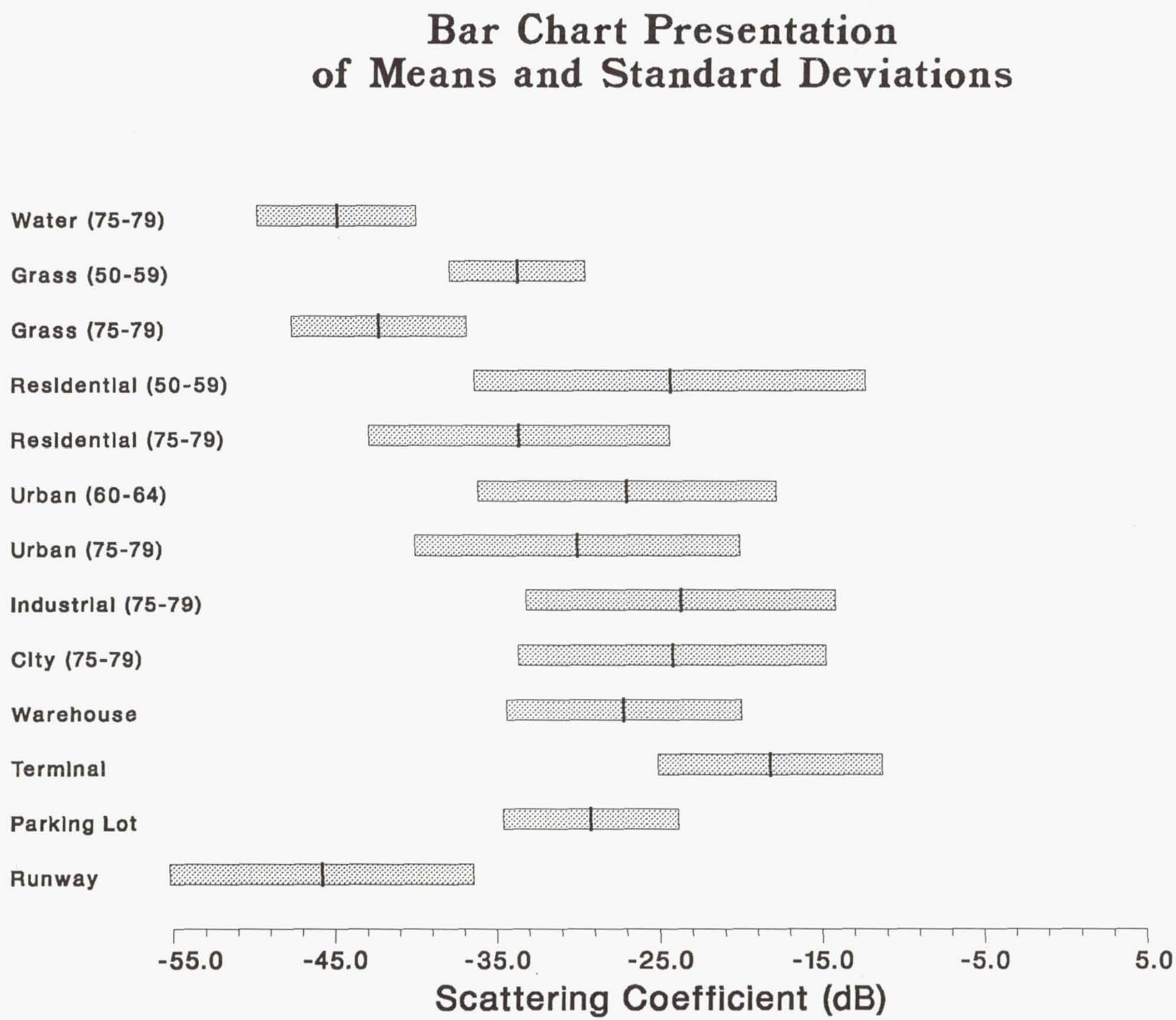


Figure 16. Mean Scattering Coefficient Values, Denver Polarimetric Set, X-VH

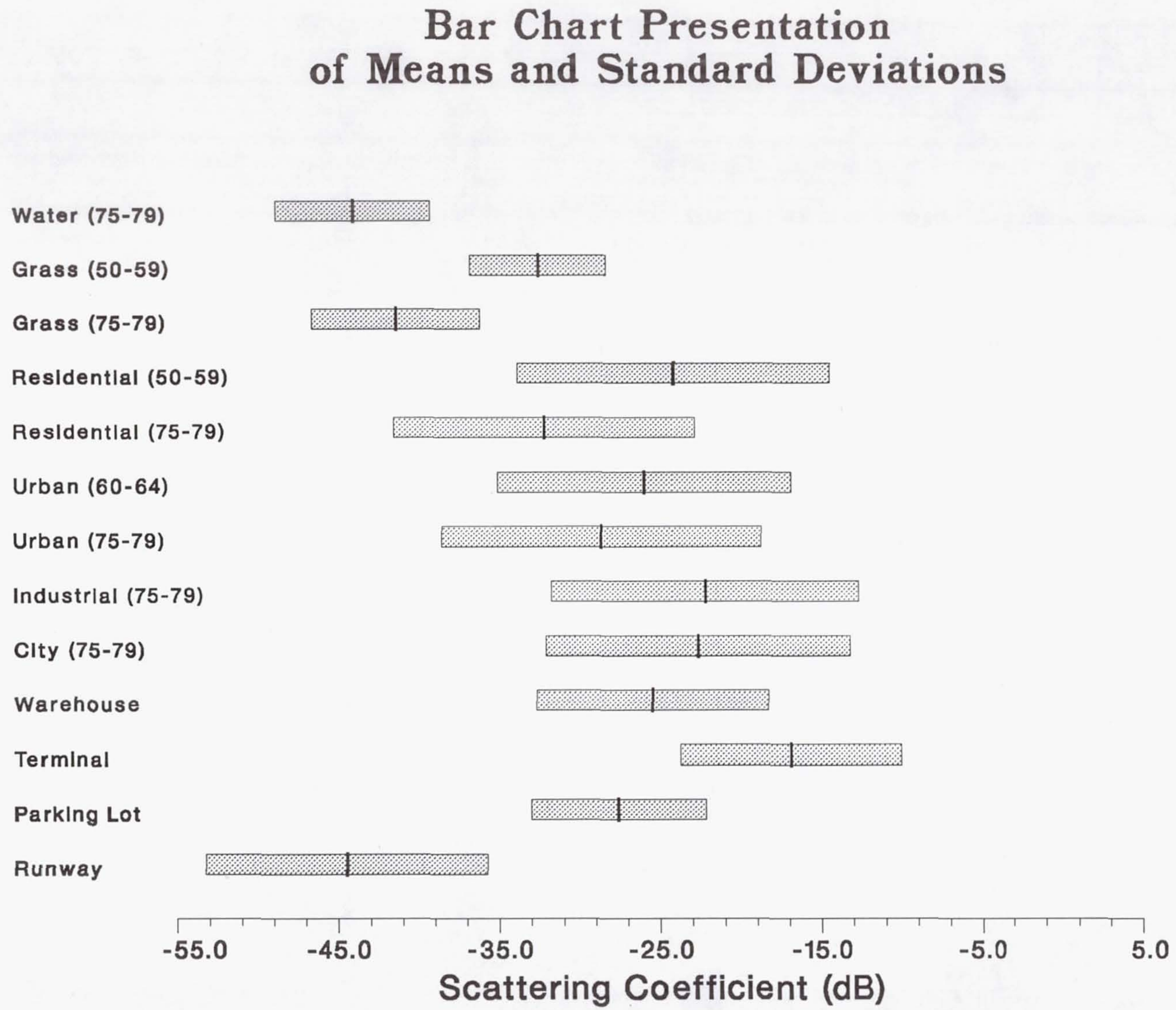


Figure 17. Mean Scattering Coefficient Values, Denver Polarimetric Set, X-HV

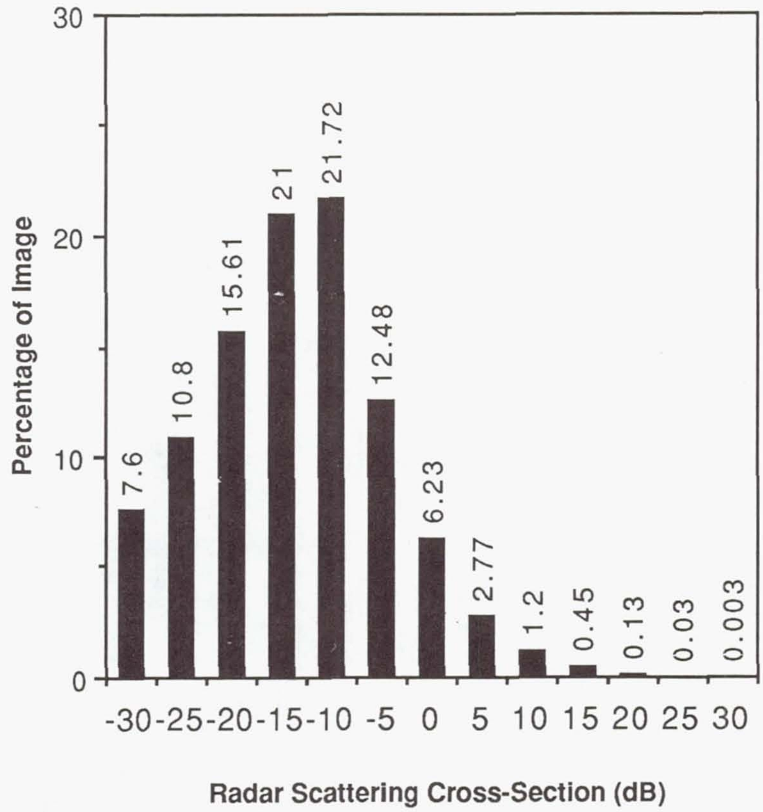


Figure 18. Distribution of Threshold Values, Denver Polarimetric Set, HH Polarization

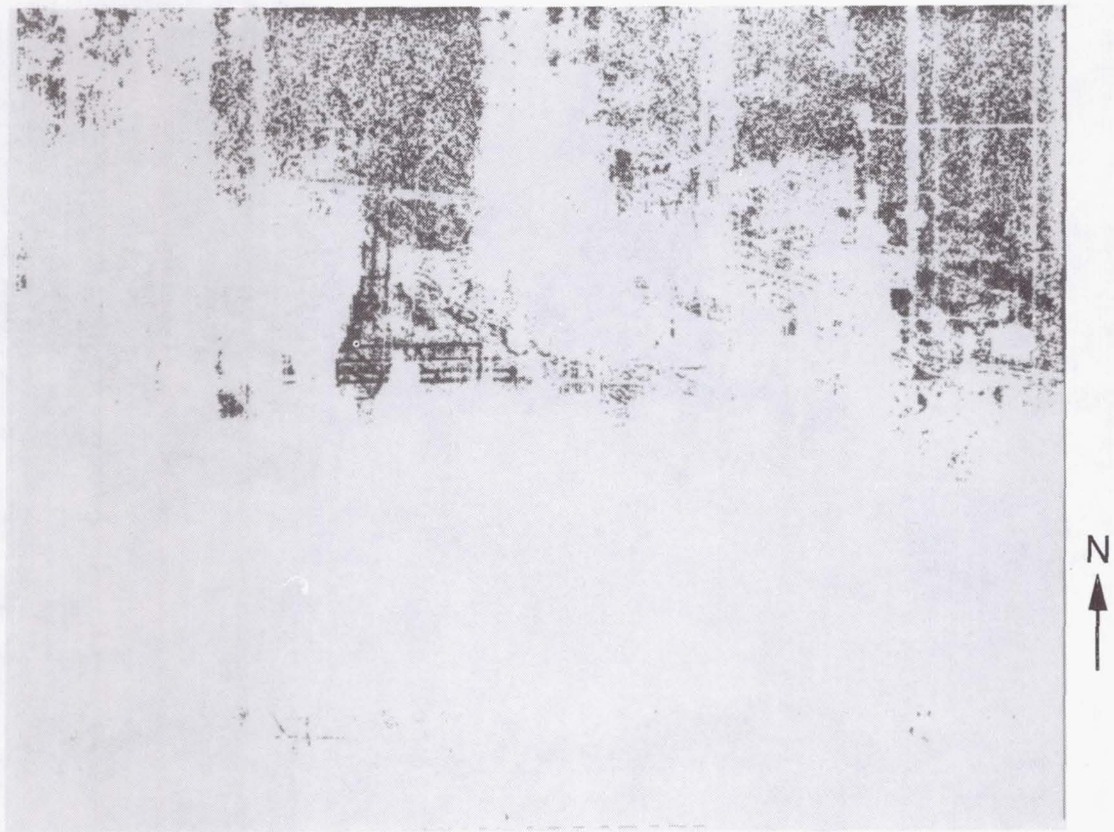


Figure 19. The Denver X-HH Polarimetric Image Thresholded at -30 dB

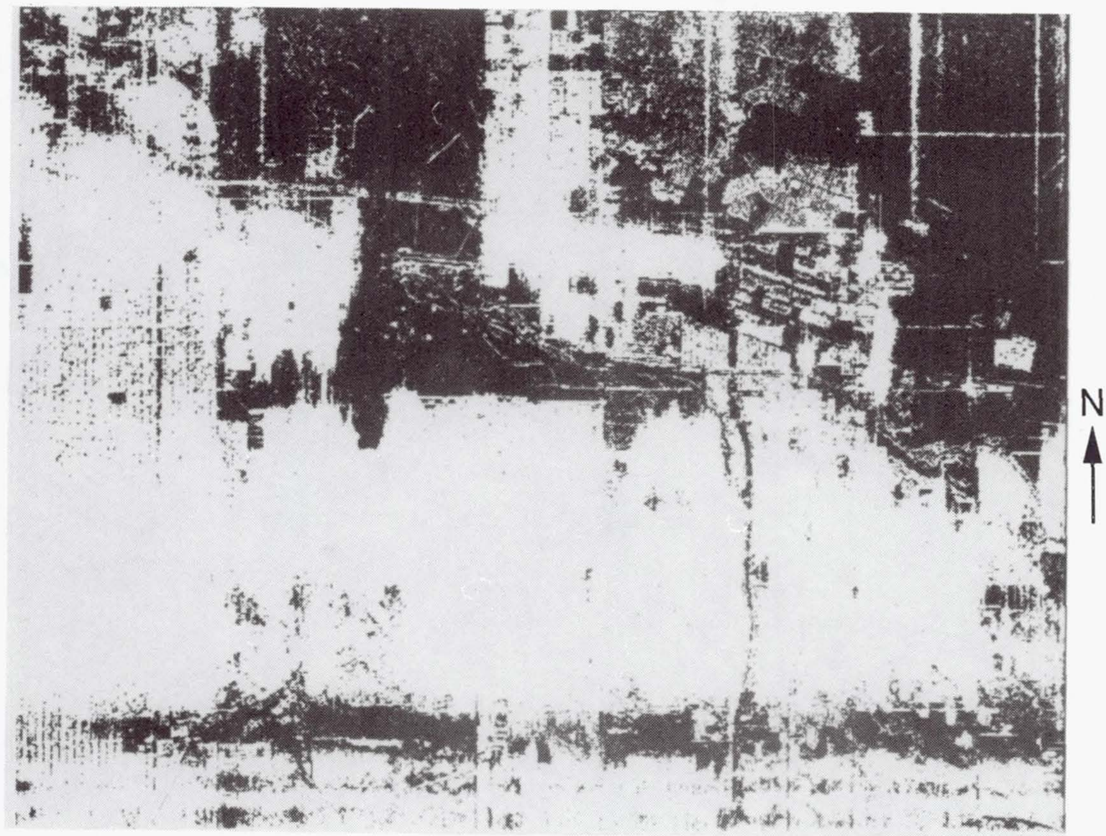


Figure 20. The Denver X-HH Polarimetric Image Thresholded at -20 dB

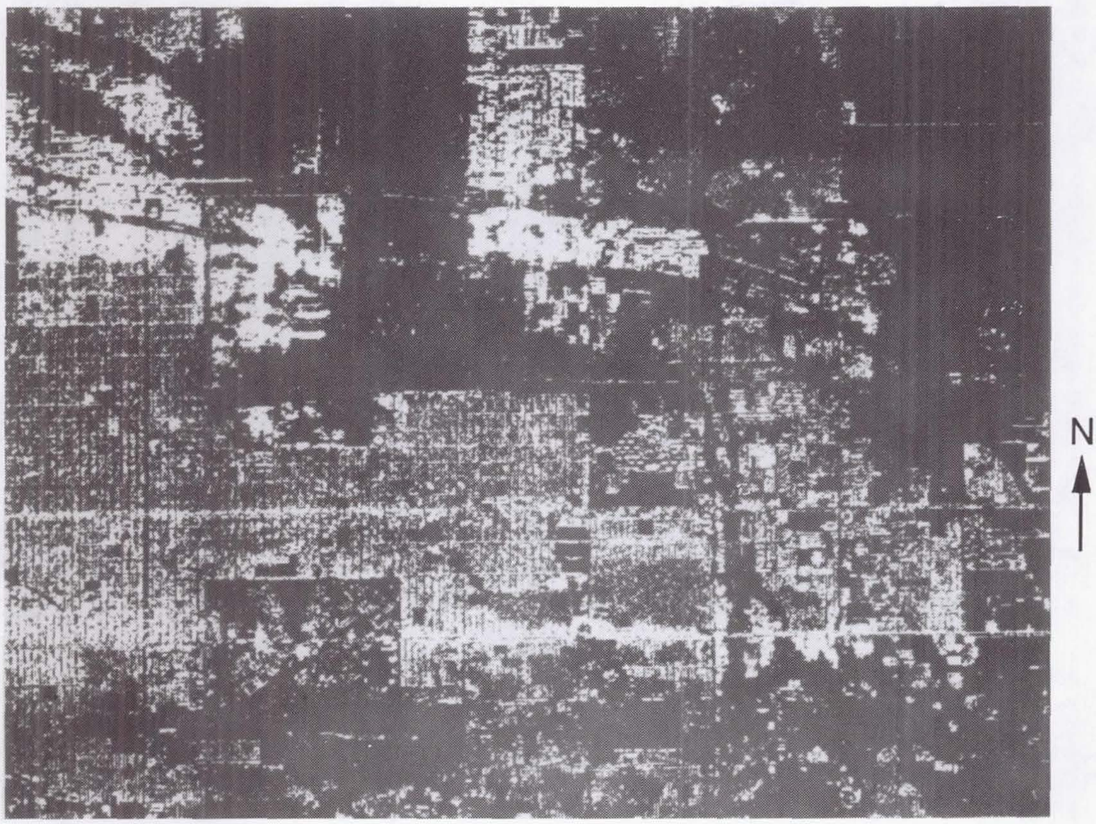


Figure 21. The Denver X-HH Polarimetric Image Thresholded at -10 dB

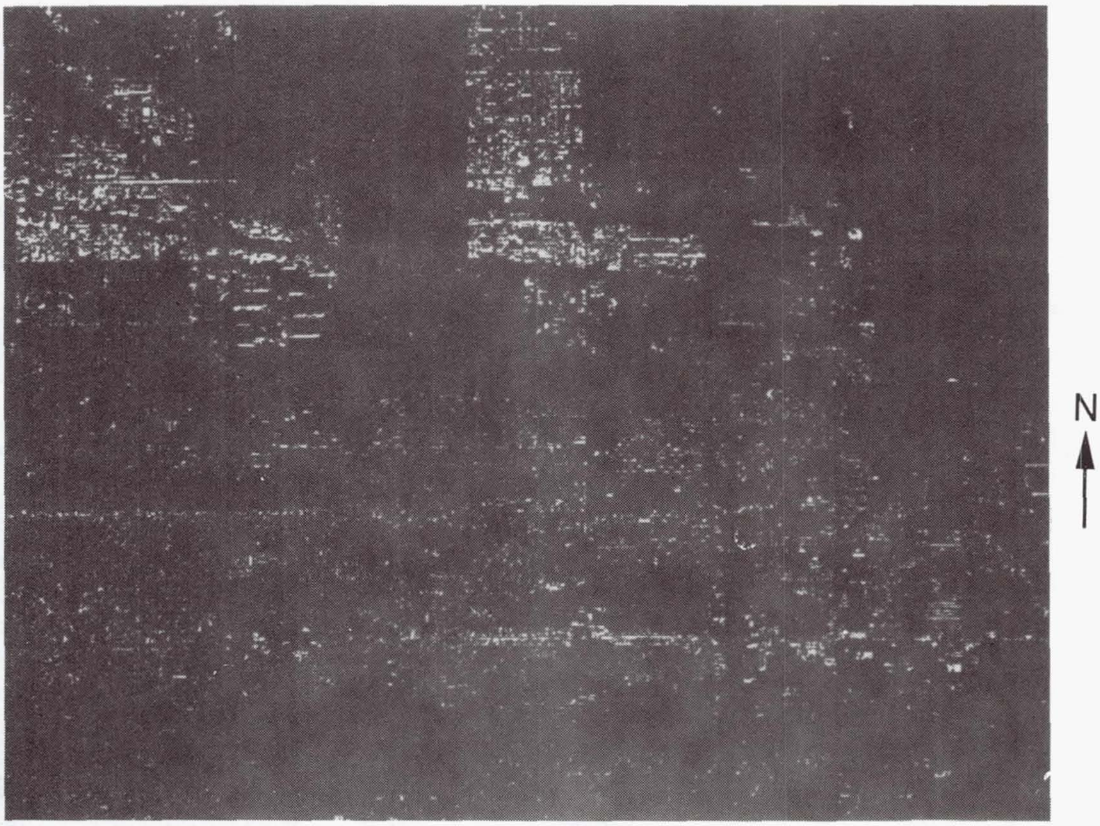


Figure 22. The Denver X-HH Polarimetric Image Thresholded at 0 dB

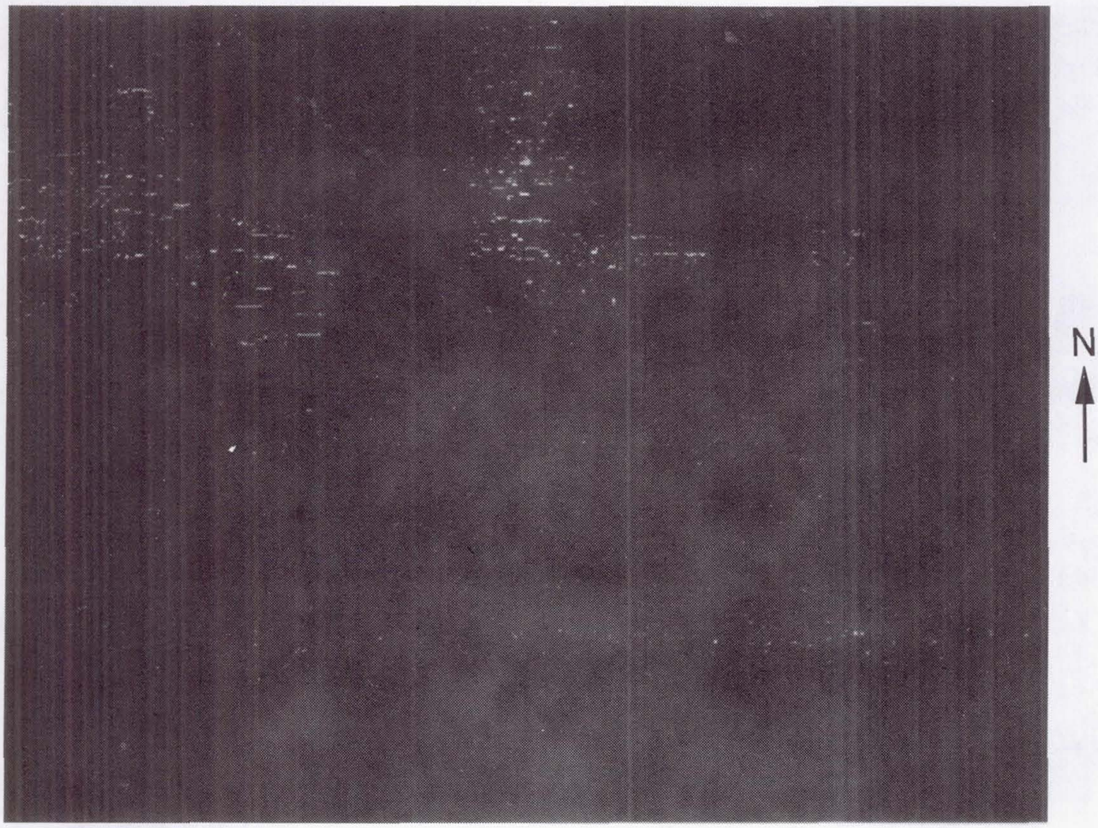


Figure 23. The Denver X-HH Polarimetric Image Thresholded at 10 dB

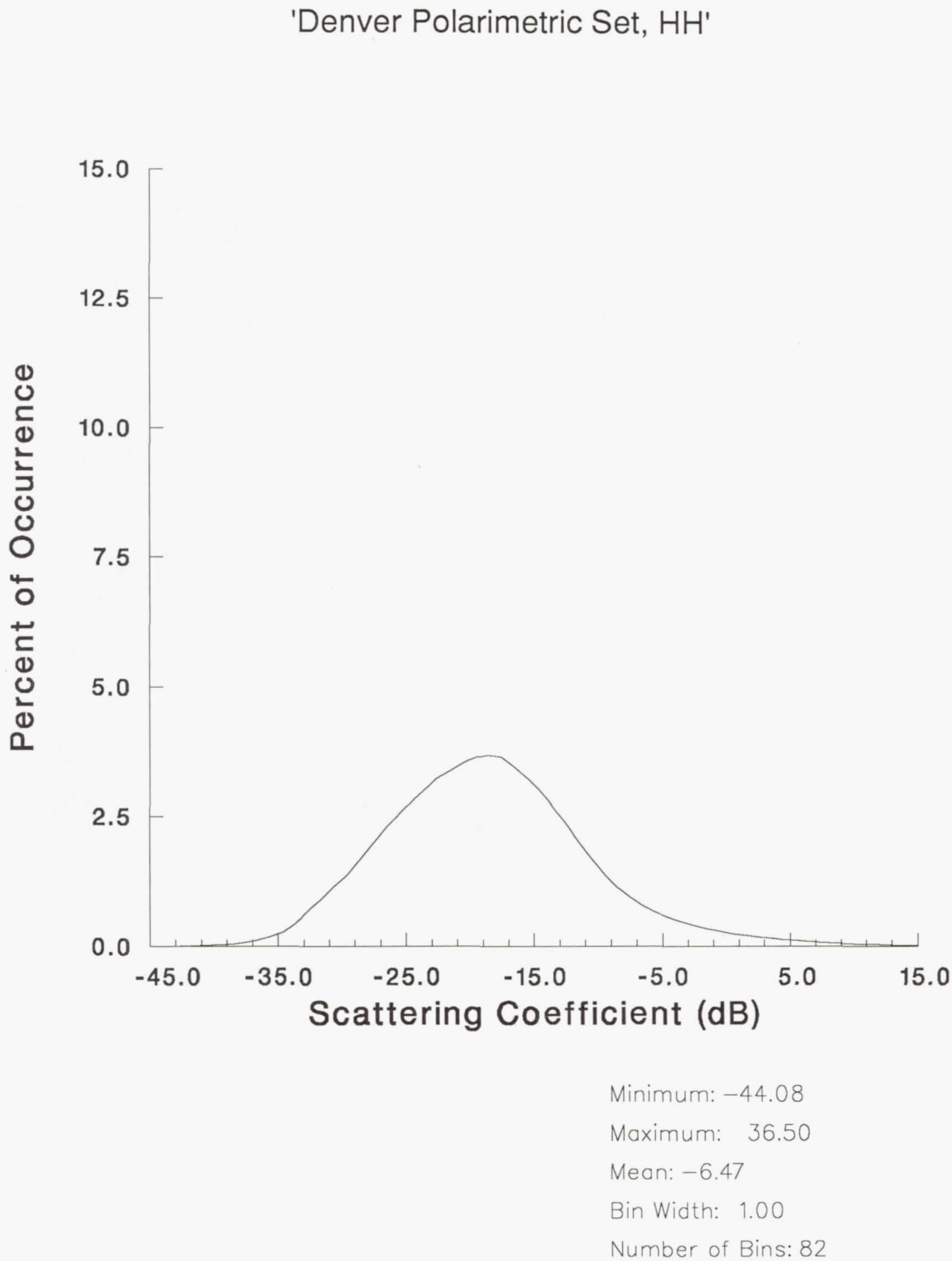


Figure 24. Clutter Distribution, Denver Polarimetric Set, X-HH

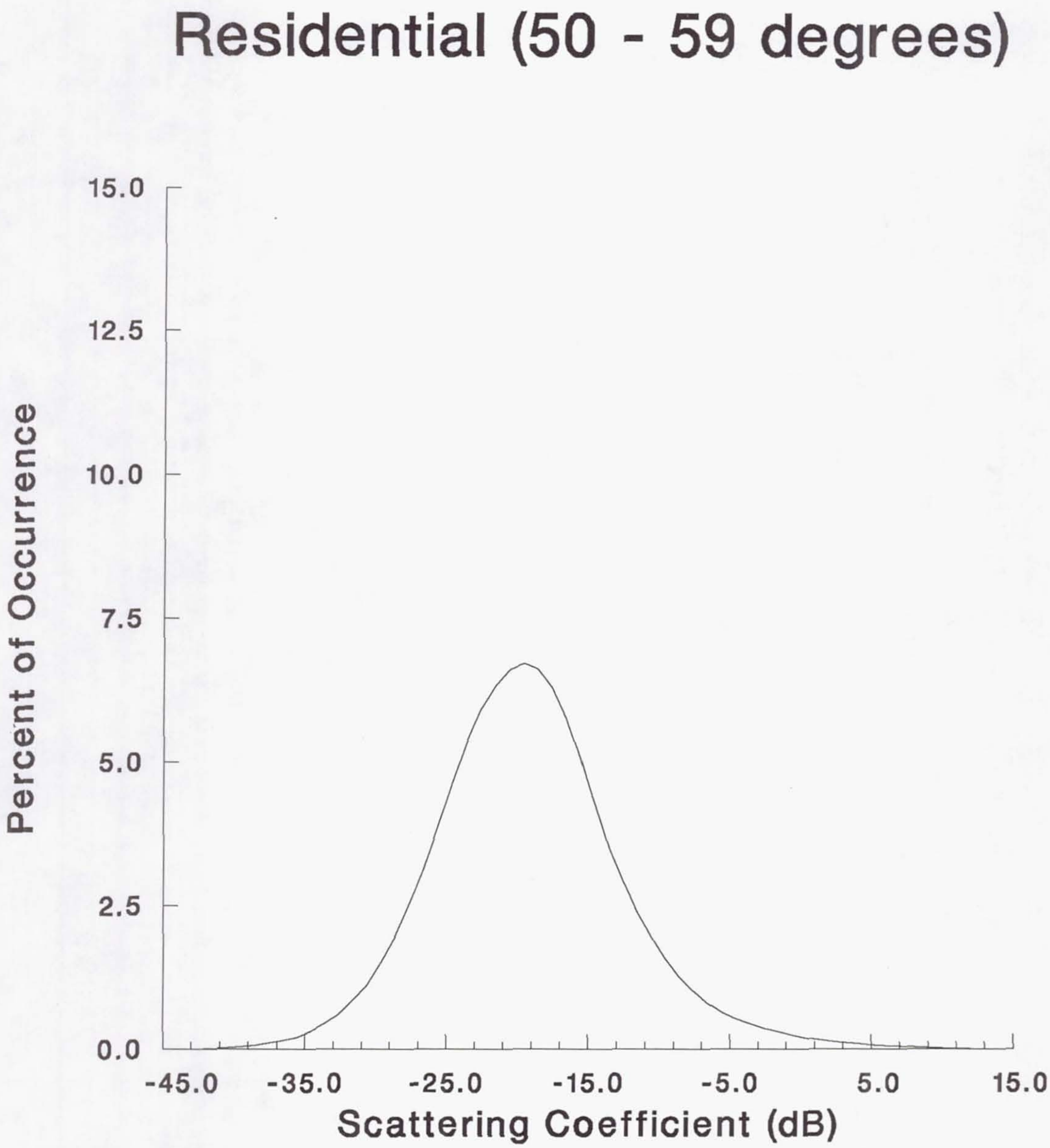


Figure 25.

Minimum: −44.08

Maximum: 19.12

Mean: −11.68

Bin Width: 1.00

Number of Bins: 64

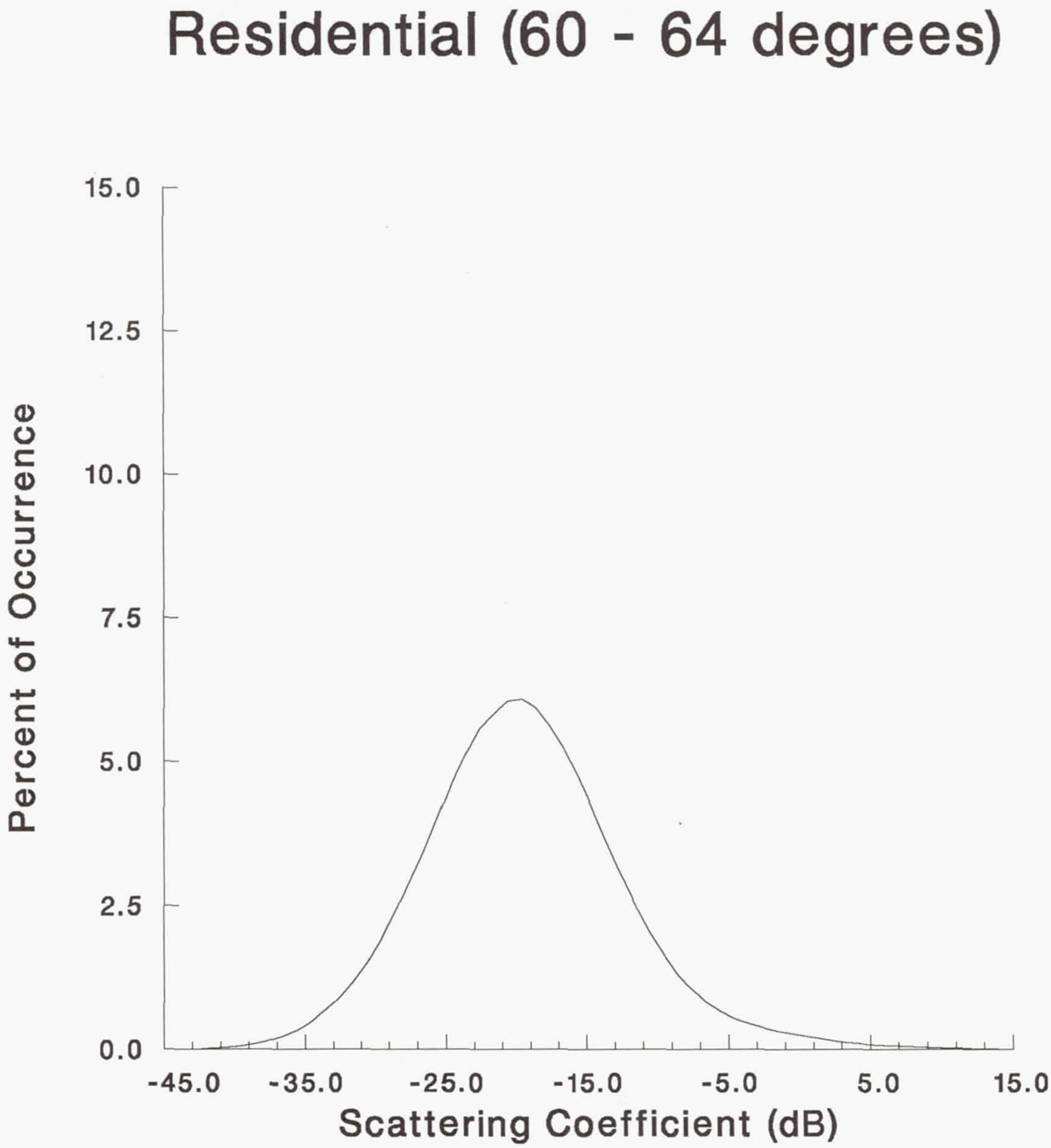


Figure 26.

Minimum: −44.08
Maximum: 21.50
Mean: −10.54
Bin Width: 1.00
Number of Bins: 67

Residential (65 - 69 degrees)

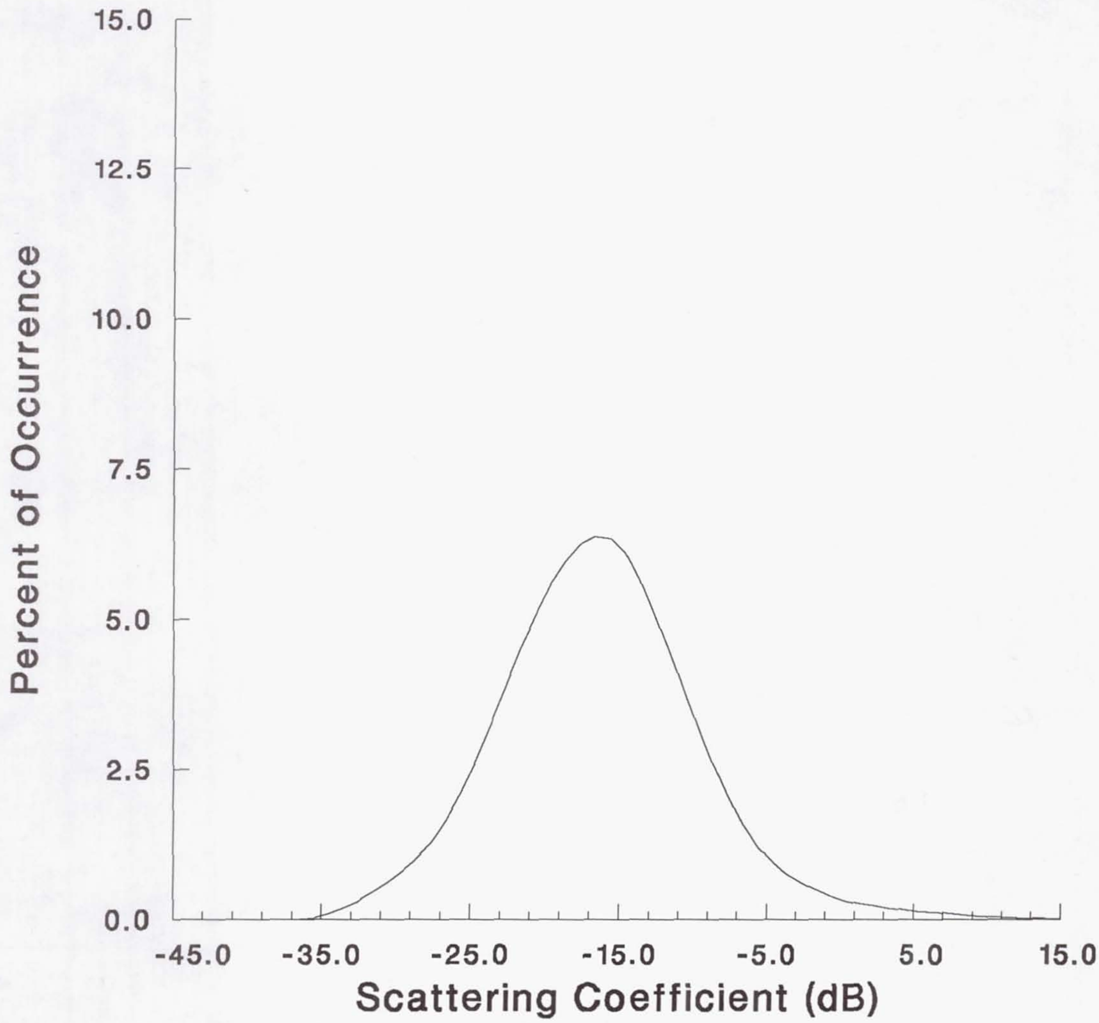


Figure 27.

Minimum: −44.08
Maximum: 22.48
Mean: −8.25
Bin Width: 1.00
Number of Bins: 68

Residential (70 - 74 degrees)

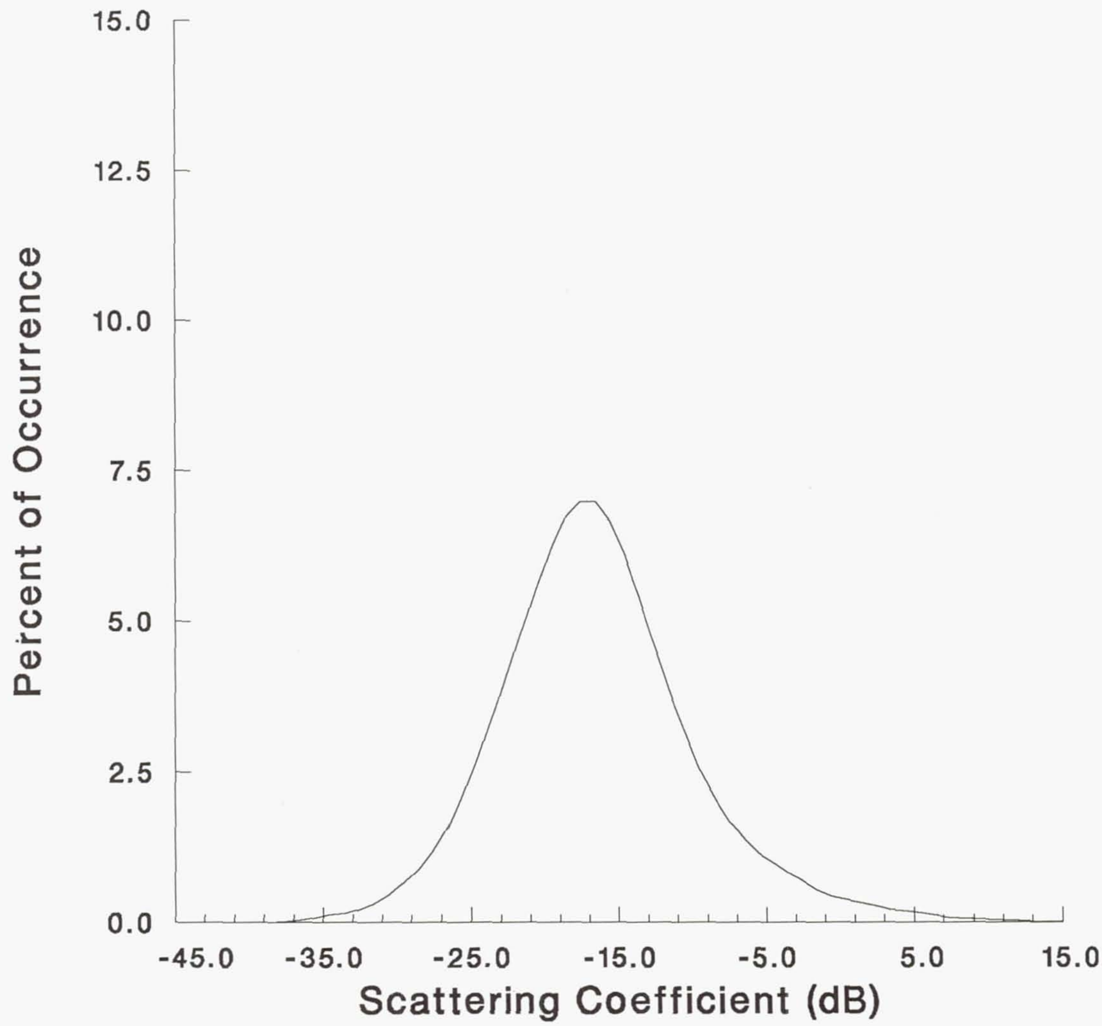


Figure 28.

Minimum: −44.08
Maximum: 18.61
Mean: −8.79
Bin Width: 1.00
Number of Bins: 64

Residential (75 - 79 degrees)

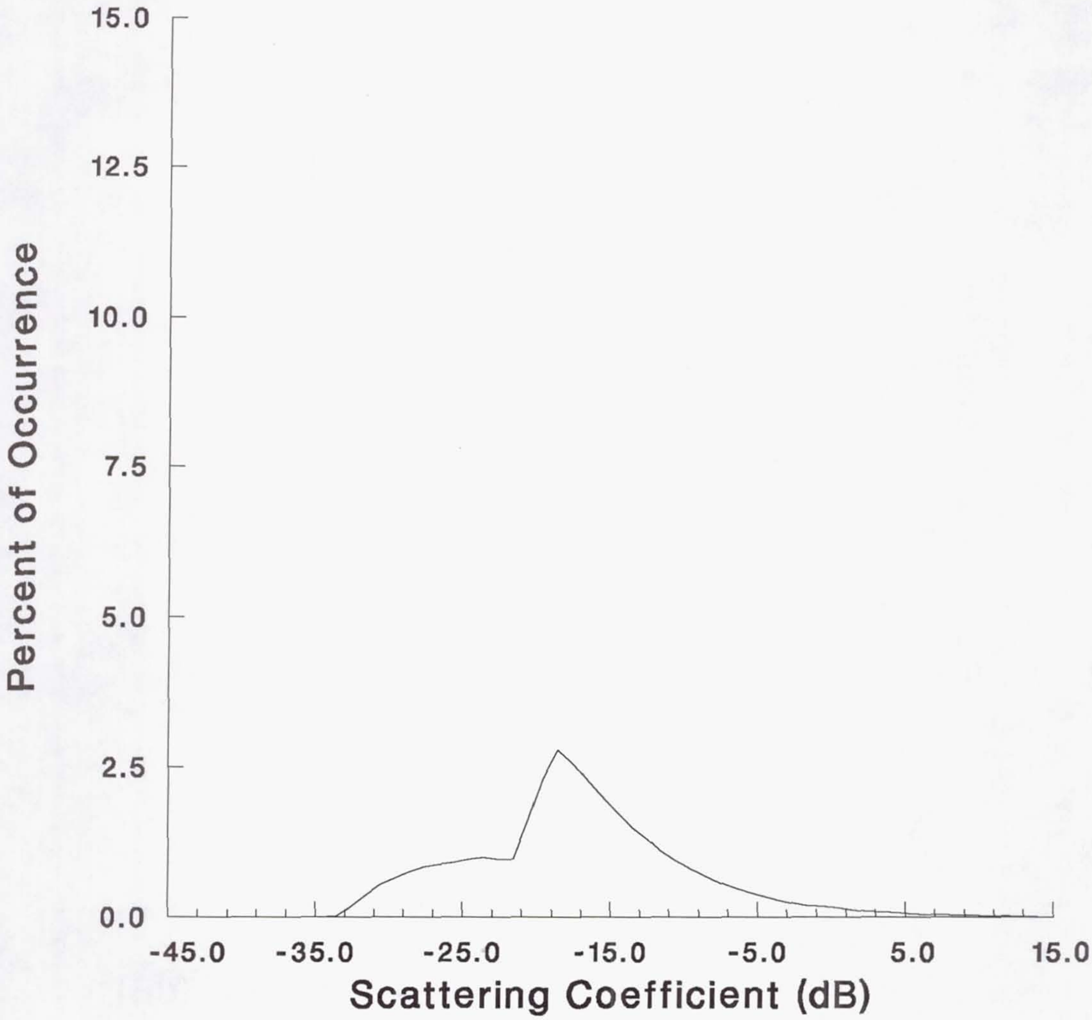


Figure 29.

Minimum: −44.08

Maximum: 18.95

Mean: −12.30

Bin Width: 1.00

Number of Bins: 64

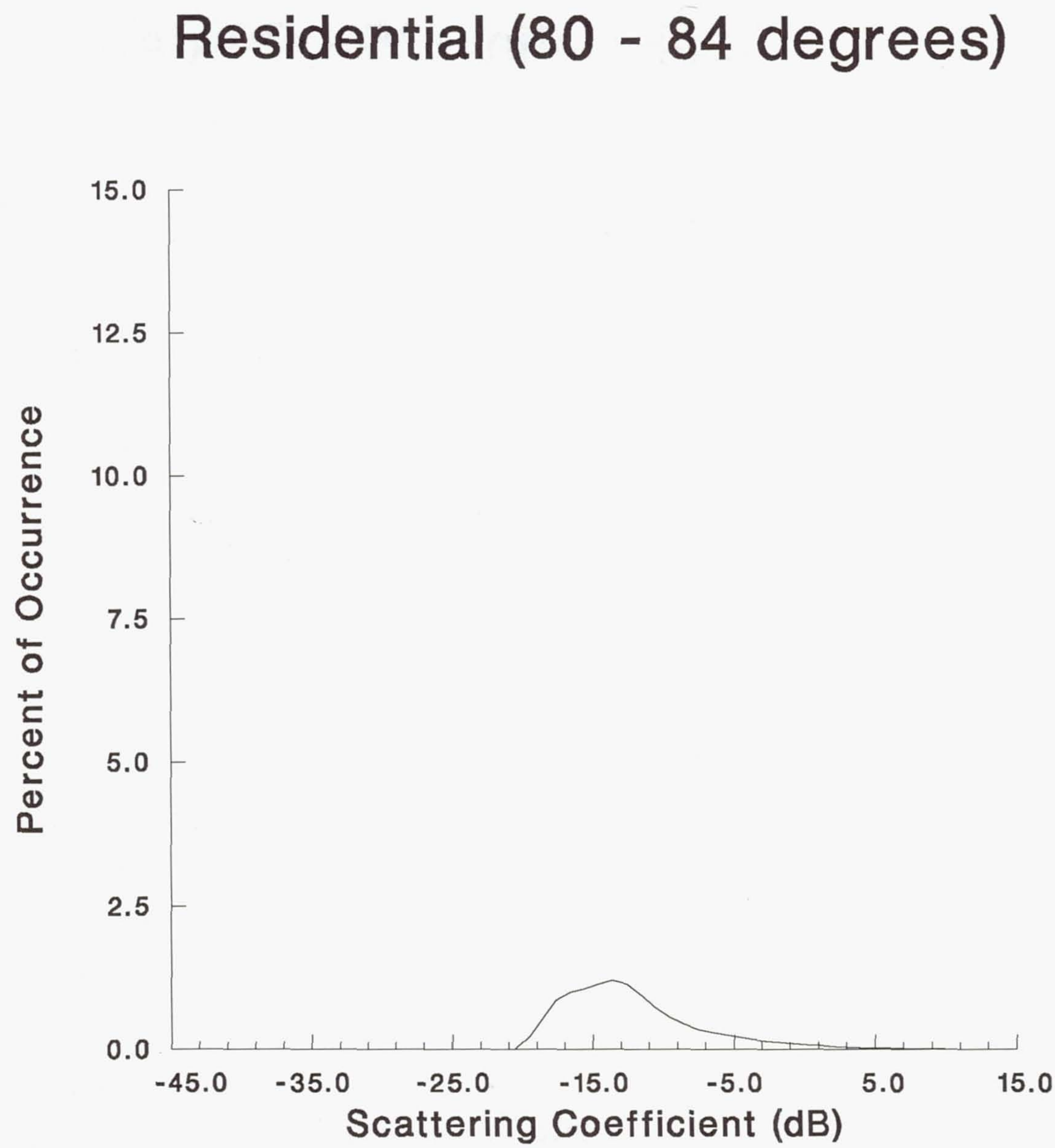


Figure 30.

Minimum: −44.08
Maximum: 23.95
Mean: −15.27
Bin Width: 1.00
Number of Bins: 69

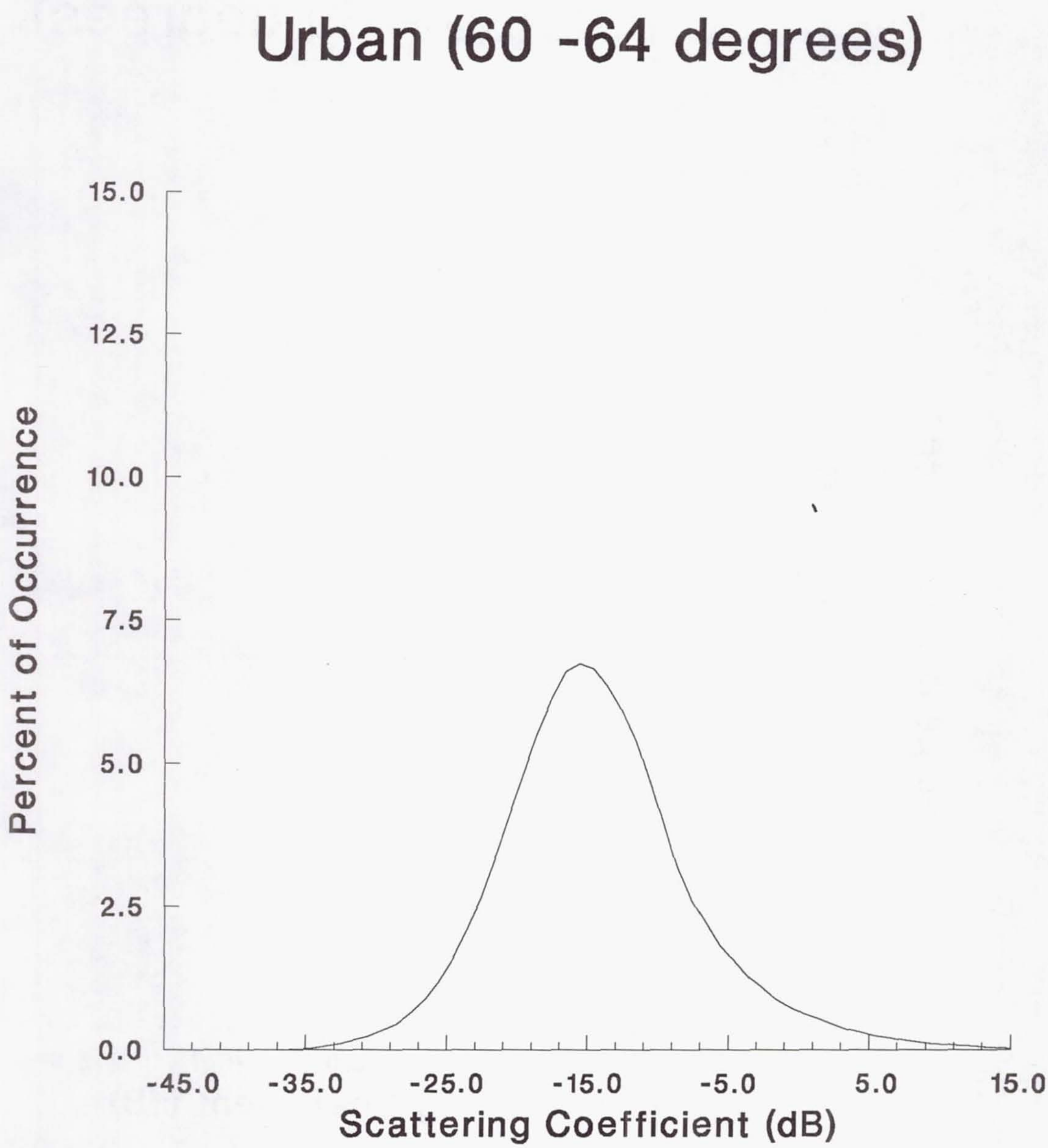


Figure 31.

Minimum: −44.08
Maximum: 23.59
Mean: −5.66
Bin Width: 1.00
Number of Bins: 69

Urban (65 - 69 degrees)

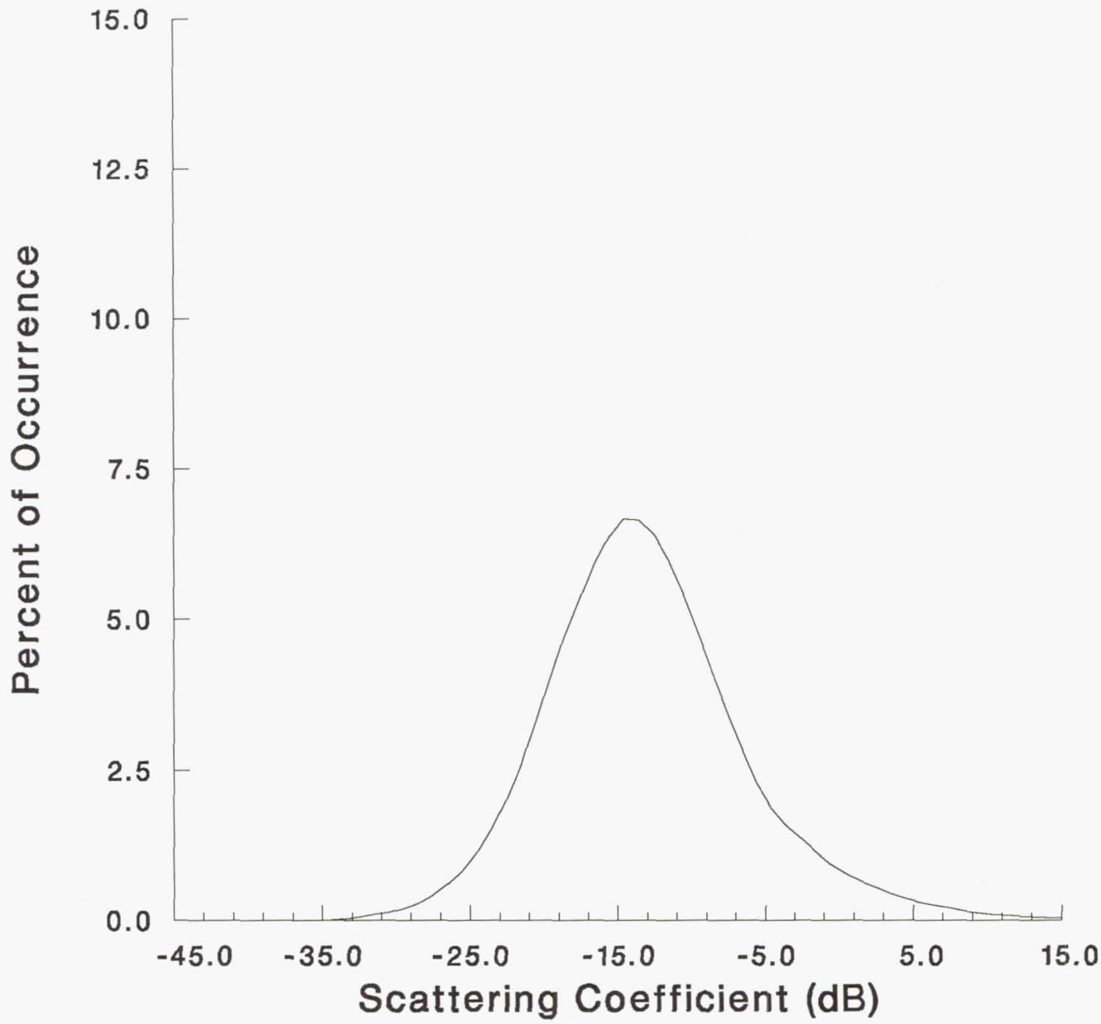


Figure 32.

Minimum: −44.08
Maximum: 22.28
Mean: −4.71
Bin Width: 1.00
Number of Bins: 67

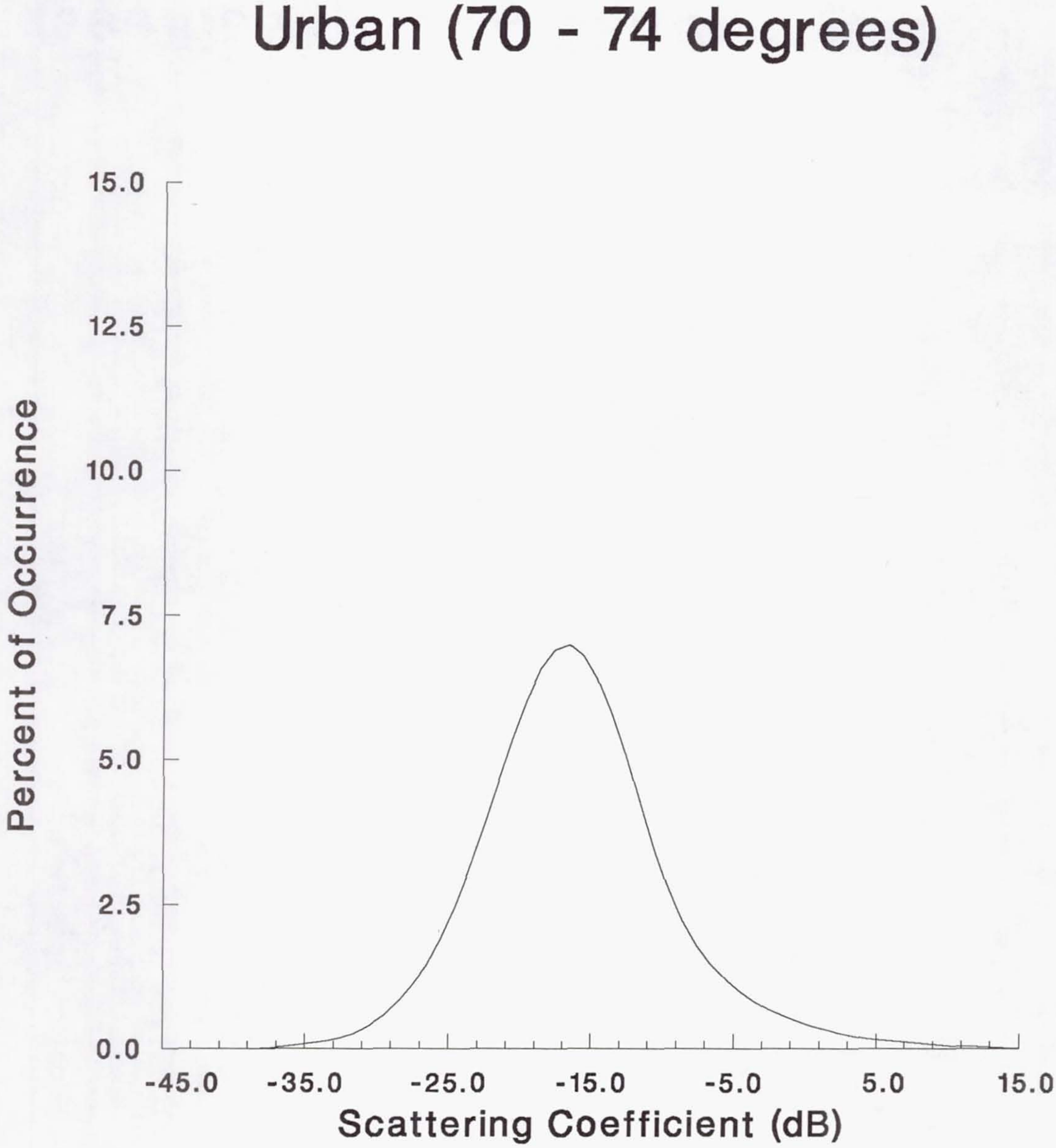


Figure 33.

Minimum: −44.08
Maximum: 22.33
Mean: −7.96
Bin Width: 1.00
Number of Bins: 67

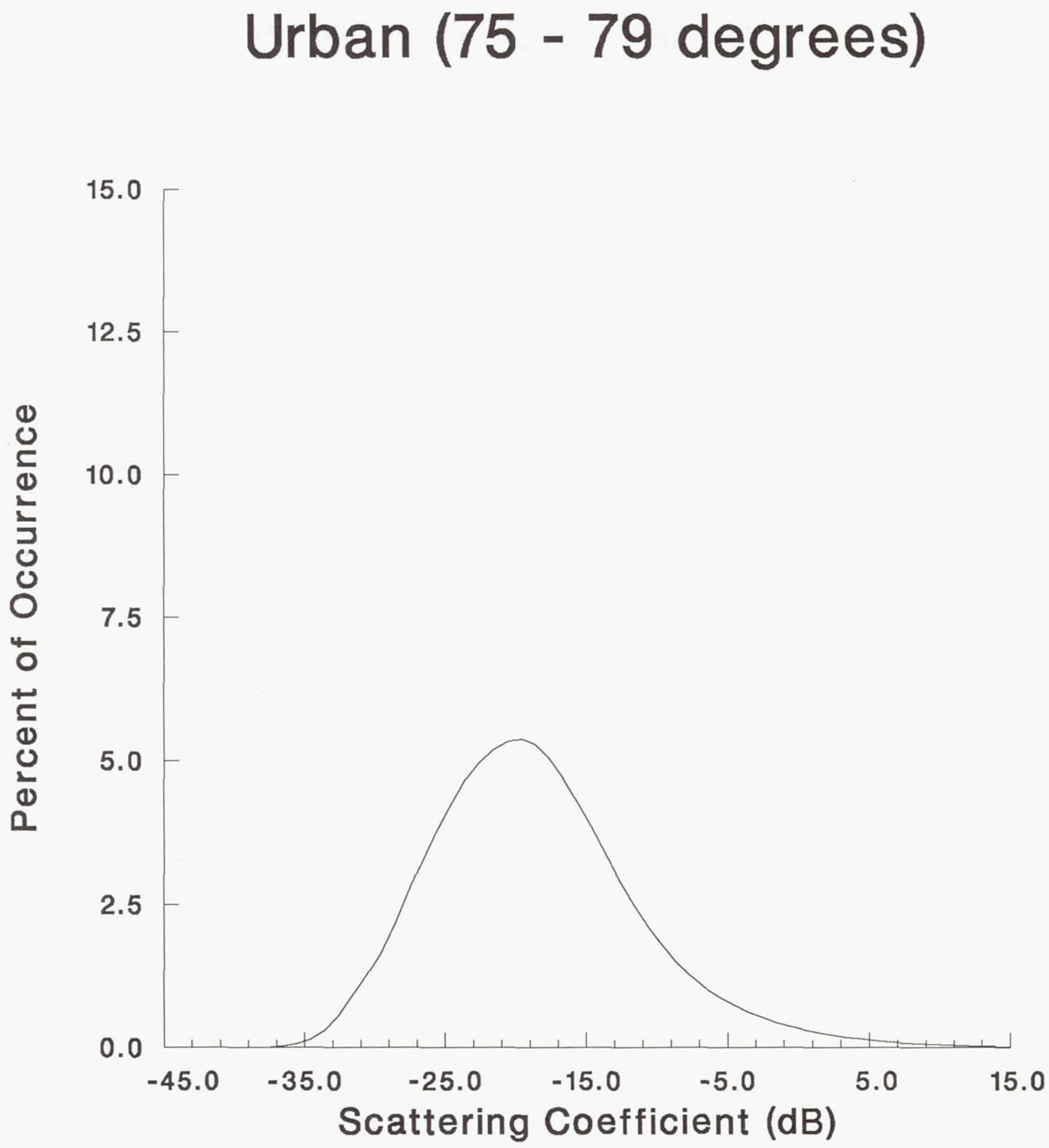


Figure 34.

Minimum: −44.08
Maximum: 29.92
Mean: −7.50
Bin Width: 1.00
Number of Bins: 75

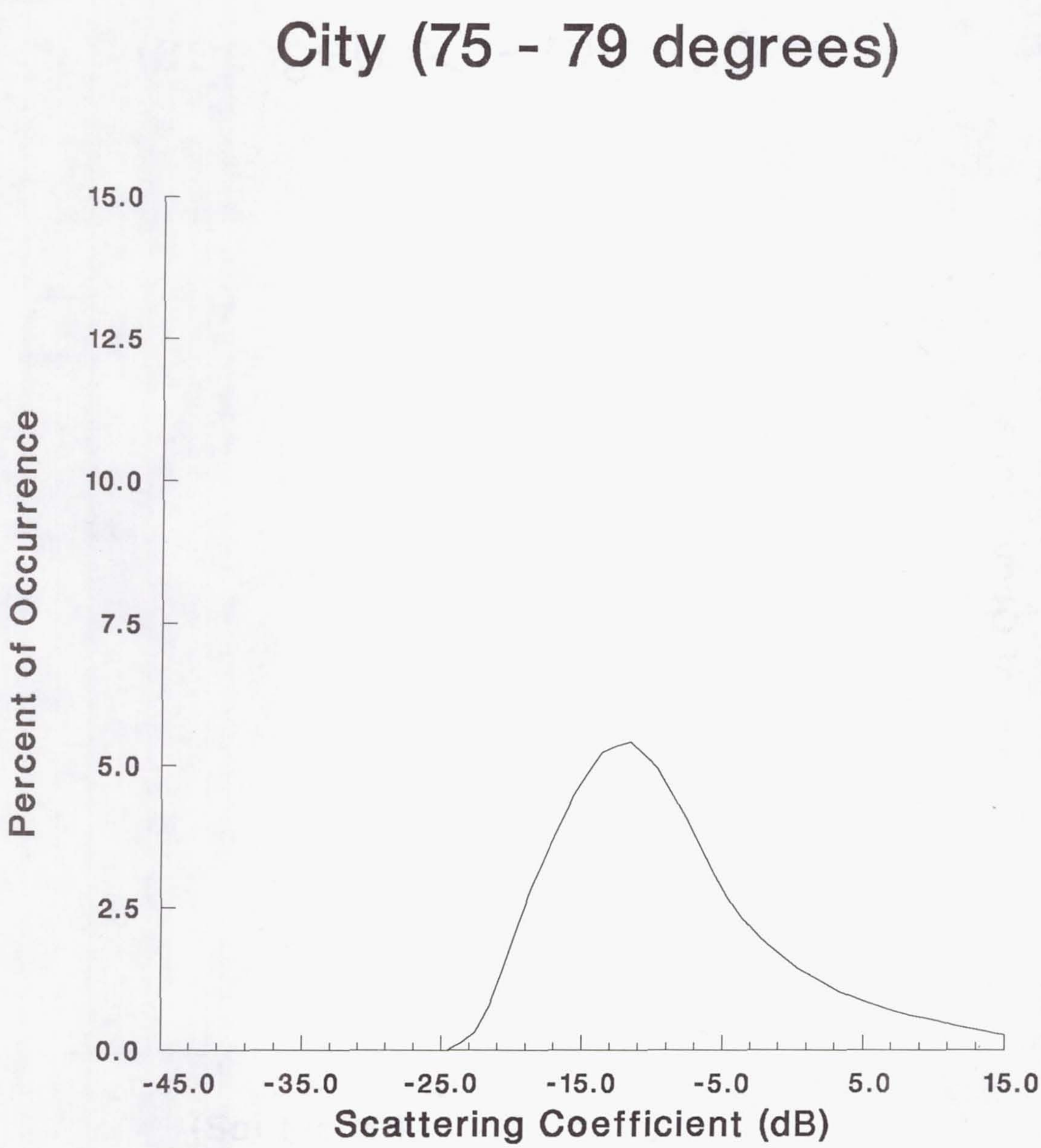


Figure 35.

Minimum: −44.08

Maximum: 34.63

Mean: 5.15

Bin Width: 1.00

Number of Bins: 80

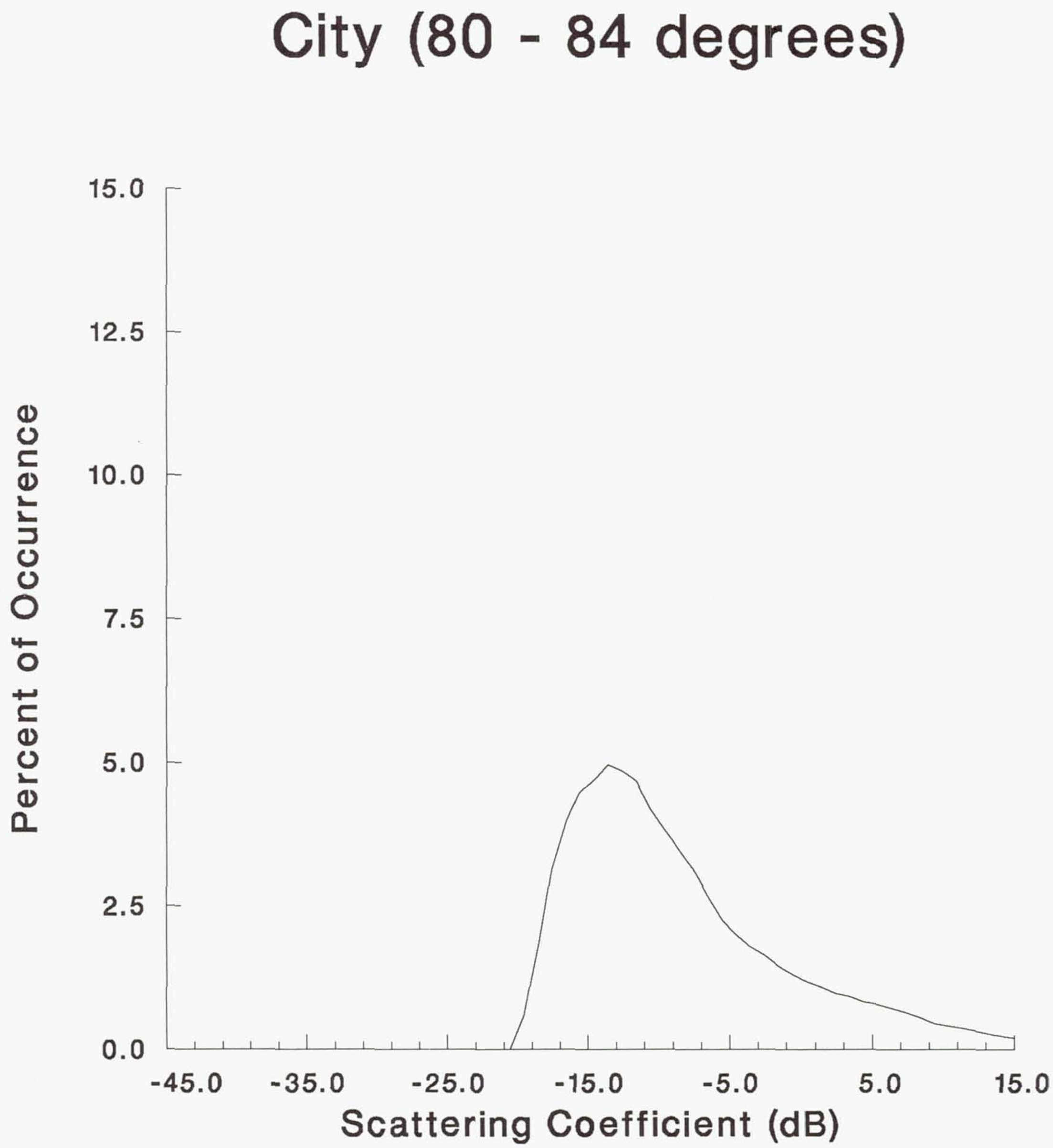


Figure 36.

Minimum: −44.08
Maximum: 35.77
Mean: 4.86
Bin Width: 1.00
Number of Bins: 81

Industrial (75 - 79 degrees)

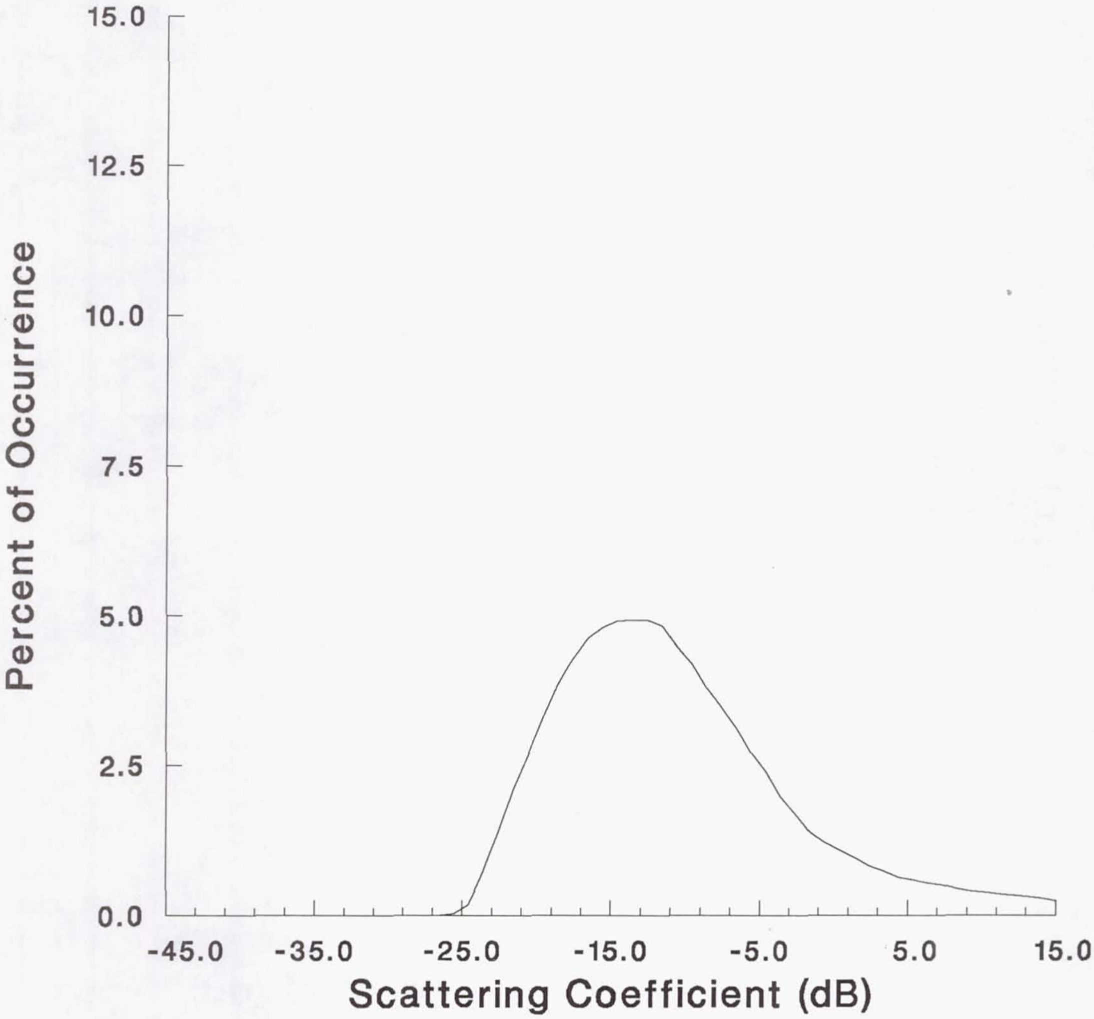


Figure 37.

Minimum: −44.08

Maximum: 29.28

Mean: 3.38

Bin Width: 1.00

Number of Bins: 74

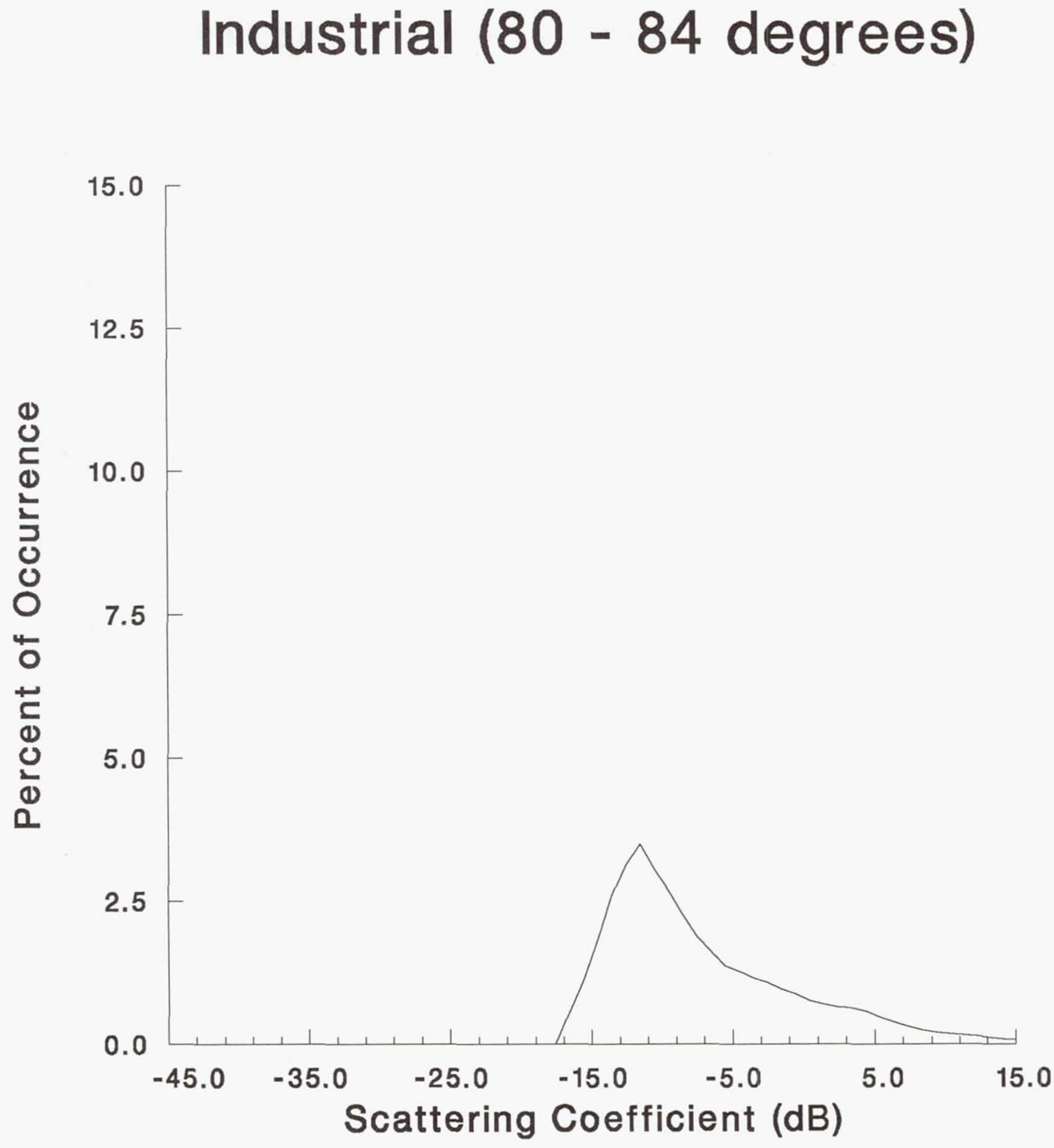


Figure 38.

Minimum: −44.08
Maximum: 27.79
Mean: −1.58
Bin Width: 1.00
Number of Bins: 73

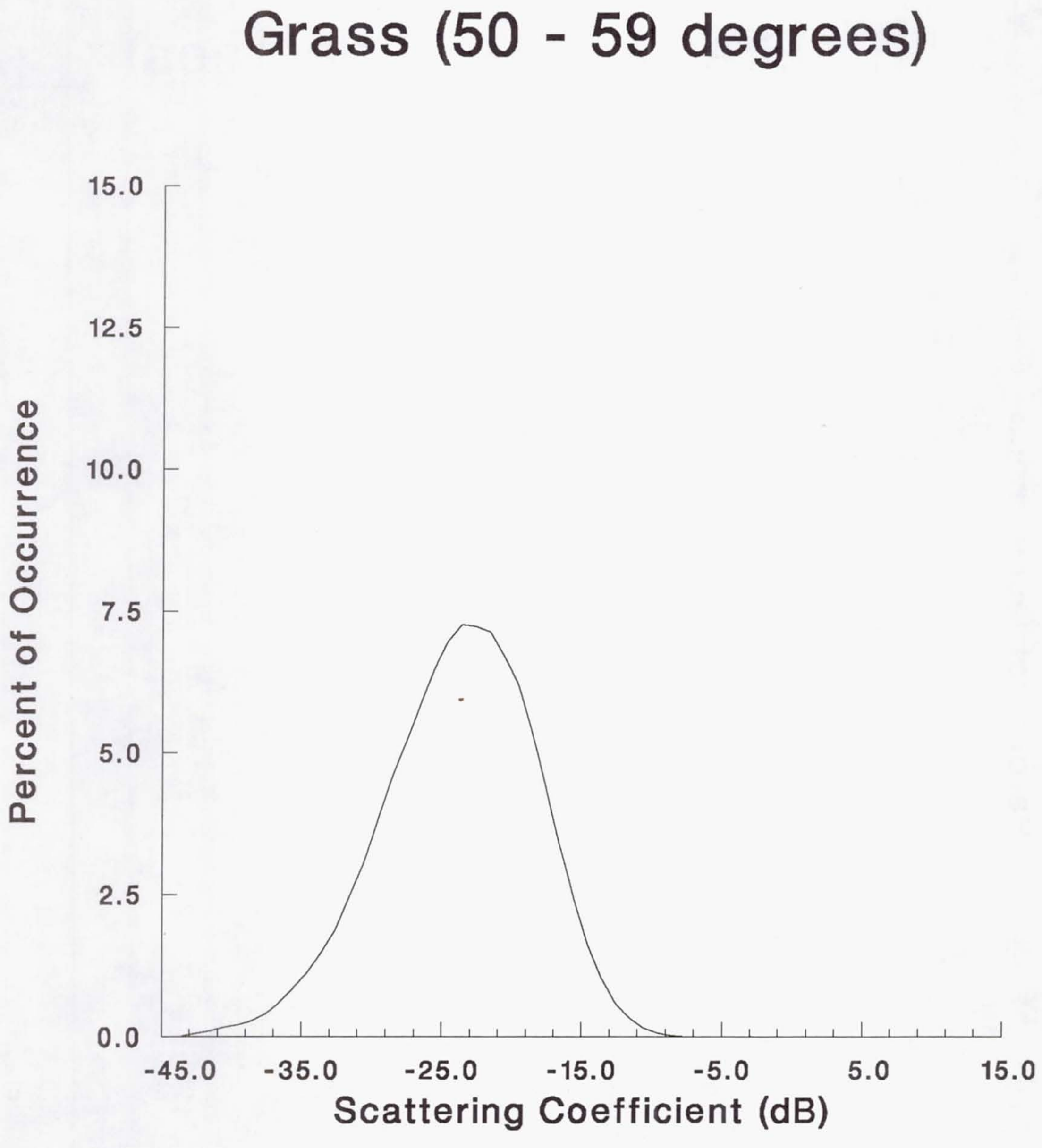


Figure 39.

Minimum: −44.08

Maximum: −6.64

Mean: −21.00

Bin Width: 1.00

Number of Bins: 38

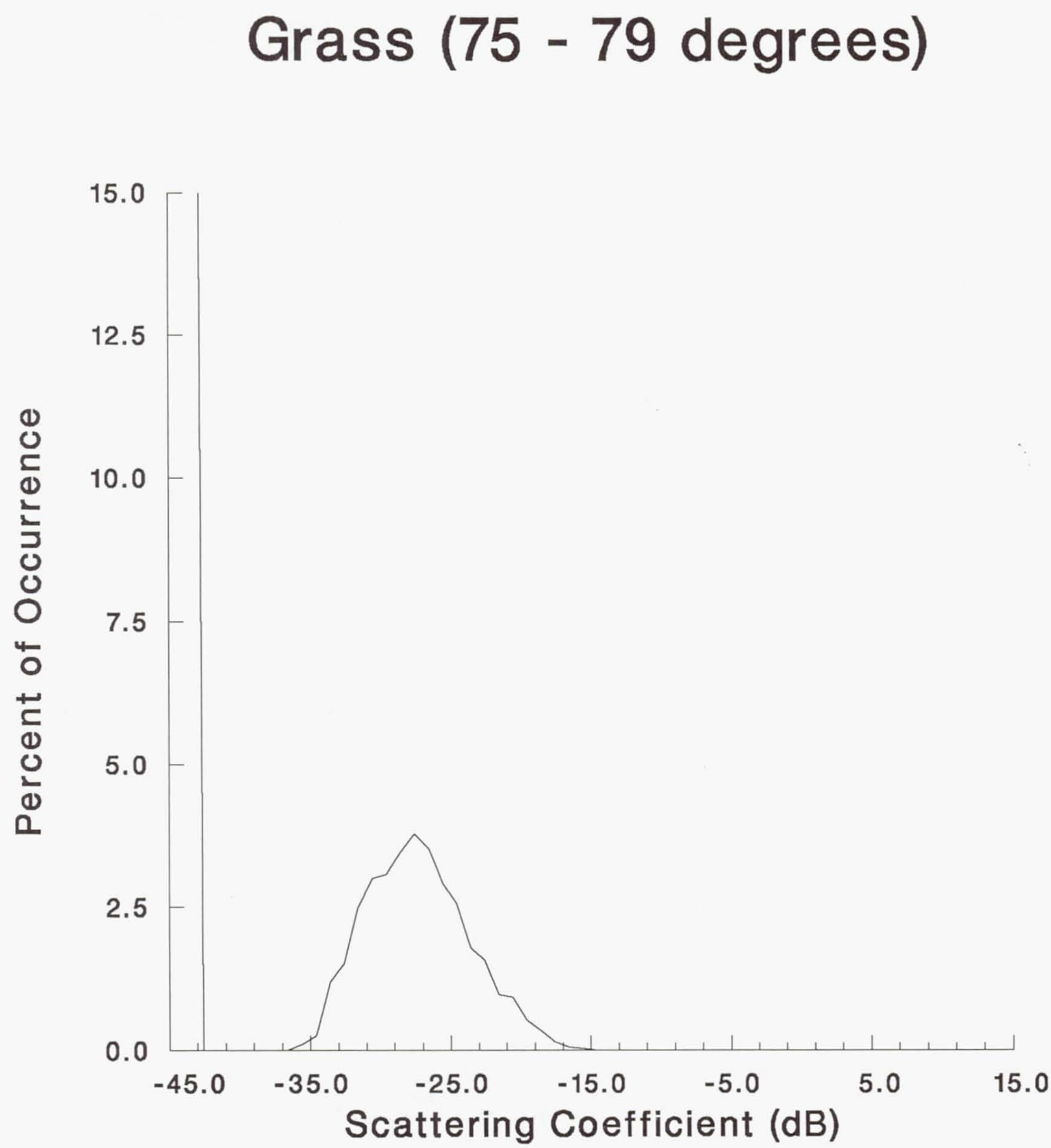


Figure 40.

Minimum: −44.08
Maximum: −13.09
Mean: −30.22
Bin Width: 1.00
Number of Bins: 32

Grass (80 - 84 degrees)

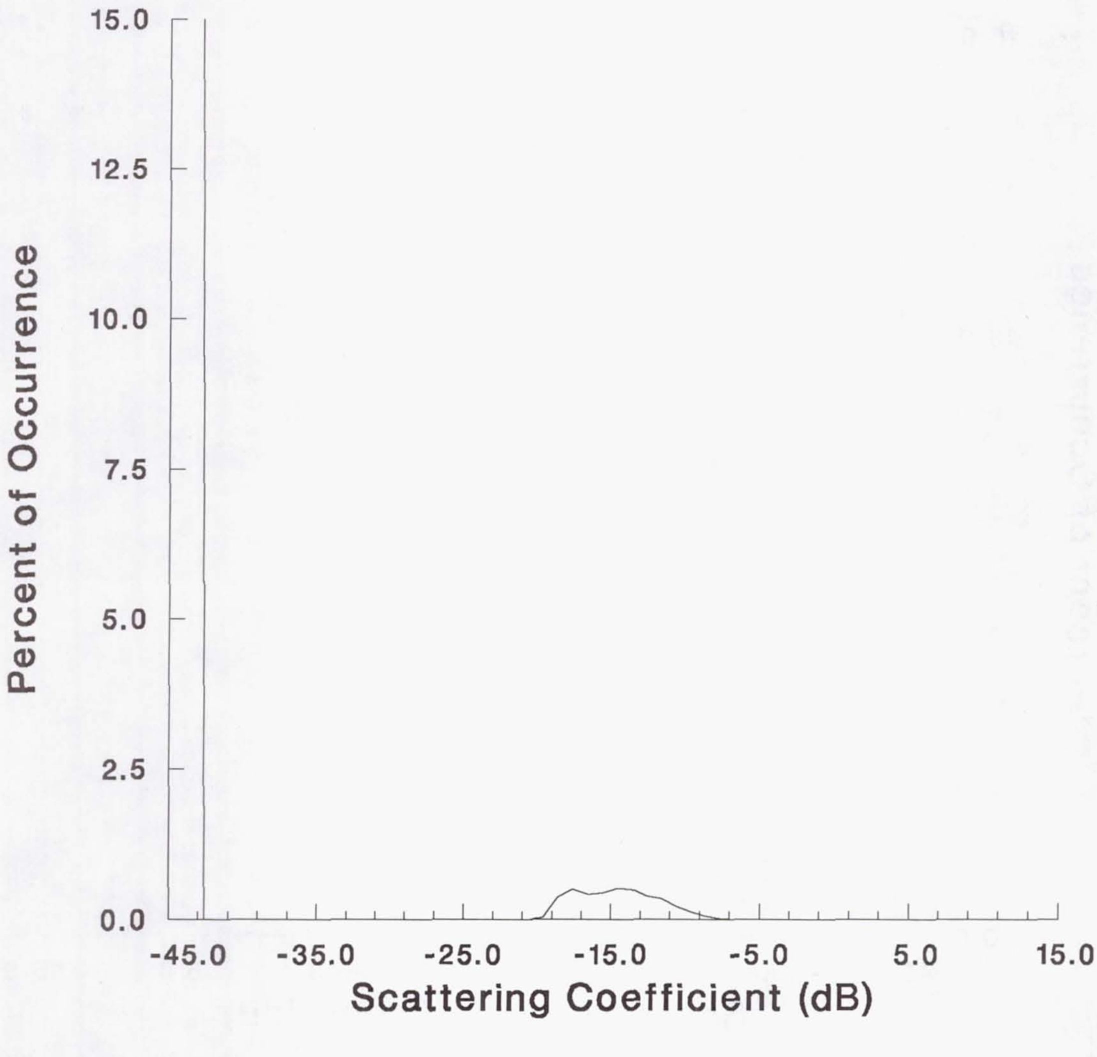


Figure 41.

Minimum: −44.08
Maximum: −3.60
Mean: −27.71
Bin Width: 1.00
Number of Bins: 41

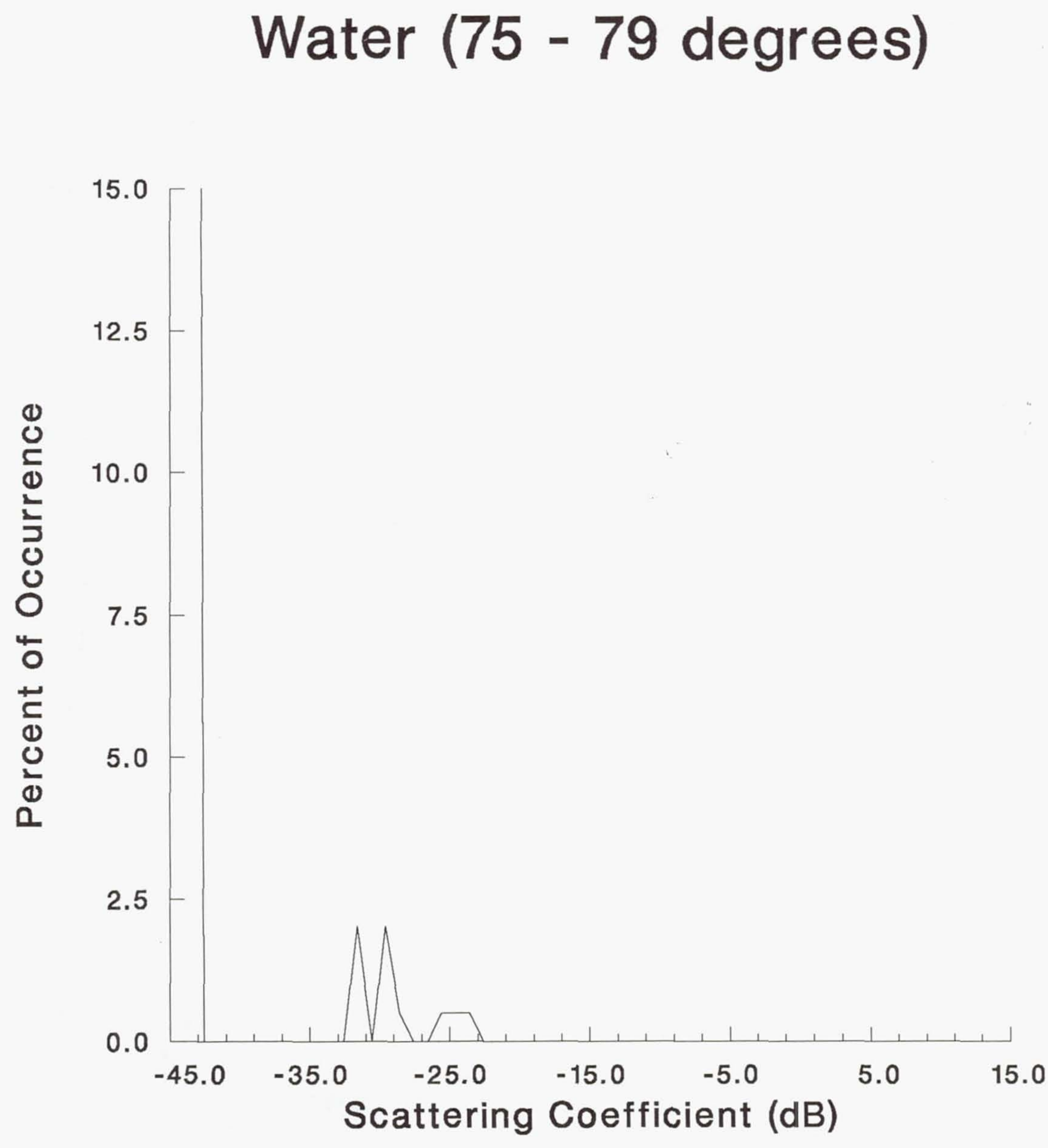


Figure 42.

Minimum: −44.08

Maximum: −23.10

Mean: −38.65

Bin Width: 1.00

Number of Bins: 22

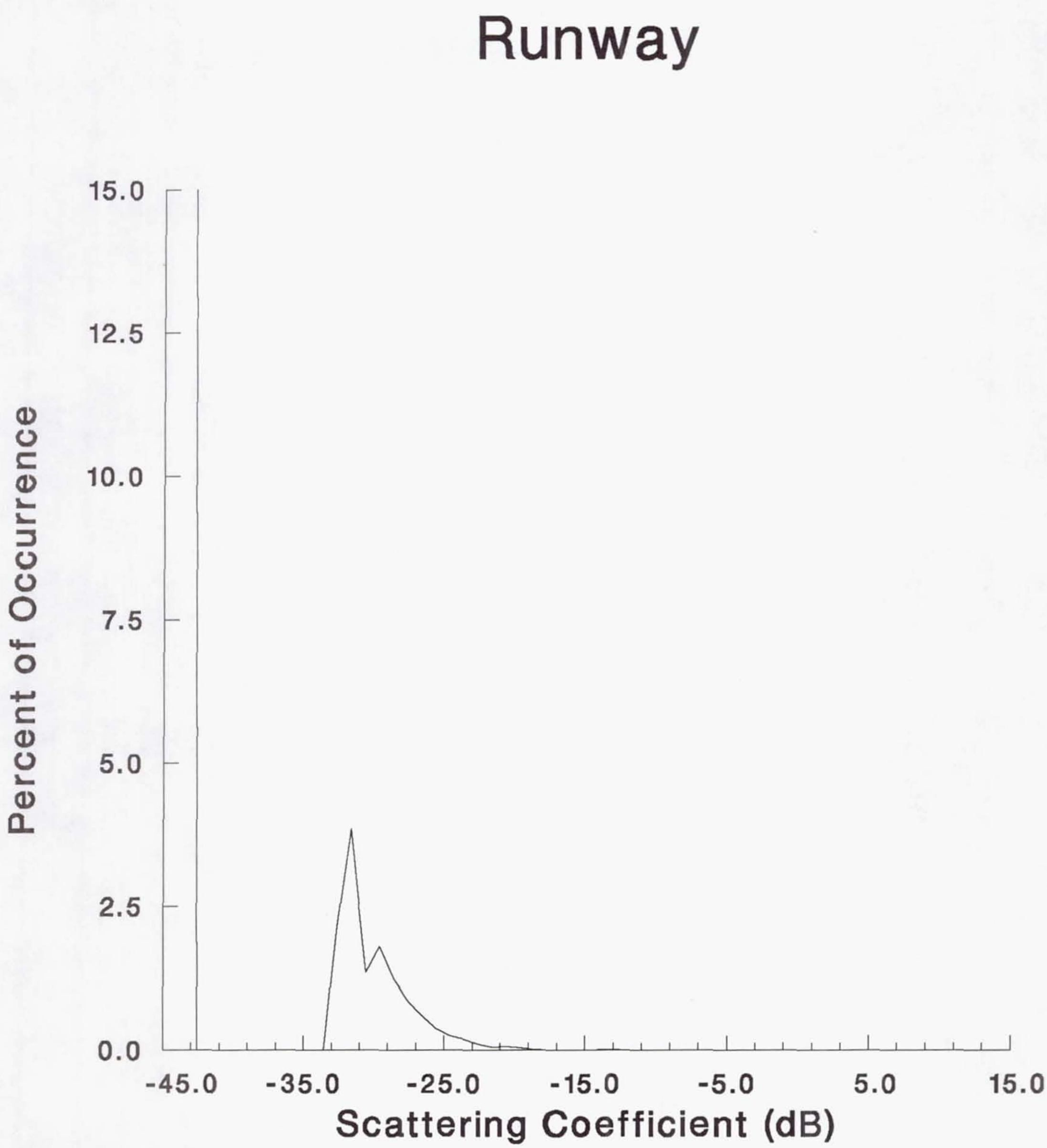


Figure 43.

Minimum: −44.08
Maximum: −12.92
Mean: −36.68
Bin Width: 1.00
Number of Bins: 32

Residential Clutter

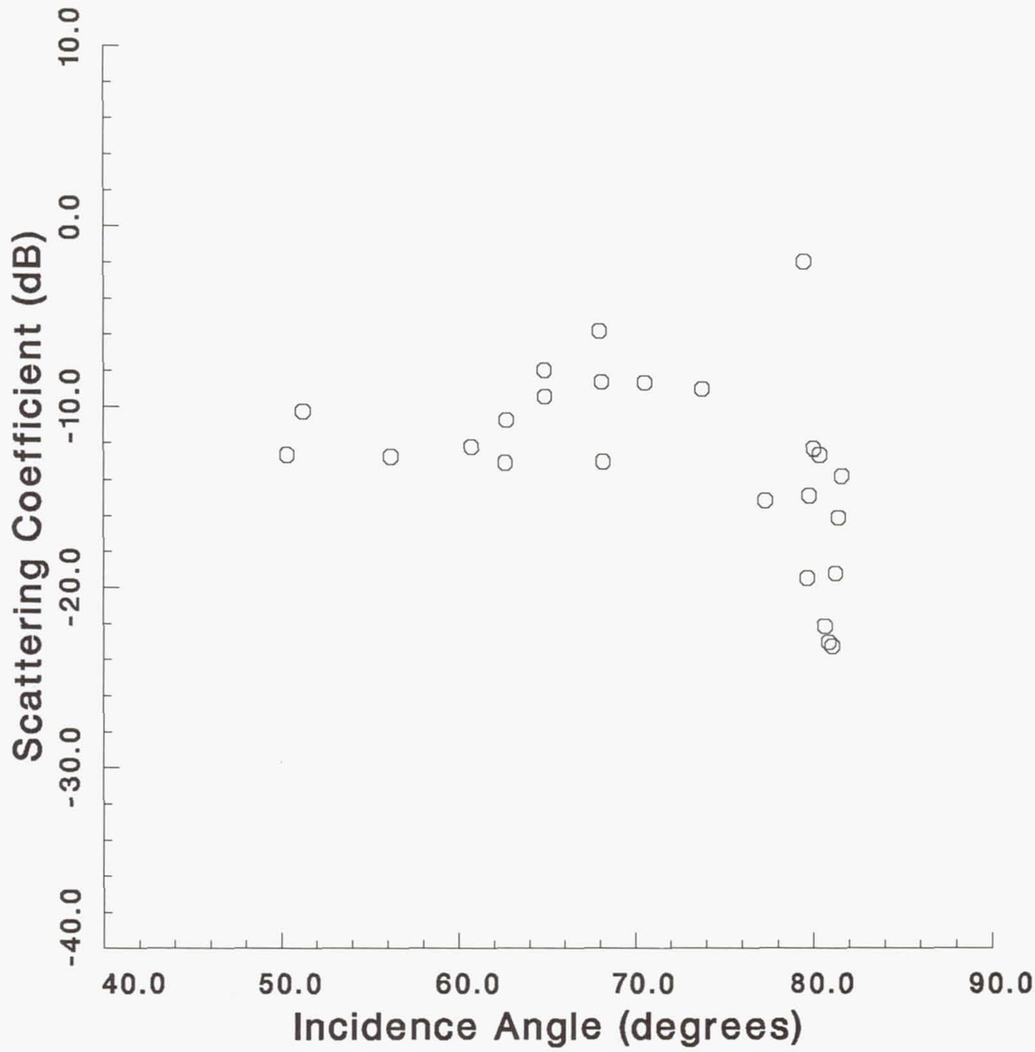


Figure 44.

Urban Clutter

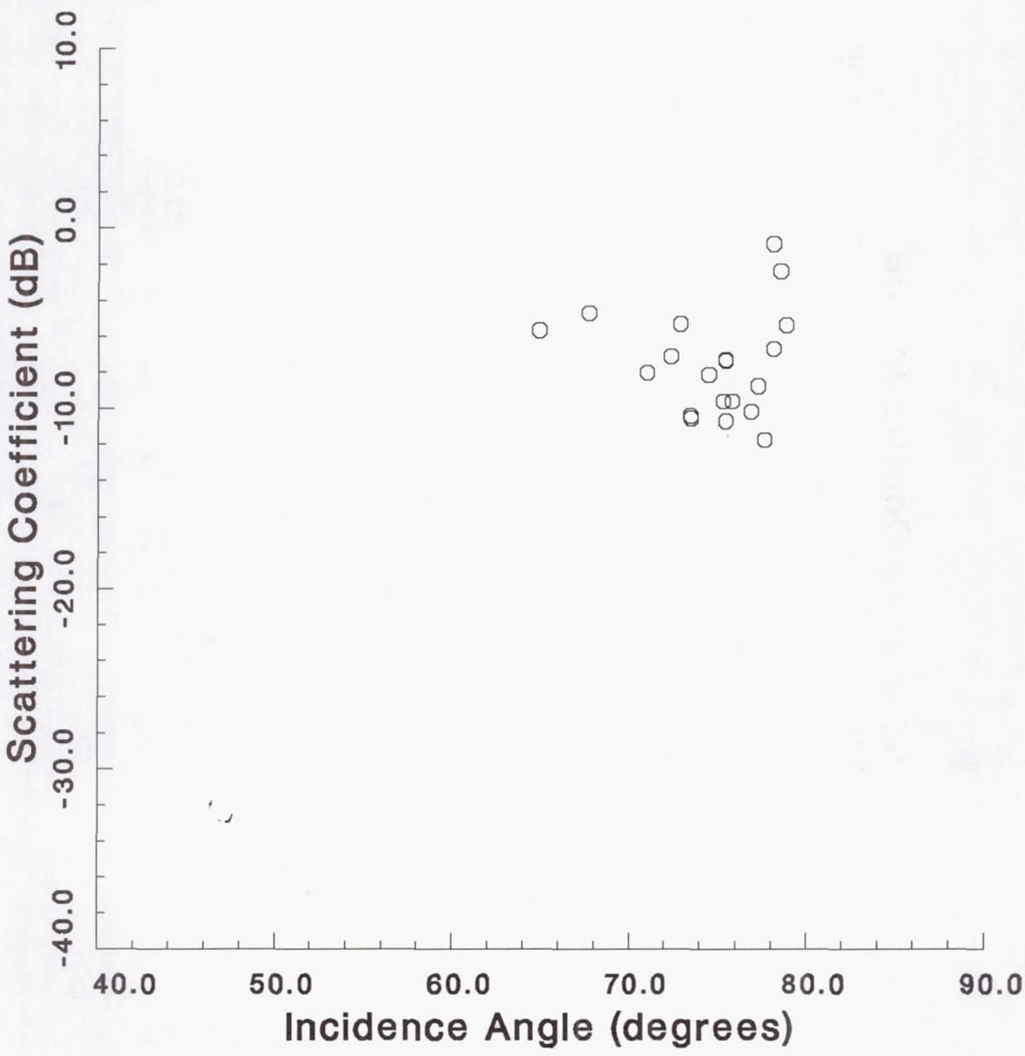


Figure 45.

City Clutter

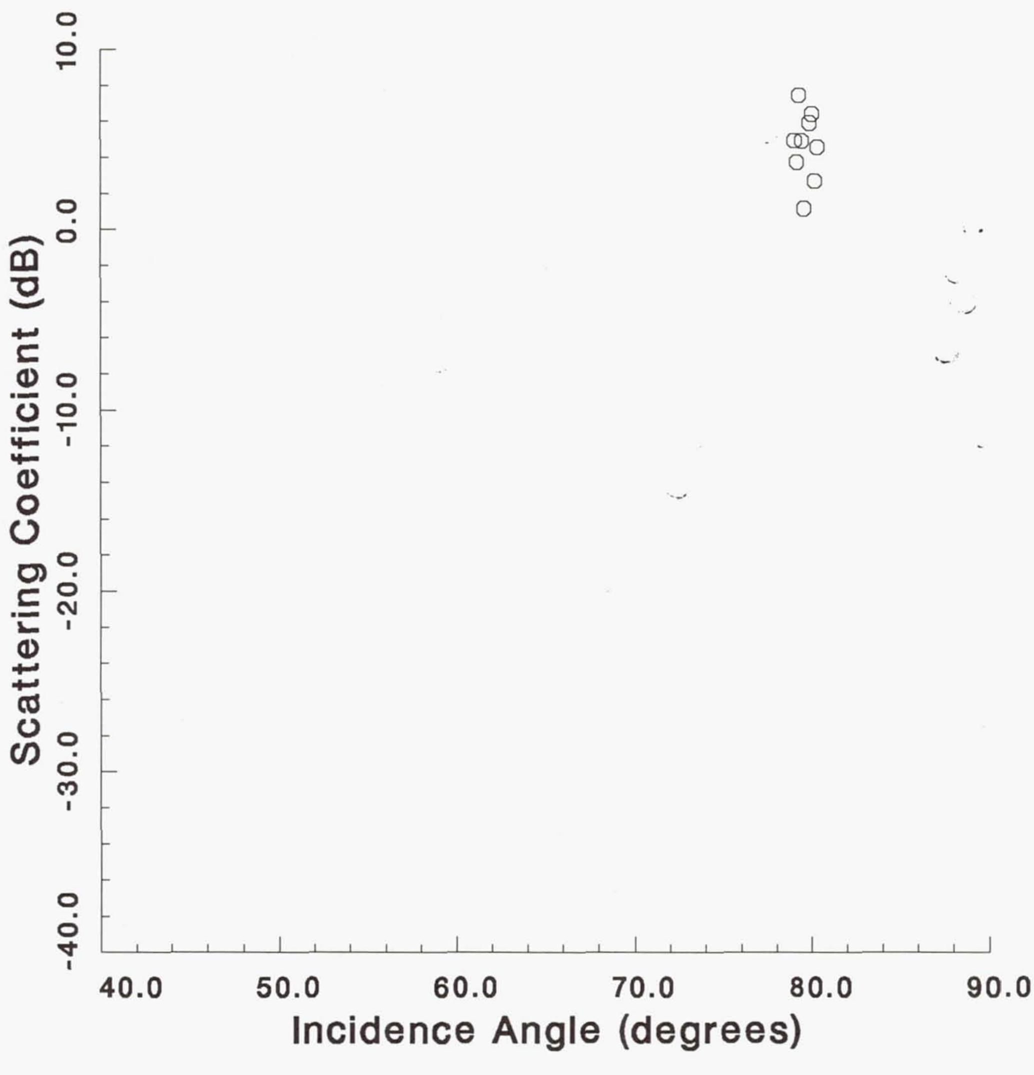


Figure 46.

Industrial Clutter

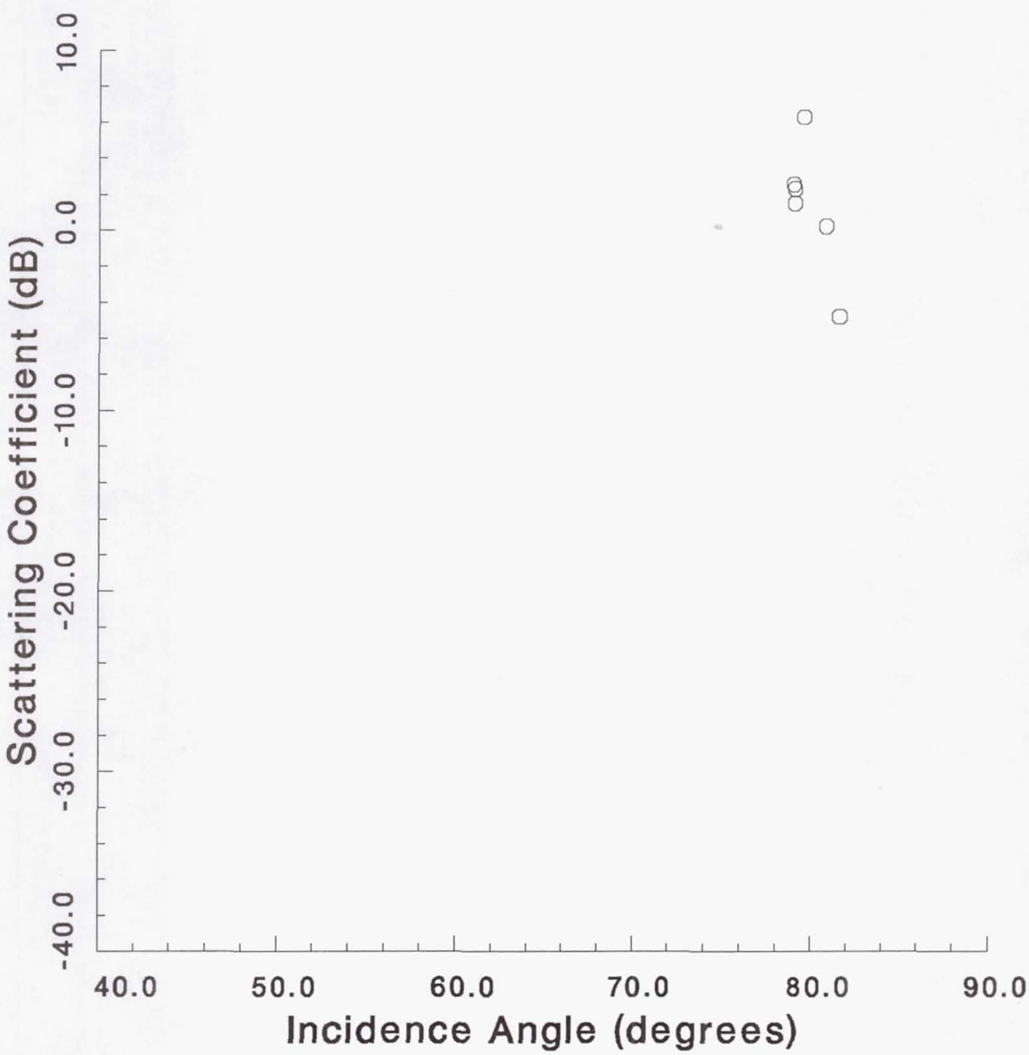


Figure 47.

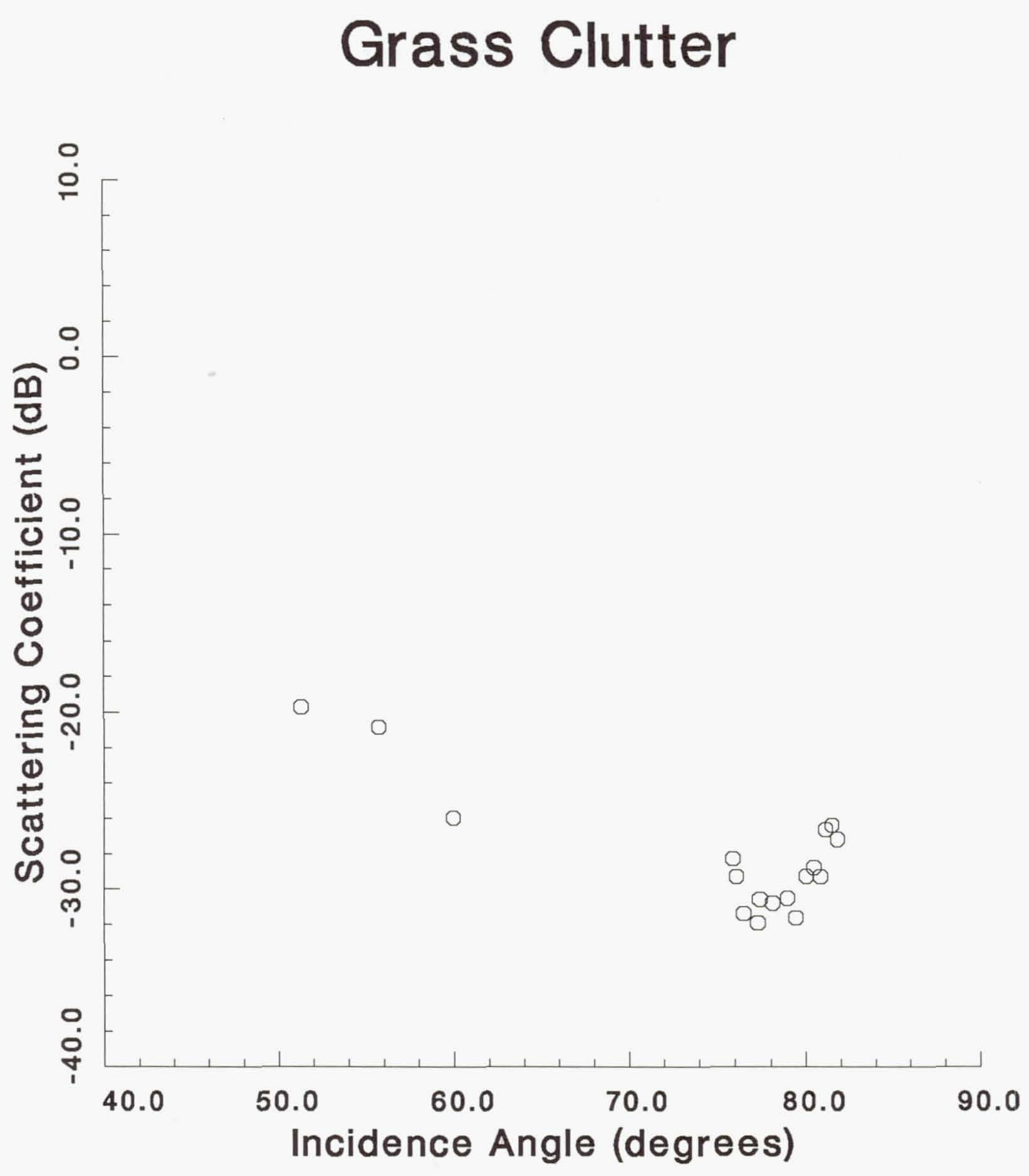

Grass Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 48.

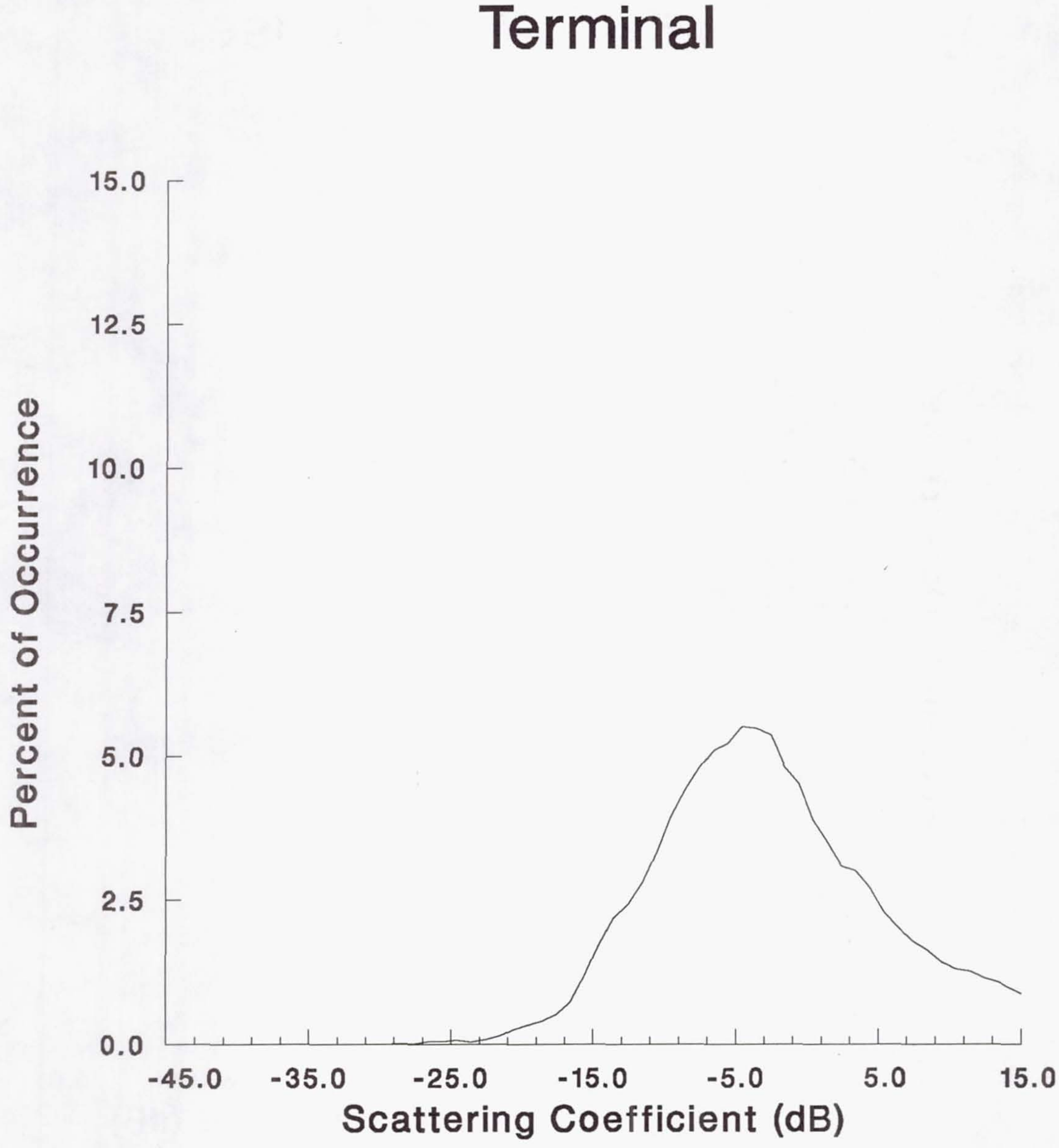


Figure 49.

Minimum: −44.08

Maximum: 25.61

Mean: 6.48

Bin Width: 1.00

Number of Bins: 71

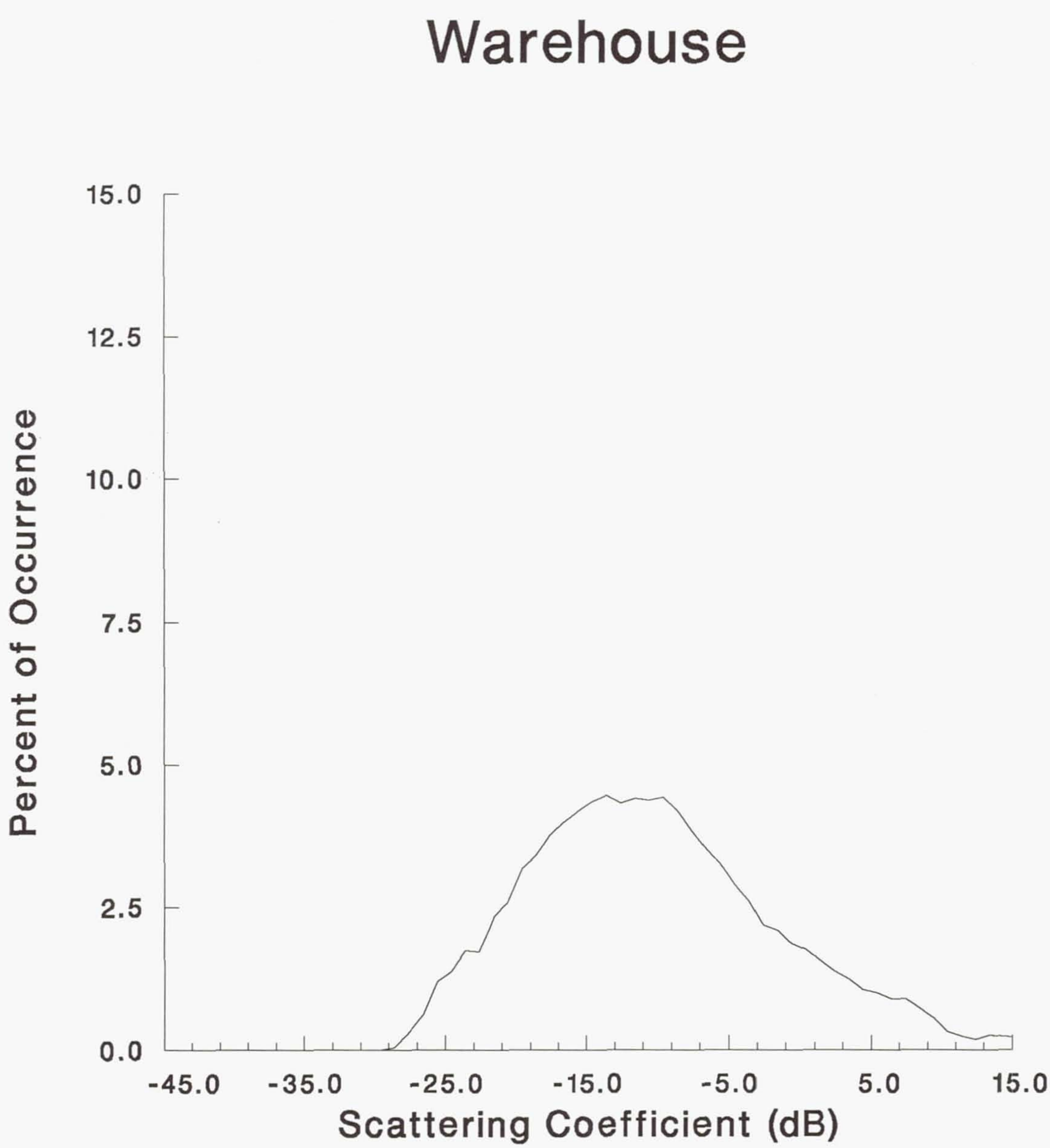


Figure 50.

Minimum: −44.08
Maximum: 20.53
Mean: −0.24
Bin Width: 1.00
Number of Bins: 66

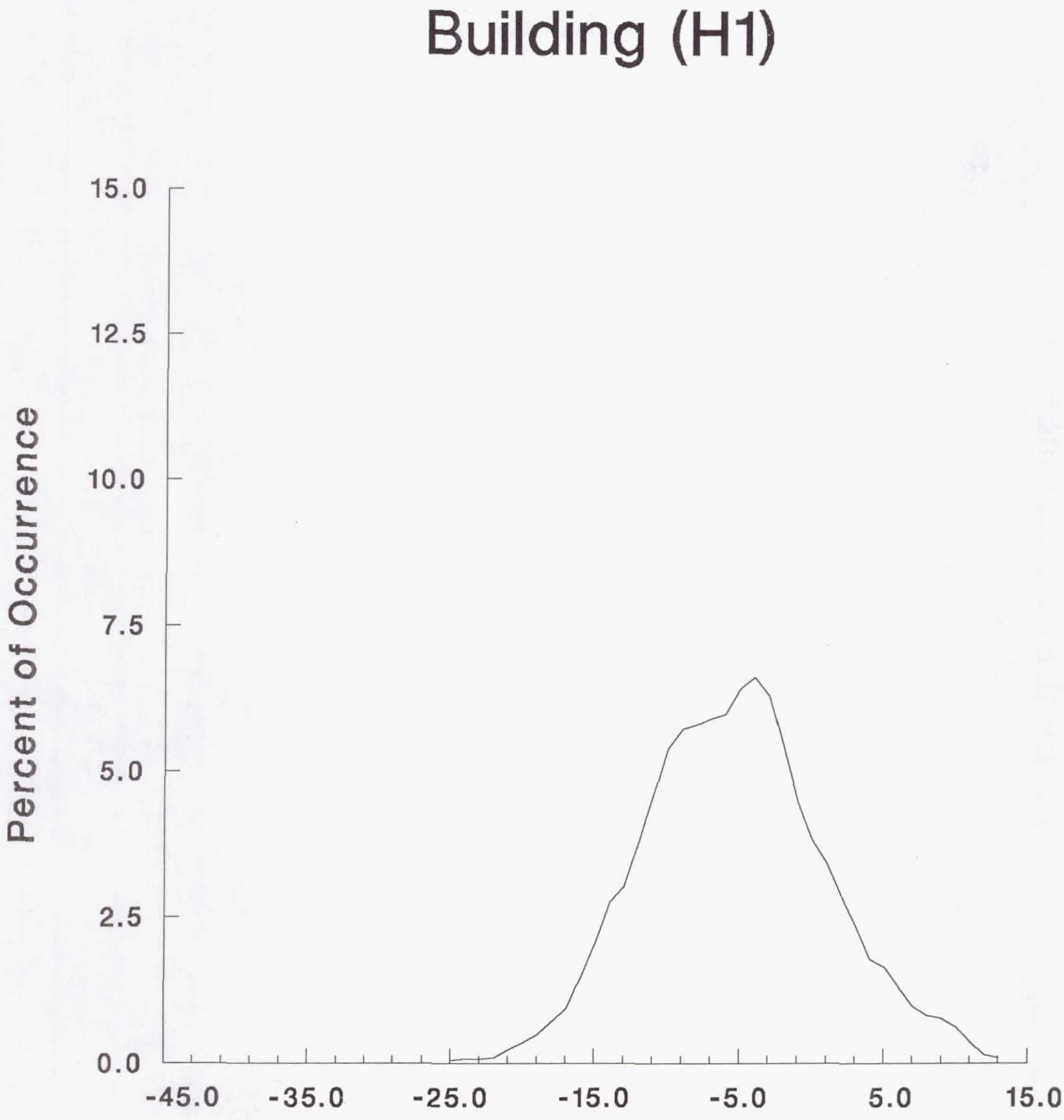


Figure 51.

Minimum: −25.46

Maximum: 12.72

Mean: −0.79

Bin Width: 1.00

Number of Bins: 39

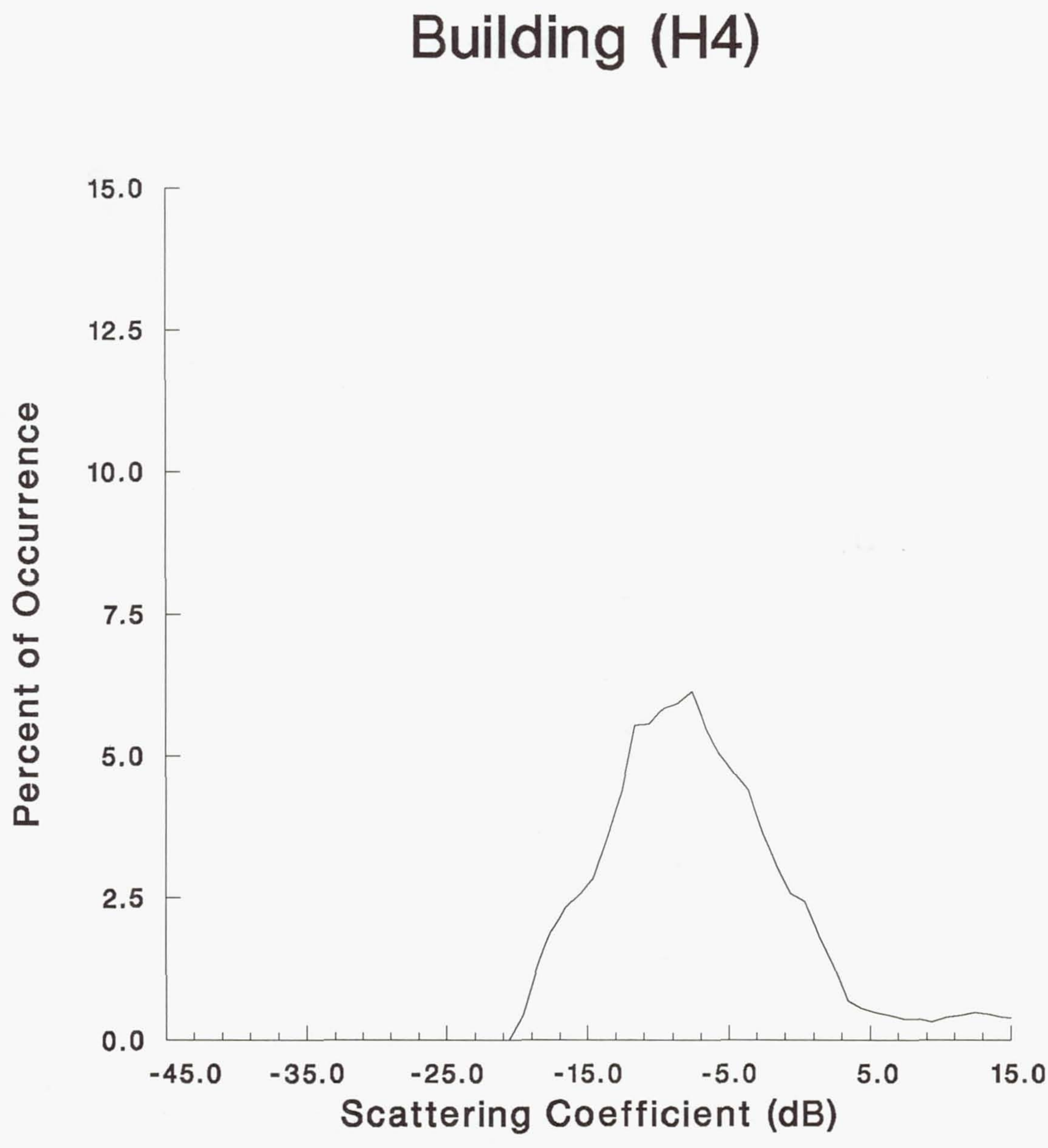


Figure 52.

Minimum: −44.08

Maximum: 24.78

Mean: 5.02

Bin Width: 1.00

Number of Bins: 70

Building (H5)

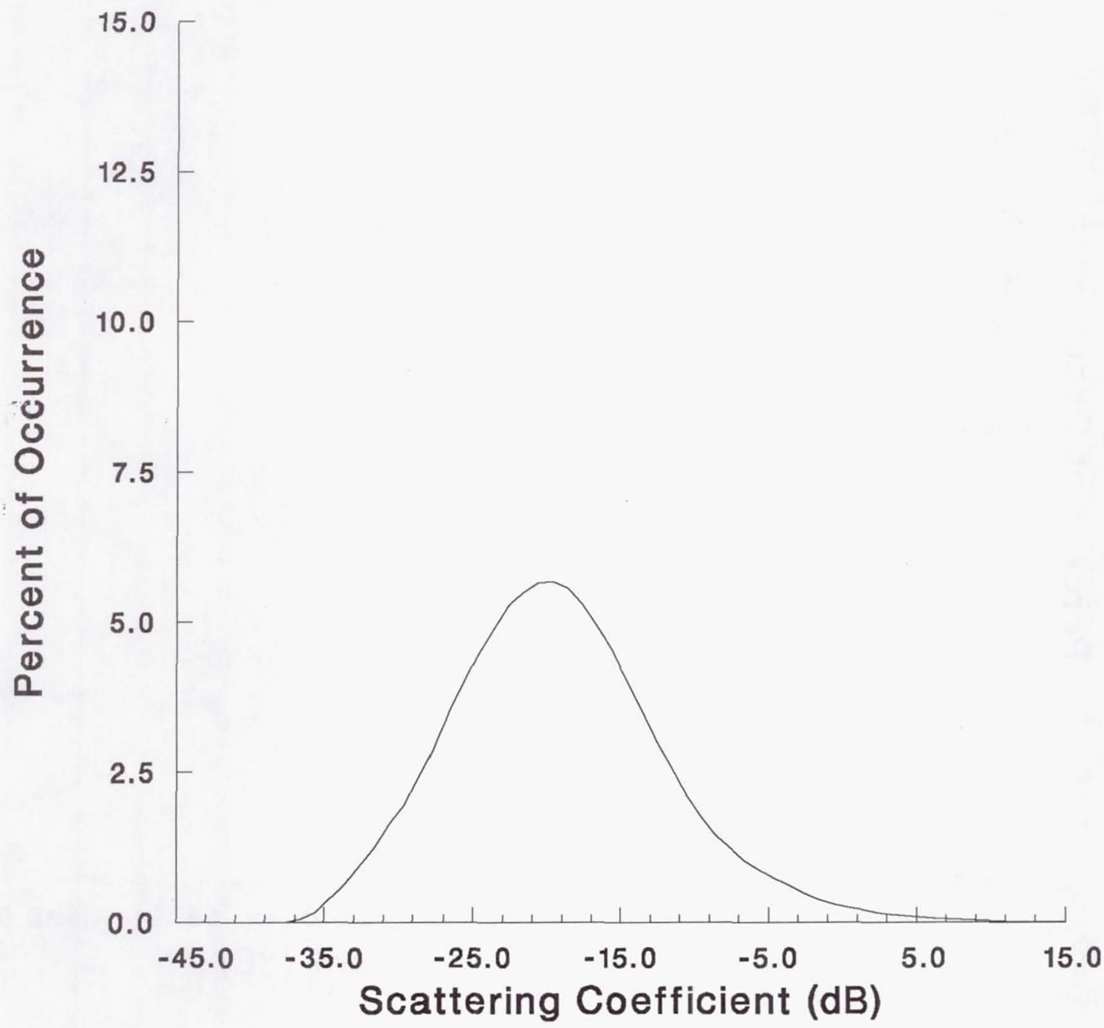


Figure 53.

Minimum: −44.08
Maximum: 27.30
Mean: 2.41
Bin Width: 1.00
Number of Bins: 67

Parking Lot

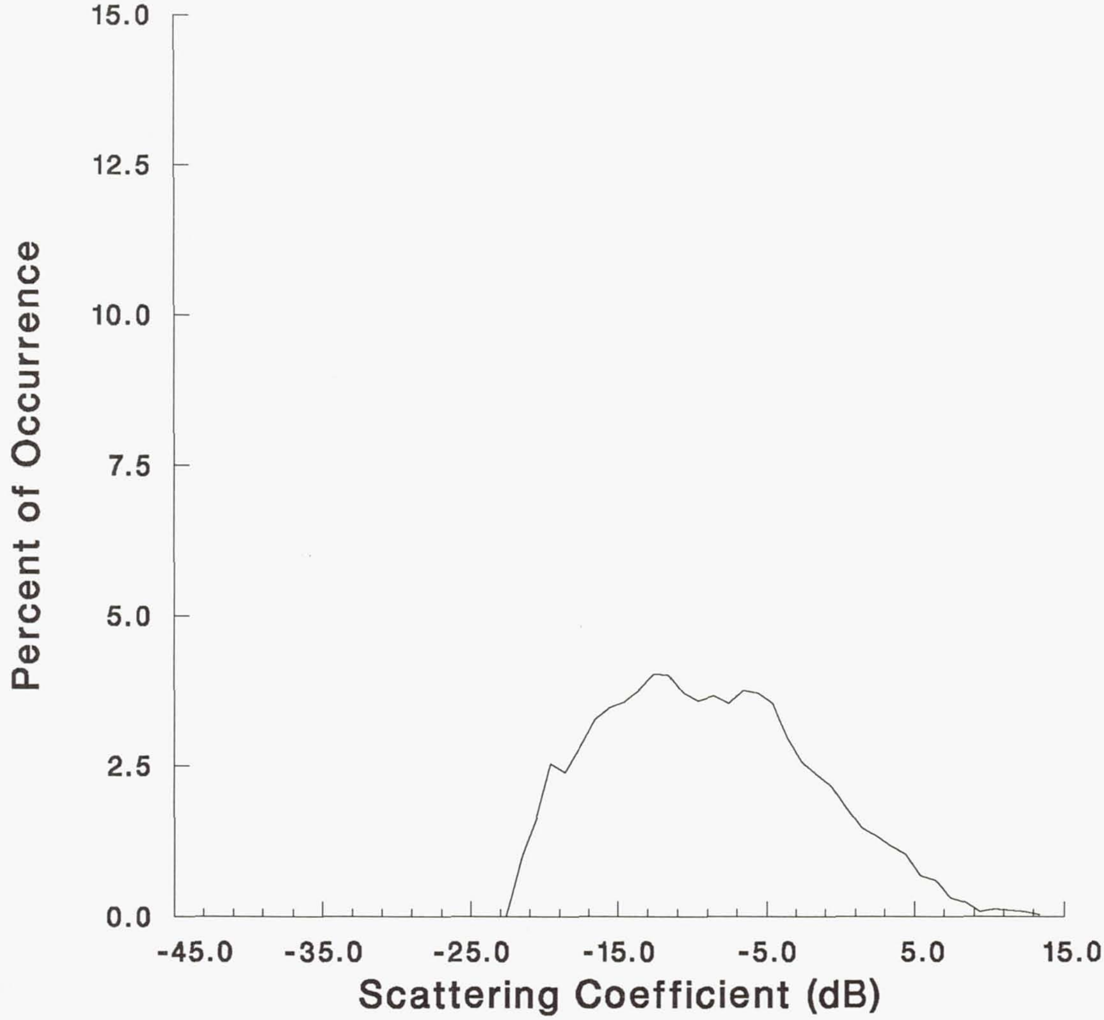


Figure 54.

Minimum: −44.08
Maximum: 13.12
Mean: −4.12
Bin Width: 1.00
Number of Bins: 58

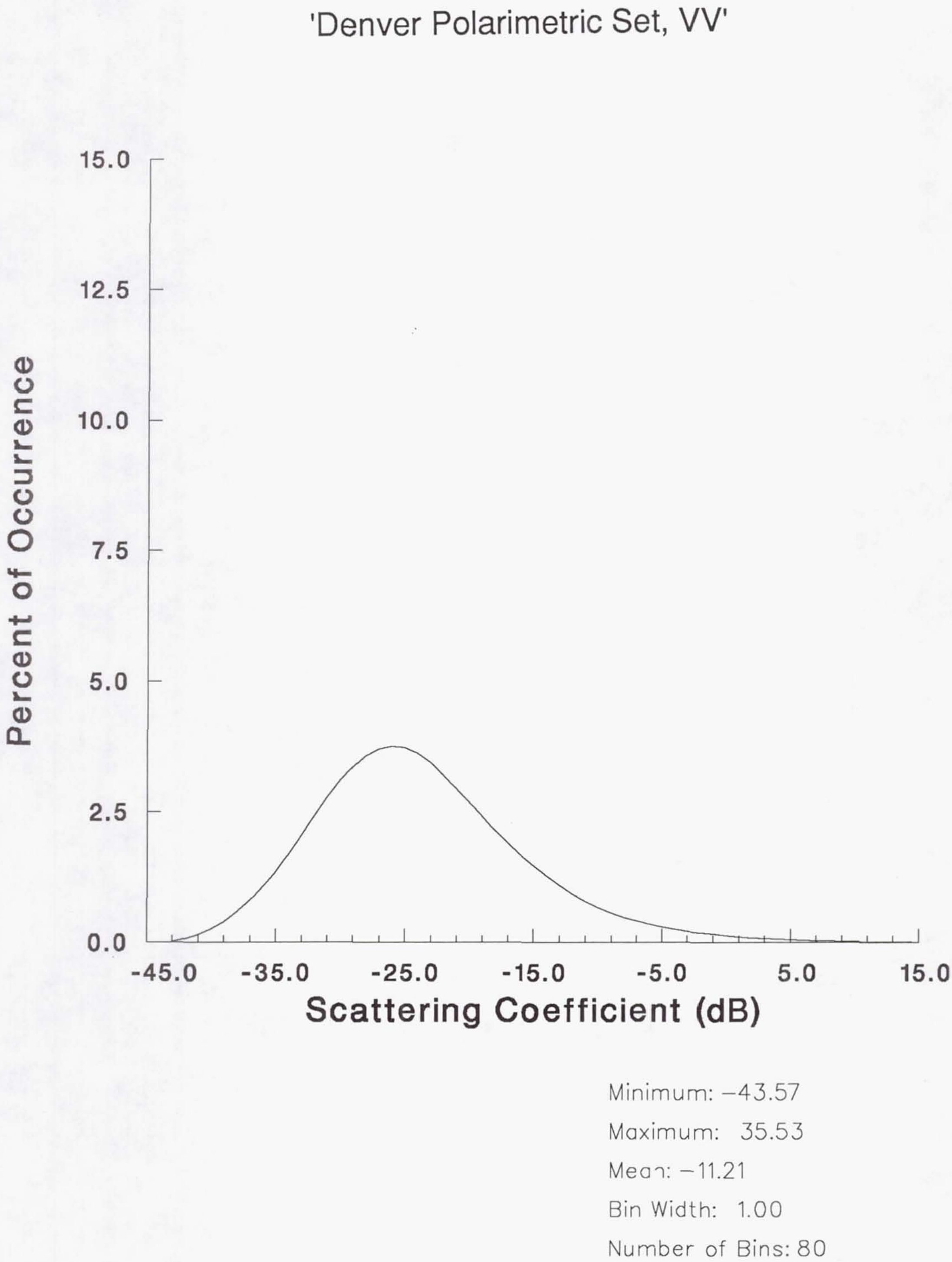


Figure 55. Clutter Distribution, Denver Polarimetric Set, X-VV

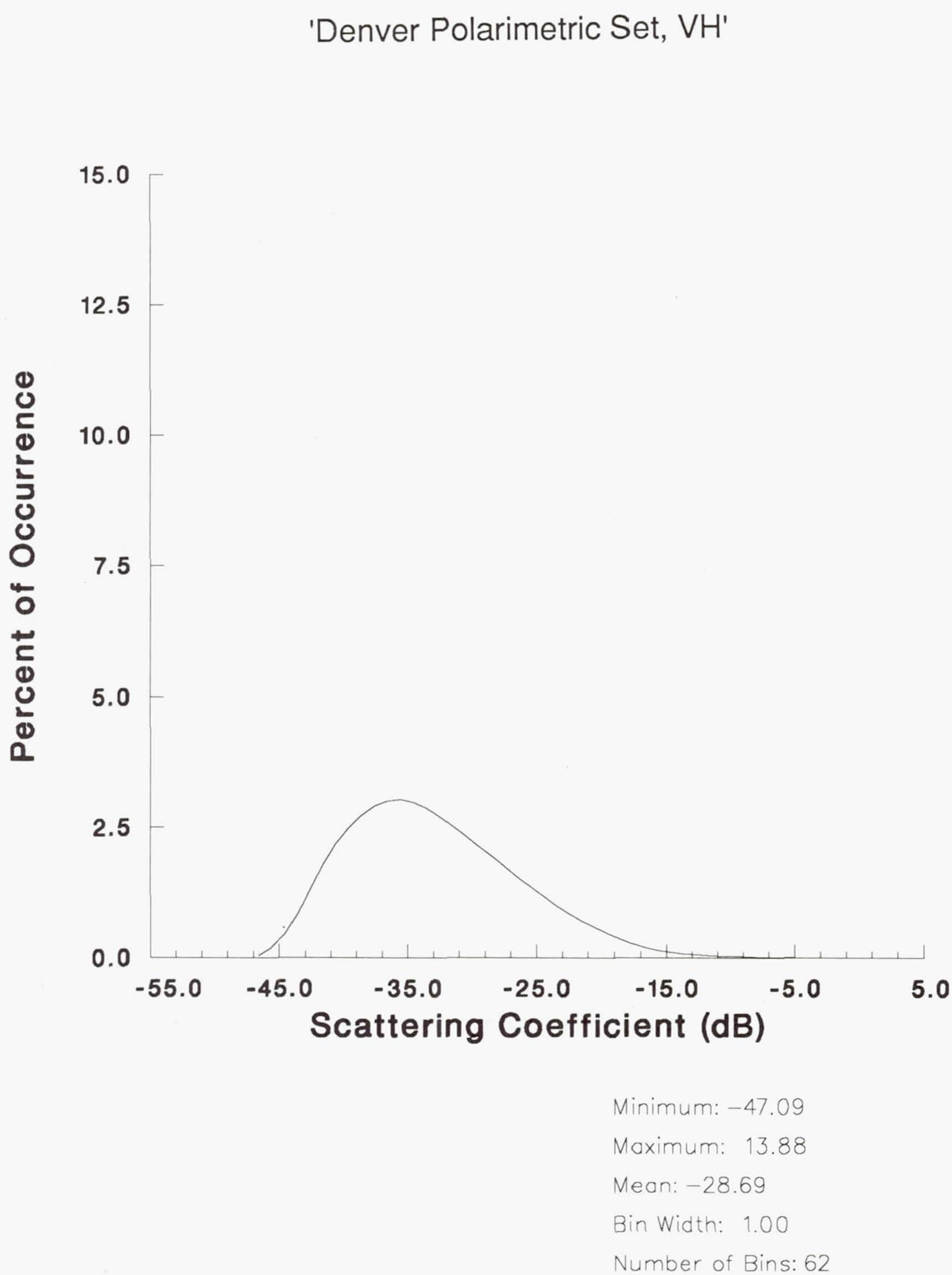


Figure 56. Clutter Distribution, Denver Polarimetric Set, X-VH

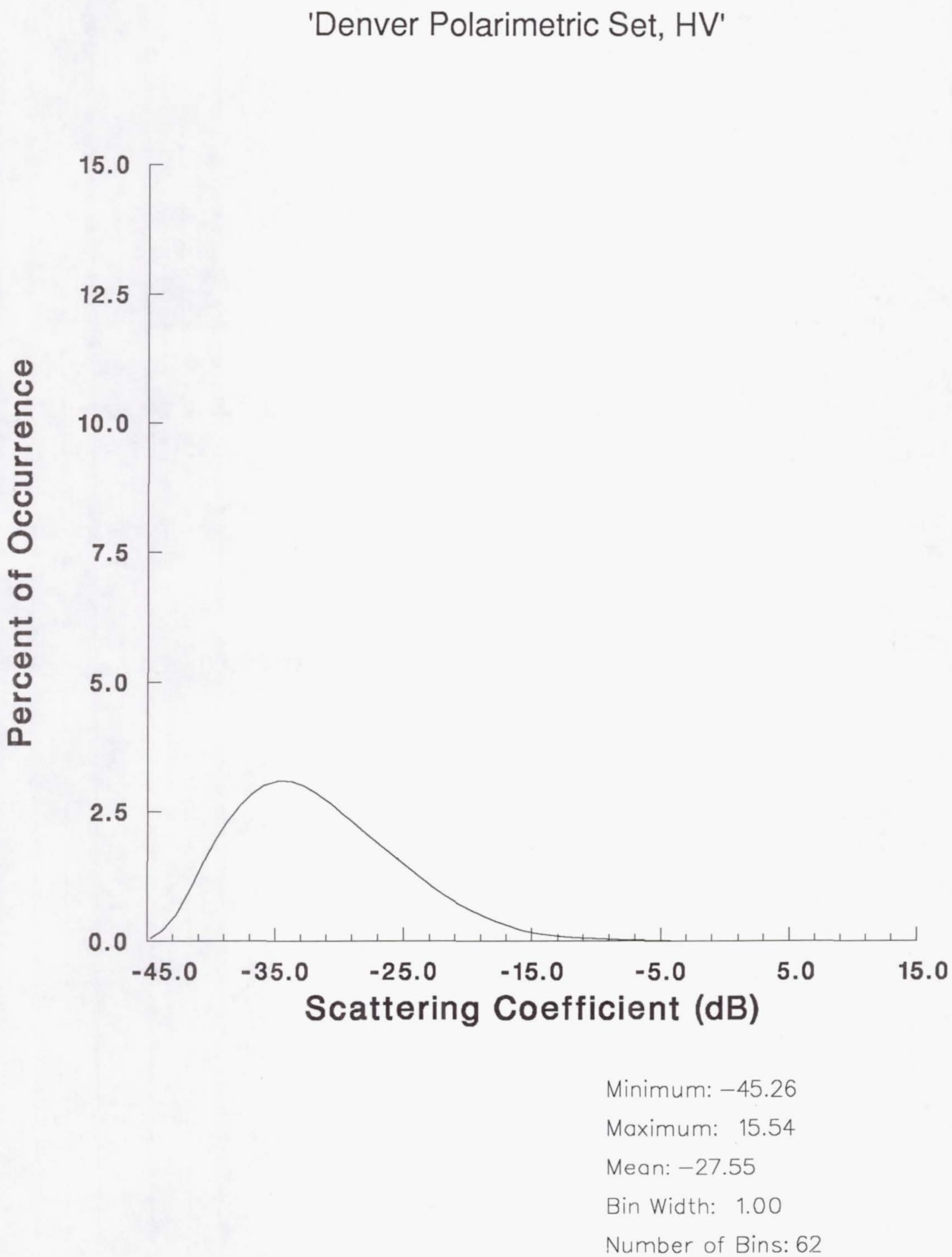
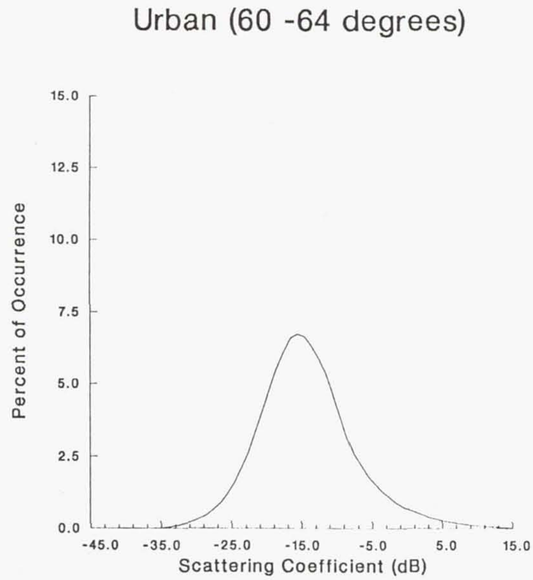
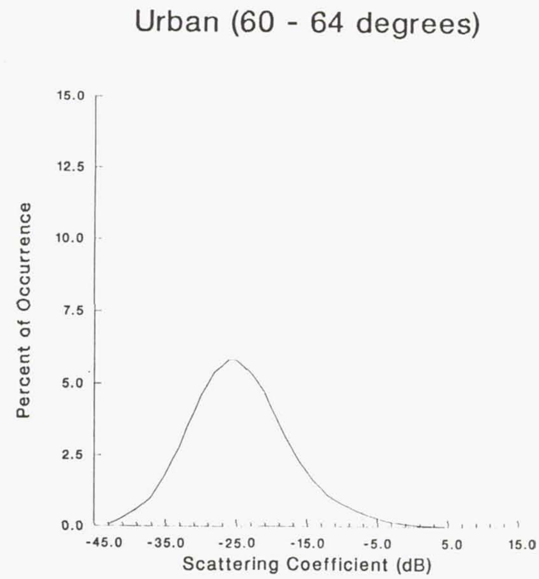


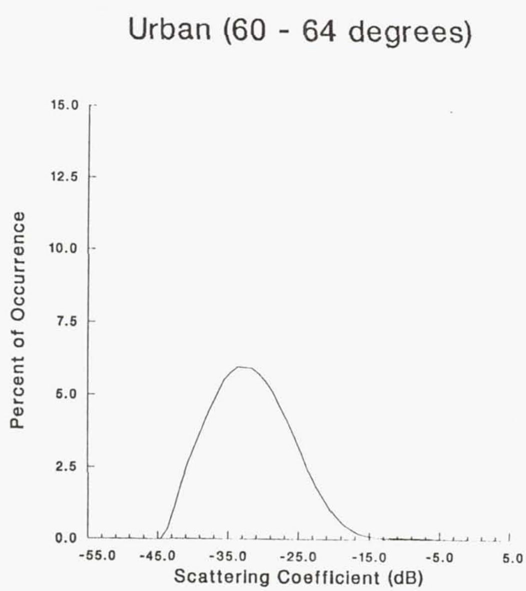
Figure 57. Clutter Distribution, Denver Polarimetric Set, X-HV



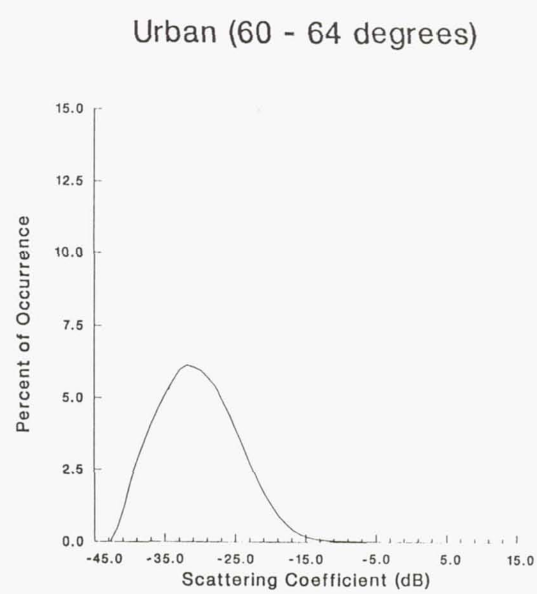
A) X-HH



B) X-VV



C) X-VH



D) X-HV

Figure 58. Urban Clutter Comparison

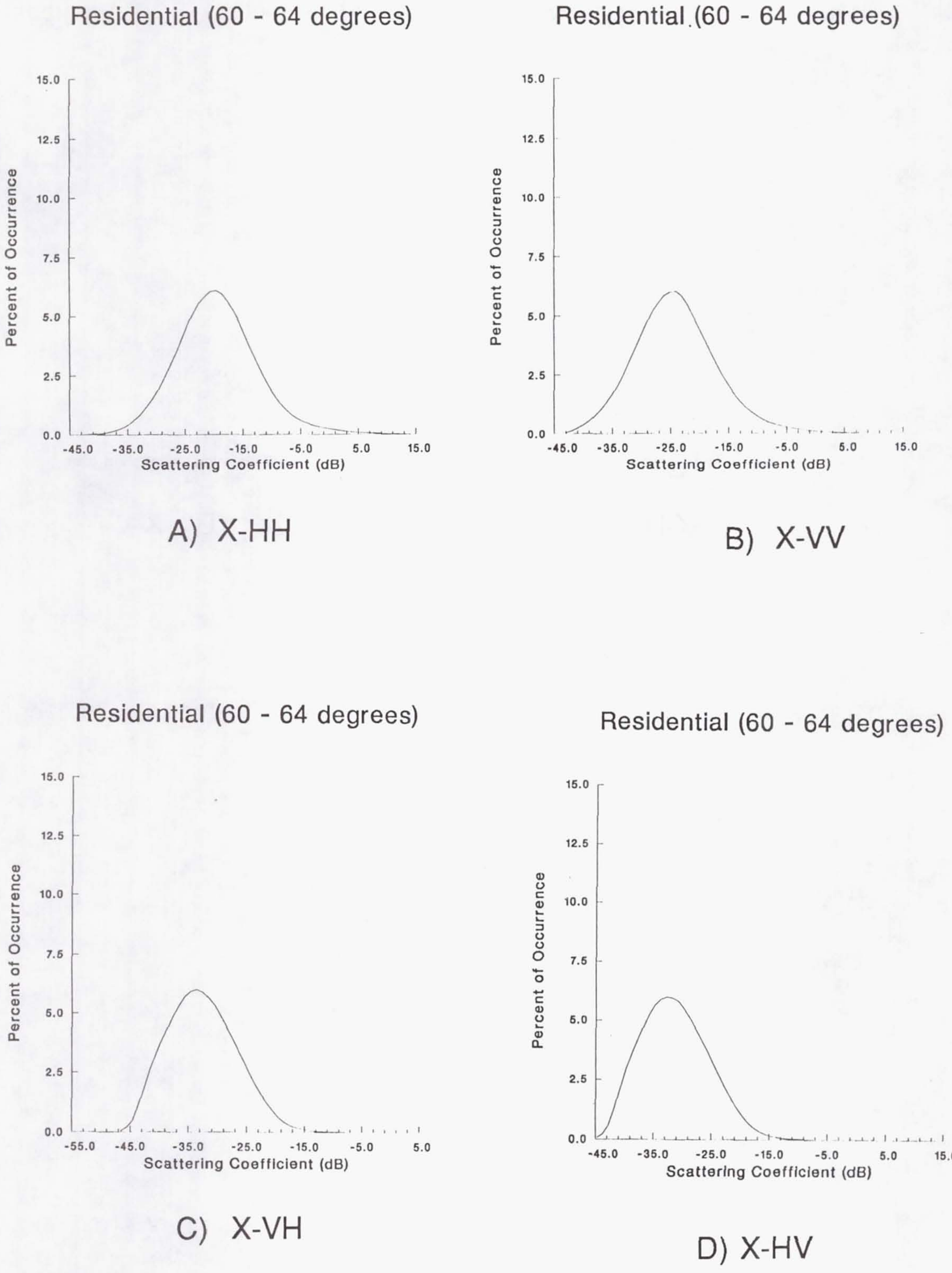
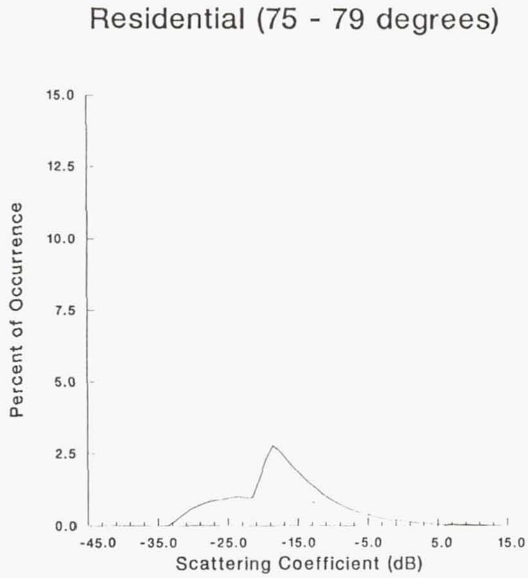
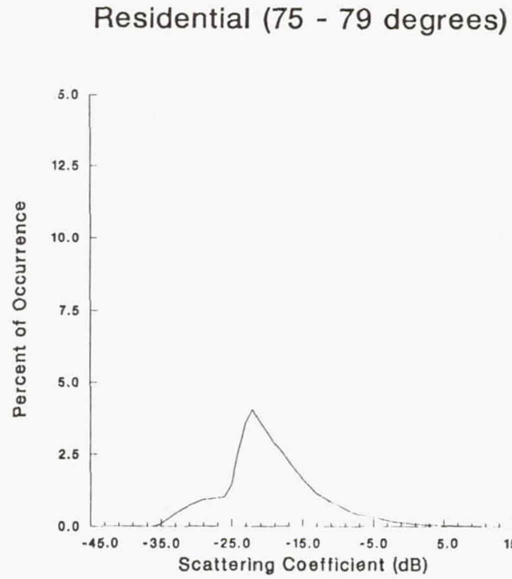


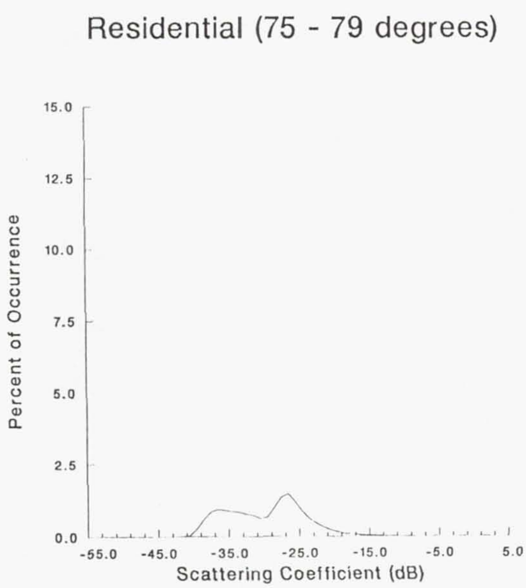
Figure 59. Residential Clutter Comparison



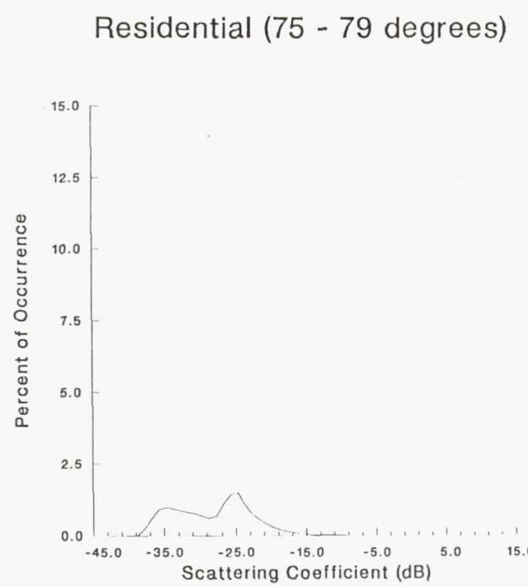
A) X-HH



B) X-VV



C) X-VH



D) X-HV

Figure 60. Residential Clutter Comparison

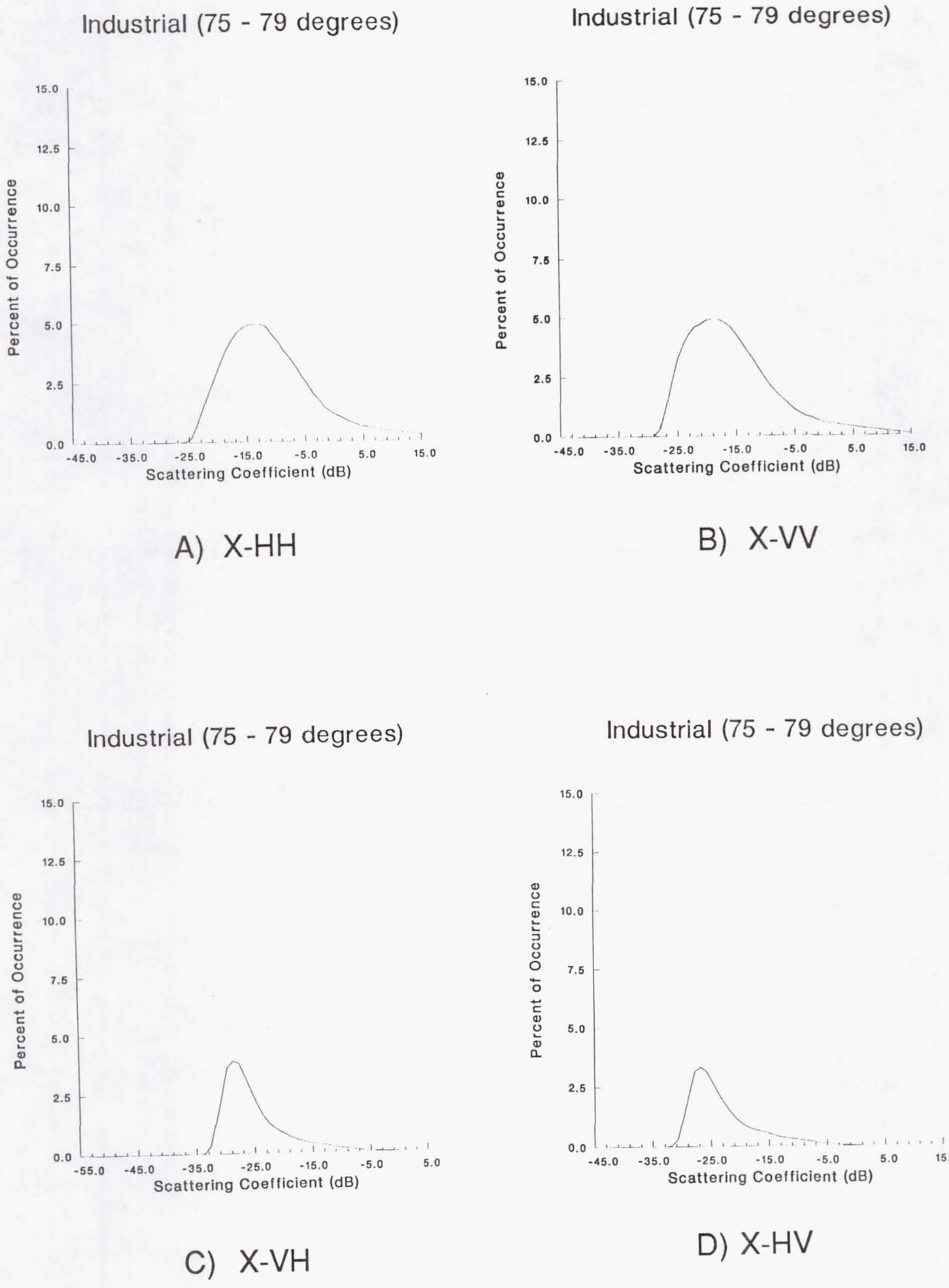
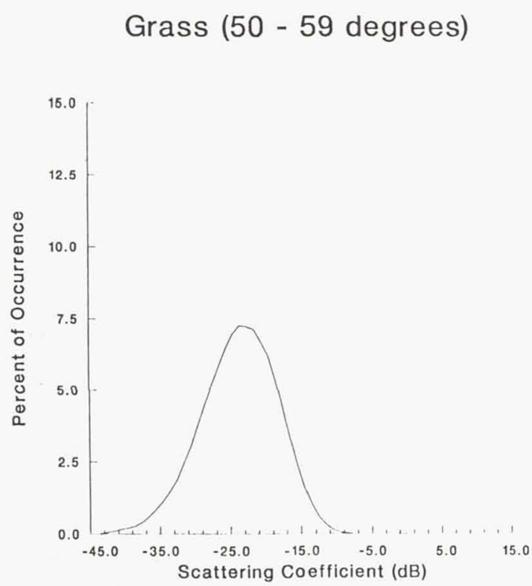
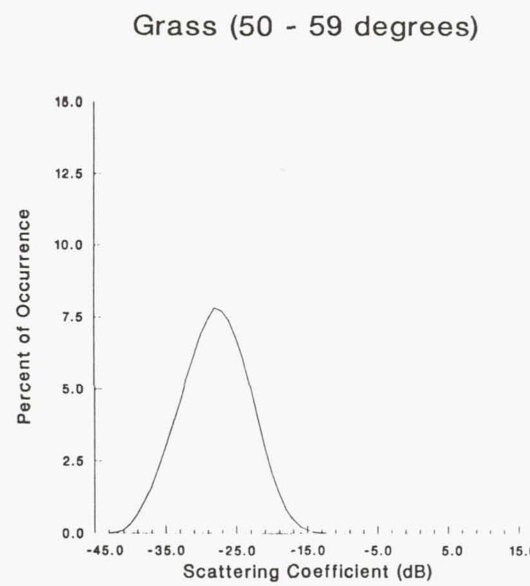


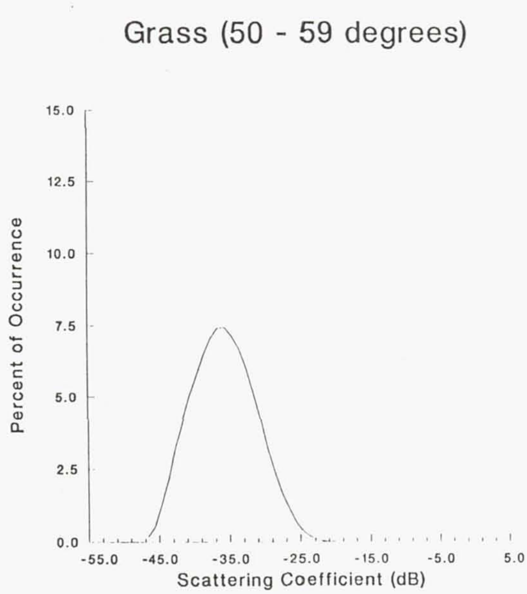
Figure 61. Industrial Clutter Comparison



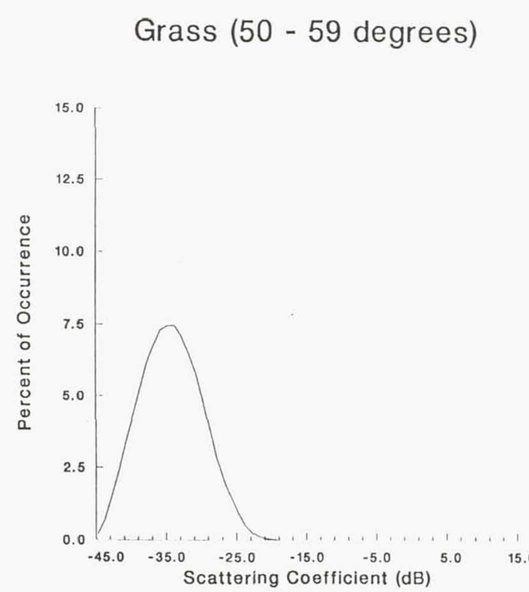
A) X-HH



B) X-VV



C) X-VH



D) X-HV

Figure 62. Grass Clutter Comparison

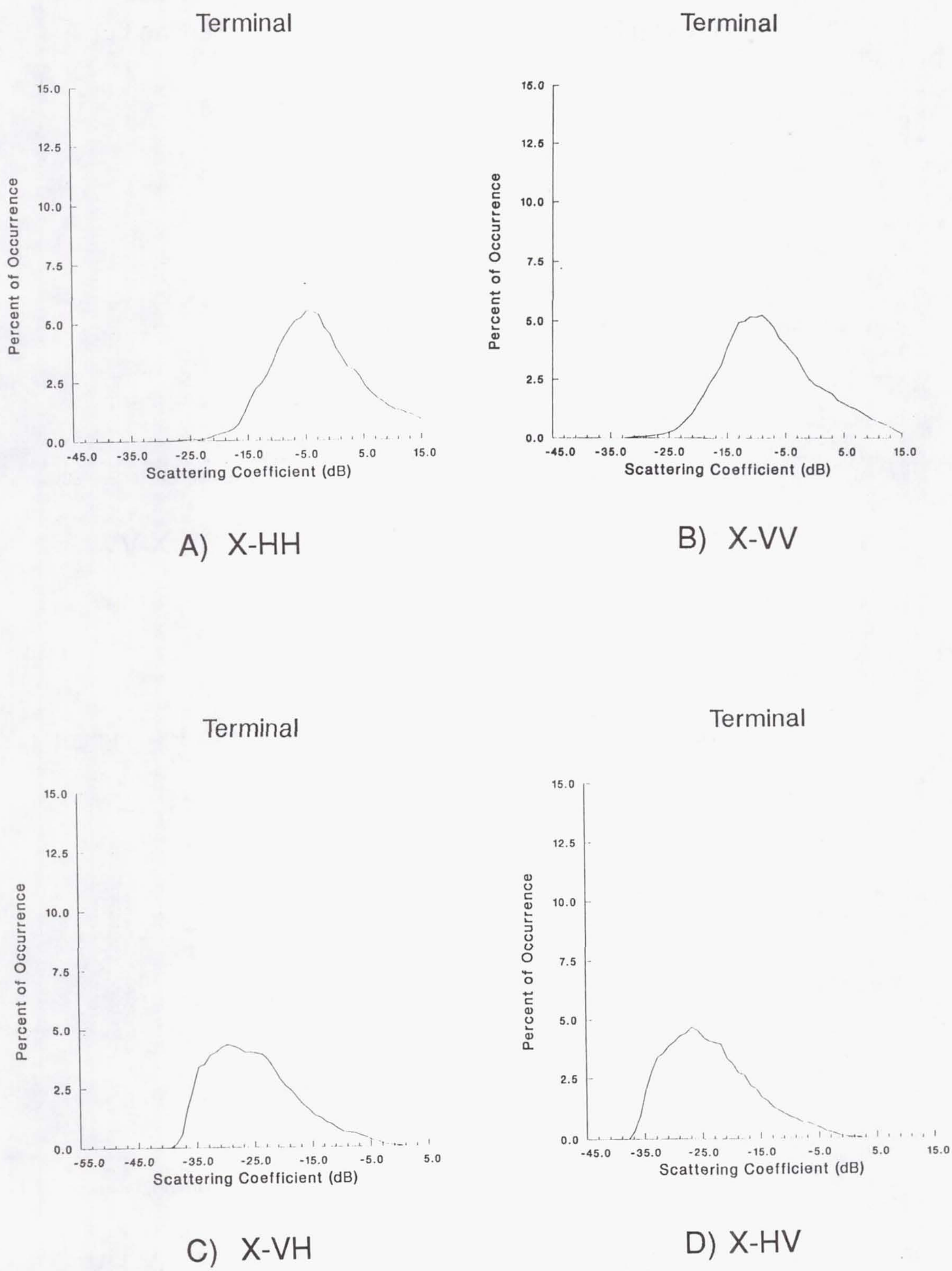


Figure 63. Terminal Clutter Comparison

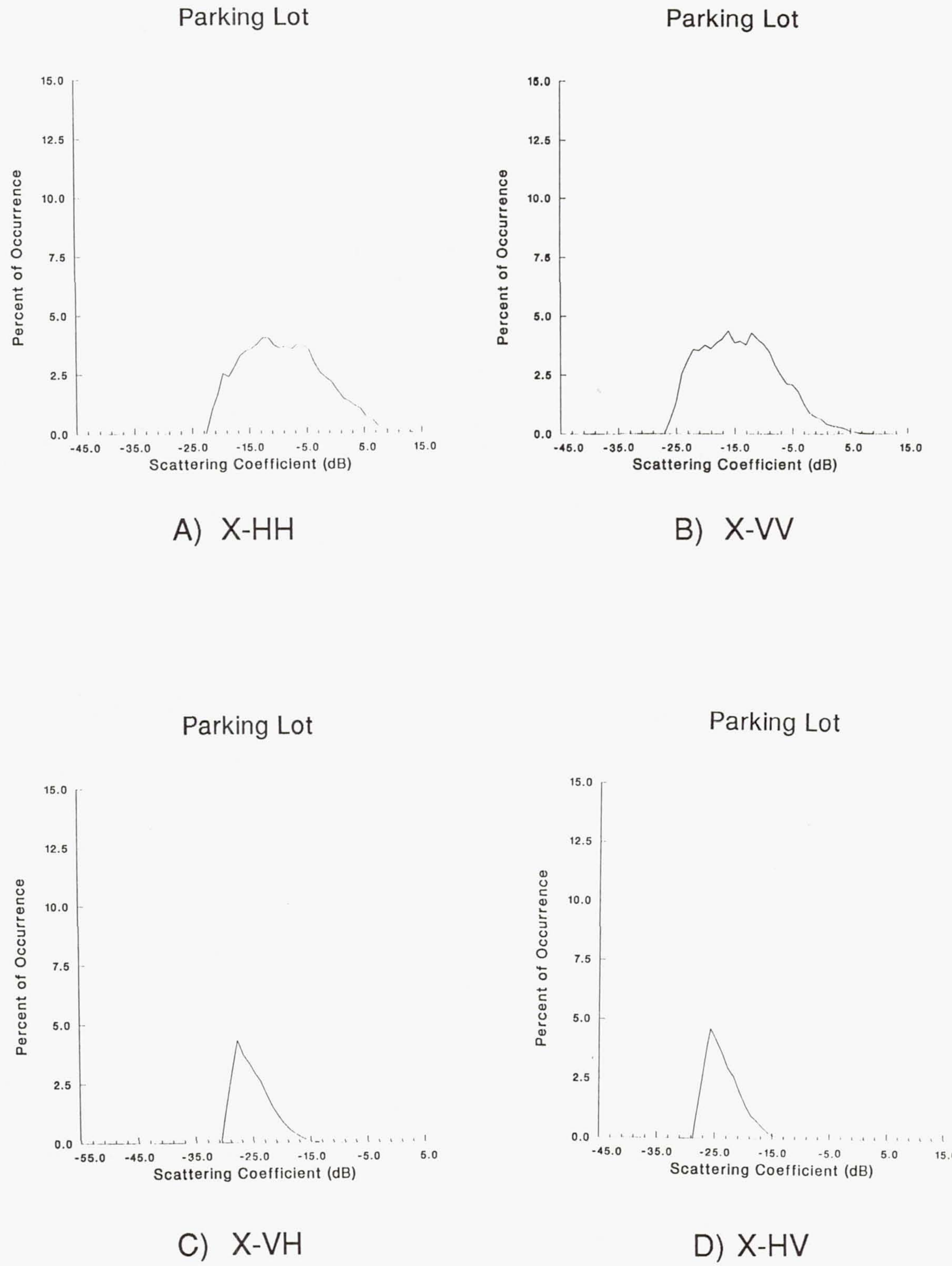


Figure 64. Parking Lot Clutter Comparison

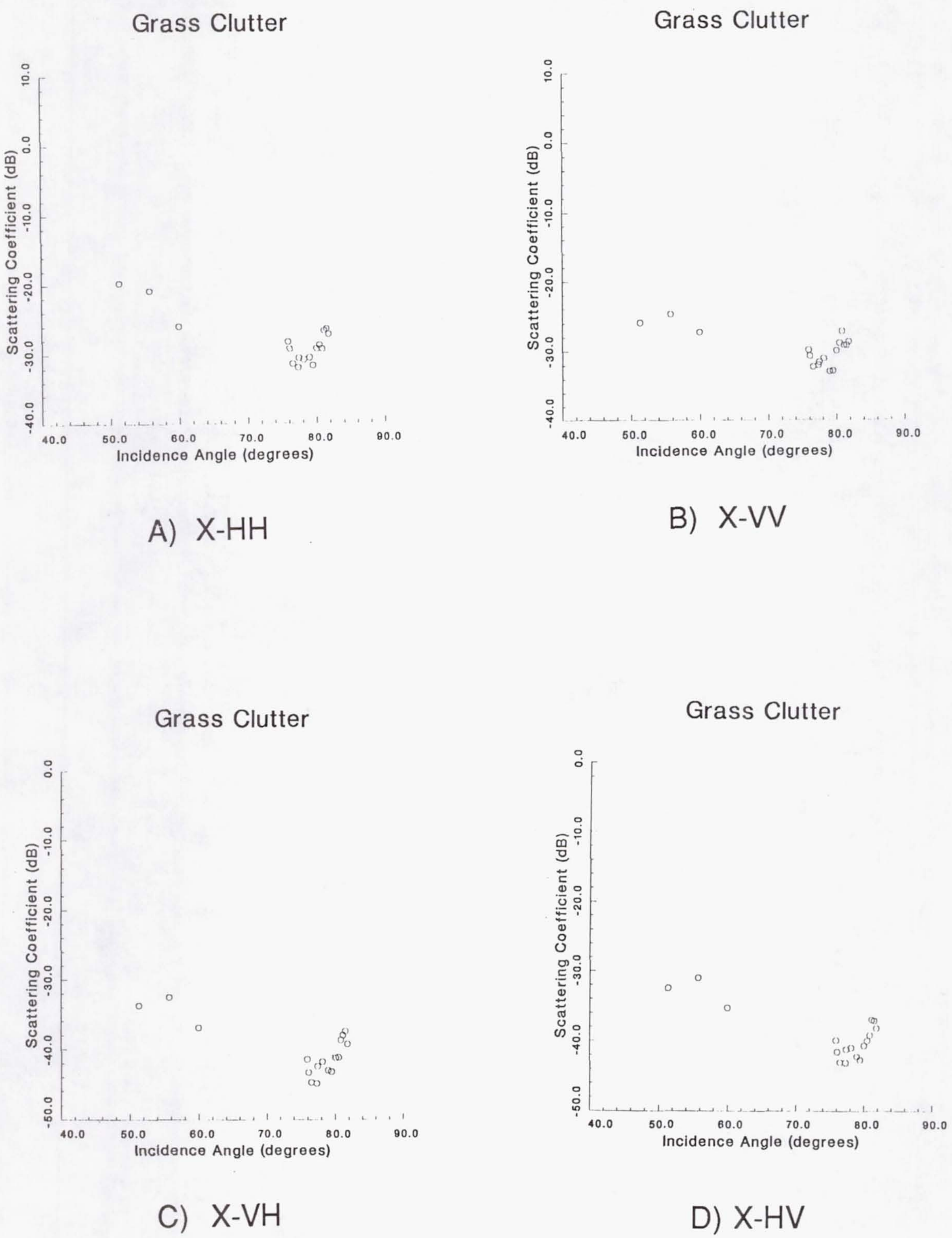


Figure 65. Grass Clutter Incidence Angle Plot Comparison

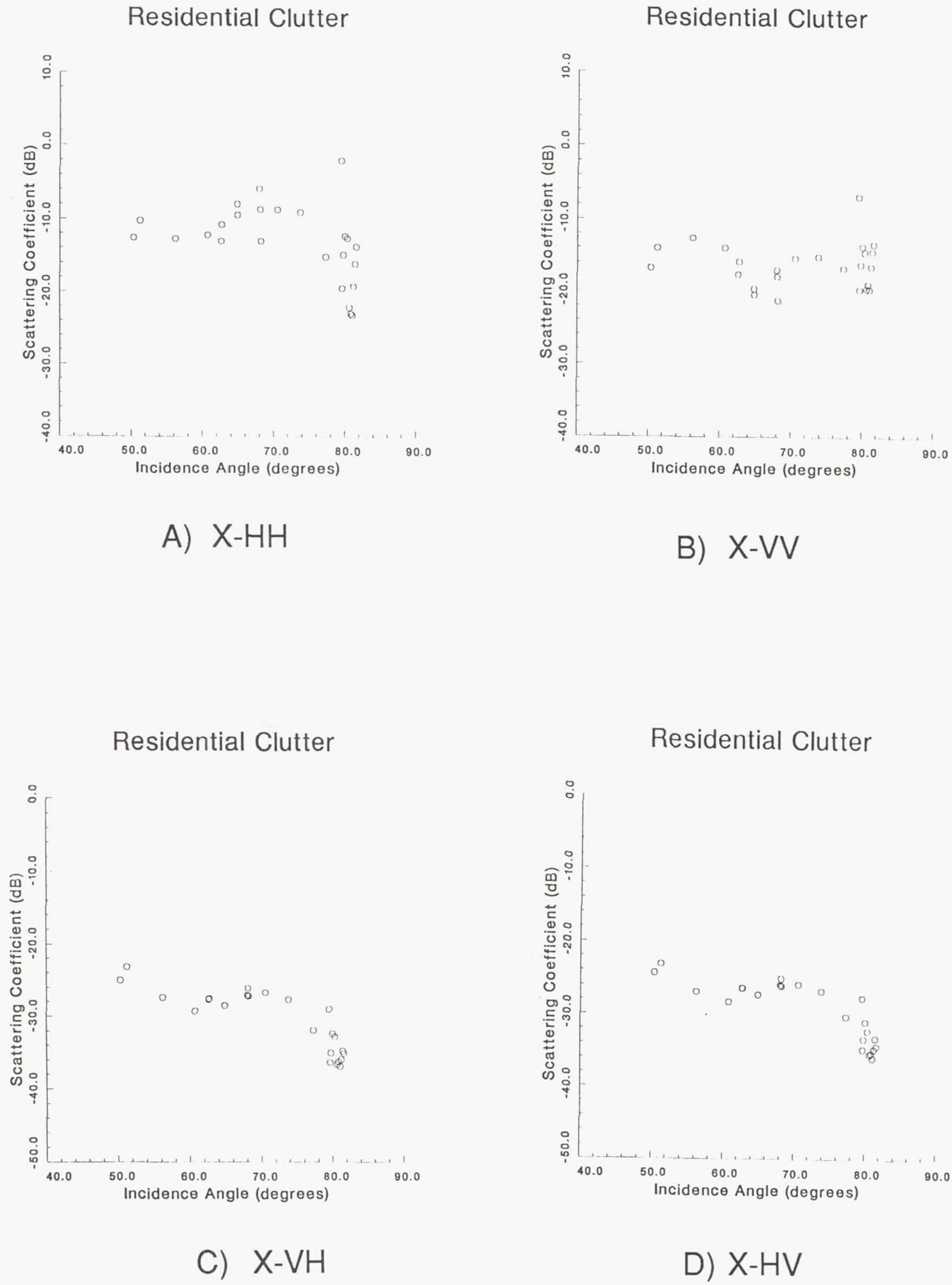
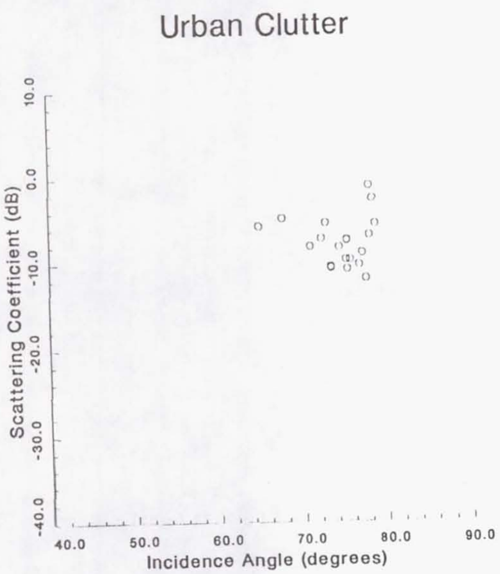
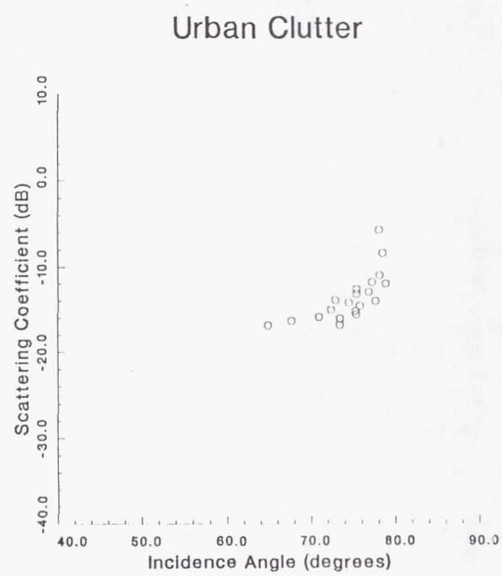


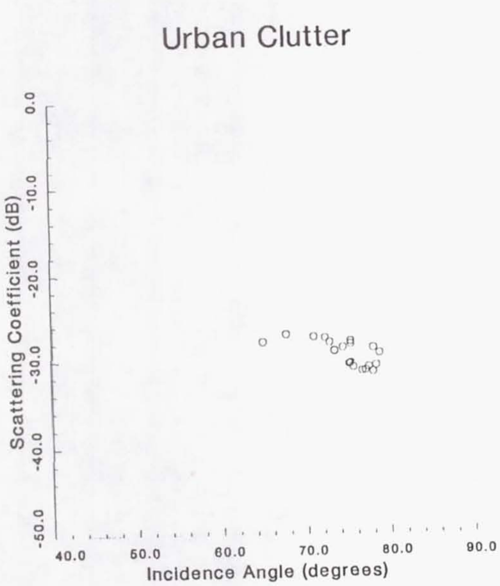
Figure 66. Residential Clutter Incidence Angle Plot Comparison



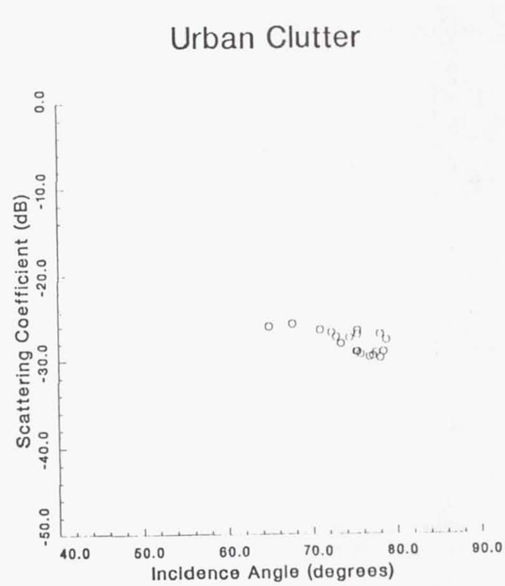
A) X-HH



B) X-VV



C) X-VH



D) X-HV

Figure 67. Urban Clutter Incidence Angle Plot Comparison

Figure 68. City Clutter Incidence Angle Plot Comparison

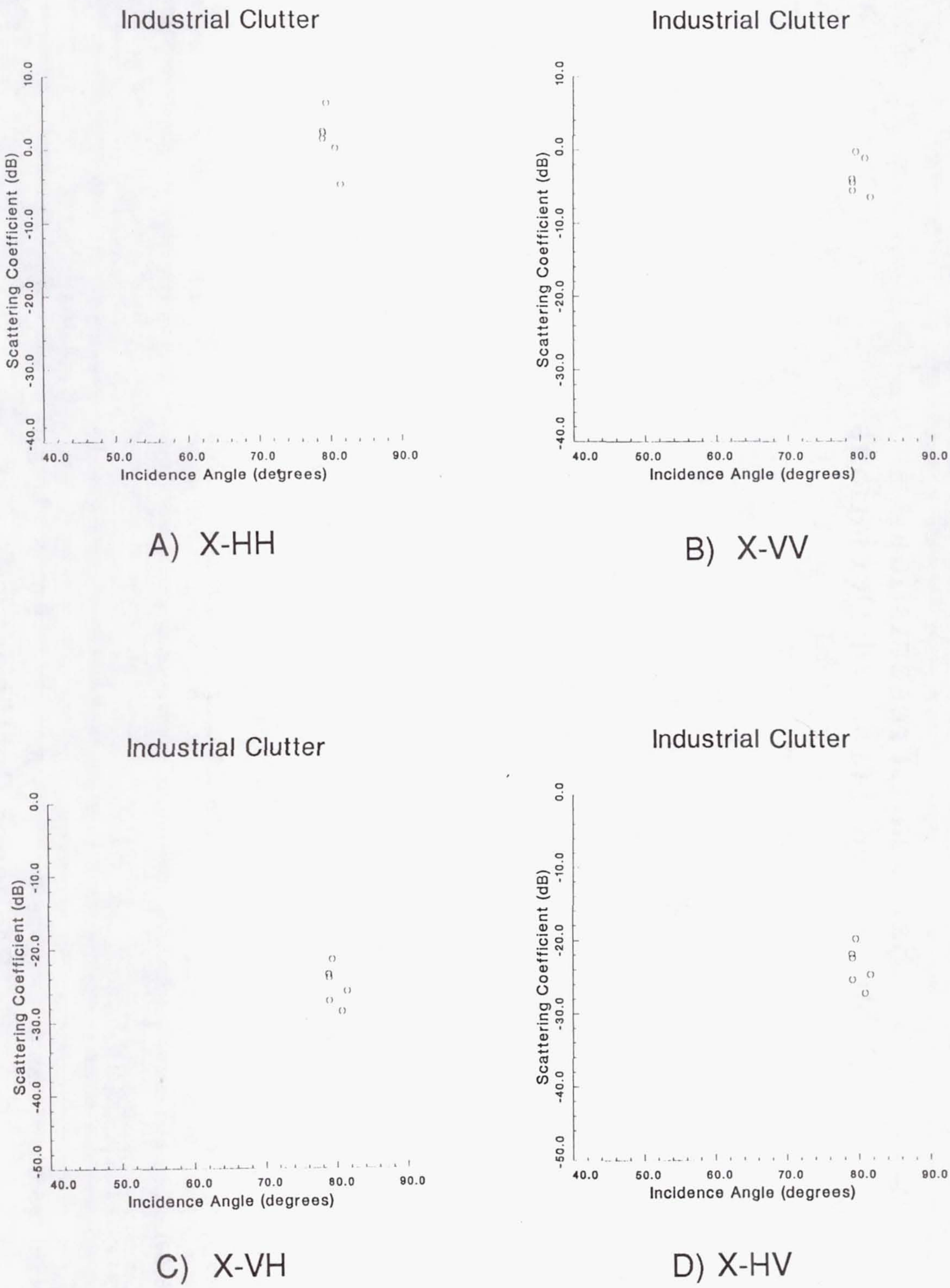


Figure 69. Industrial Clutter Incidence Angle Plot Comparison

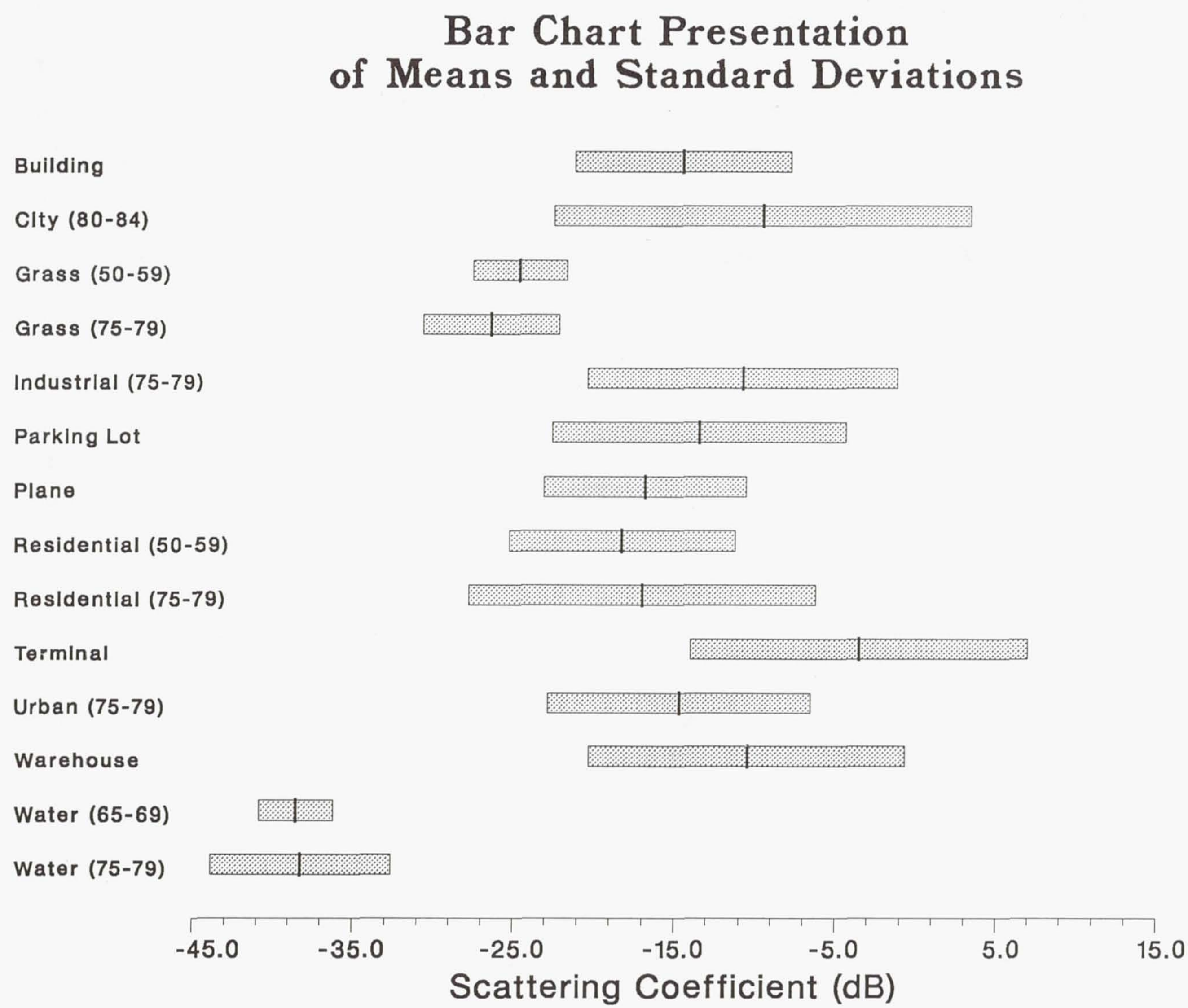


Figure 70. Mean NRCS Values, Denver First 'Step West'

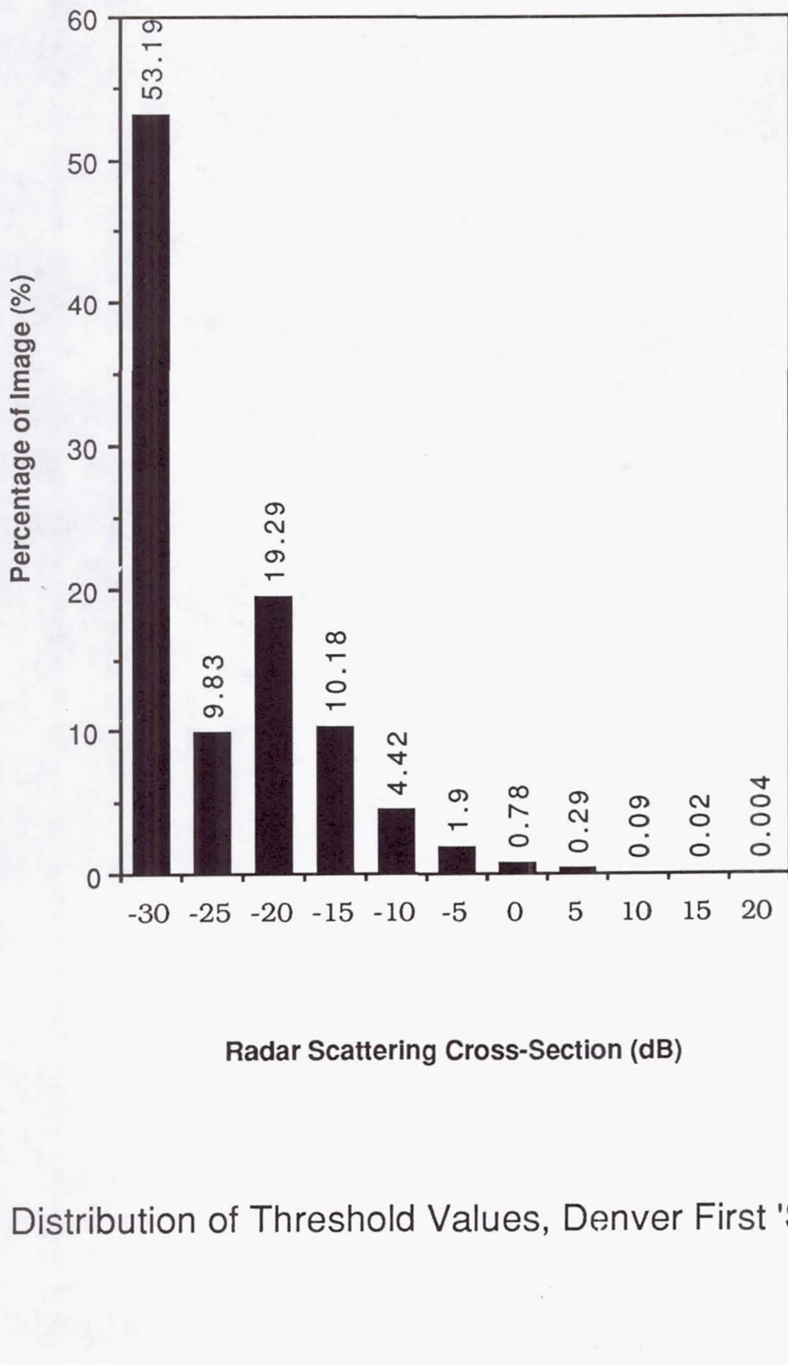


Figure 71. Distribution of Threshold Values, Denver First 'Step West'

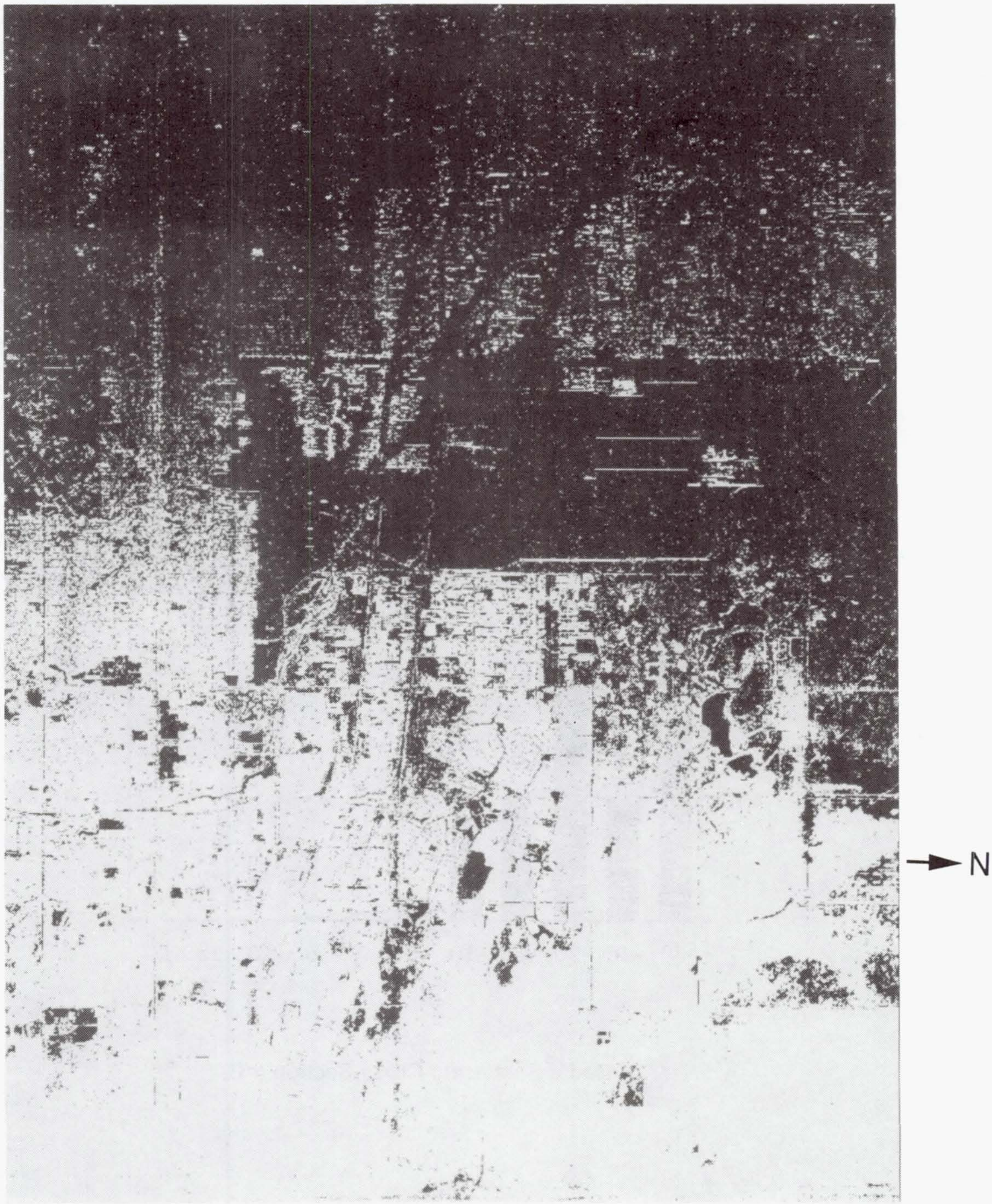


Figure 72. The First Denver 'Step West' Image Thresholded at -30 dB

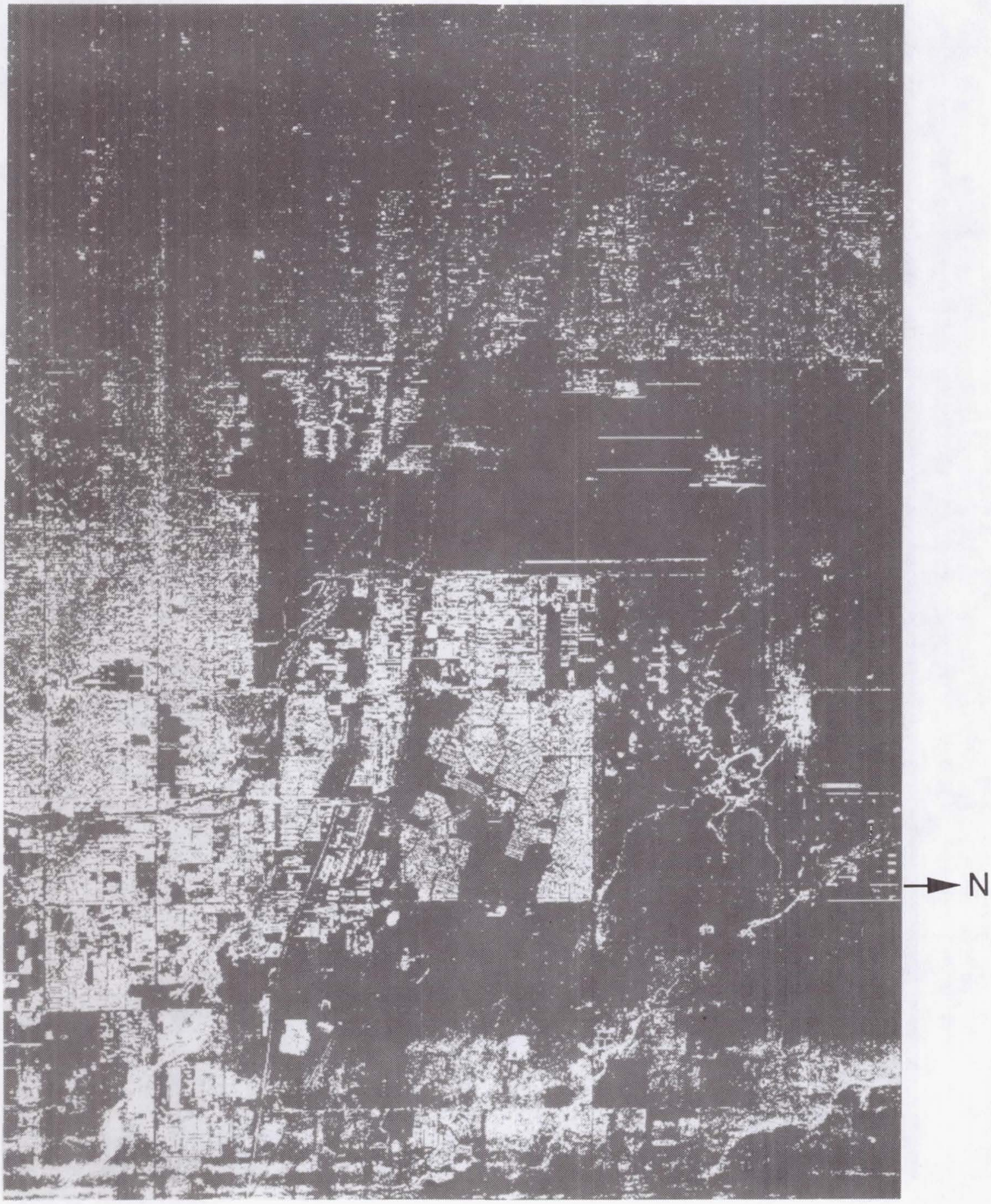


Figure 73. The First Denver 'Step West' Image Thresholded at -20 dB

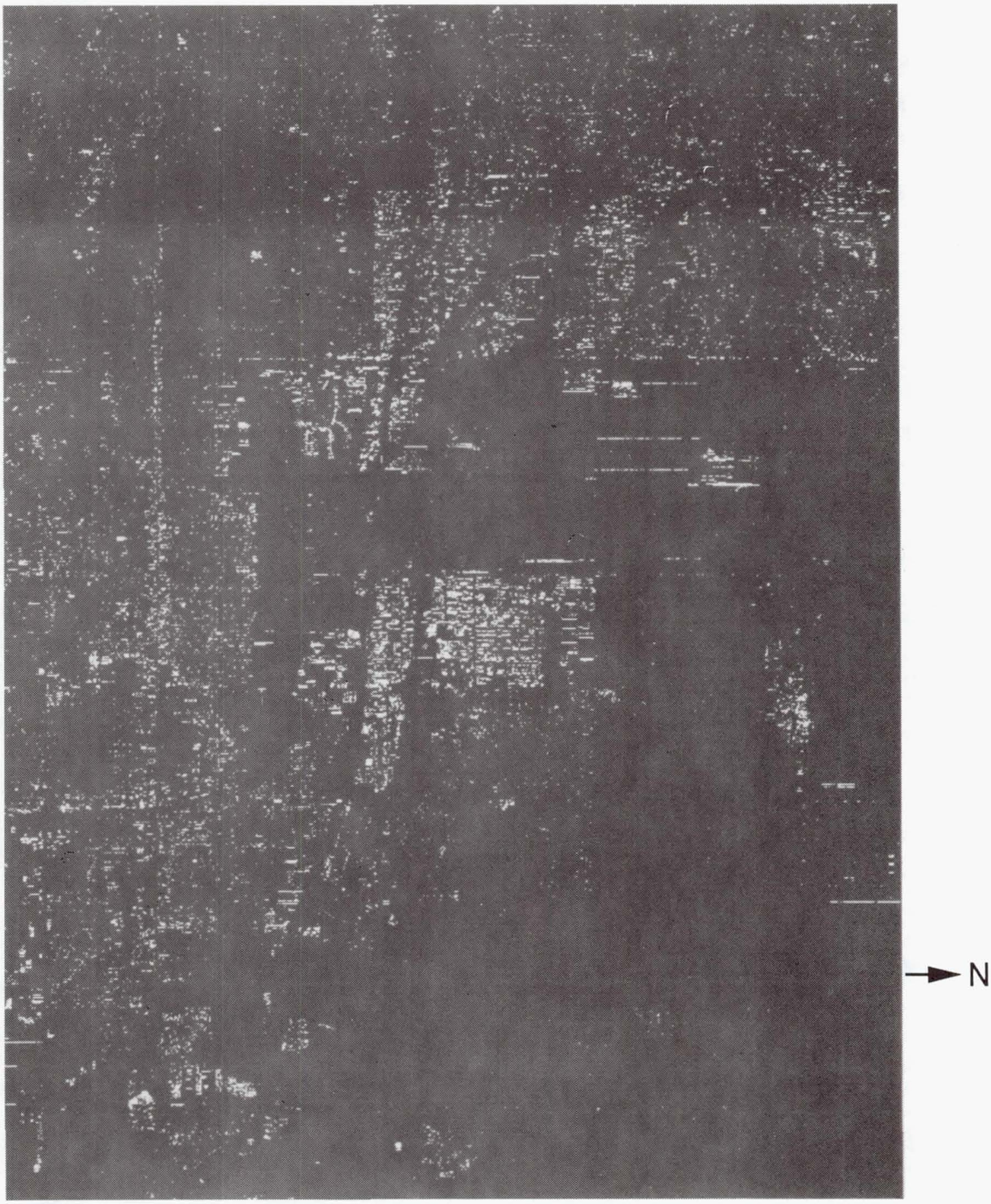


Figure 74. The First Denver 'Step West' Image Thresholded at -10 dB

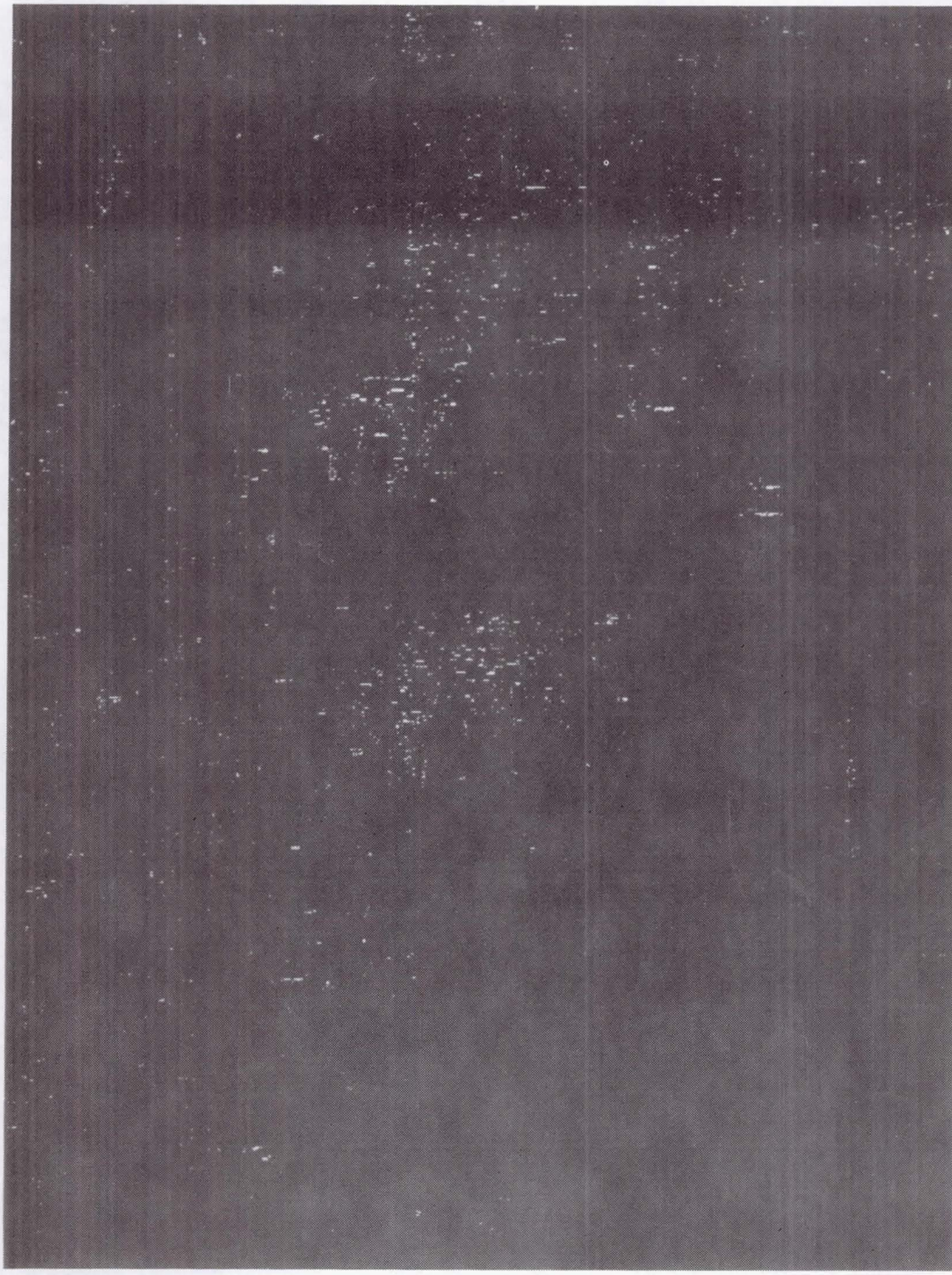


Figure 75. The First Denver 'Step West' Image Thresholded at 0 dB

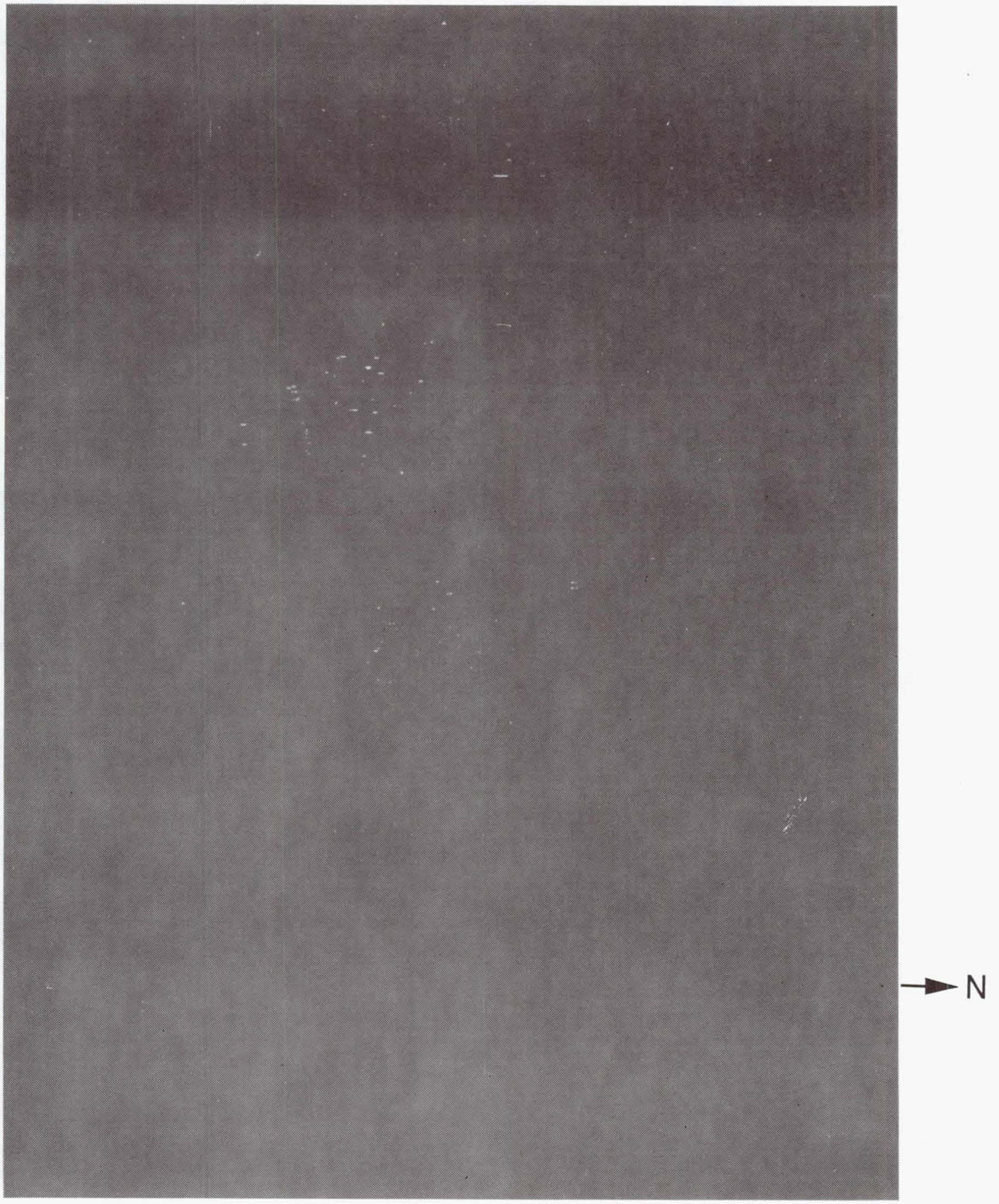


Figure 76. The First Denver 'Step West' Image Thresholded at 10 dB

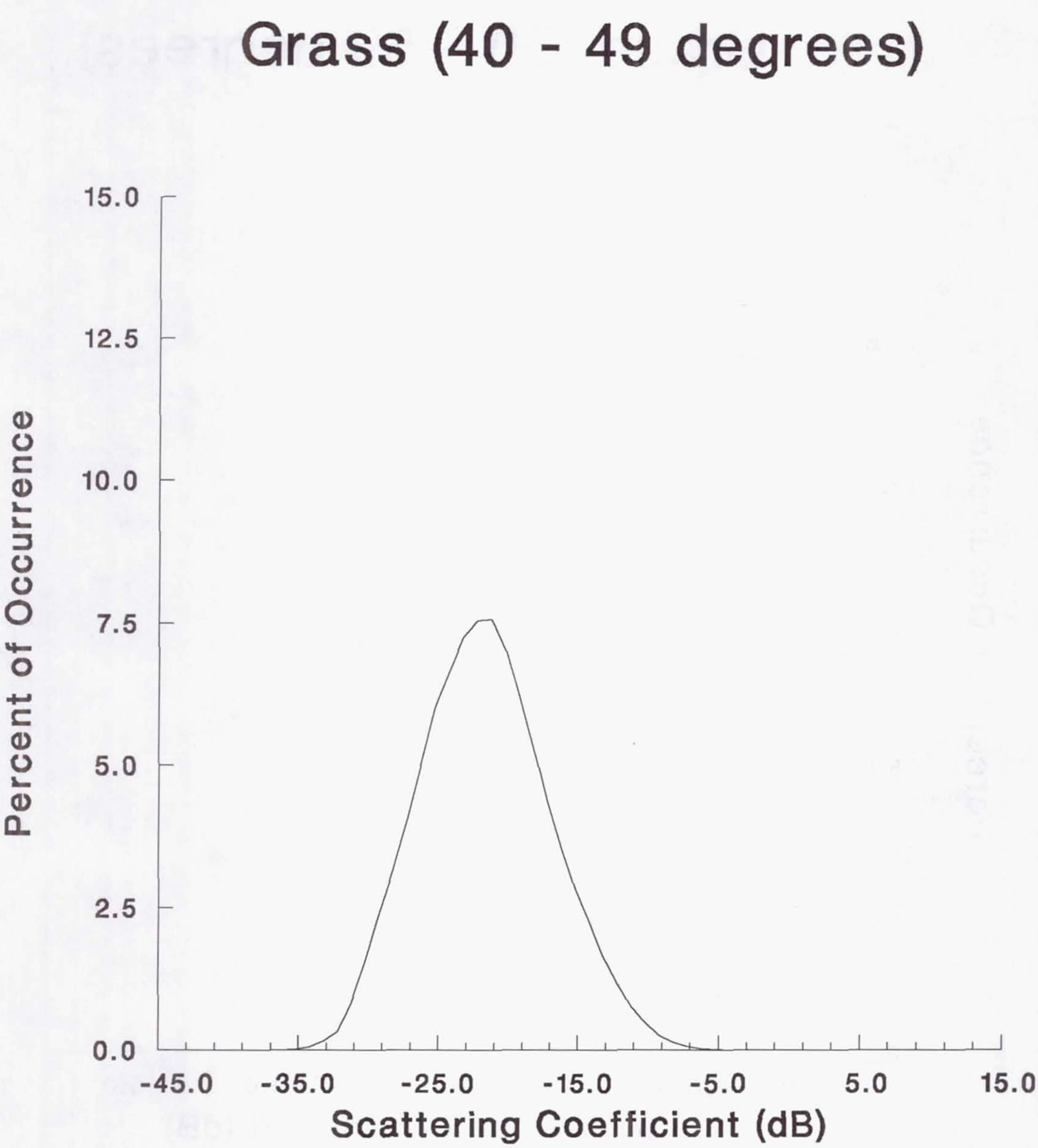


Figure 77.

Minimum: −38.71
Maximum: −4.66
Mean: −19.64
Bin Width: 1.00
Number of Bins: 35

Grass (50 - 59 degrees)

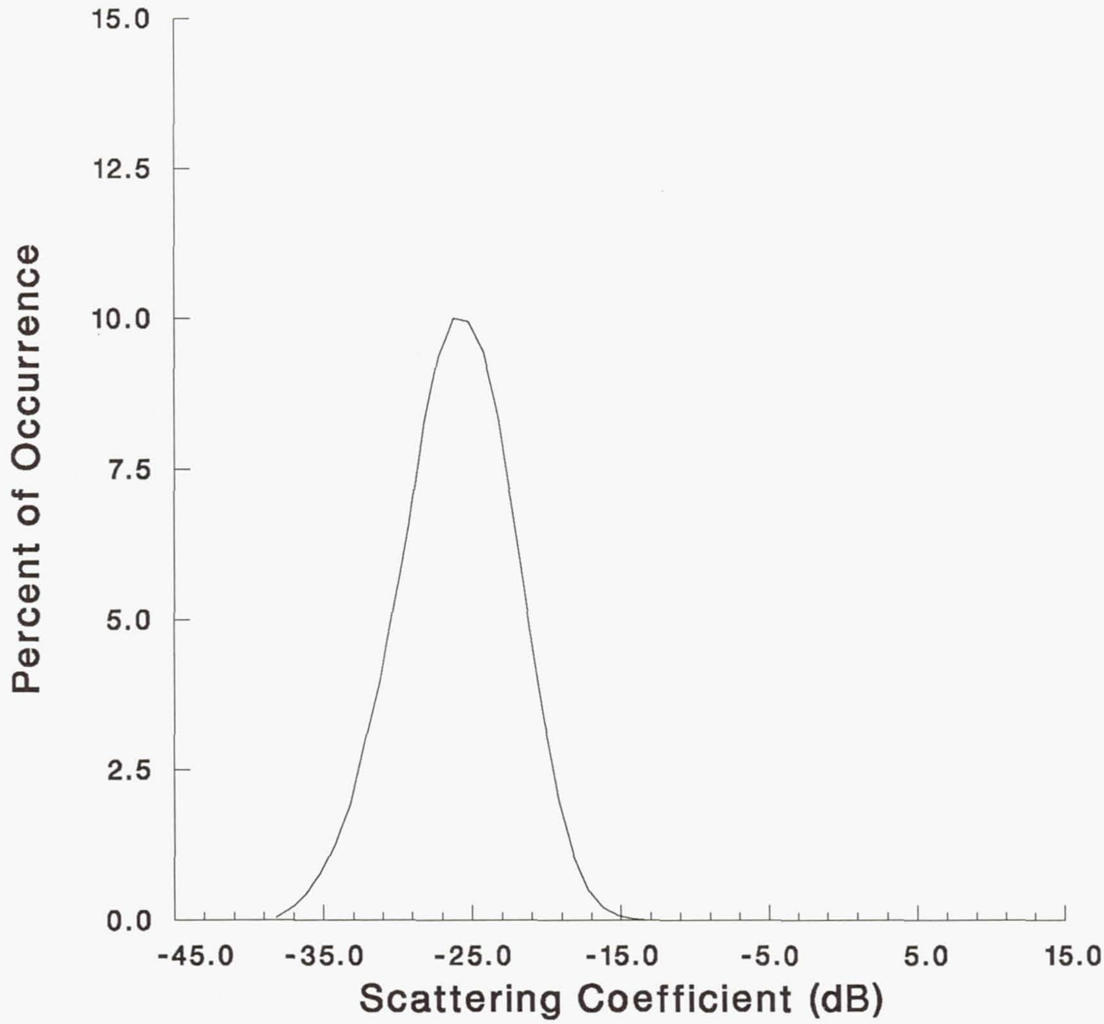


Figure 78.

Minimum: −38.71

Maximum: −6.60

Mean: −24.64

Bin Width: 1.00

Number of Bins: 33

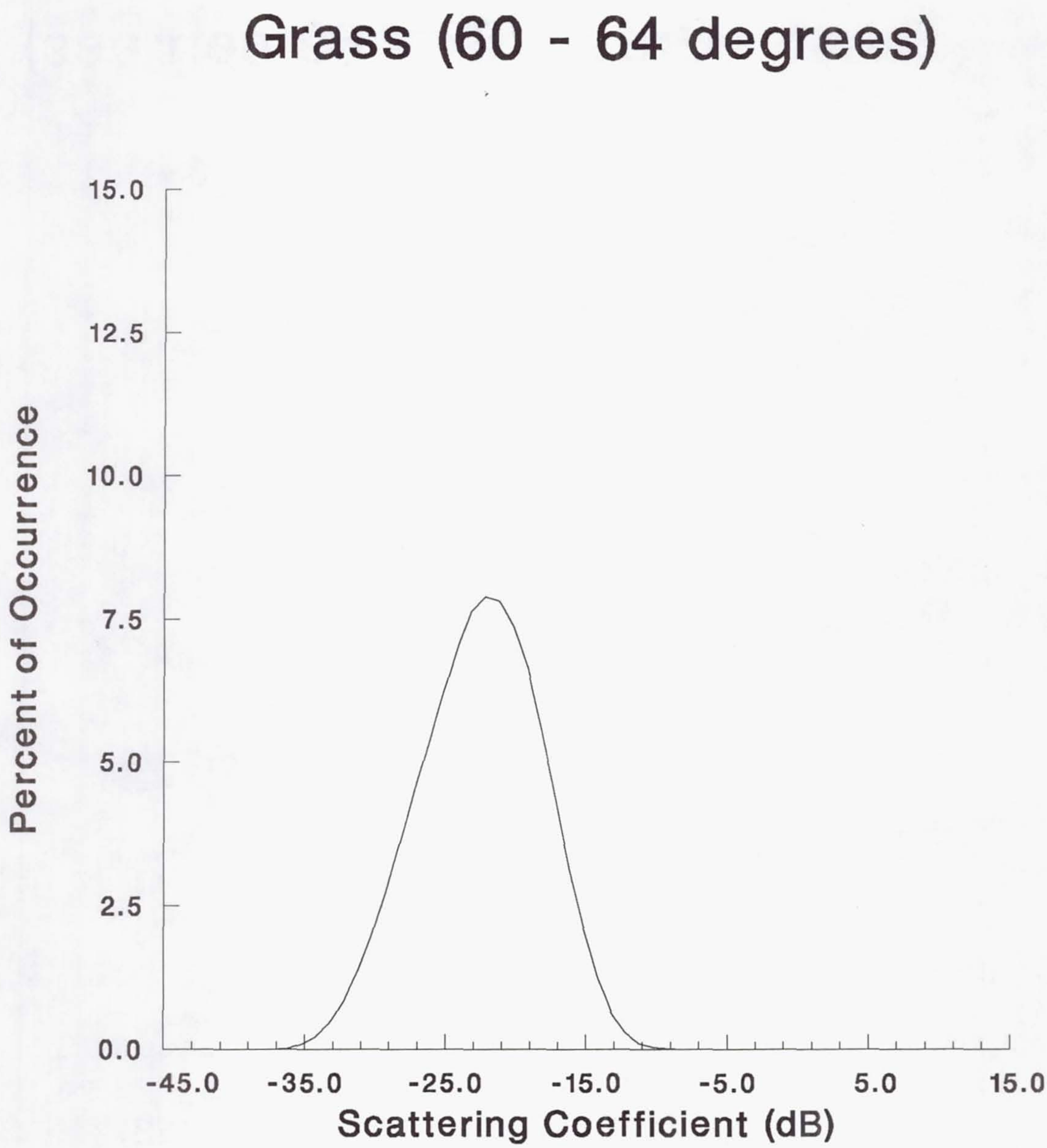


Figure 79.

Minimum: −38.71

Maximum: −8.89

Mean: −21.11

Bin Width: 1.00

Number of Bins: 31

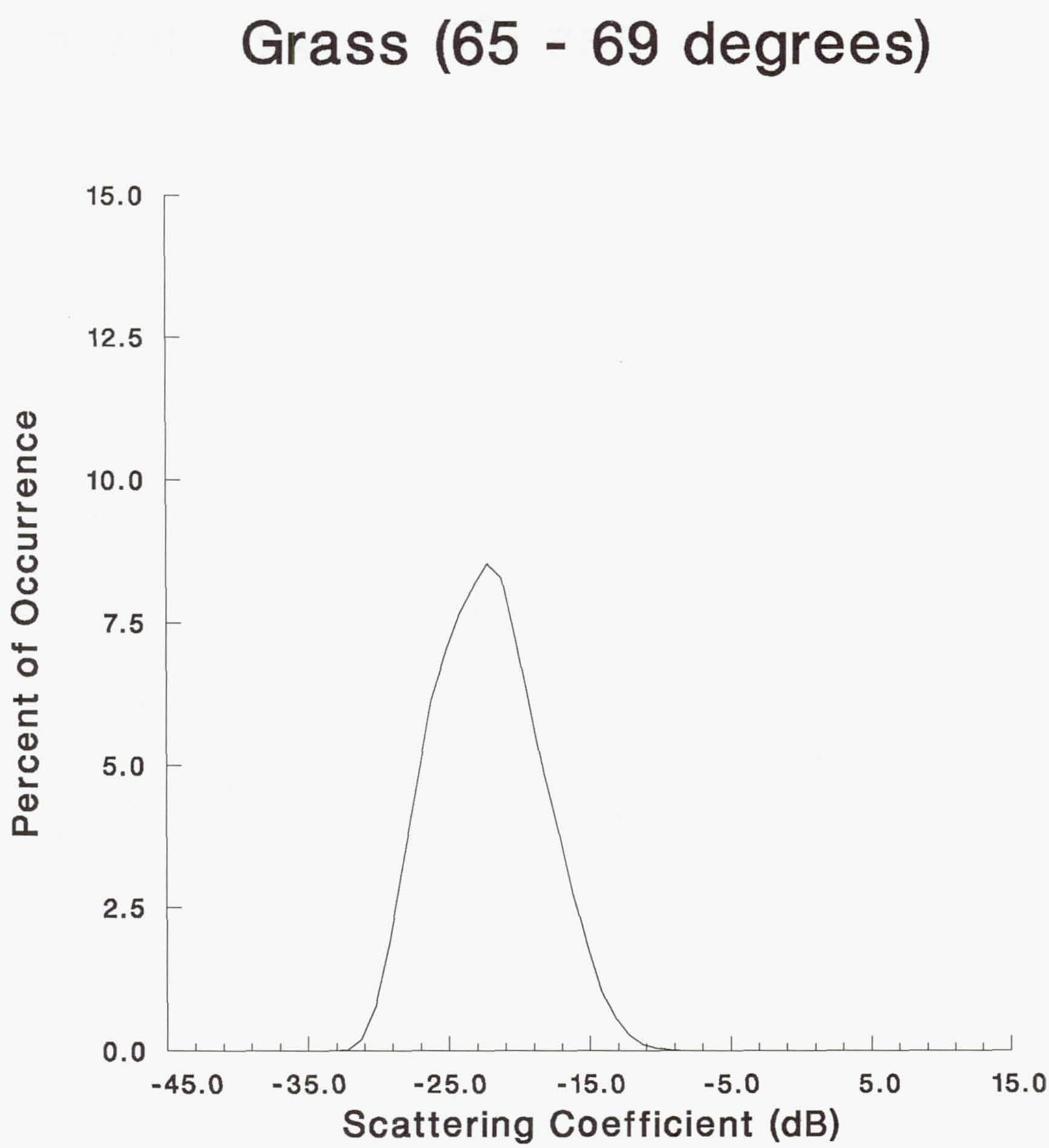


Figure 80.

Minimum: −38.71
Maximum: −8.03
Mean: −21.35
Bin Width: 1.00
Number of Bins: 32

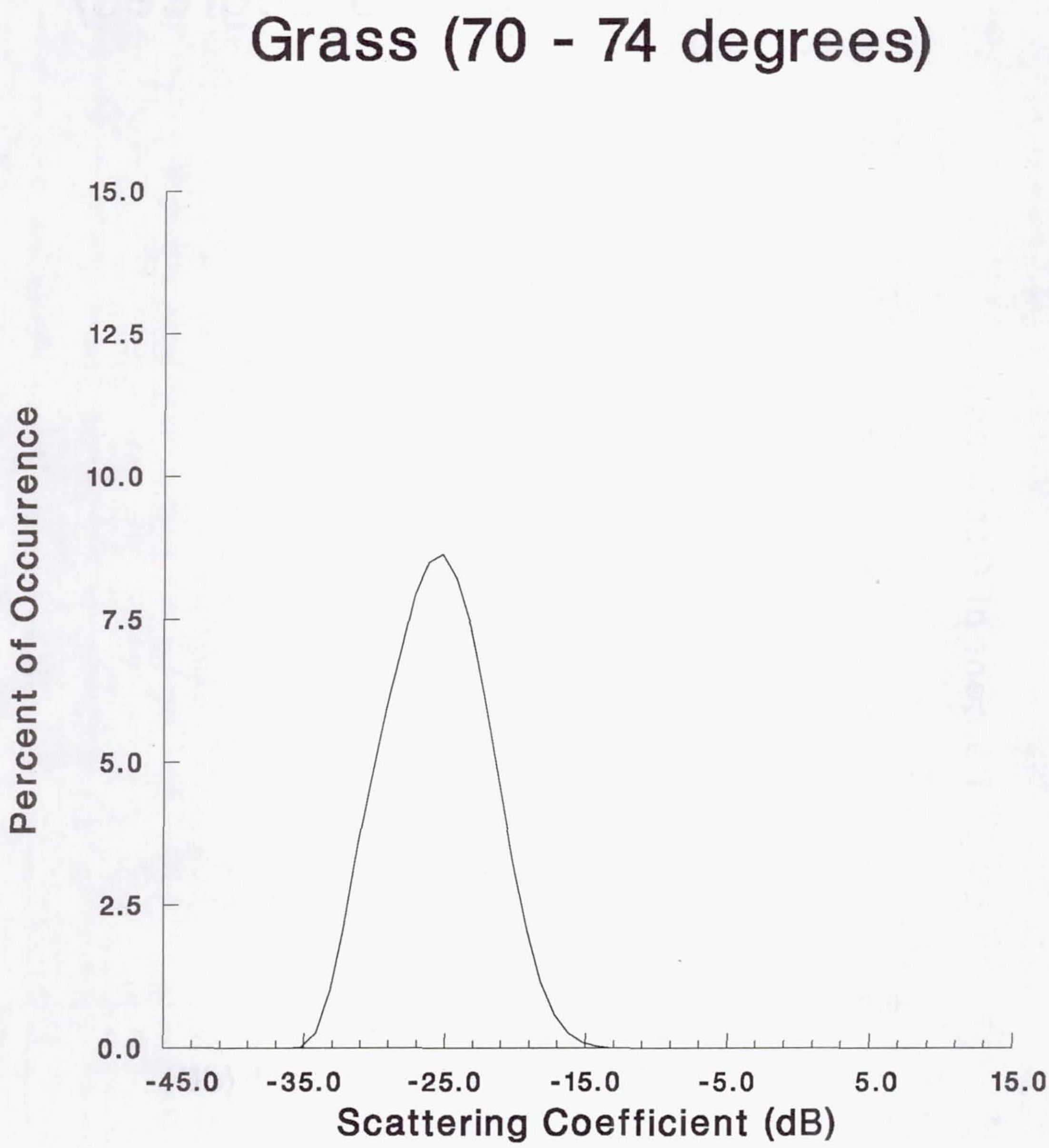


Figure 81.

Minimum: −38.71
Maximum: −6.42
Mean: −24.95
Bin Width: 1.00
Number of Bins: 33

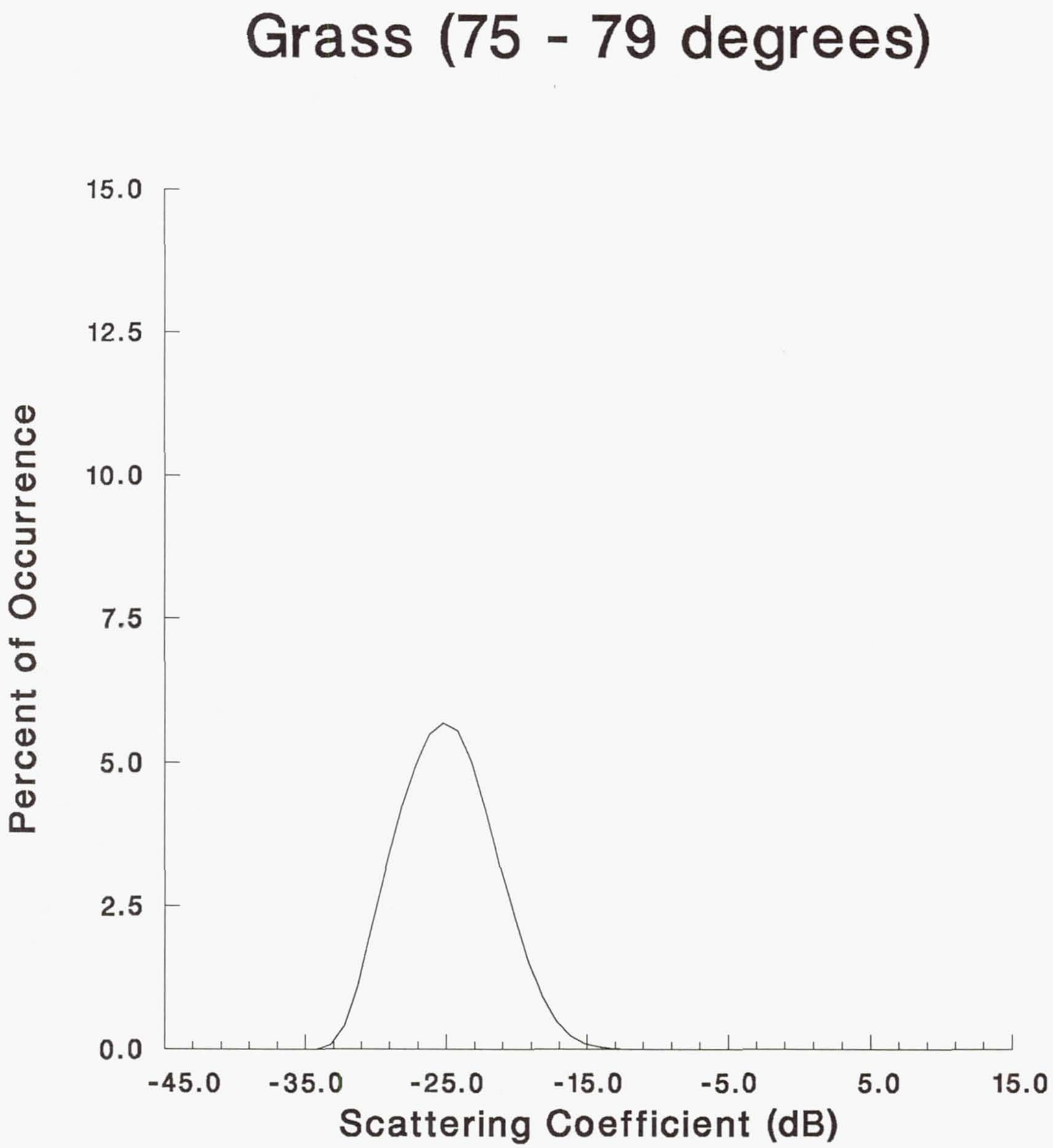


Figure 82.

Minimum: −38.71

Maximum: −4.33

Mean: −26.42

Bin Width: 1.00

Number of Bins: 35

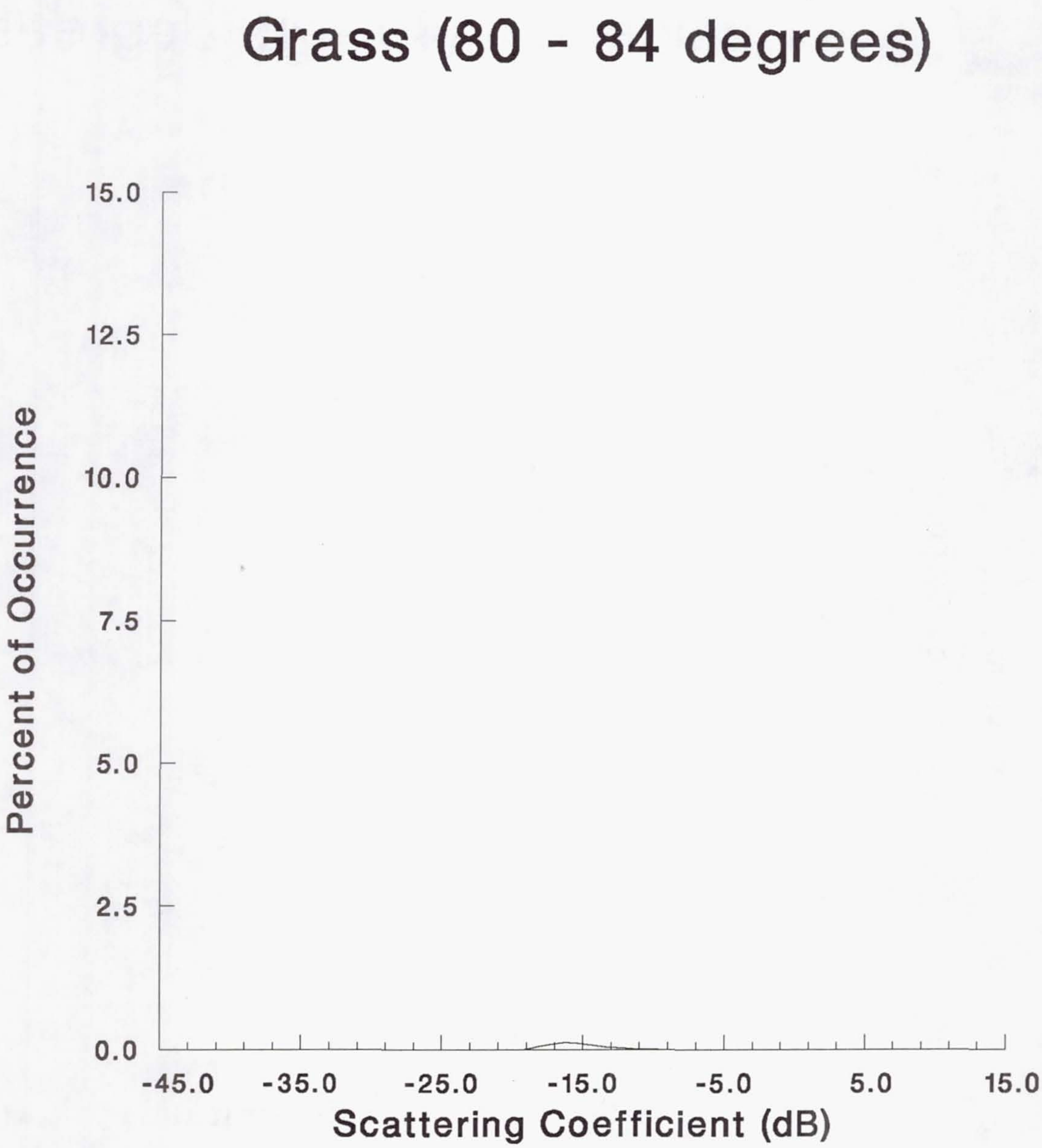


Figure 83.

Minimum: −38.71
Maximum: −6.06
Mean: −34.54
Bin Width: 1.00
Number of Bins: 34

Residential (40 - 49 degrees)

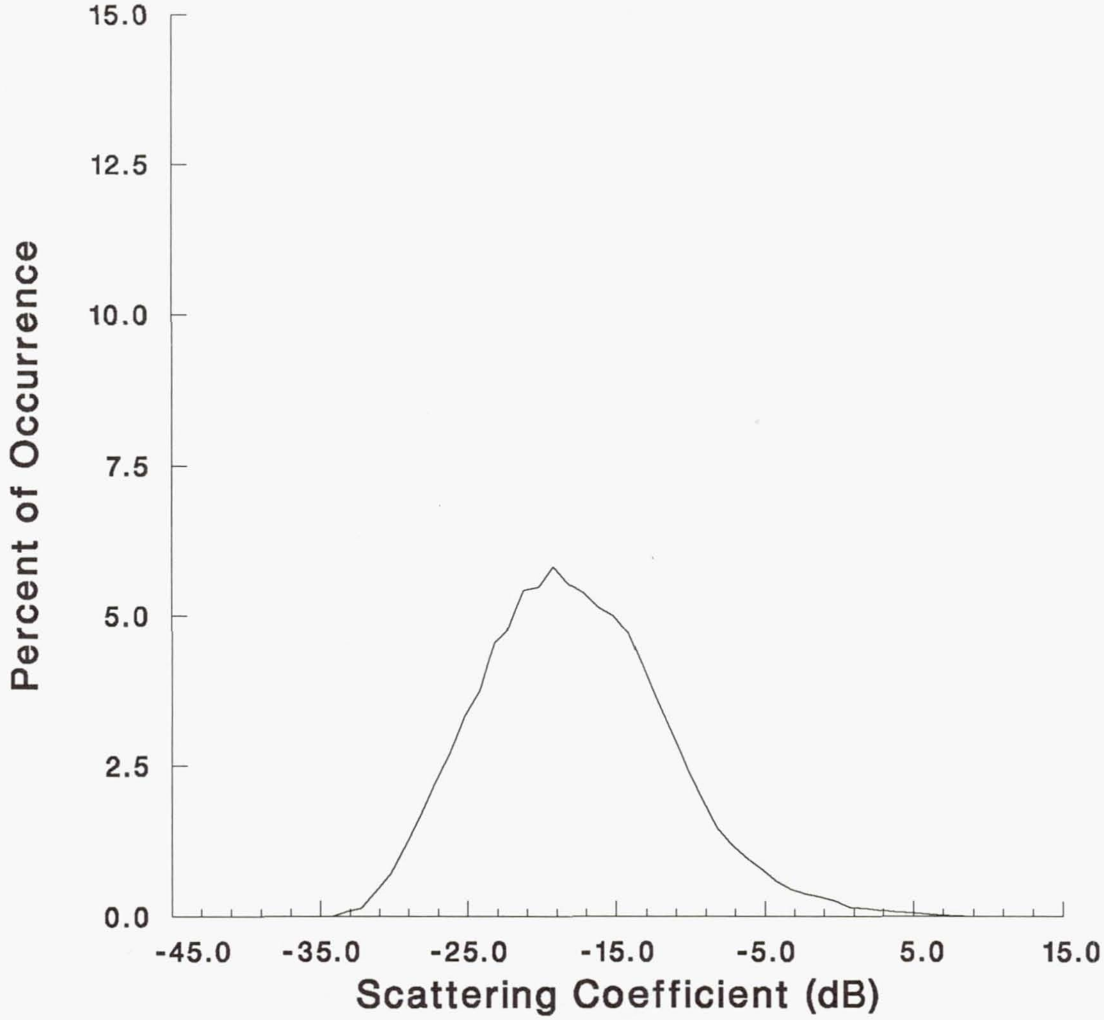


Figure 84.

Minimum: −38.71
Maximum: 8.81
Mean: −12.61
Bin Width: 1.00
Number of Bins: 49

Residential (50 - 59 degrees)

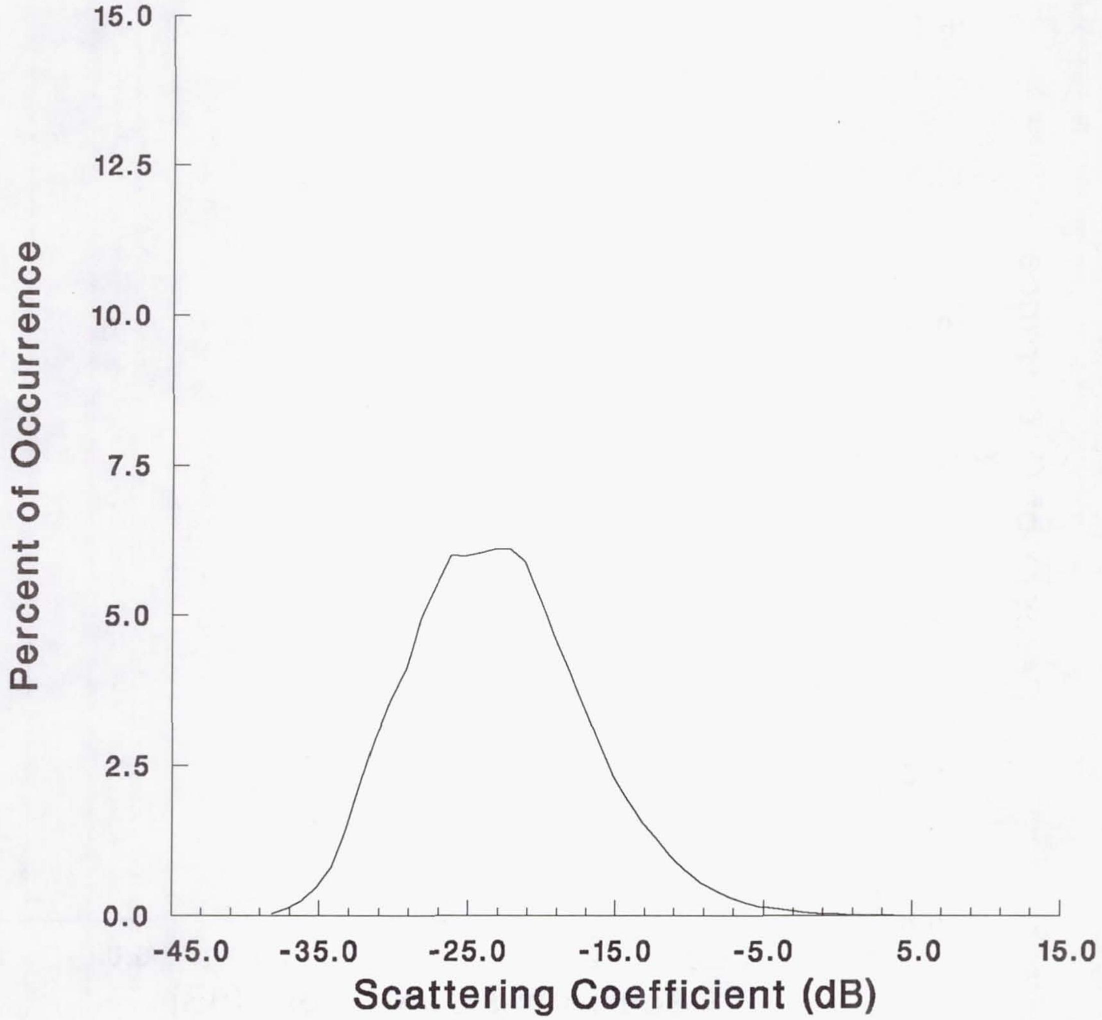


Figure 85.

Minimum: −38.71
Maximum: 3.58
Mean: −18.24
Bin Width: 1.00
Number of Bins: 43

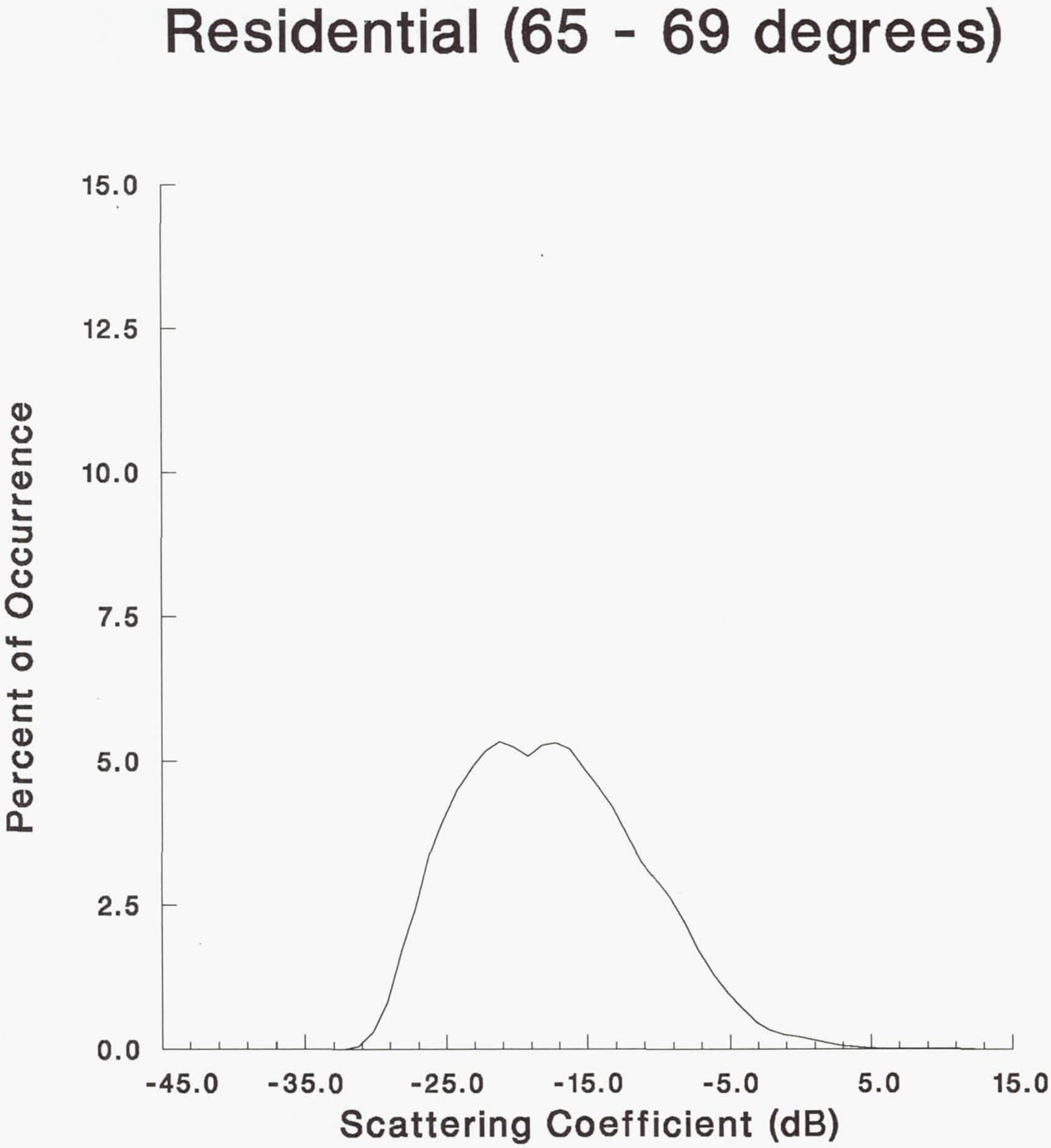


Figure 86.

Minimum: −38.71
Maximum: 15.06
Mean: −11.59
Bin Width: 1.00
Number of Bins: 55

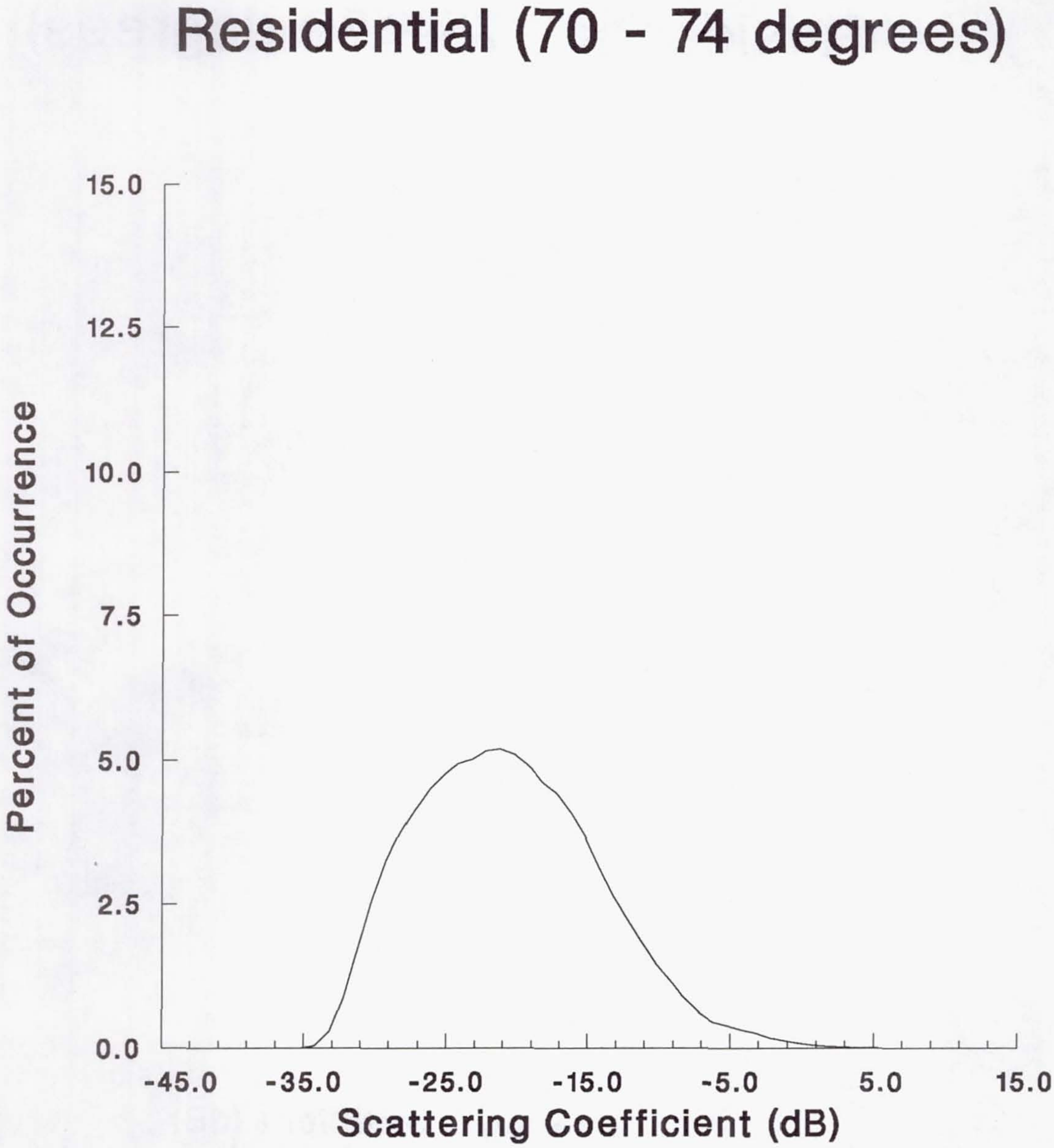


Figure 87.

Minimum: −38.71
Maximum: 6.96
Mean: −15.62
Bin Width: 1.00
Number of Bins: 47

Residential (75 - 79 degrees)

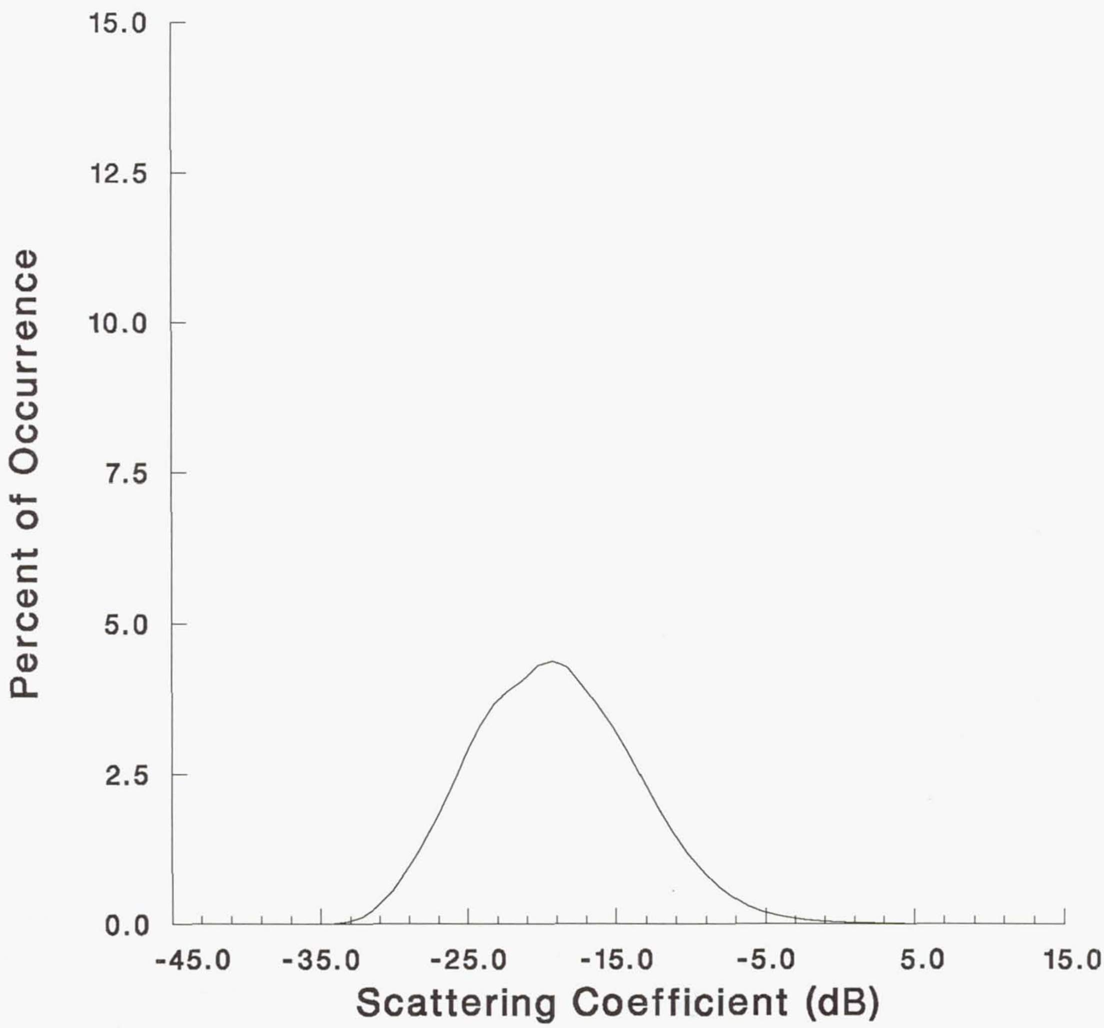


Figure 88.

Minimum: −38.71
Maximum: 19.34
Mean: −17.00
Bin Width: 1.00
Number of Bins: 59

Residential (80 - 84 degrees)

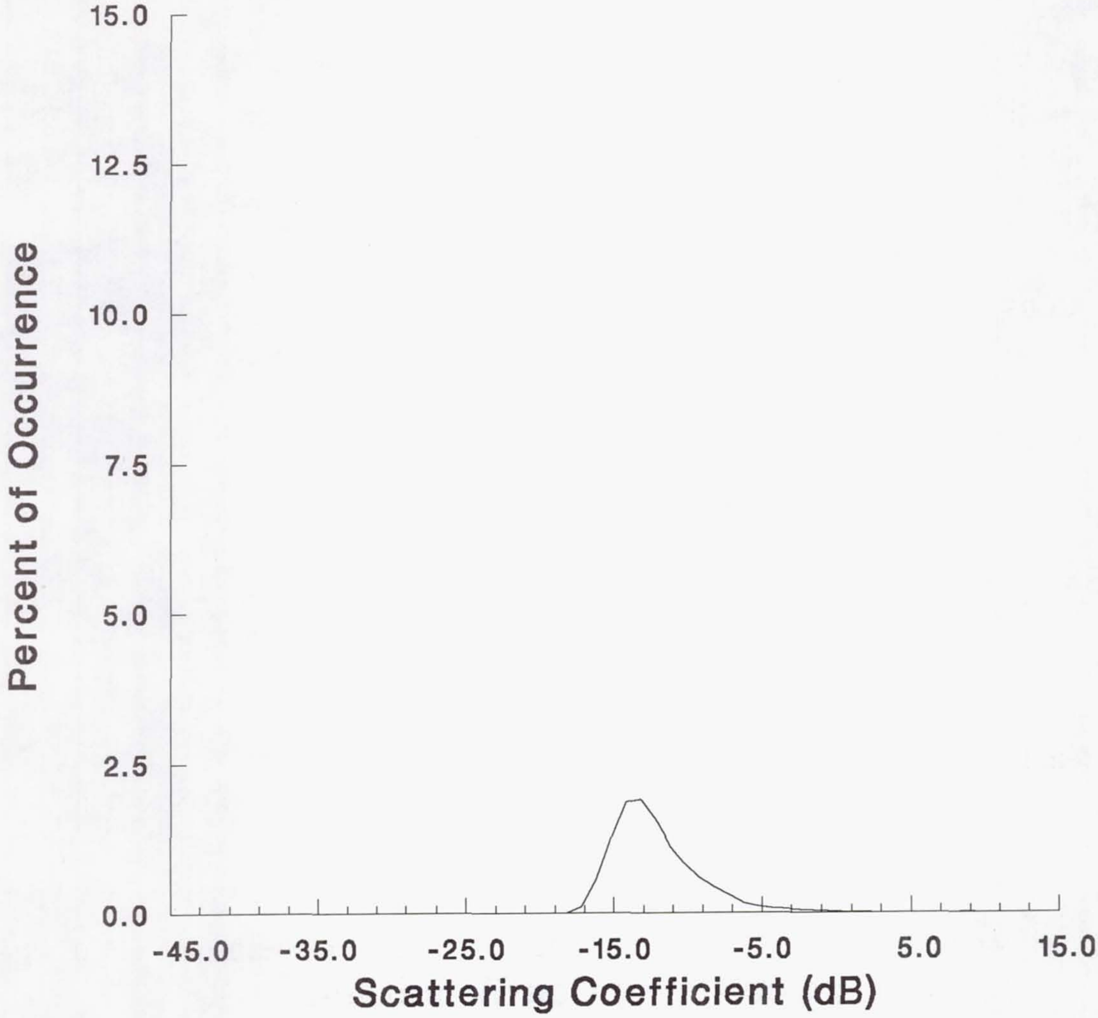


Figure 89.

Minimum: −38.71
Maximum: 9.72
Mean: −19.15
Bin Width: 1.00
Number of Bins: 49

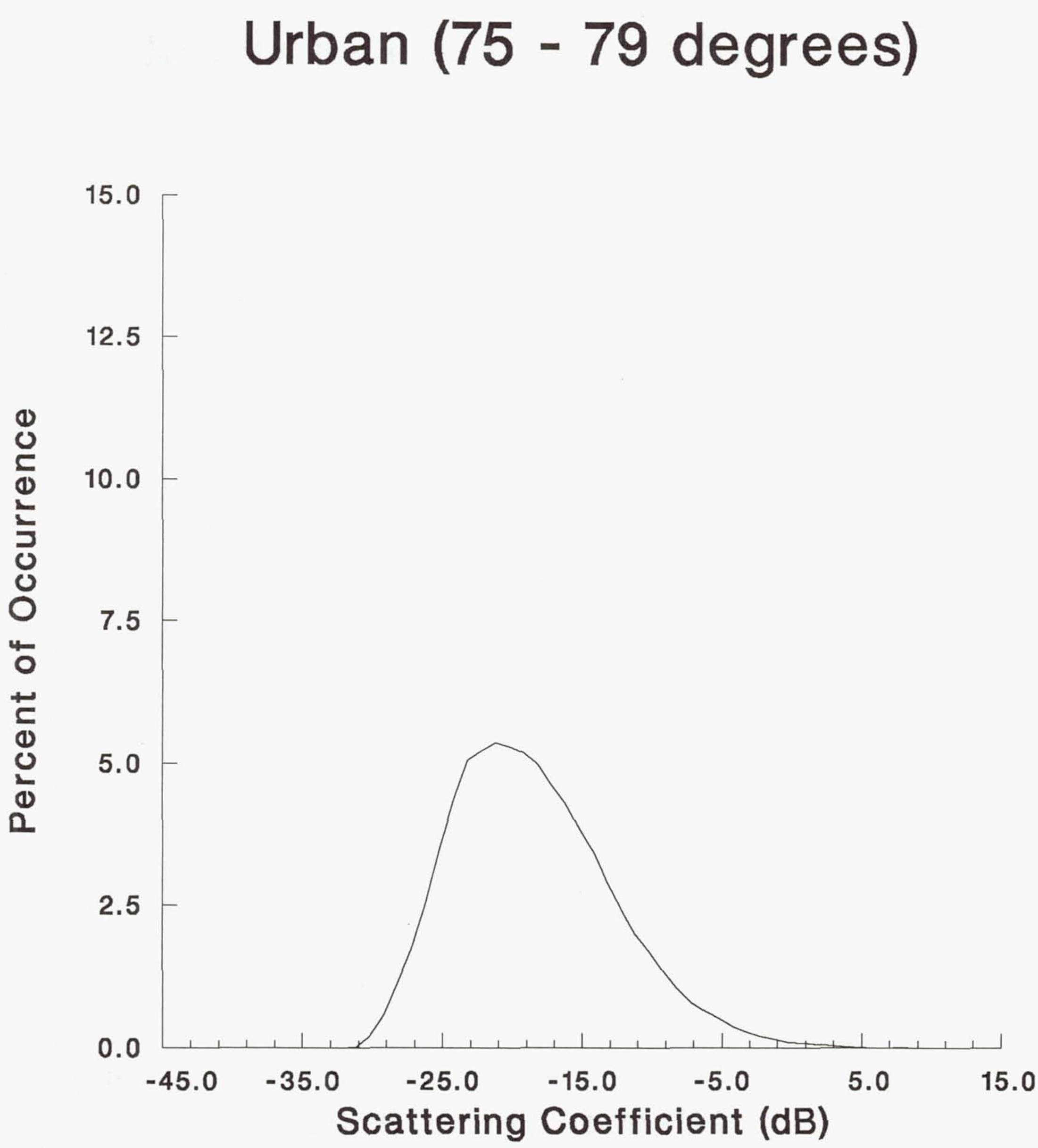


Figure 90.

Minimum: −38.71
Maximum: 11.42
Mean: −14.65
Bin Width: 1.00
Number of Bins: 51

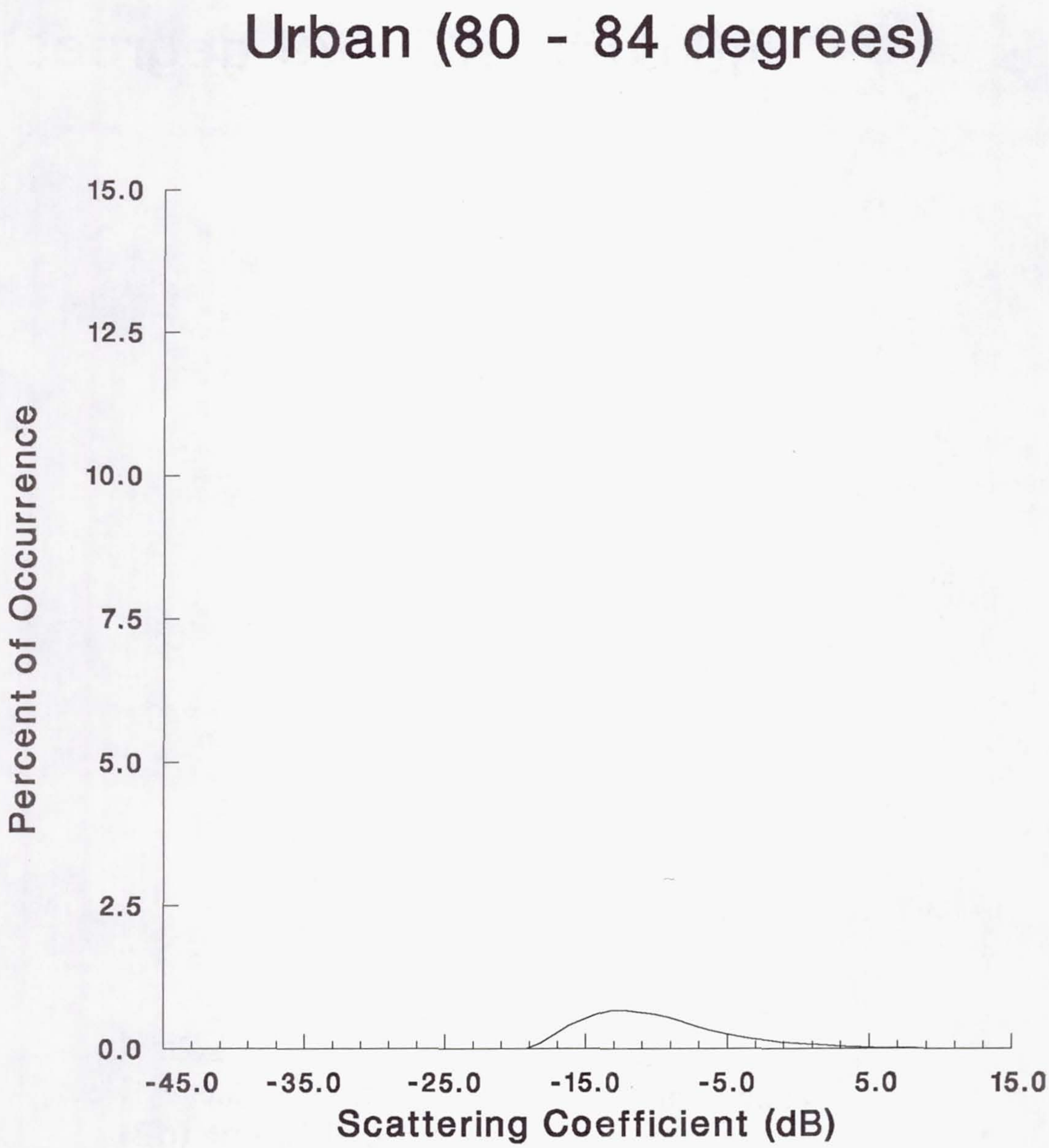


Figure 91.

Minimum: −38.71
Maximum: 23.72
Mean: −15.91
Bin Width: 1.00
Number of Bins: 63

Industrial (75 - 79 degrees)

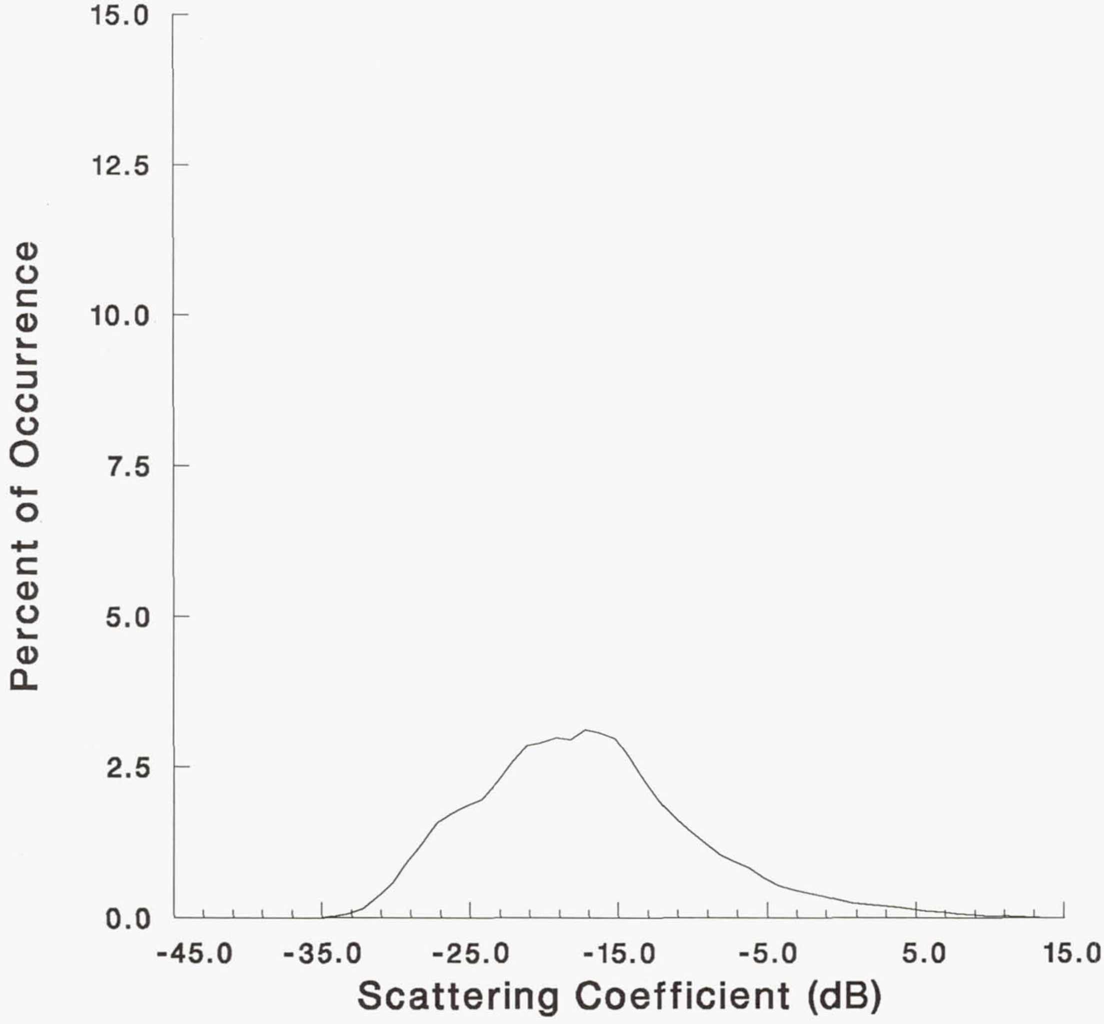


Figure 92.

Minimum: −38.71
Maximum: 17.33
Mean: −10.78
Bin Width: 1.00
Number of Bins: 57

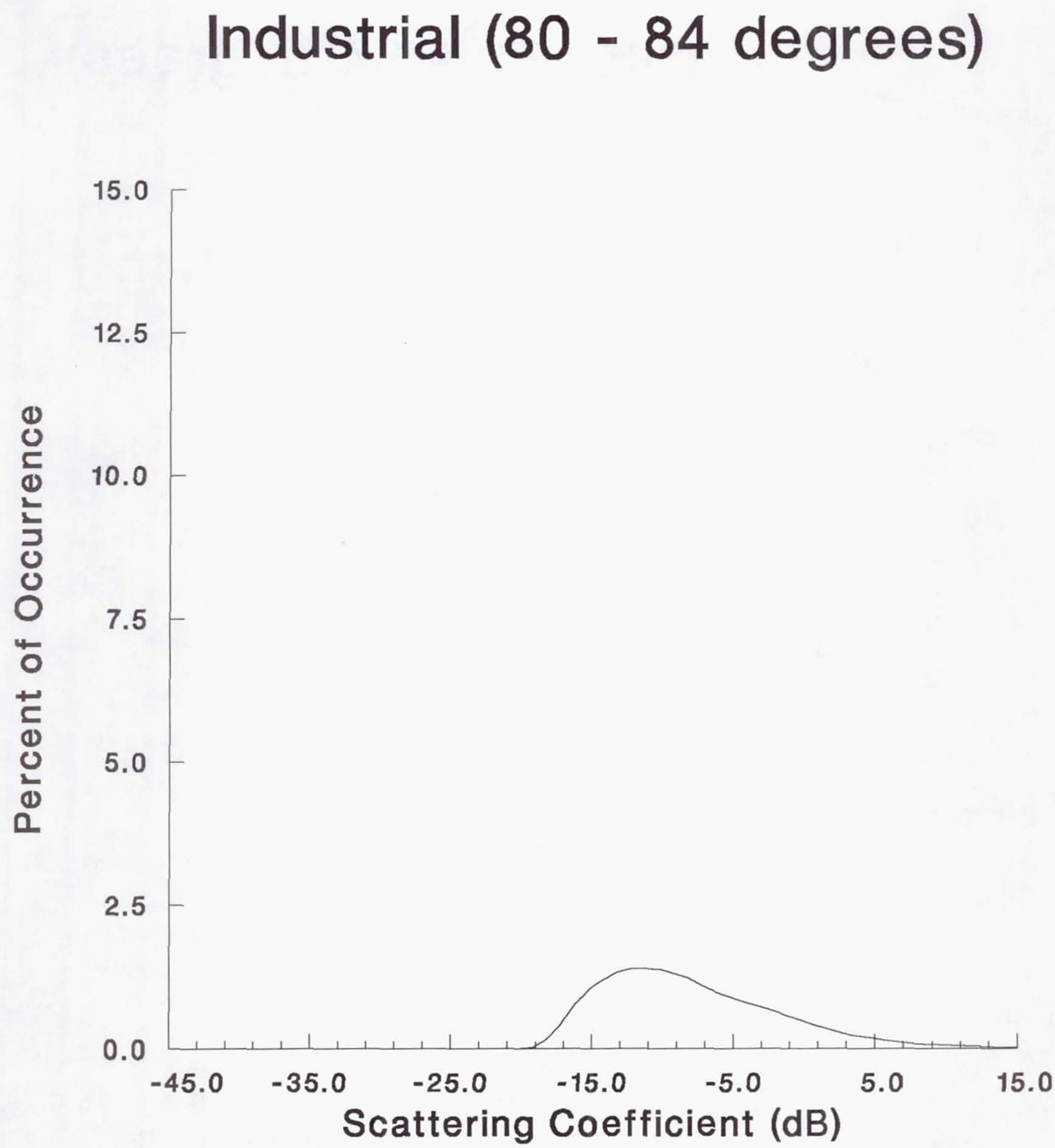


Figure 93.

Minimum: −38.71
Maximum: 26.27
Mean: −7.26
Bin Width: 1.00
Number of Bins: 66

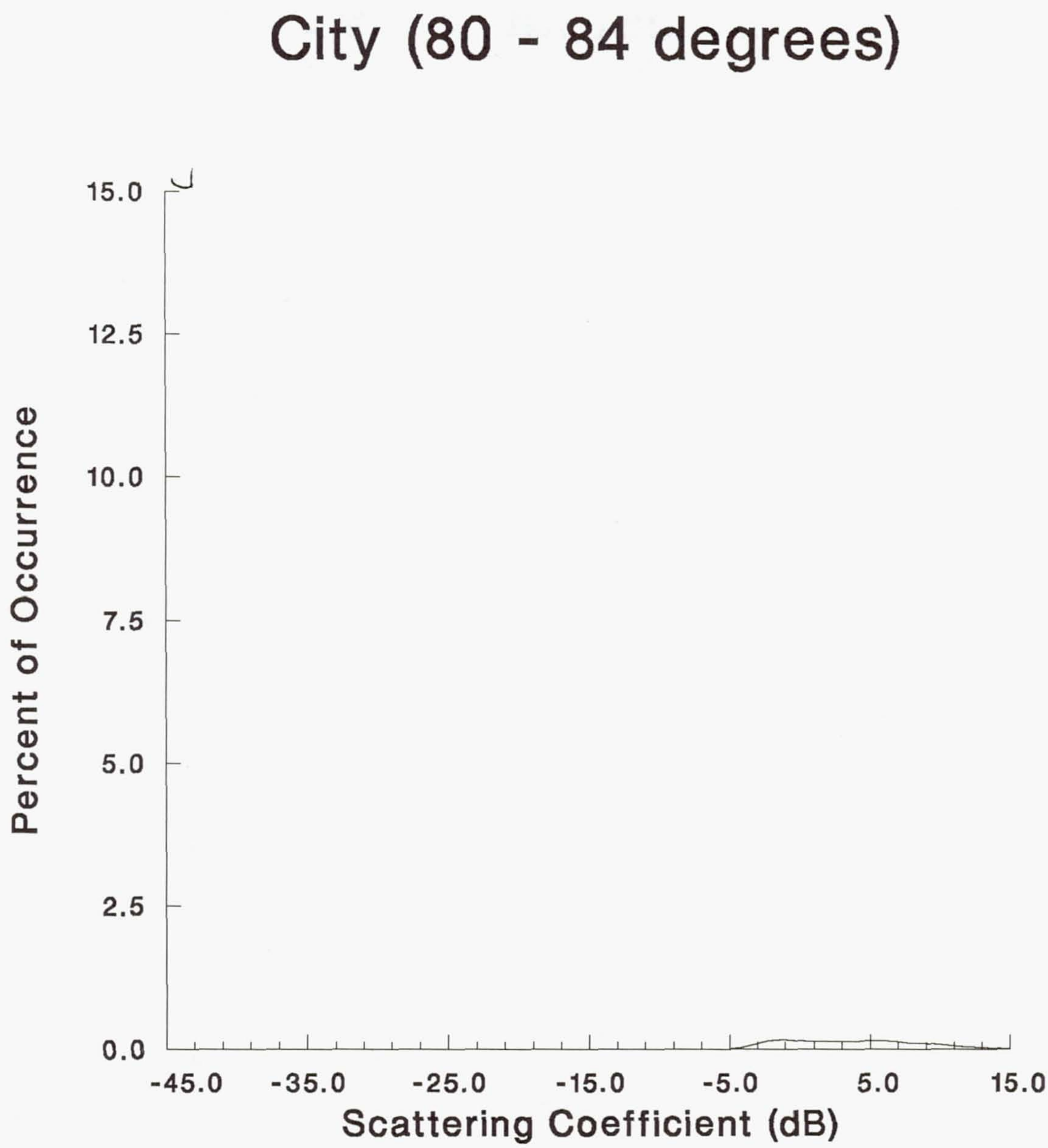


Figure 94.

Minimum: −38.71
Maximum: 24.06
Mean: −9.53
Bin Width: 1.00
Number of Bins: 64

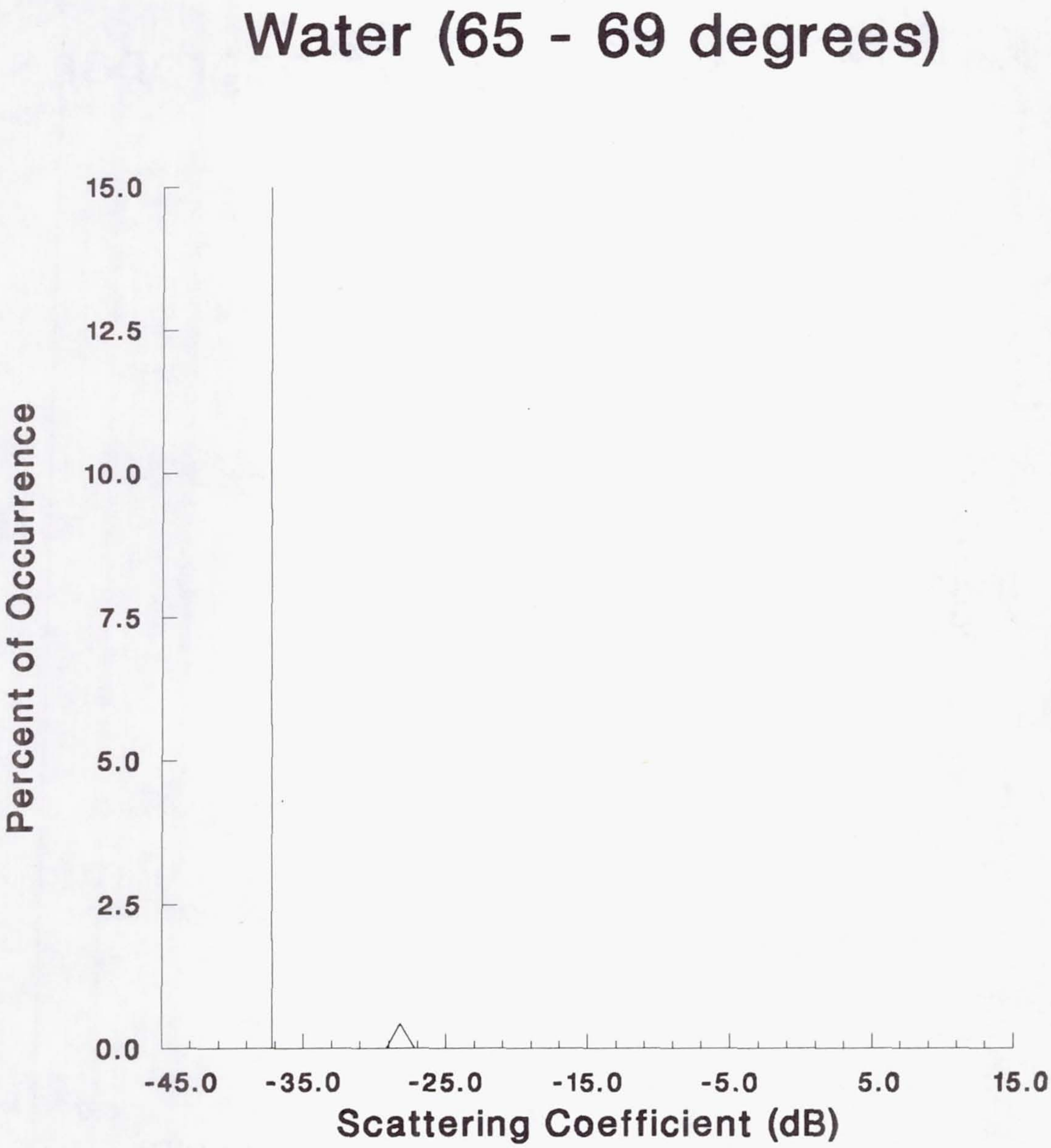


Figure 95.

Minimum: −38.71

Maximum: −27.90

Mean: −38.50

Bin Width: 1.00

Number of Bins: 12

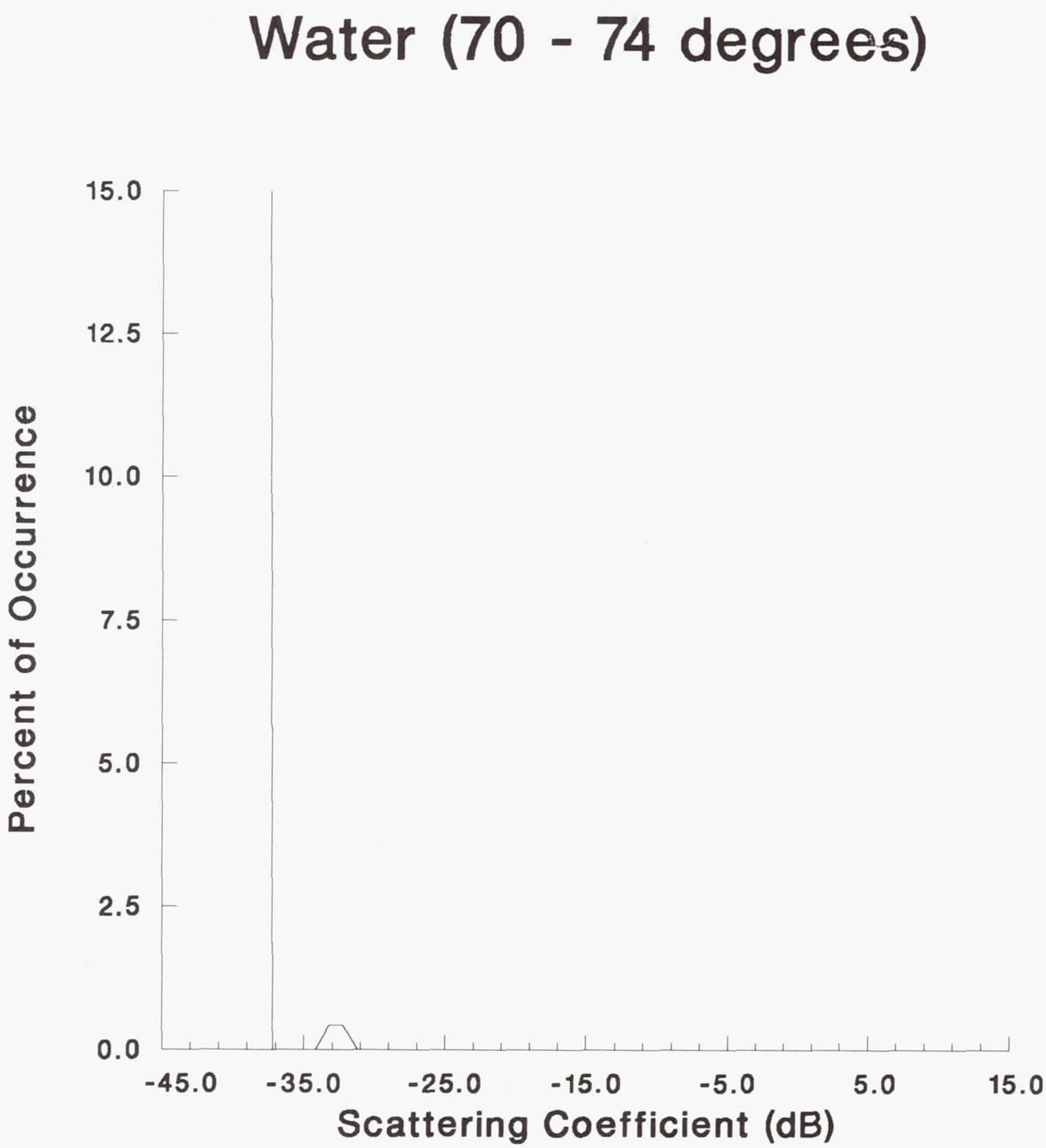


Figure 96.

Minimum: −38.71
Maximum: −31.82
Mean: −38.58
Bin Width: 1.00
Number of Bins: 8

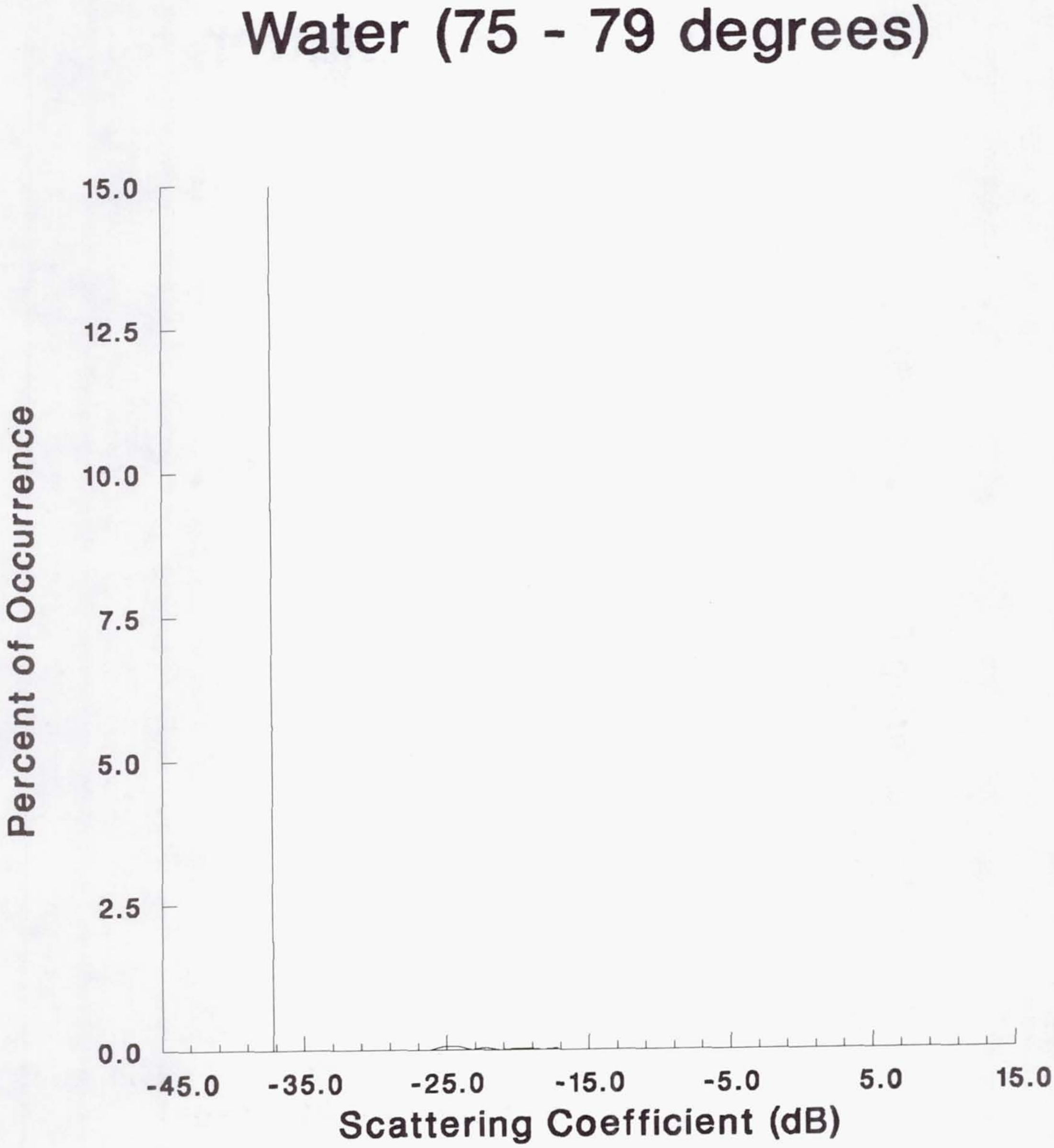


Figure 97.

Minimum: −38.71

Maximum: −17.26

Mean: −38.22

Bin Width: 1.00

Number of Bins: 22

Grass Clutter

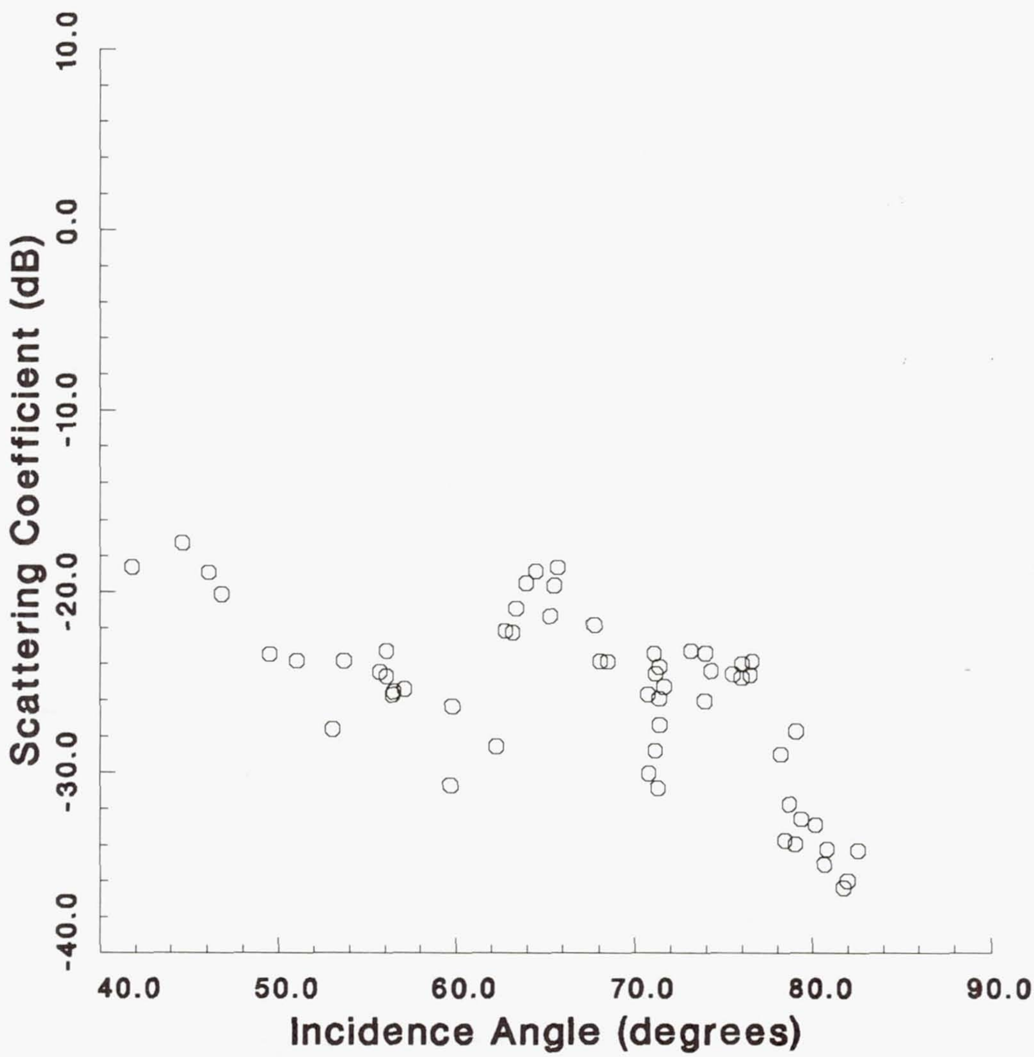
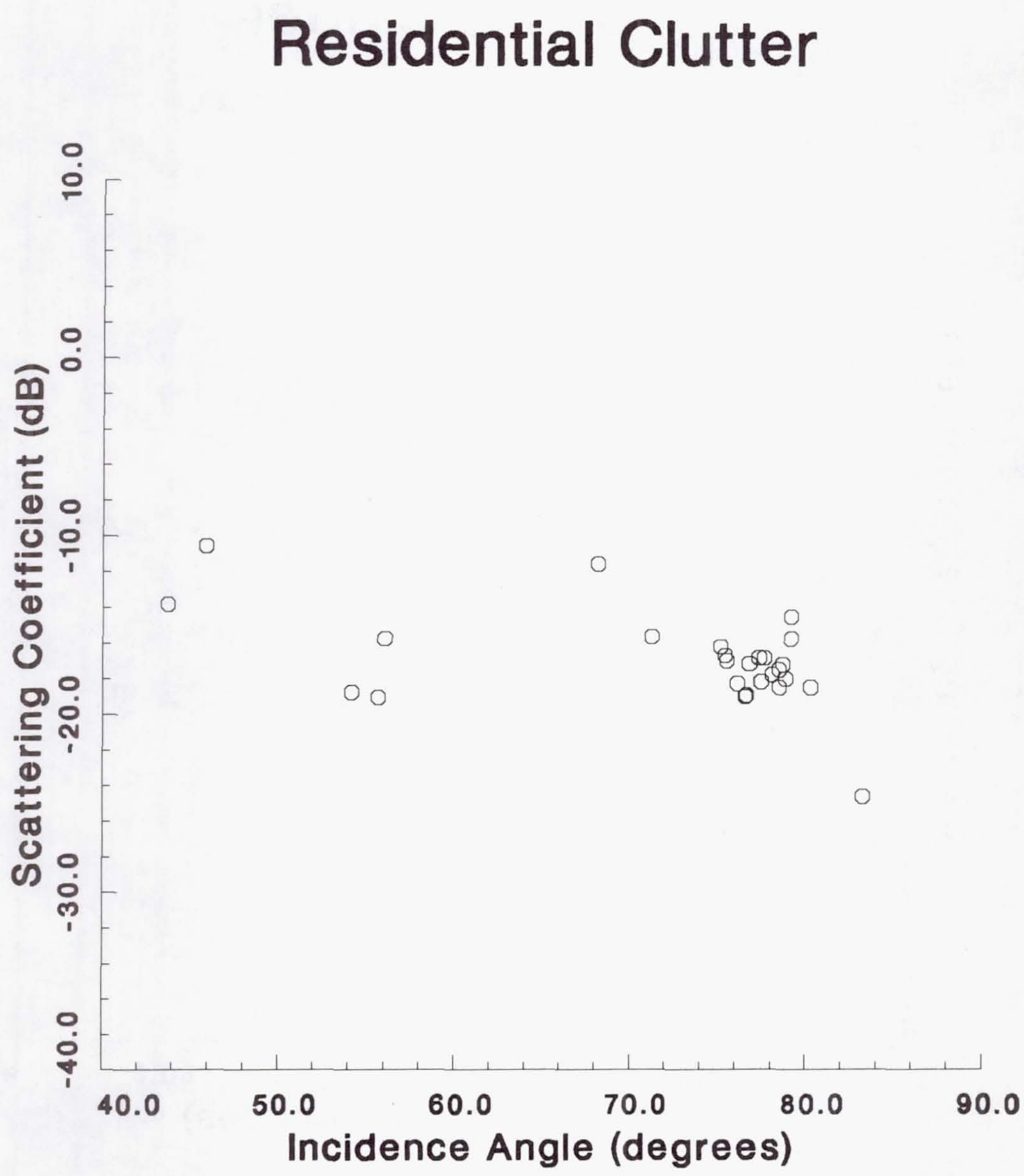


Figure 98.



Residential Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 99.

Urban Clutter

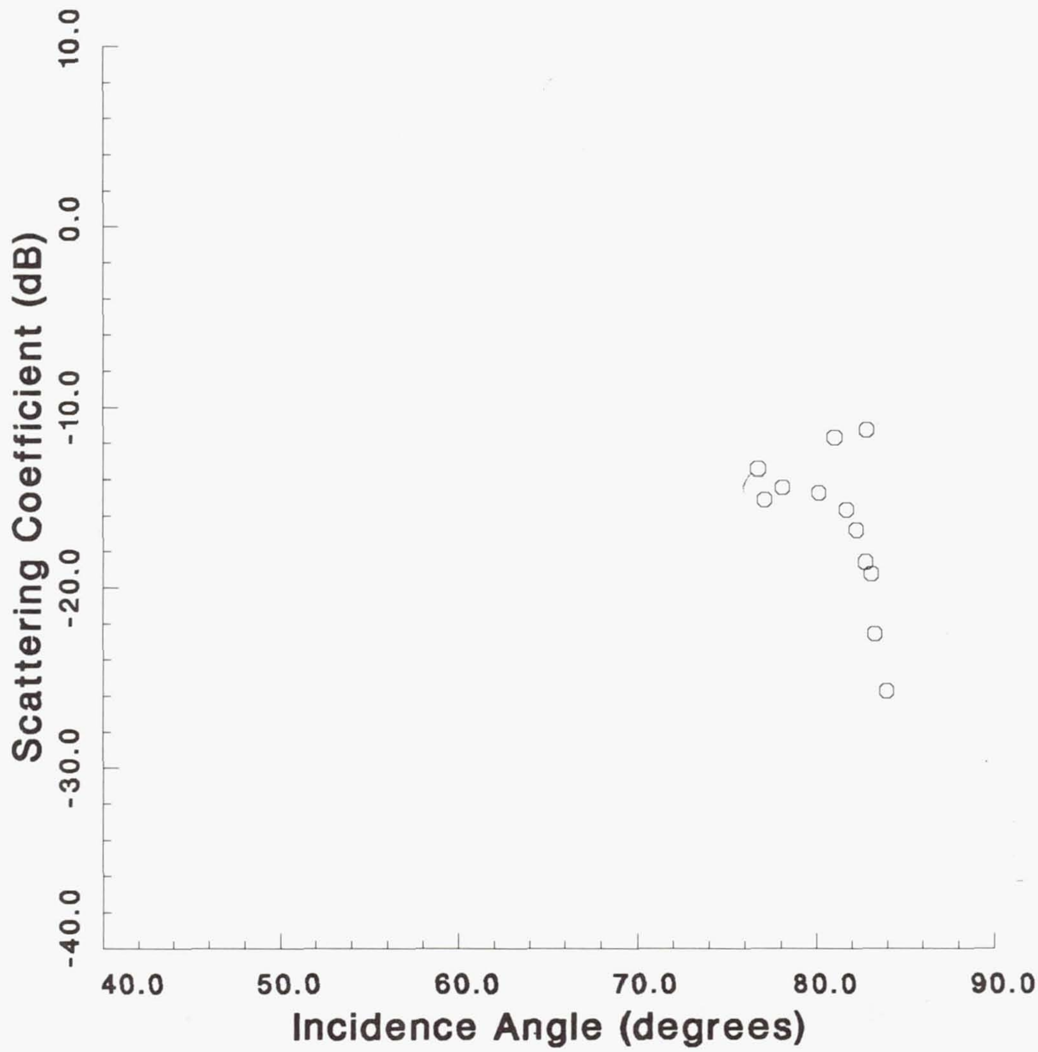


Figure 100.

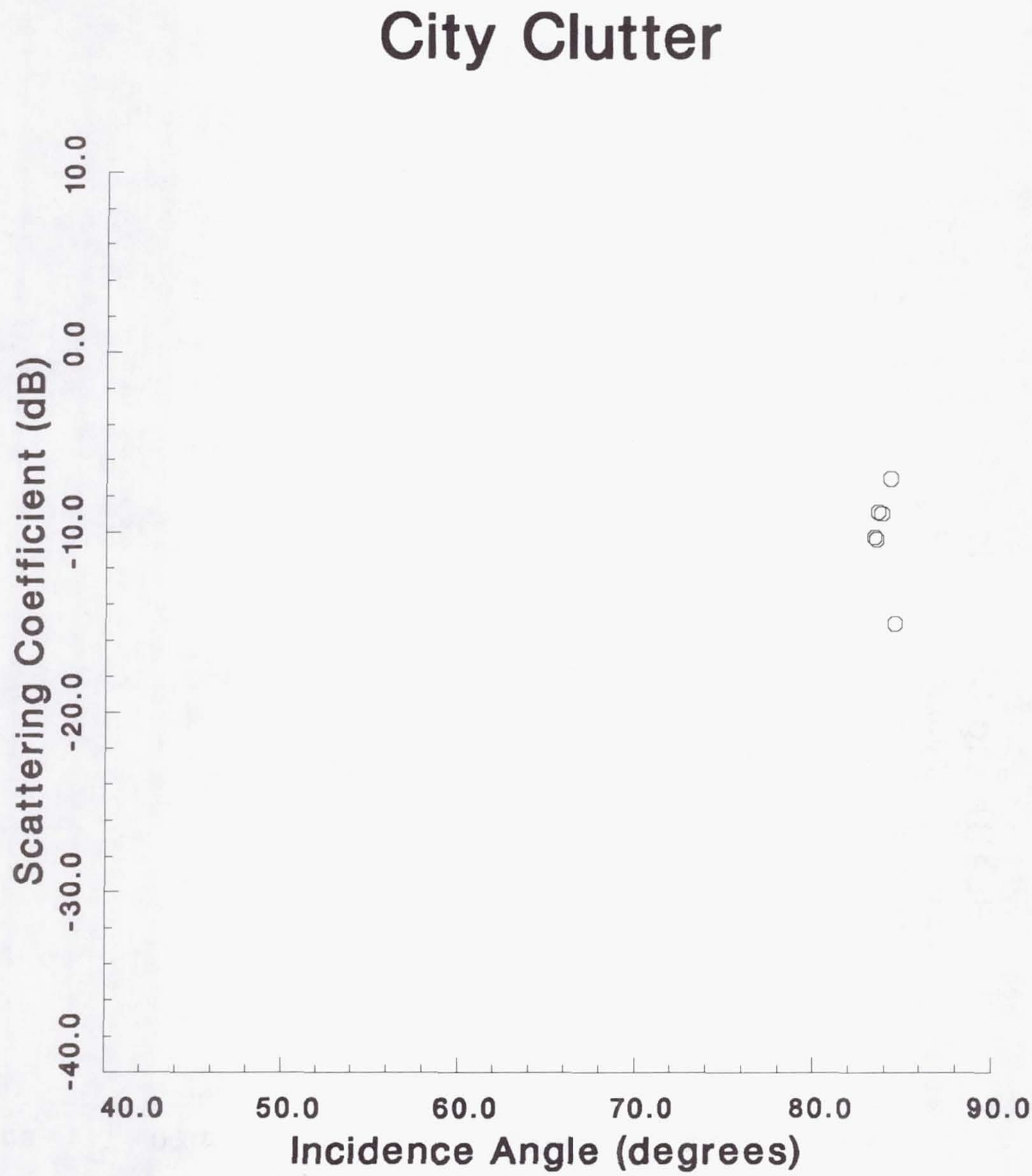

City Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 101.

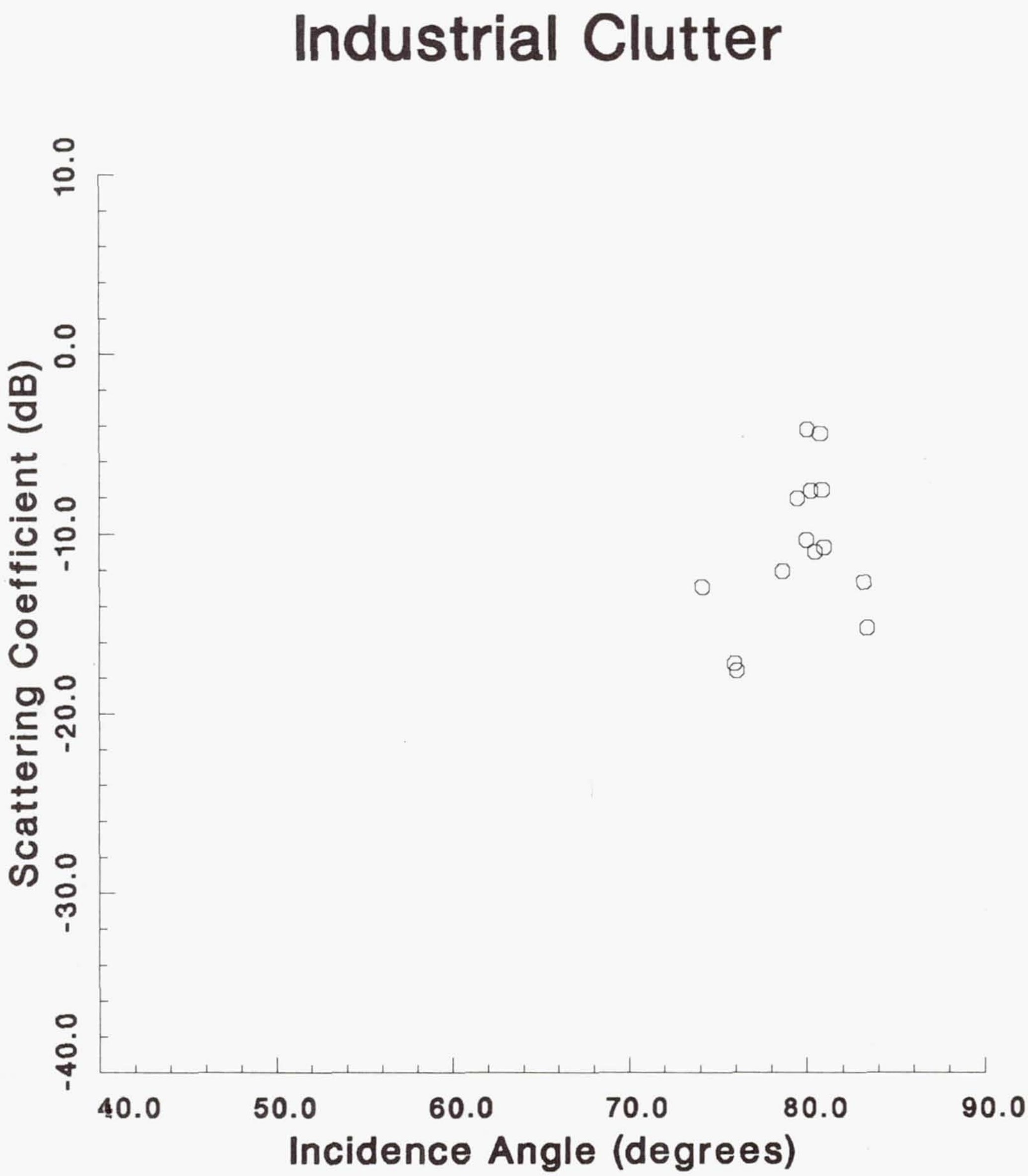

Industrial Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 102.

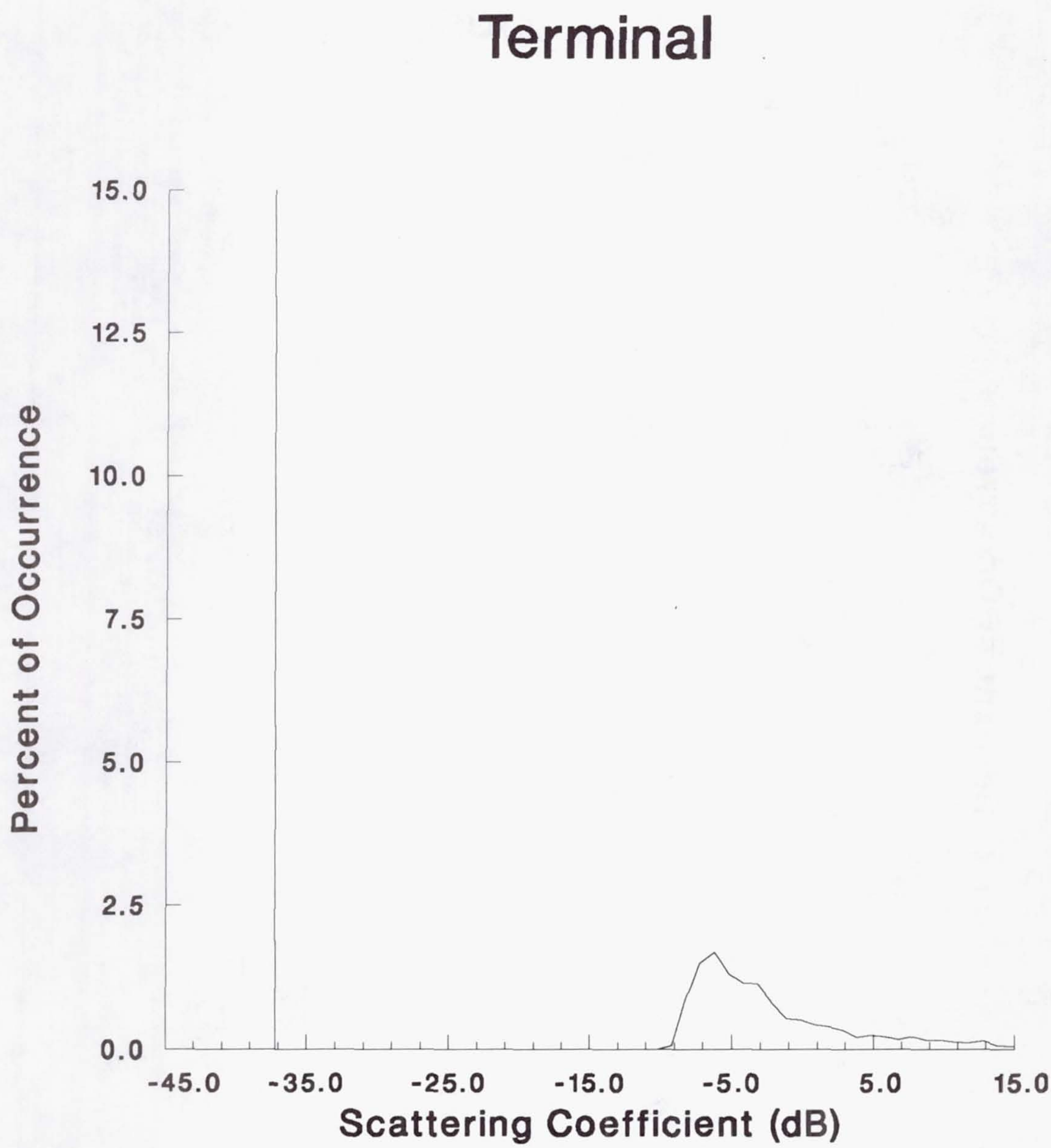


Figure 103.

Minimum: −38.71

Maximum: 21.97

Mean: −3.50

Bin Width: 1.00

Number of Bins: 62

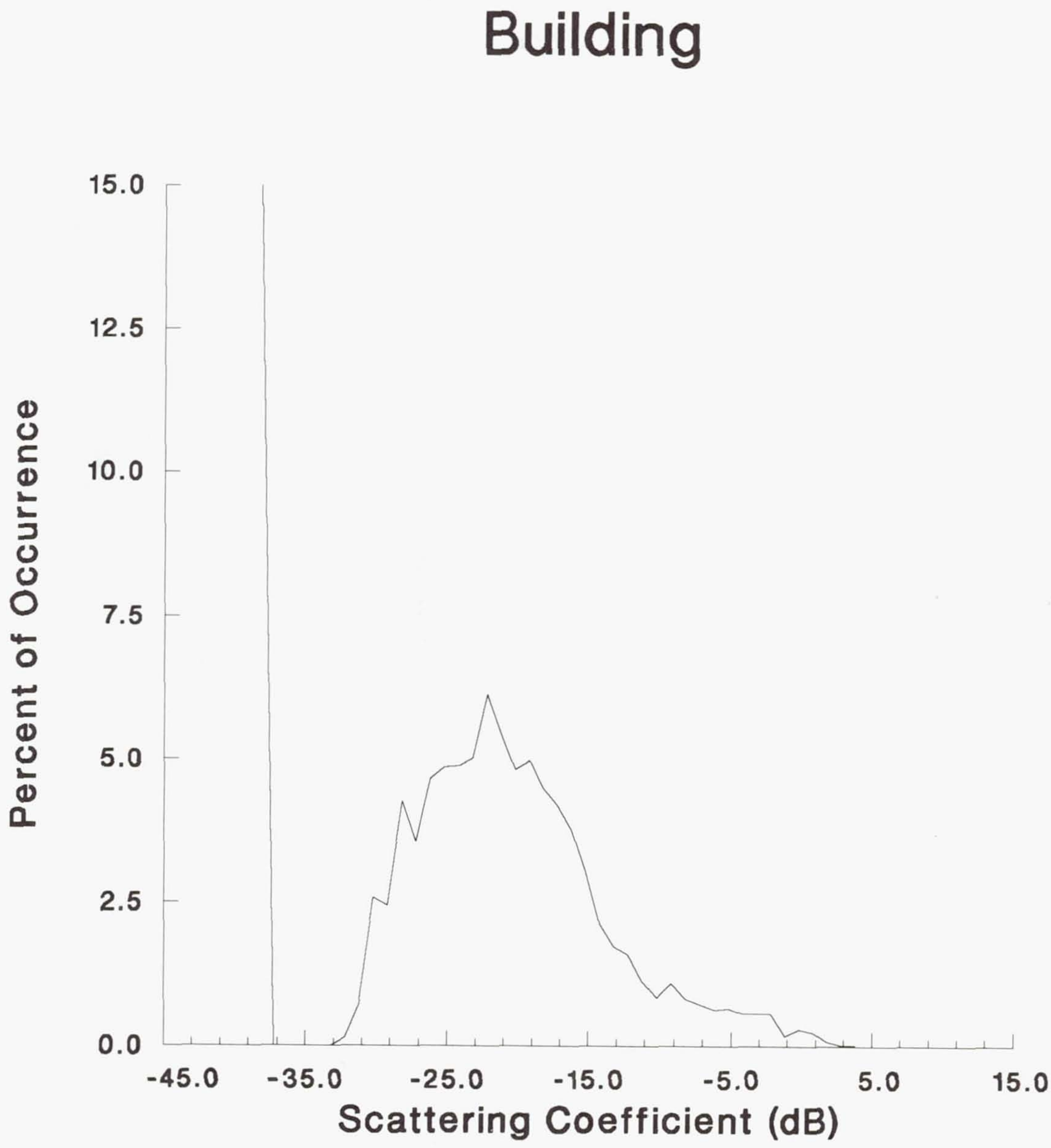


Figure 104.

Minimum: −38.71
Maximum: 3.61
Mean: −14.50
Bin Width: 1.00
Number of Bins: 43

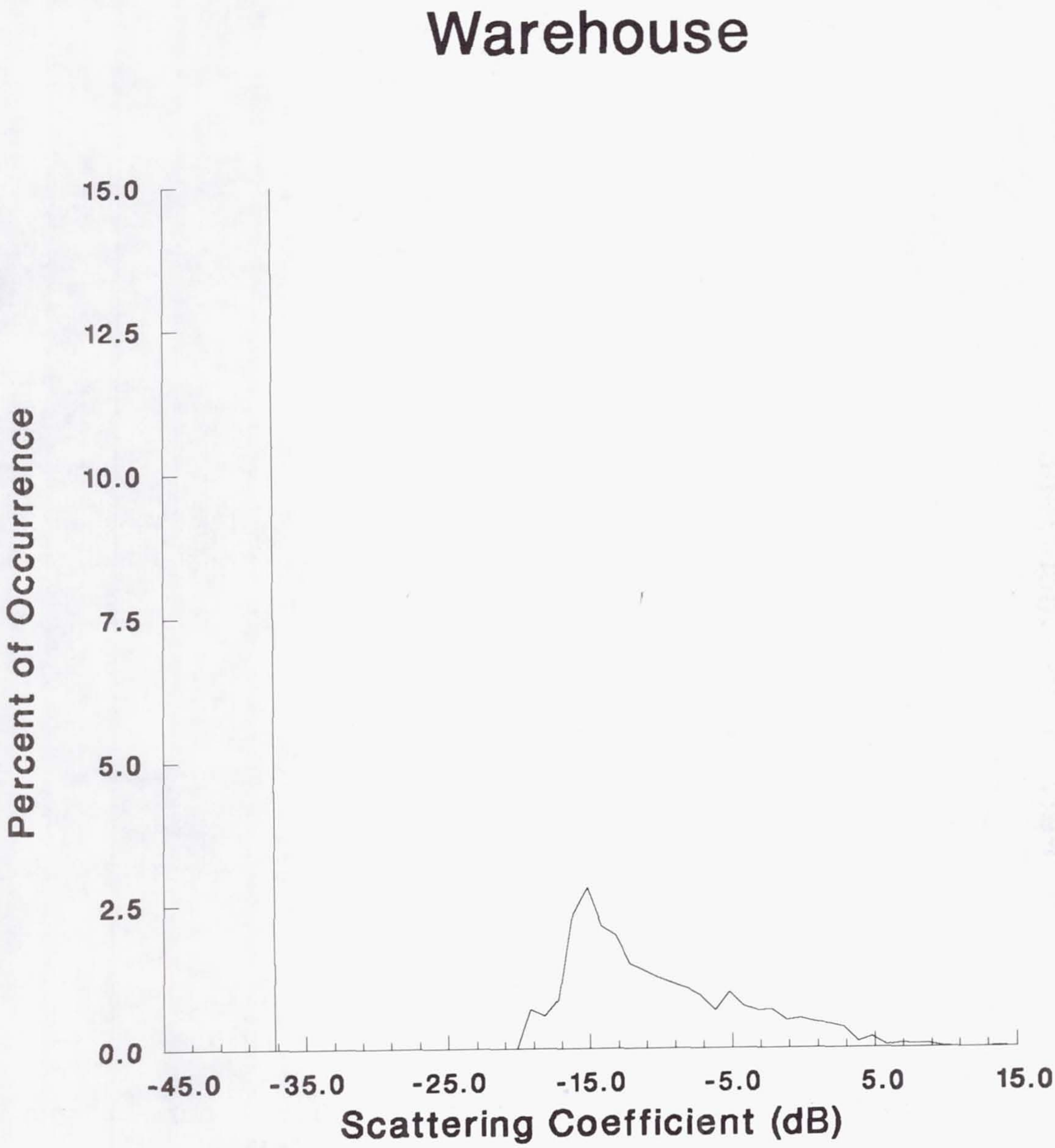


Figure 105.

Minimum: −38.71
Maximum: 16.43
Mean: −10.46
Bin Width: 1.00
Number of Bins: 56

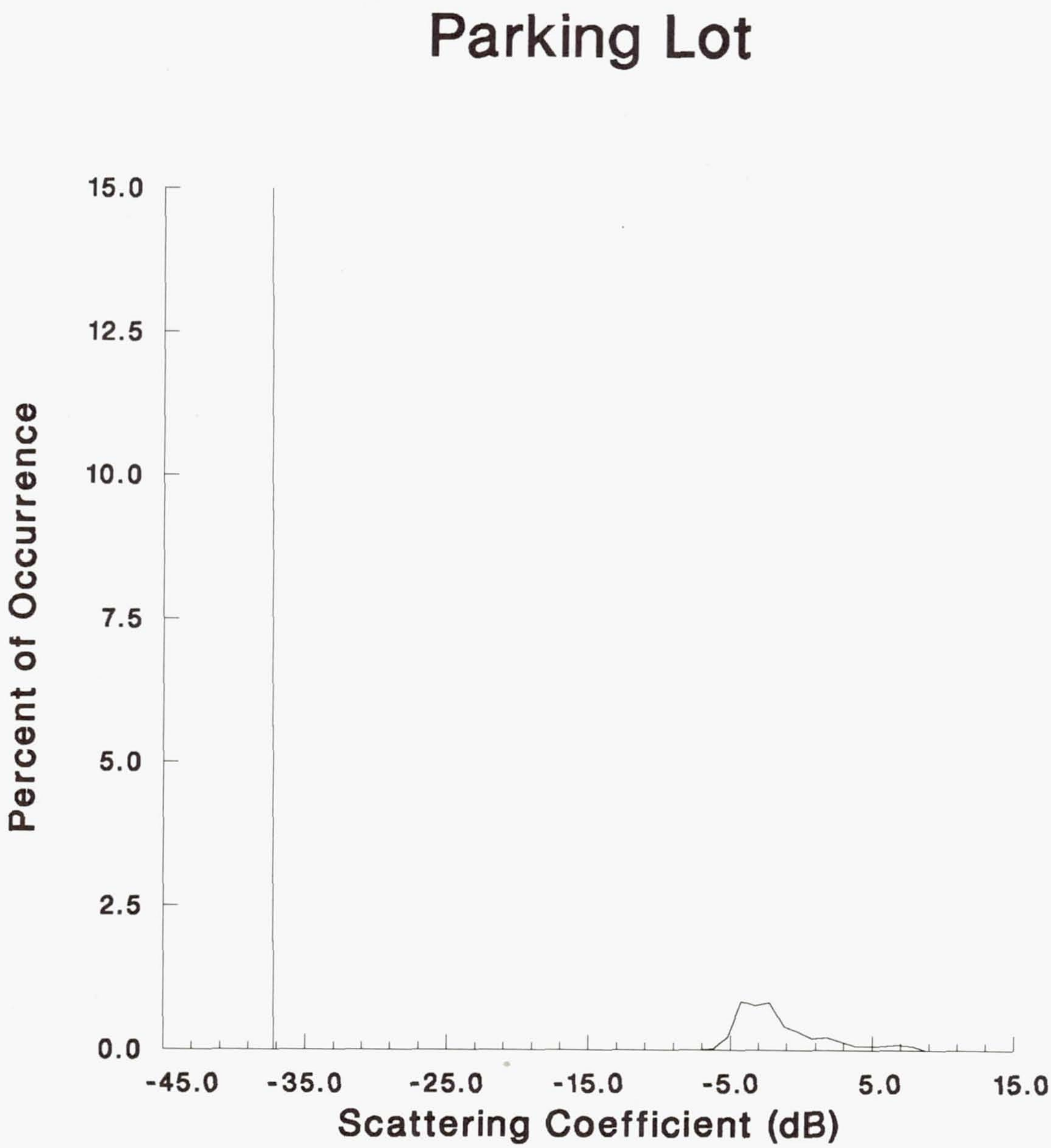


Figure 106.

Minimum: −38.71
Maximum: 8.15
Mean: −13.49
Bin Width: 1.00
Number of Bins: 48

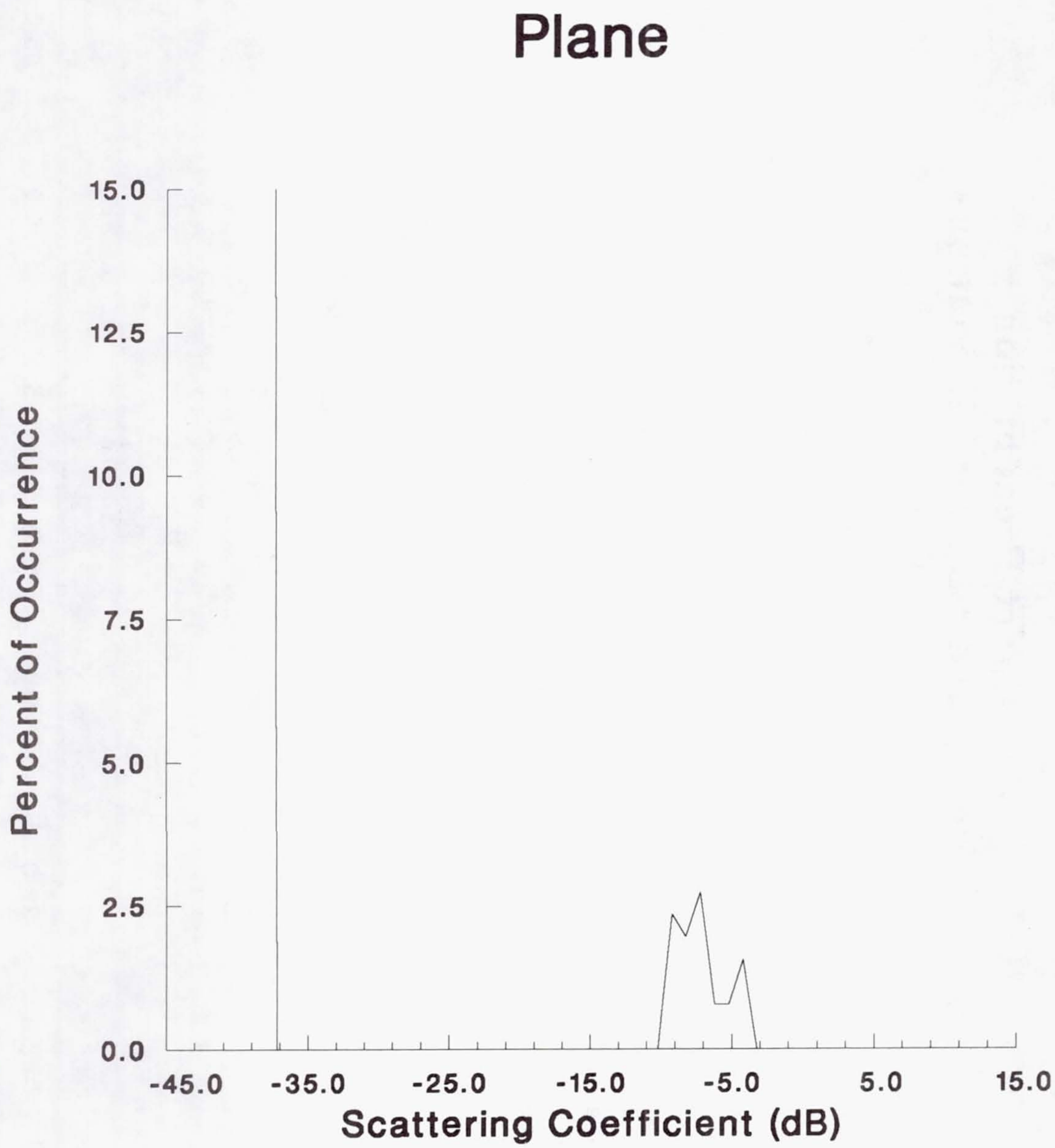


Figure 107.

Minimum: −38.71

Maximum: −4.13

Mean: −16.82

Bin Width: 1.00

Number of Bins: 36

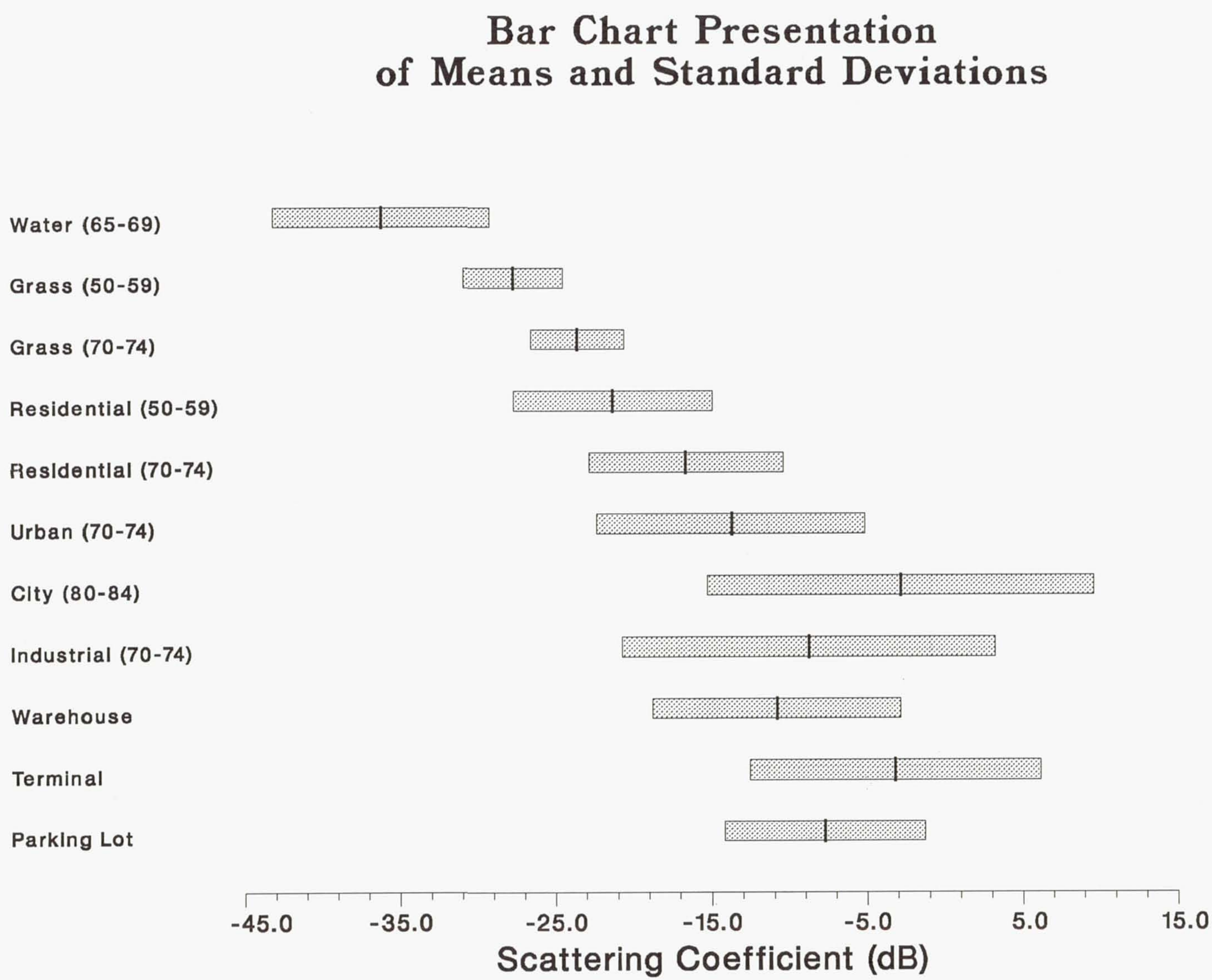


Figure 108. Mean NRCS Values Denver Second 'Step West'

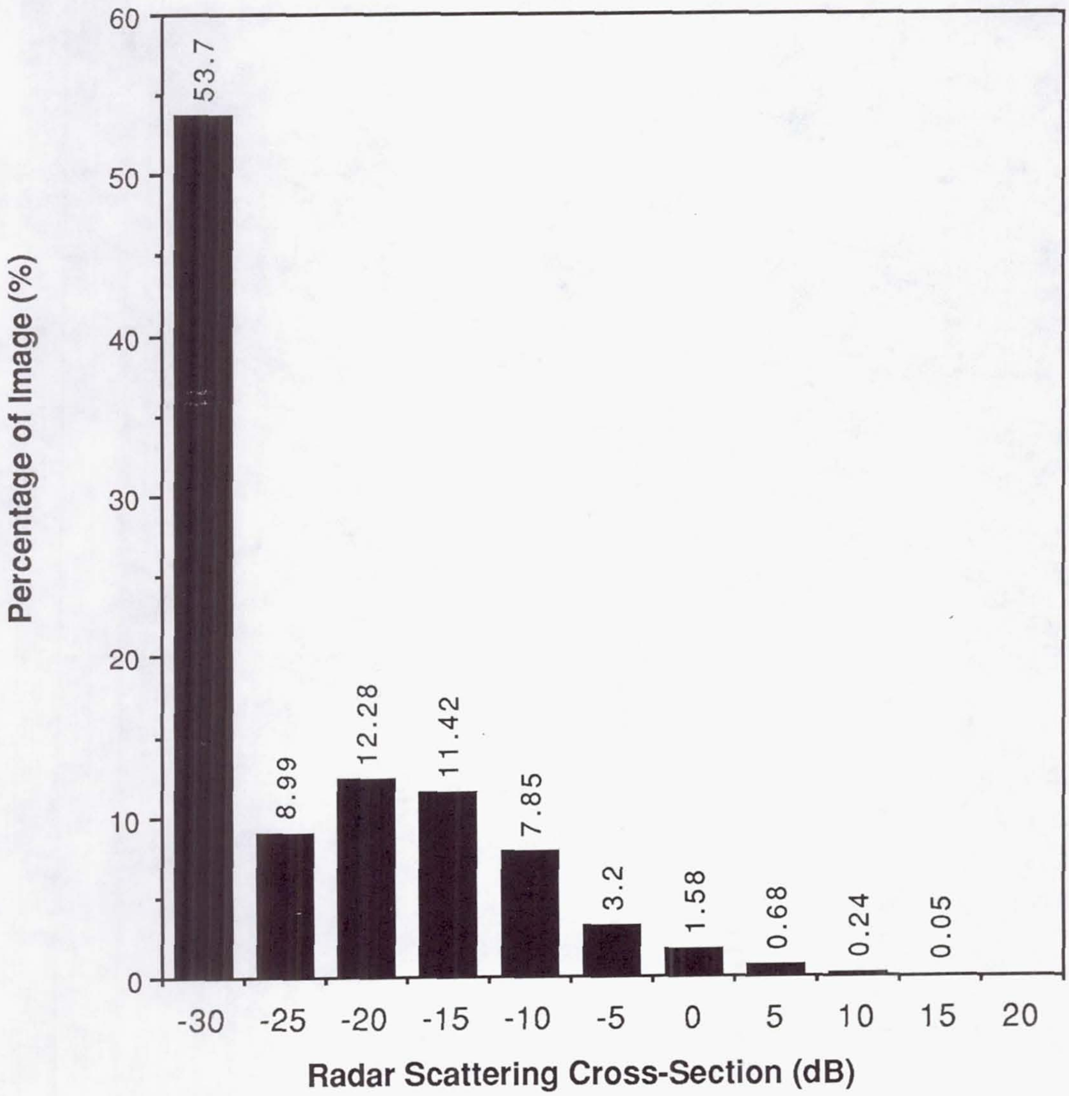


Figure 109. Distribution of Threshold Values Denver Second 'Step West'

Figure 110. The Second Denver 'Step West' Image Thresholded at -30 dB

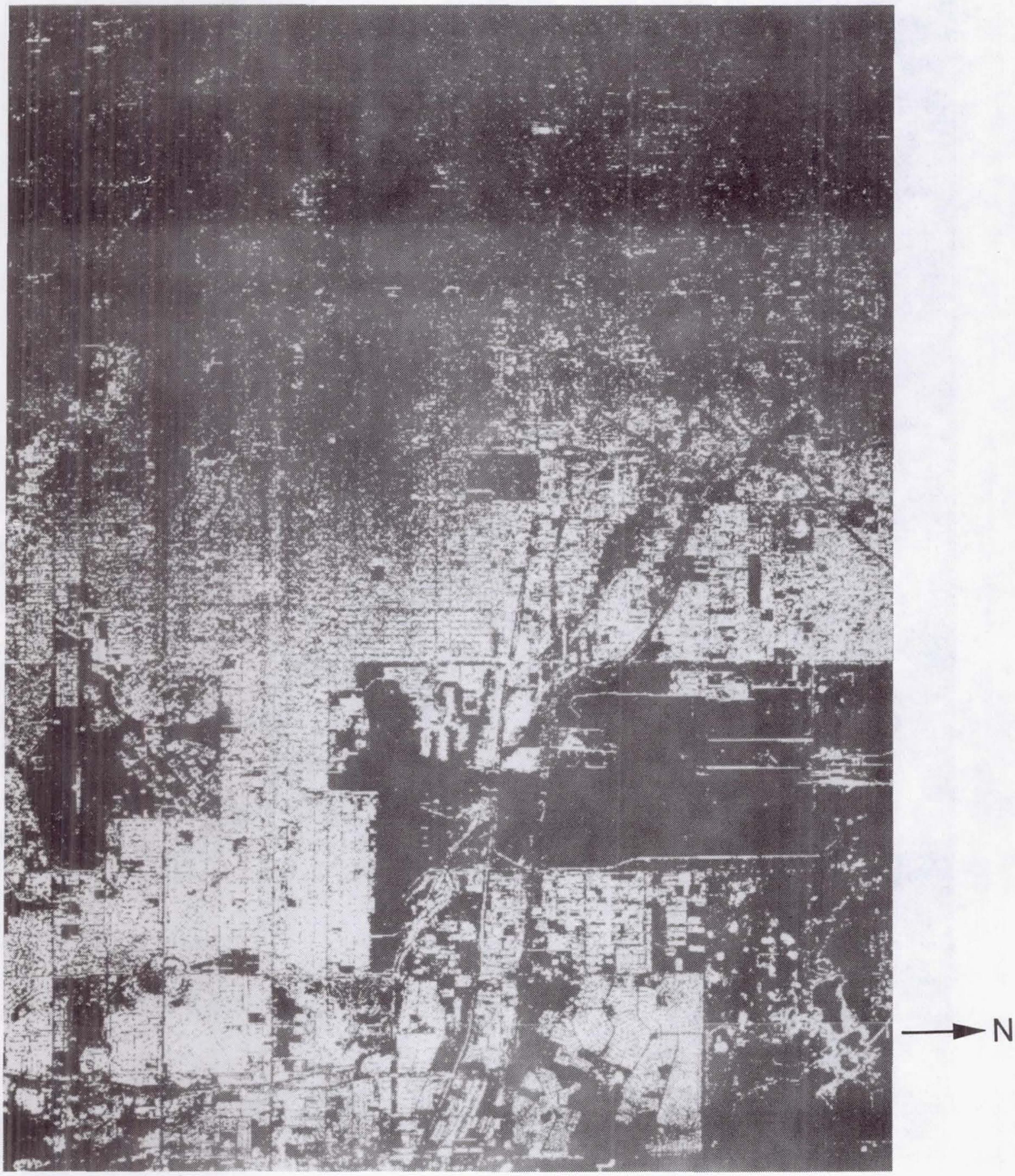


Figure 111. The Second Denver 'Step West' Image Thresholded at -20 dB

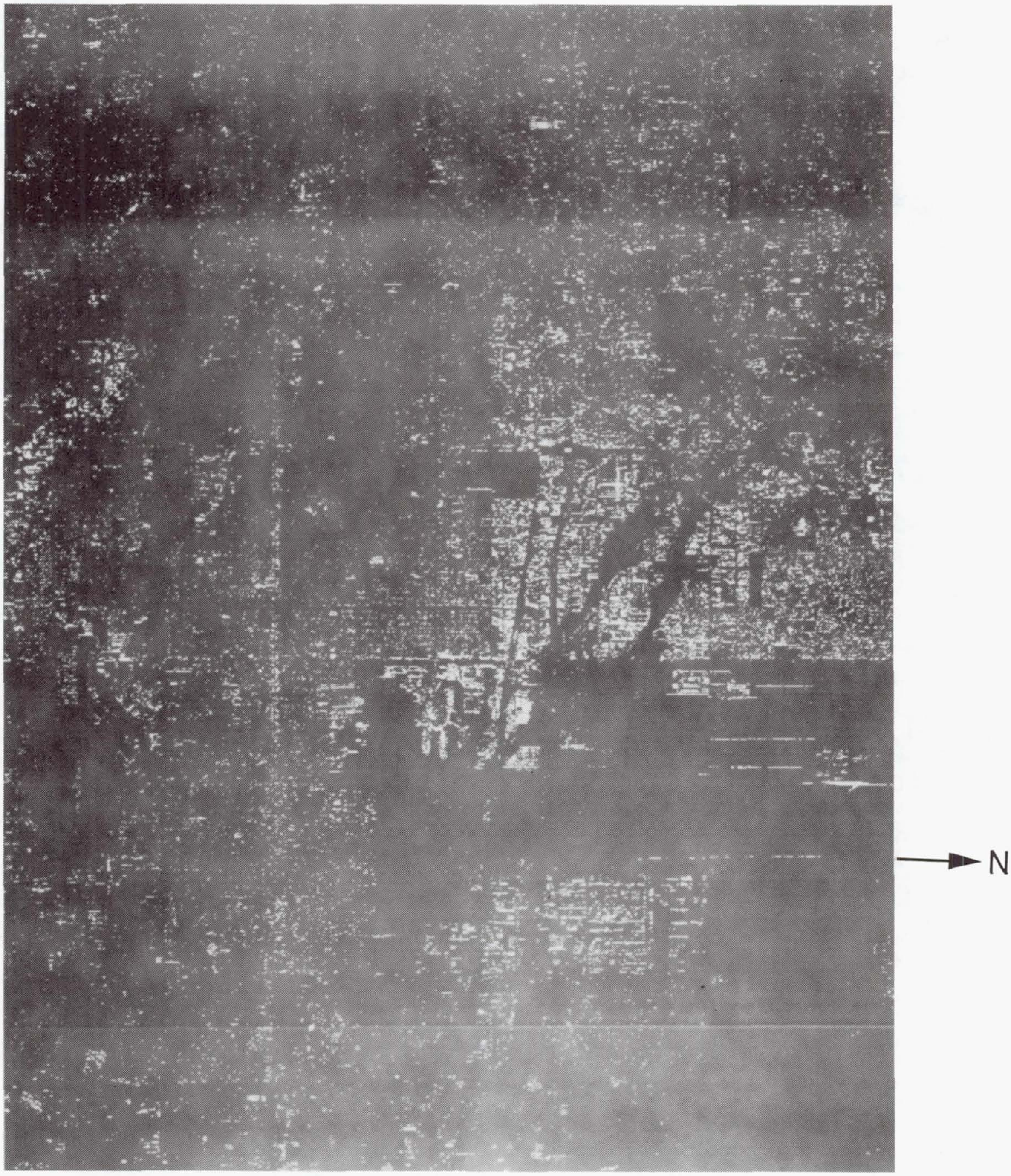


Figure 112. The Second Denver 'Step West' Image Thresholded at -10 dB

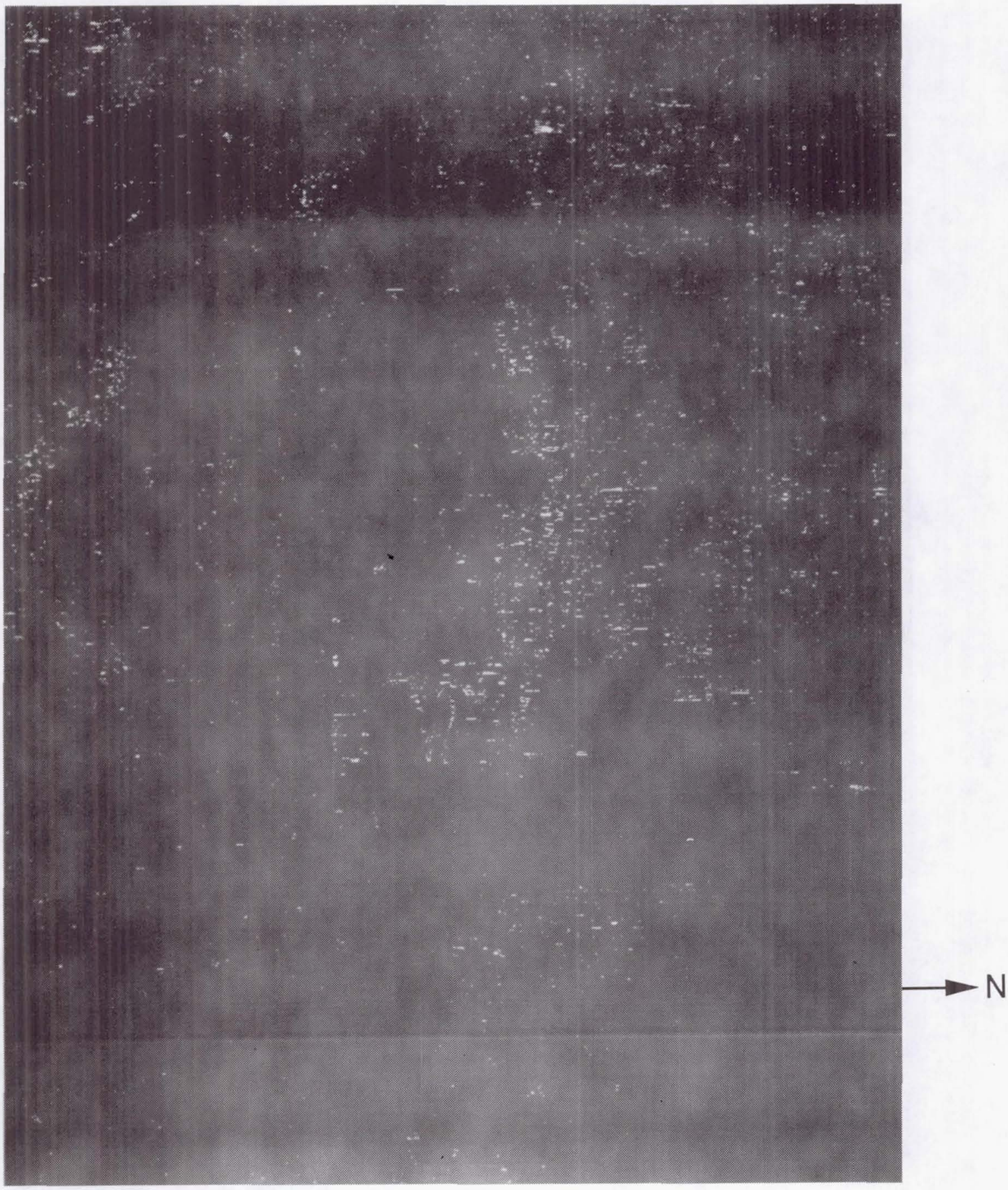


Figure 113. The Second Denver 'Step West' Image Threholded at 0 dB

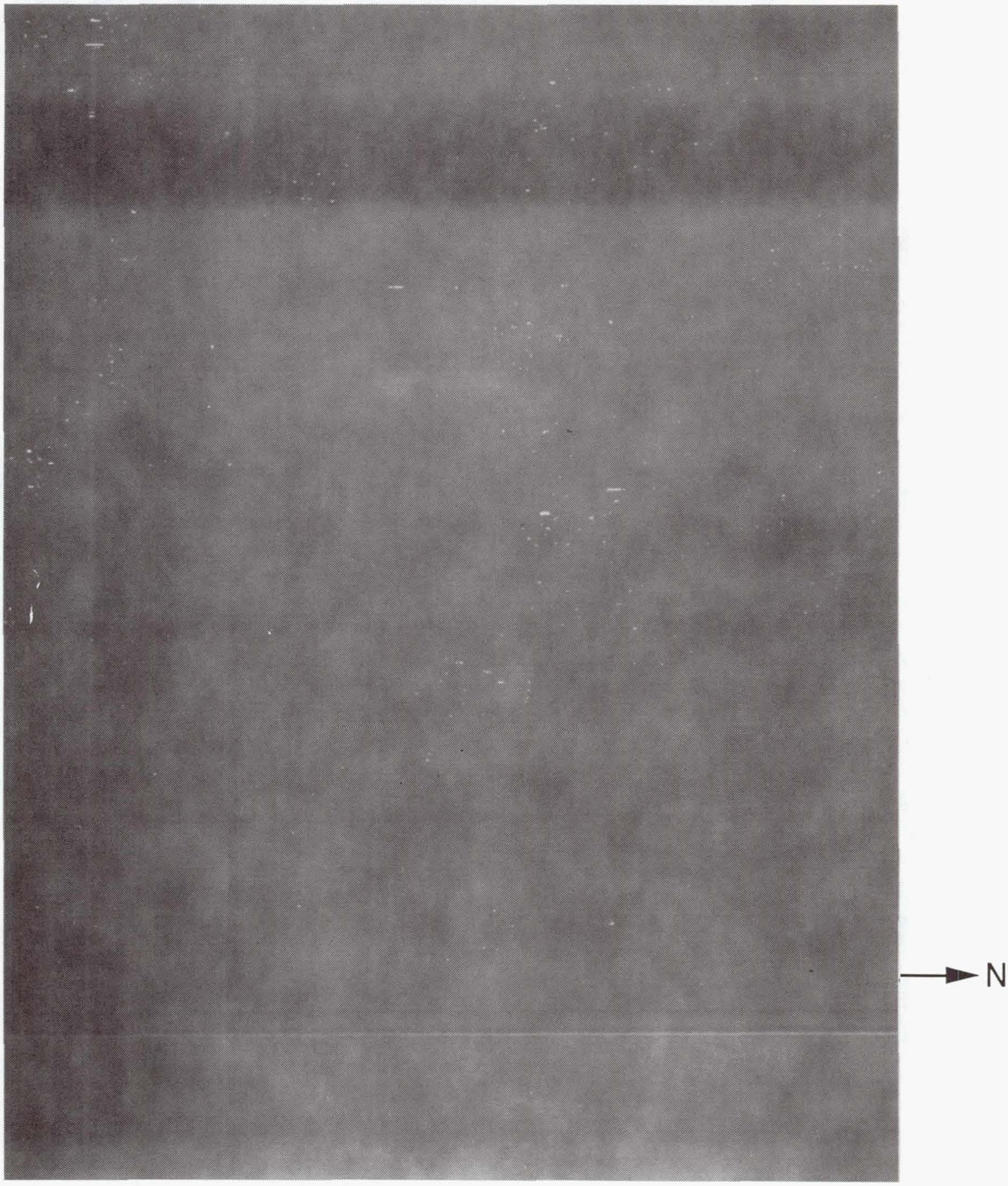


Figure 114. The Second Denver 'Step West' Image Threholded at 10 dB

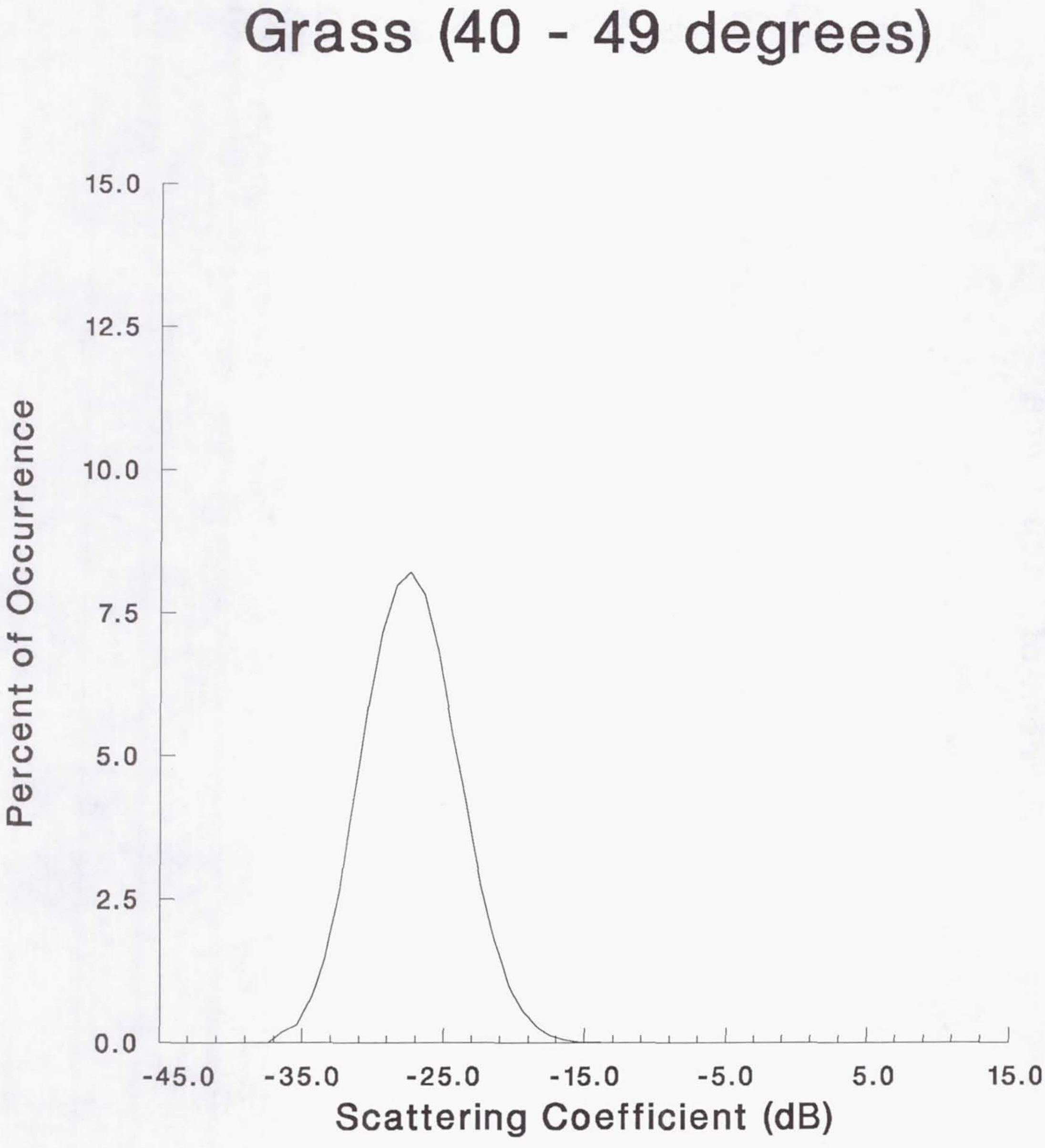


Figure 115.

Minimum: −39.89

Maximum: −13.37

Mean: −27.57

Bin Width: 1.00

Number of Bins: 28

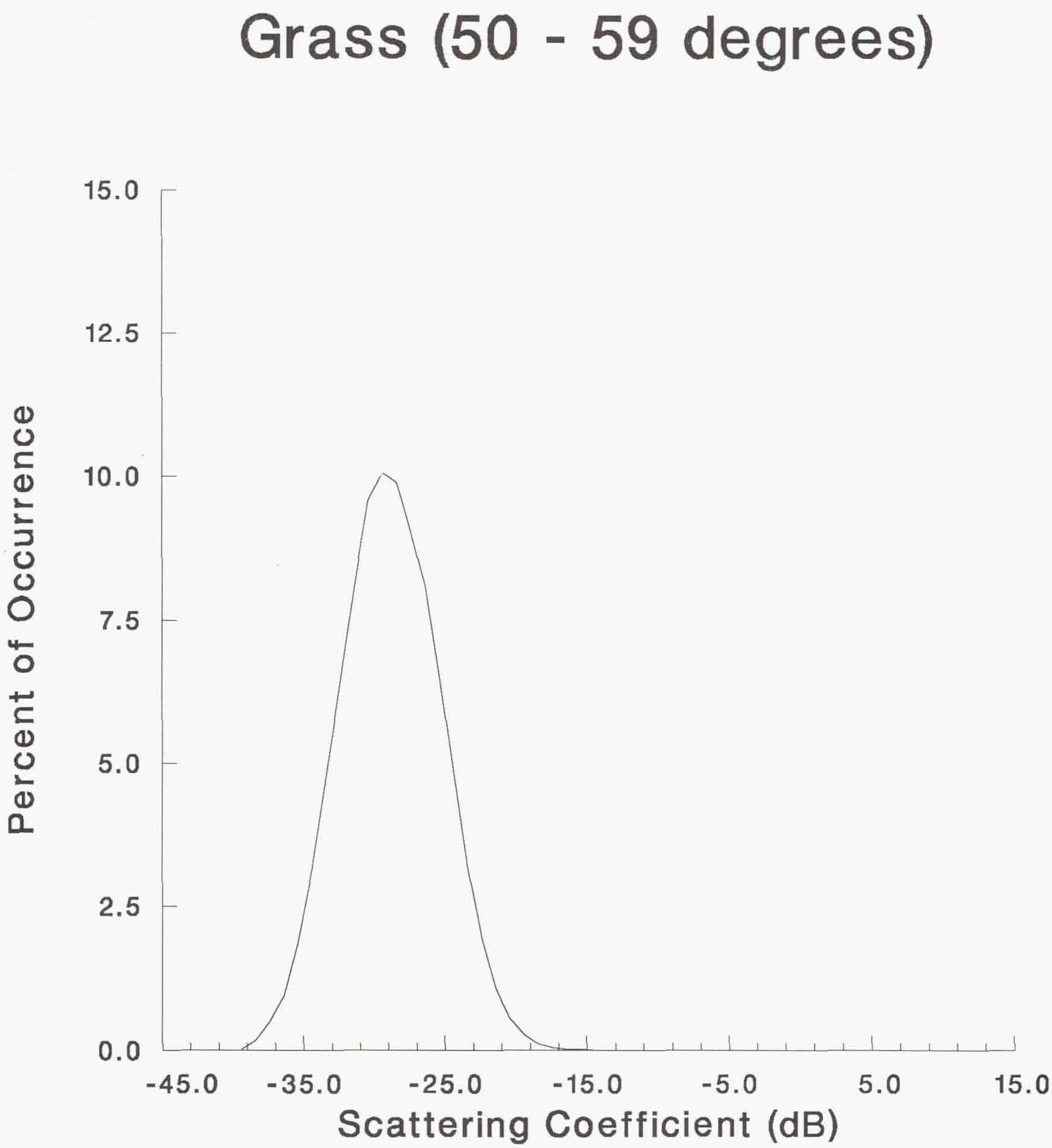


Figure 116.

Minimum: −39.89
Maximum: −10.94
Mean: −27.82
Bin Width: 1.00
Number of Bins: 30

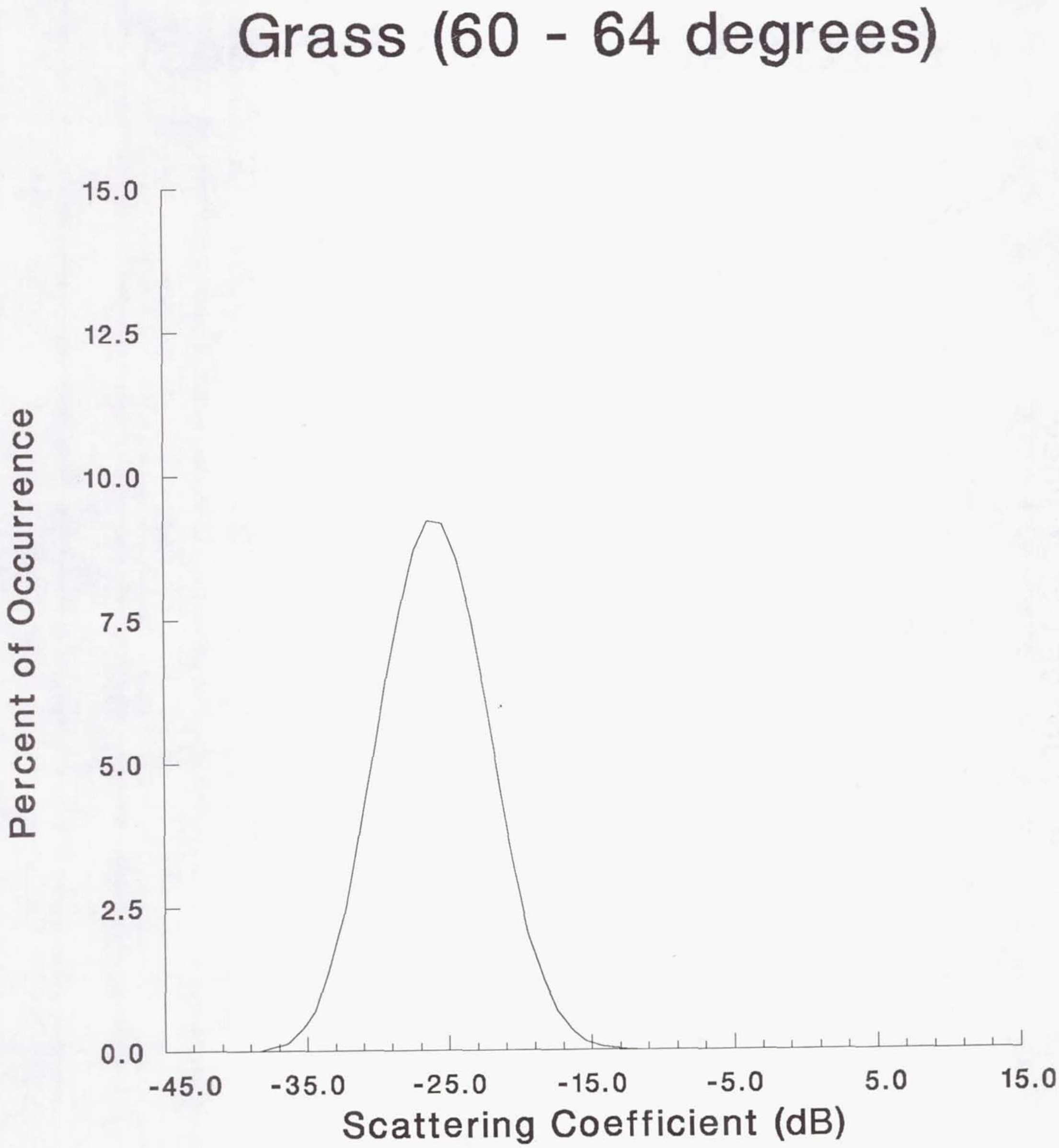


Figure 117.

Minimum: −39.89
Maximum: −10.24
Mean: −24.94
Bin Width: 1.00
Number of Bins: 31

Grass (65 - 69 degrees)

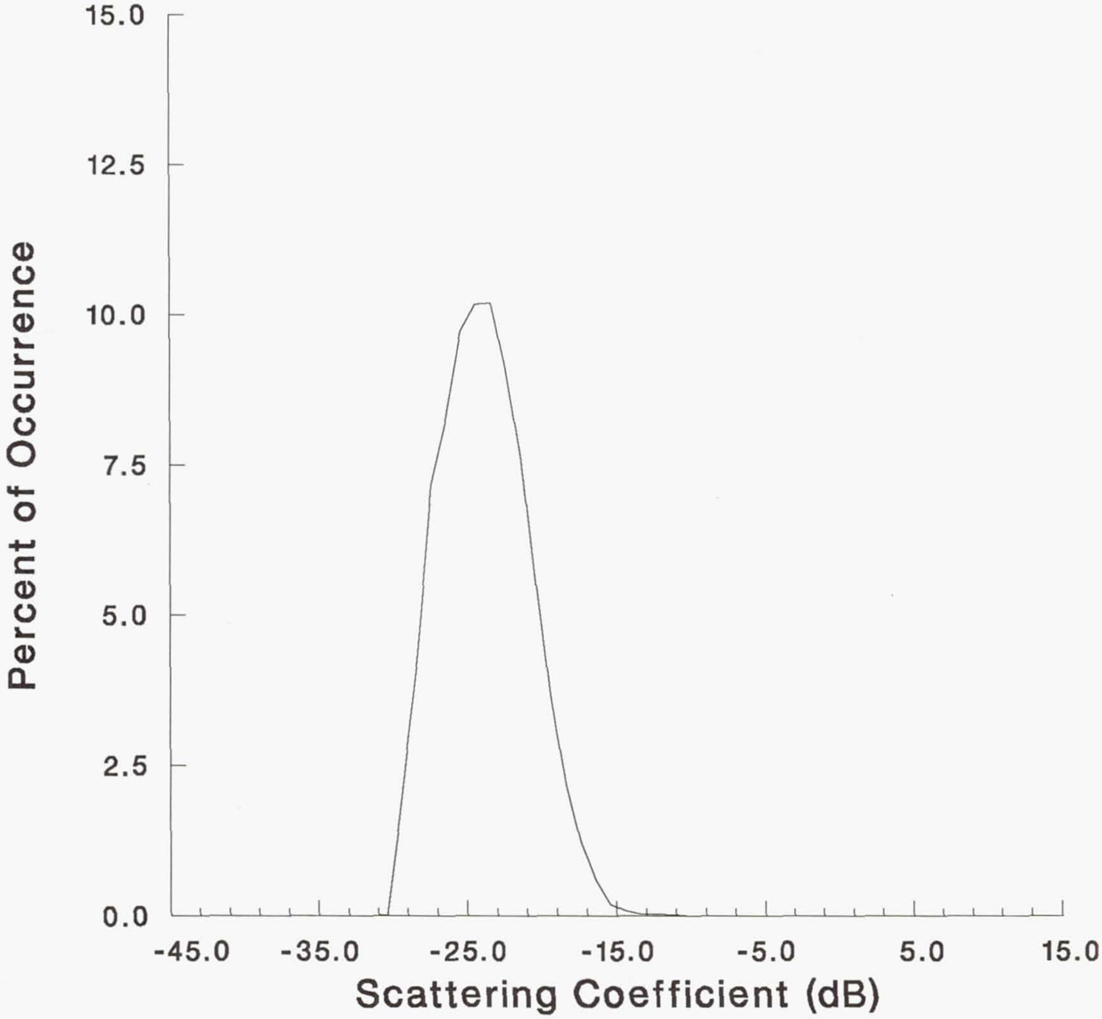


Figure 118.

Minimum: −39.89
Maximum: −10.95
Mean: −23.67
Bin Width: 1.00
Number of Bins: 30

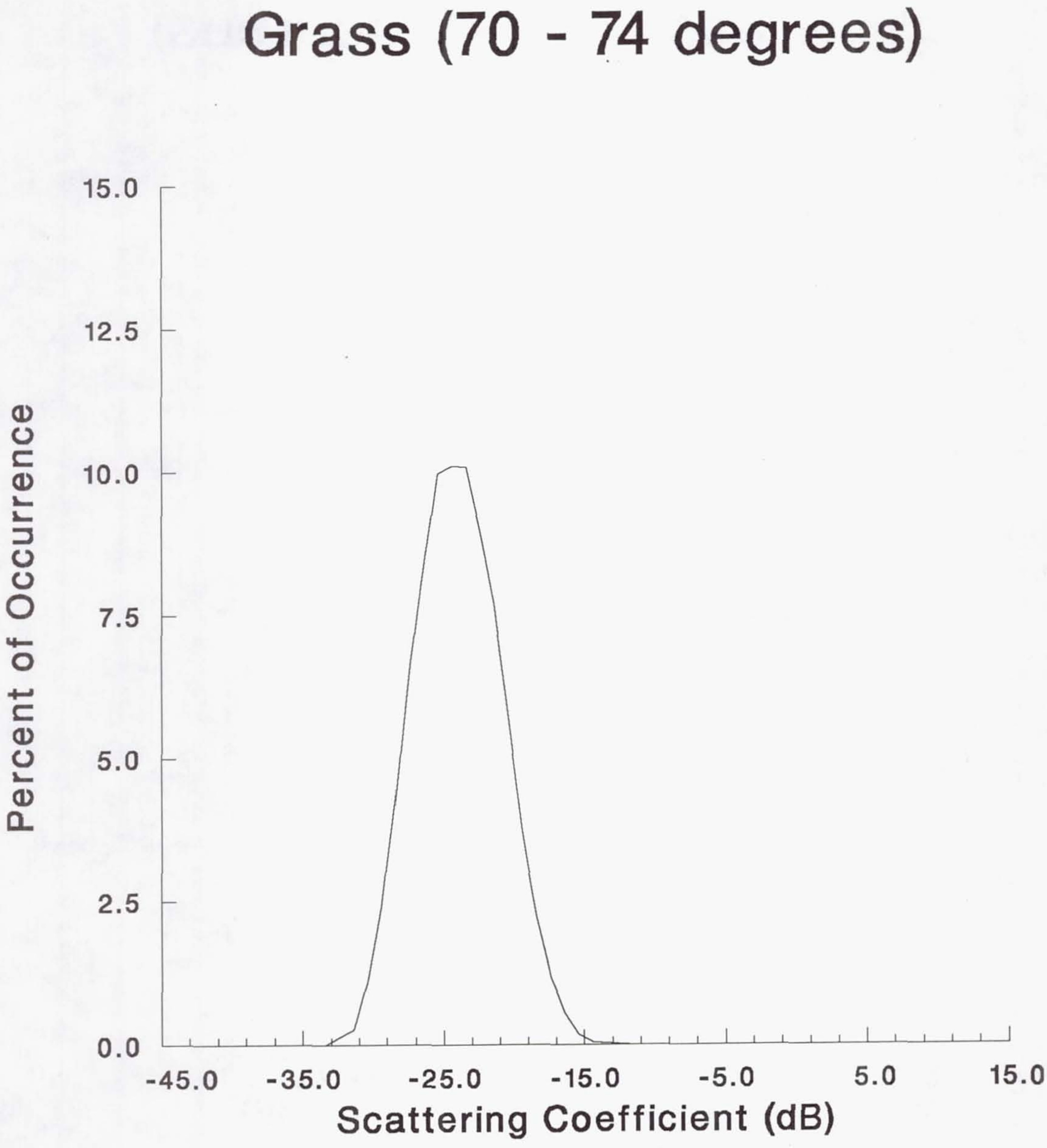


Figure 119.

Minimum: −39.89

Maximum: −8.16

Mean: −23.68

Bin Width: 1.00

Number of Bins: 33

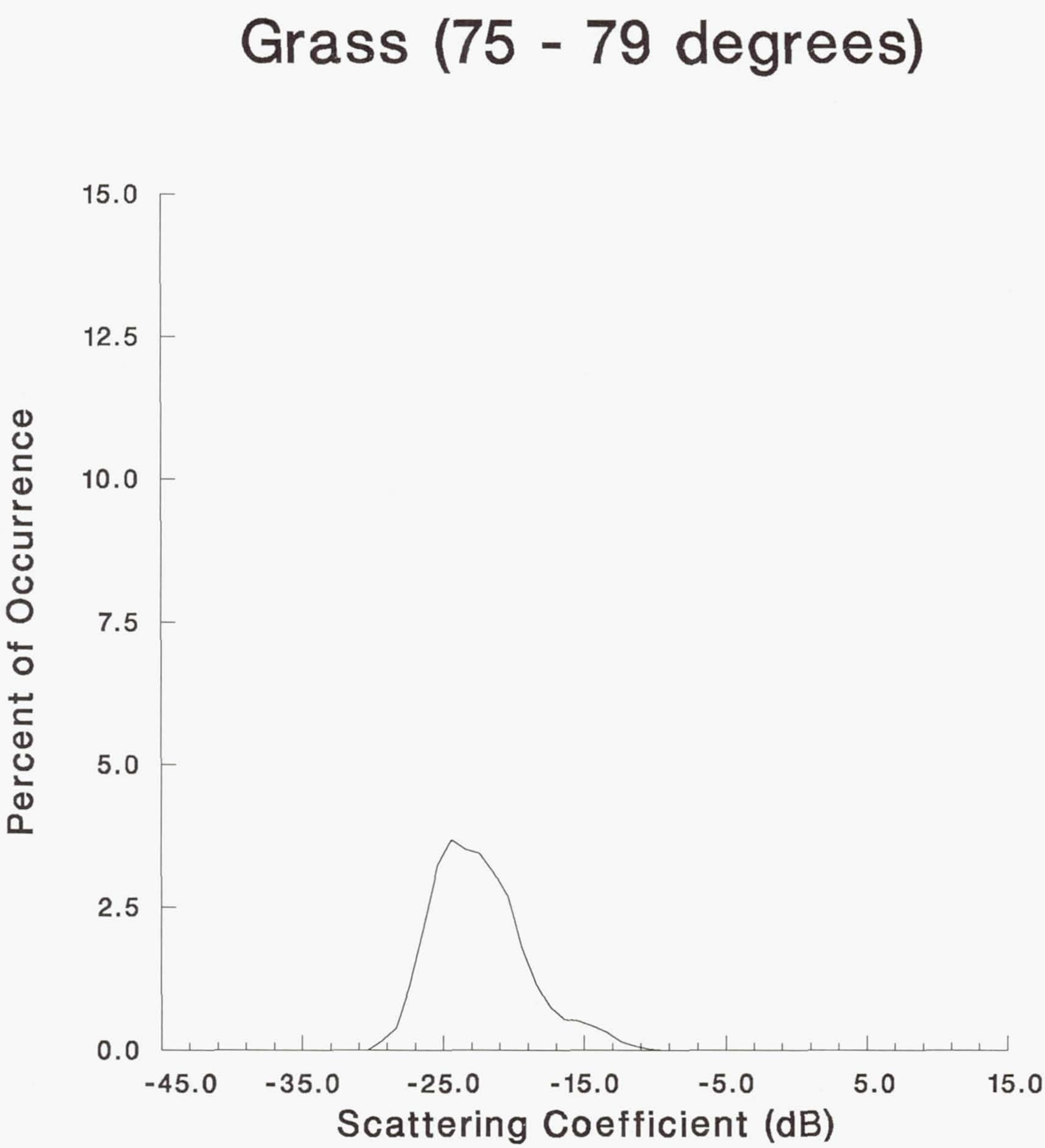


Figure 120.

Minimum: −39.89
Maximum: −10.11
Mean: −26.16
Bin Width: 1.00
Number of Bins: 31

Residential (40 - 49 degrees)

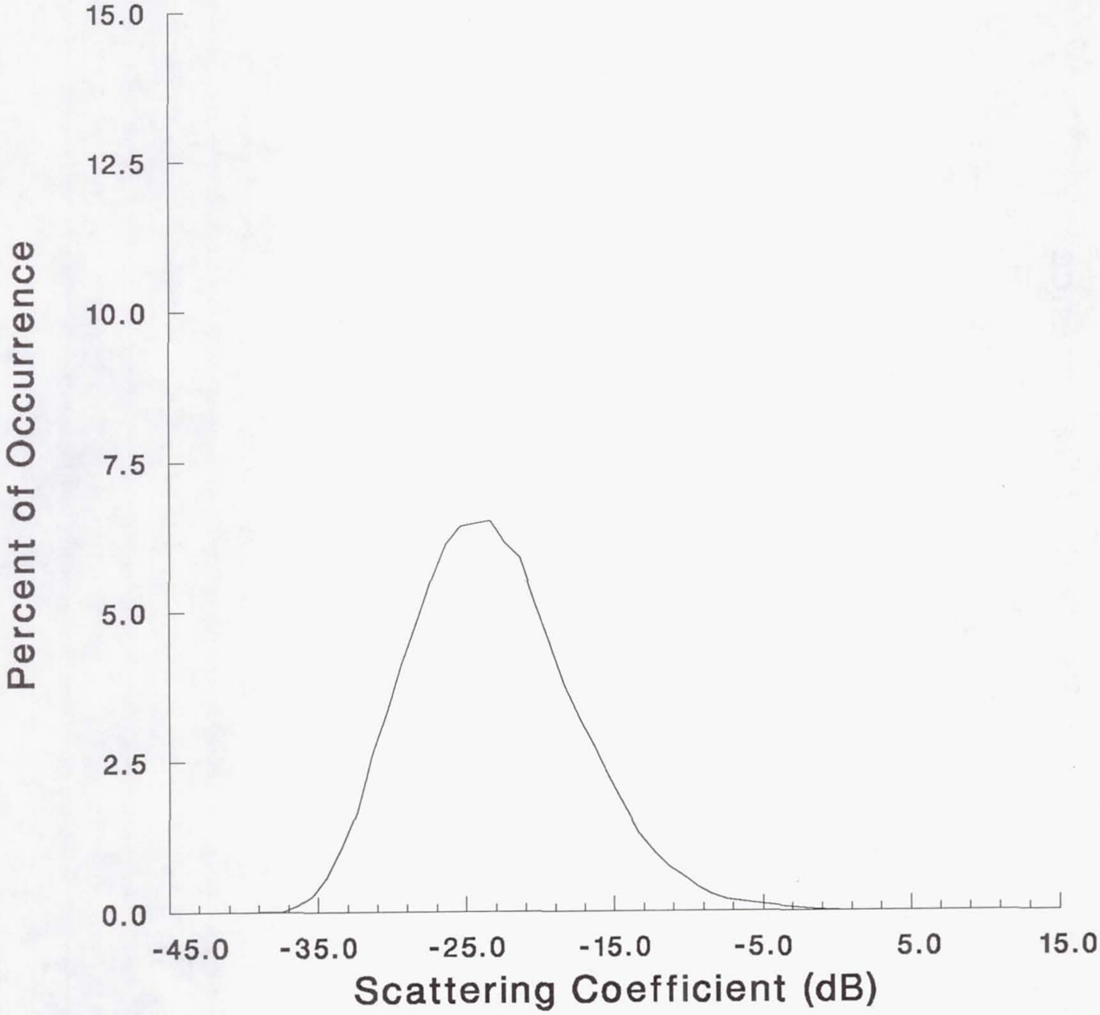


Figure 121.

Minimum: −39.89
Maximum: 8.59
Mean: −18.98
Bin Width: 1.00
Number of Bins: 49

Residential (50 - 59 degrees)

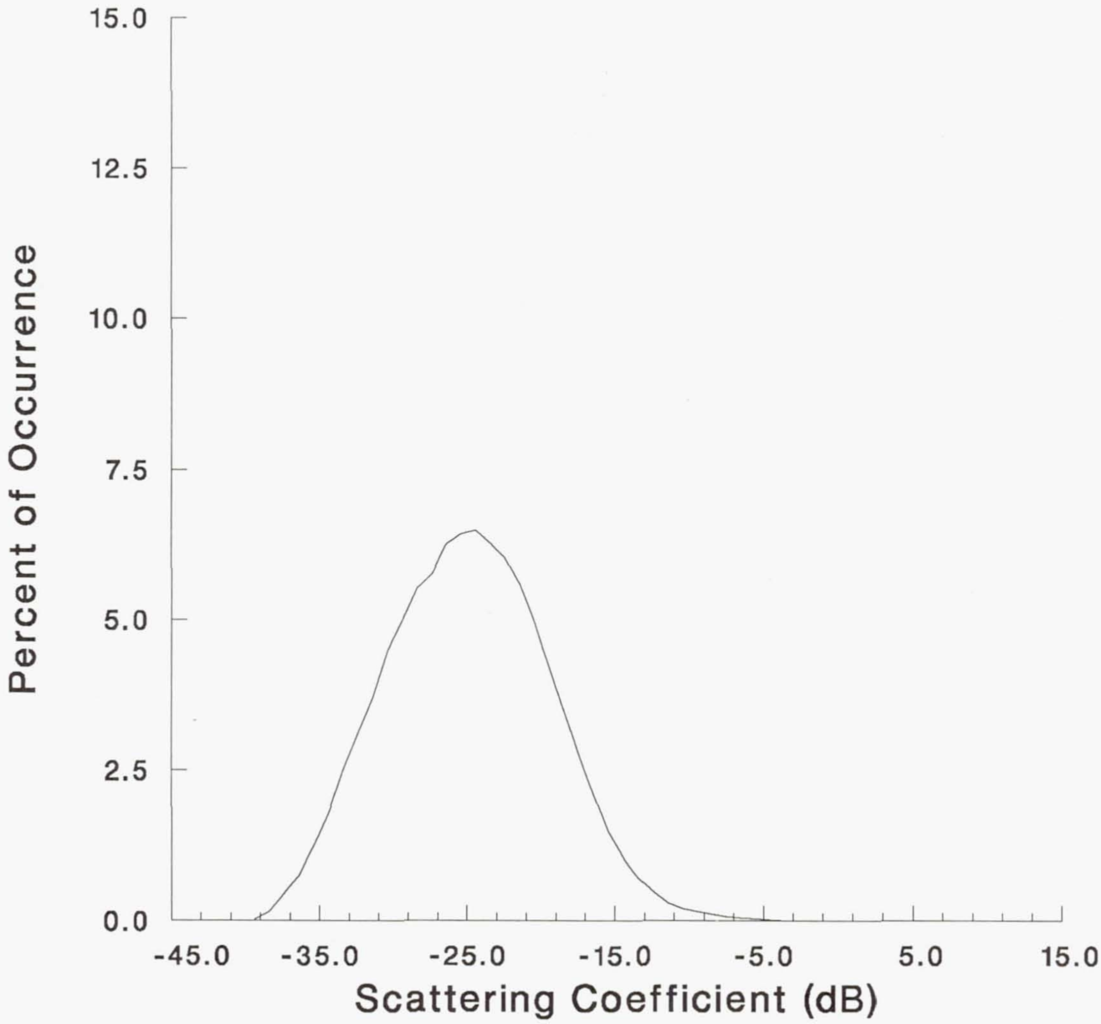


Figure 122.

Minimum: −39.89
Maximum: 1.80
Mean: −21.42
Bin Width: 1.00
Number of Bins: 43

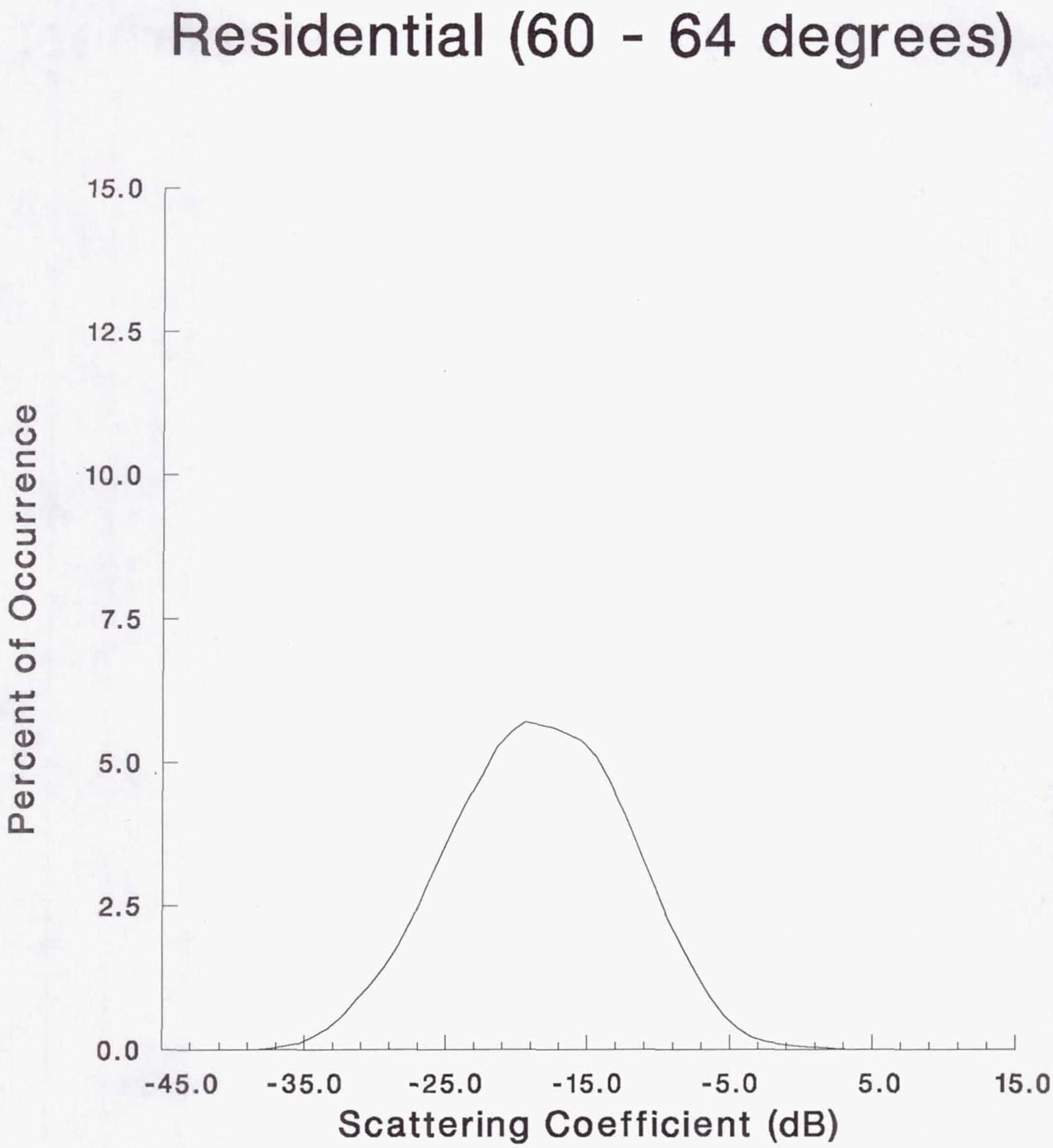


Figure 123.

Minimum: −39.89
Maximum: 11.00
Mean: −14.37
Bin Width: 1.00
Number of Bins: 52

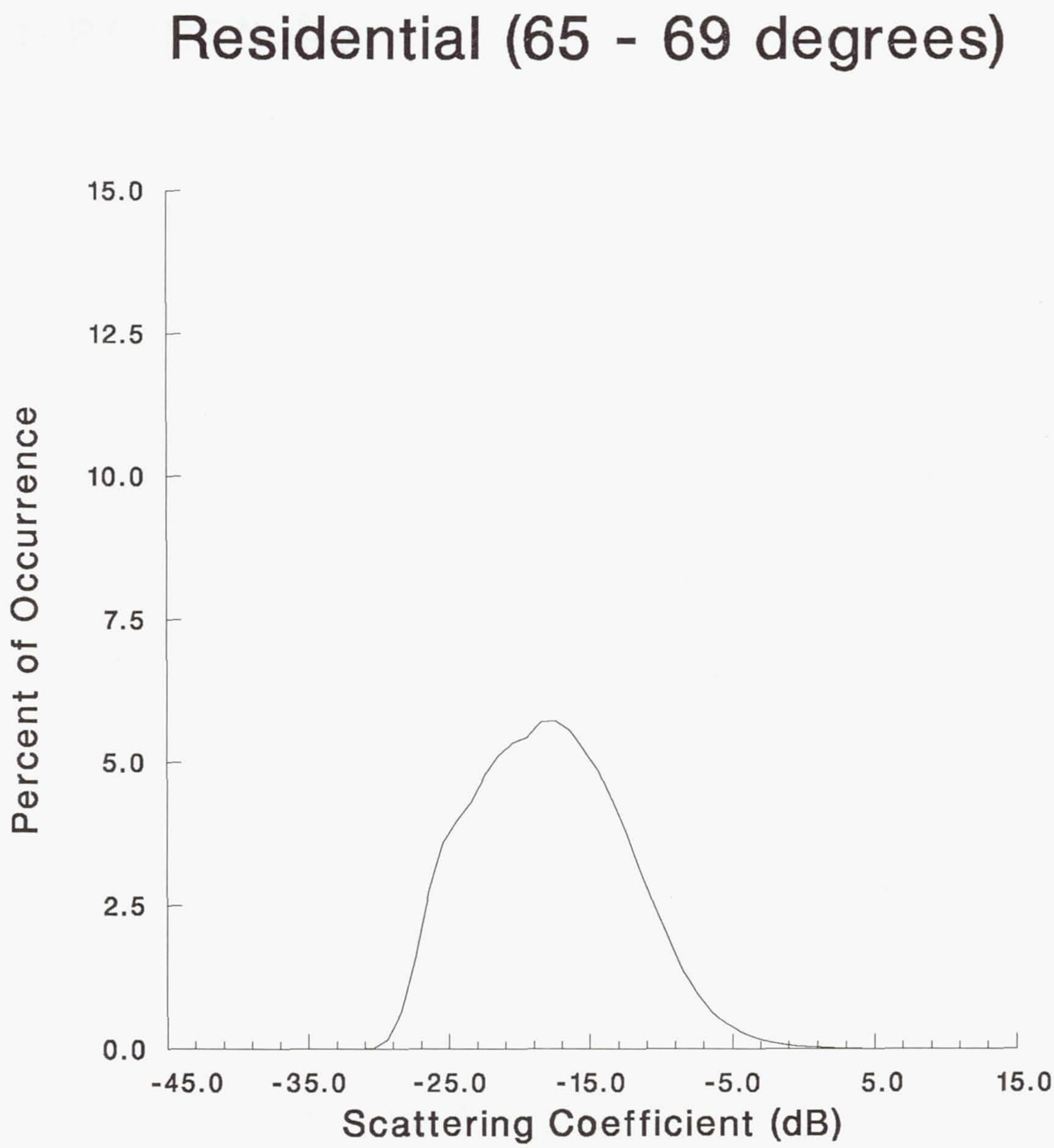


Figure 124.

Minimum: −39.89

Maximum: 20.21

Mean: −14.54

Bin Width: 1.00

Number of Bins: 61

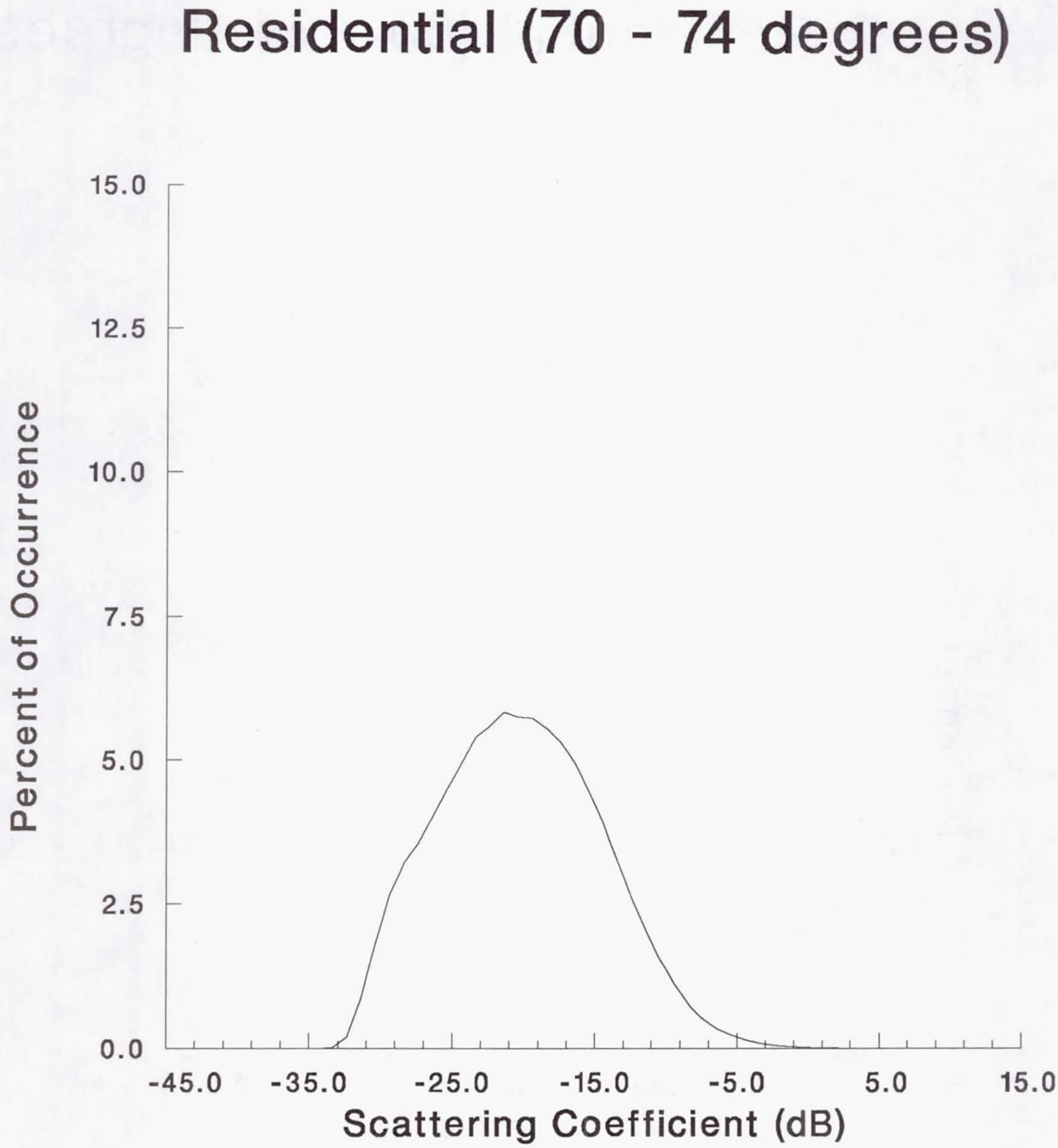


Figure 125.

Minimum: −39.89
Maximum: 8.22
Mean: −16.70
Bin Width: 1.00
Number of Bins: 49

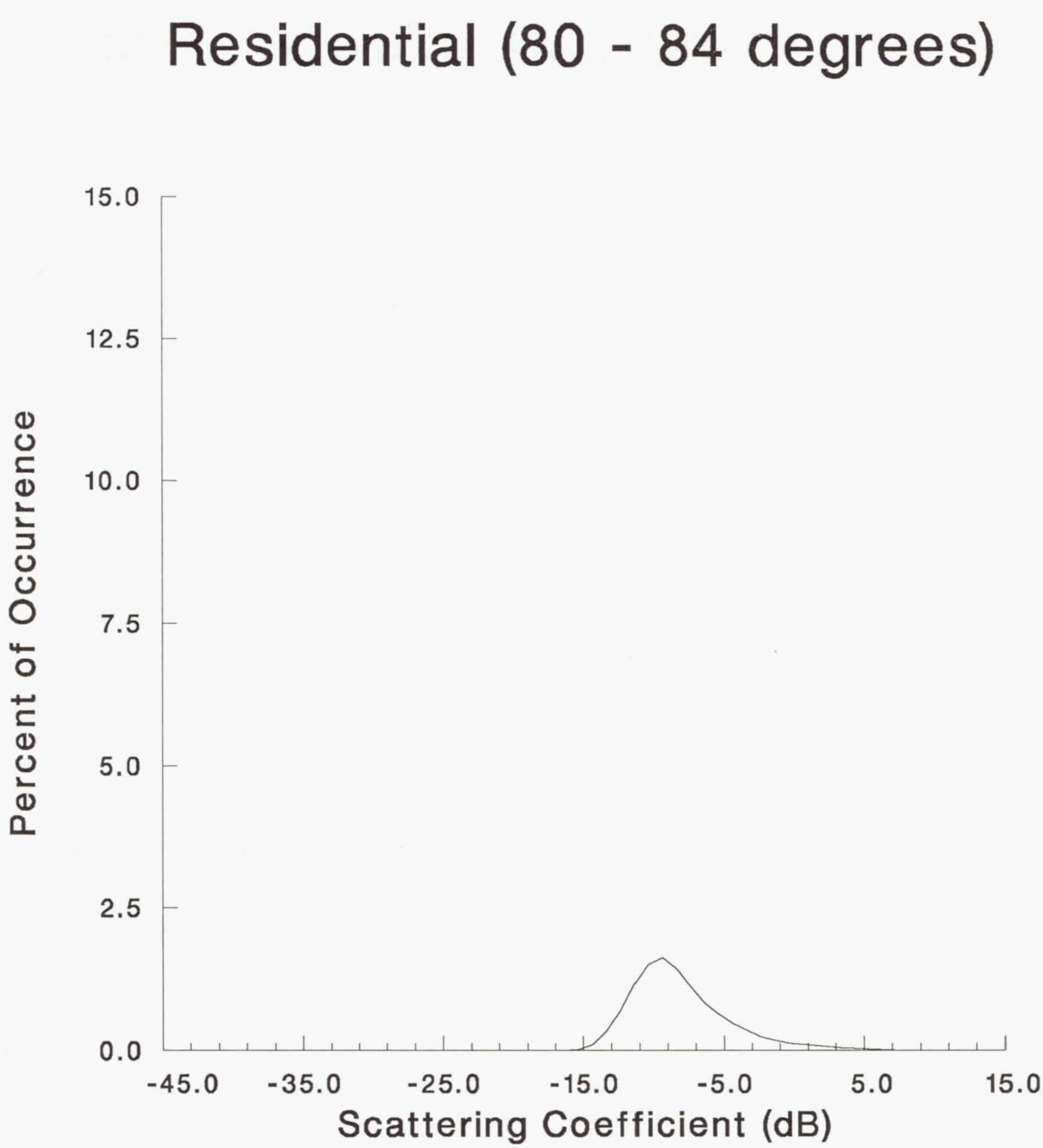


Figure 126.

Minimum: −39.89
Maximum: 9.91
Mean: −15.35
Bin Width: 1.00
Number of Bins: 51

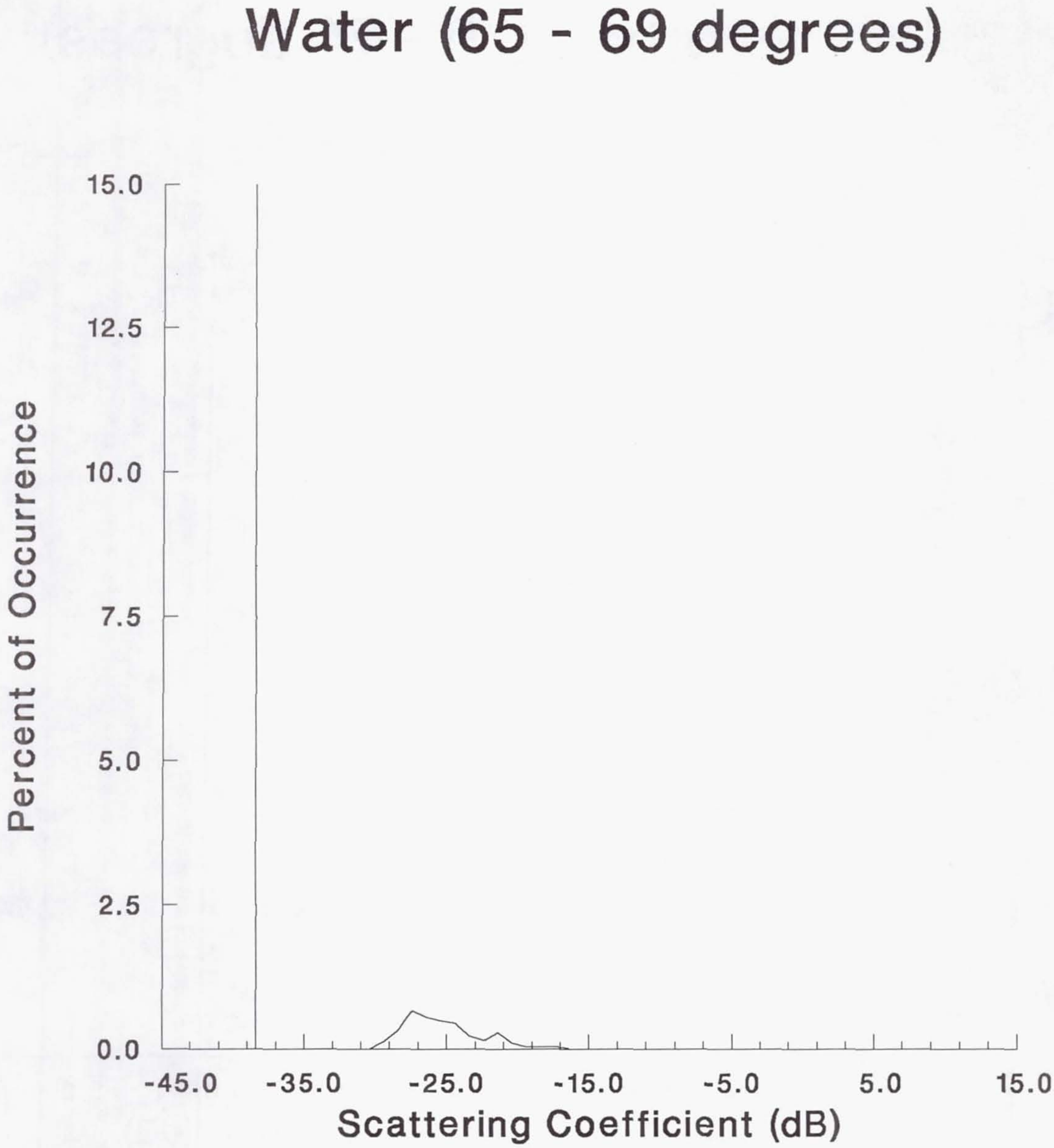


Figure 127.

Minimum: −39.89
Maximum: −16.76
Mean: −36.28
Bin Width: 1.00
Number of Bins: 24

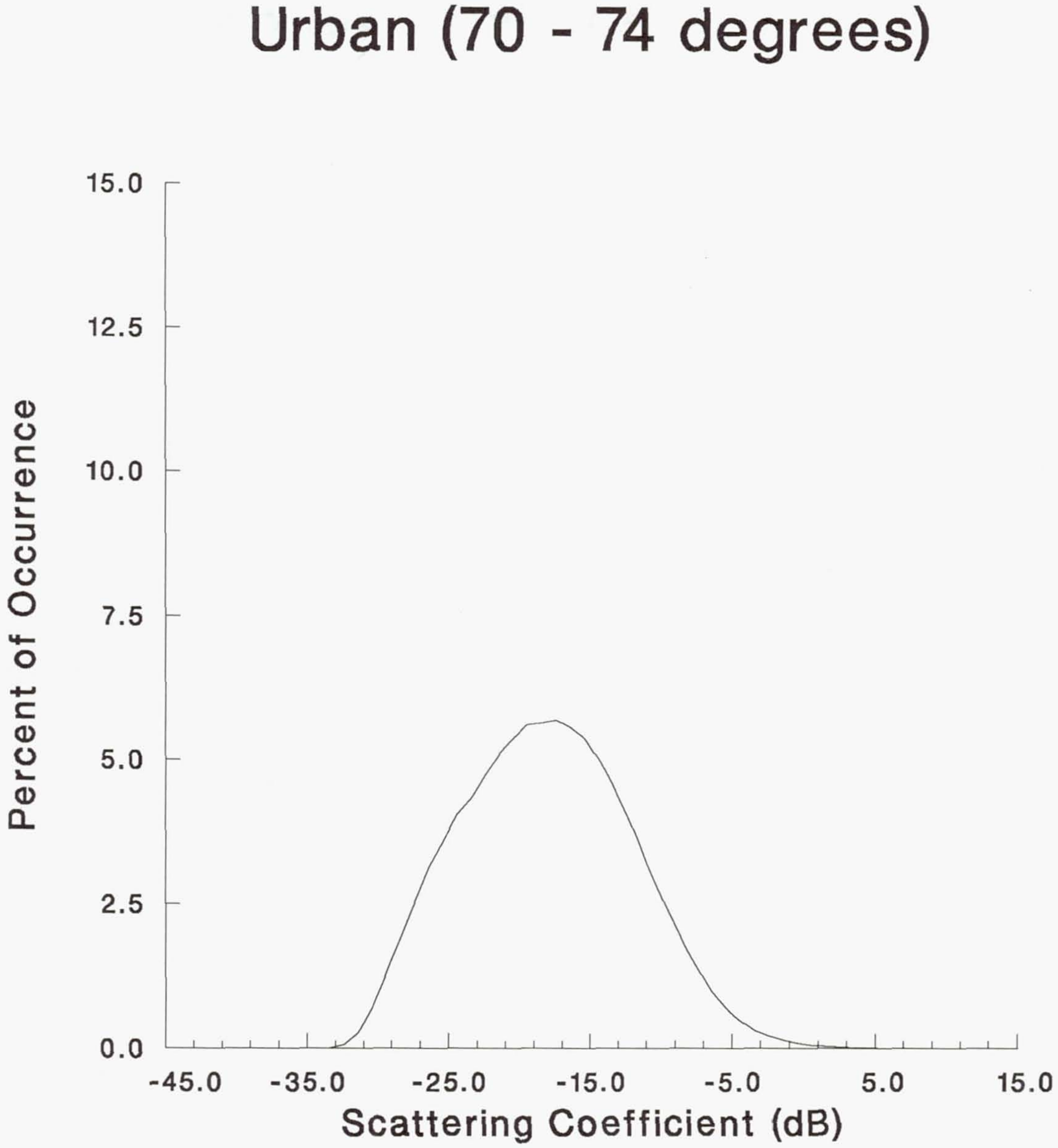


Figure 128.

Minimum: −39.89

Maximum: 16.36

Mean: −13.80

Bin Width: 1.00

Number of Bins: 57

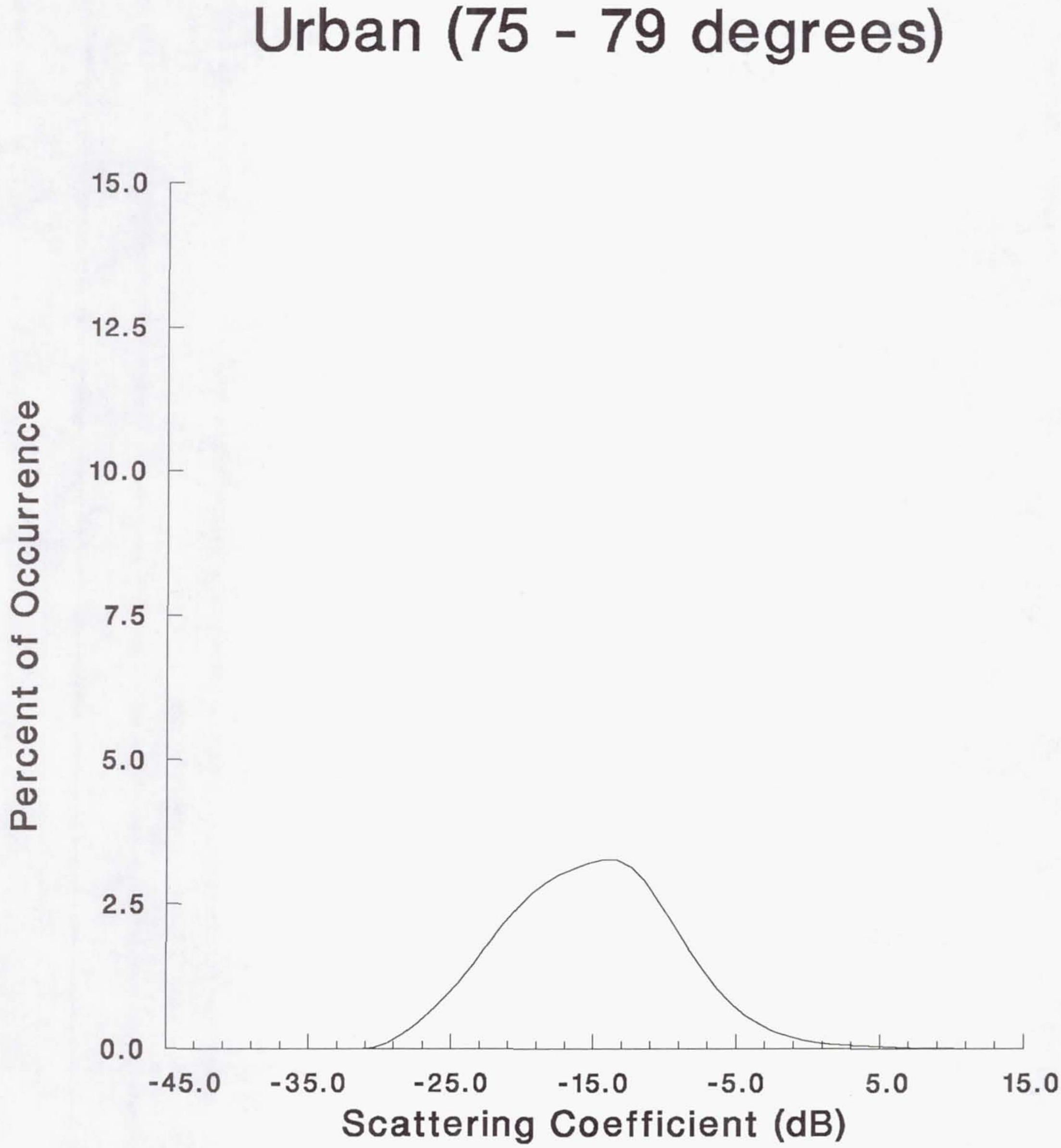


Figure 129.

Minimum: −39.89
Maximum: 19.65
Mean: −12.49
Bin Width: 1.00
Number of Bins: 61

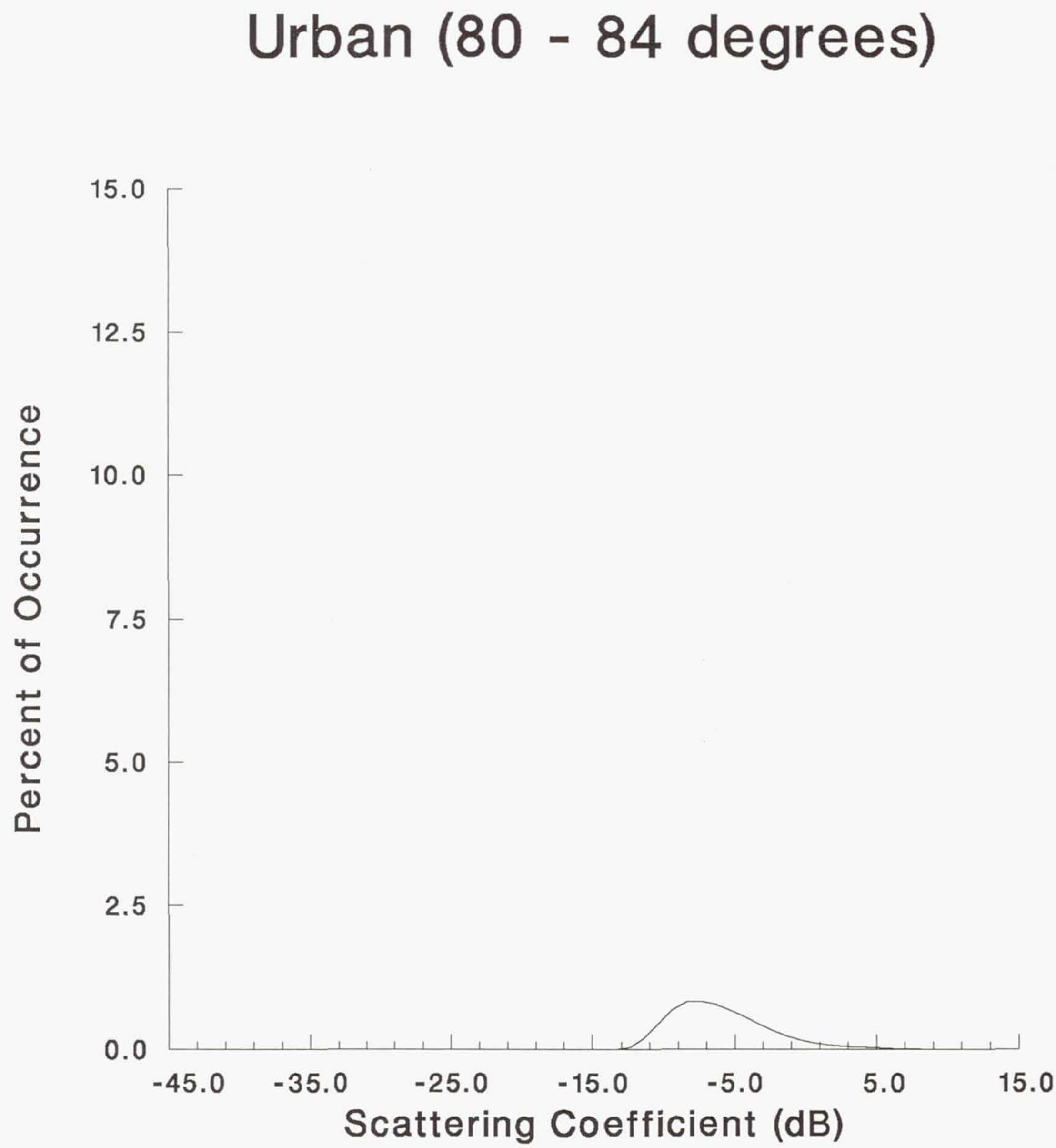


Figure 130.

Minimum: −39.89
Maximum: 16.82
Mean: −15.33
Bin Width: 1.00
Number of Bins: 58

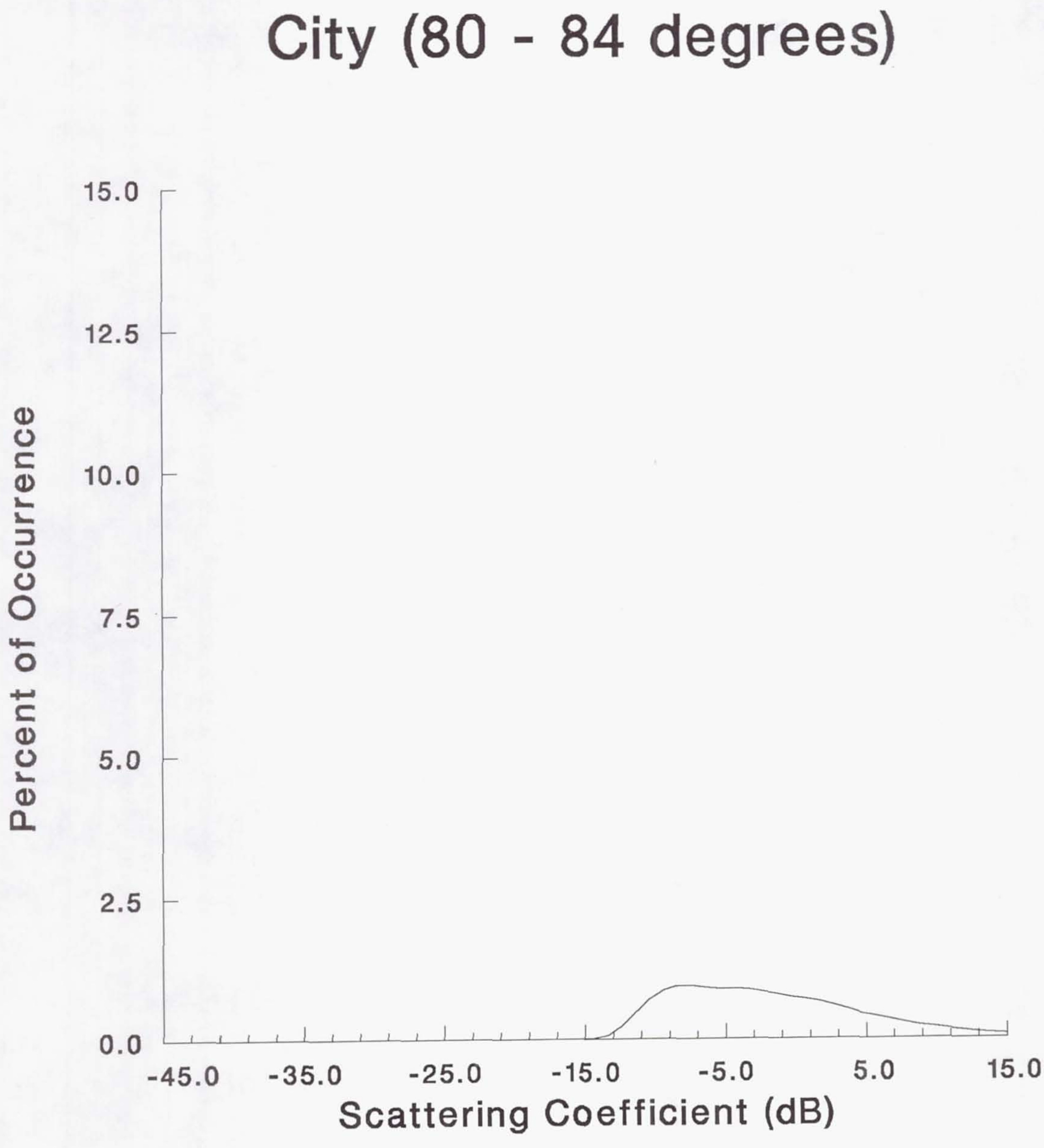


Figure 131.

Minimum: −39.89

Maximum: 31.08

Mean: −2.91

Bin Width: 1.00

Number of Bins: 72

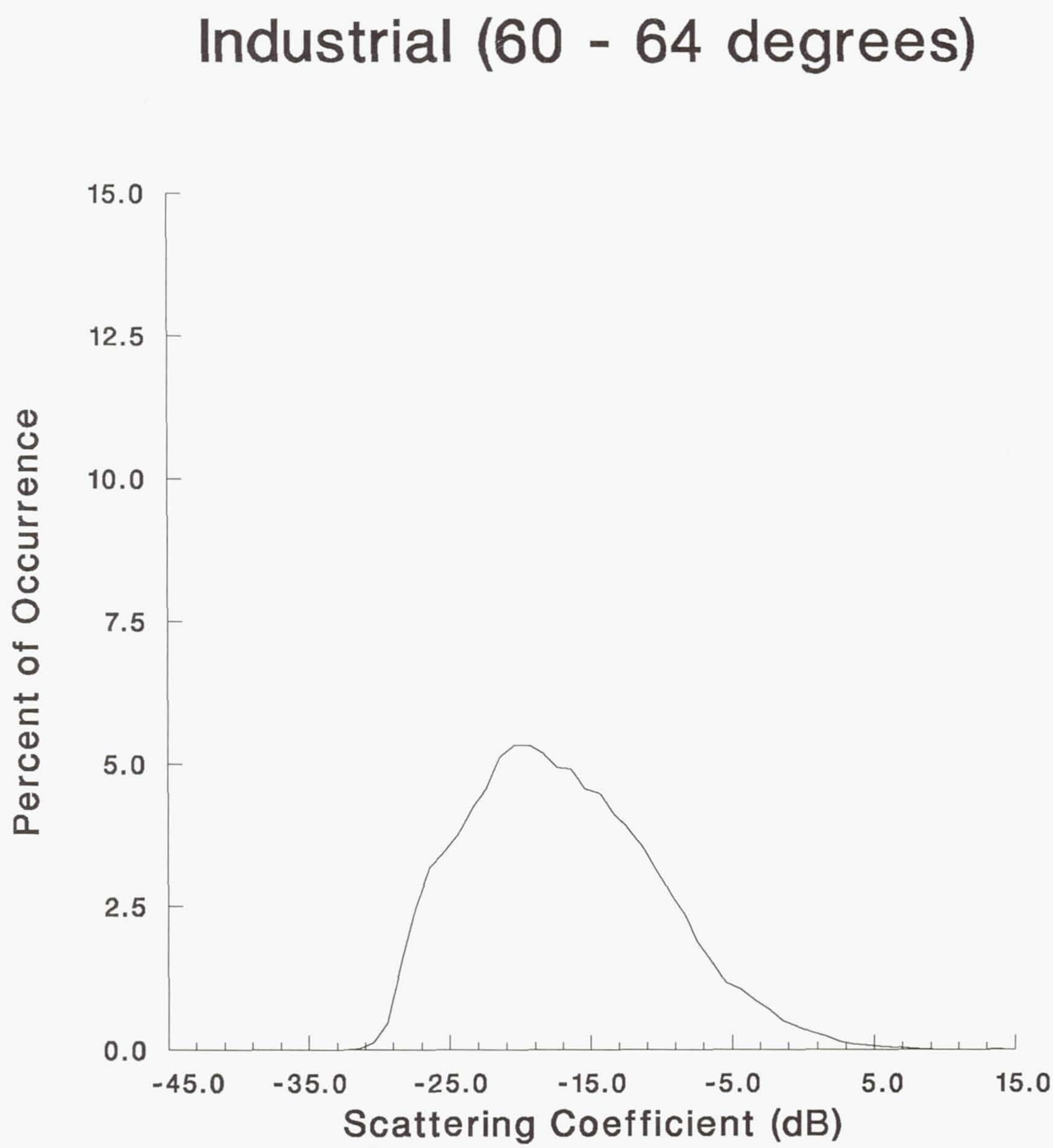


Figure 132.

Minimum: −39.89
Maximum: 17.90
Mean: −10.03
Bin Width: 1.00
Number of Bins: 59

Industrial (65 - 69 degrees)

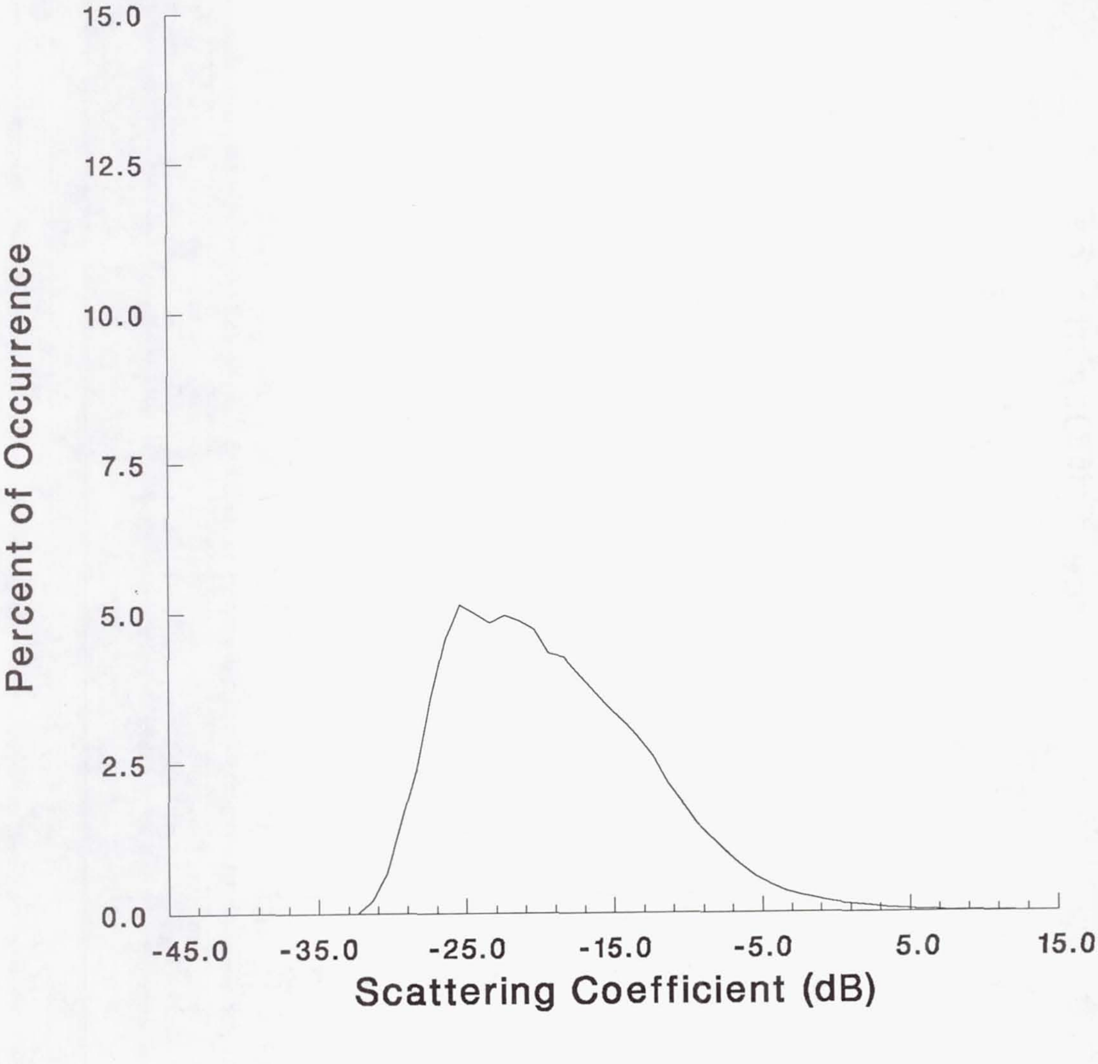


Figure 133.

Minimum: −39.89
Maximum: 15.40
Mean: −12.61
Bin Width: 1.00
Number of Bins: 56

Industrial (70 - 74 degrees)

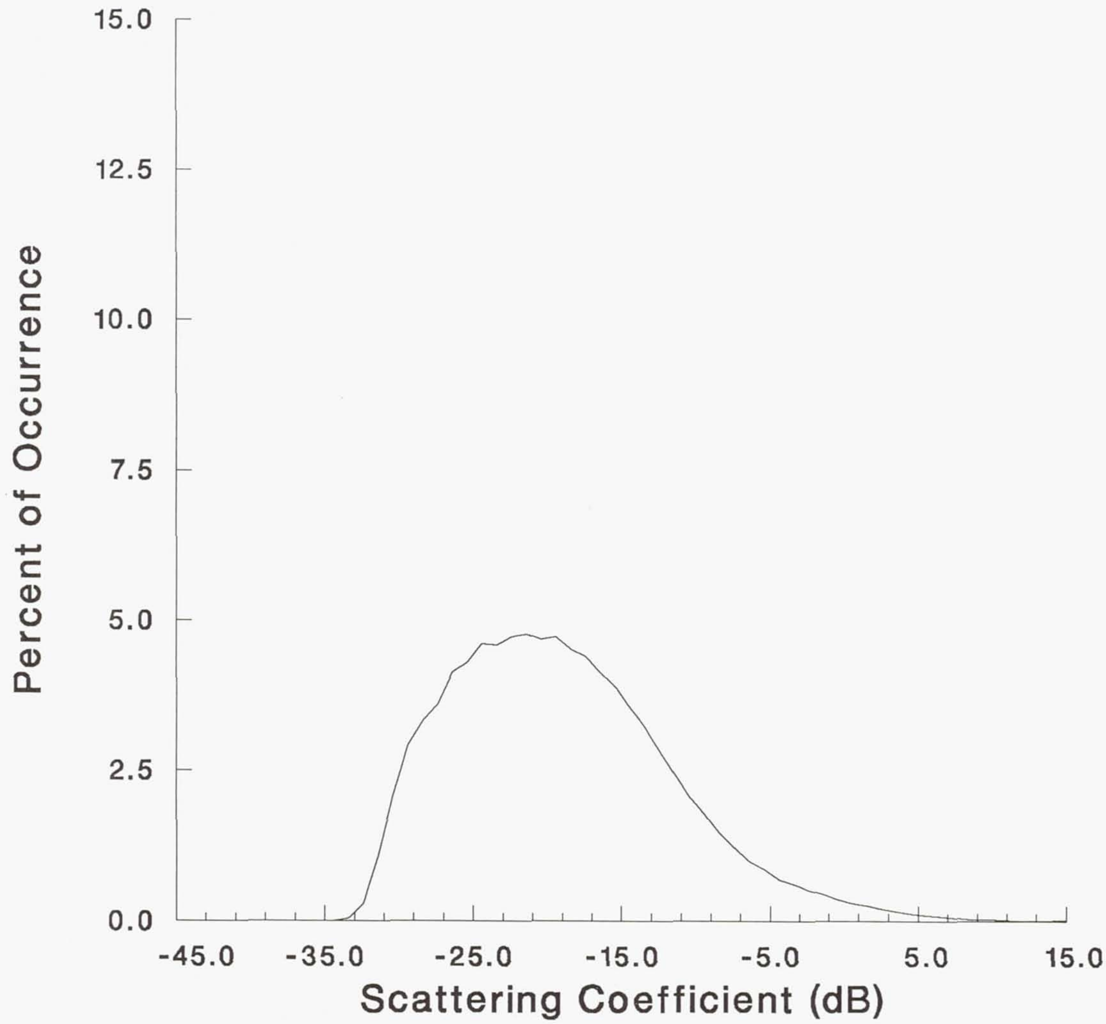


Figure 134.

Minimum: −39.89
Maximum: 22.28
Mean: −8.80
Bin Width: 1.00
Number of Bins: 63

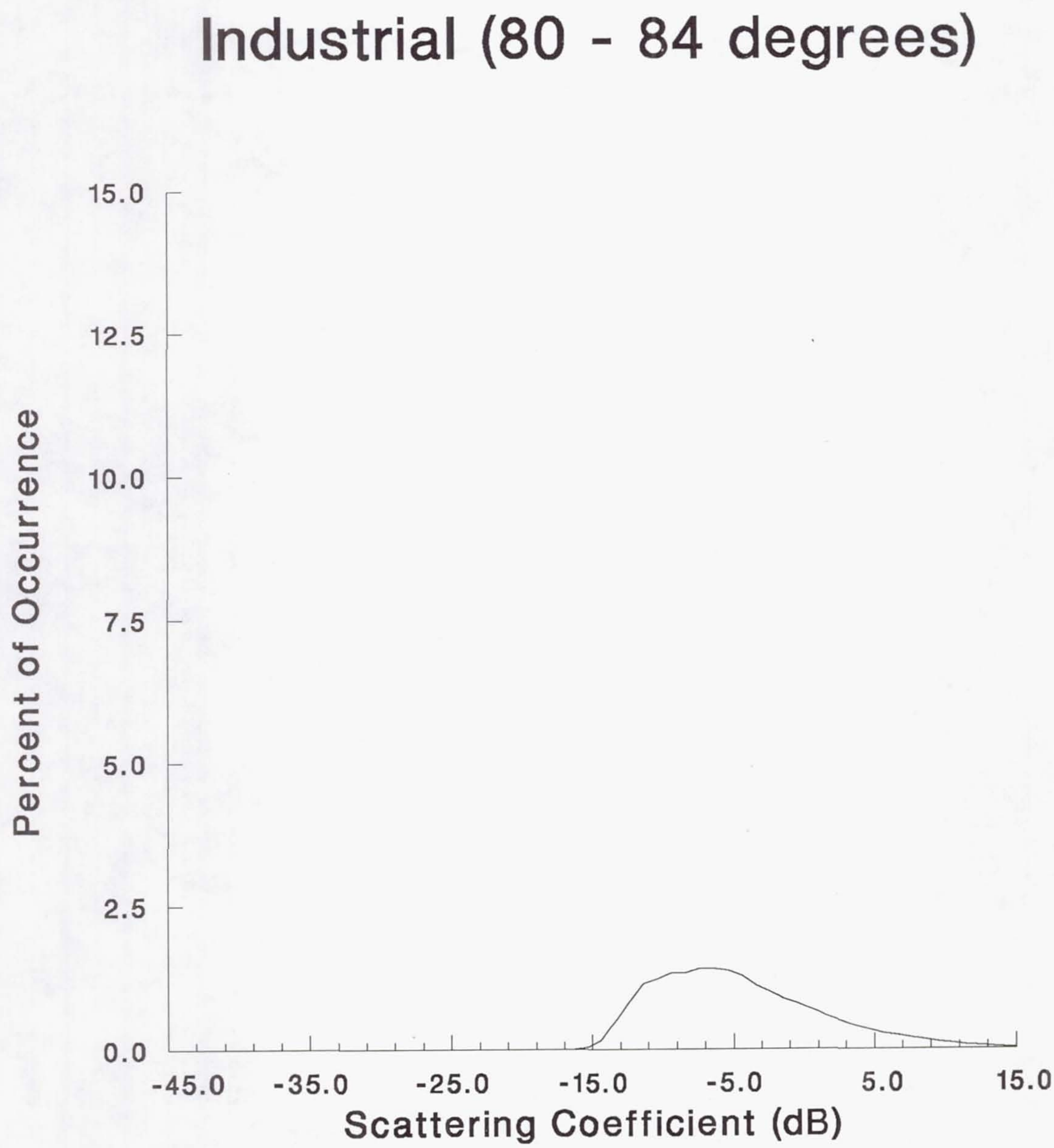


Figure 135.

Minimum: −39.89

Maximum: 21.06

Mean: −6.69

Bin Width: 1.00

Number of Bins: 62

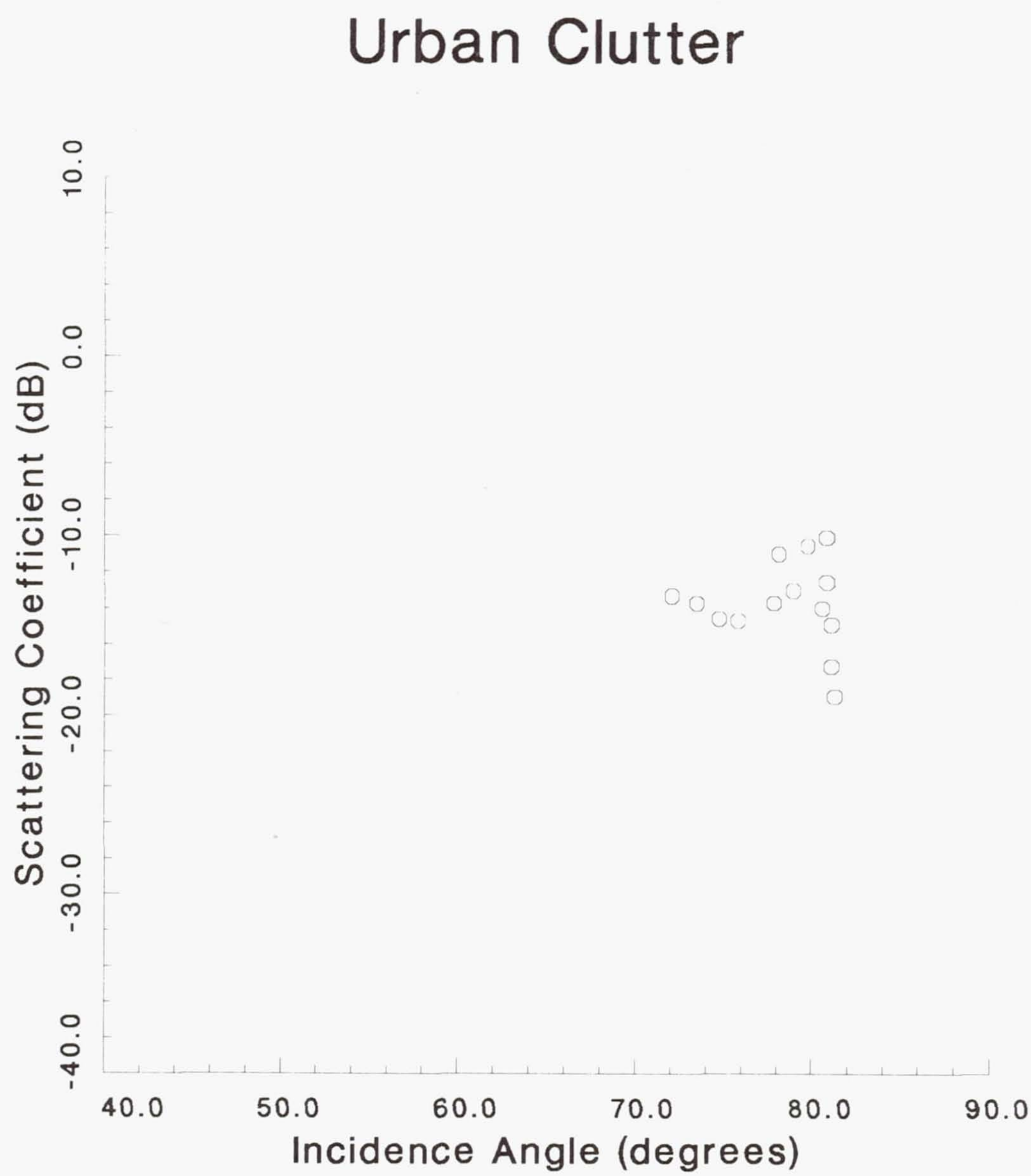

Urban Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 136.

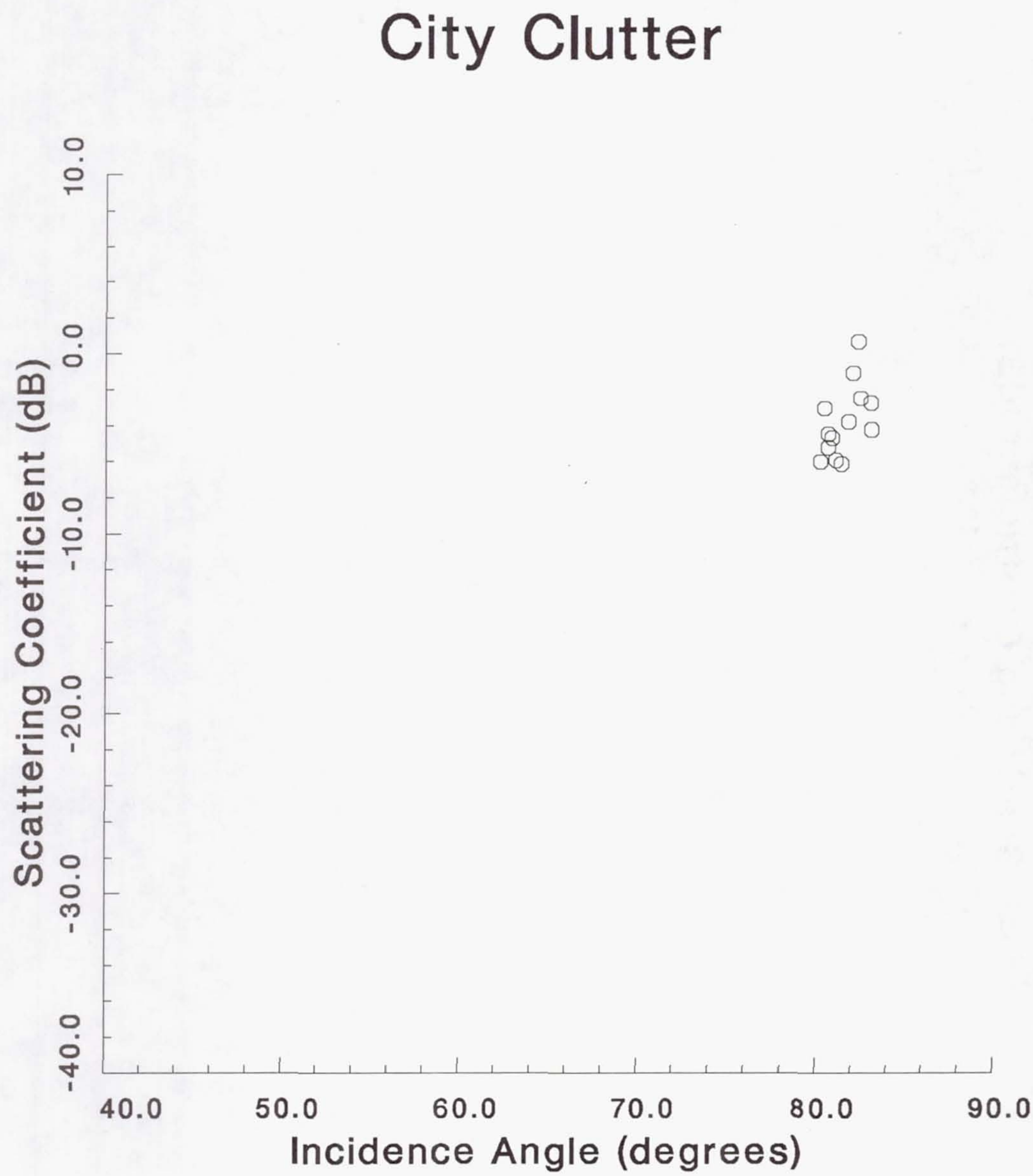
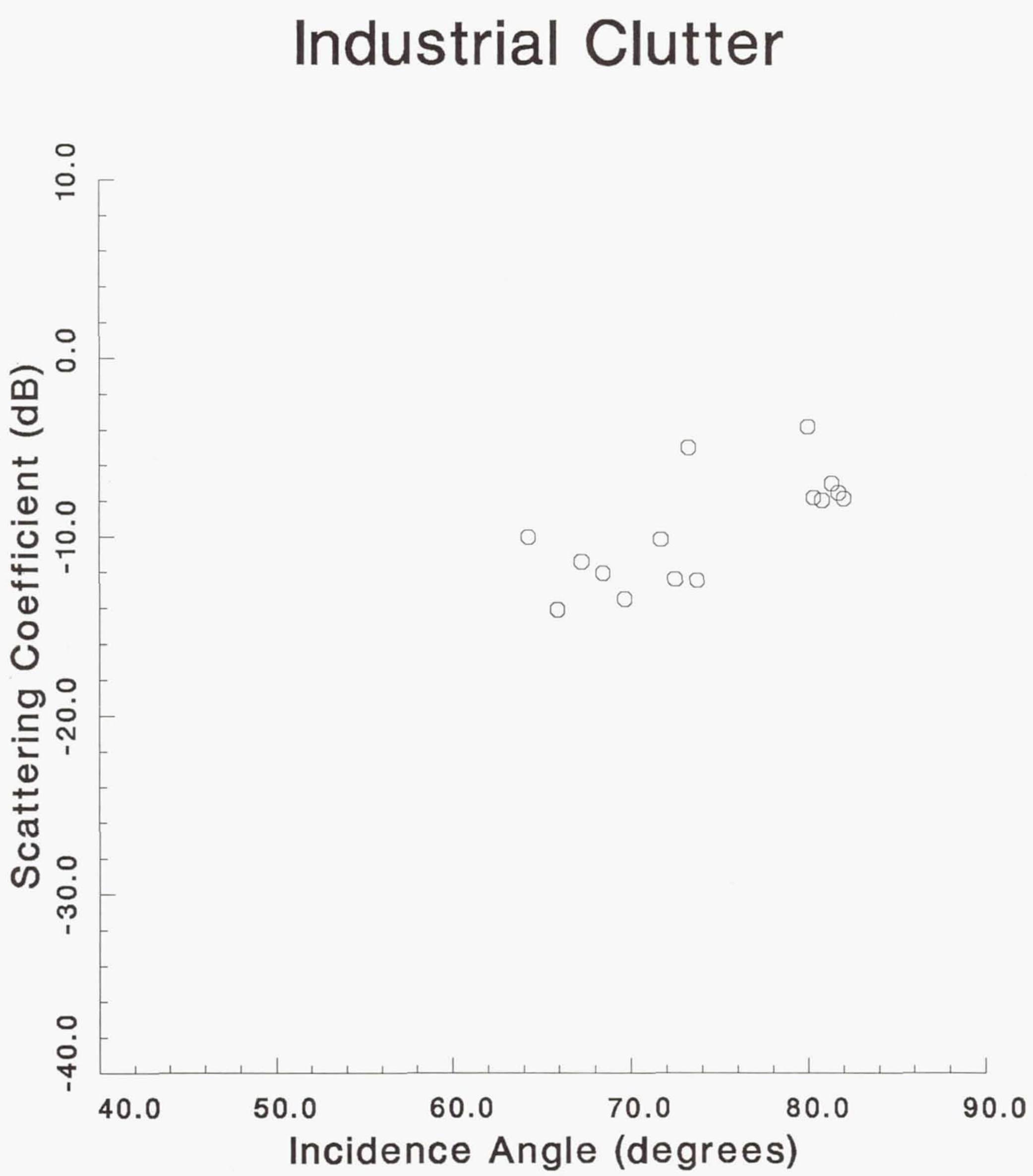

City Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 137.



Industrial Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 138.

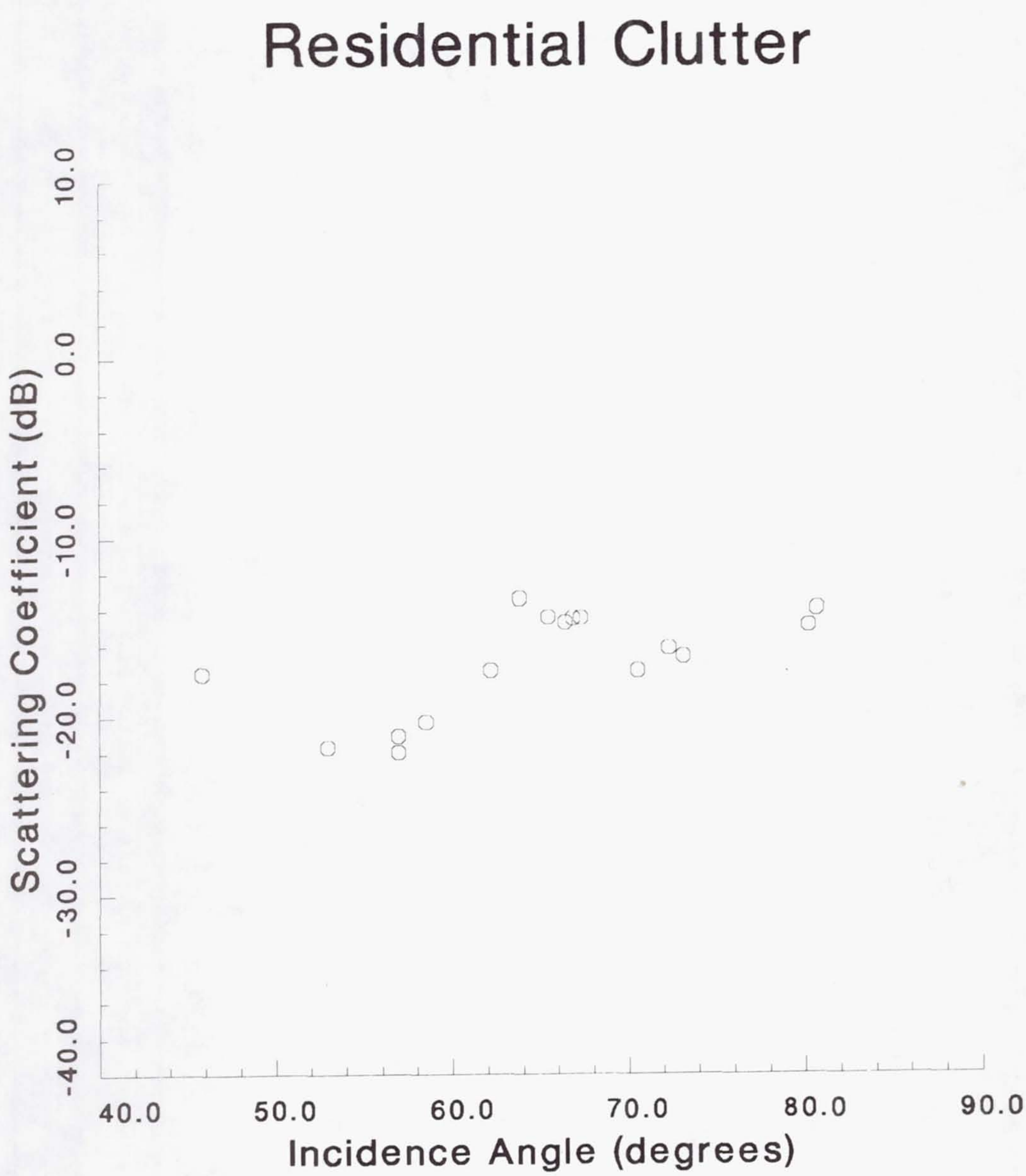

Residential Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 139.

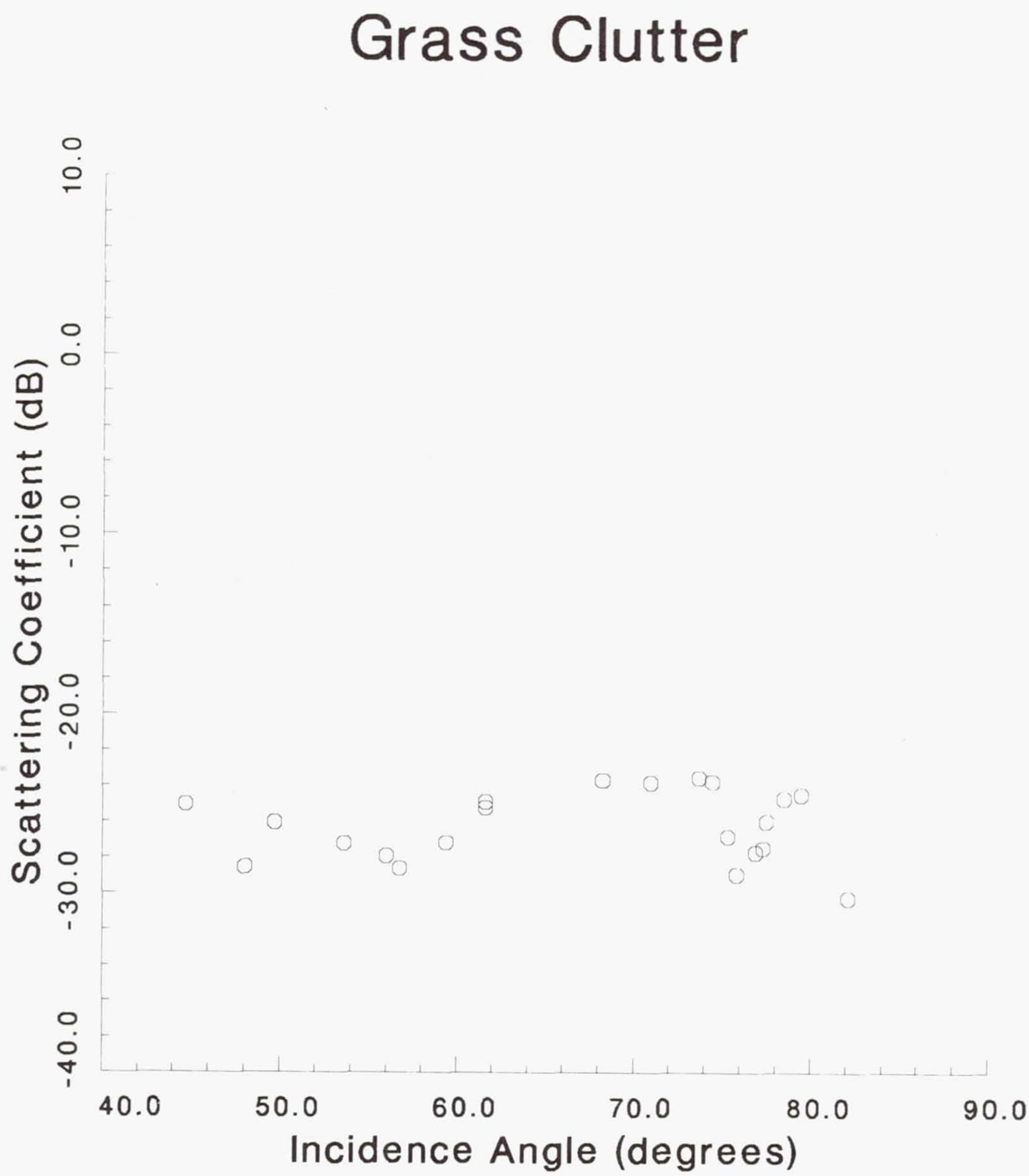

Grass Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 140.

Terminal

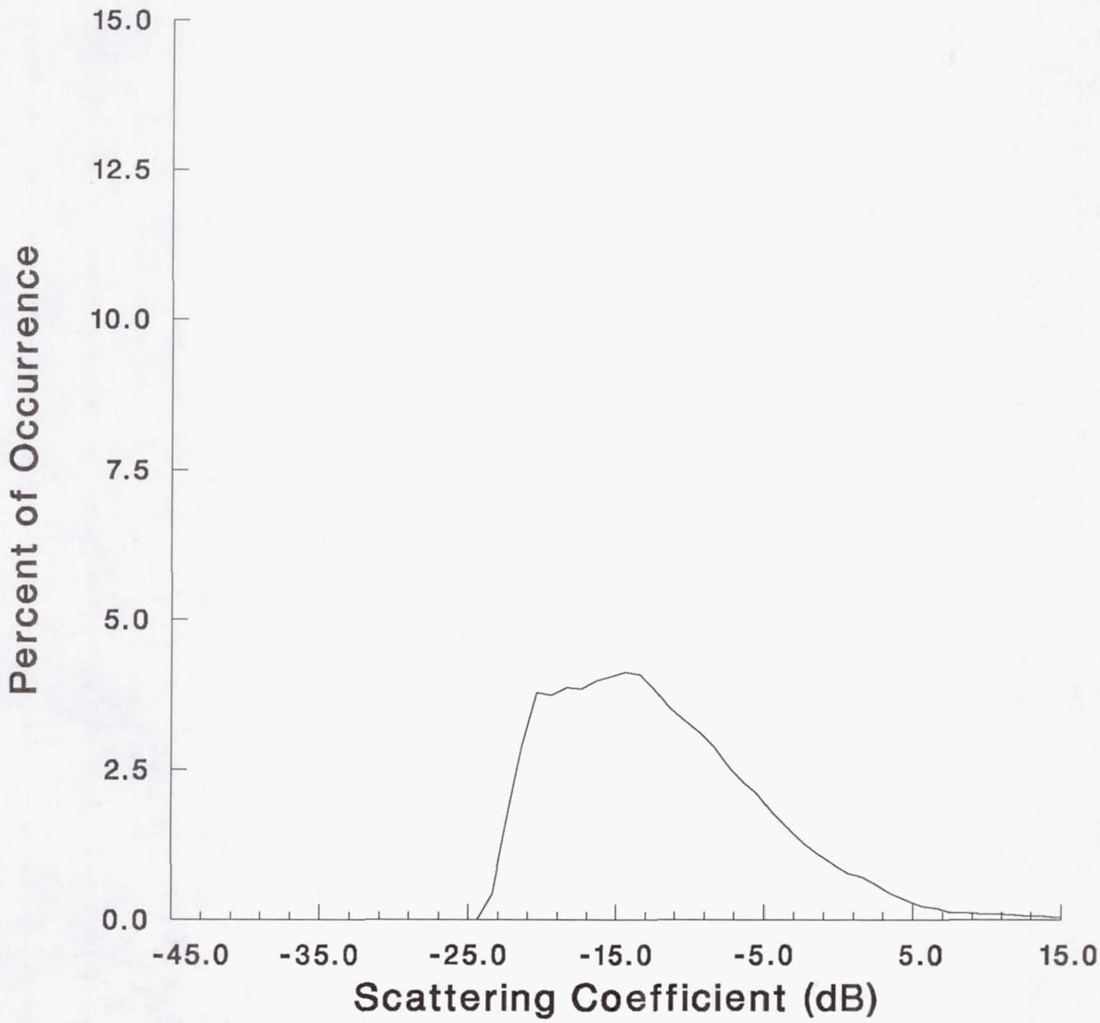


Figure 141.

Minimum: −39.89
Maximum: 21.98
Mean: −4.74
Bin Width: 1.00
Number of Bins: 63

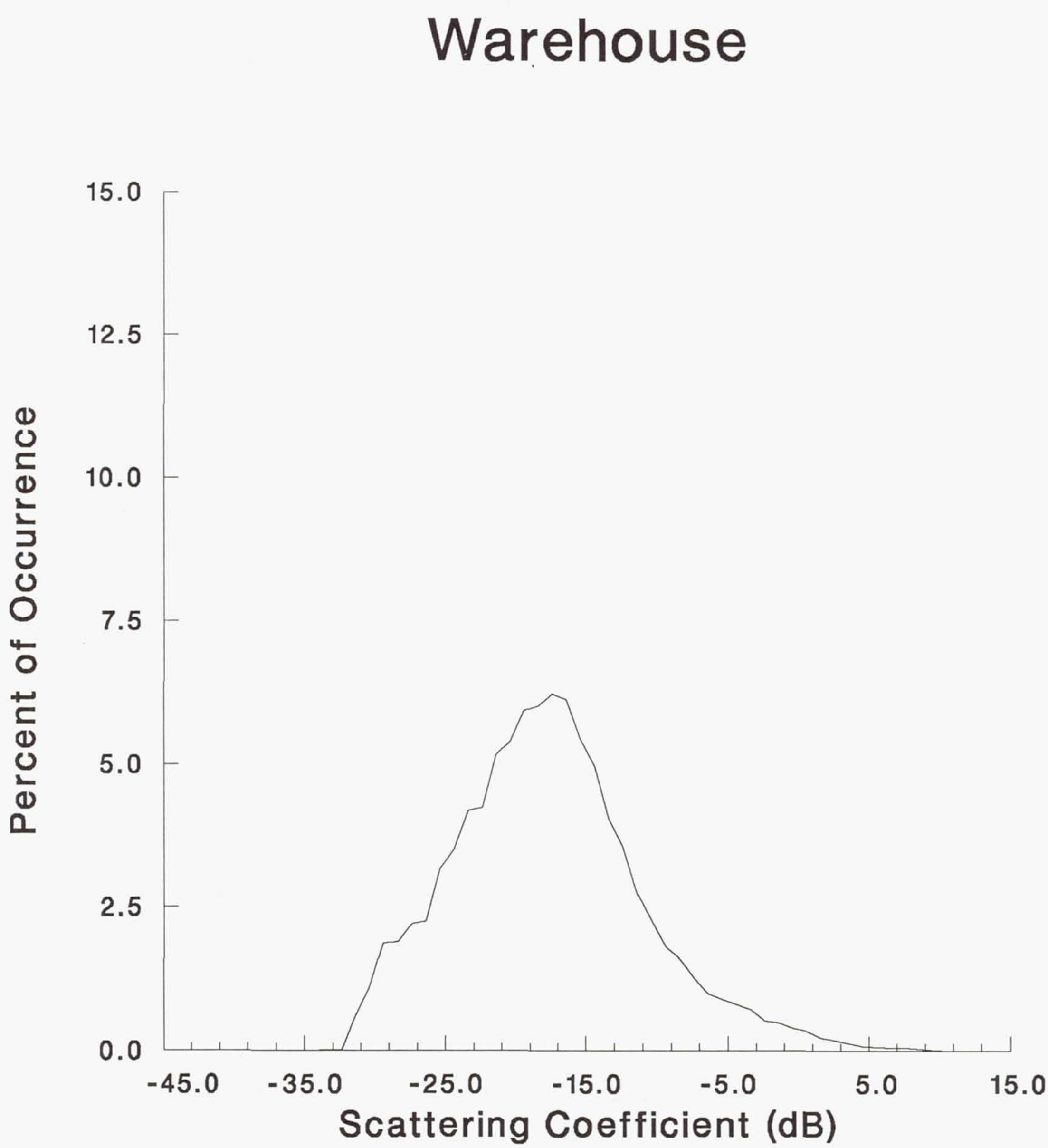


Figure 142.

Minimum: −39.89
Maximum: 12.40
Mean: −11.14
Bin Width: 1.00
Number of Bins: 53

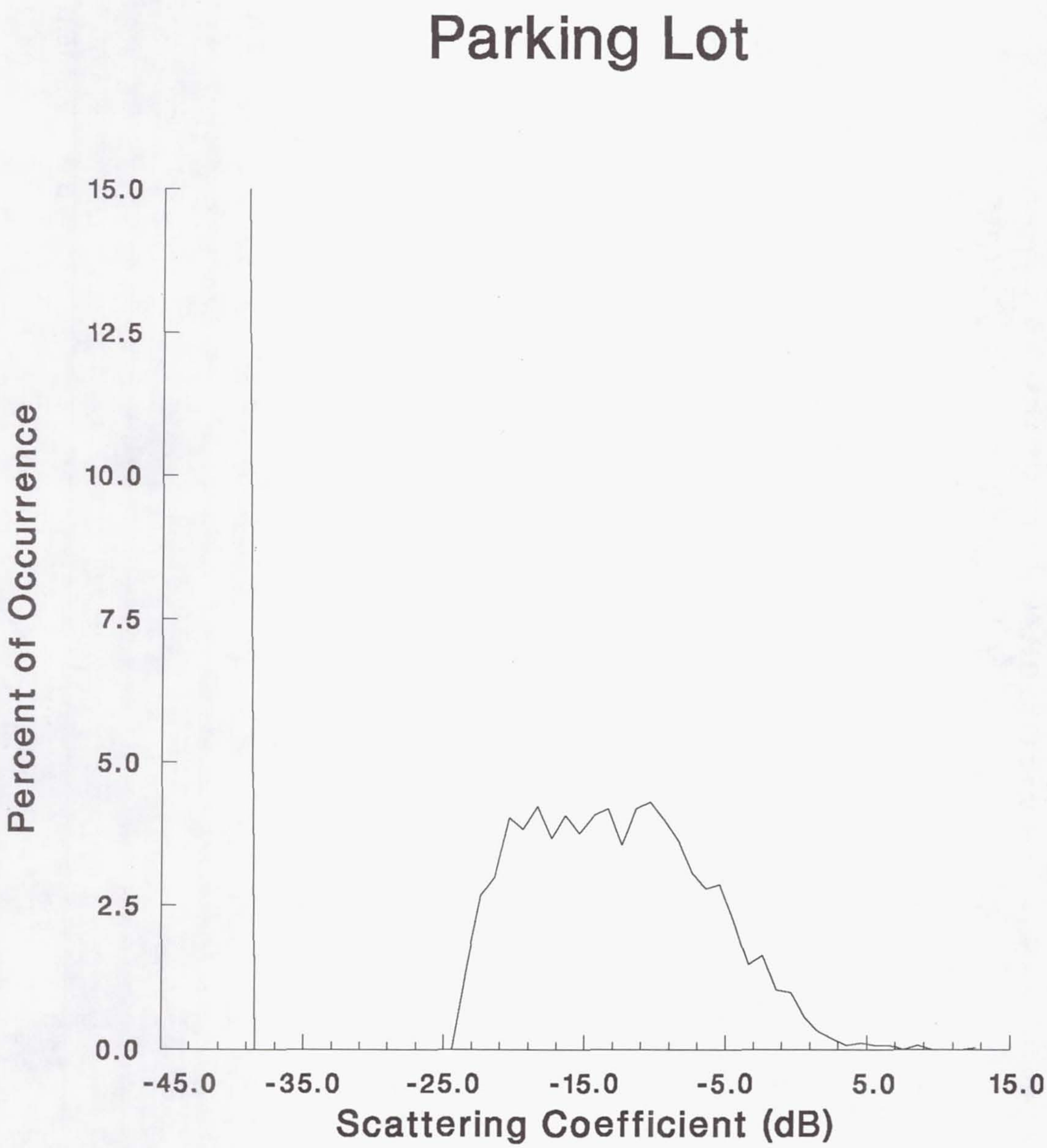


Figure 143.

Minimum: −39.89
Maximum: 12.59
Mean: −8.95
Bin Width: 1.00
Number of Bins: 53

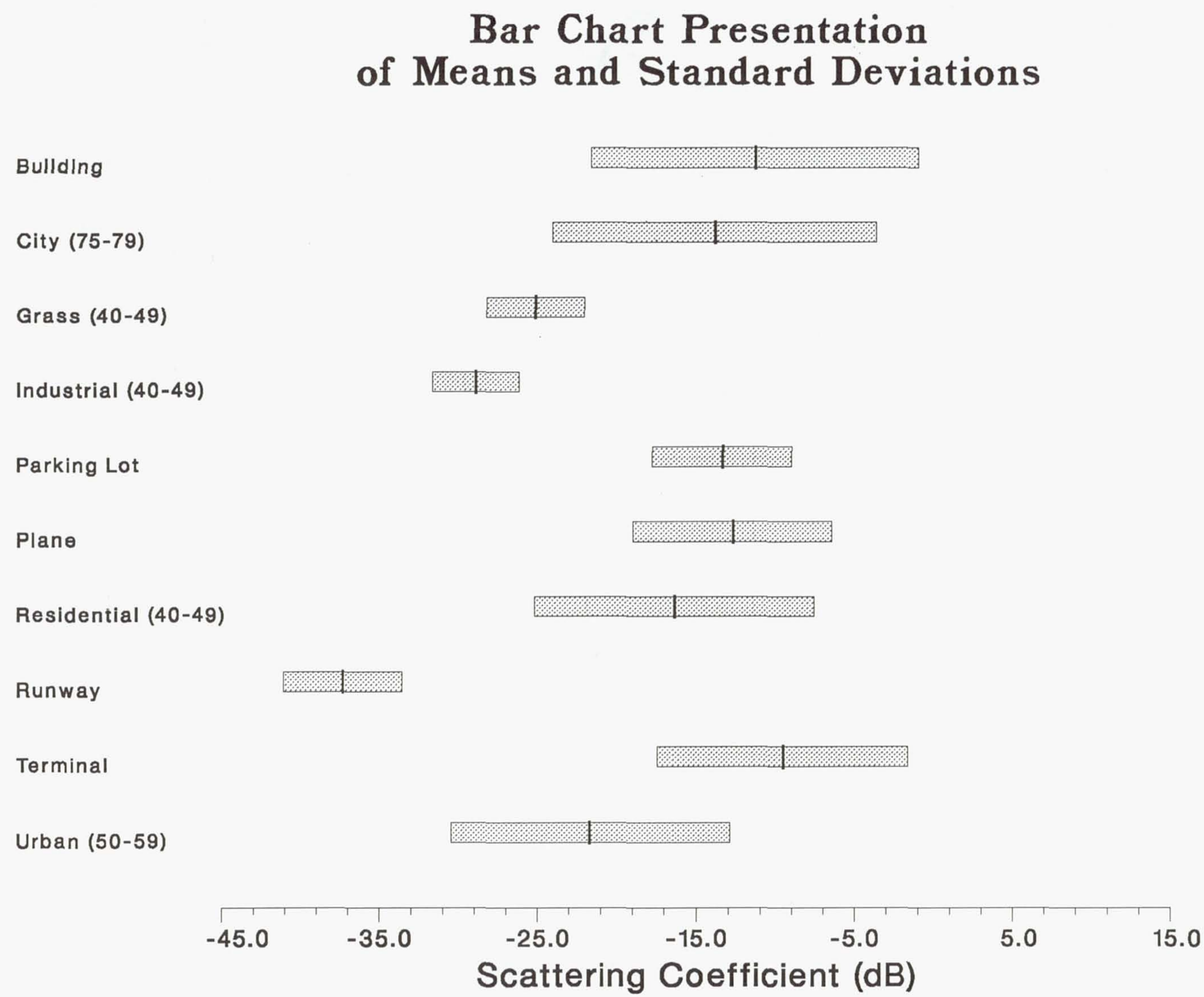


Figure 144. Mean NRCS Values, Denver Third 'Step West'

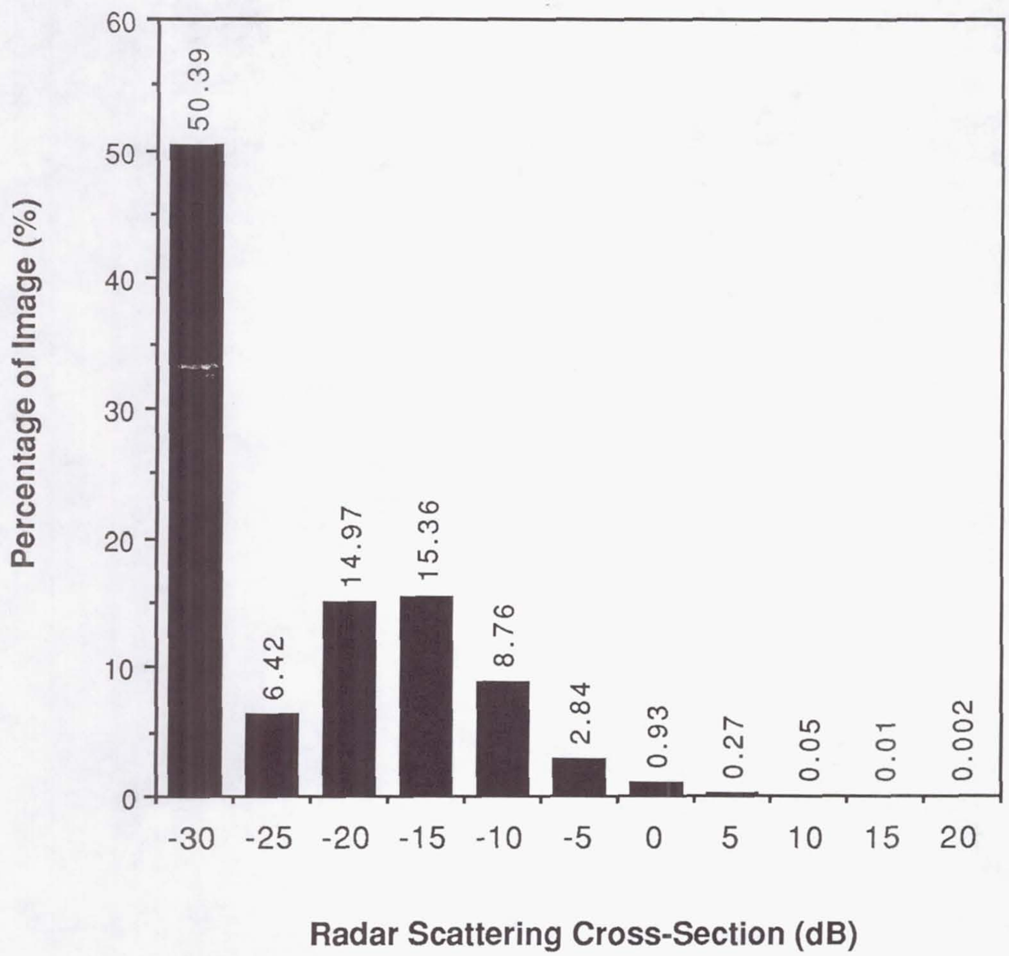


Figure 145. Distribution of Threshold Values, Denver Third 'Step West'

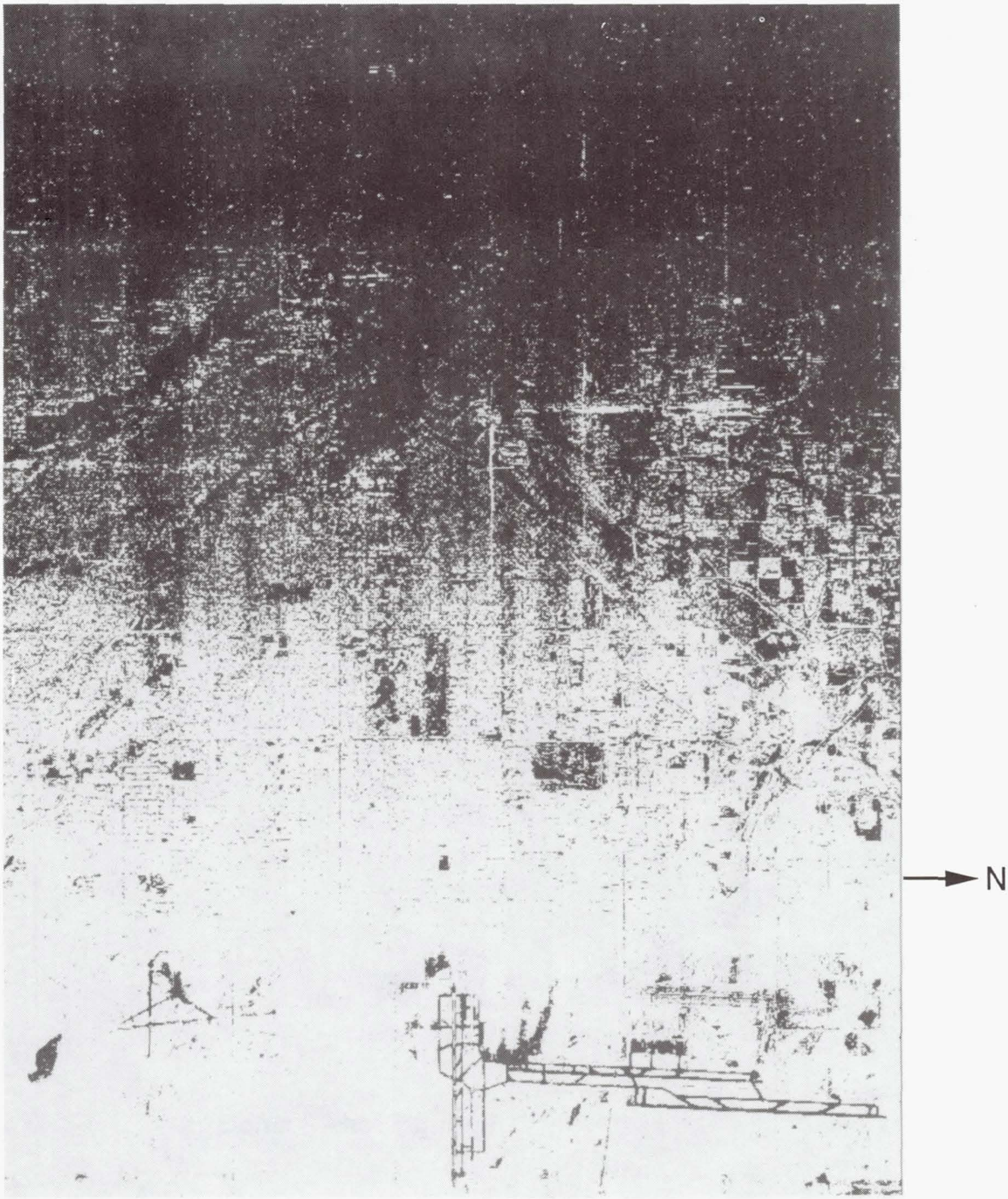


Figure 146. The Third Denver 'Step West' Image Thresholded at -30 dB

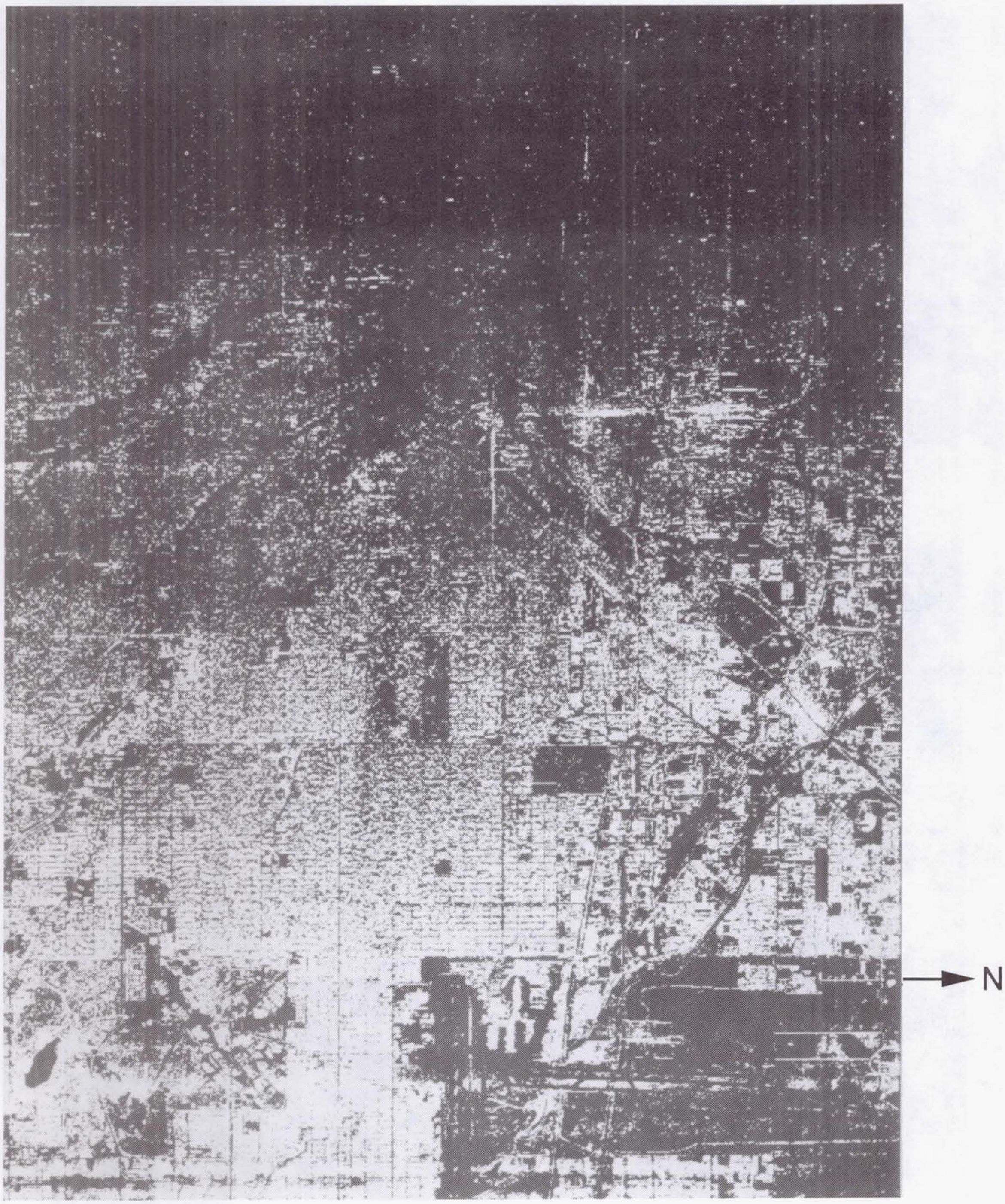


Figure 147. The Third Denver 'Step West' Image Thresholded at -20 dB

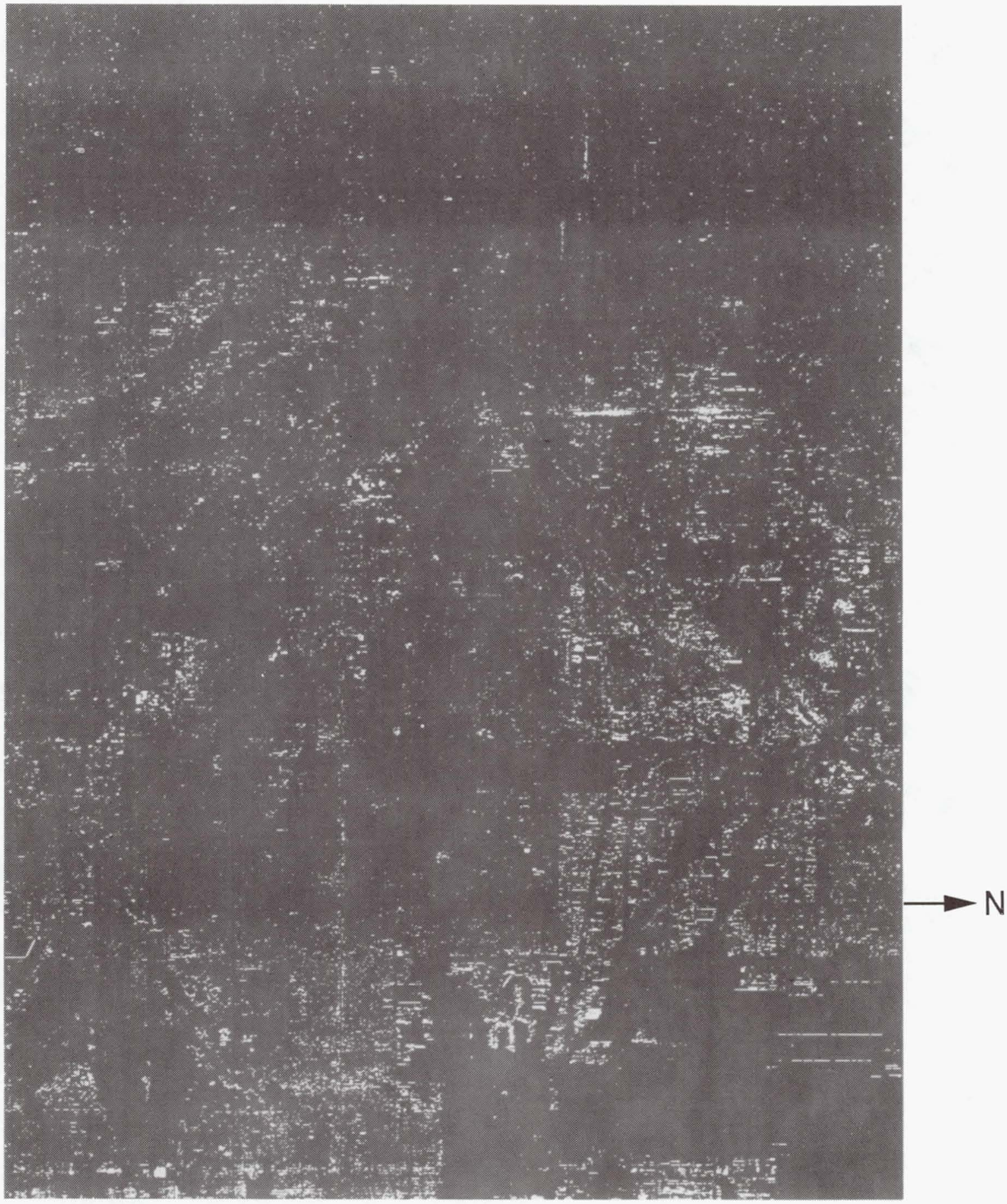


Figure 148. The Third Denver 'Step West' Image Thresholded at -10 dB

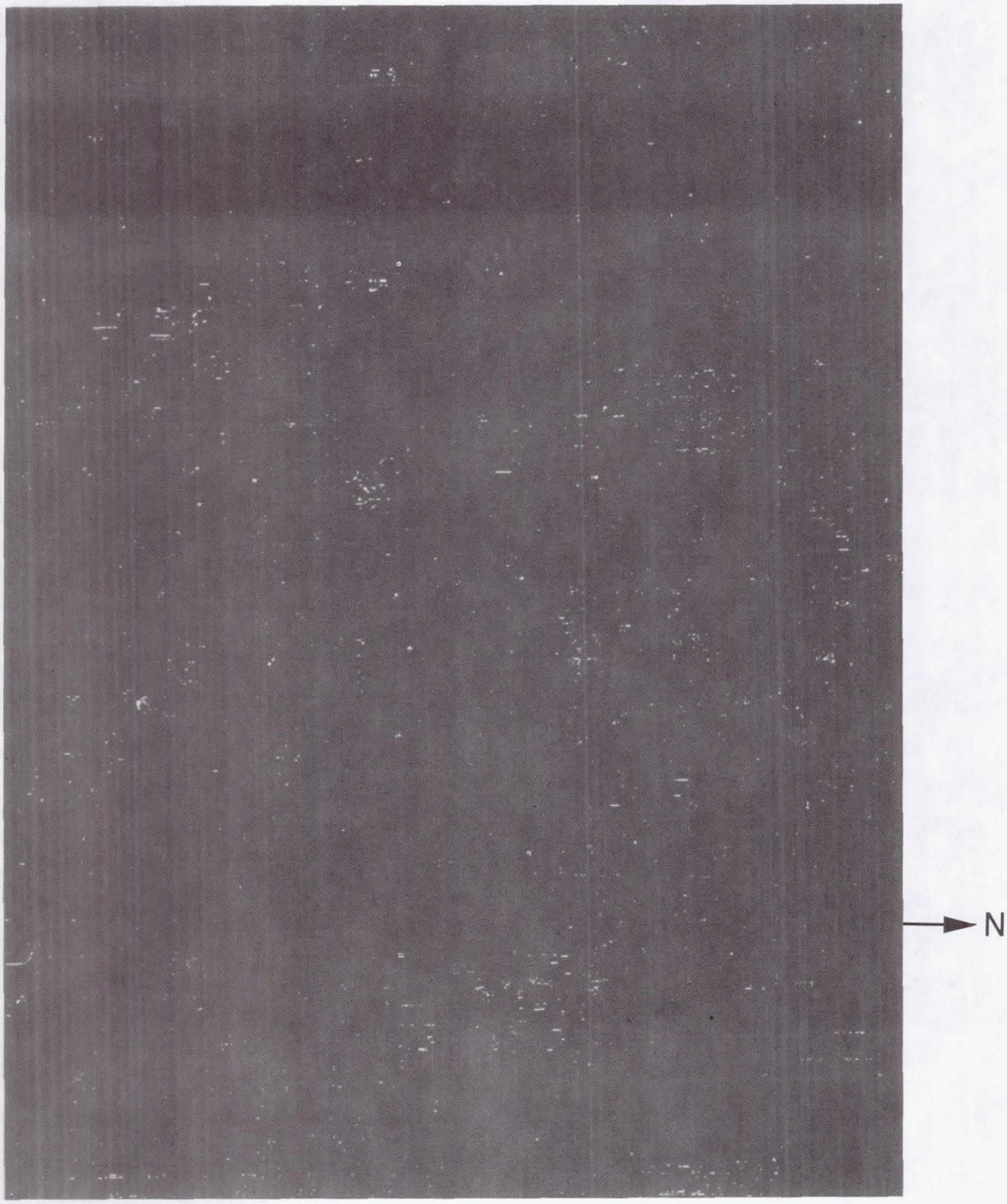


Figure 149. The Third Denver 'Step West' Image Thresholded at 0dB

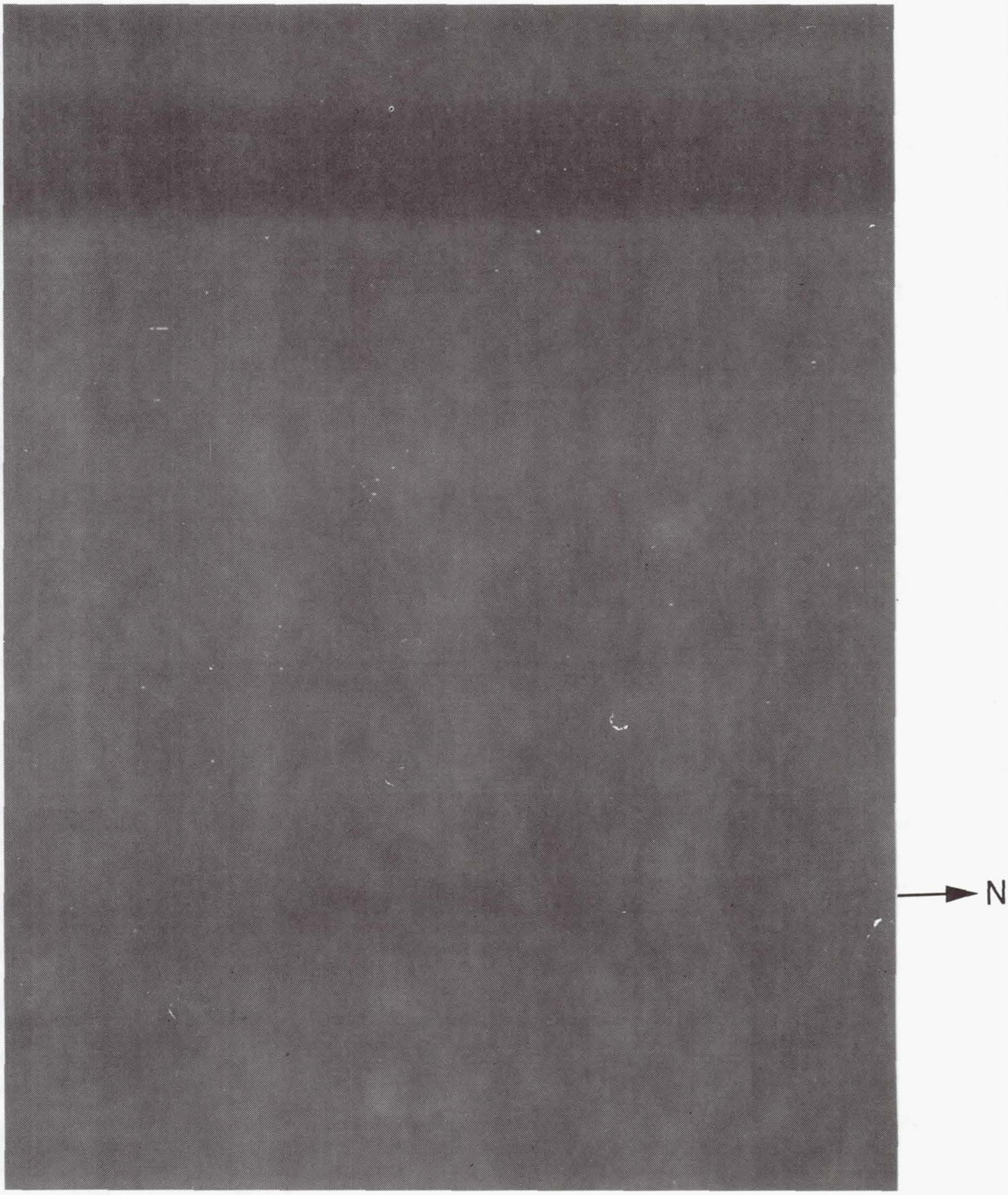


Figure 150. The Third Denver 'Step West' Image Thresholded at 10 dB

Grass (35 - 39 degrees)

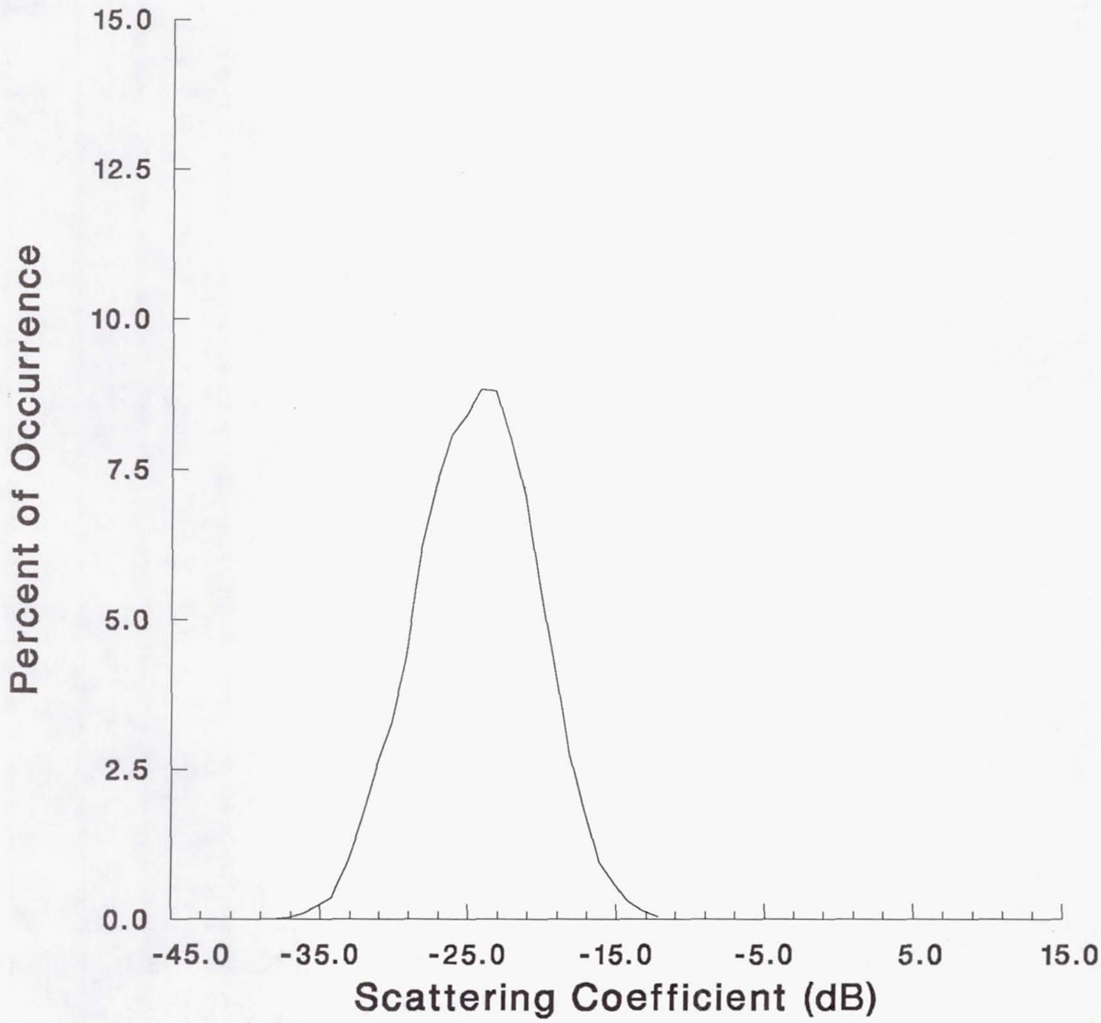


Figure 151.

Minimum: −39.69
Maximum: −12.55
Mean: −23.06
Bin Width: 1.00
Number of Bins: 28

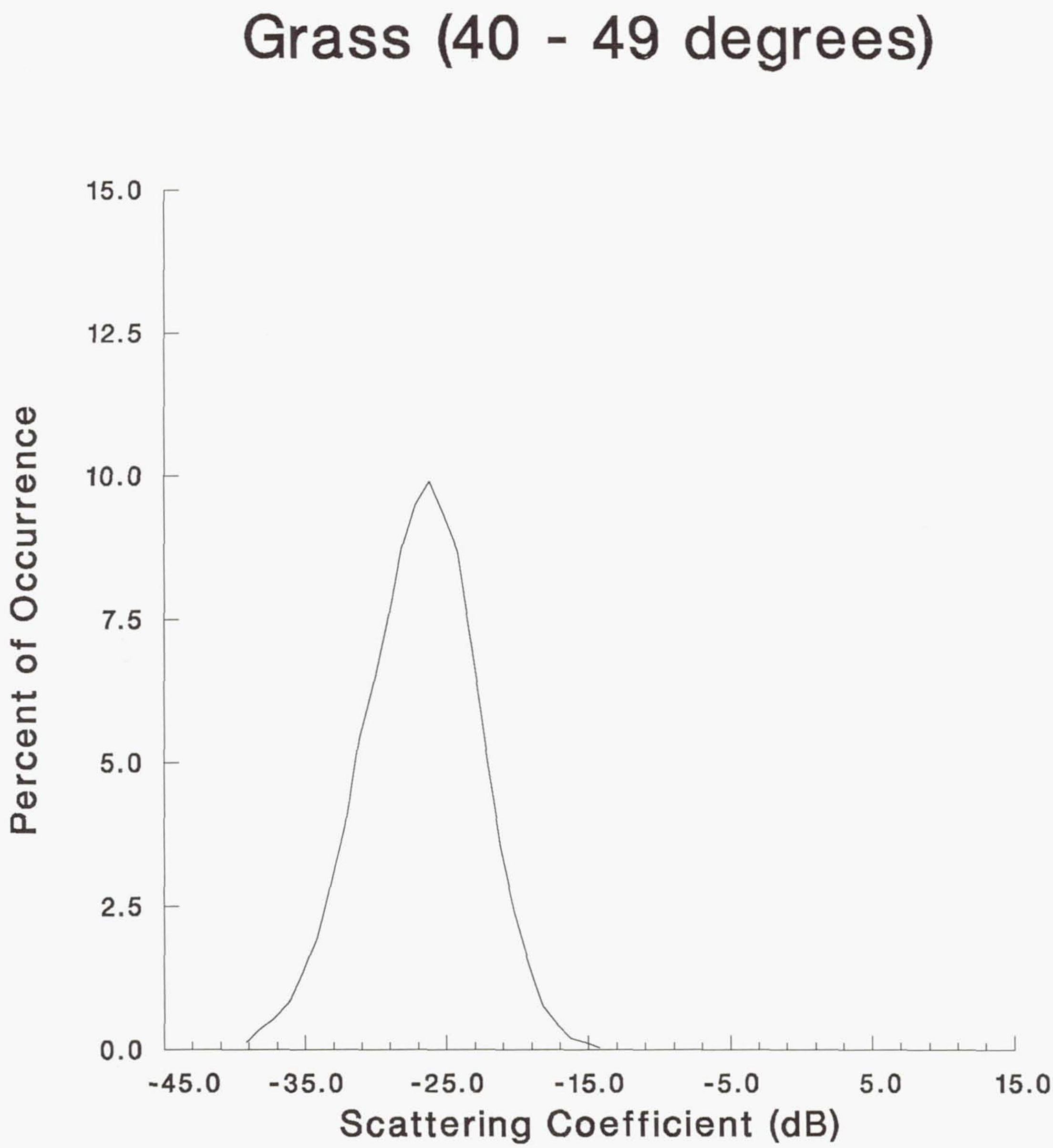


Figure 152.

Minimum: −39.69
Maximum: −14.74
Mean: −25.26
Bin Width: 1.00
Number of Bins: 26

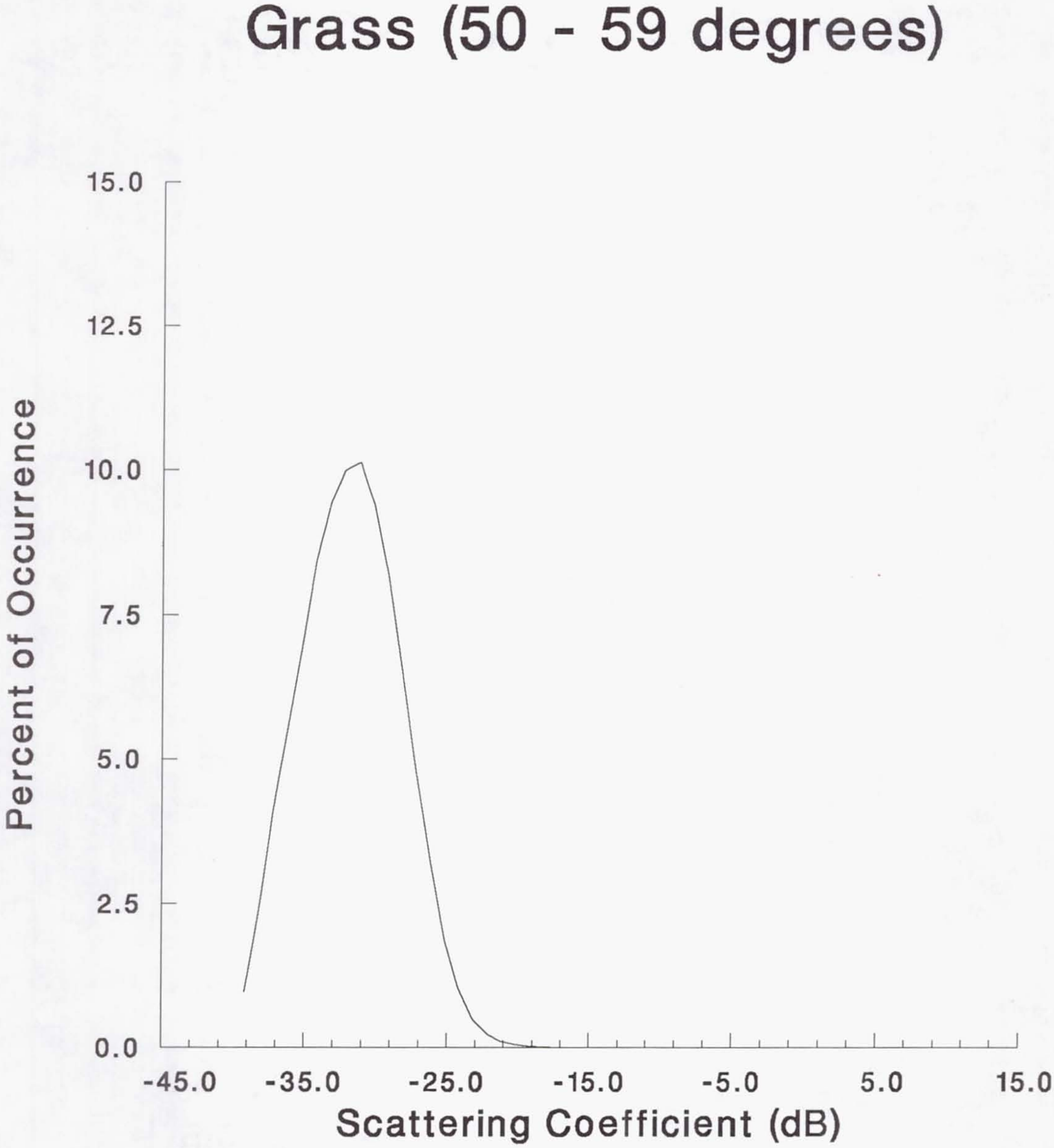


Figure 153.

Minimum: −39.69

Maximum: −14.79

Mean: −30.61

Bin Width: 1.00

Number of Bins: 26

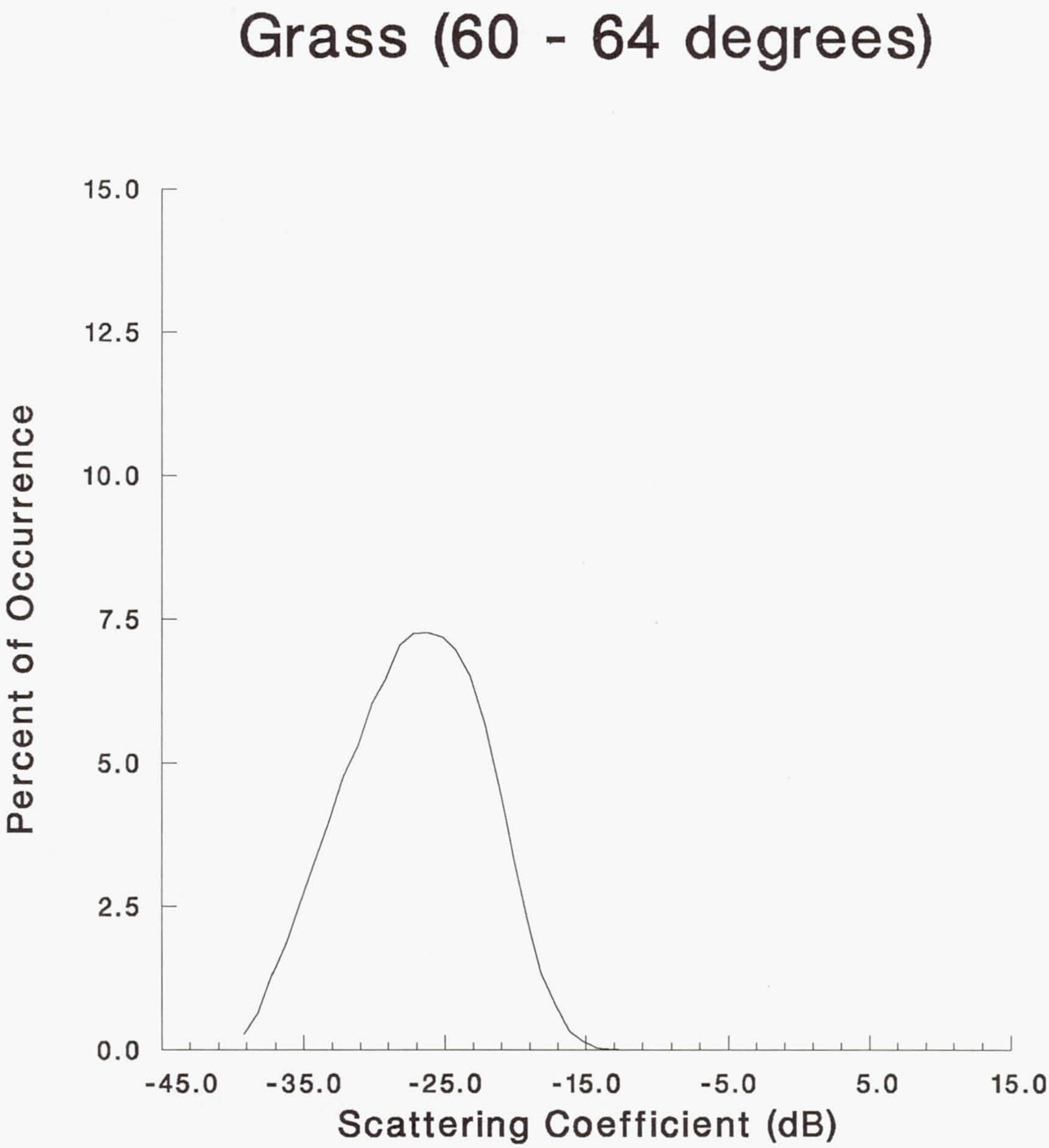


Figure 154.

Minimum: −39.69
Maximum: −12.20
Mean: −24.92
Bin Width: 1.00
Number of Bins: 28

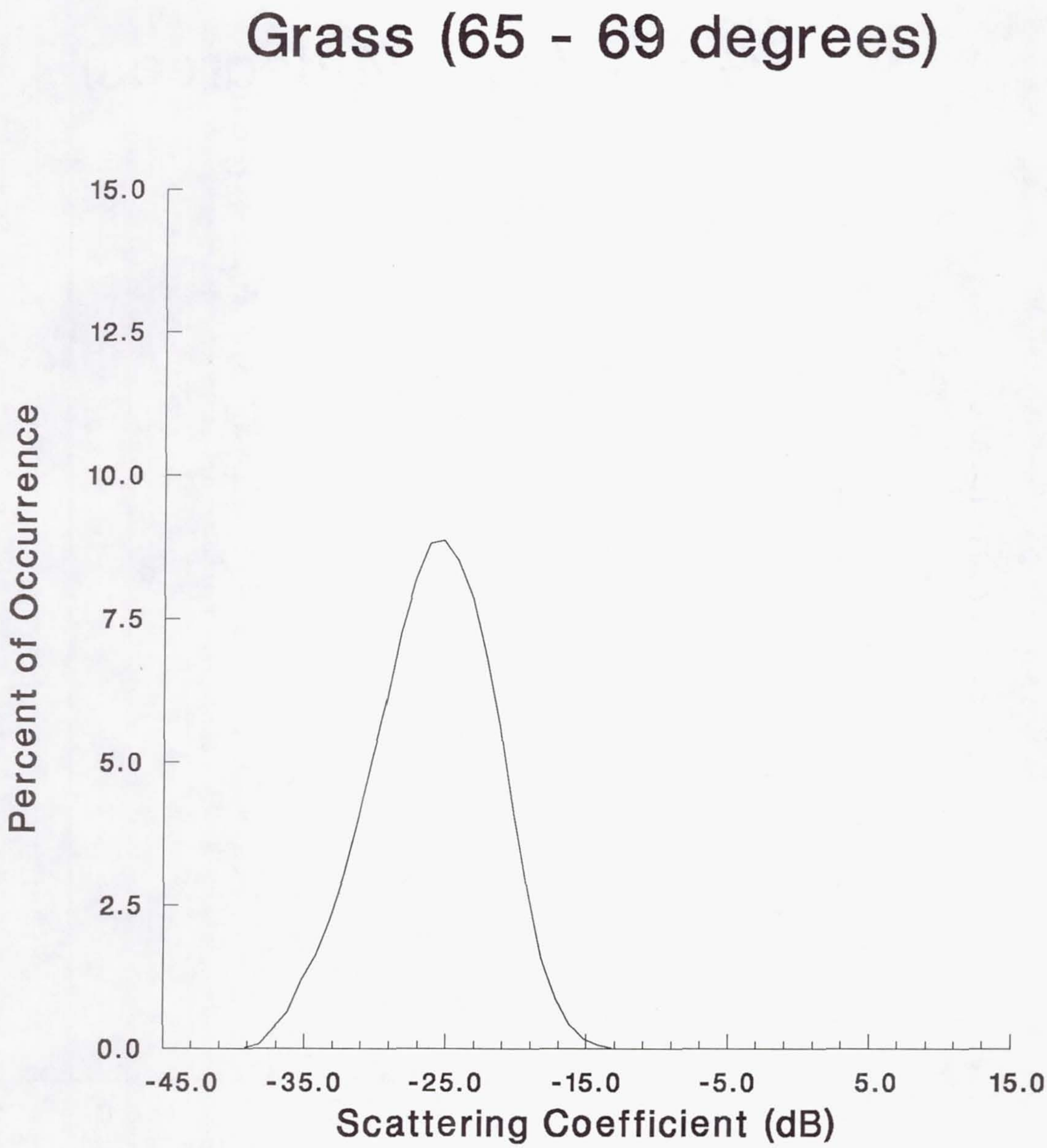


Figure 155.

Minimum: −39.69

Maximum: −13.47

Mean: −24.29

Bin Width: 1.00

Number of Bins: 27

Grass (70 - 74 degrees)

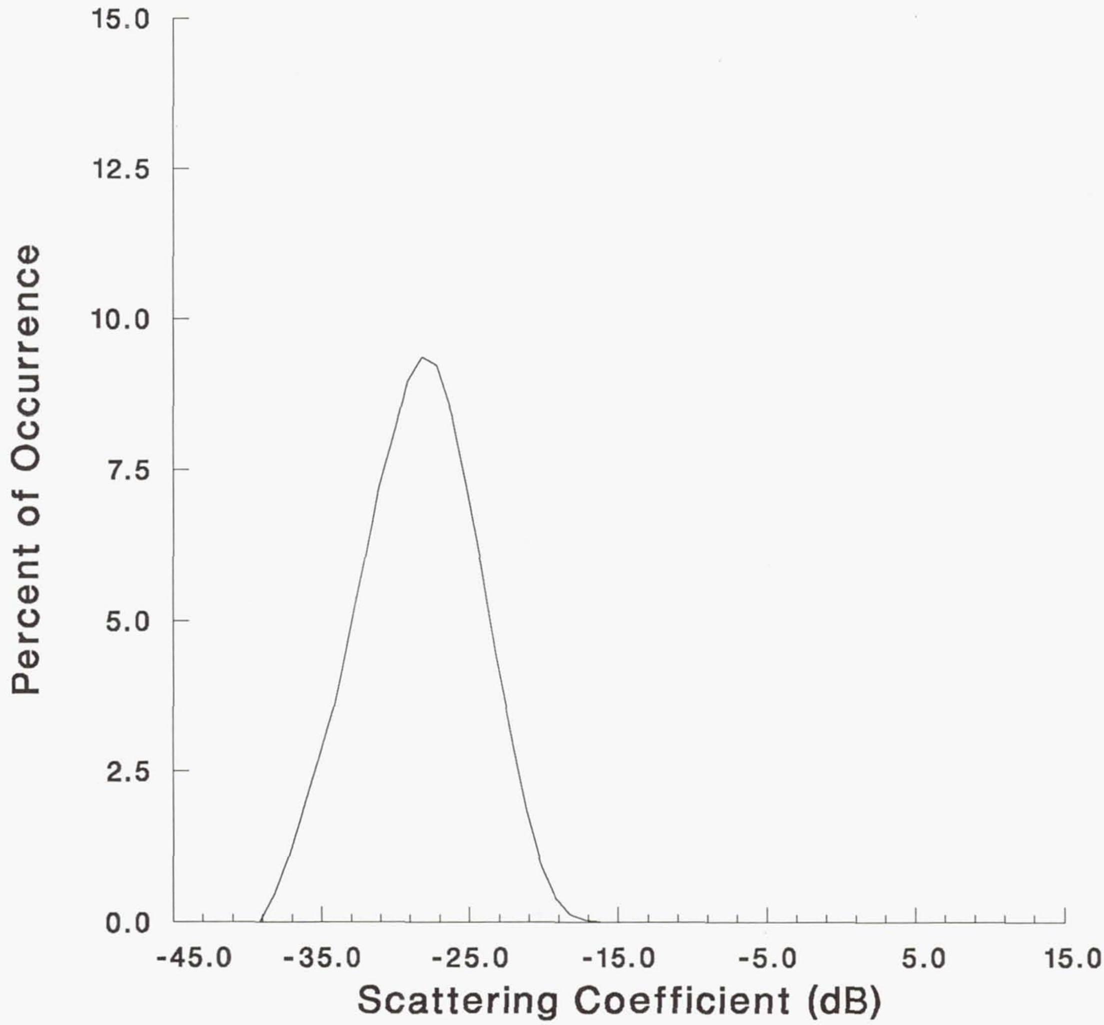


Figure 156.

Minimum: −39.69
Maximum: −16.97
Mean: −27.06
Bin Width: 1.00
Number of Bins: 24

Grass (75 - 79 degrees)

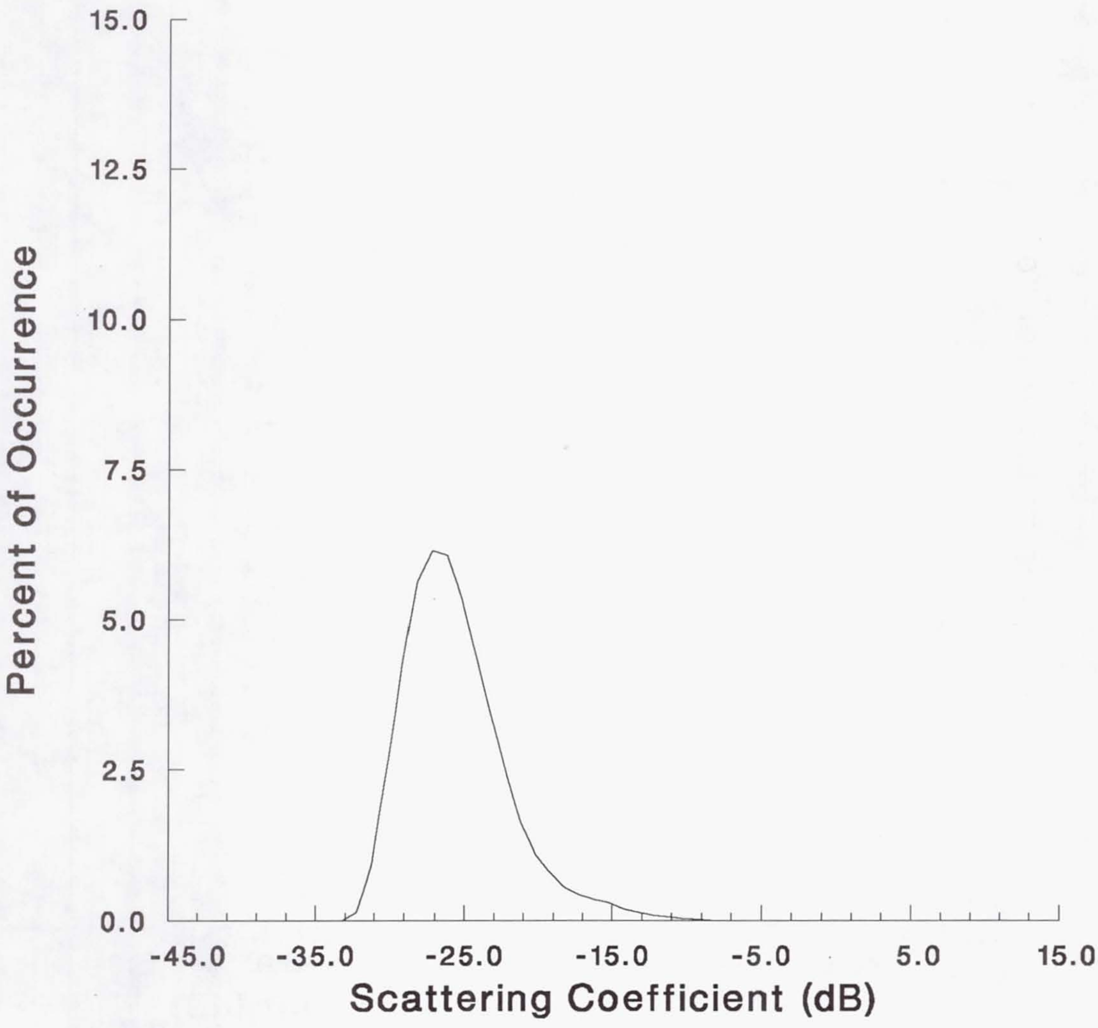


Figure 157.

Minimum: −39.69
Maximum: −7.76
Mean: −26.81
Bin Width: 1.00
Number of Bins: 33

Residential (30 - 34 degrees)

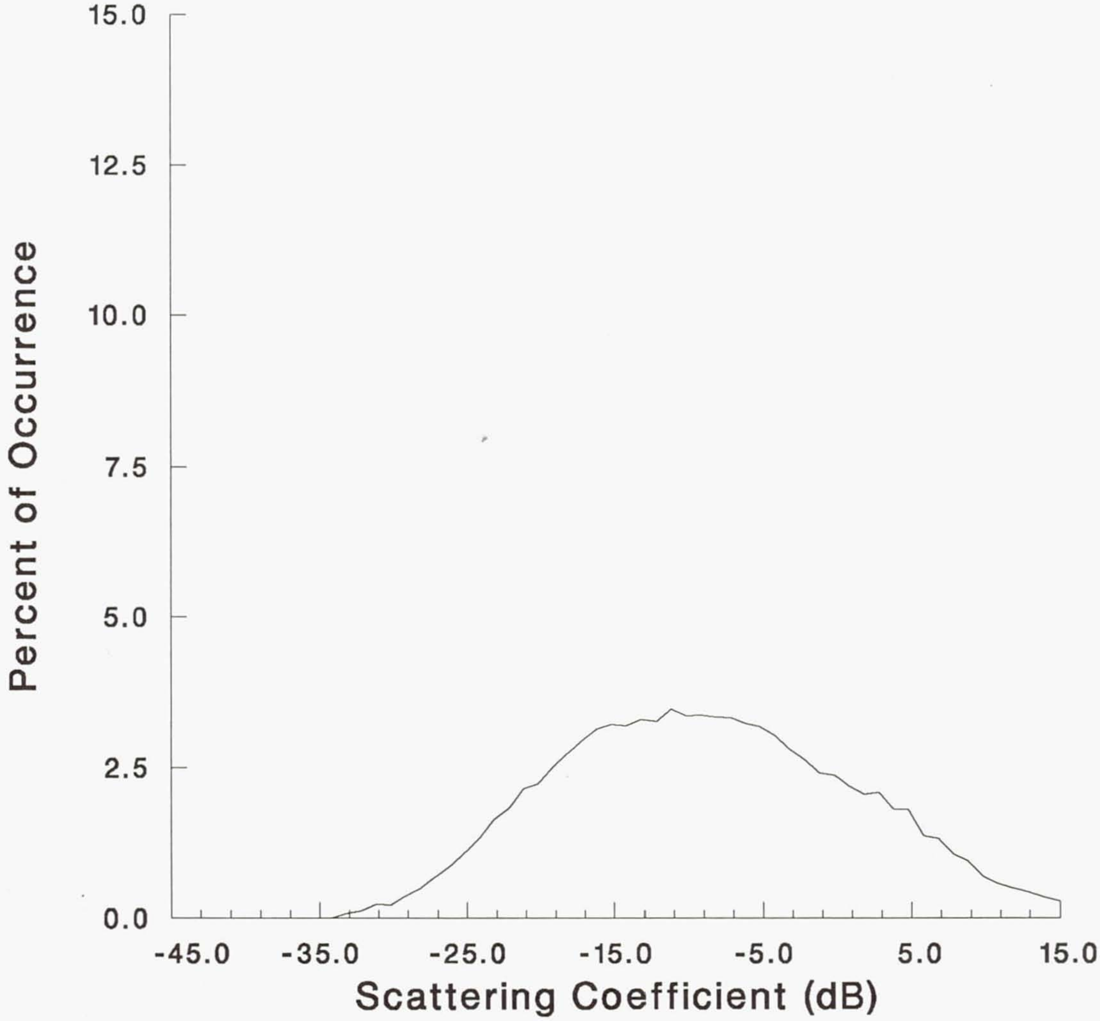


Figure 158.

Minimum: −39.69
Maximum: 30.89
Mean: −3.75
Bin Width: 1.00
Number of Bins: 72

Residential (35 - 39 degrees)

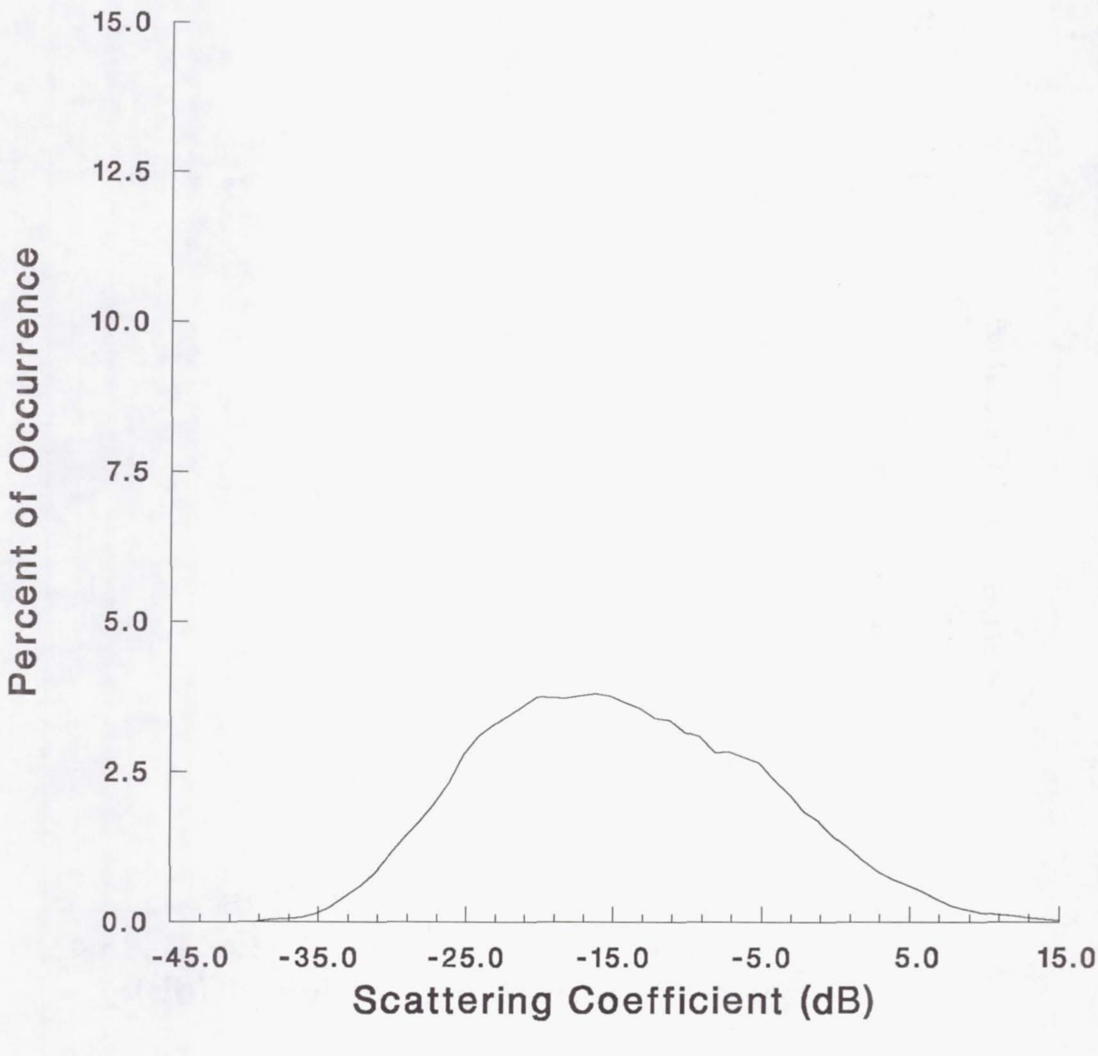


Figure 159.

Minimum: −39.69
Maximum: 27.25
Mean: −2.28
Bin Width: 1.00
Number of Bins: 68

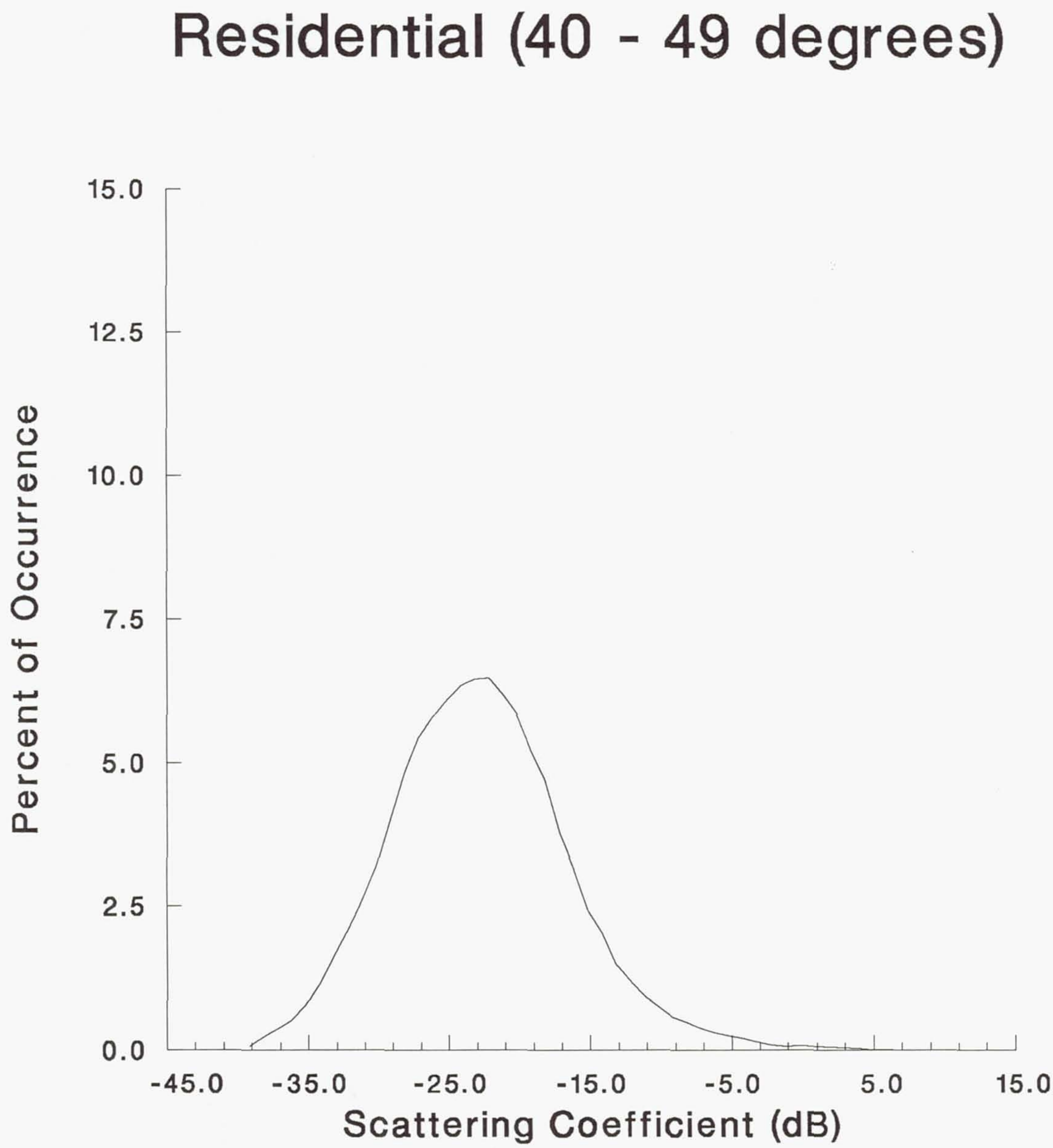


Figure 160.

Minimum: −39.69
Maximum: 8.87
Mean: −16.44
Bin Width: 1.00
Number of Bins: 50

Residential (70 - 74 degrees)

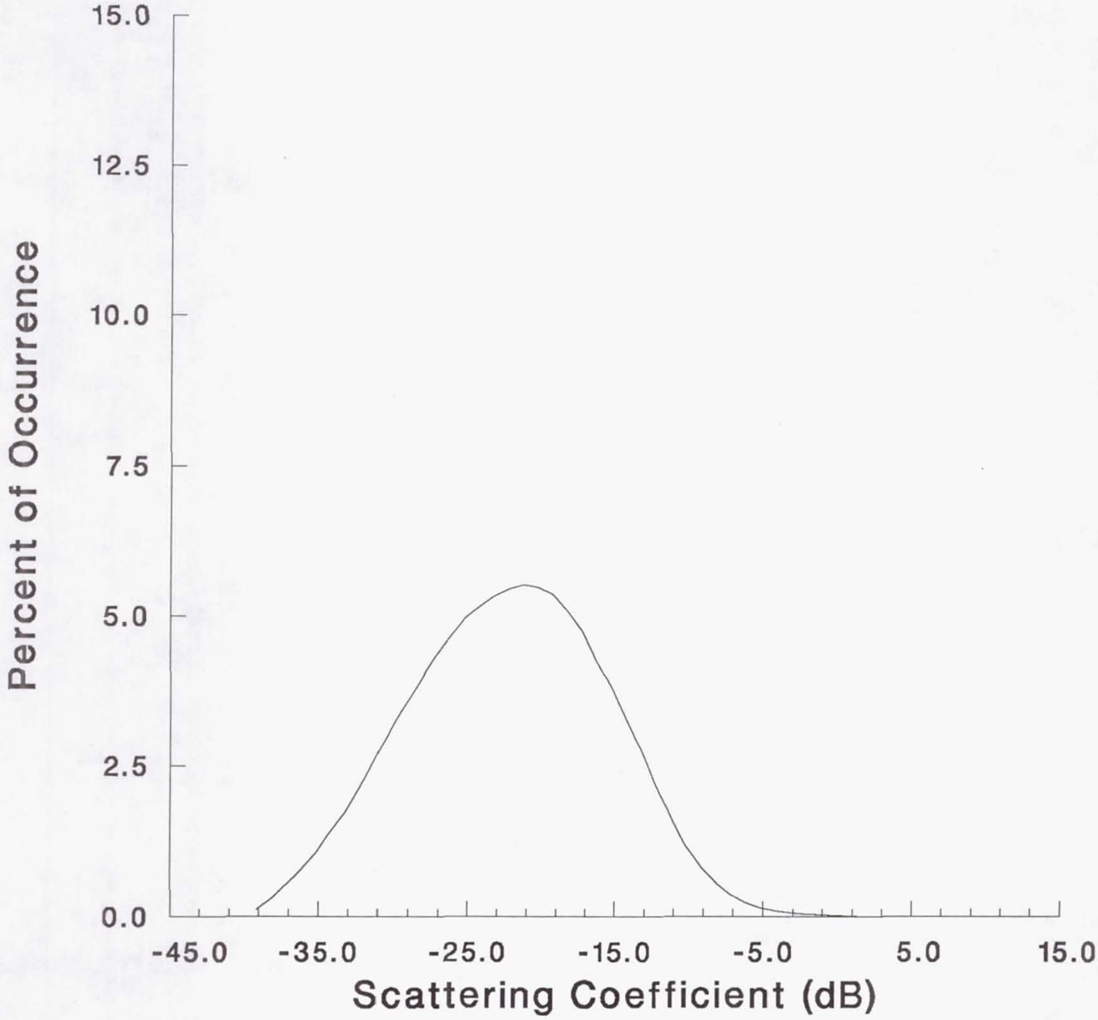


Figure 161.

Minimum: −39.69
Maximum: 8.48
Mean: −17.19
Bin Width: 1.00
Number of Bins: 49

Residential (75 - 79 degrees)

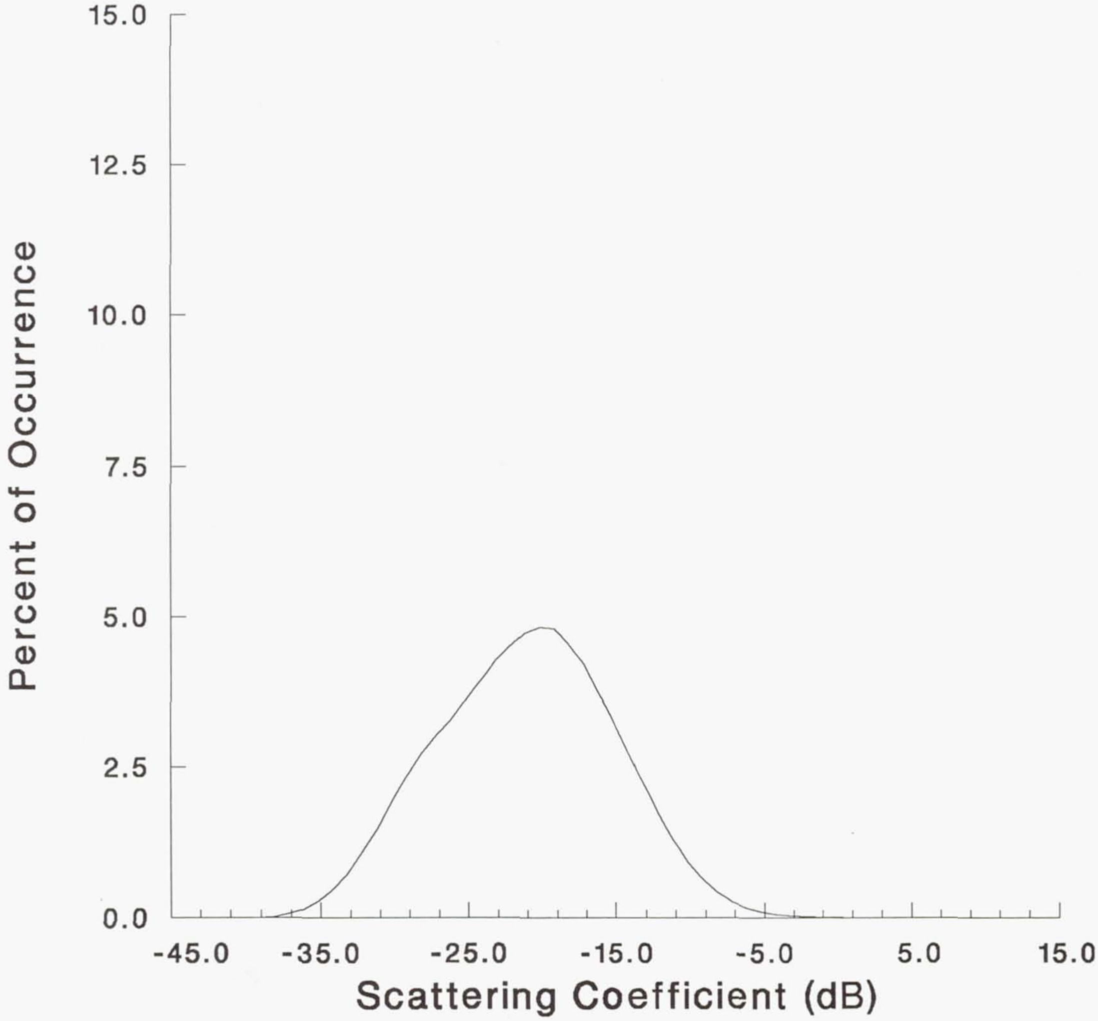


Figure 162.

Minimum: −39.69
Maximum: 9.69
Mean: −18.40
Bin Width: 1.00
Number of Bins: 50

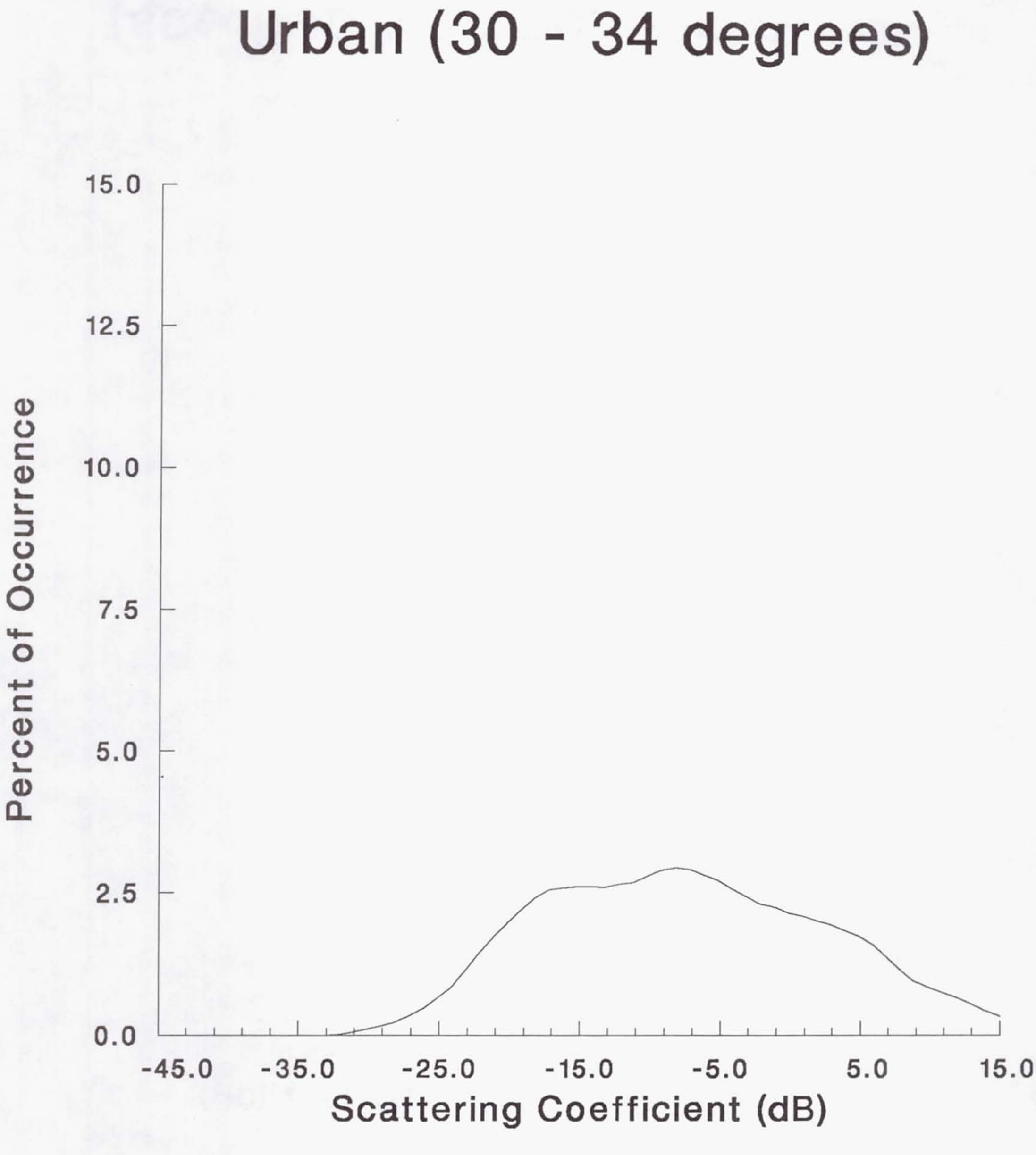


Figure 163.

Minimum: −39.69

Maximum: 24.70

Mean: 2.38

Bin Width: 1.00

Number of Bins: 65

Urban (50 - 59 degrees)

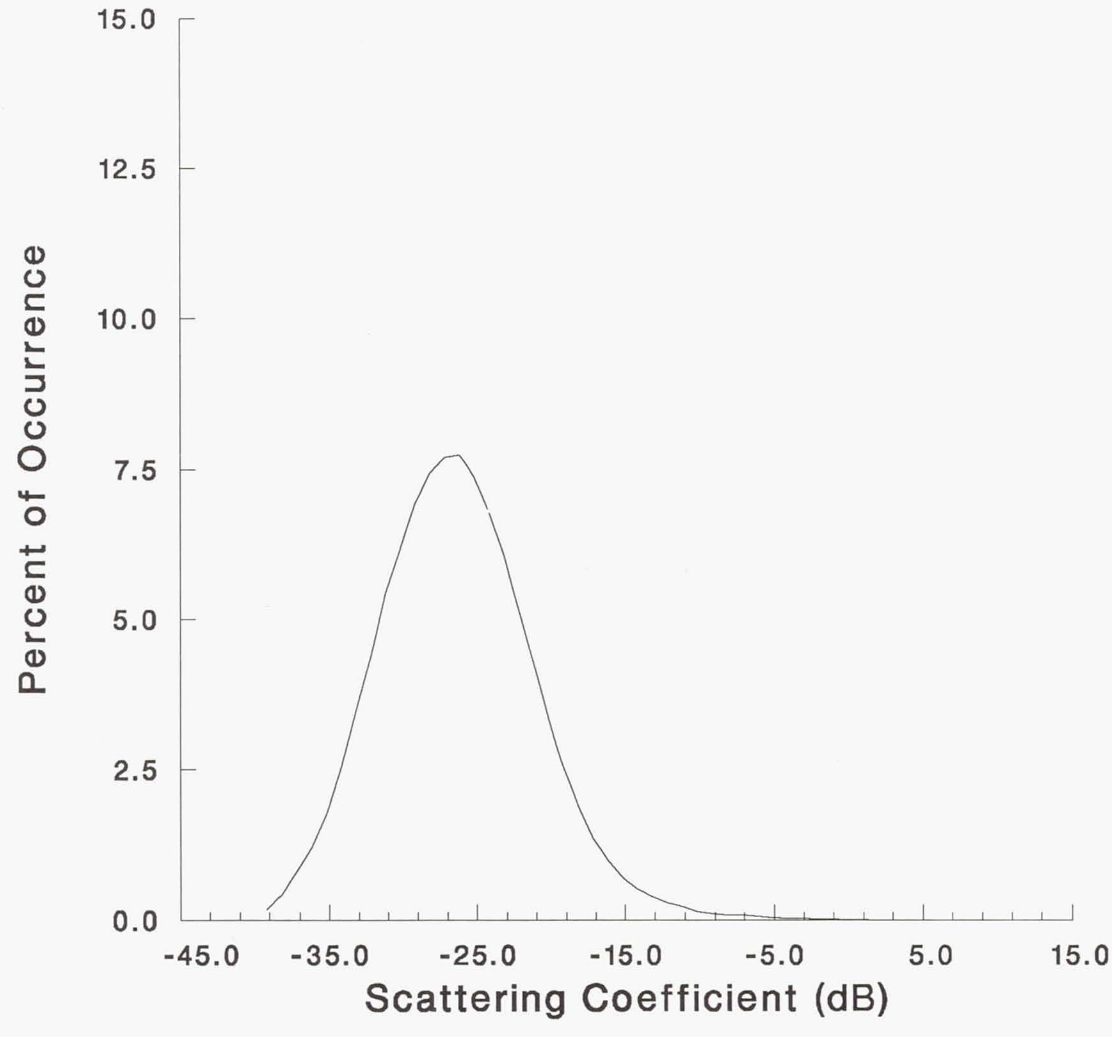


Figure 164.

Minimum: −39.69
Maximum: 5.64
Mean: −21.72
Bin Width: 1.00
Number of Bins: 46

Urban (60 - 64 degrees)

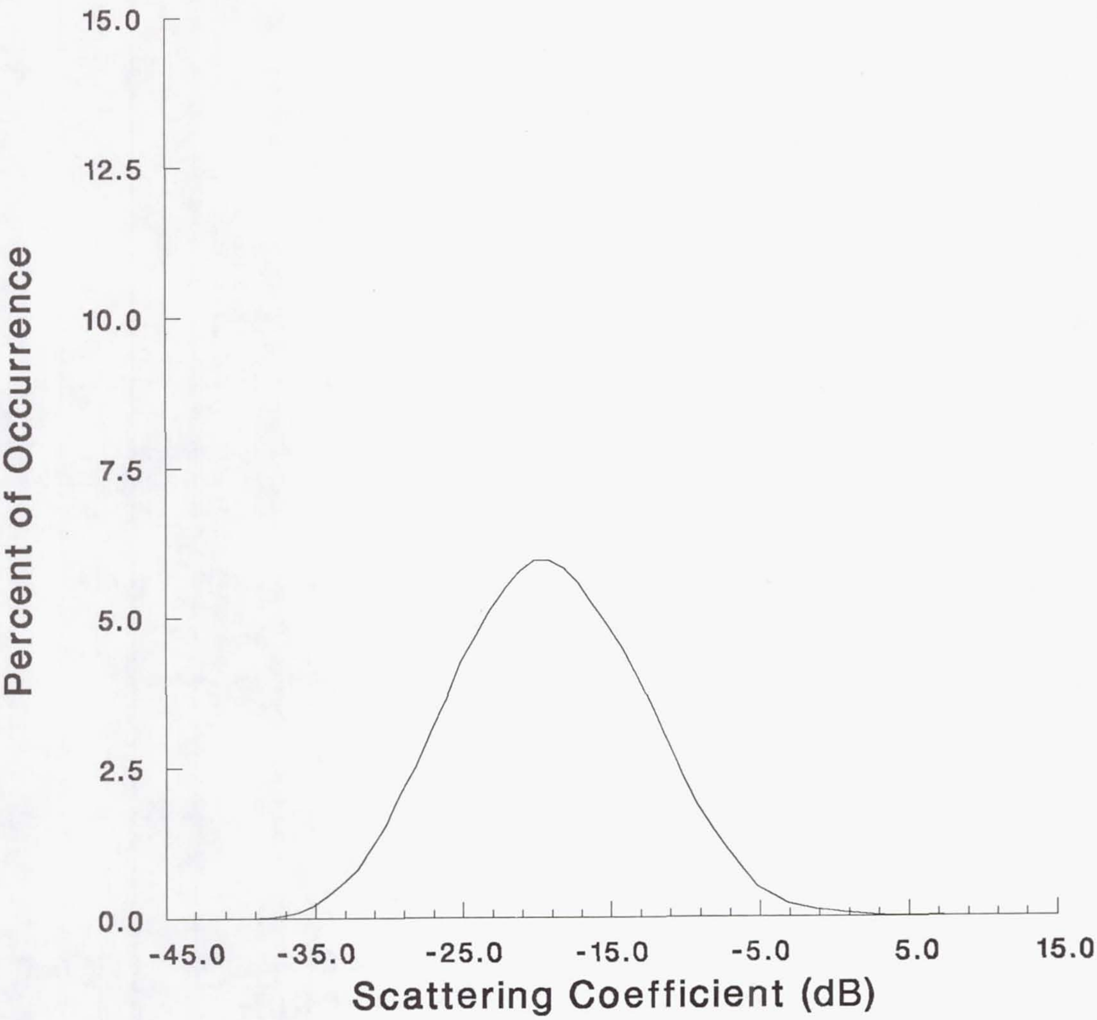


Figure 165.

Minimum: −39.69
Maximum: 14.12
Mean: −14.00
Bin Width: 1.00
Number of Bins: 55

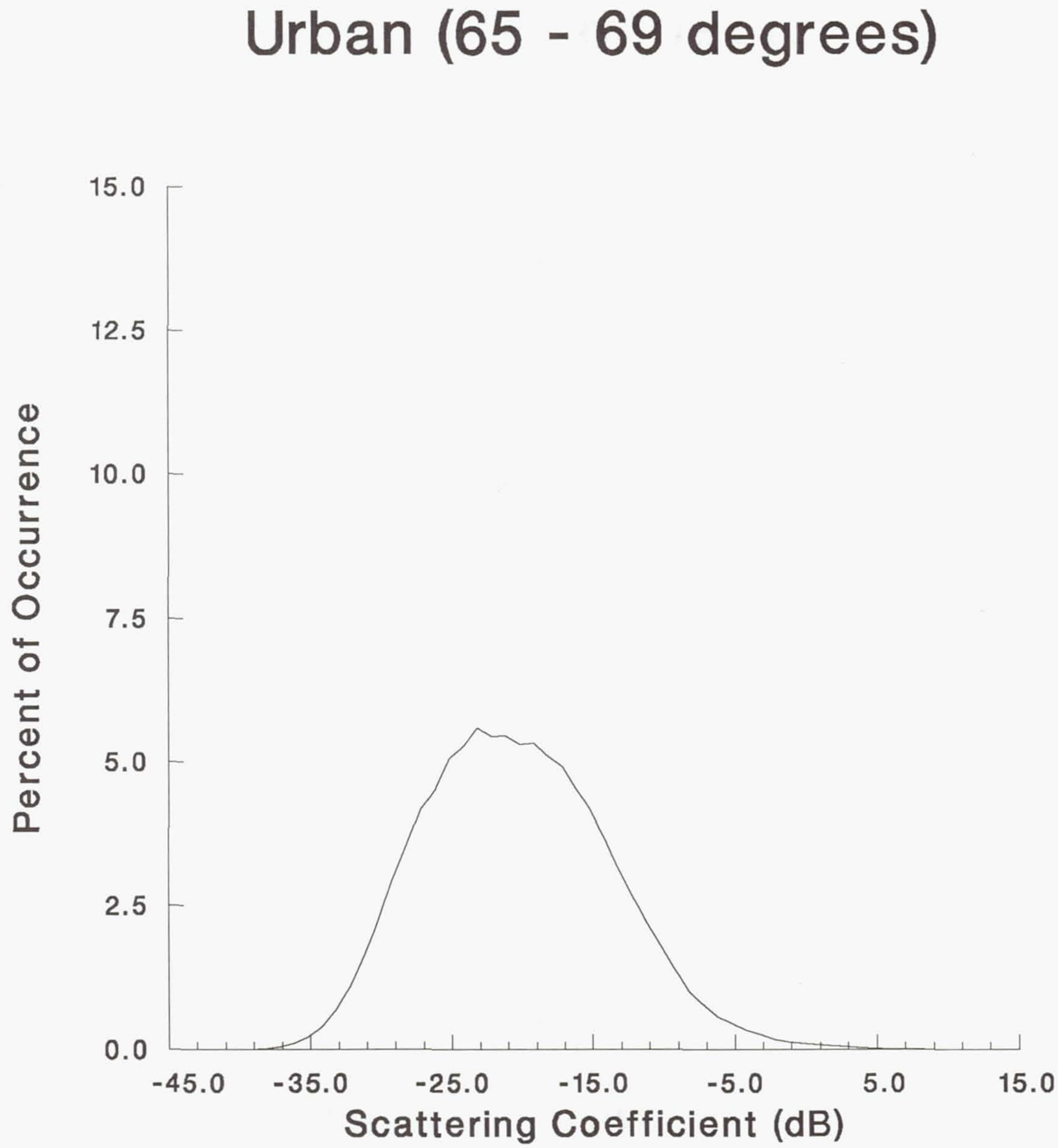


Figure 166.

Minimum: −39.69
Maximum: 10.24
Mean: −12.94
Bin Width: 1.00
Number of Bins: 51

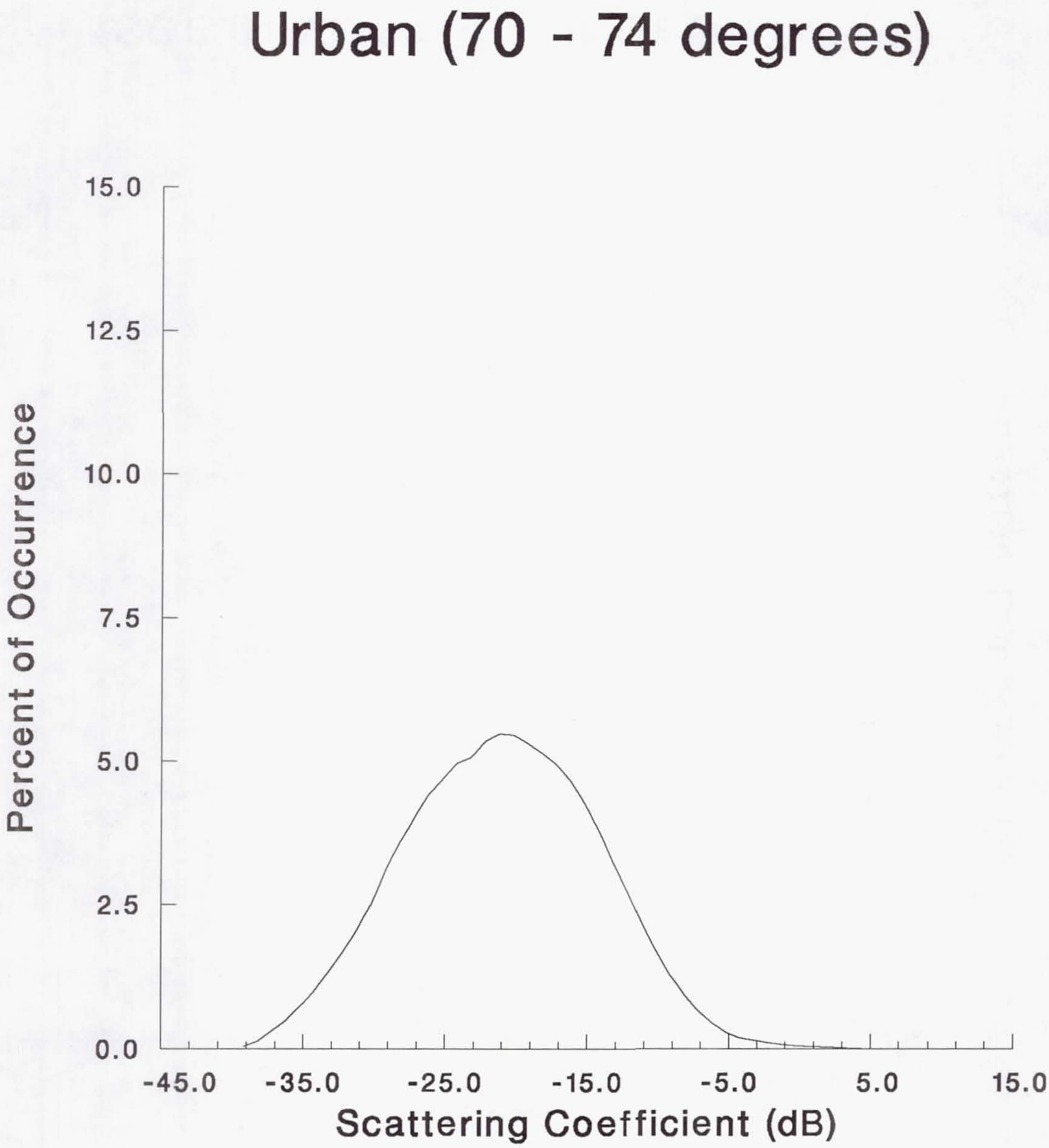


Figure 167.

Minimum: −39.69
Maximum: 7.73
Mean: −15.70
Bin Width: 1.00
Number of Bins: 48

Urban (75 - 79 degrees)

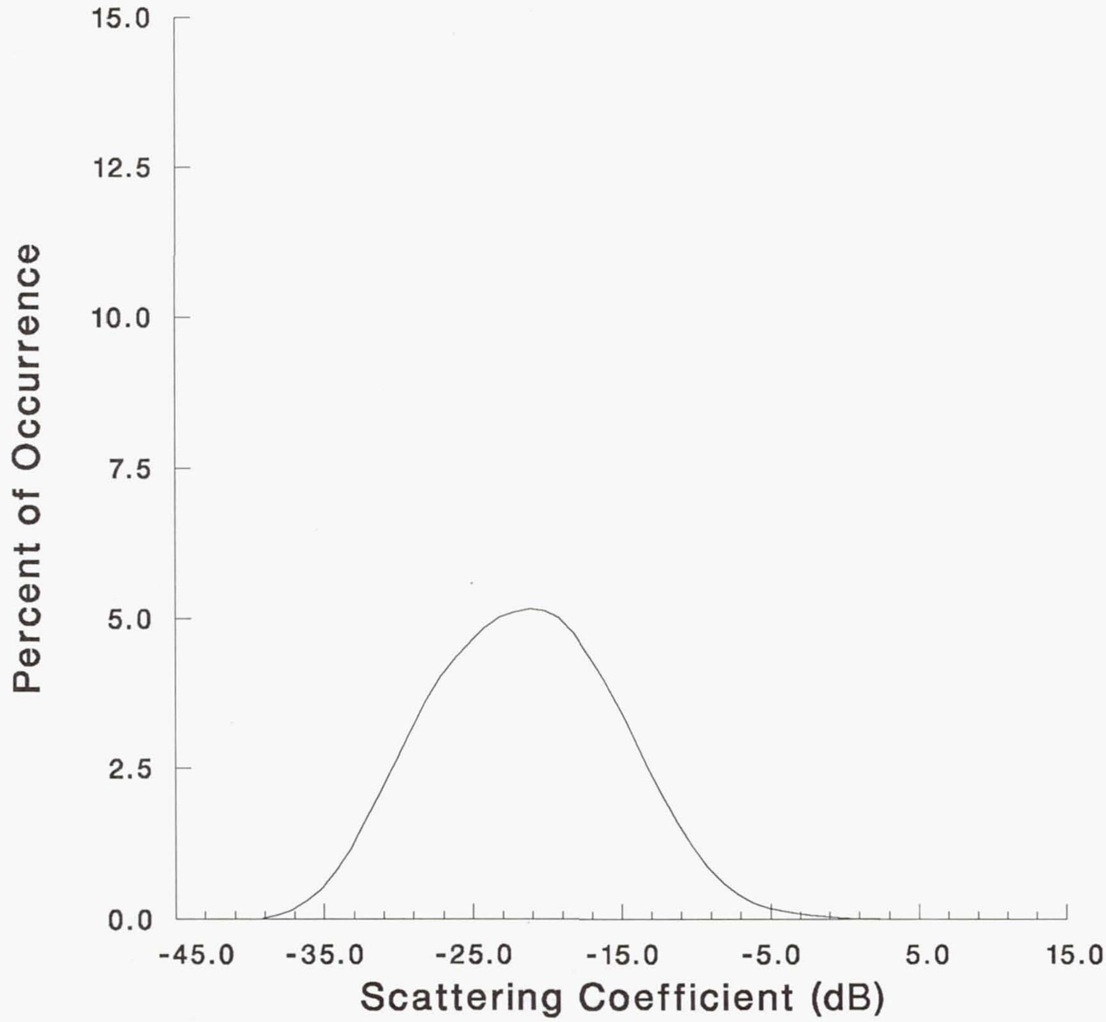


Figure 168.

Minimum: −39.69
Maximum: 8.83
Mean: −17.13
Bin Width: 1.00
Number of Bins: 50

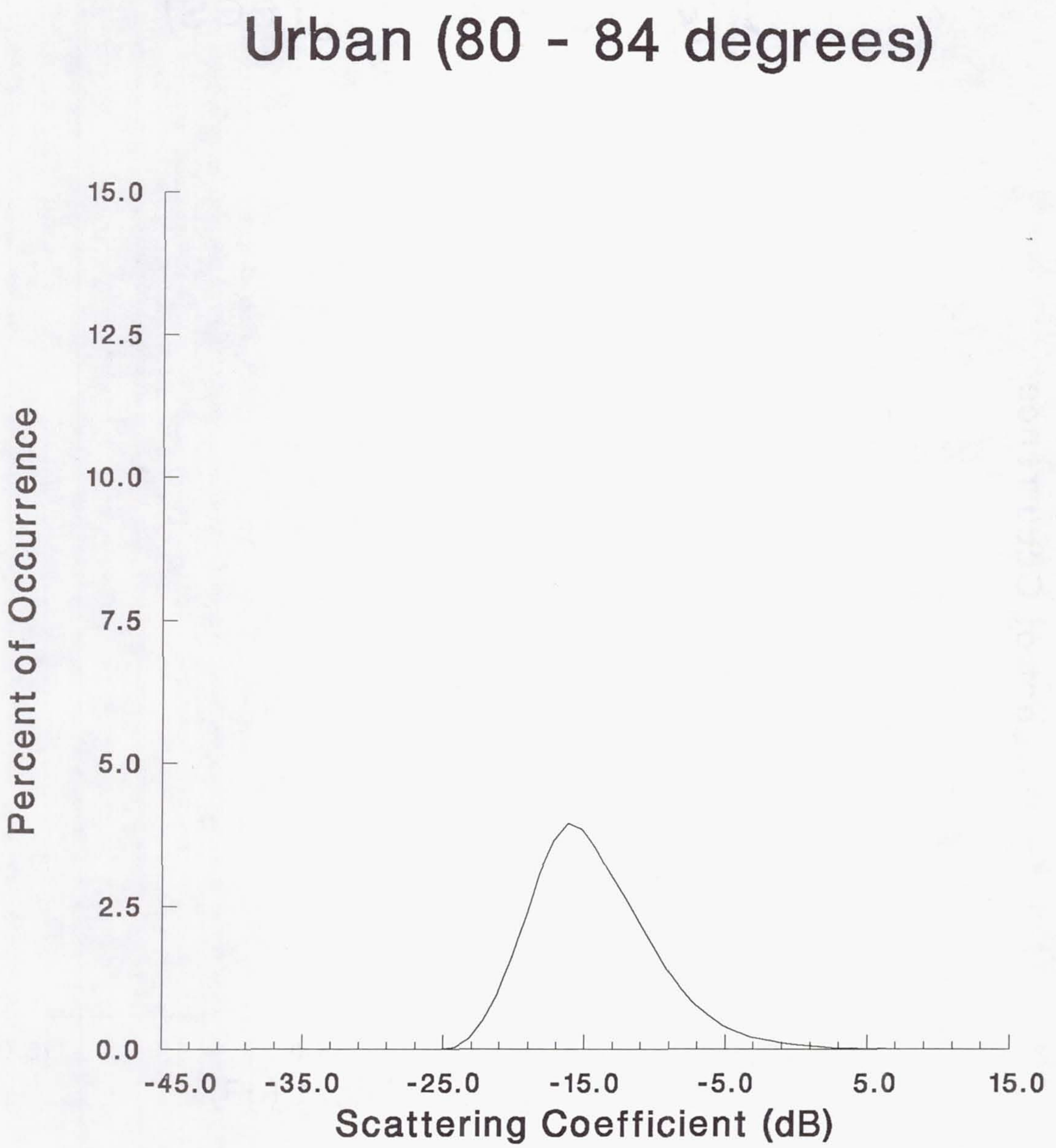


Figure 169.

Minimum: −39.69
Maximum: 26.96
Mean: −12.70
Bin Width: 1.00
Number of Bins: 68

City (70 - 74 degrees)

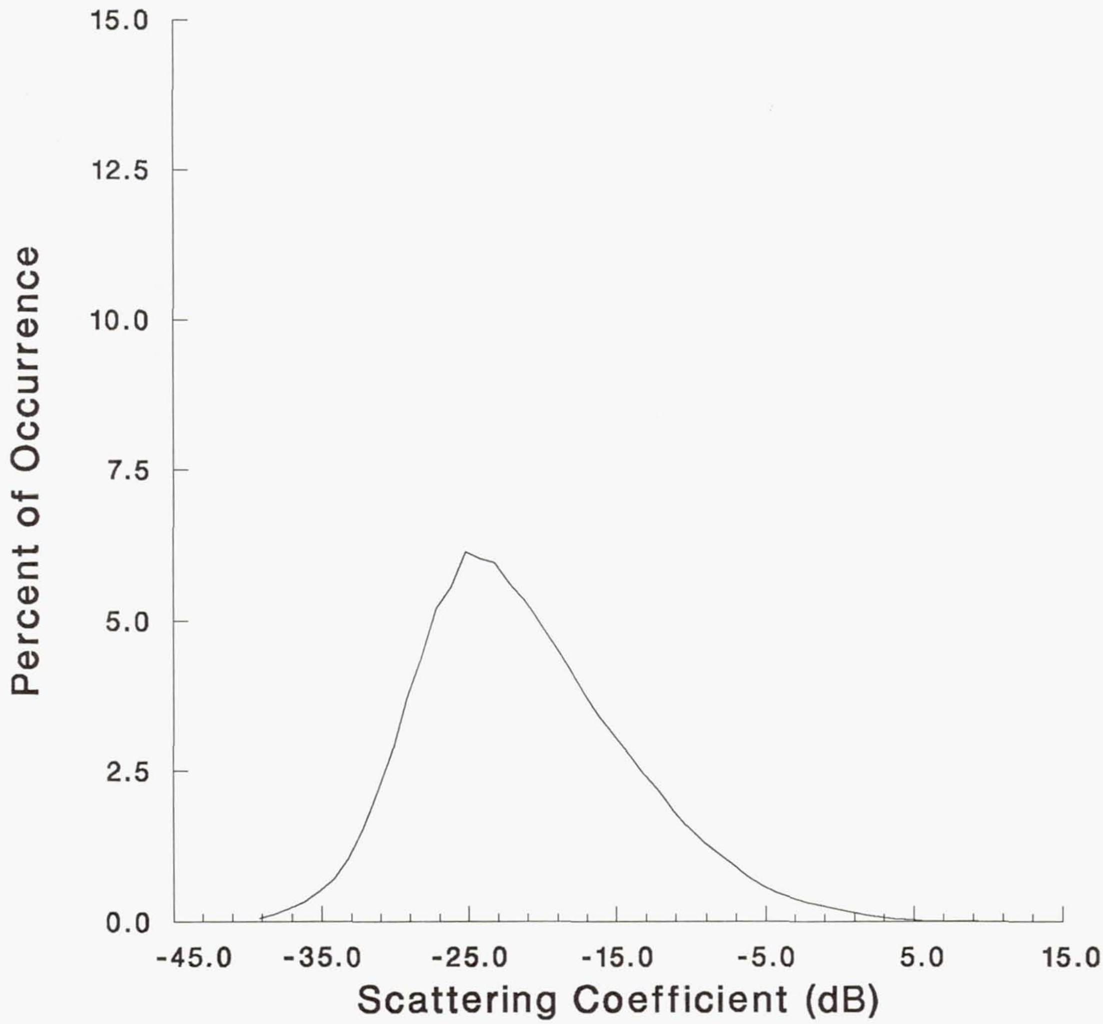


Figure 170.

Minimum: −39.69
Maximum: 17.20
Mean: −13.11
Bin Width: 1.00
Number of Bins: 58

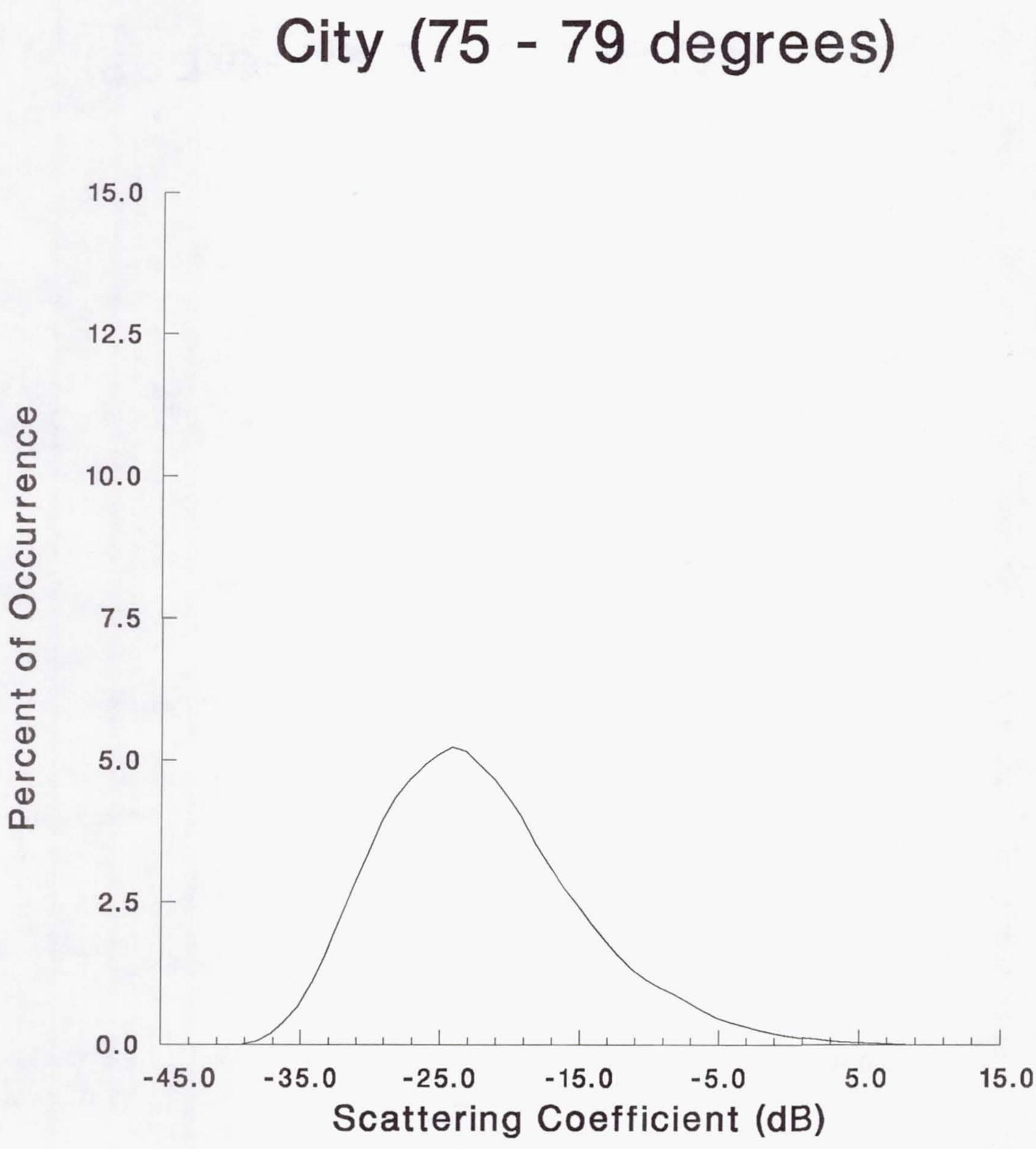


Figure 171.

Minimum: −39.69

Maximum: 16.47

Mean: −13.98

Bin Width: 1.00

Number of Bins: 57

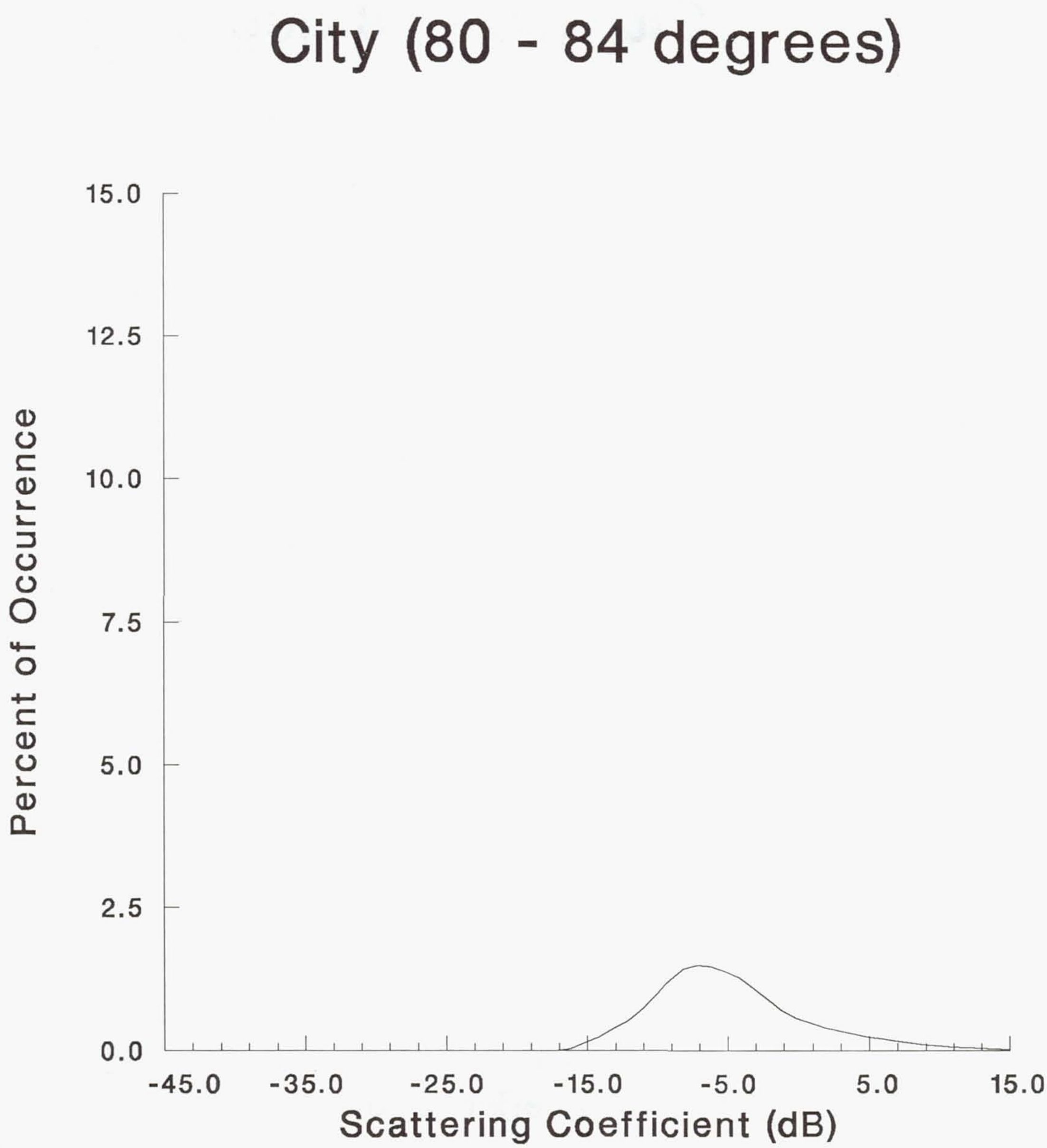


Figure 172.

Minimum: −39.69

Maximum: 29.64

Mean: −6.29

Bin Width: 1.00

Number of Bins: 70

Industrial (35 - 39 degrees)

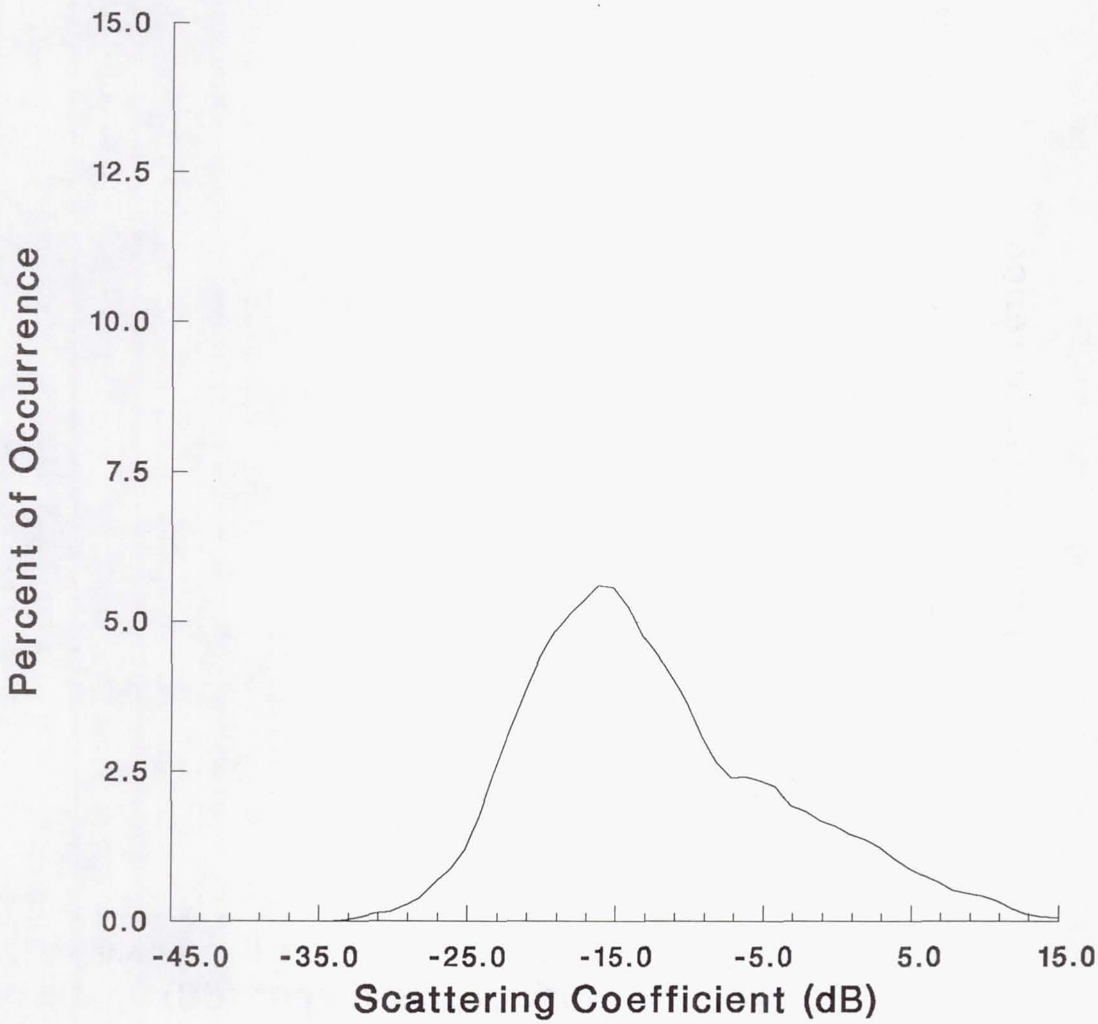


Figure 173.

Minimum: −39.69
Maximum: 21.74
Mean: −1.95
Bin Width: 1.00
Number of Bins: 62

Industrial (40 - 49 degrees)

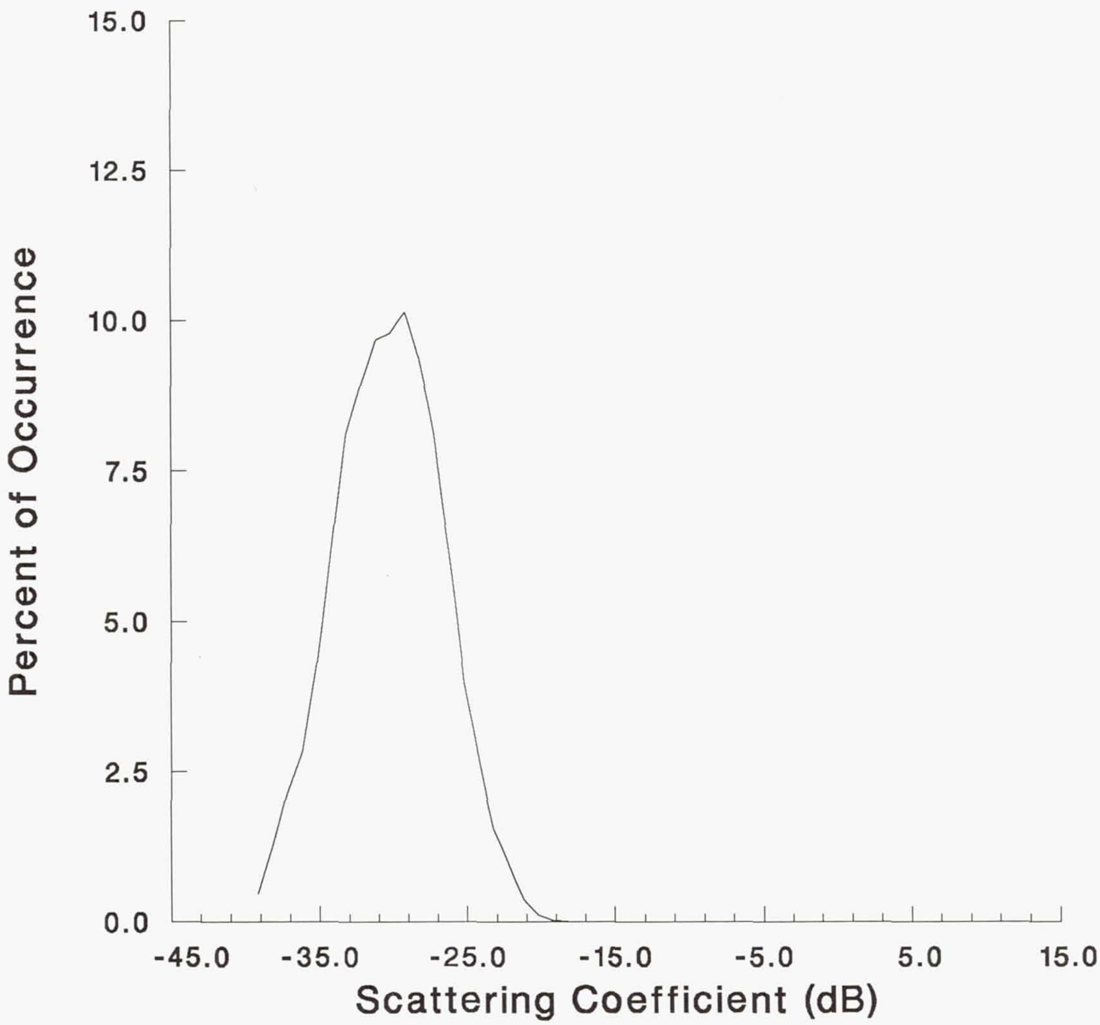


Figure 174.

Minimum: −39.69
Maximum: −18.57
Mean: −29.02
Bin Width: 1.00
Number of Bins: 22

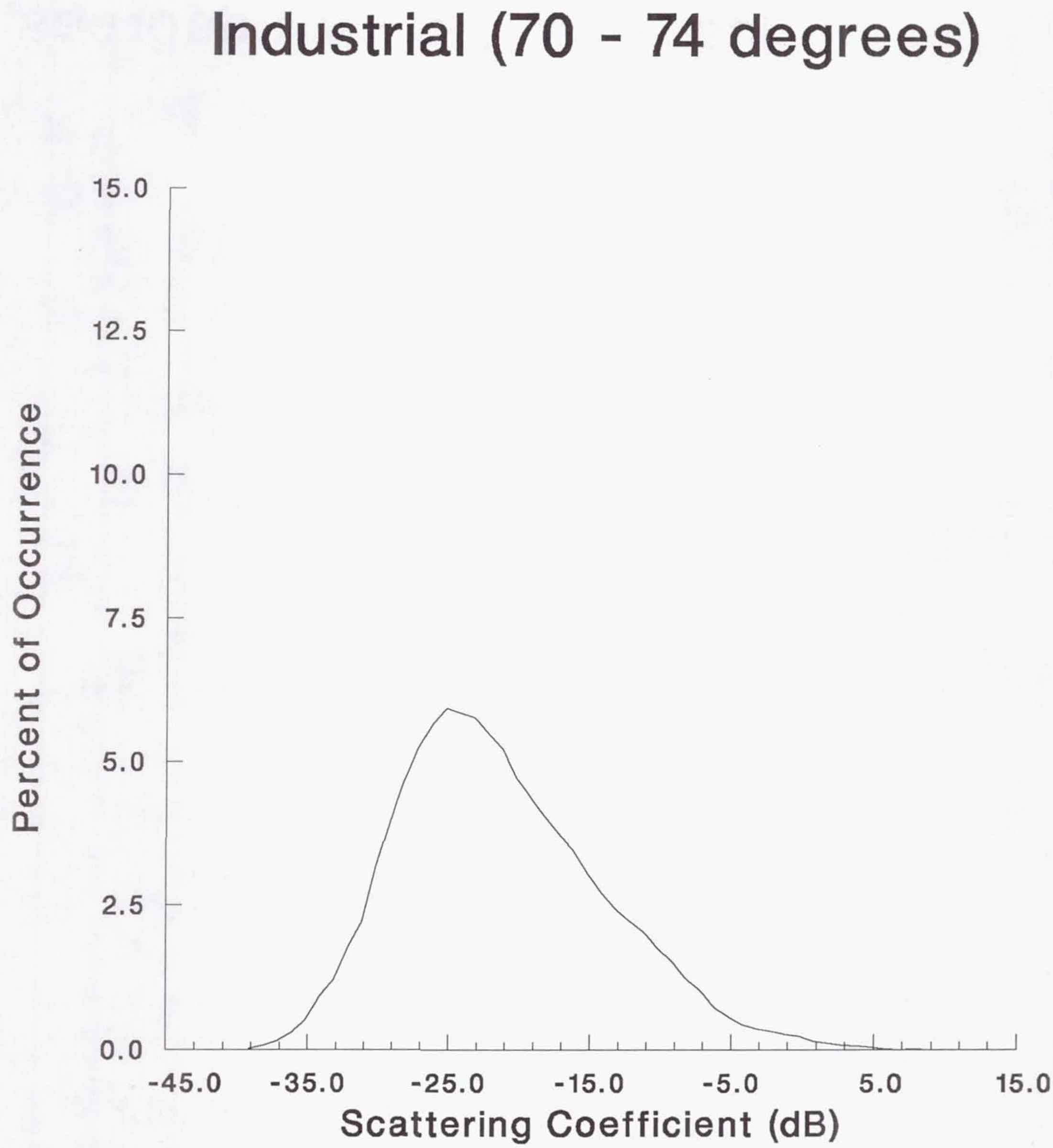


Figure 175.

Minimum: −39.69

Maximum: 8.96

Mean: −13.76

Bin Width: 1.00

Number of Bins: 50

Industrial (75 - 79 degrees)

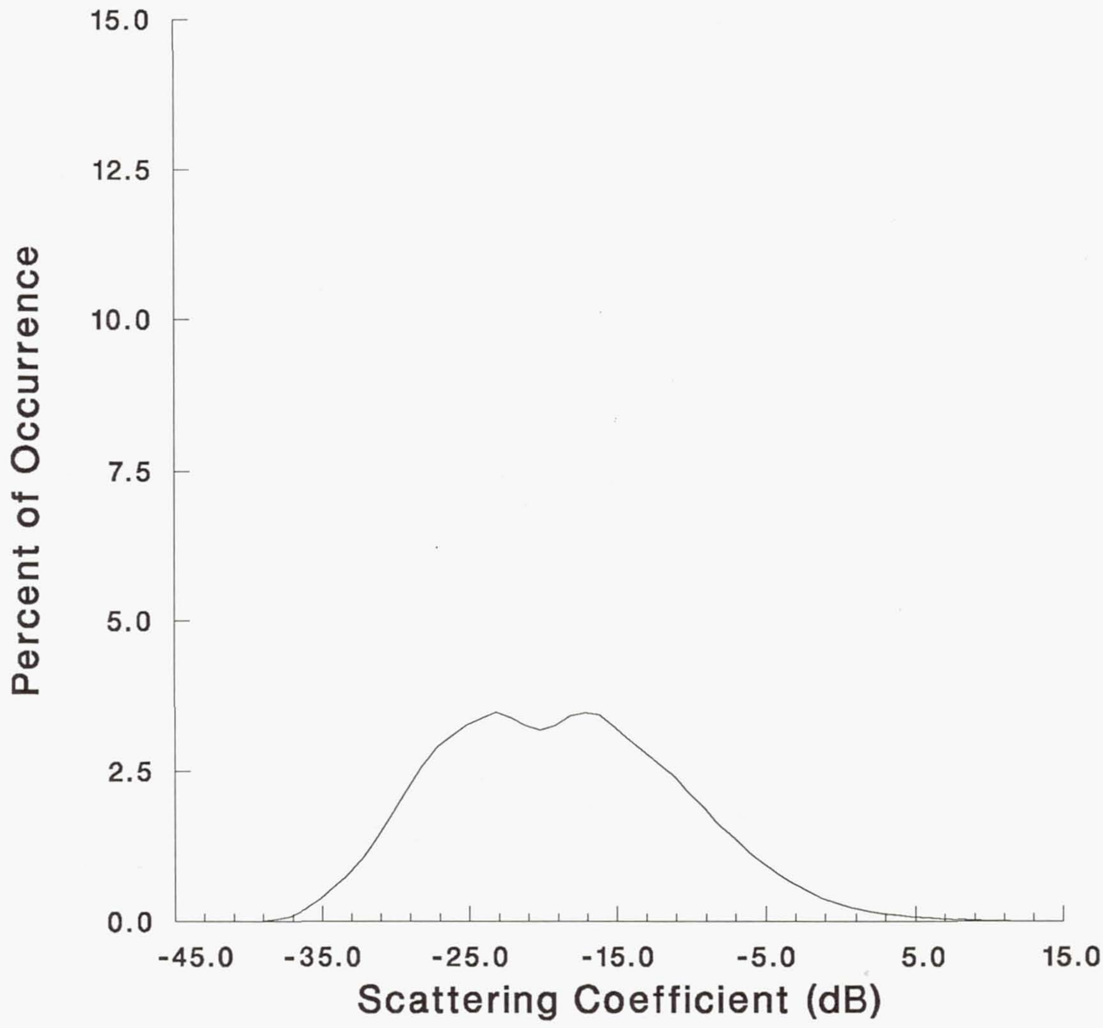


Figure 176.

Minimum: −39.69
Maximum: 26.96
Mean: −10.34
Bin Width: 1.00
Number of Bins: 68

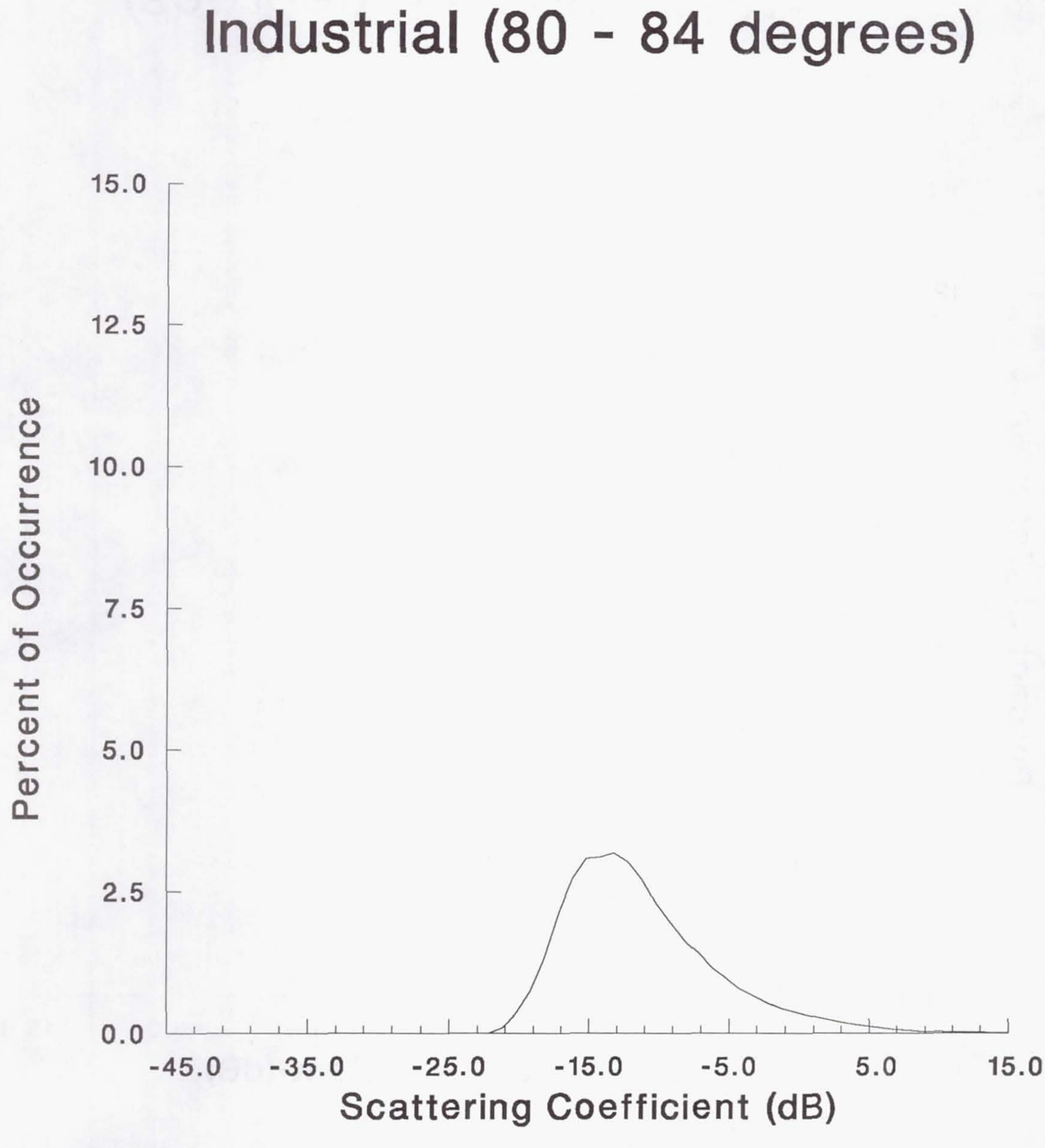


Figure 177.

Minimum: −39.69
Maximum: 26.96
Mean: −8.77
Bin Width: 1.00
Number of Bins: 68

Water (60 - 64 degrees)

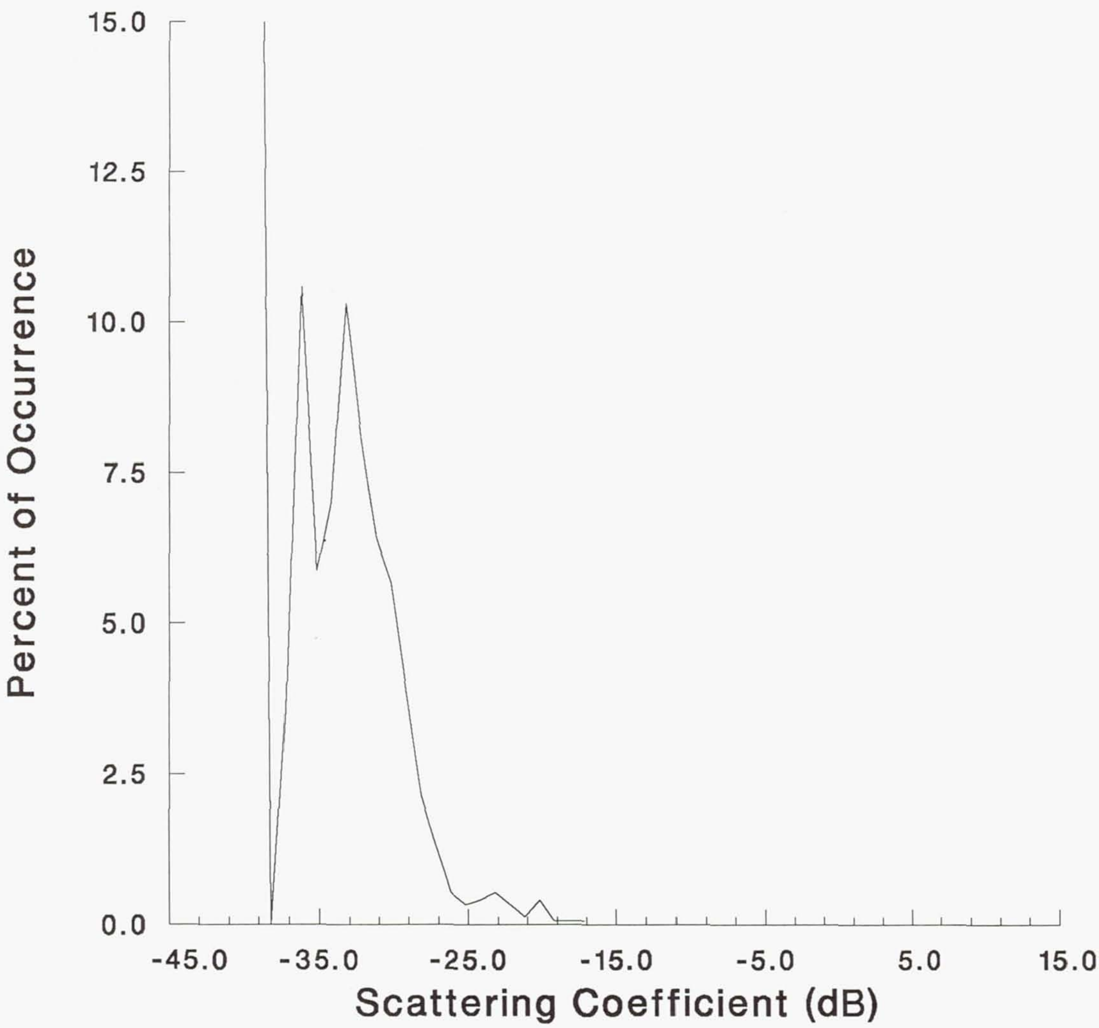


Figure 178.

Minimum: −39.69
Maximum: −17.67
Mean: −32.33
Bin Width: 1.00
Number of Bins: 23

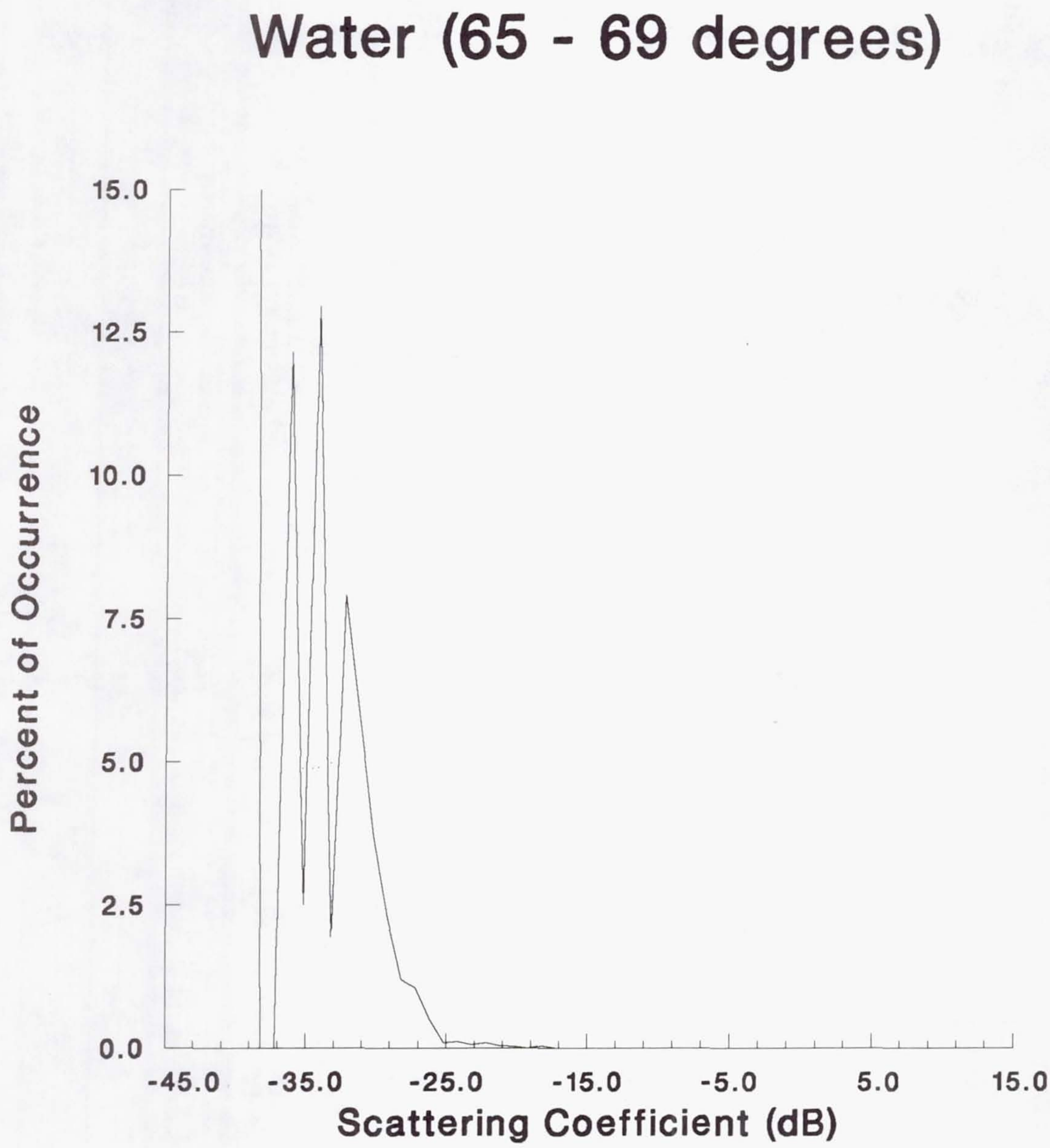


Figure 179.

Minimum: −39.69
Maximum: −18.18
Mean: −34.14
Bin Width: 1.00
Number of Bins: 23

Runway

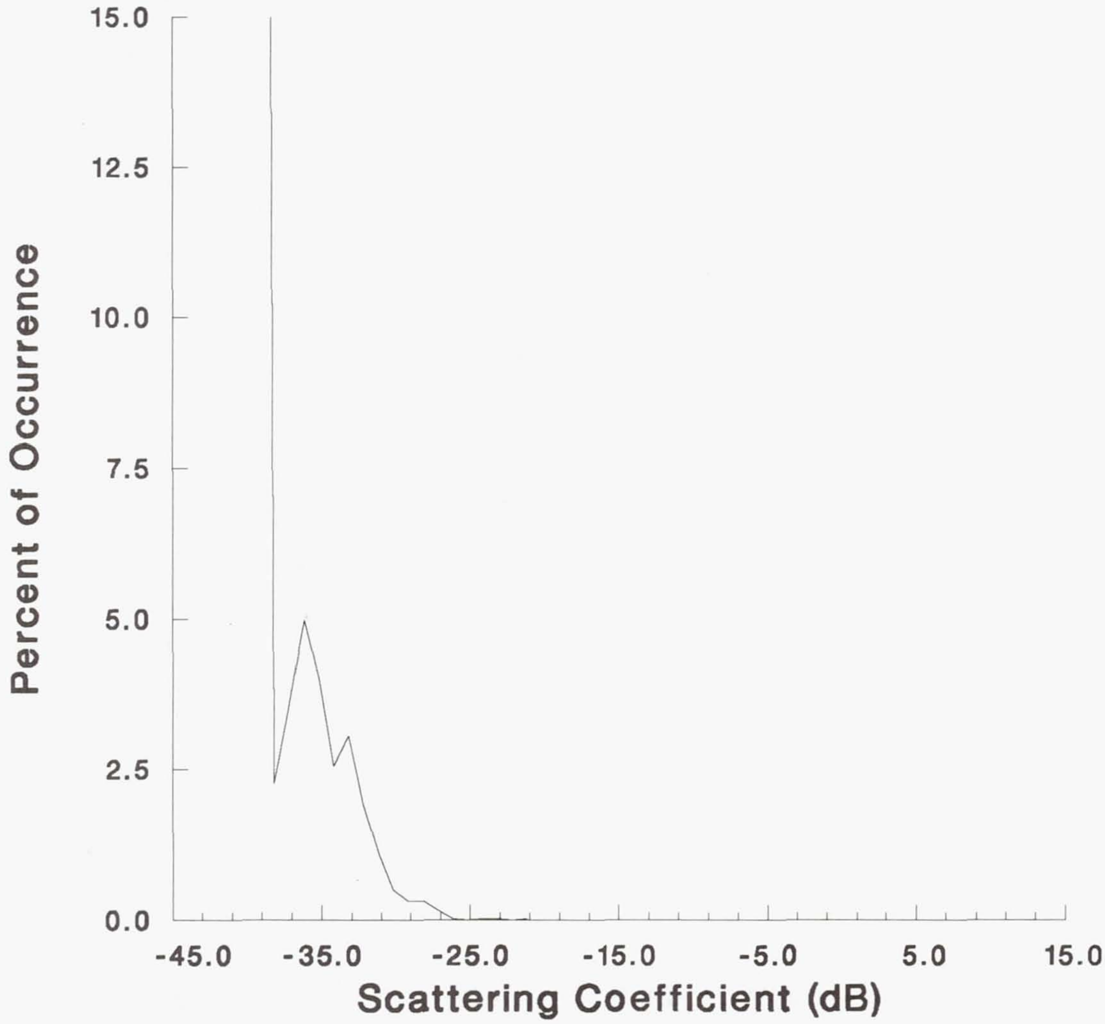


Figure 180.

Minimum: −39.69

Maximum: −21.49

Mean: −37.38

Bin Width: 1.00

Number of Bins: 19

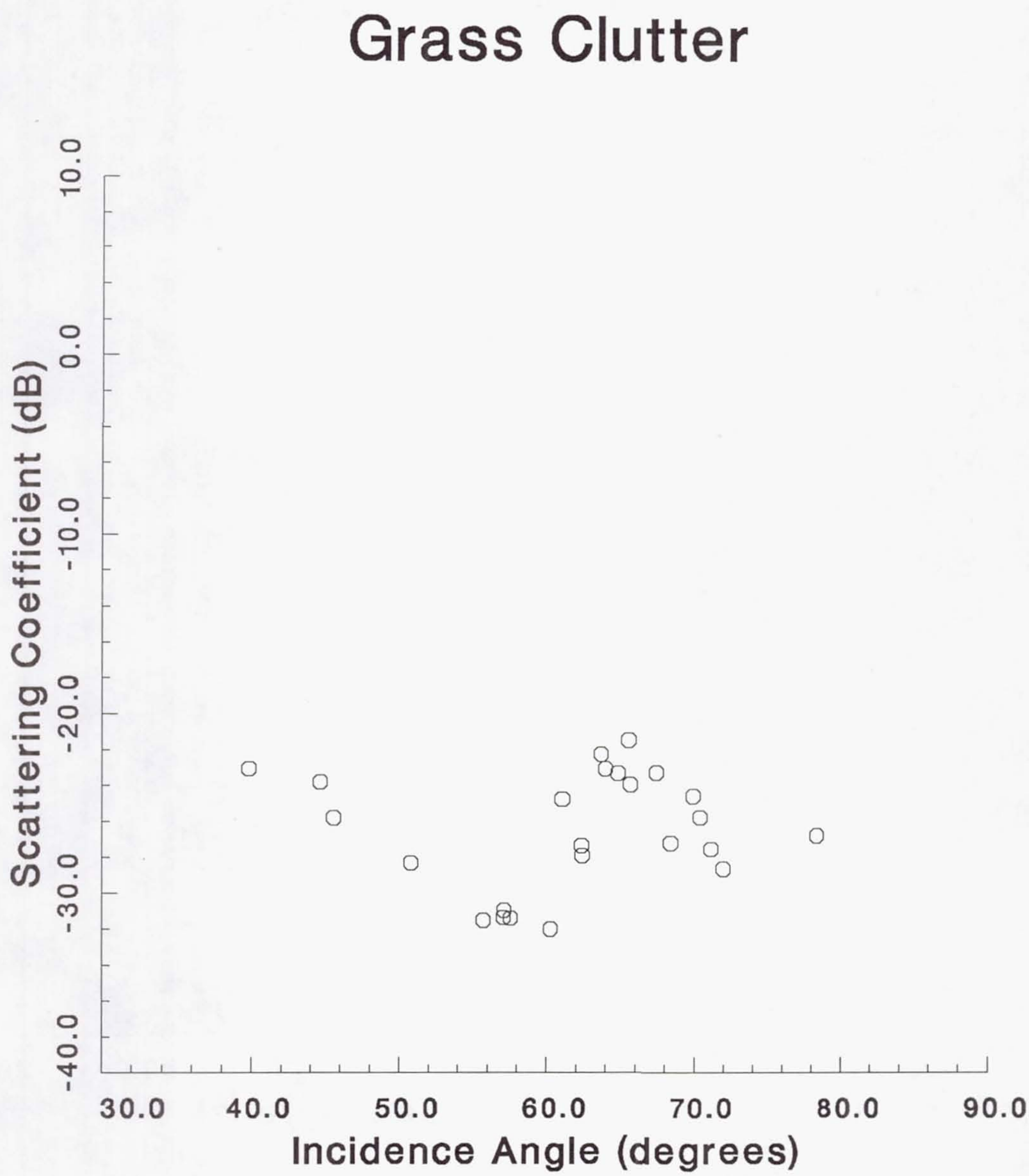
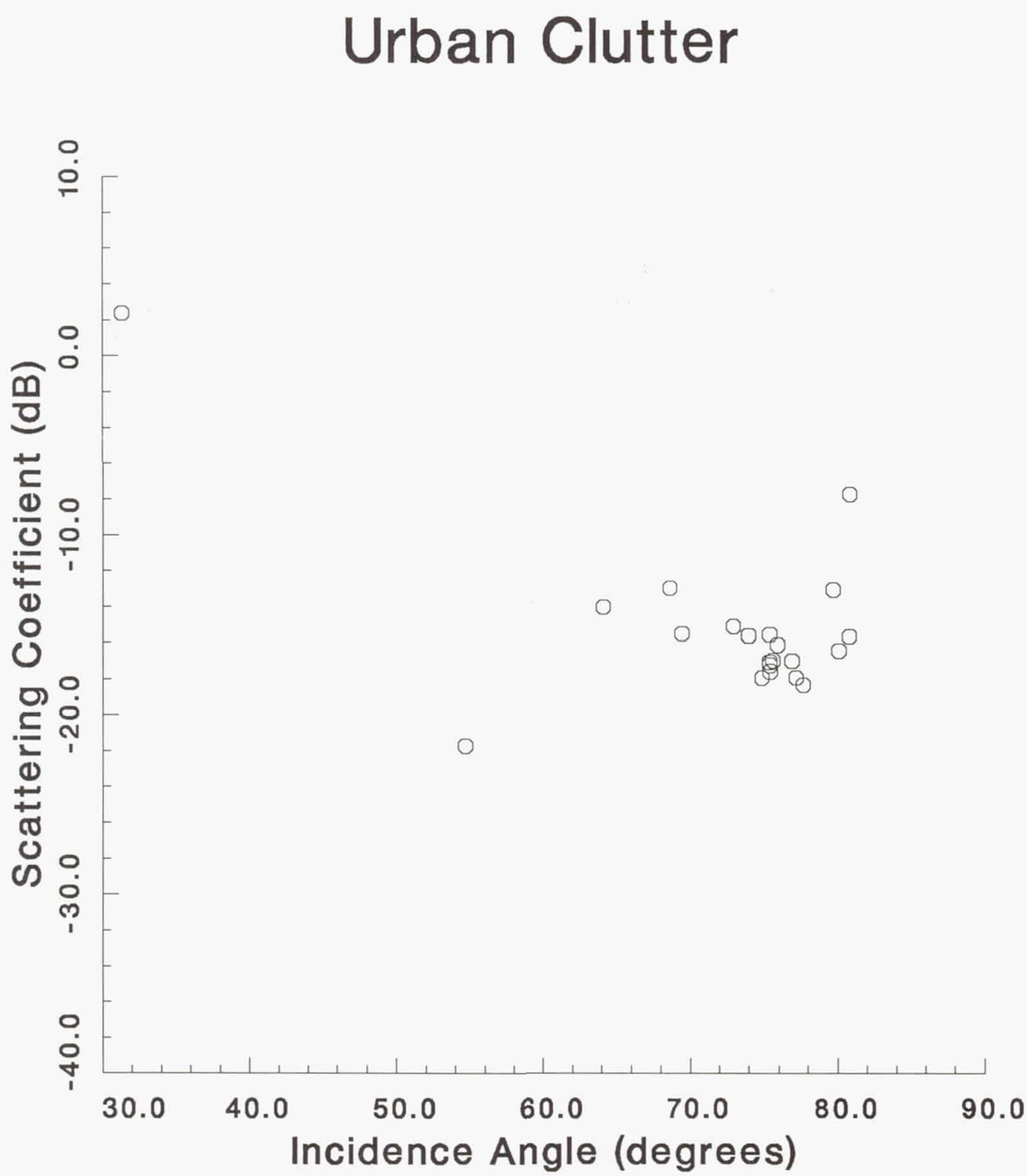
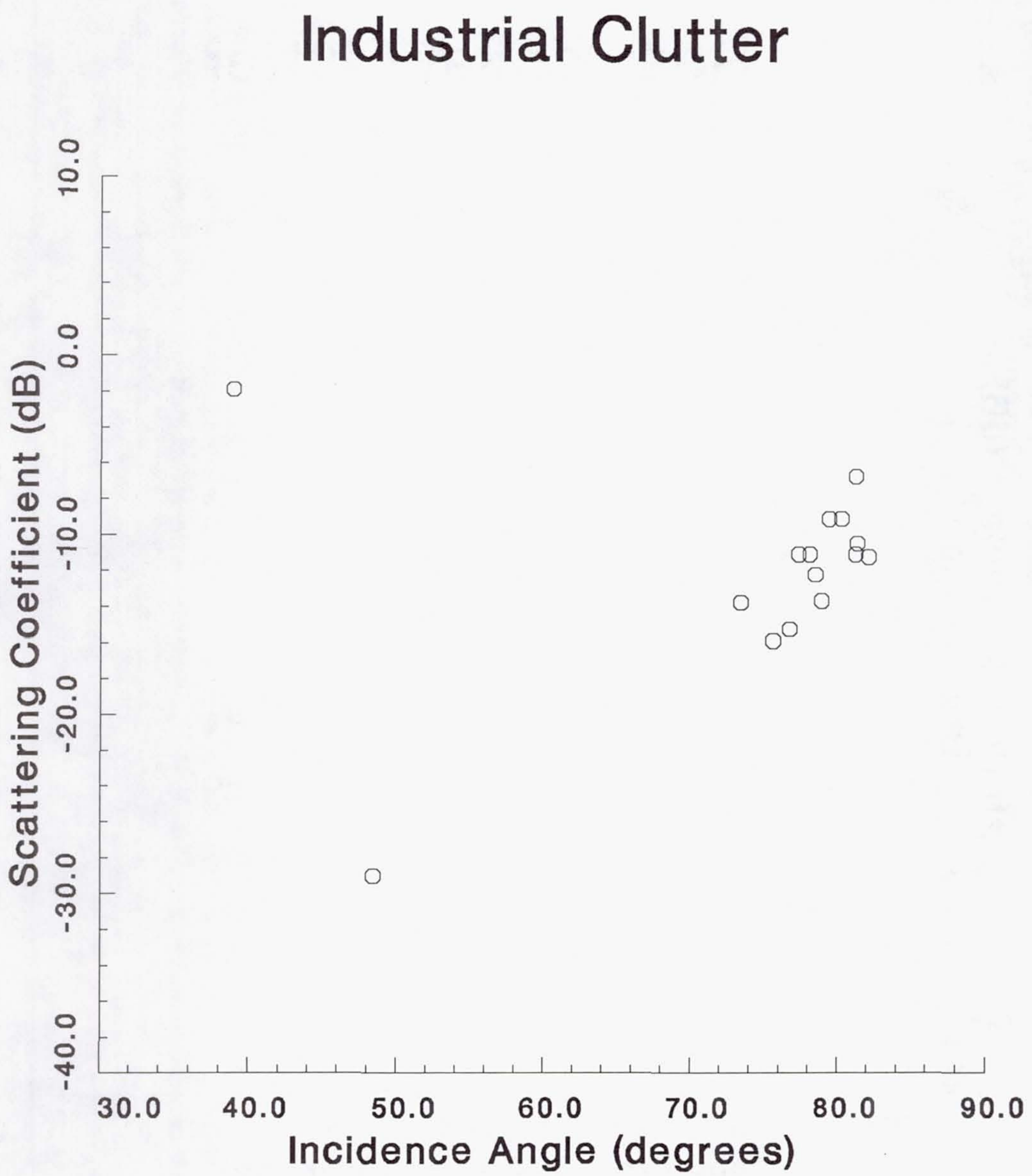

Grass Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 181.



Urban Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 182.



Industrial Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 183.

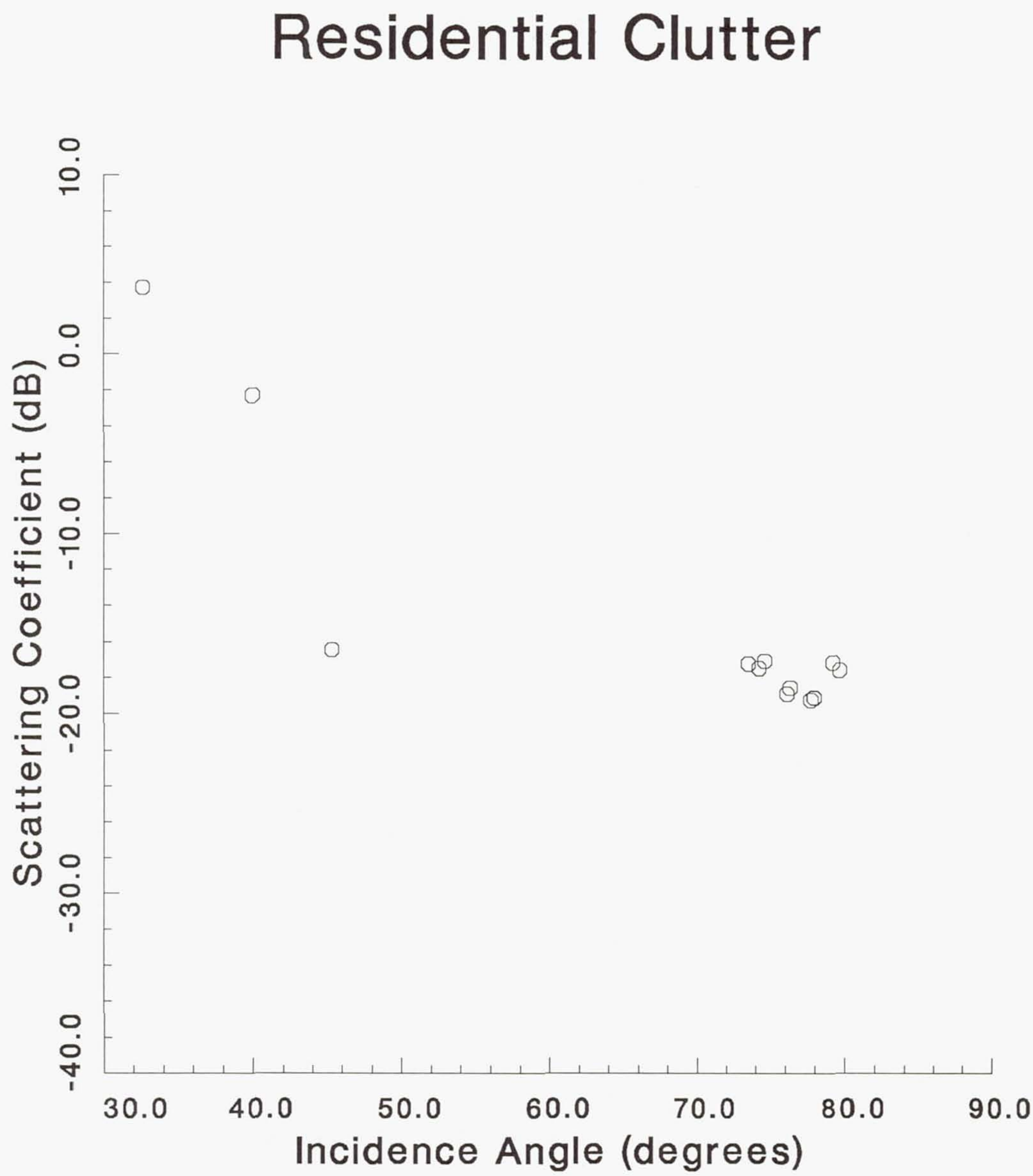

Residential Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 184.

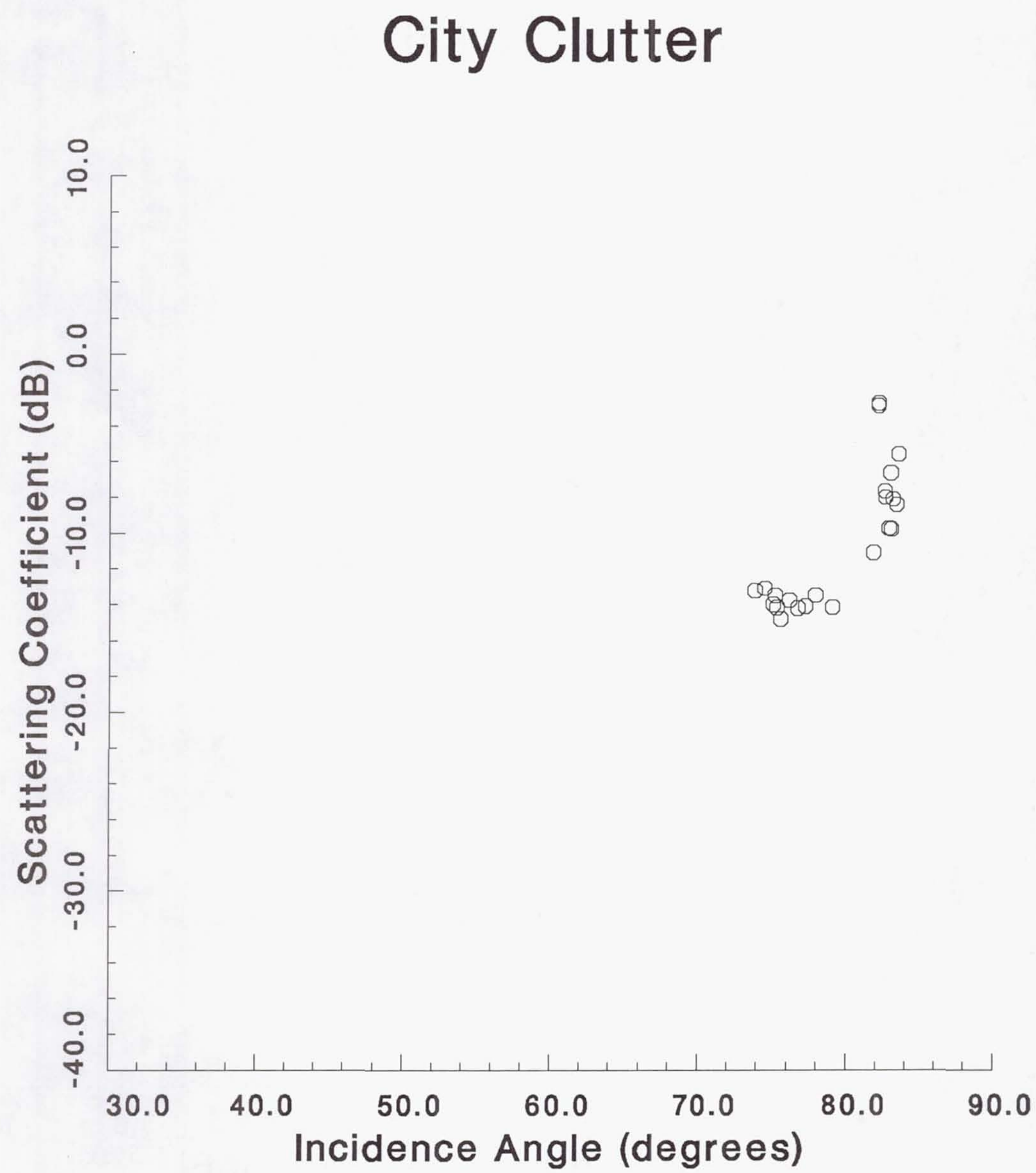

City Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 185.

Building

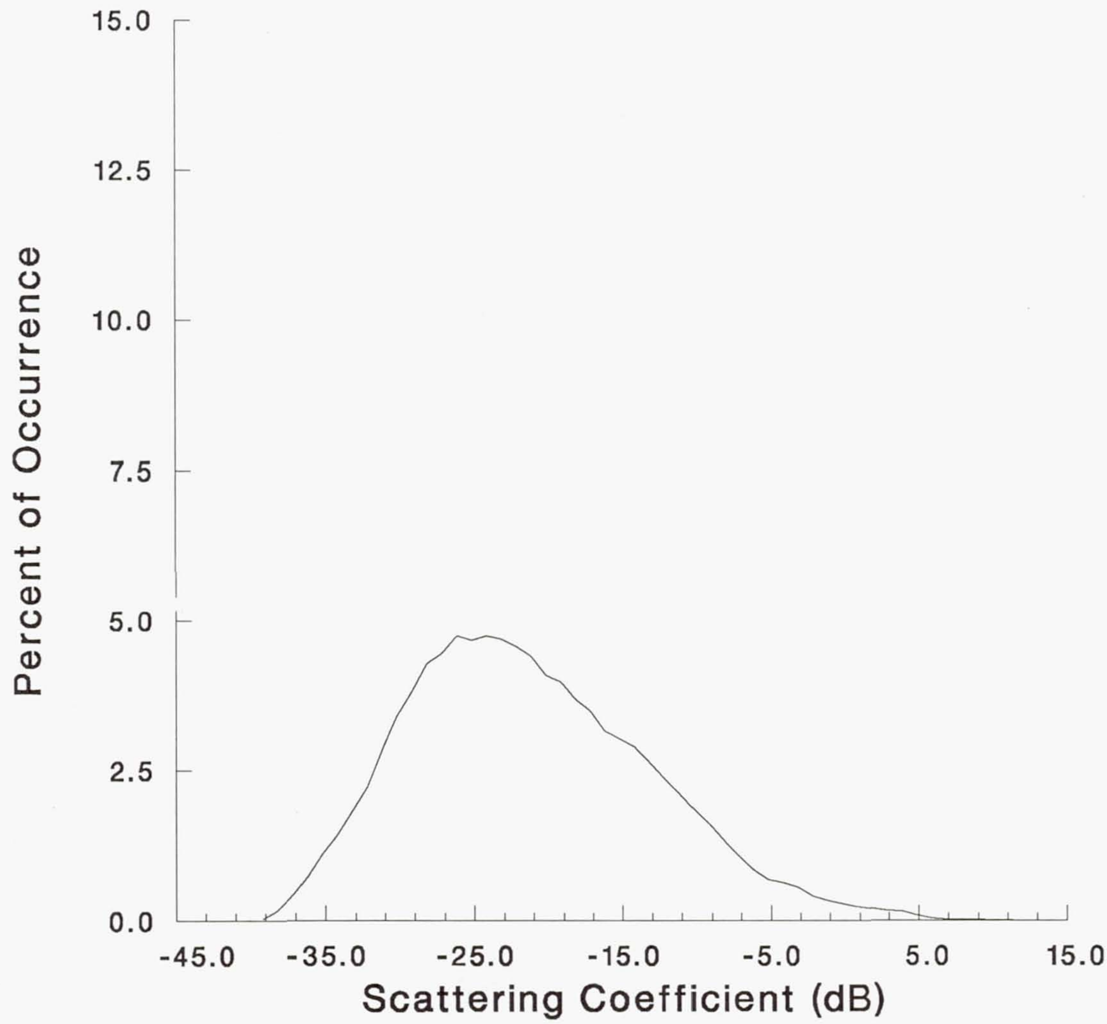


Figure 186.

Minimum: −39.69
Maximum: 16.97
Mean: −11.45
Bin Width: 1.00
Number of Bins: 58

Terminal

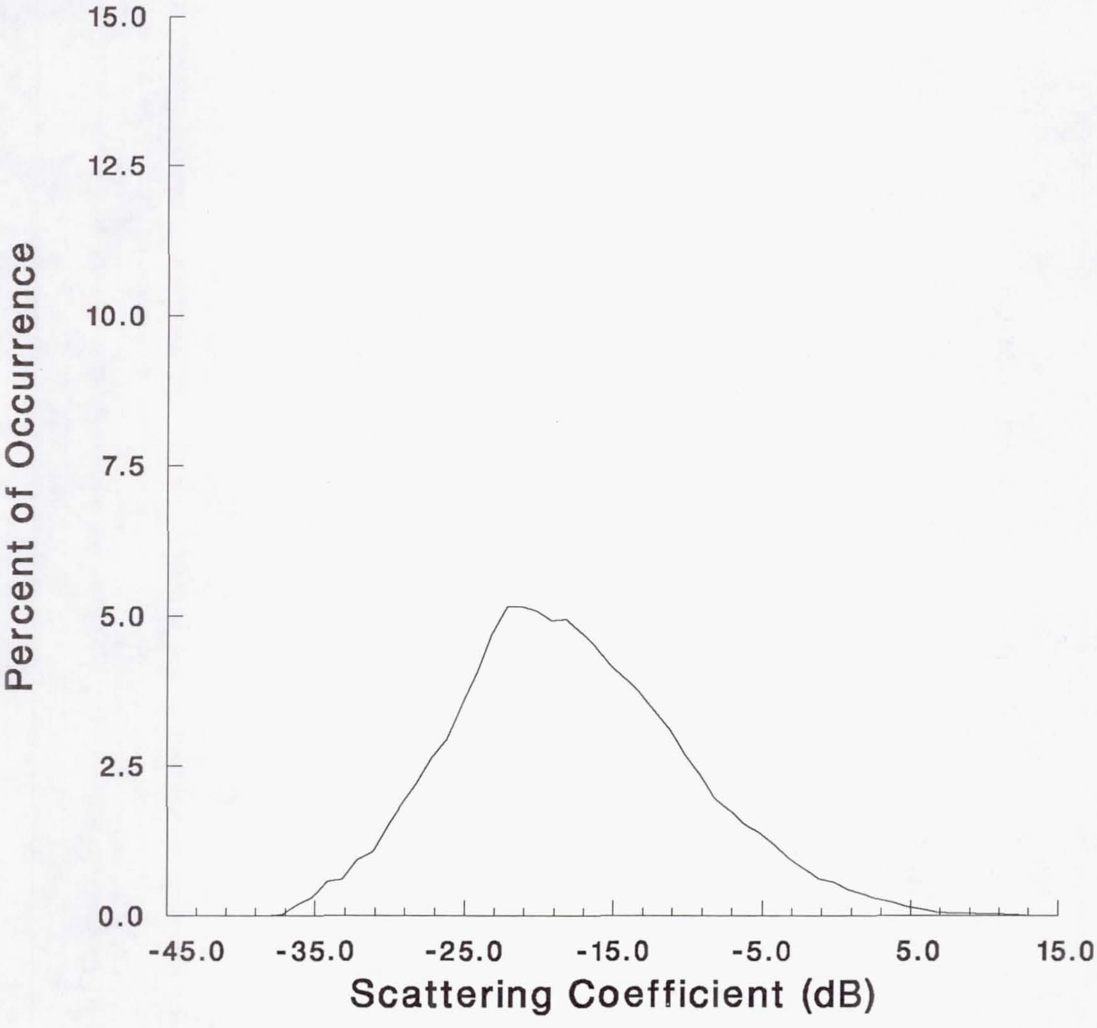


Figure 187.

Minimum: −39.69
Maximum: 12.61
Mean: −9.56
Bin Width: 1.00
Number of Bins: 53

Parking Lot

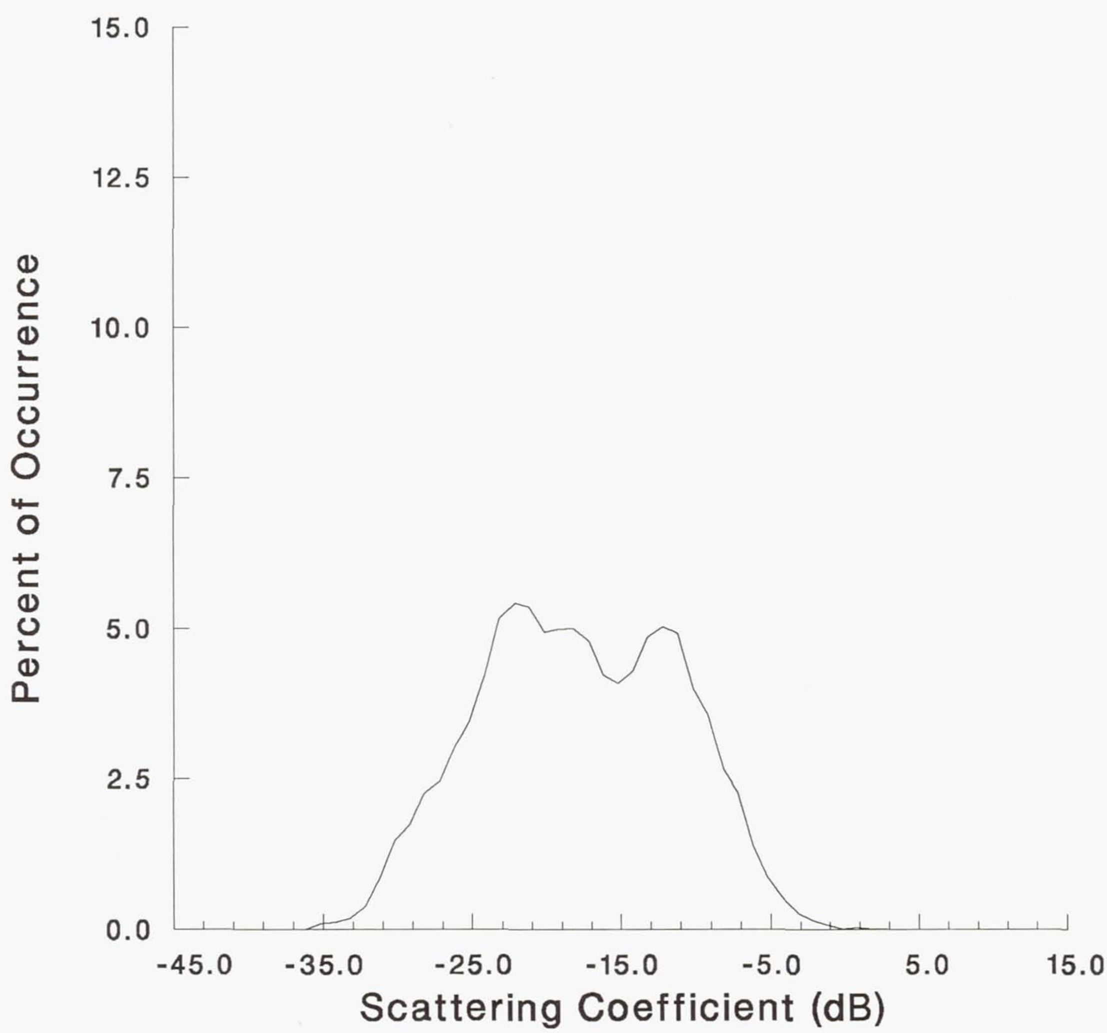


Figure 188.

Minimum: −39.69
Maximum: 1.91
Mean: −13.48
Bin Width: 1.00
Number of Bins: 43

Plane

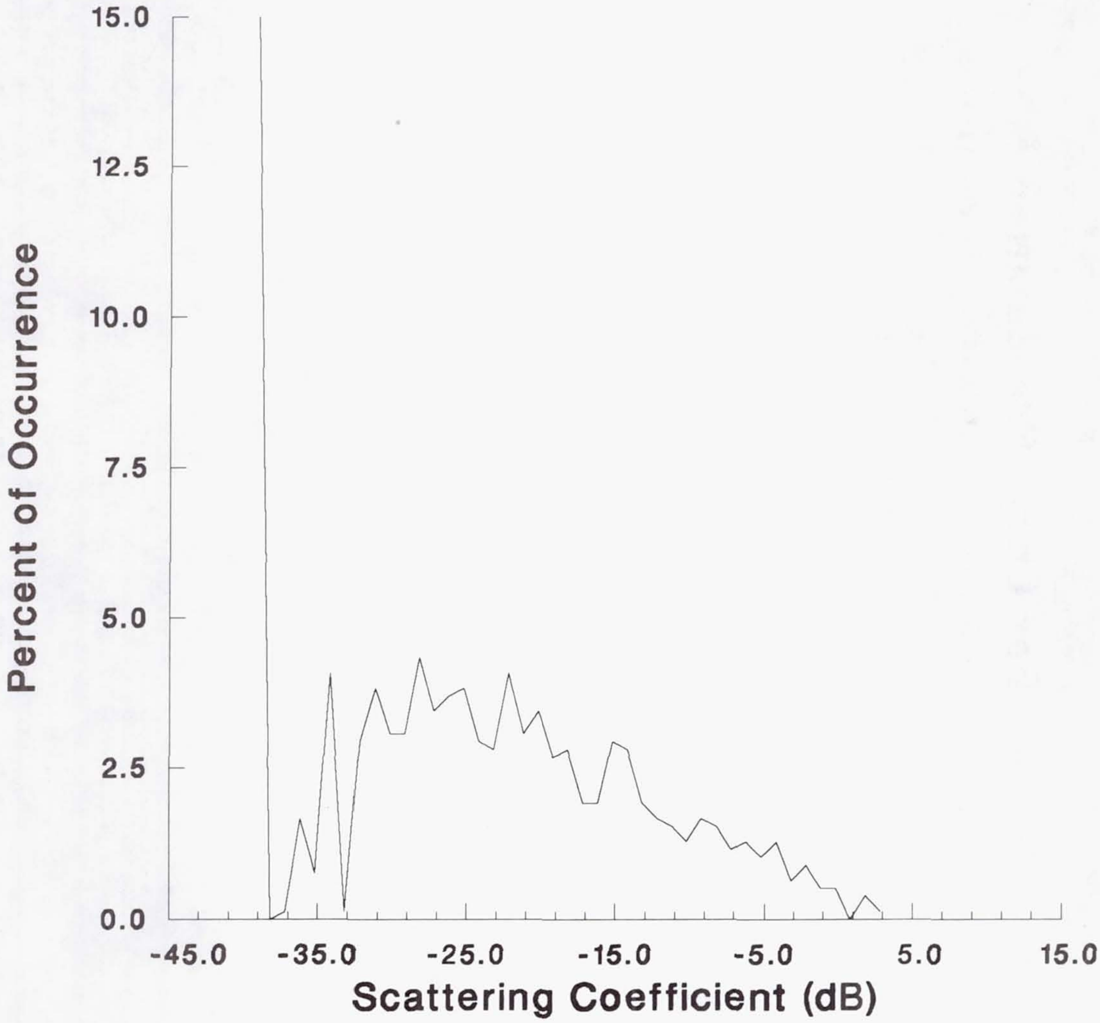


Figure 189.

Minimum: −39.69

Maximum: 2.40

Mean: −12.80

Bin Width: 1.00

Number of Bins: 43

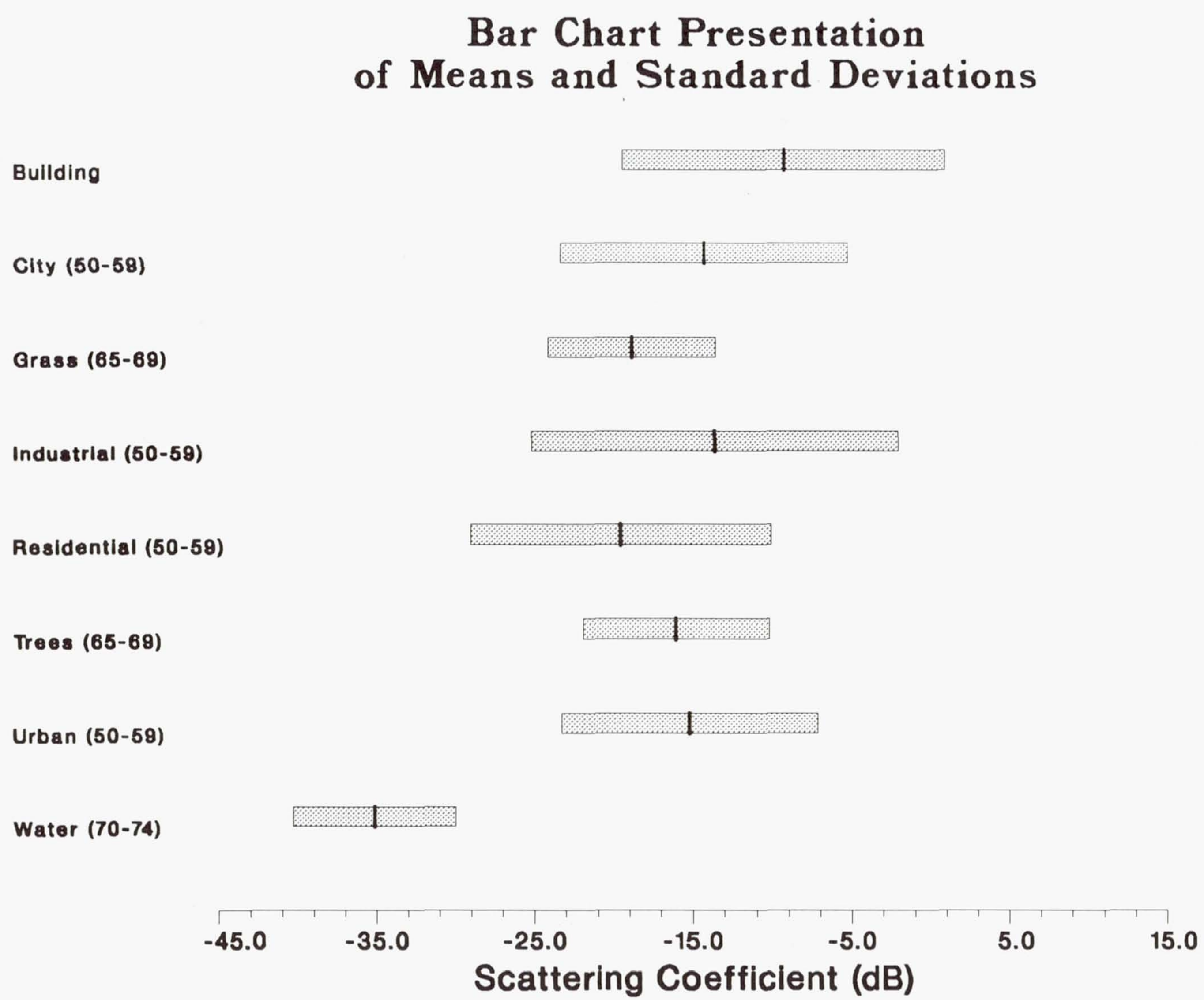


Figure 190. Mean NRCS Values, Denver Fourth 'Step West'

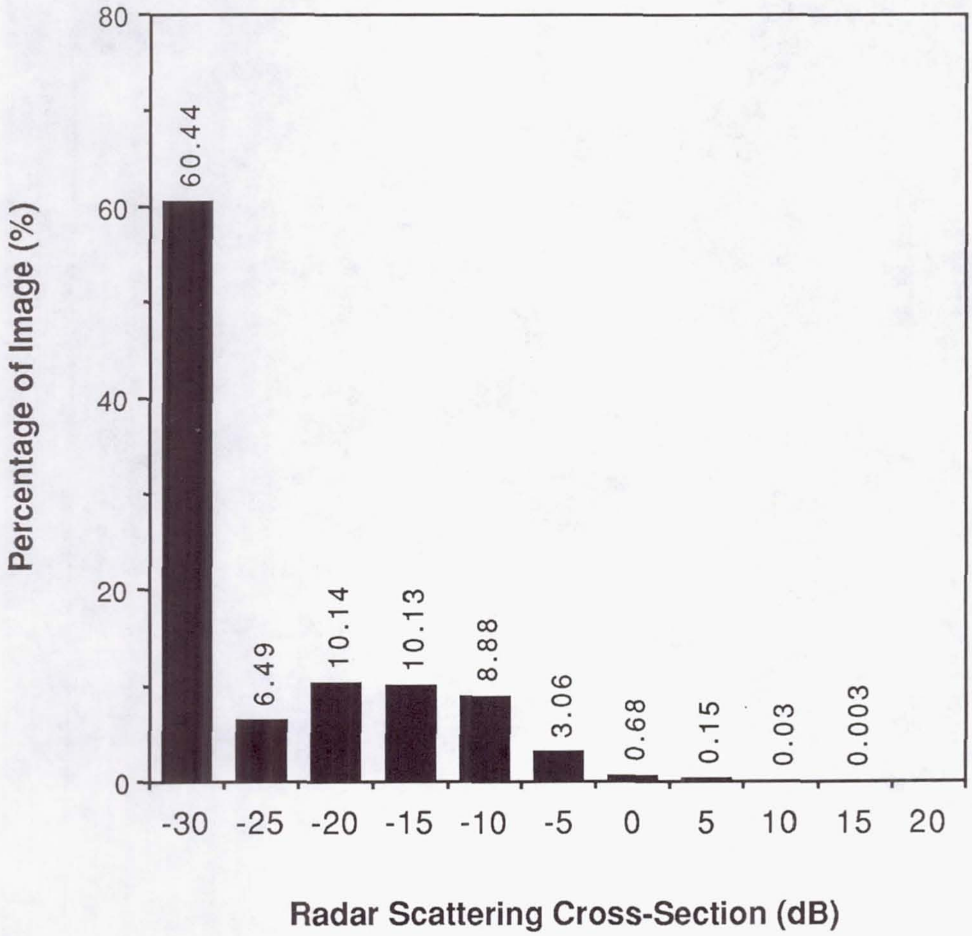


Figure 191. Distribution of Threshold Values, Denver Fourth 'Step West'

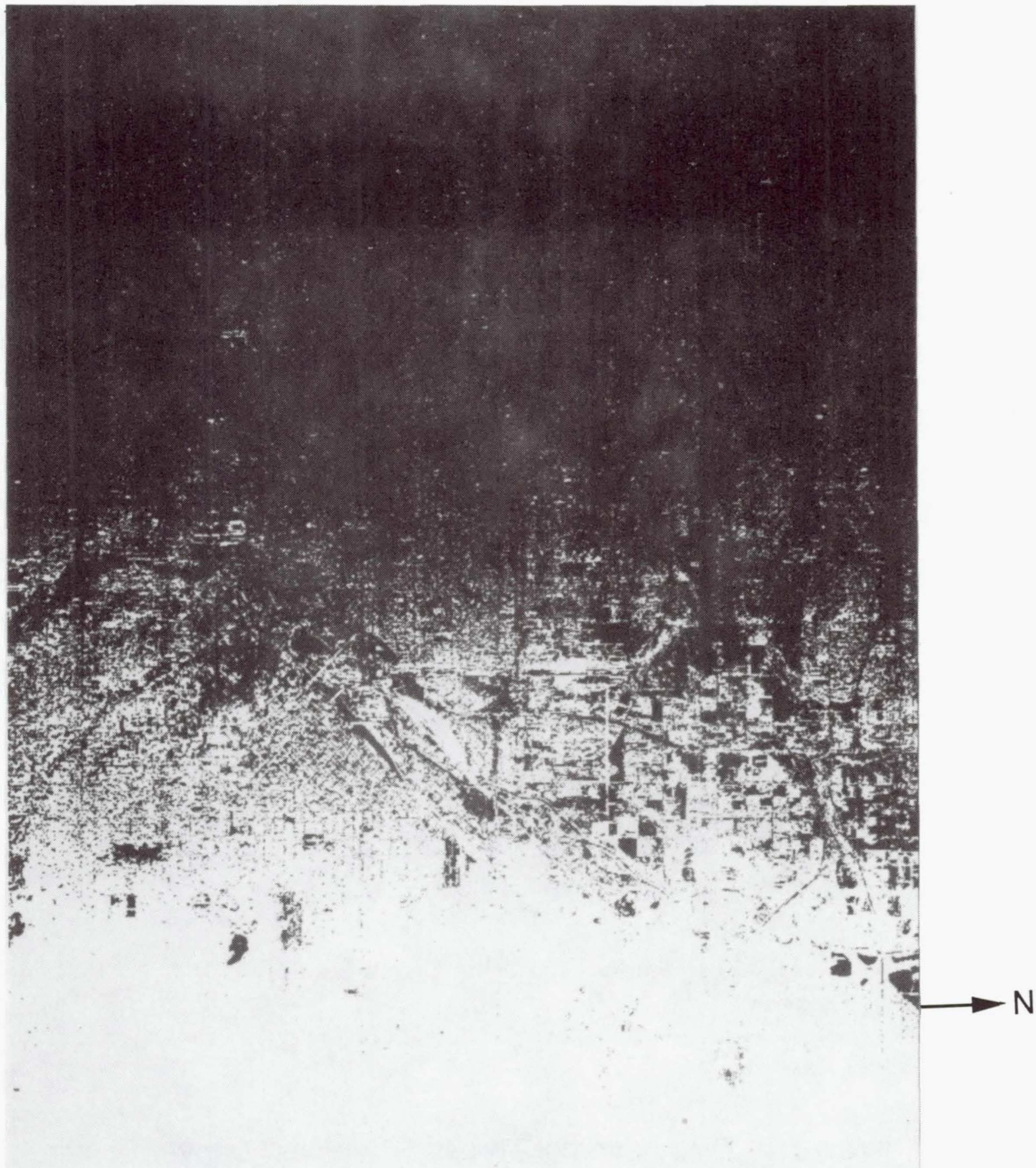


Figure 192. The Fourth Denver 'Step West' Image Thresholded at -30 dB

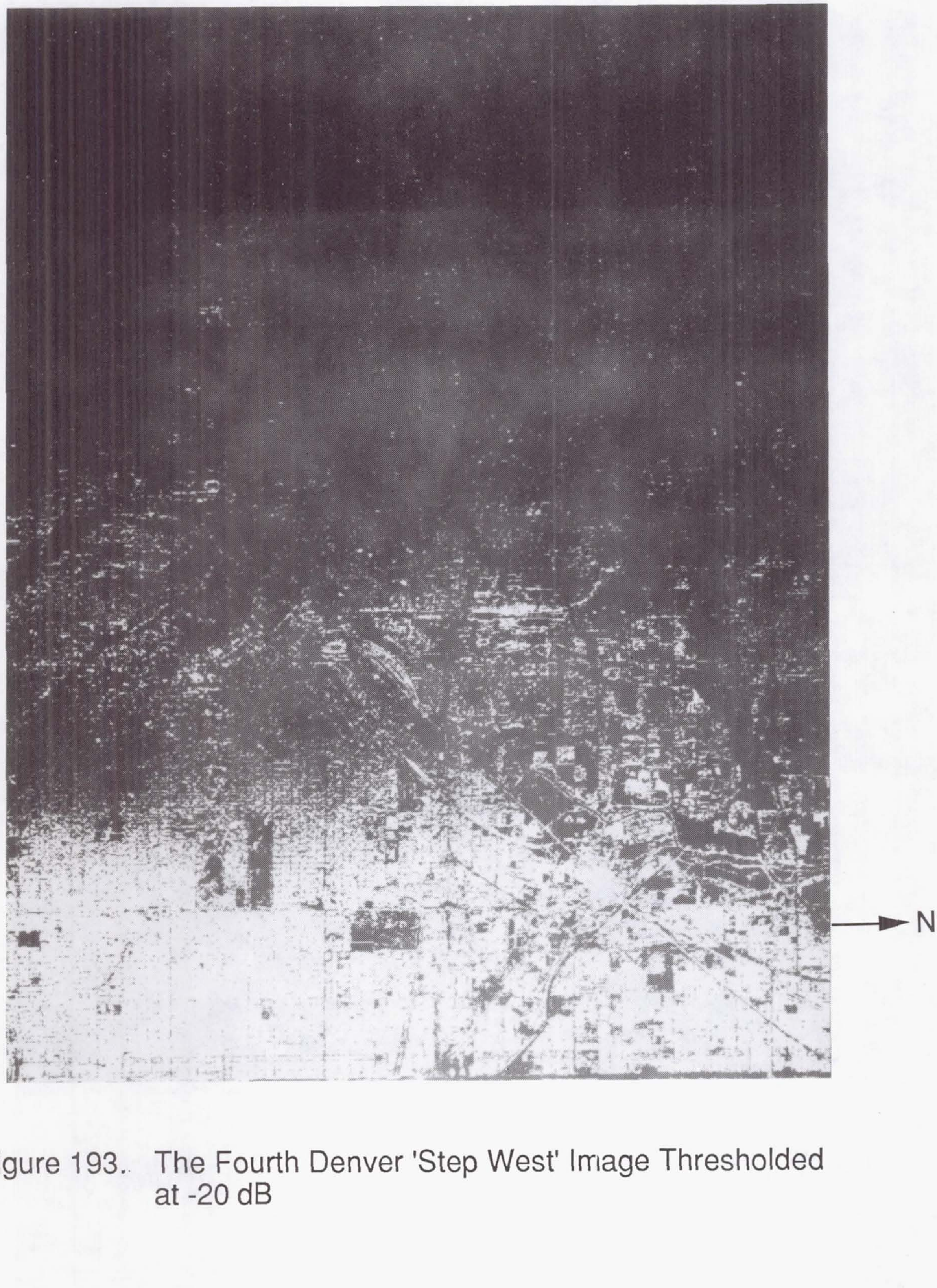


Figure 193.. The Fourth Denver 'Step West' Image Thresholded at -20 dB

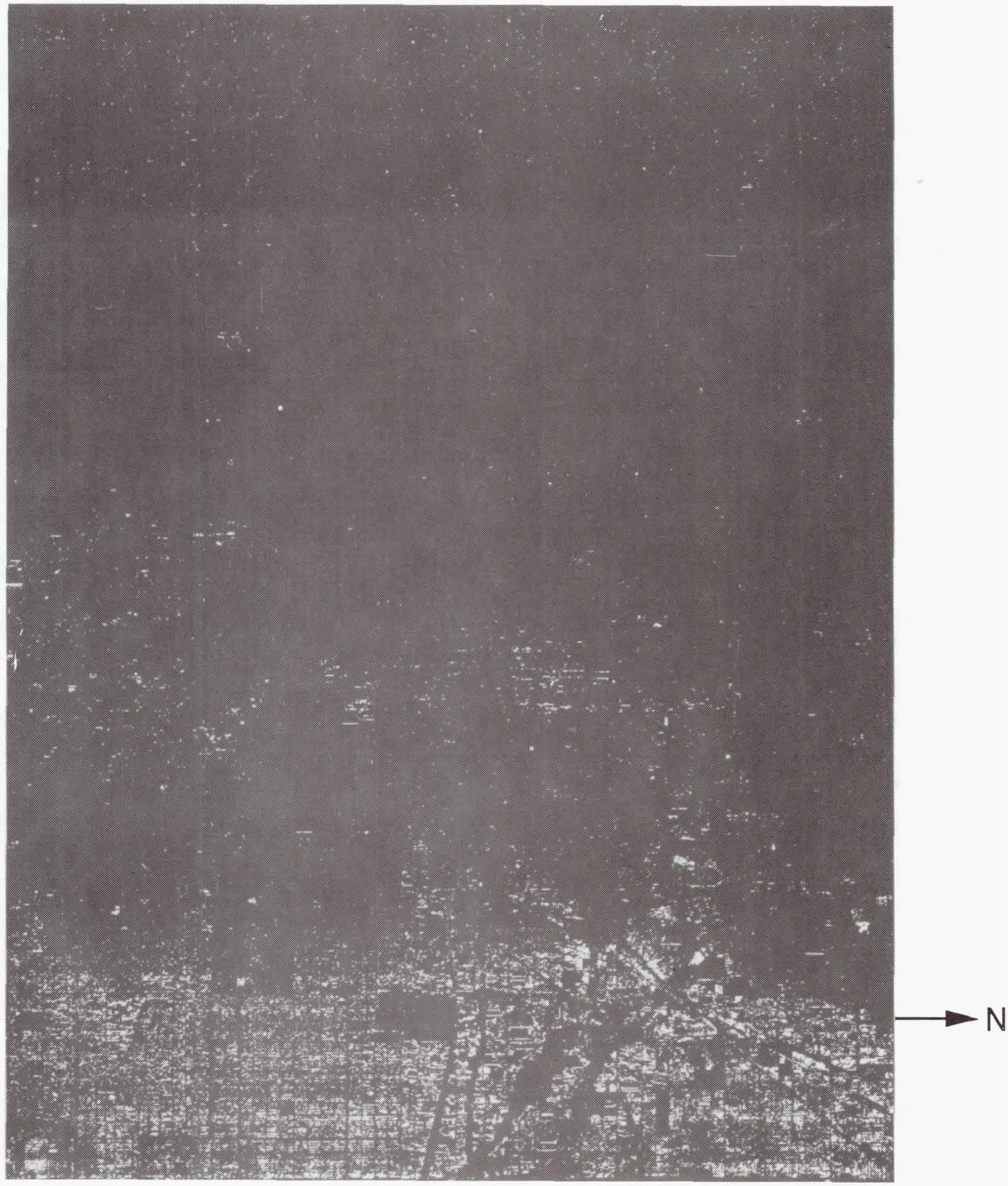


Figure 194. The Fourth Denver 'Step West' Image Thresholded at -10 dB

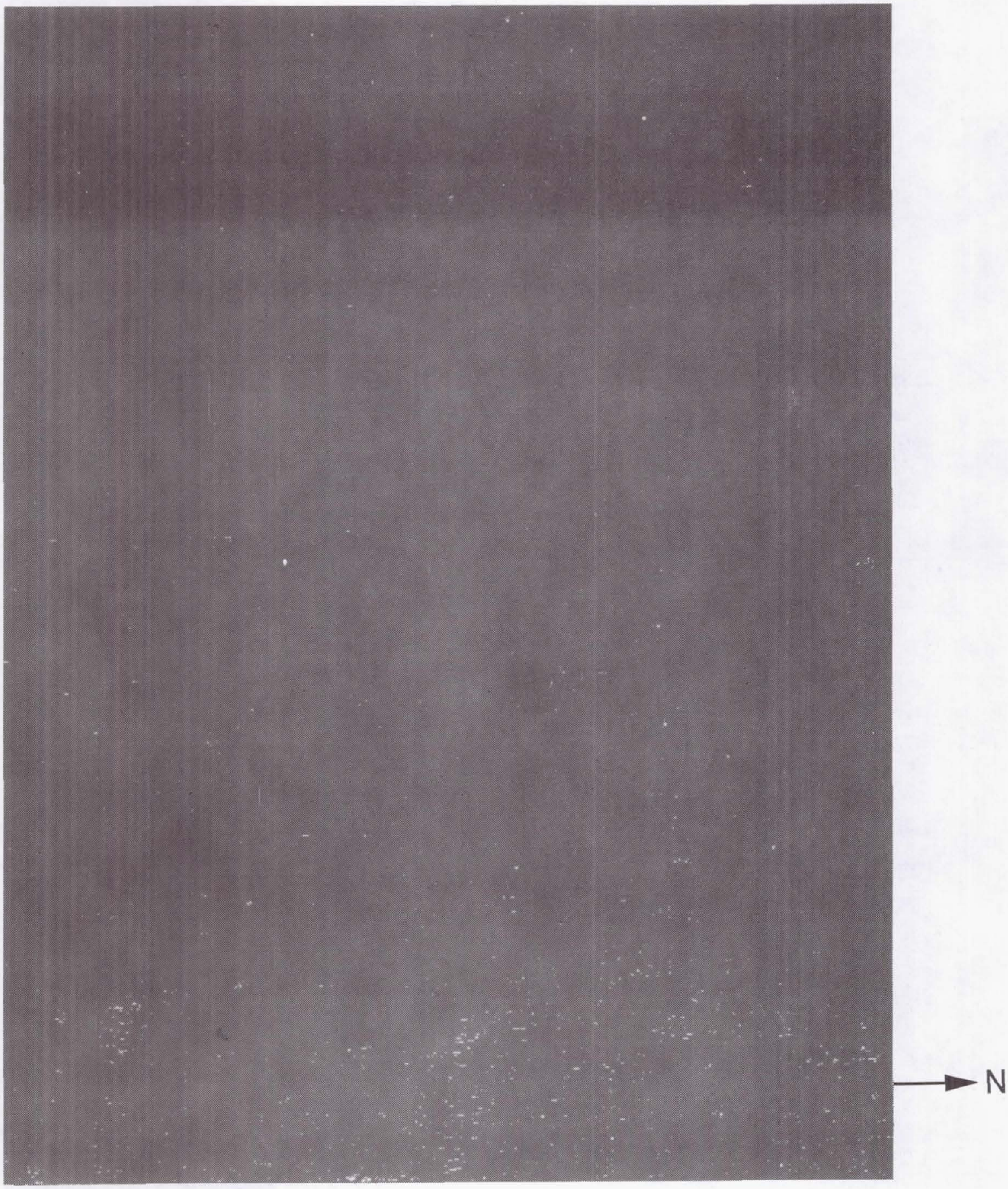


Figure 195. The Fourth Denver 'Step West' Image Thresholded at 0 dB

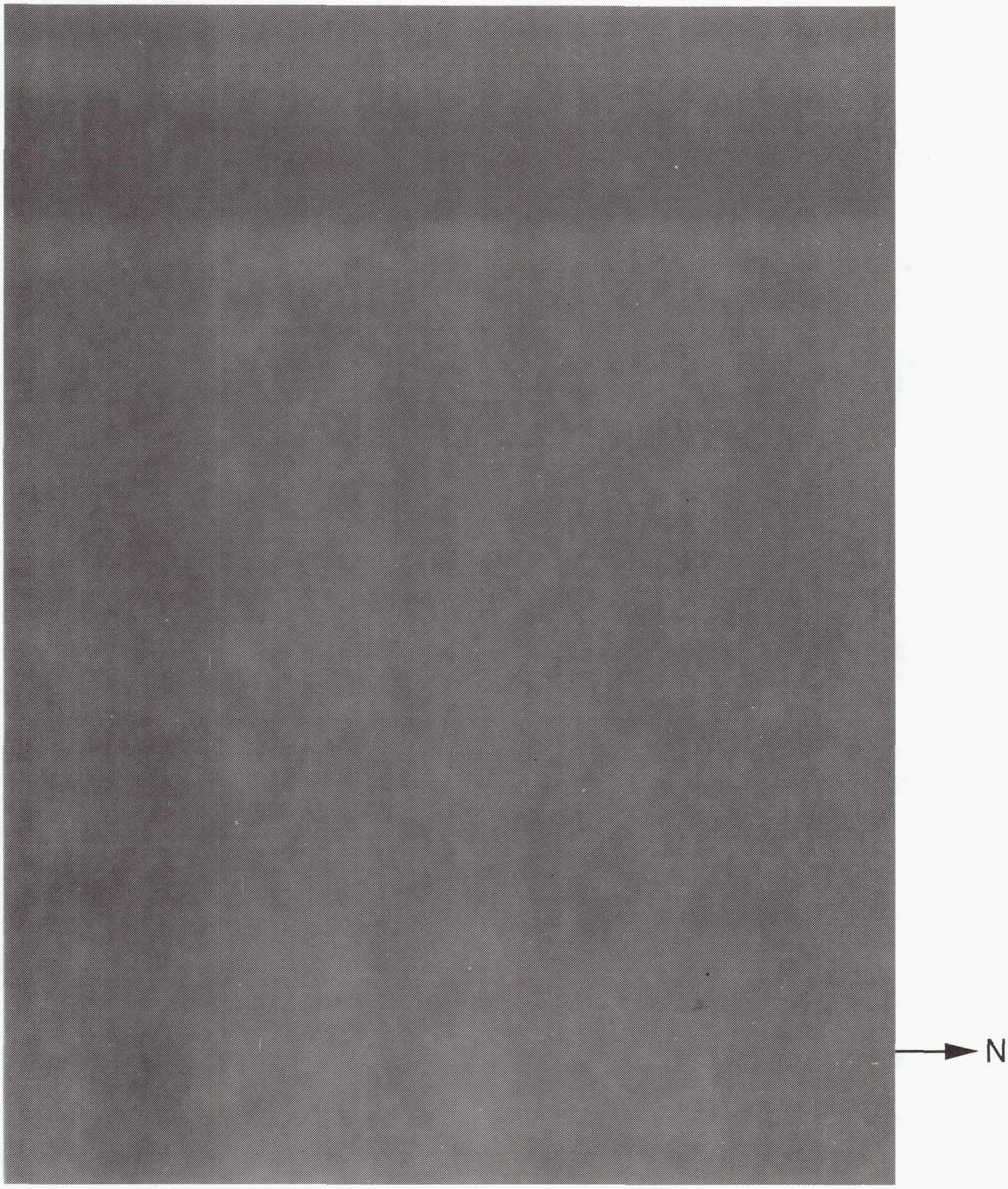


Figure 196. The Fourth Denver 'Step West' Image Thresholded at 10 dB

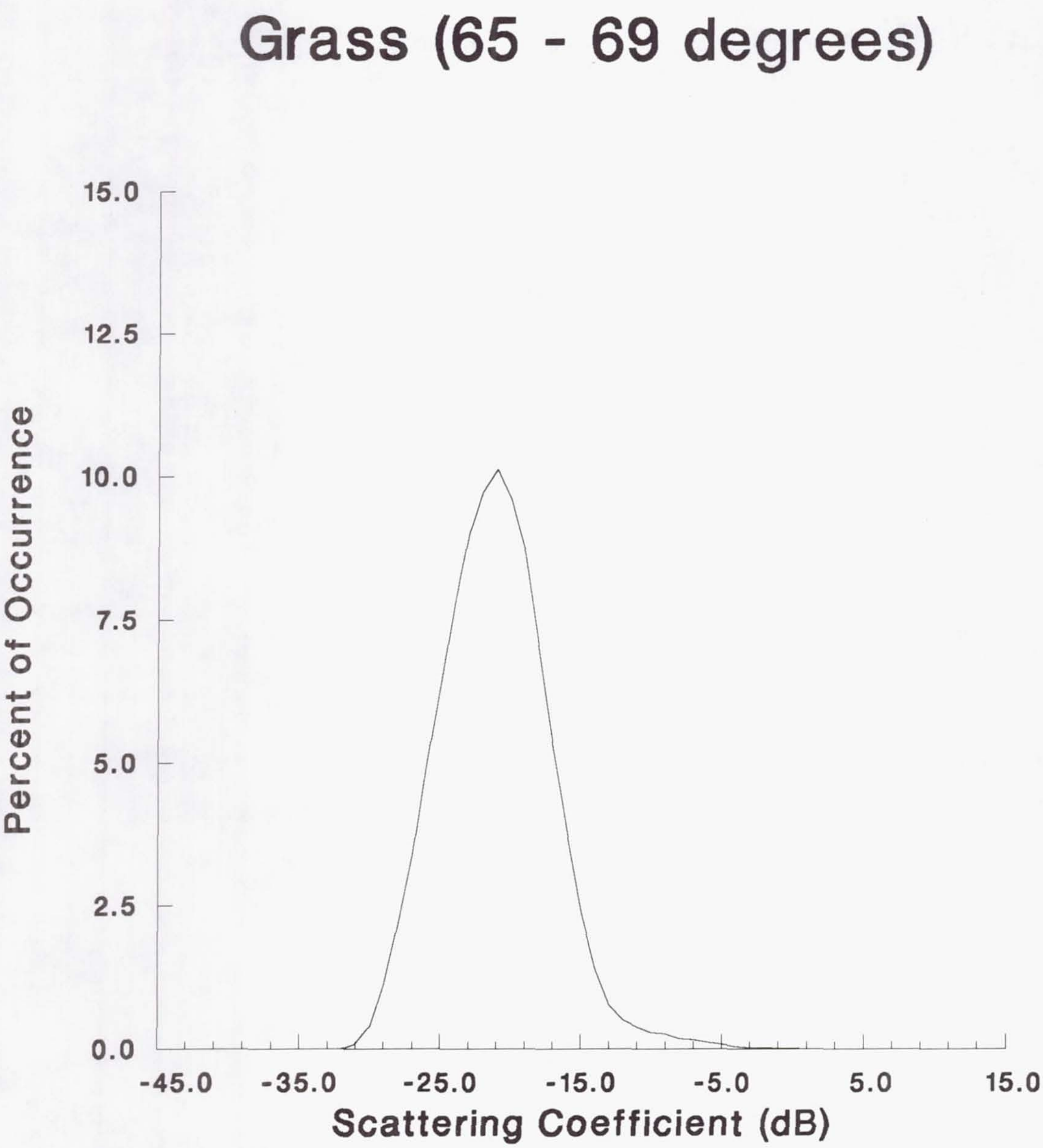


Figure 197.

Minimum: −39.53

Maximum: 0.14

Mean: −19.01

Bin Width: 1.00

Number of Bins: 41

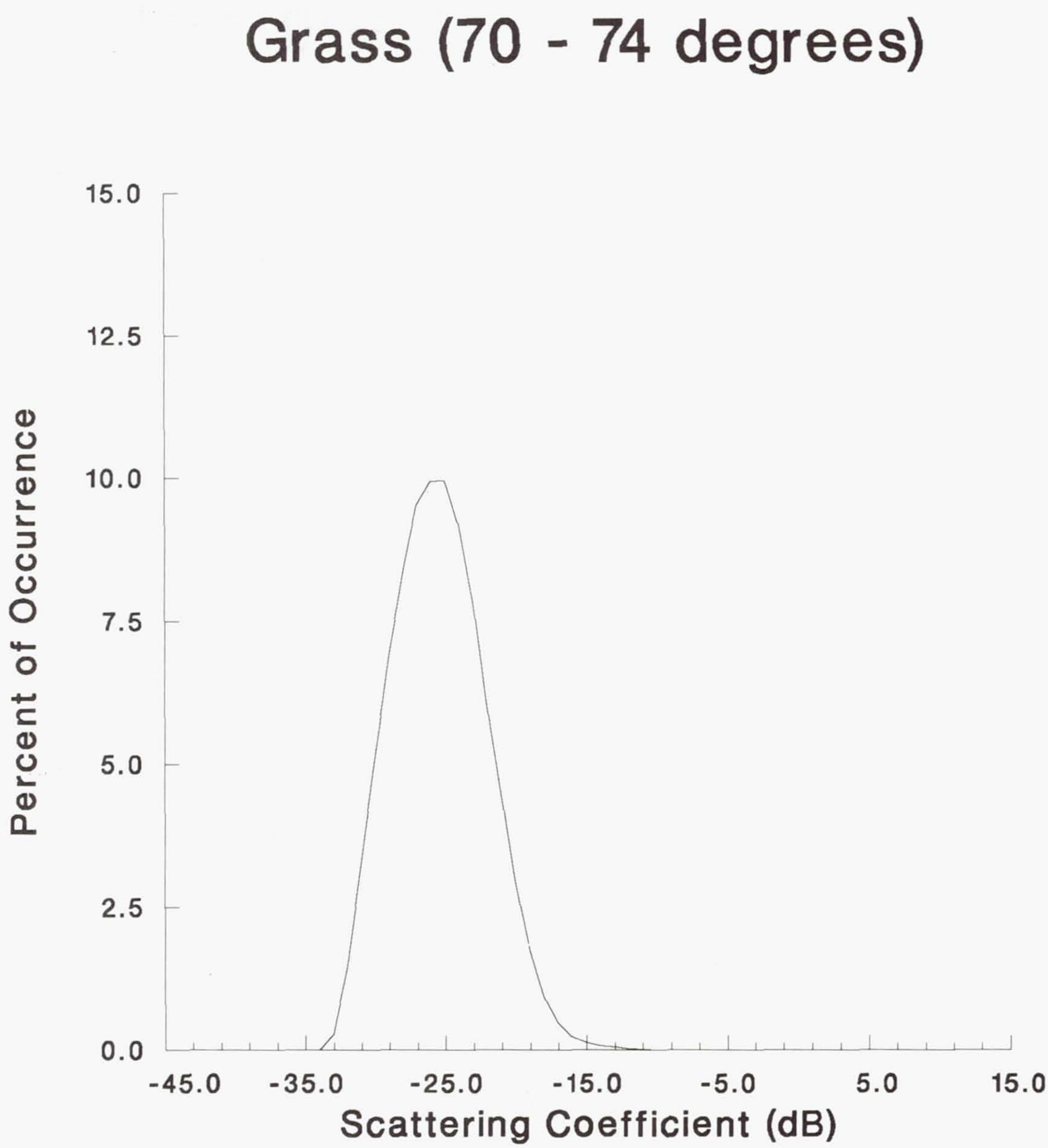


Figure 198.

Minimum: −39.53

Maximum: −9.74

Mean: −24.63

Bin Width: 1.00

Number of Bins: 31

Residential (50 - 59 degrees)

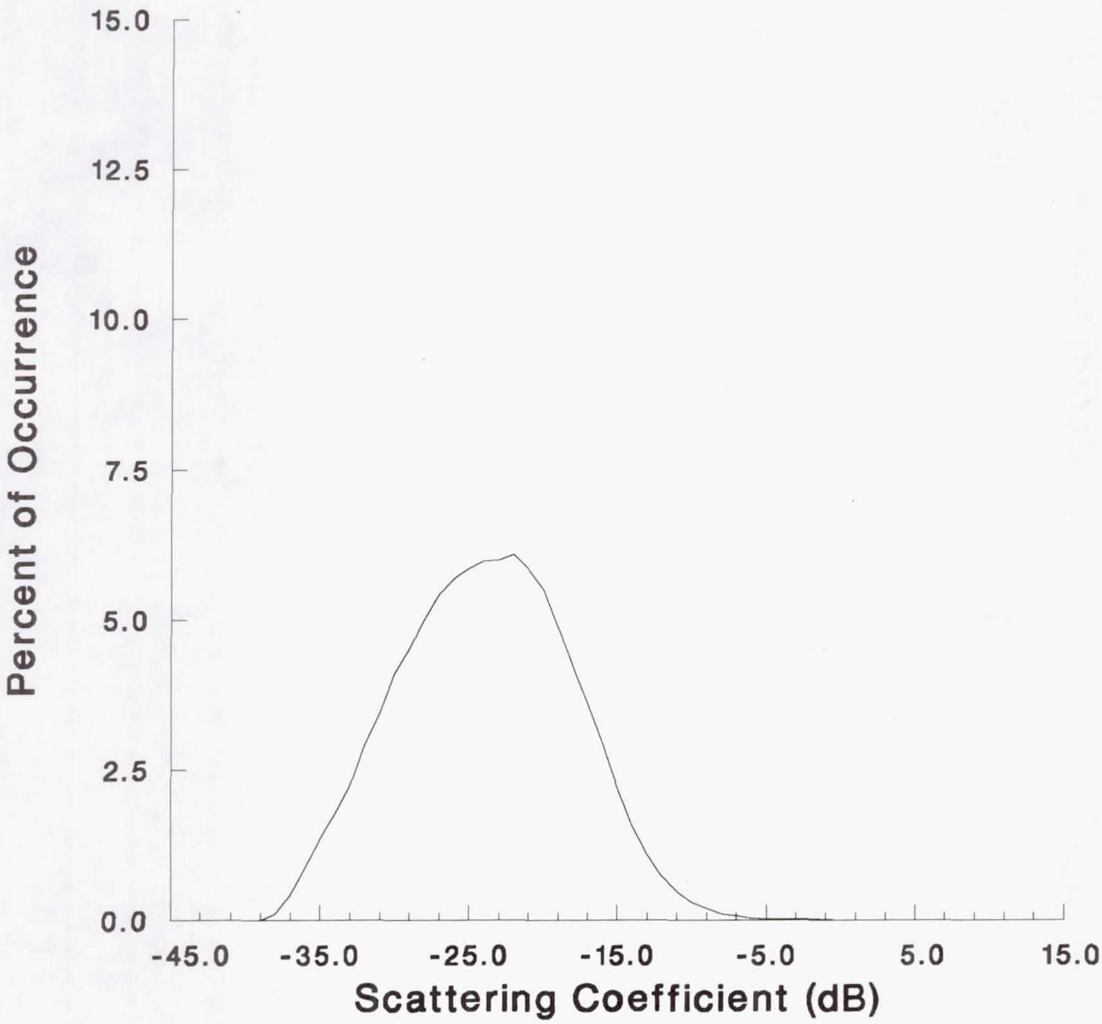


Figure 199.

Minimum: −39.53
Maximum: 9.47
Mean: −19.67
Bin Width: 1.00
Number of Bins: 50

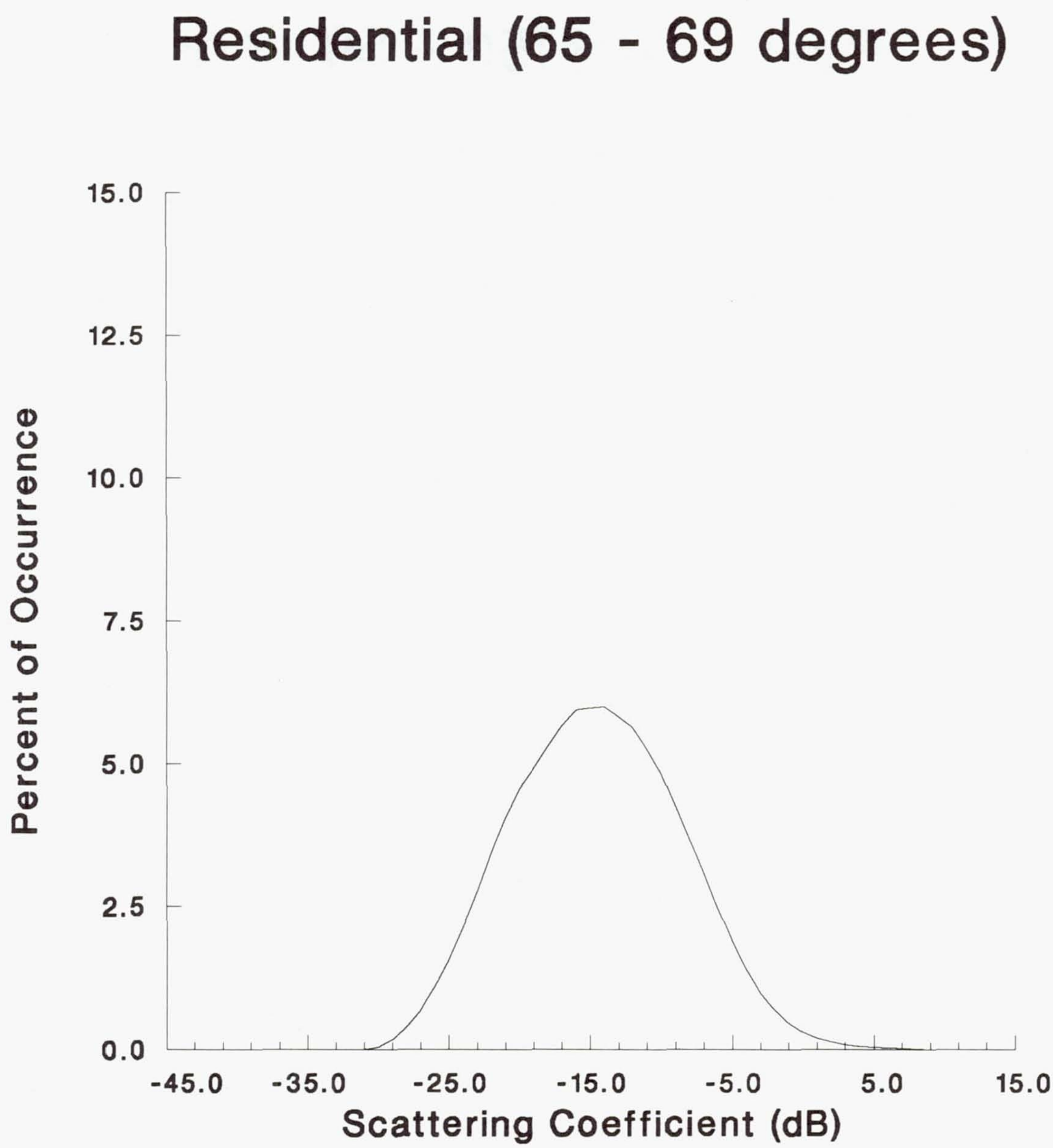


Figure 200.

Minimum: −39.53
Maximum: 12.79
Mean: −10.43
Bin Width: 1.00
Number of Bins: 53

Residential (70 - 74 degrees)

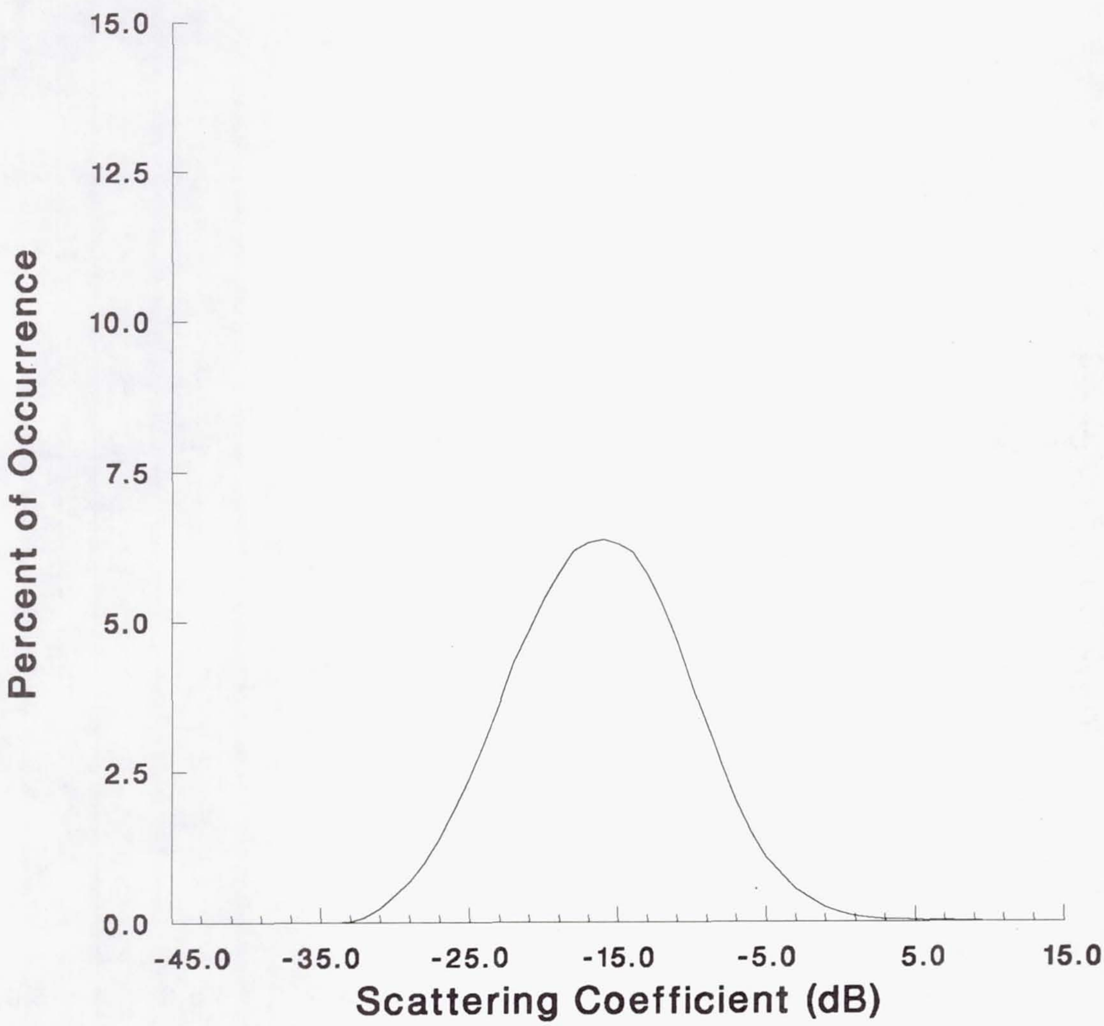


Figure 201.

Minimum: −39.53
Maximum: 11.72
Mean: −11.76
Bin Width: 1.00
Number of Bins: 52

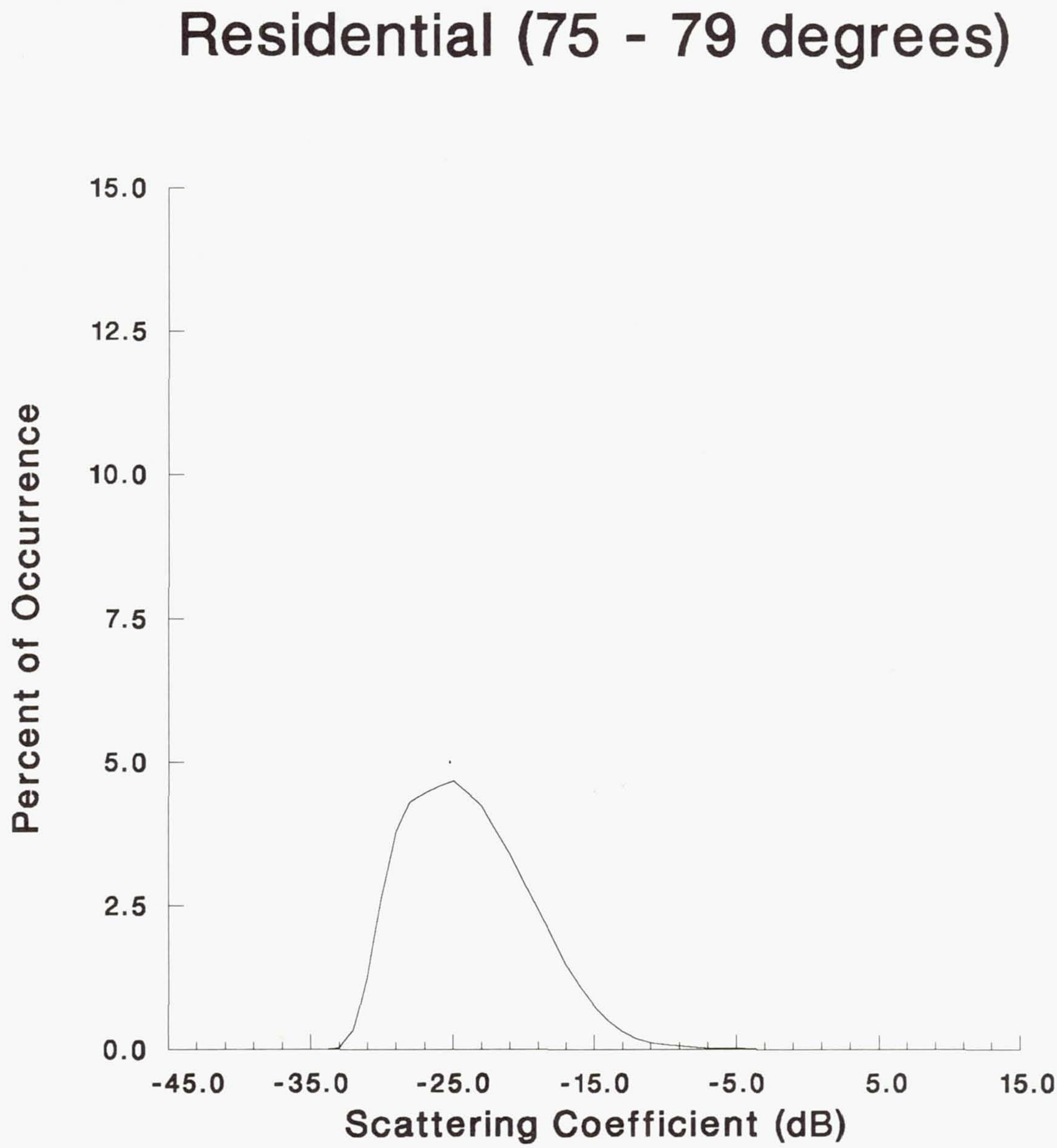


Figure 202.

Minimum: −39.53

Maximum: 3.65

Mean: −23.61

Bin Width: 1.00

Number of Bins: 44

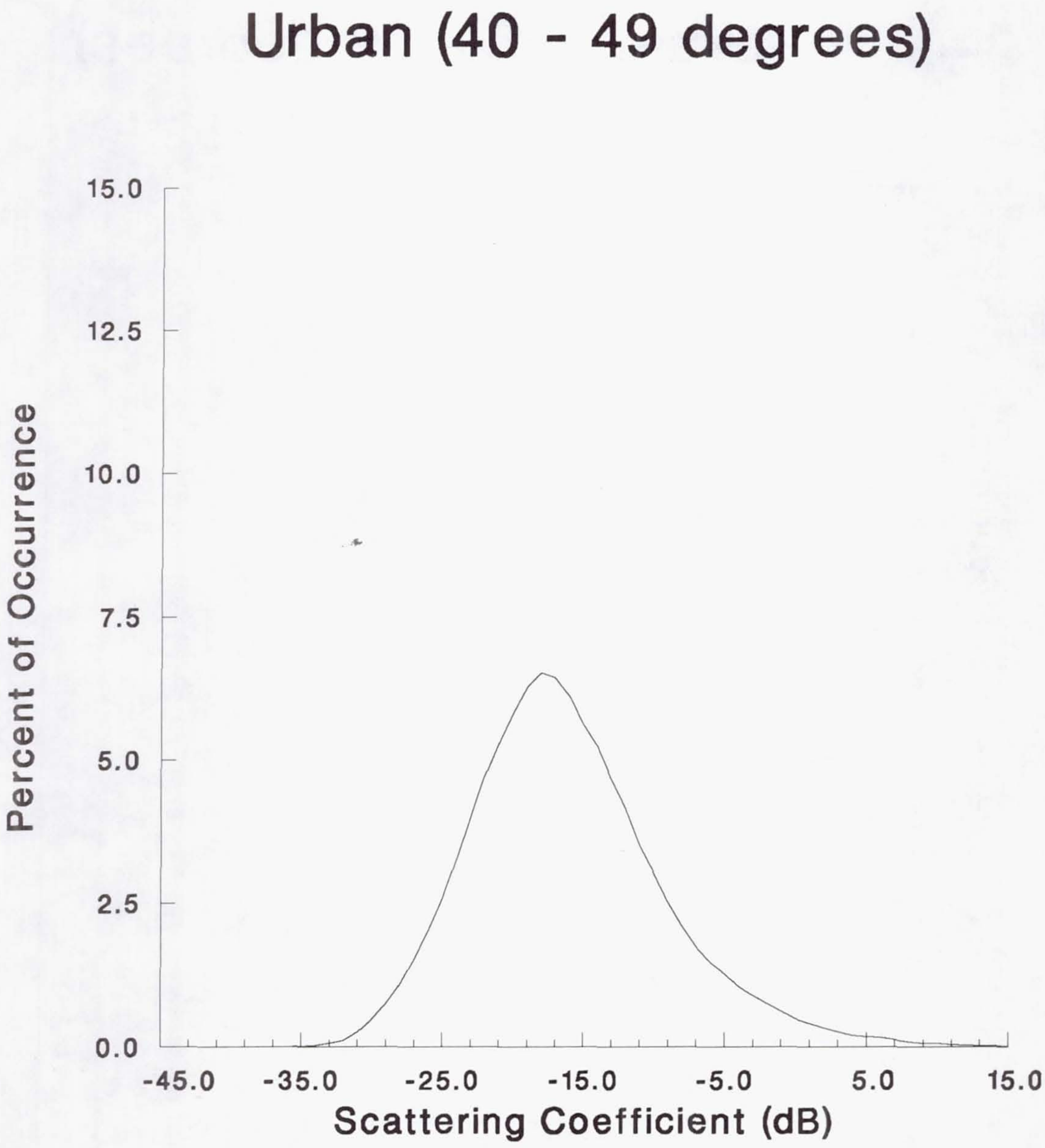


Figure 203.

Minimum: −39.53

Maximum: 27.34

Mean: −6.65

Bin Width: 1.00

Number of Bins: 68

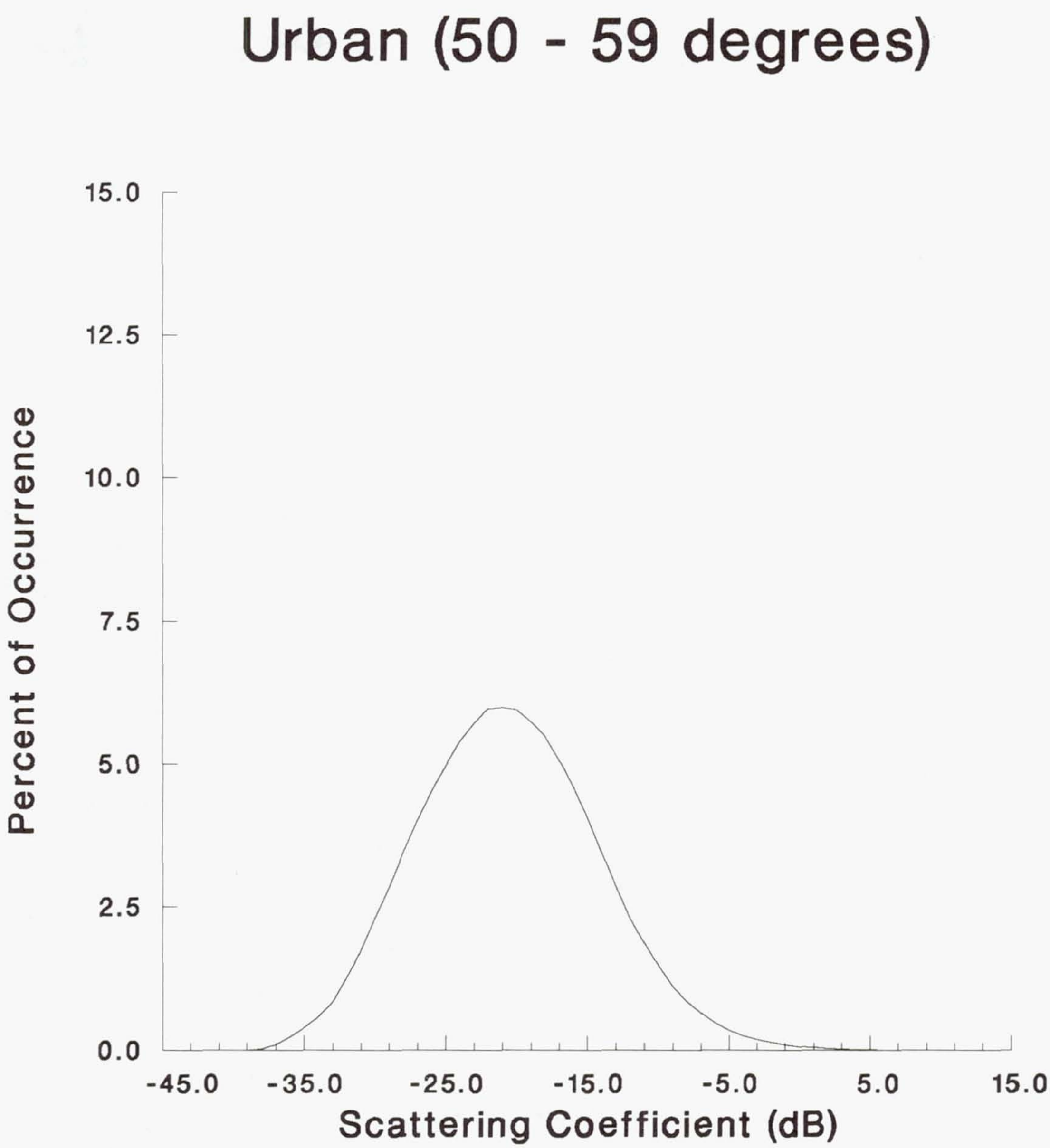


Figure 204.

Minimum: −39.53
Maximum: 14.80
Mean: −15.27
Bin Width: 1.00
Number of Bins: 55

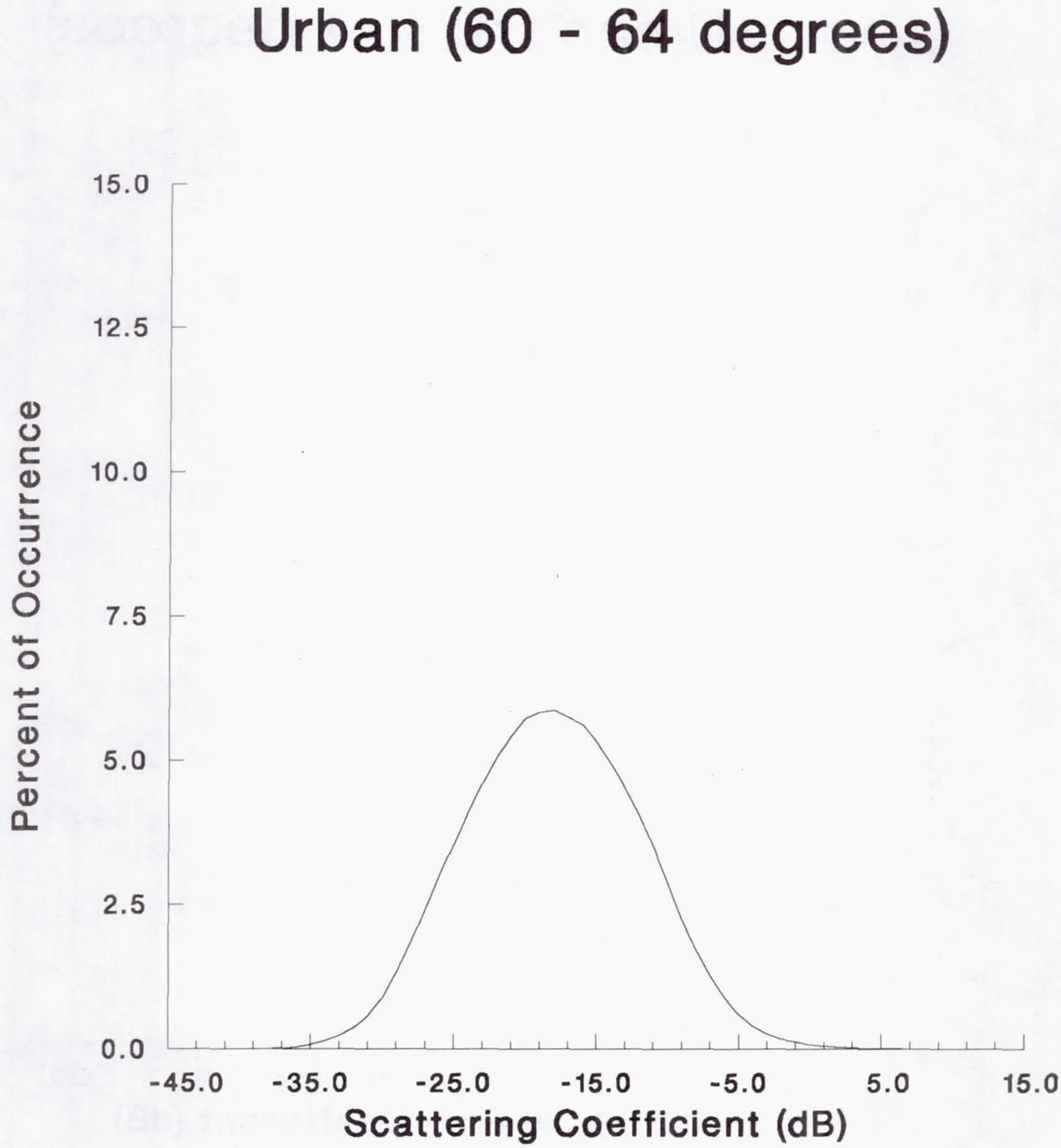


Figure 205.

Minimum: −39.53

Maximum: 12.18

Mean: −13.65

Bin Width: 1.00

Number of Bins: 53

Urban (70 - 74 degrees)

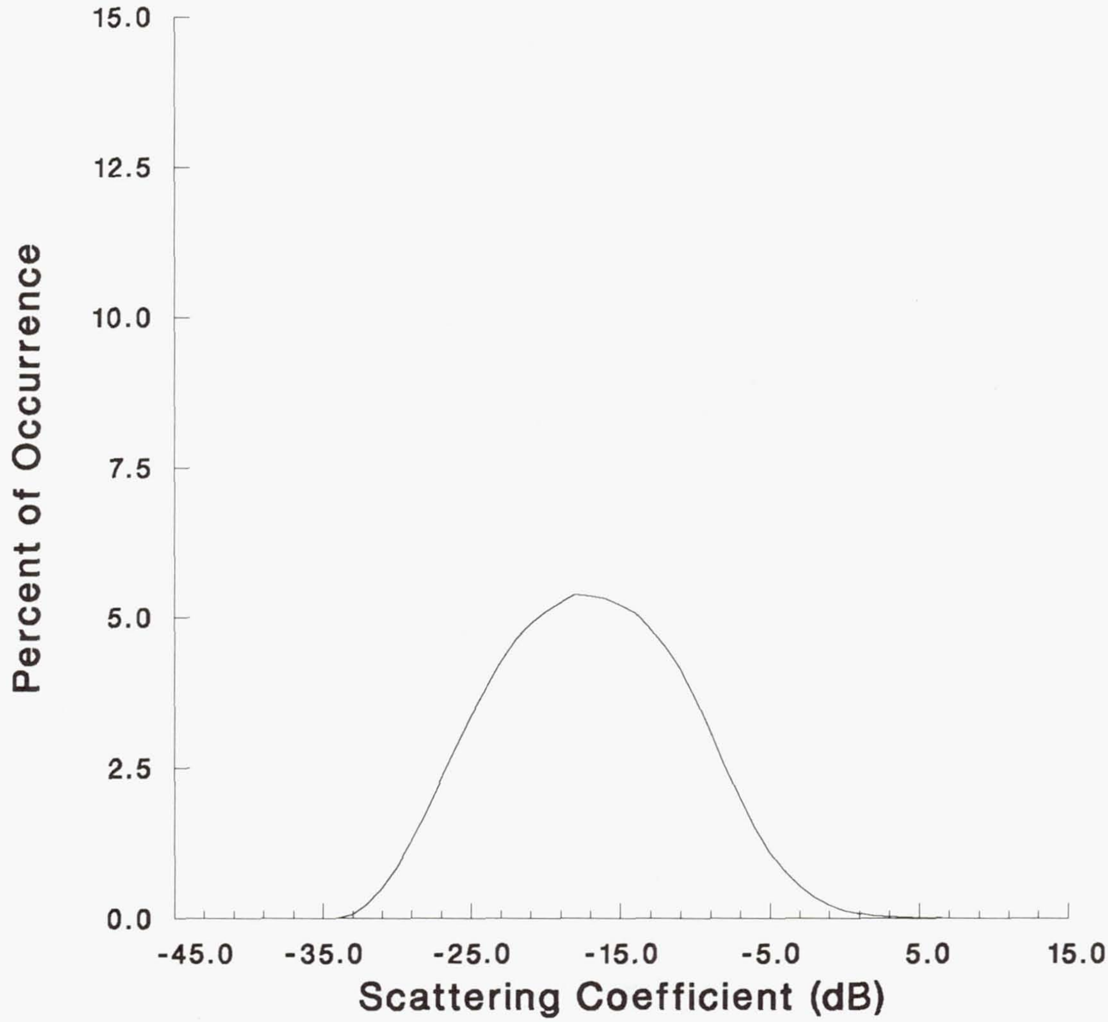


Figure 206.

Minimum: −39.53
Maximum: 15.86
Mean: −12.45
Bin Width: 1.00
Number of Bins: 56

Urban (75 - 79 degrees)

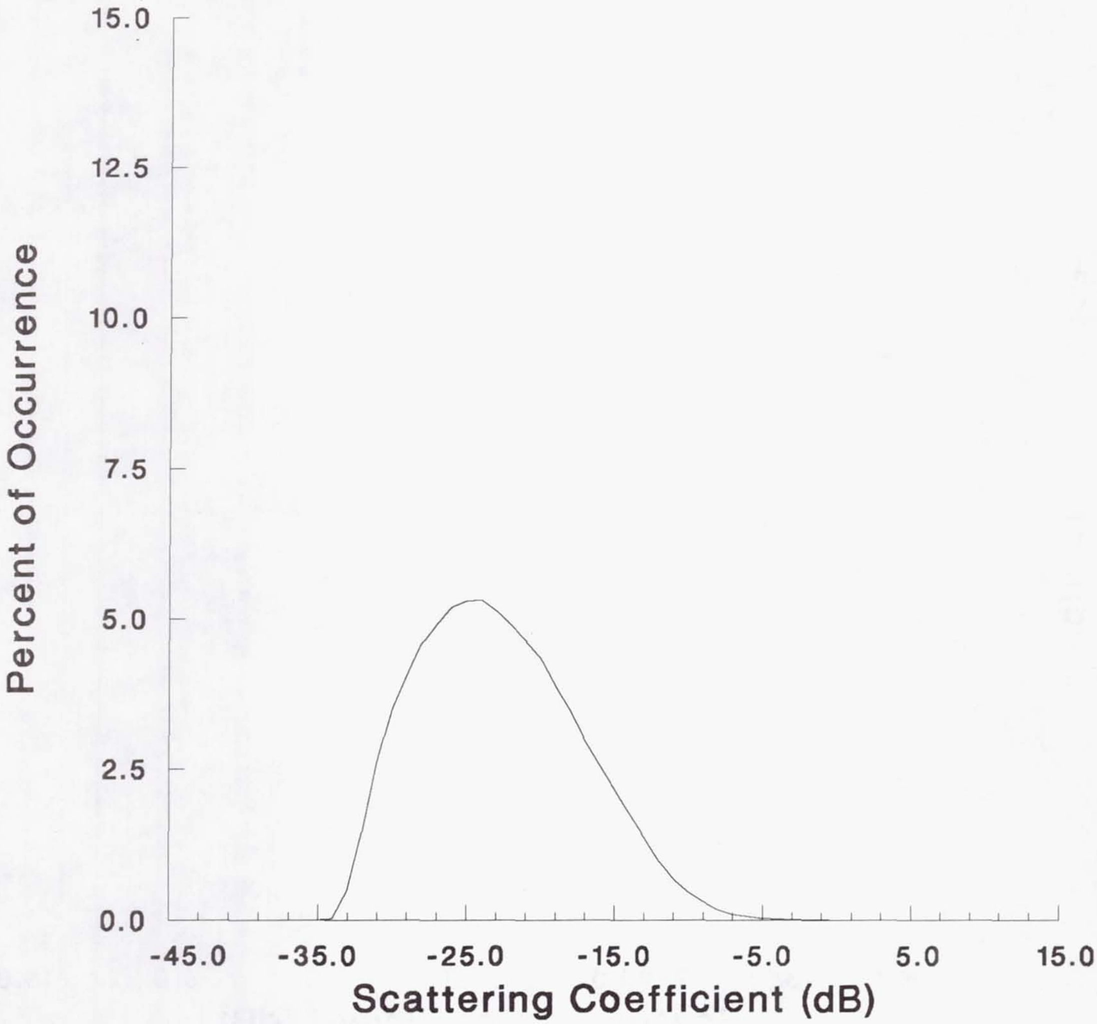


Figure 207.

Minimum: −39.53

Maximum: 3.75

Mean: −20.10

Bin Width: 1.00

Number of Bins: 44

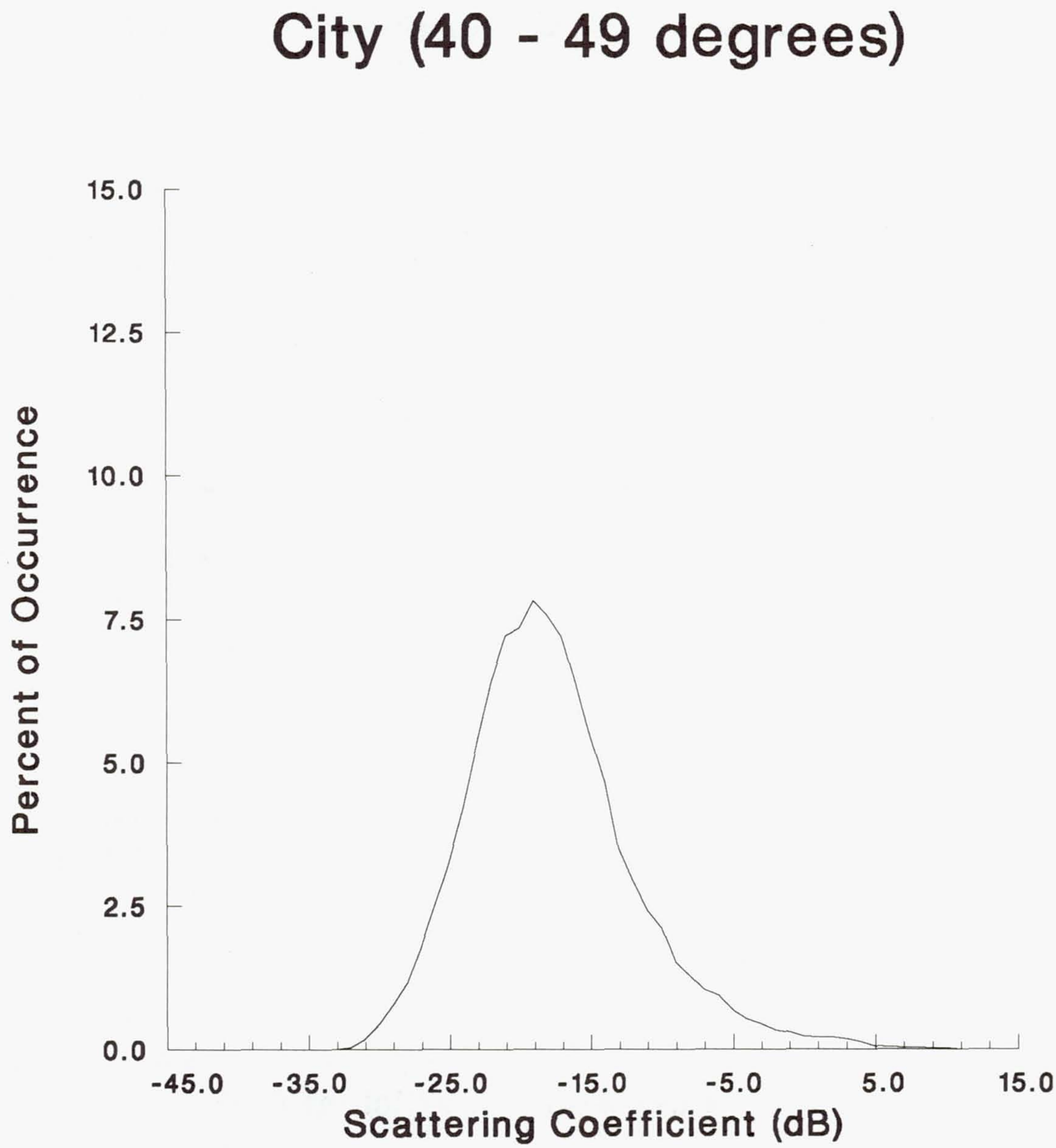


Figure 208.

Minimum: −39.53

Maximum: 11.18

Mean: −11.76

Bin Width: 1.00

Number of Bins: 52

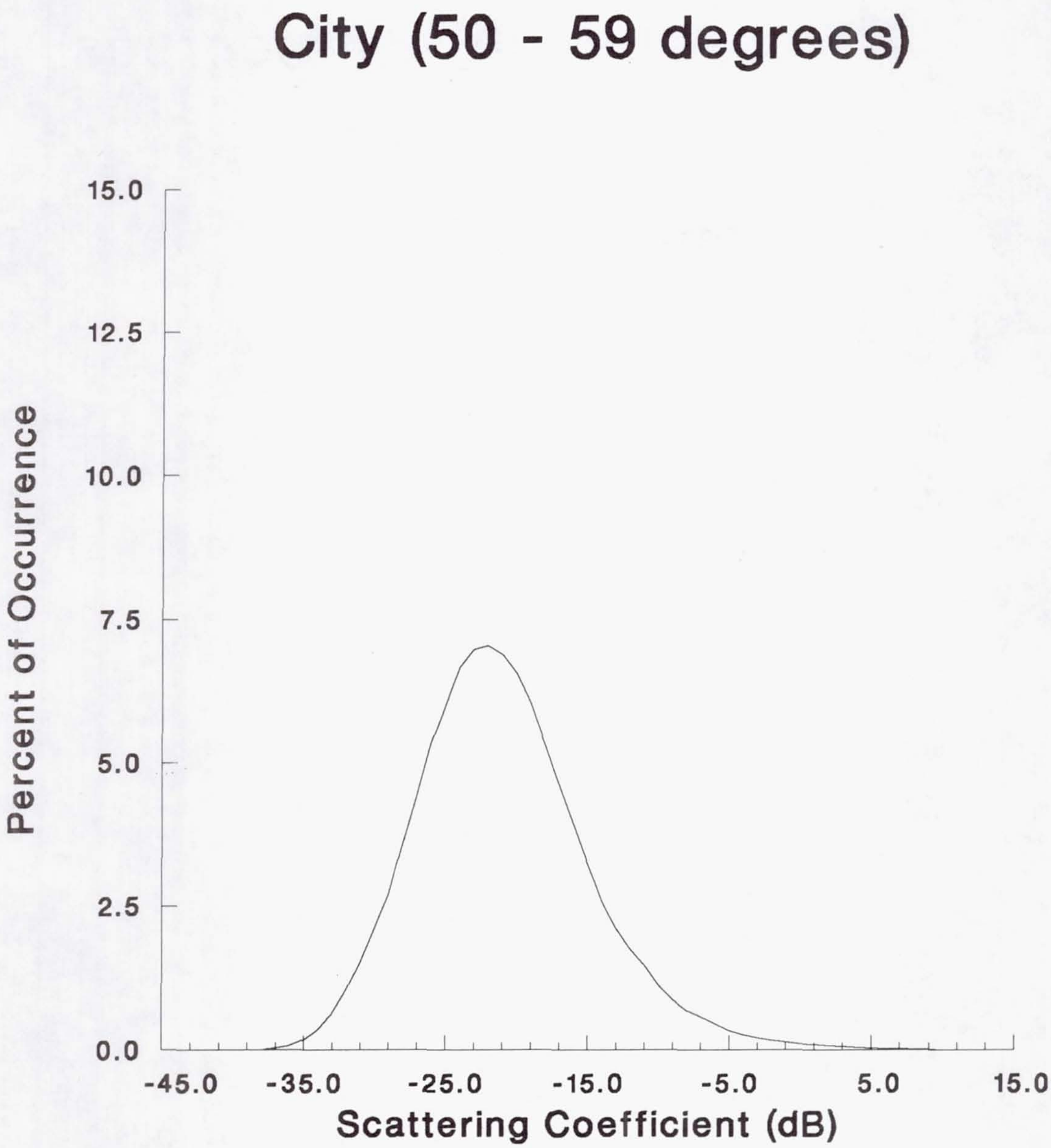


Figure 209.

Minimum: −39.53

Maximum: 12.58

Mean: −14.48

Bin Width: 1.00

Number of Bins: 53

City (60 - 64 degrees)

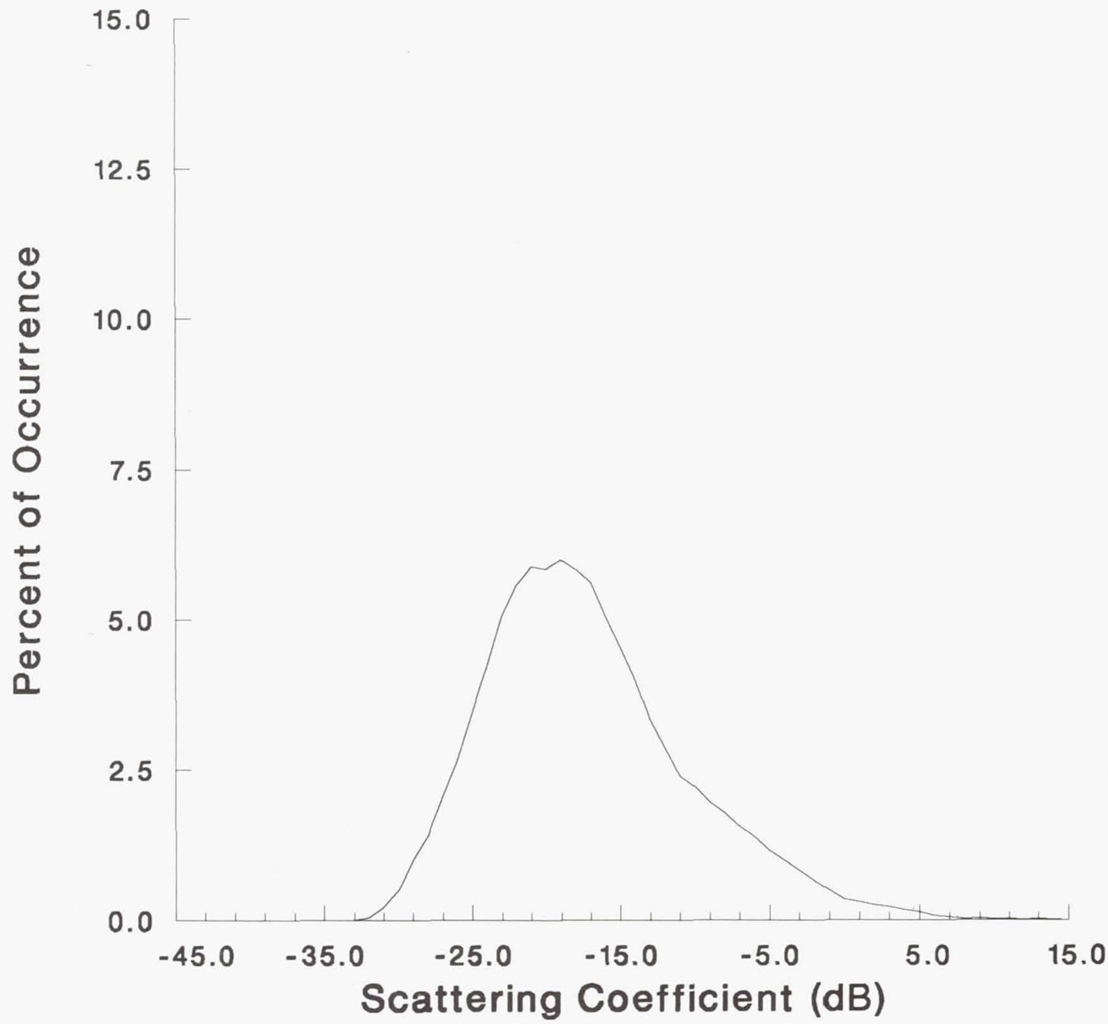


Figure 210.

Minimum: −39.53
Maximum: 17.35
Mean: −9.58
Bin Width: 1.00
Number of Bins: 58

City (65 - 69 degrees)

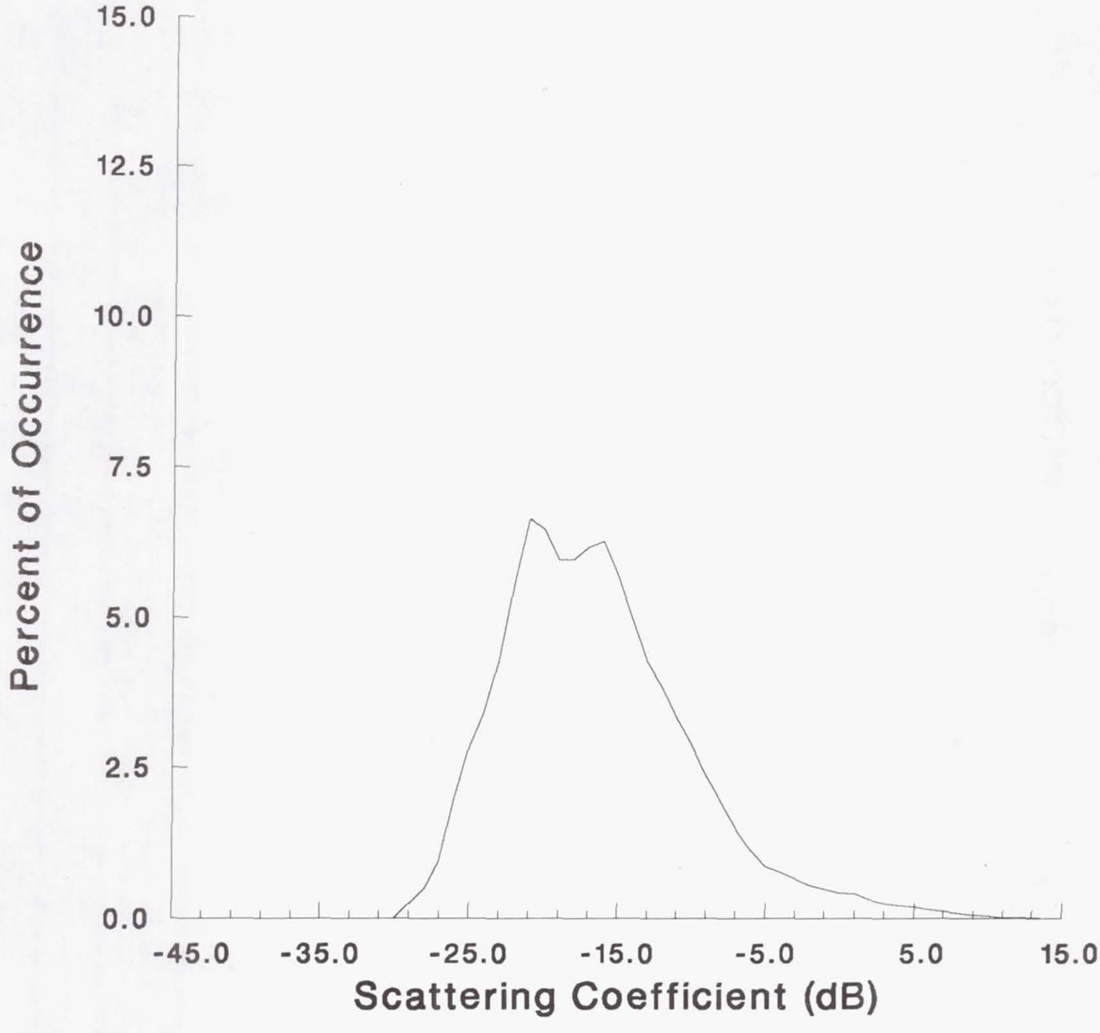


Figure 211.

Minimum: −39.53
Maximum: 15.78
Mean: −9.16
Bin Width: 1.00
Number of Bins: 56

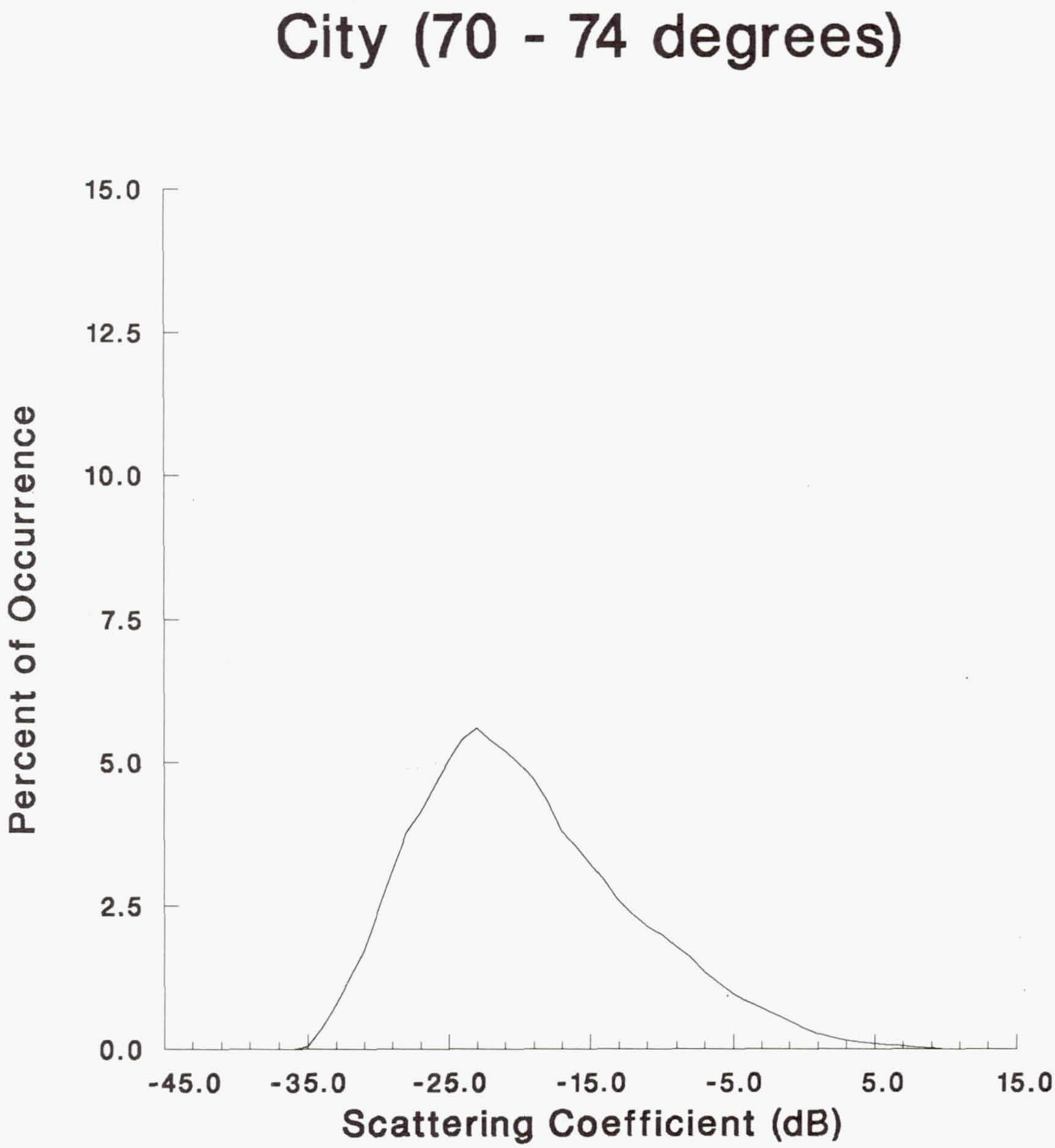


Figure 212.

Minimum: −39.53
Maximum: 9.95
Mean: −11.48
Bin Width: 1.00
Number of Bins: 50

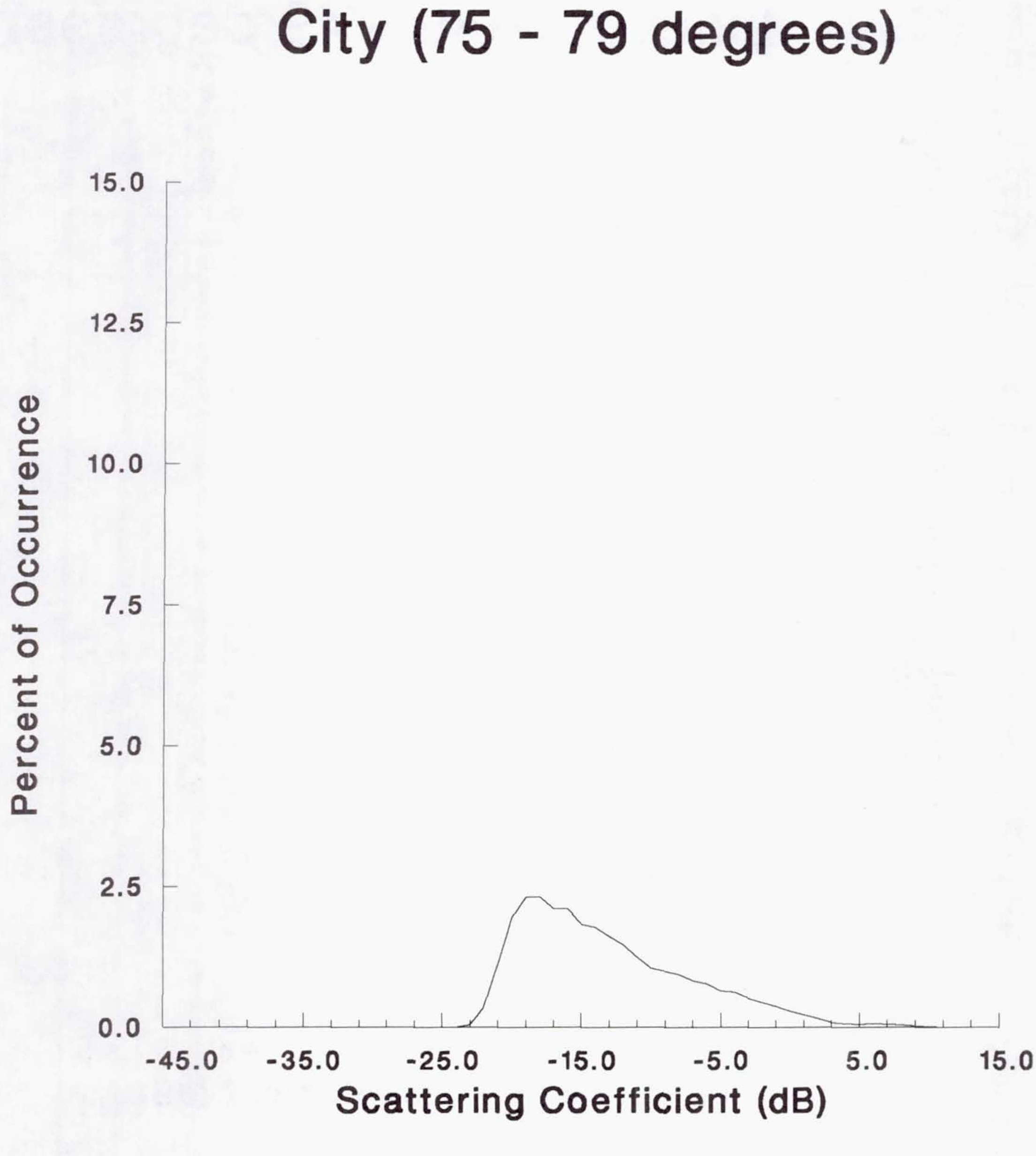


Figure 213.

Minimum: −39.53
Maximum: 10.13
Mean: −12.93
Bin Width: 1.00
Number of Bins: 51

Industrial (40 - 49 degrees)

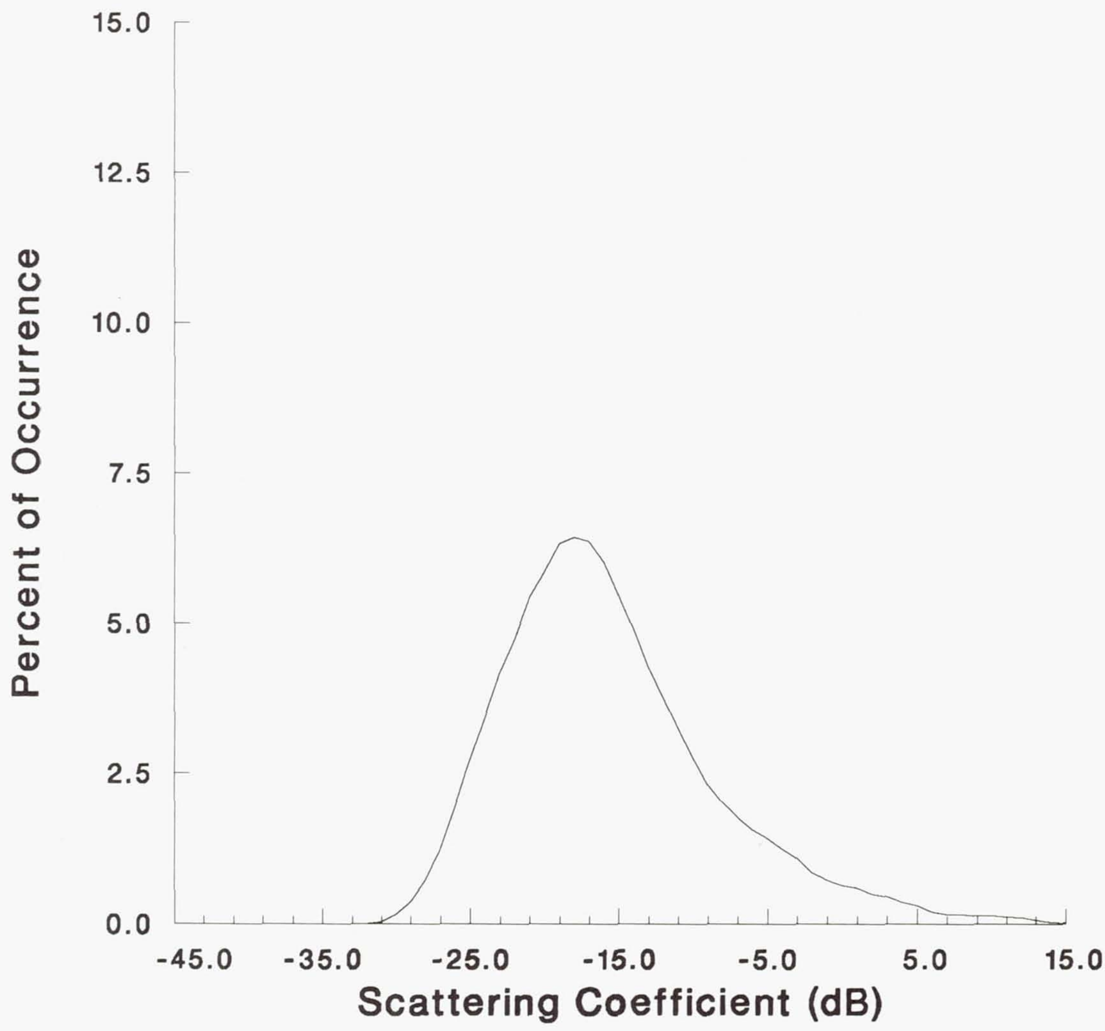


Figure 214.

Minimum: −39.53

Maximum: 16.51

Mean: −6.25

Bin Width: 1.00

Number of Bins: 57

Industrial (50 - 59 degrees)

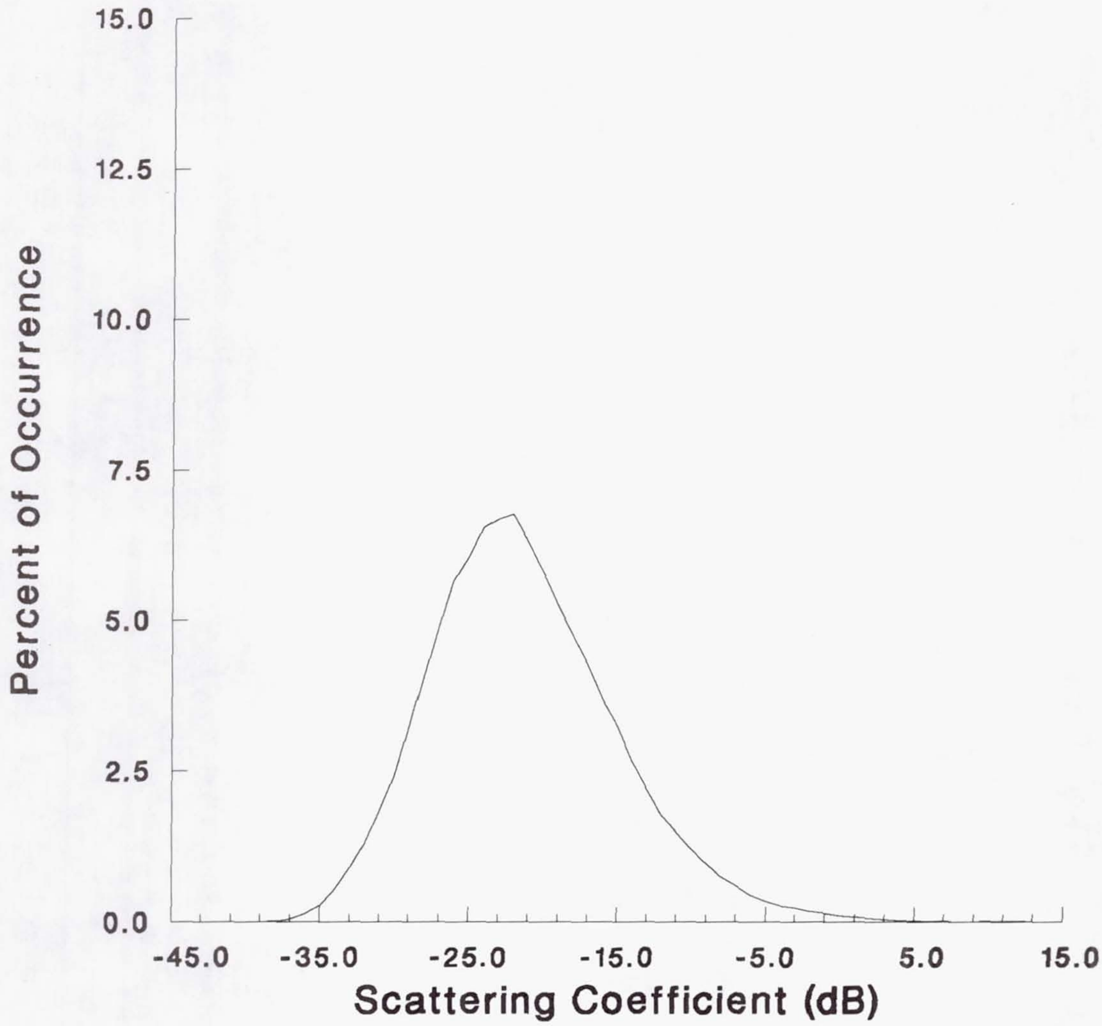


Figure 215.

Minimum: −39.53
Maximum: 16.88
Mean: −13.76
Bin Width: 1.00
Number of Bins: 57

Industrial (60 - 64 degrees)

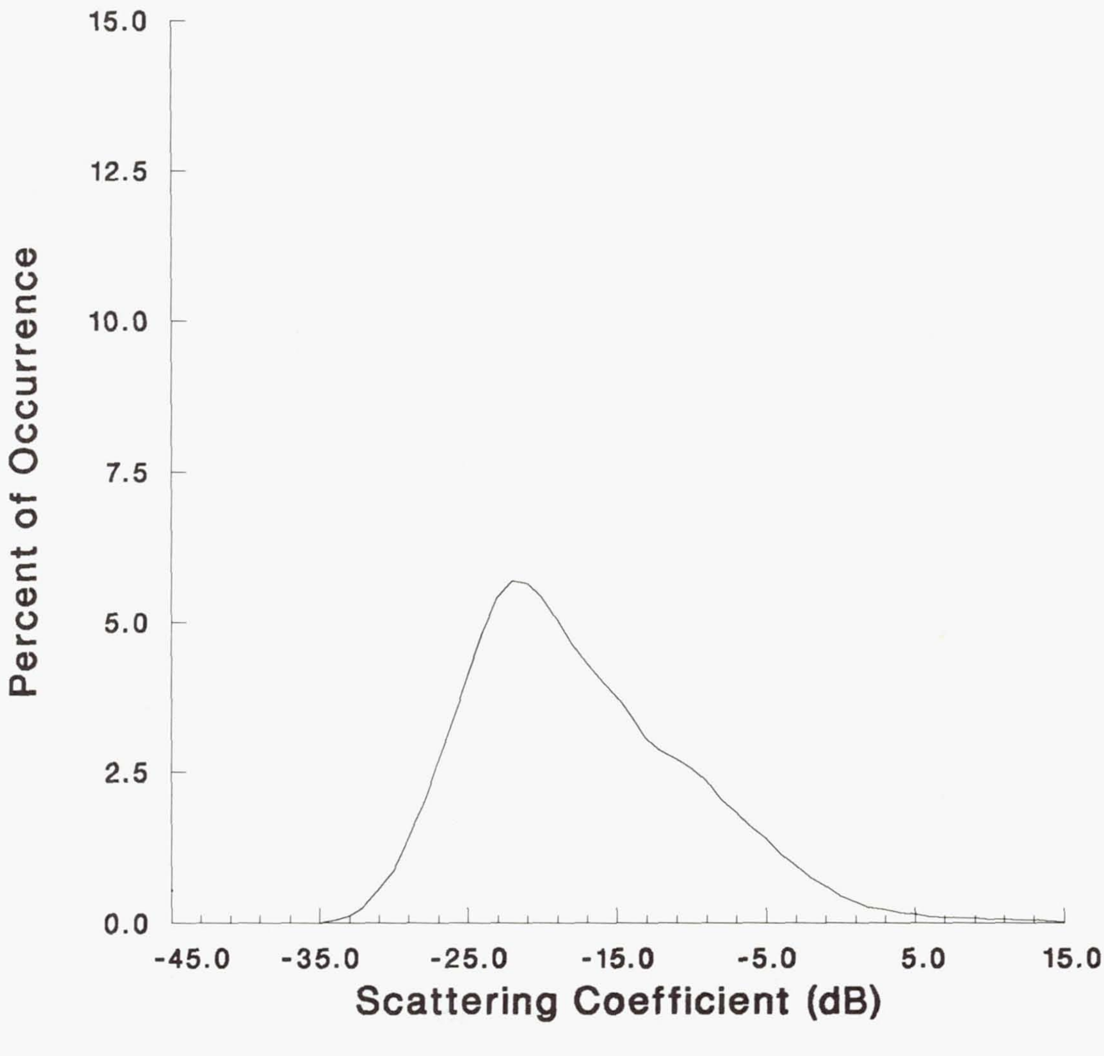


Figure 216.

Minimum: −39.53
Maximum: 18.64
Mean: −7.85
Bin Width: 1.00
Number of Bins: 59

Industrial (65 - 69 degrees)

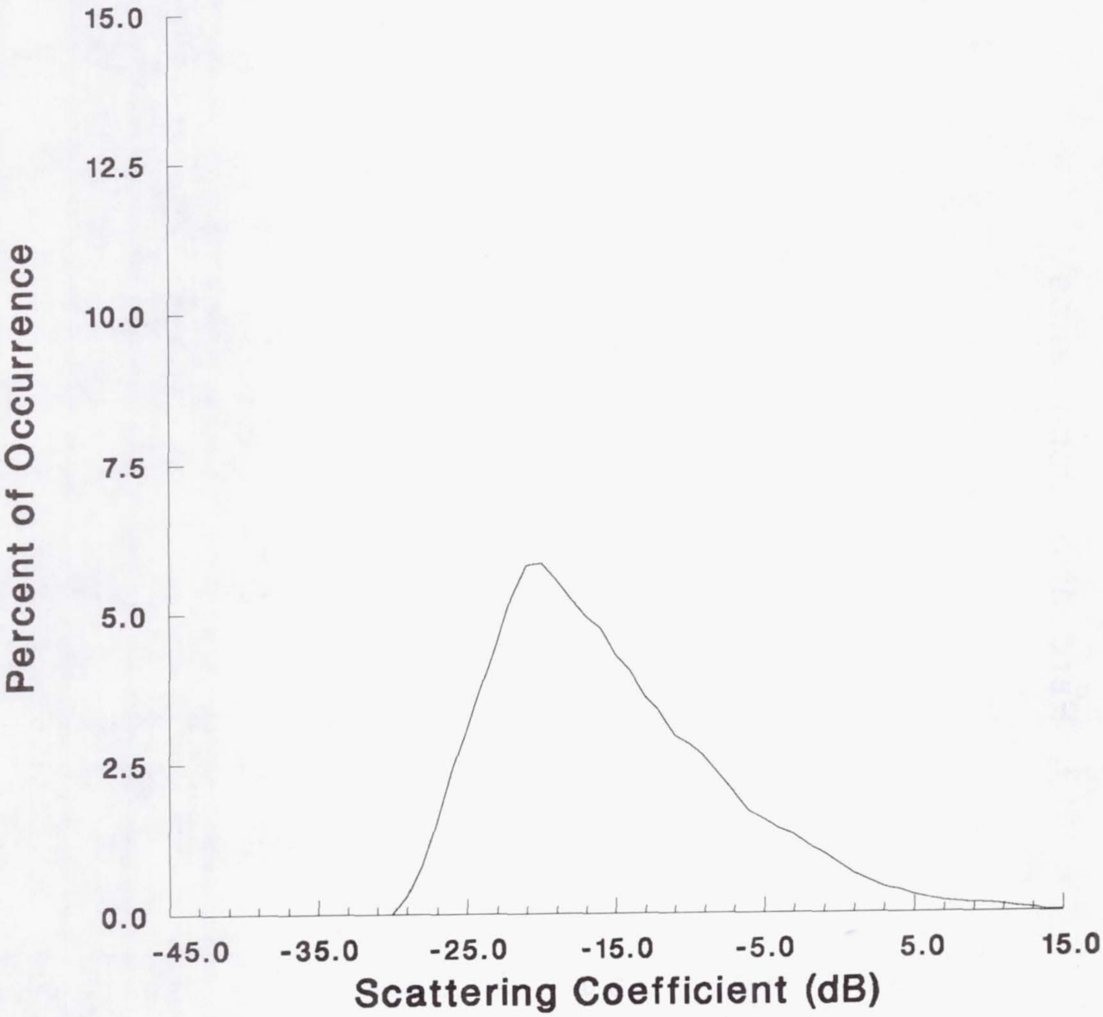


Figure 217.

Minimum: −39.53
Maximum: 20.24
Mean: −5.54
Bin Width: 1.00
Number of Bins: 61

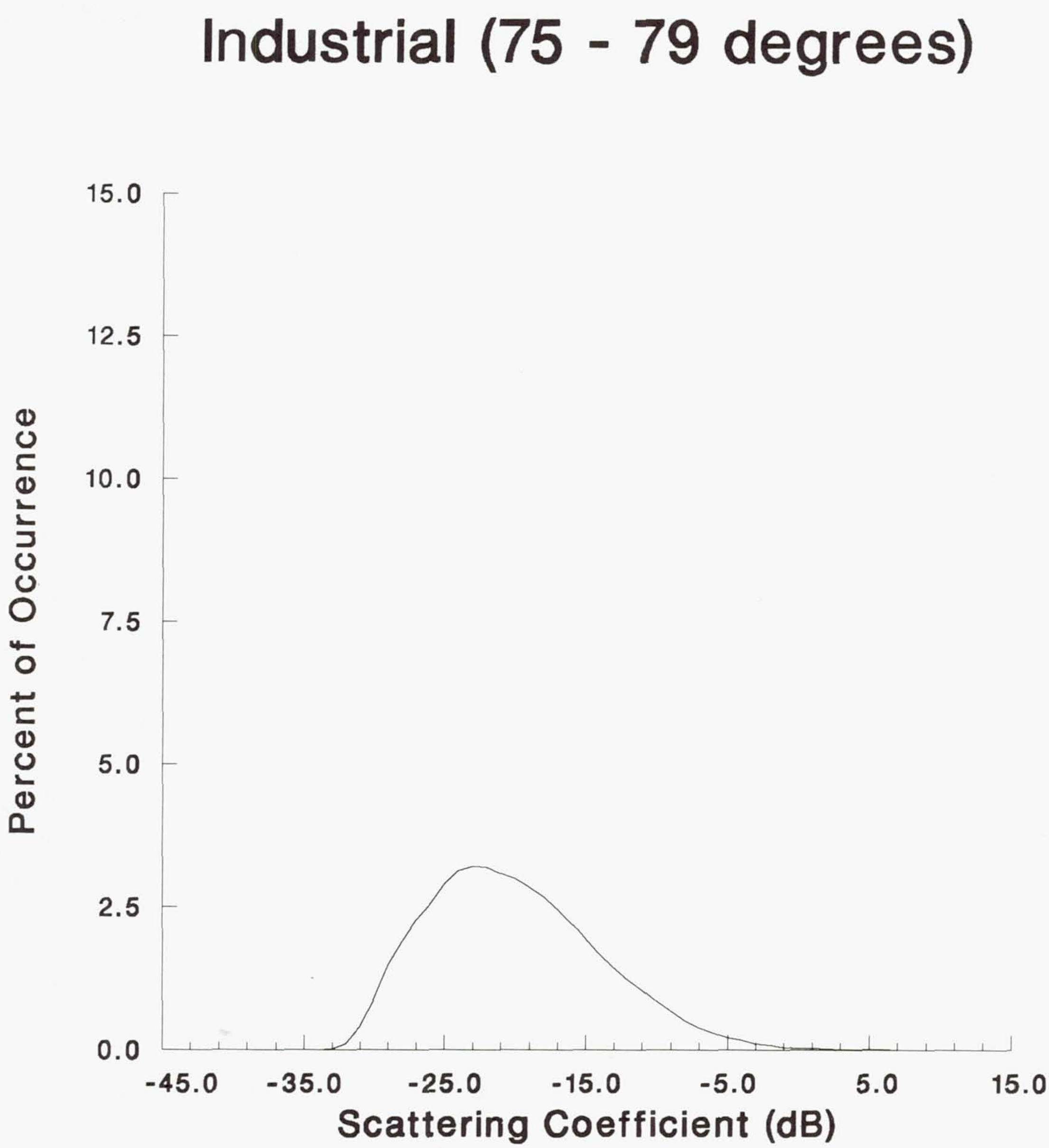


Figure 218.

Minimum: −39.53
Maximum: 9.89
Mean: −17.53
Bin Width: 1.00
Number of Bins: 50

Water (70 - 74 degrees)

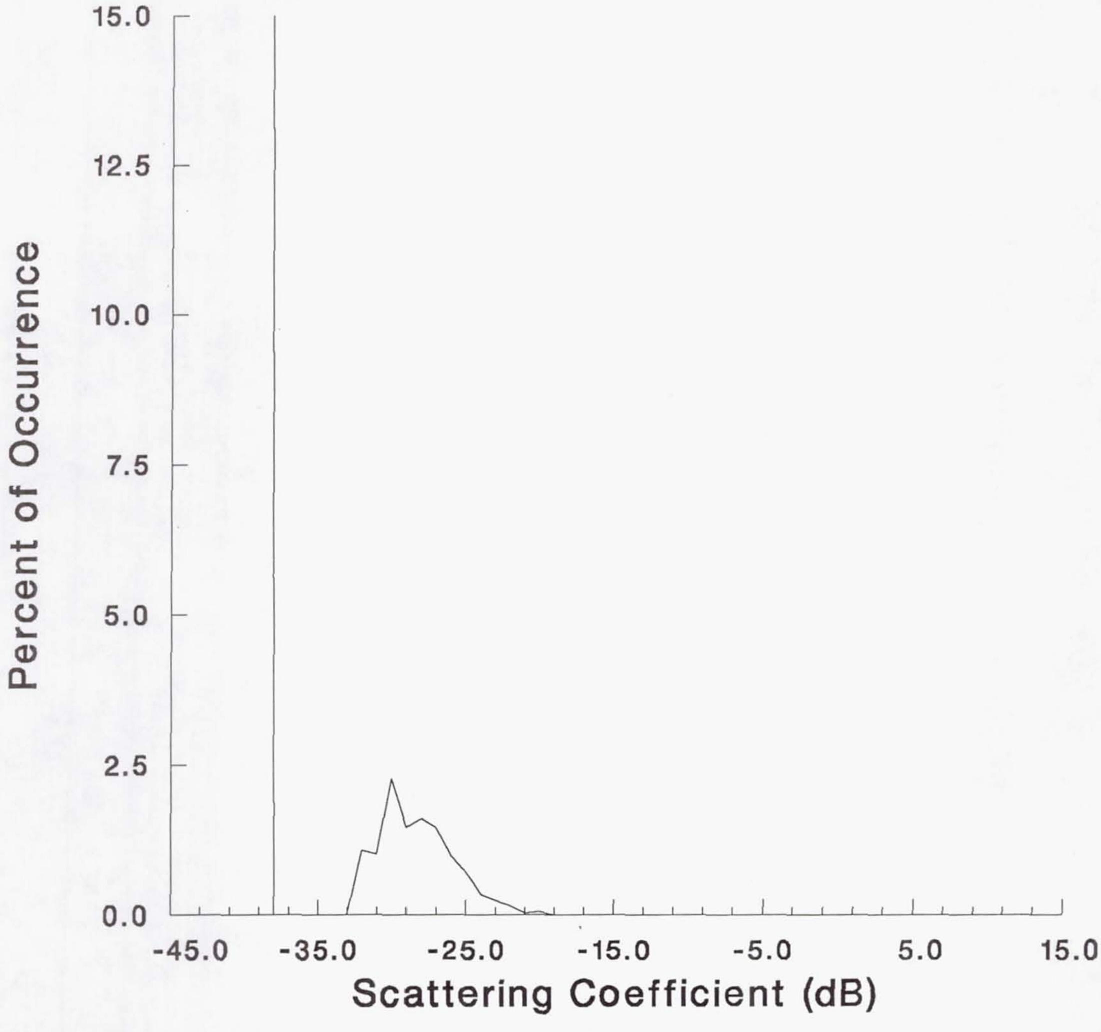


Figure 219.

Minimum: −39.53

Maximum: −19.90

Mean: −35.19

Bin Width: 1.00

Number of Bins: 21

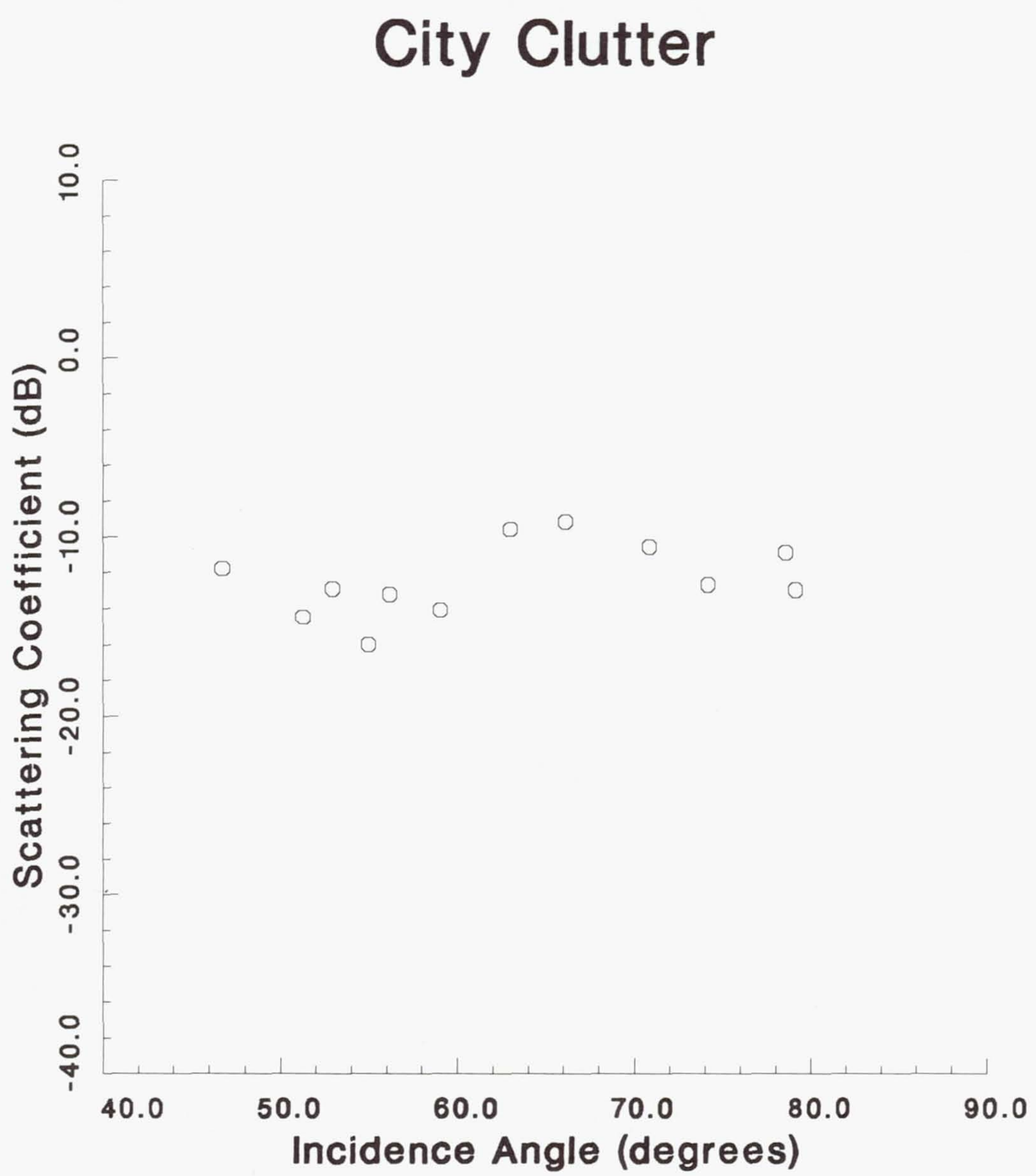
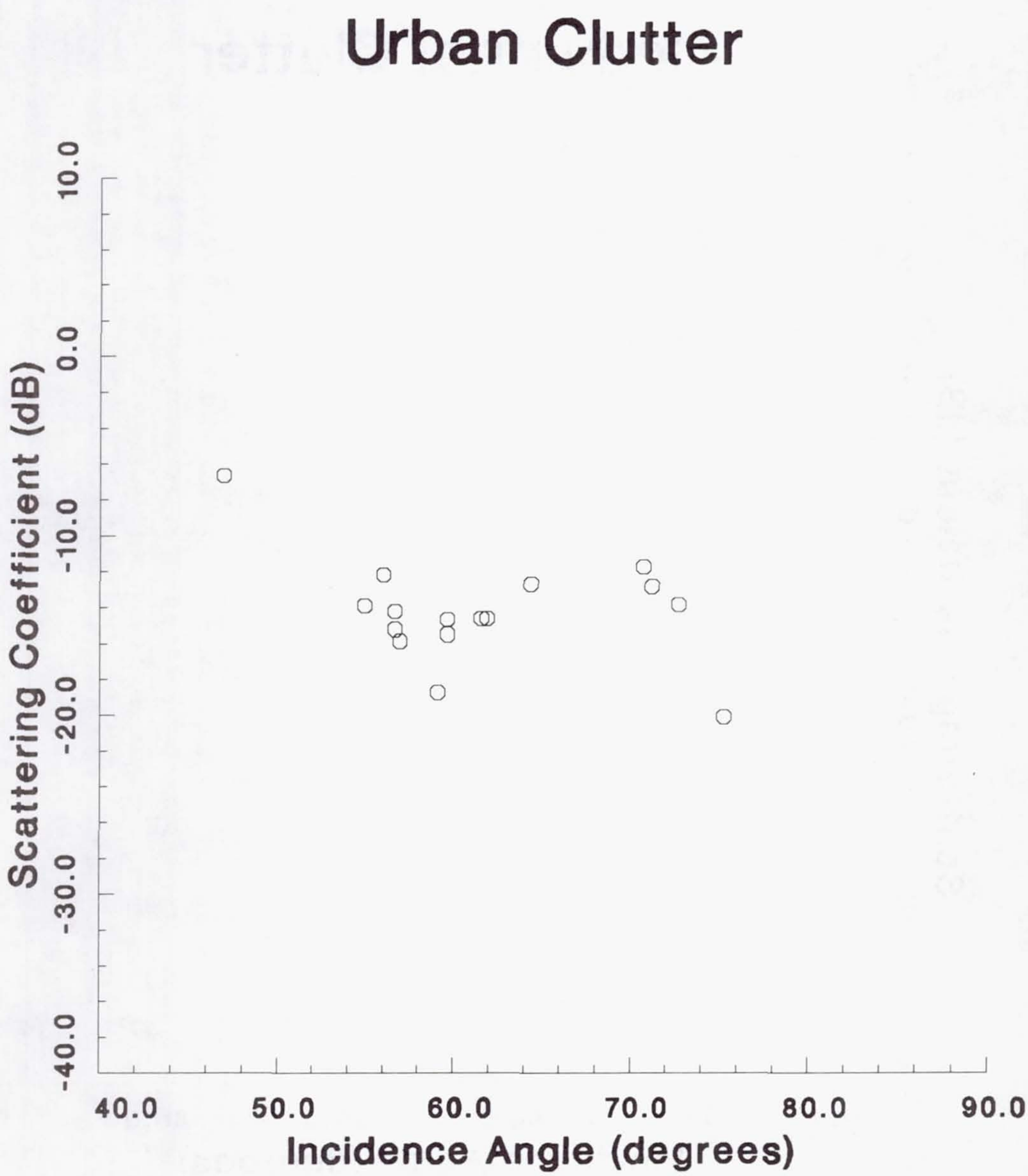

City Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 220.



Urban Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 221.

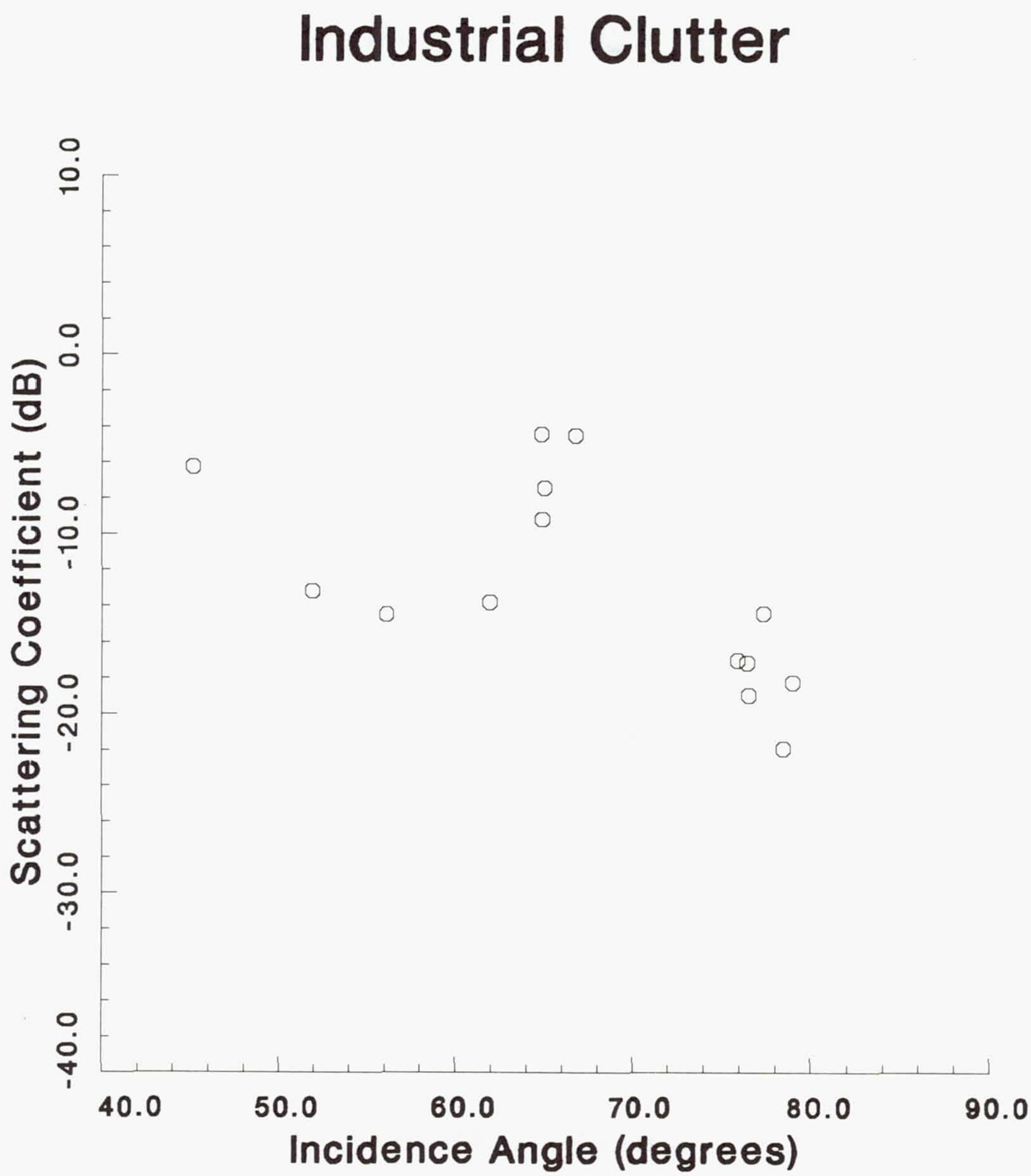

Industrial Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 222.

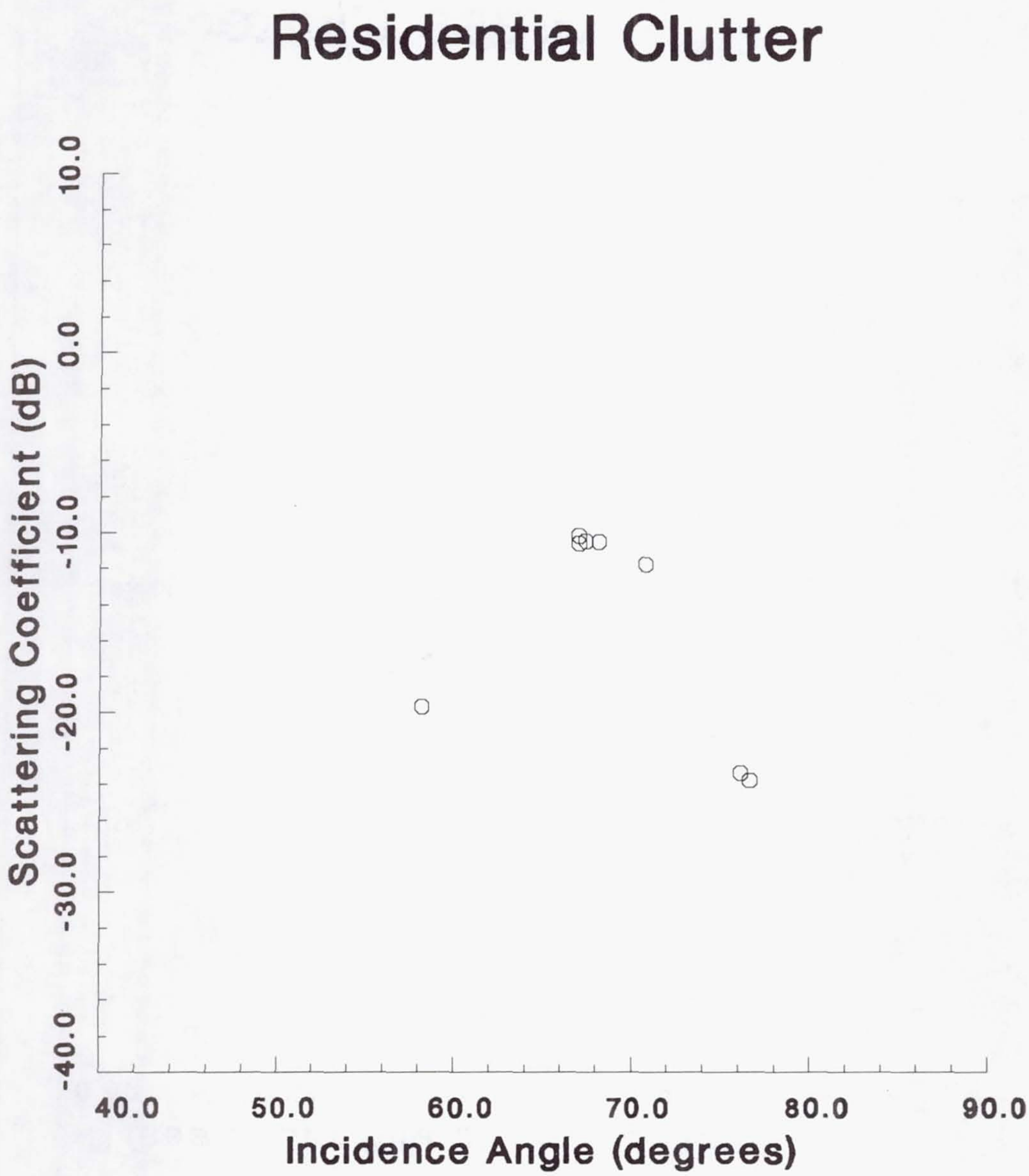

Residential Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 223.

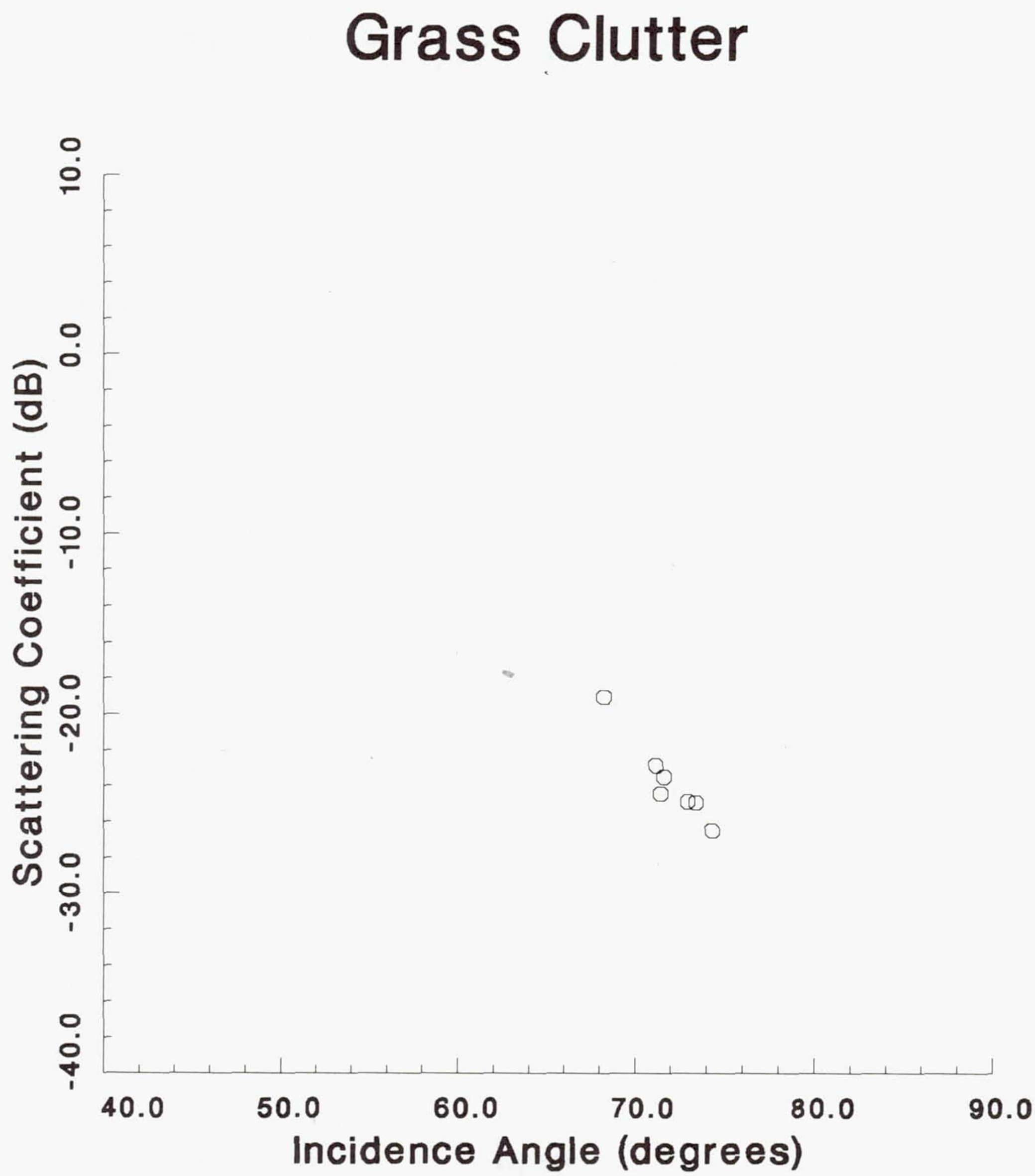

Grass Clutter
Scattering Coefficient (dB)
10.0
0.0
-10.0
-20.0
-30.0
-40.0
40.0
50.0
60.0
70.0
80.0
90.0
Incidence Angle (degrees)

Figure 224.

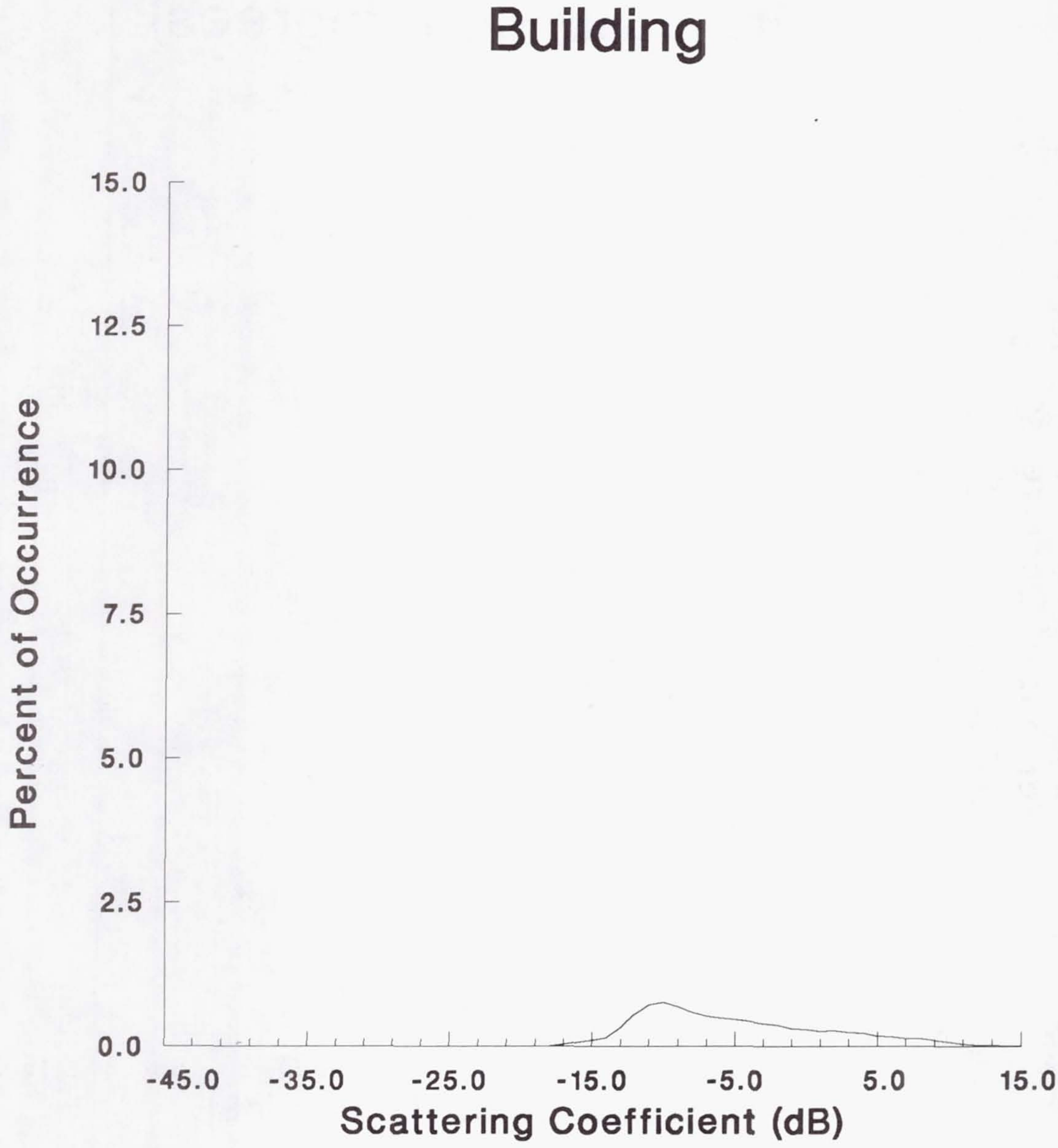


Figure 225.

Minimum: −39.53

Maximum: 17.18

Mean: −9.48

Bin Width: 1.00

Number of Bins: 58

Tree (65 - 69 degrees)

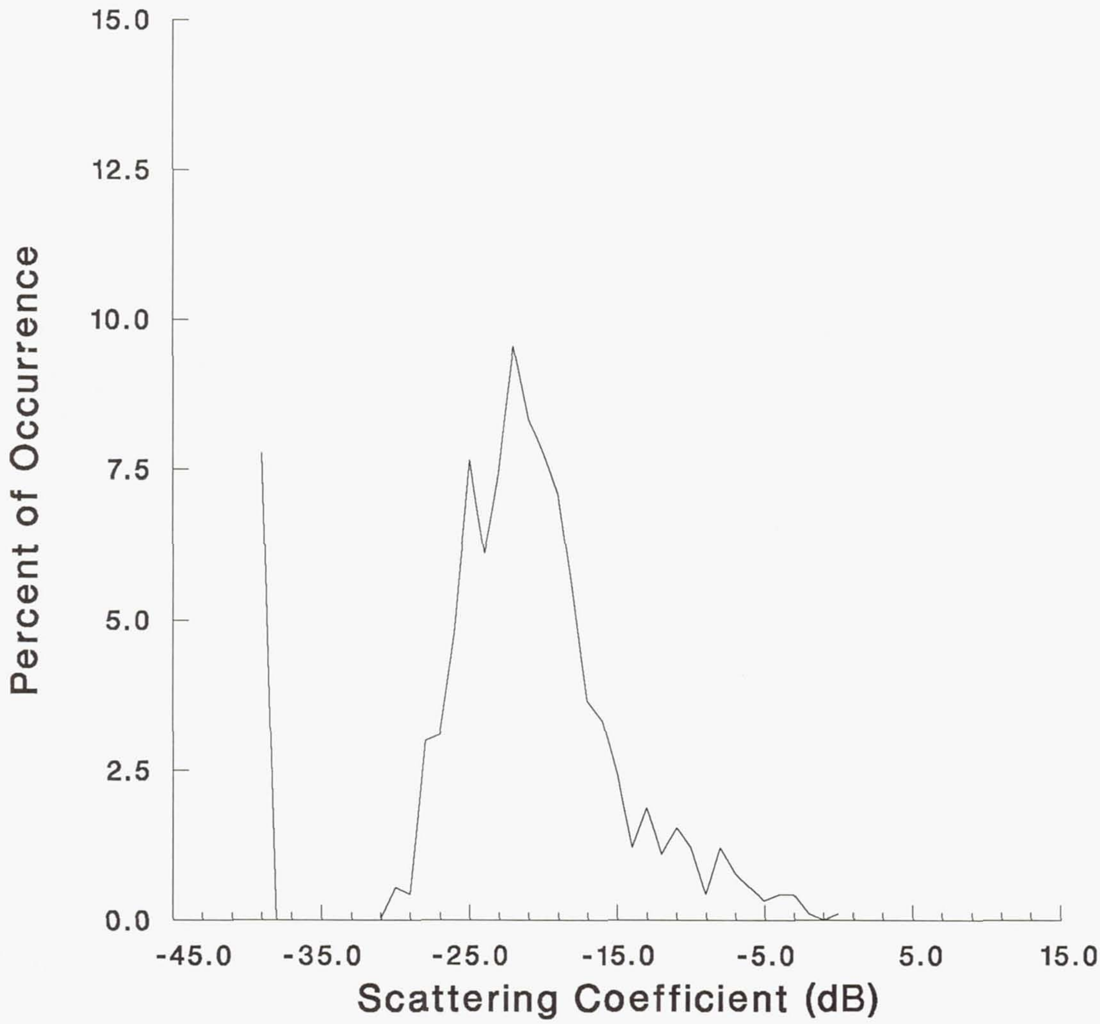


Figure 226.

Minimum: −39.53
Maximum: −0.07
Mean: −16.16
Bin Width: 1.00
Number of Bins: 40

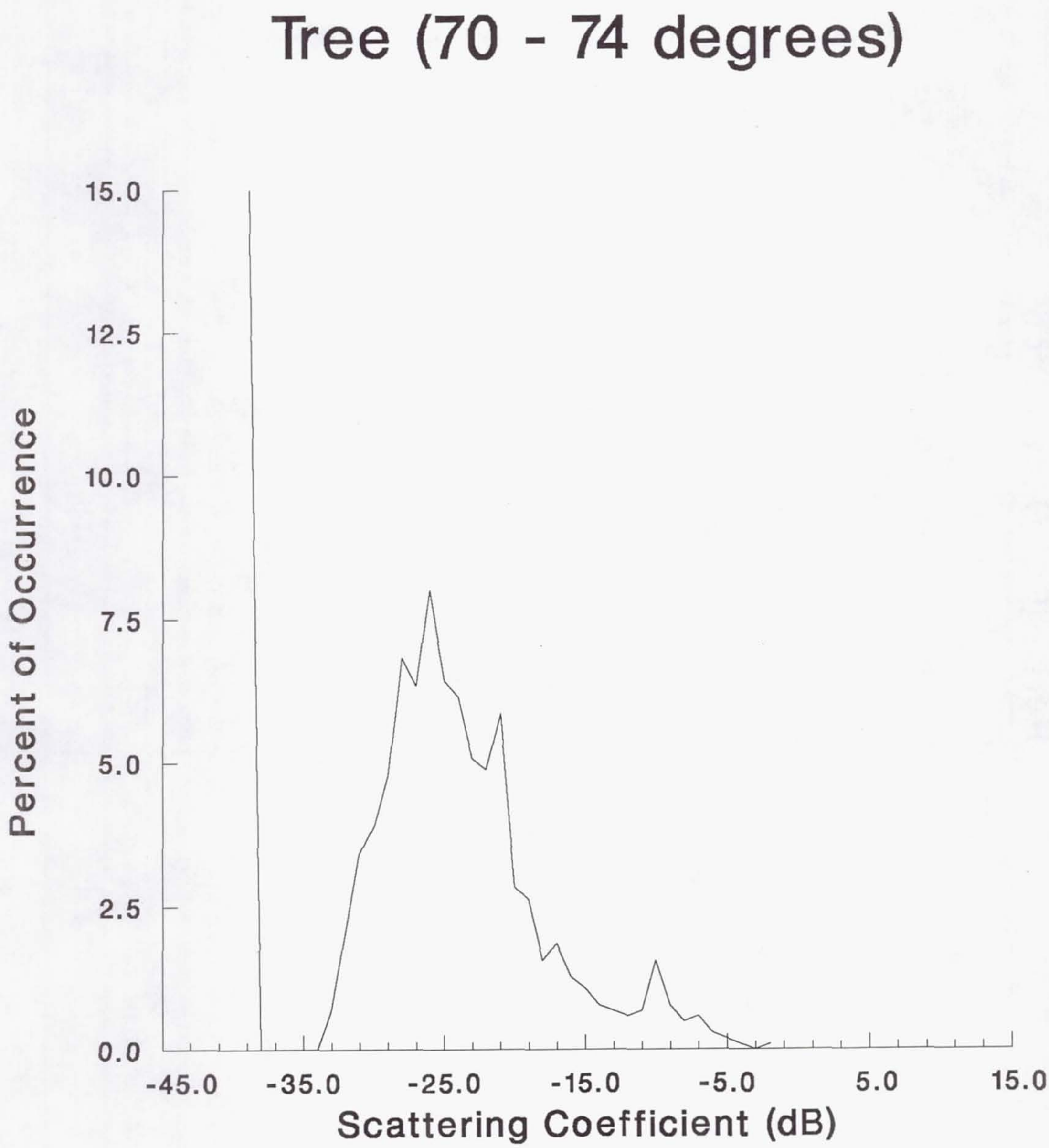


Figure 227.

Minimum: −39.53

Maximum: −2.51

Mean: −19.15

Bin Width: 1.00

Number of Bins: 38

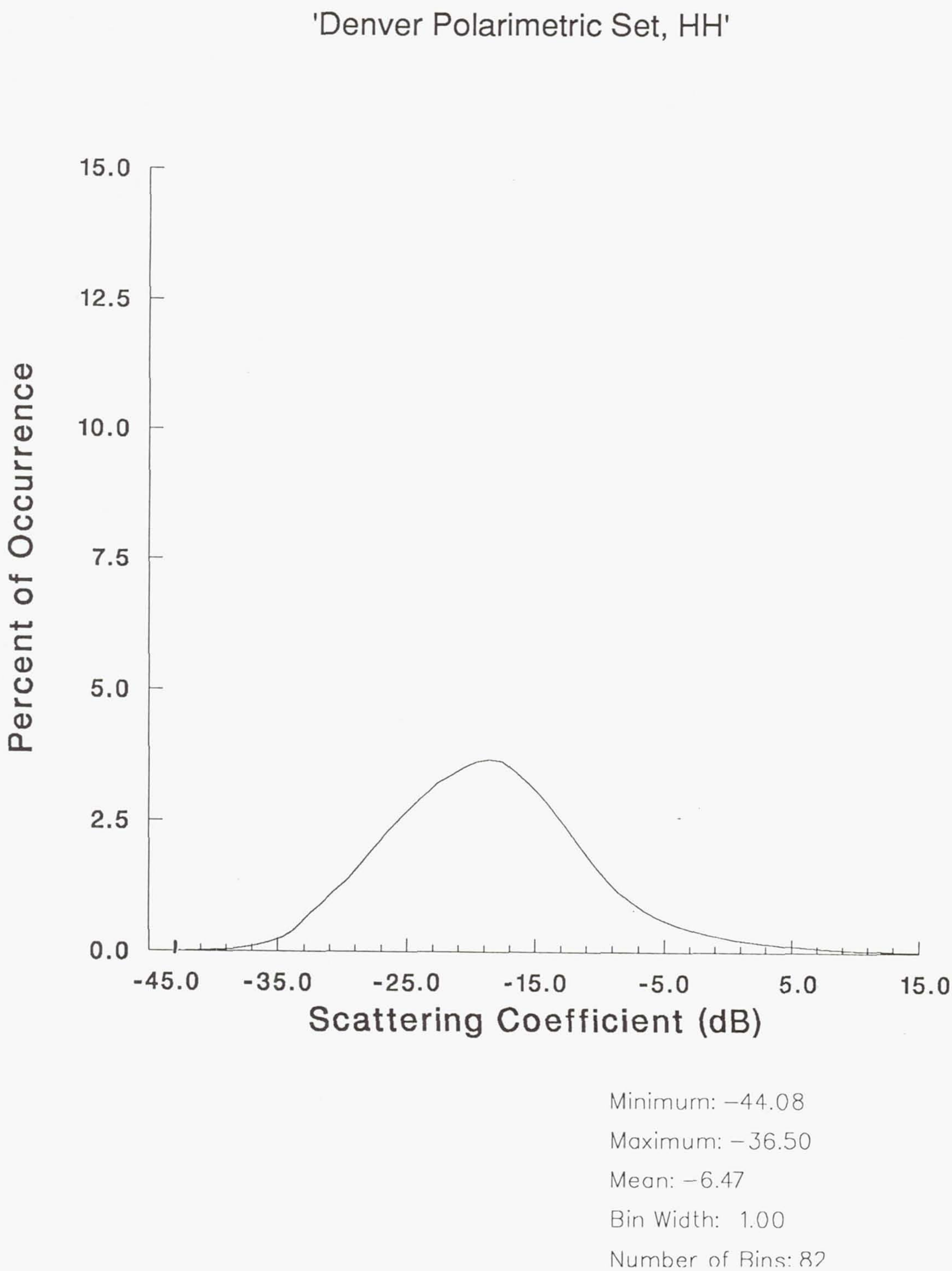
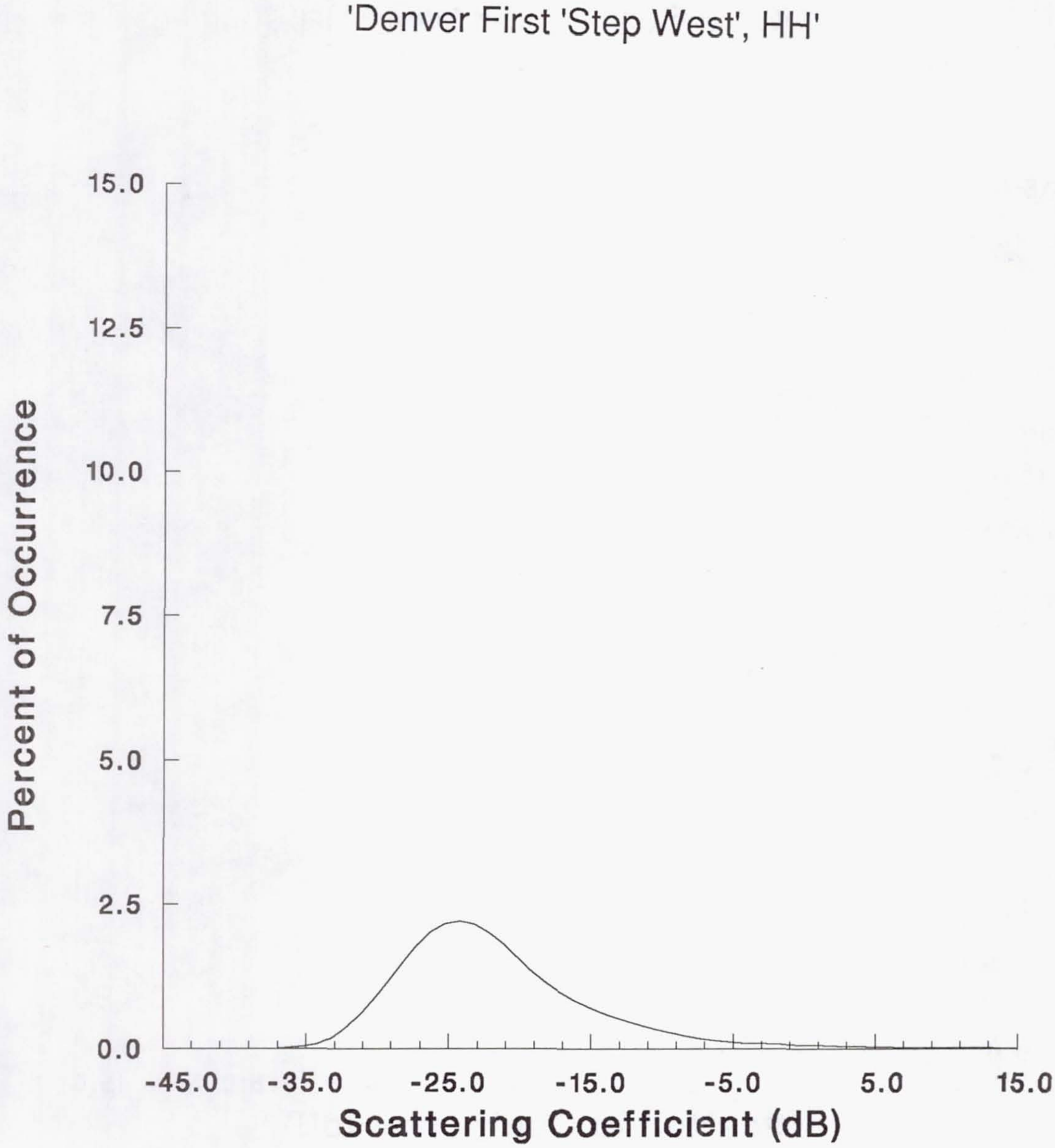
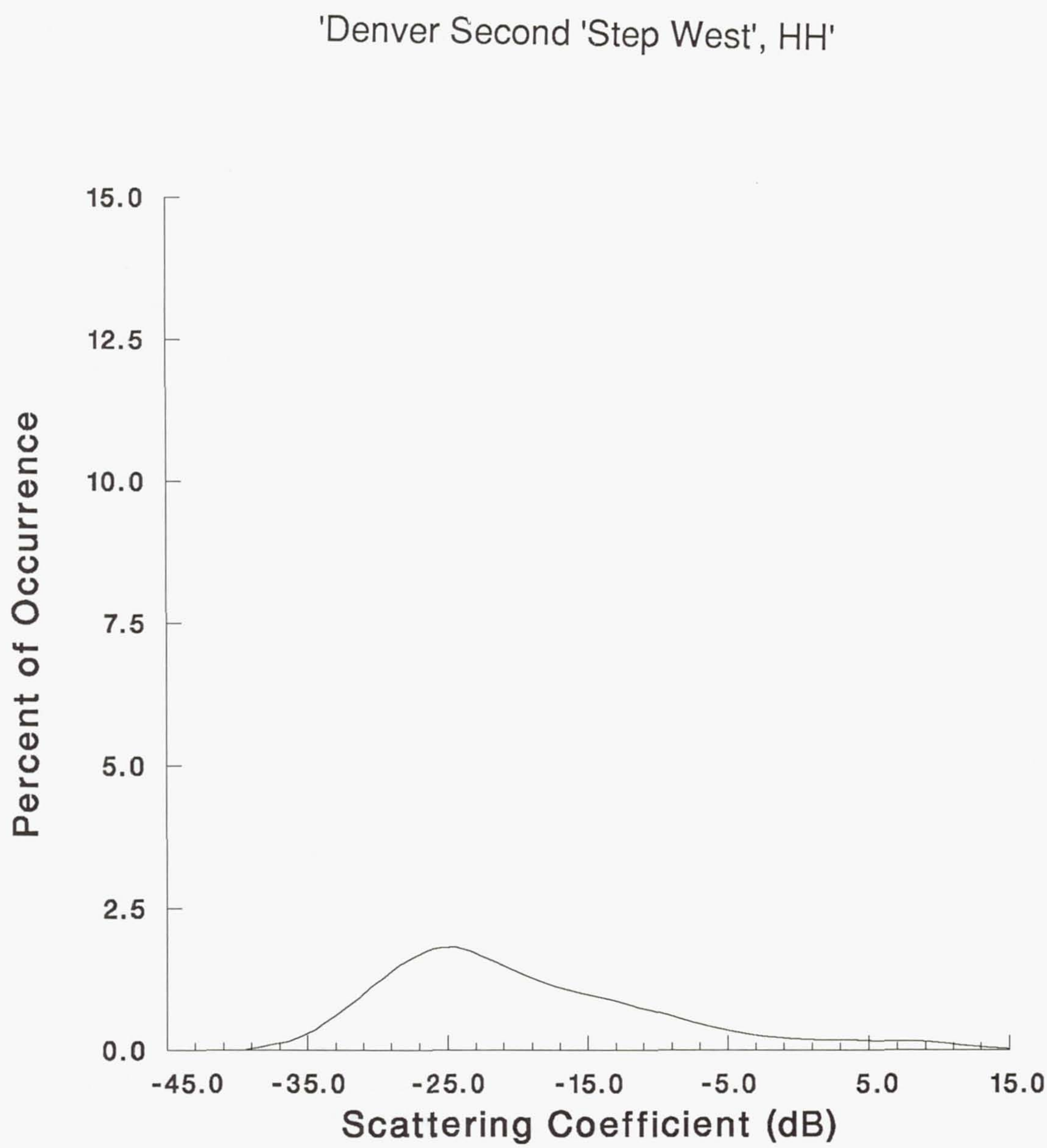


Figure 228. Clutter Distribution, Denver Polarimetric Set, X-HH



Minimum: −38.71
Maximum: 35.54
Mean: −8.61
Bin Width: 1.00
Number of Bins: 75

Figure 229. Clutter Distribution, Denver First 'Step West'



Minimum: −39.89

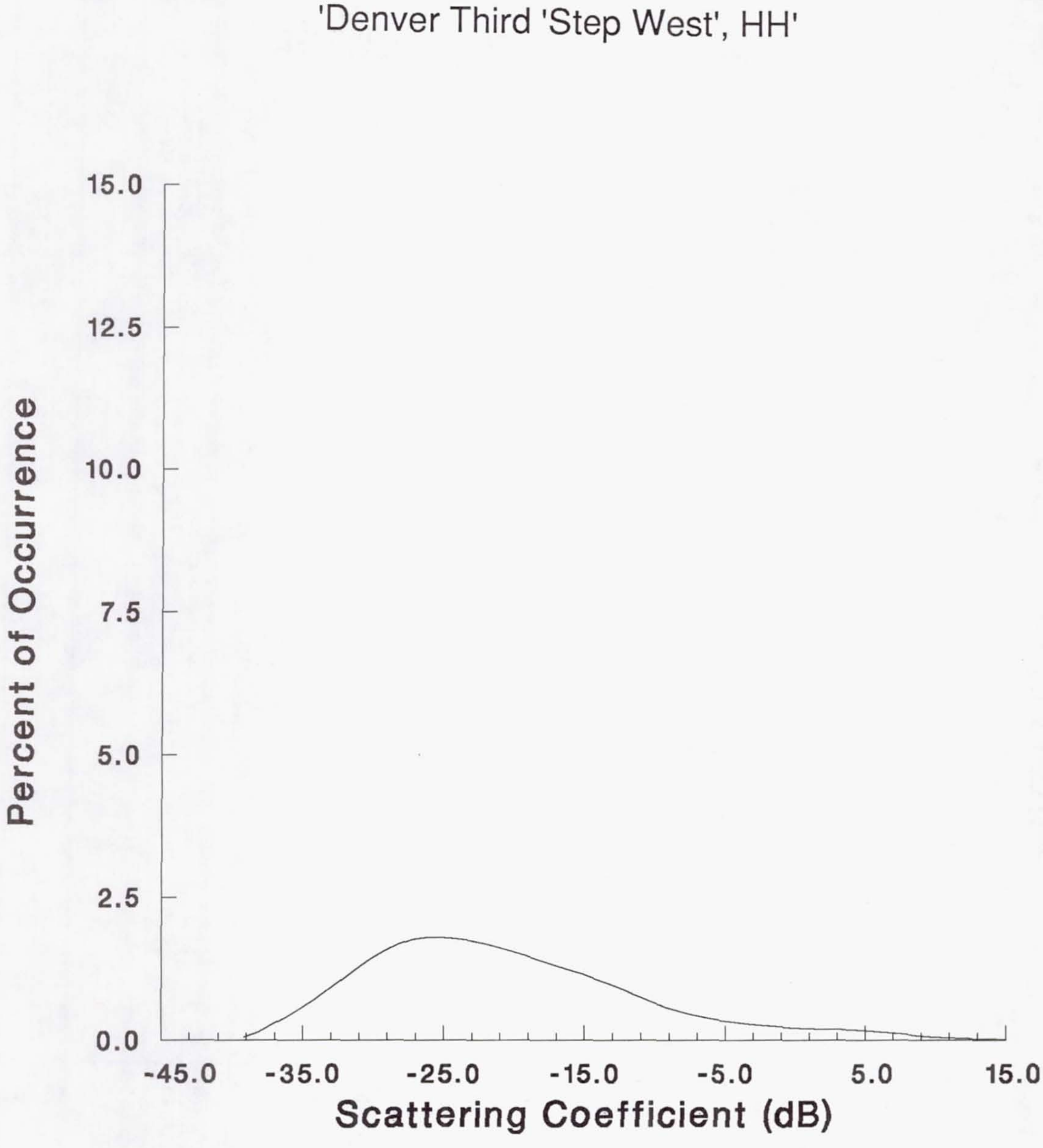
Maximum: 37.17

Mean: −6.80

Bin Width: 1.00

Number of Bins: 78

Figure 230. Clutter Distribution, Denver Second 'Step West'



Minimum: −39.69

Maximum: 42.08

Mean: −7.64

Bin Width: 1.00

Number of Bins: 83

Figure 231. Clutter Distribution, Denver Third 'Step West'

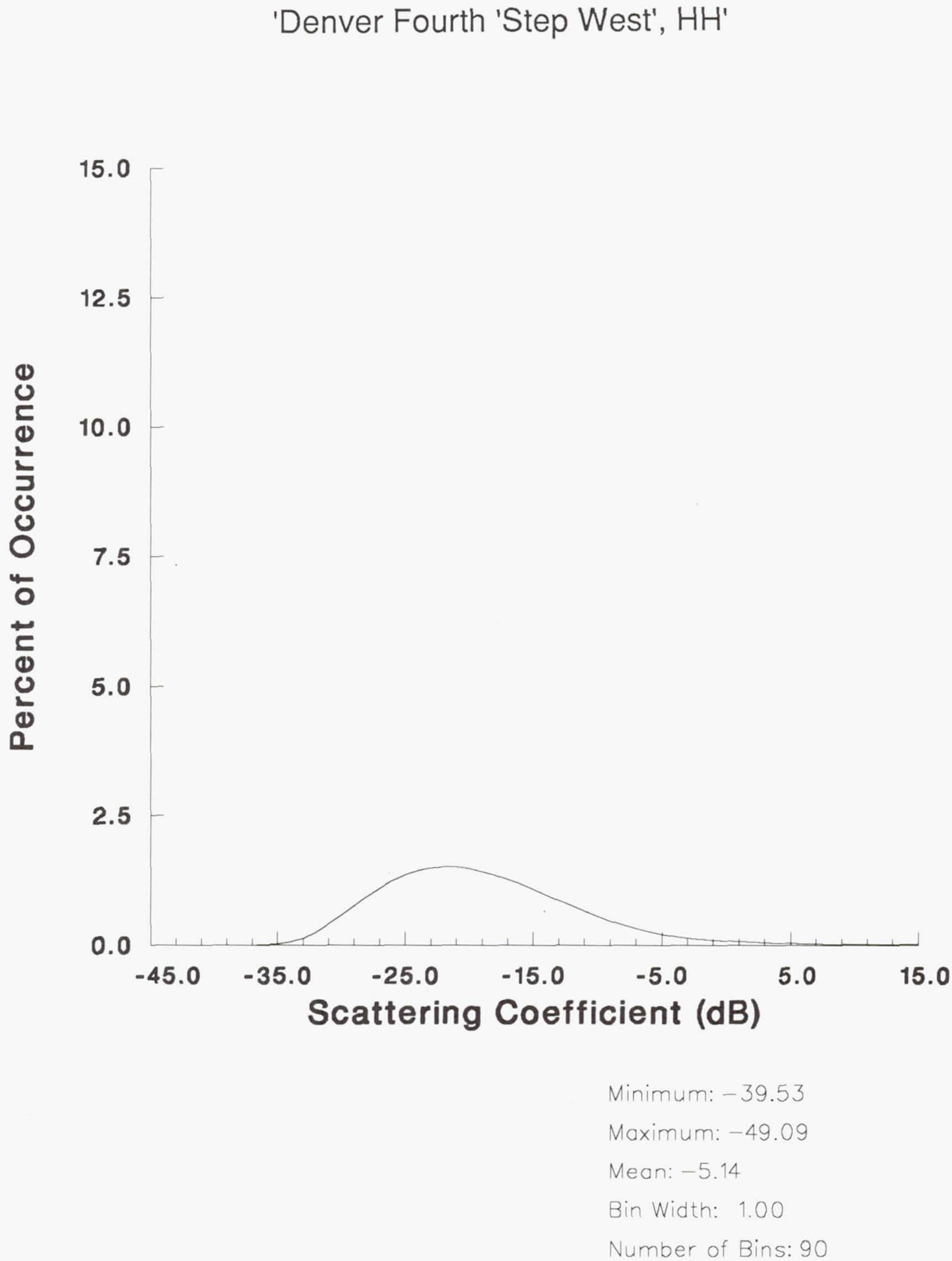


Figure 232. Clutter Distribution, Denver Fourth 'Step West'

APPENDIX A

APPENDIX A
Ground Truth Data

Deployment of calibration targets and ground truthing were major ground activities during the Denver P-3 SAR collection. Each of these activities is described in detail in this section.

CALIBRATION ARRAY

During the period of November 14, 1988 to November 16, 1988 a calibration array was deployed at the Denver Stapleton International Airport and at Lowry Air Force Base. The purpose of this array was three-fold: 1) to provide an on-site calibration array from which to derive the system gain function for the collection, 2) to provide a wide-spread reflector array for use in antenna pattern studies, and 3) to provide a polarimetric array for use in the calibration of polarimetric data. A series of twenty-four 60 cm trihedral corner reflectors, tilted forward 10° in order to align the peak response of the reflectors to the antenna boresight angle, formed the main calibration and antenna pattern array. Sixty-centimeter trihedral corner reflectors with metallic grid bases and radar absorbing material (RAM), 50-cm dihedral corner reflectors, and active radar calibrators (ARC's) were deployed as the polarimetric array. The reflectors were arranged in clusters throughout an area extending from the south end of Lowry Air Force Base to the north end of the Denver Stapleton International Airport. The location of the calibration target arrays and a brief description of the targets in each area is given in figures A-1a through A-1c, and A-2a through A-2k.

GROUND TRUTH

Ground truth was performed on November 15, 1988 and November 16, 1988. The ground truth effort consisted of the photography of several locations in the Denver area and the measurement of dielectric constants at several locations around the Denver Stapleton International Airport. The photographs are crucial to the clutter analysis of the Denver images. They provide information about the size, location, and condition of the man-made and distributed targets in the Denver scenes. The dielectric measurements are presented in Table A-1. These measurements were taken throughout the day of the flight and can be used to calculate the moisture content and composition of the airport grounds. The measurements also allow for more accurate characterization of certain distributed targets.

Table A-1. Dielectric Measurements

Target Area	Date and Time	Real Value	Imag. Value	Real St. Dev.	Imag. St. Dev.	Sample Type	Comments
1	11/16/88 5:19 PM	0.62	-0.66	0.10	0.04	Air	
	11/16/88 5:21 PM	1.04	0.03	0.10	8.02 -07	Air	
	11/16/88 5:23 PM	23.61	6.67	0.92	0.52	Hand	
	11/16/88 5:25 PM	0.94	0.00	0.21	0.00	Air	
	11/16/88 5:27 PM	3.52	0.02	0.65	0.04	Tarmac	
	11/16/88 5:29 PM	3.26	0.00	0.78	0.00	Tarmac	
	11/16/88 5:31 PM	1.15	0.00	0.06	0.00	Air	
	11/16/88 5:34 PM	1.00	0.06	0.00	0.05	Grass	Grass in plastic container.
	11/16/88 5:36 PM	1.04	0.09	0.10	1.79 -06	Grass	Grass in plastic container.

Table A-1. (Cont.) Dielectric Measurements

Target Area	Date and Time	Real Value	Imag. Value	Real St. Dev.	Imag. St. Dev.	Sample Type	Comments
1	11/16/88 5:51 PM	4.88	0.51	2.19	0.35	Soil	
	11/16/88 5:54 PM	6.56	0.44	2.19	0.27	Soil	
	11/16/88 5:56 PM	4.89	0.32	0.39	0.05	Soil	
	11/16/88 5:58 PM	3.47	0.08	0.56	0.04	Soil	
	11/16/88 5:59 PM	2.96	0.00	0.28	0.00	Soil	
	11/16/88 6:02 PM	4.18	0.15	2.59	0.15	Snow	
	11/16/88 6:05 PM	1.89	0.00	0.49	0.00	Snow	
	11/16/88 6:06 PM	2.15	-0.06	0.58	0.05	Snow	
	11/16/88 6:09 PM	2.96	0.06	0.51	0.05	Soil	

Table A-1. (Cont.) Dielectric Measurements

Target Area	Date and Time	Real Value	Imag. Value	Real St. Dev.	Imag. St. Dev.	Sample Type	Comments
2	11/16/88 6:14 PM	1.00	0.00	0.00	0.00	Air	
	11/16/88 6:17 PM	6.04	0.56	4.06	0.69	Soil	
	11/16/88 6:19 PM	2.30	0.11	0.49	0.04	Soil	
	11/16/88 6:21 PM	15.86	2.26	2.18	0.36	Soil	
	11/16/88 6:23 PM	4.03	0.24	1.31	0.15	Soil	
	11/16/88 6:25 PM	2.90	0.13	0.61	0.04	Soil	
	11/16/88 6:27 PM	7.55	1.20	5.09	0.94	Moss	
	11/16/88 6:29 PM	1.94	0.20	0.39	0.10	Grass	

Table A-1. (Cont.) Dielectric Measurements

Target Area	Date and Time	Real Value	Imag. Value	Real St. Dev.	Imag. St. Dev.	Sample Type	Comments
3	11/16/88 6:35 PM	0.97	0.00	0.05	0.00	Air	
	11/16/88 6:37 PM	6.20	0.68	3.65	0.60	Soil	
	11/16/88 6:39 PM	4.89	0.67	1.52	0.32	Moss	
	11/16/88 6:41 PM	2.19	0.26	0.79	0.17	Grass	
	11/16/88 6:42 PM	4.46	0.39	1.57	0.23	Soil	
	11/16/88 6:44 PM	1.79	0.18	0.14	3.85 -05	Grass	

Table A-1. (Cont.) Dielectric Measurements

Target Area	Date and Time	Real Value	Imag. Value	Real St. Dev.	Imag. St. Dev.	Sample Type	Comments
4	11/16/88 6:48 PM	0.94	0.00	0.10	0.00	Air	
	11/16/88 6:50 PM	1.00	0.00	0.00	0.00	Air	
	11/16/88 7:01	3.90	0.32	0.42	0.11	Soil	
	11/16/88 7:03 PM	1.85	0.07	0.48	0.04	Soil	
	11/16/88 7:05 PM	2.53	0.15	0.23	0.05	Soil	
	11/16/88 7:06 PM	2.70	0.06	0.97	0.13	Soil	
	11/16/88 7:08 PM	4.96	0.34	1.61	0.15	Soil	

Table A-1. (Cont.) Dielectric Measurements

Target Area	Date and Time	Real Value	Imag. Value	Real St. Dev.	Imag. St. Dev.	Sample Type	Comments
5B	11/16/88 12:42 PM	1.00	0.00	0.00	0.00	Air	
	11/16/88 12:44 PM	31.29	13.43	0.23	0.09	Human Hand	
	11/16/88 12:46 PM	1.60	0.00	0.10	0.00	Vinyl	
	11/16/88 12:58 PM	38.33	14.41	1.67	0.48	Wet Hand	
	11/16/88 1:00 PM	0.93	0.01	1.00	5.00	Air	
	11/16/88 1:02 PM	4.25	0.08	1.65	0.12	Snow	
	11/16/88 1:05 PM	1.94	0.04	0.56	0.08	Snow	
	11/16/88 1:07 PM	1.72	0.00	0.12	0.00	Snow	
	11/16/88 1:09 PM	2.36	0.12	0.49	0.04	Snow	

Table A-1. (Cont.) Dielectric Measurements

Target Area	Date and Time	Real Value	Imag. Value	Real St. Dev.	Imag. St. Dev.	Sample Type	Comments
5B	11/16/88 1:12 PM	1.89	0.06	0.28	0.05	Snow	
	11/16/88 1:14 PM	17.12	2.28	4.74	0.86	Soil	
	11/16/88 1:16 PM	4.01	0.34	0.82	0.13	Soil	
	11/16/88 1:18 PM	13.63	1.79	4.72	0.57	Soil	
	11/16/88 1:21 PM	20.65	2.23	1.75	0.25	Soil	
	11/16/88 1:23 PM	15.69	1.87	6.49	0.84	Soil	
	11/16/88 1:31 PM	1.01	0.00	0.04	0.00	Air	

Table A-1. (Cont.) Dielectric Measurements

Target Area	Date and Time	Real Value	Imag. Value	Real St. Dev.	Imag. St. Dev.	Sample Type	Comments
6	11/17/88 10:52 AM	0.96	0.00	0.10	0.00	Air	
	11/17/88 10:53 AM	3.09	0.40	0.59	0.14	Soil	
	11/17/88 10:55 AM	18.72	3.19	11.32	1.95	Soil	
	11/17/88 10:57 AM	1.19	0.00	0.05	0.00	Air	
	11/17/88 10:58 AM	5.87	0.94	1.48	0.33	Soil	
	11/17/88 11:00 AM	21.83	3.30	0.40	0.04	Soil	
	11/17/88 11:02 AM	7.45	1.10	2.94	0.51	Soil	
	11/17/88 11:04 AM	1.00	0.04	0.00	0.08	Grass	
	11/17/88 11:05 AM	1.81	0.17	0.41	0.08	Grass	

Table A-1. (Cont.) Dielectric Measurements

Target Area	Date and Time	Real Value	Imag. Value	Real St. Dev.	Imag. St. Dev.	Sample Type	Comments
6	11/17/88 11:07 AM	2.64	0.47	0.40	0.19	Grass	
	11/17/88 11:08 AM	1.72	0.11	0.36	0.10	Grass	
	11/17/88 11:10 AM	1.00	0.08	0.00	0.02	Air	

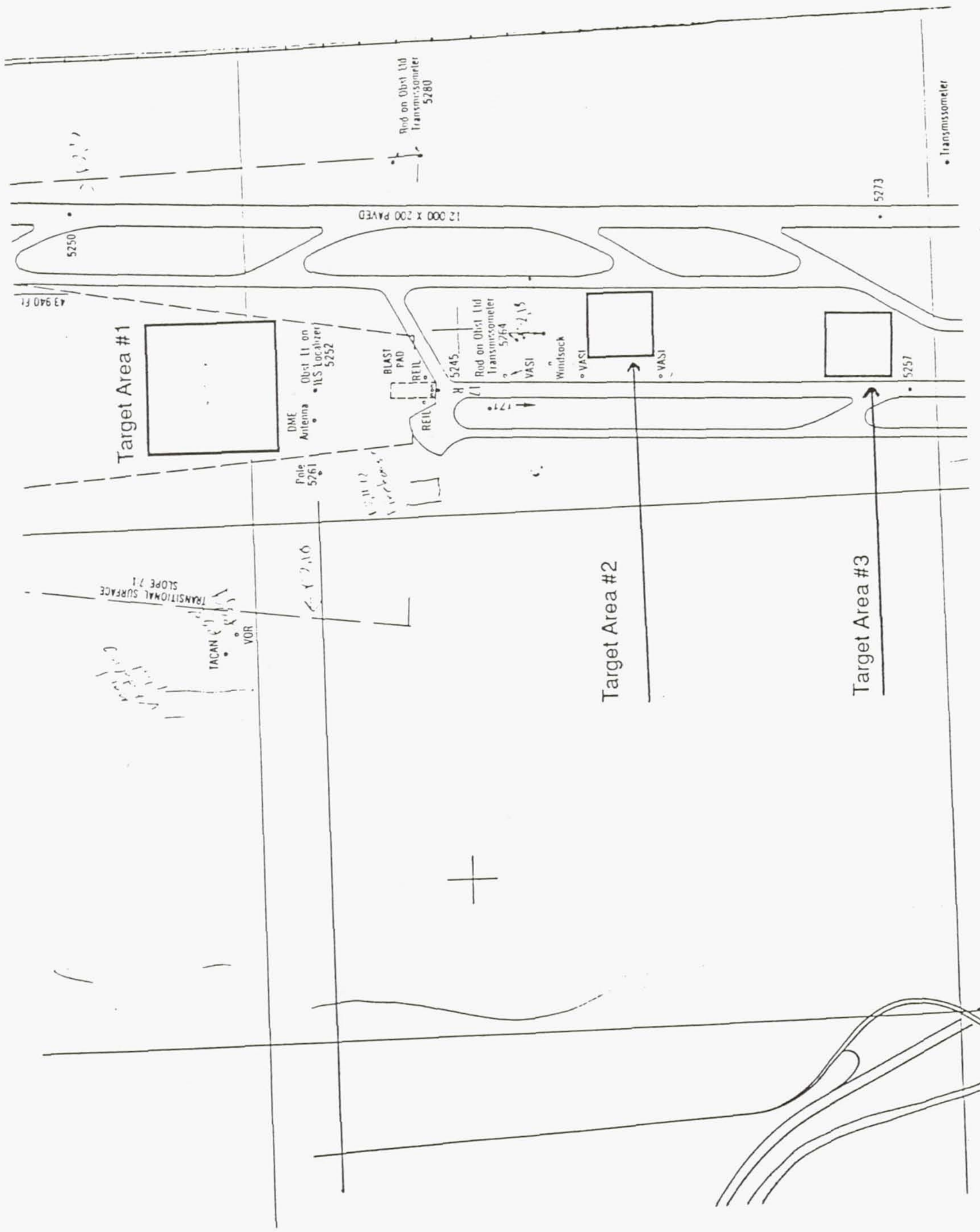


Figure A-1a.

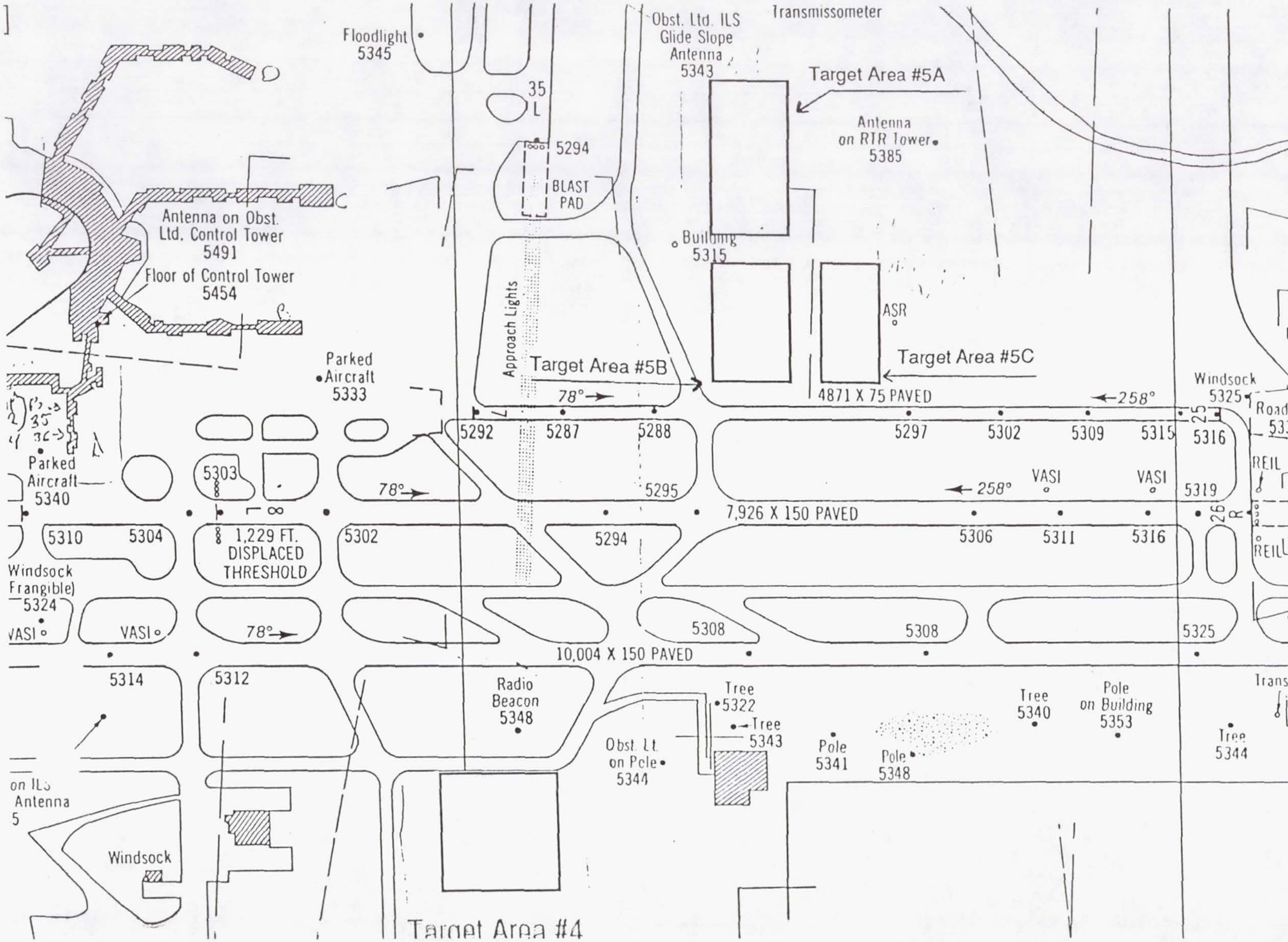
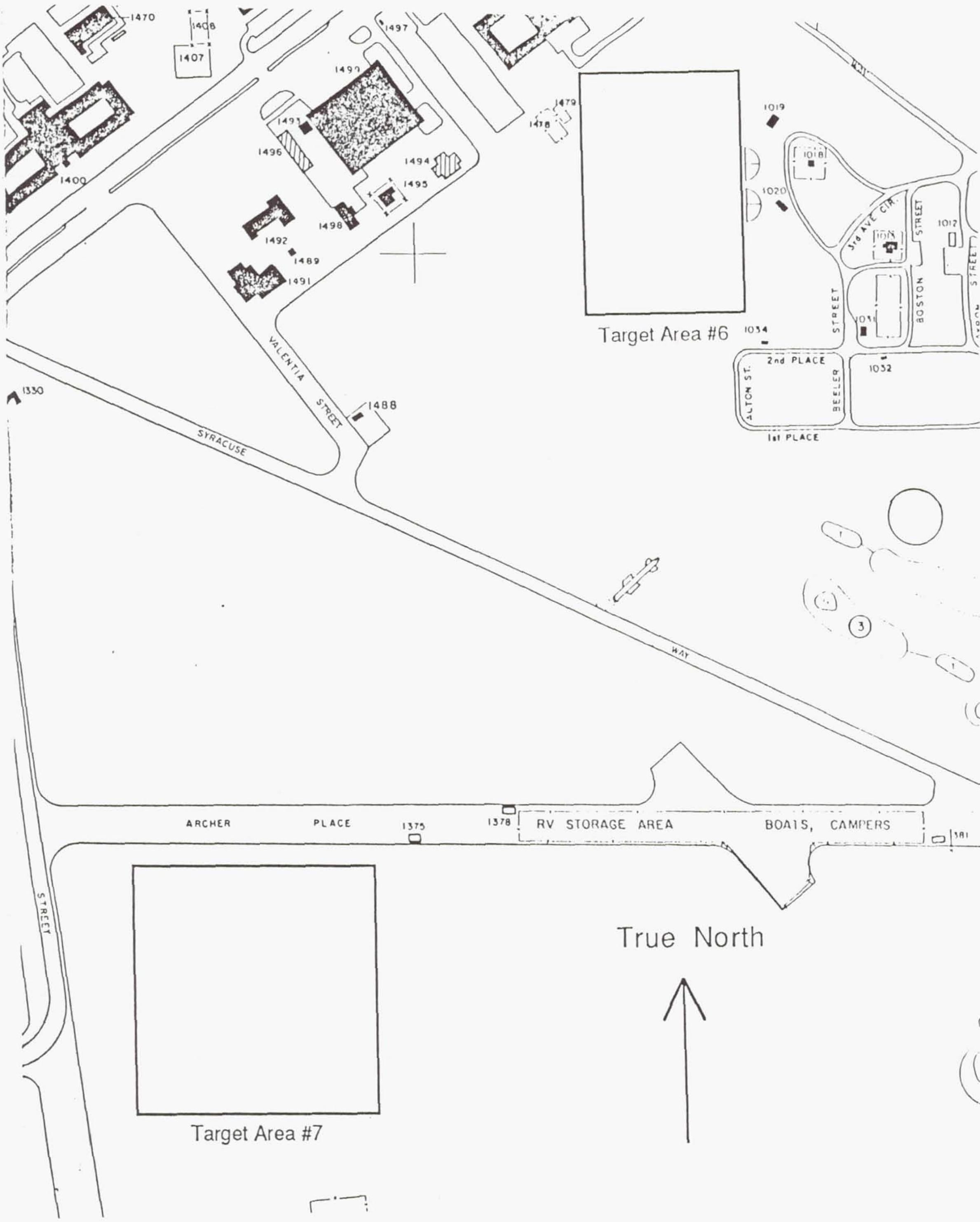

Floodlight
5345
Obst. Ltd. ILS
Glide Slope
Antenna
5343
Transmissometer
Target Area #5A
Antenna
on RTR Tower
5385
35
L
5294
BLAST
PAD
Antenna on Obst.
Ltd. Control Tower
5491
Floor of Control Tower
5454
Building
5315
ASR
Approach Lights
Target Area #5B
Target Area #5C
Parked
Aircraft
5333
78°
4871 X 75 PAVED
258°
Windsock
5325
5292
5287
5288
5297
5302
5309
5315
5316
25
Road
5333
Parked
Aircraft
5340
5303
78°
5295
258°
VASI
VASI
5319
REIL
7,926 X 150 PAVED
26
R
5310
5304
1,229 FT.
DISPLACED
THRESHOLD
5302
5294
5306
5311
5316
REIL
Windsock
Frangible)
5324
VASI
VASI
78°
5308
5308
5325
10,004 X 150 PAVED
5314
5312
Radio
Beacon
5348
Tree
5322
Tree
5343
Obst. Lt.
on Pole
5344
Pole
5341
Pole
5348
Tree
5340
Pole
on Building
5353
Tree
5344
on ILS
Antenna
Windsock
Target Area #4

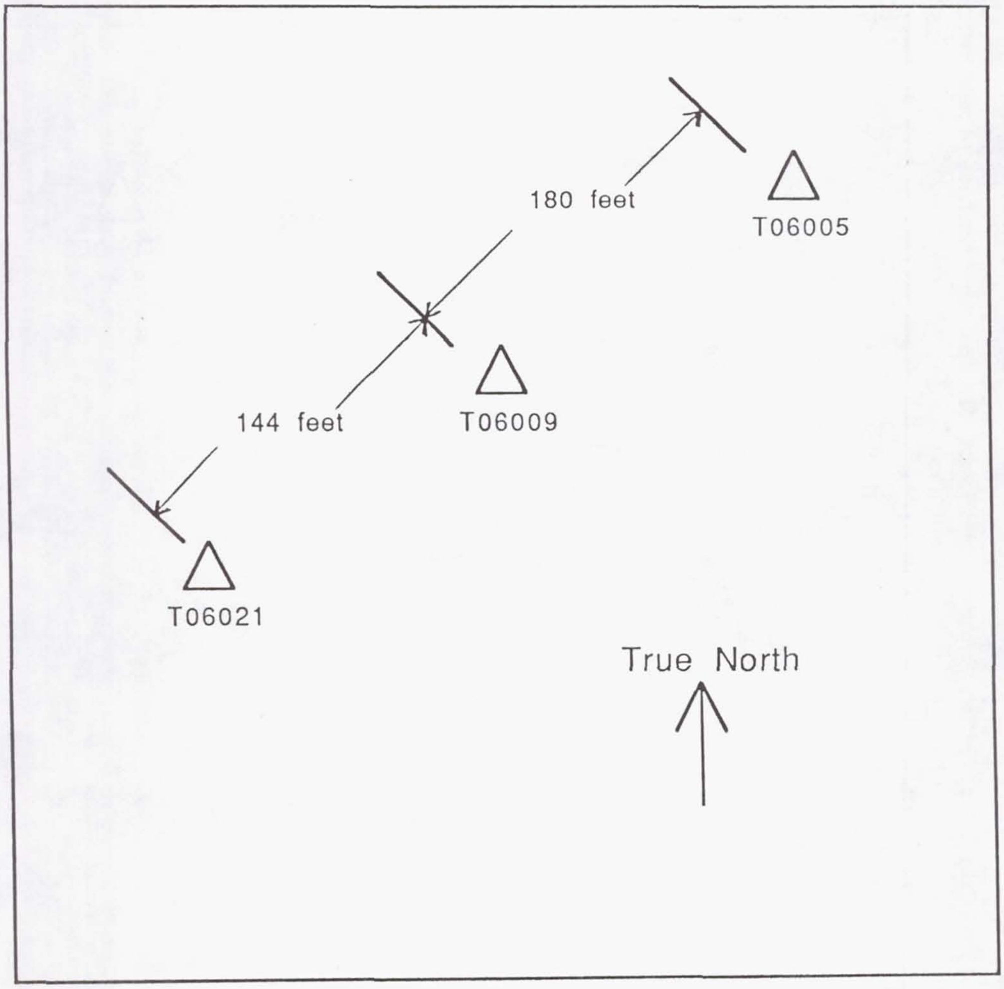
Figure A-1b.



Target Area #6
Target Area #7
True North
SYRACUSE
WAY
VALENTIA STREET
ARCHER PLACE
RV STORAGE AREA
BOATS, CAMPERS
2nd PLACE
1st PLACE
ALTON ST.
BEELER
BOSTON STREET
3rd AVE CIR.
STREET

Figure A-1c.

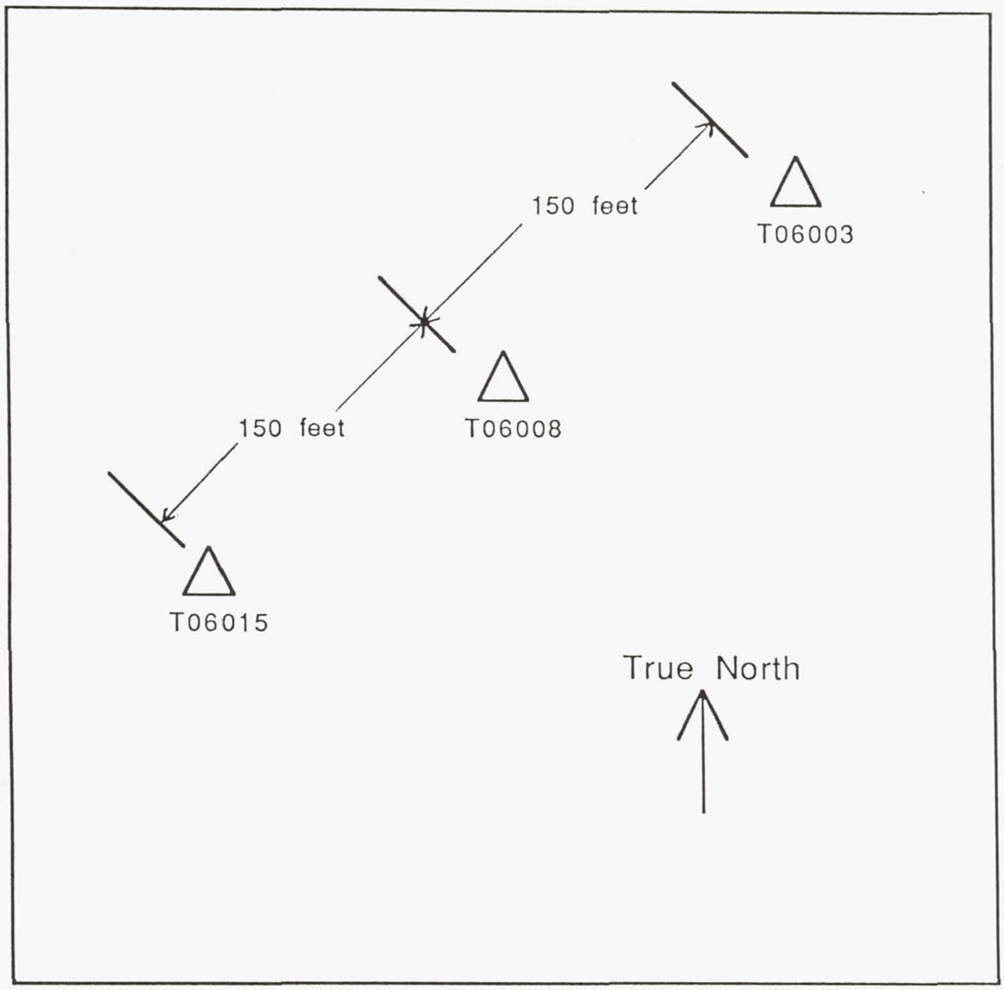
Target Area #1



Trihedral look direction is due South (180 degrees).
Trihedral inclination angle is 10 degrees.

Figure A-2a.

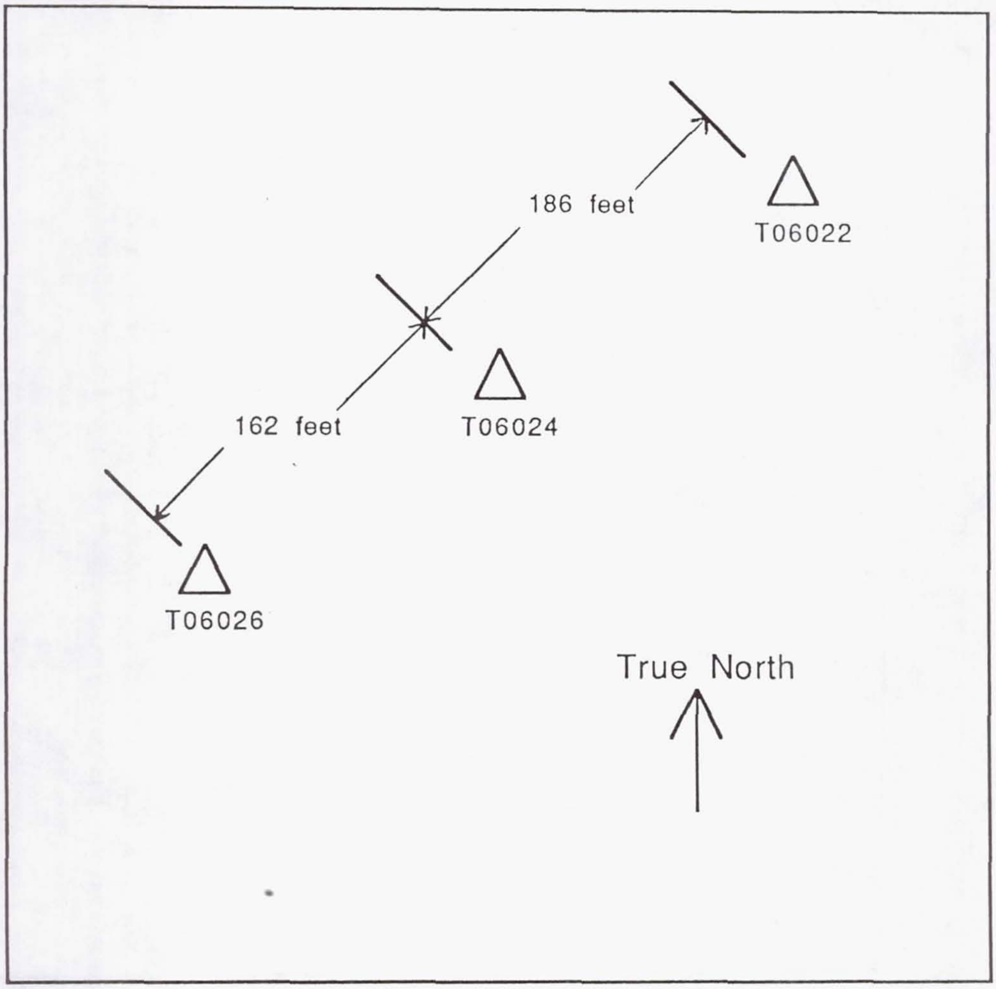
Target Area #2



Trihedral look direction is due South (180 degrees).
Trihedral inclination angle is 10 degrees.

Figure A-2b.

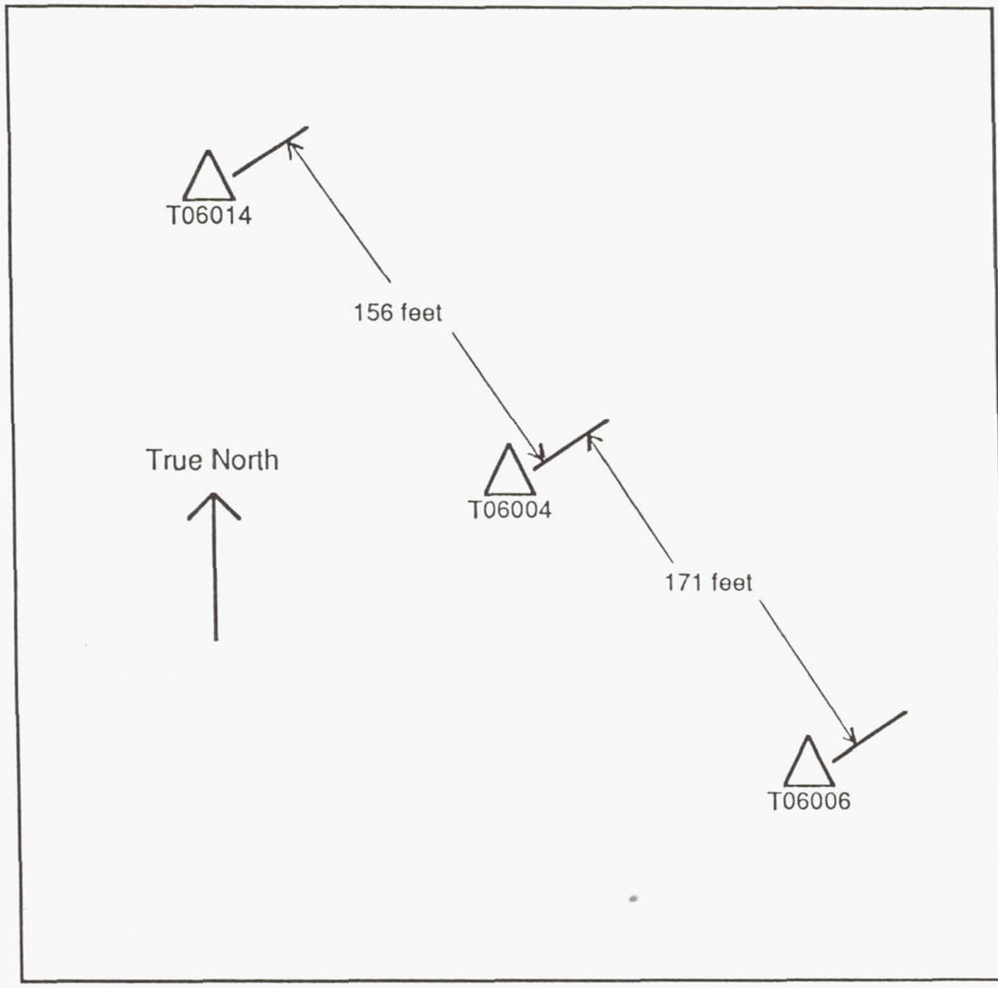
Target Area #3



Trihedral look direction is due South (180 degrees).
Trihedral inclination angle is 10 degrees.

Figure A-2c.

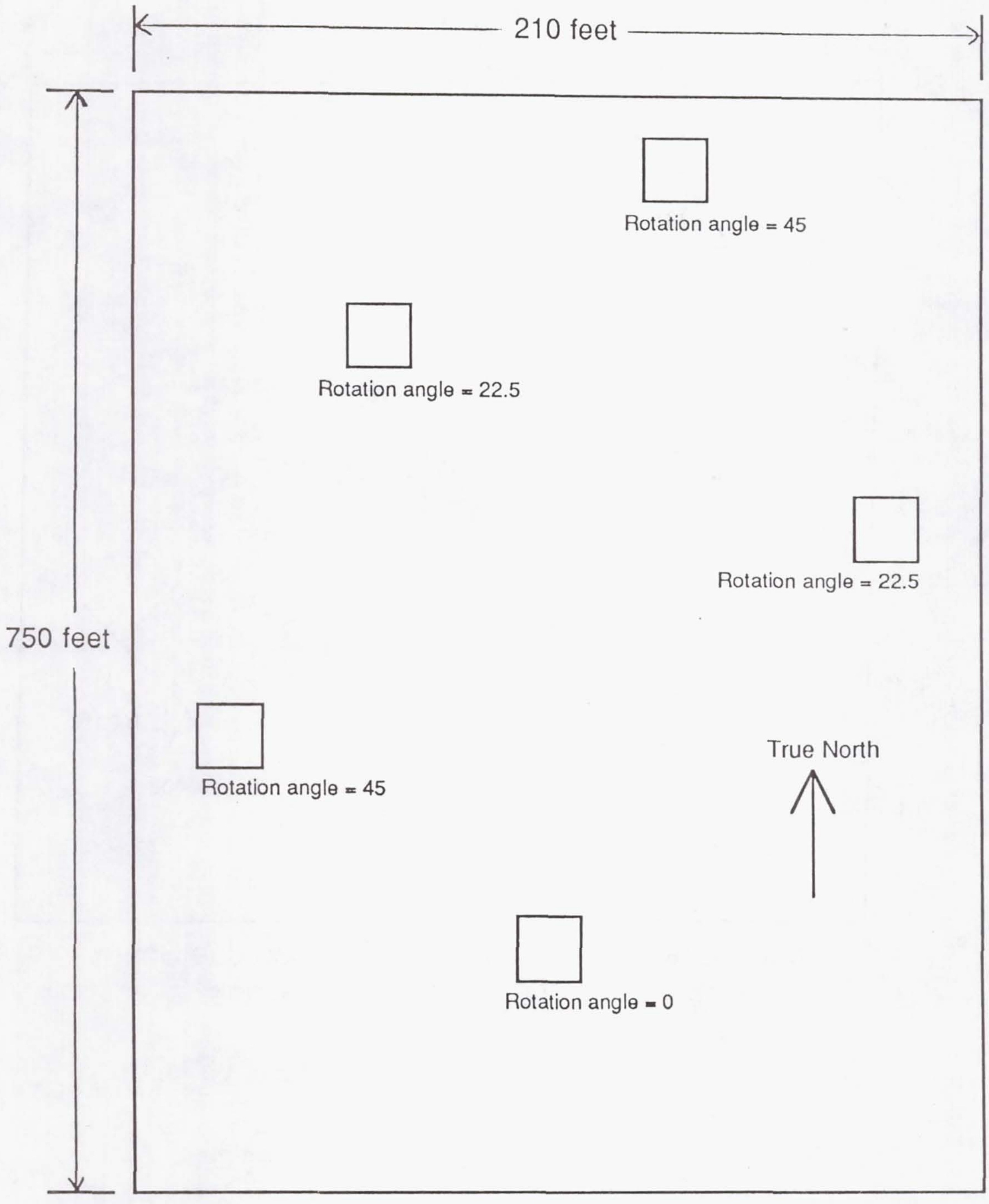
Target Area #4



Trihedral look direction is due South (180 degrees).
Trihedral inclination angle is 10 degrees.

Figure A-2d.

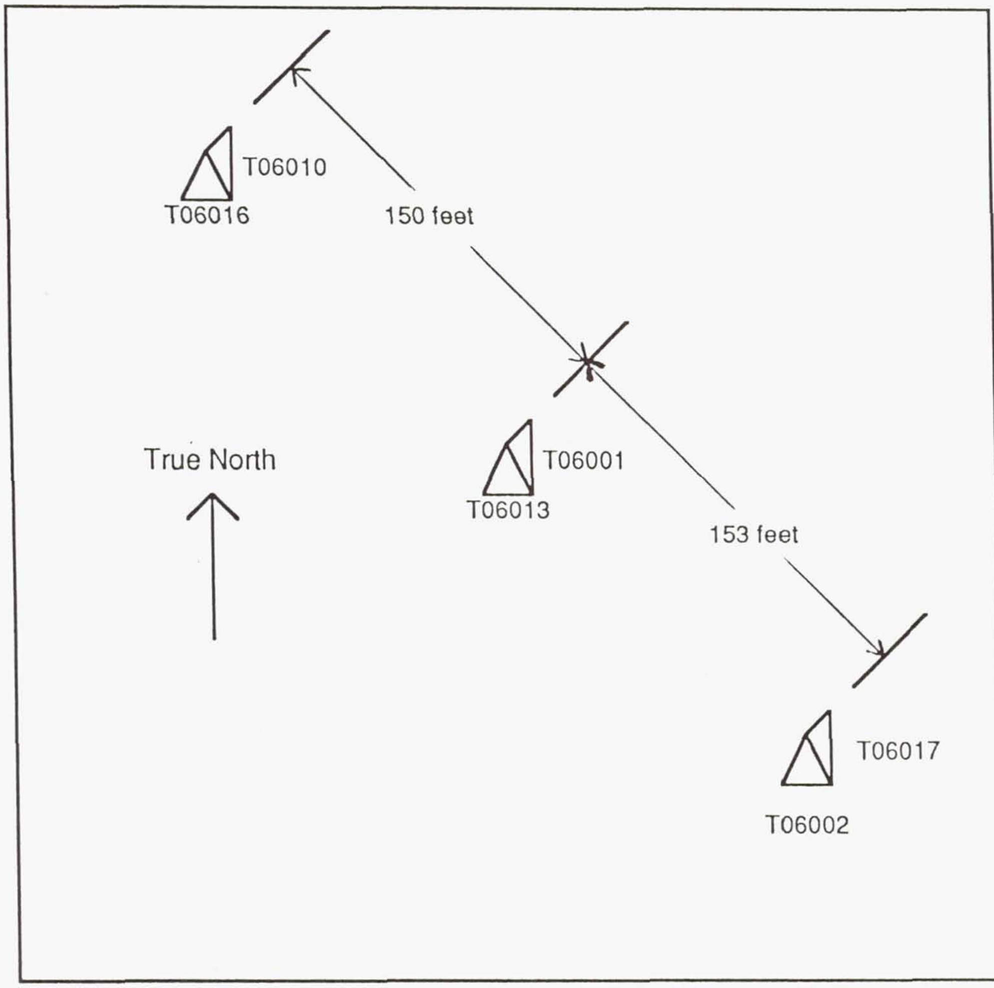
Target Area #5A



Dihedral look direction is due South.
Dihedral inclination angle is 11 degrees.

Figure A-2e

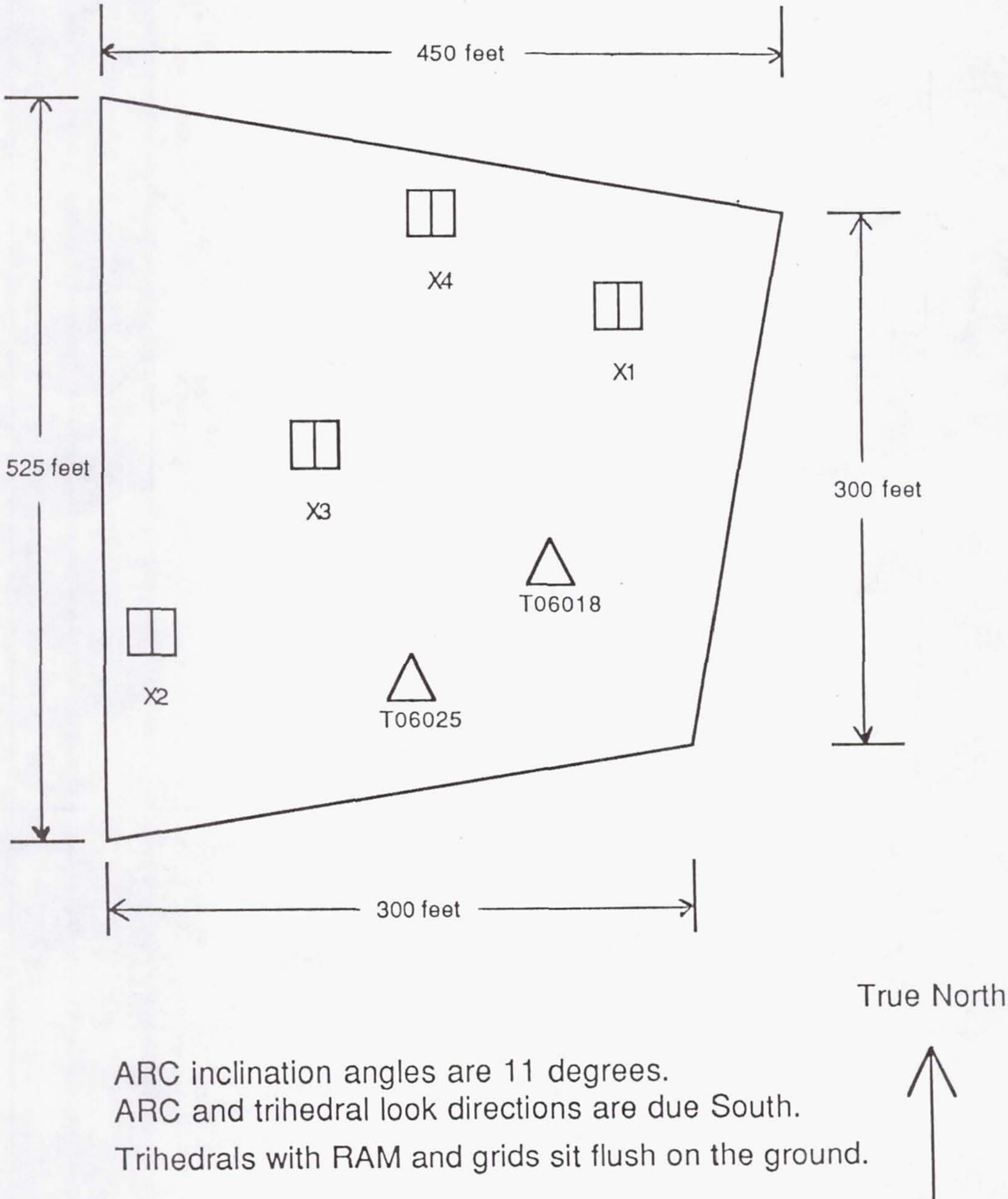
Target Area #5B



Trihedral look directions are due East and due South.
Trihedral inclination angle is 10 degrees.

Figure A-2f.

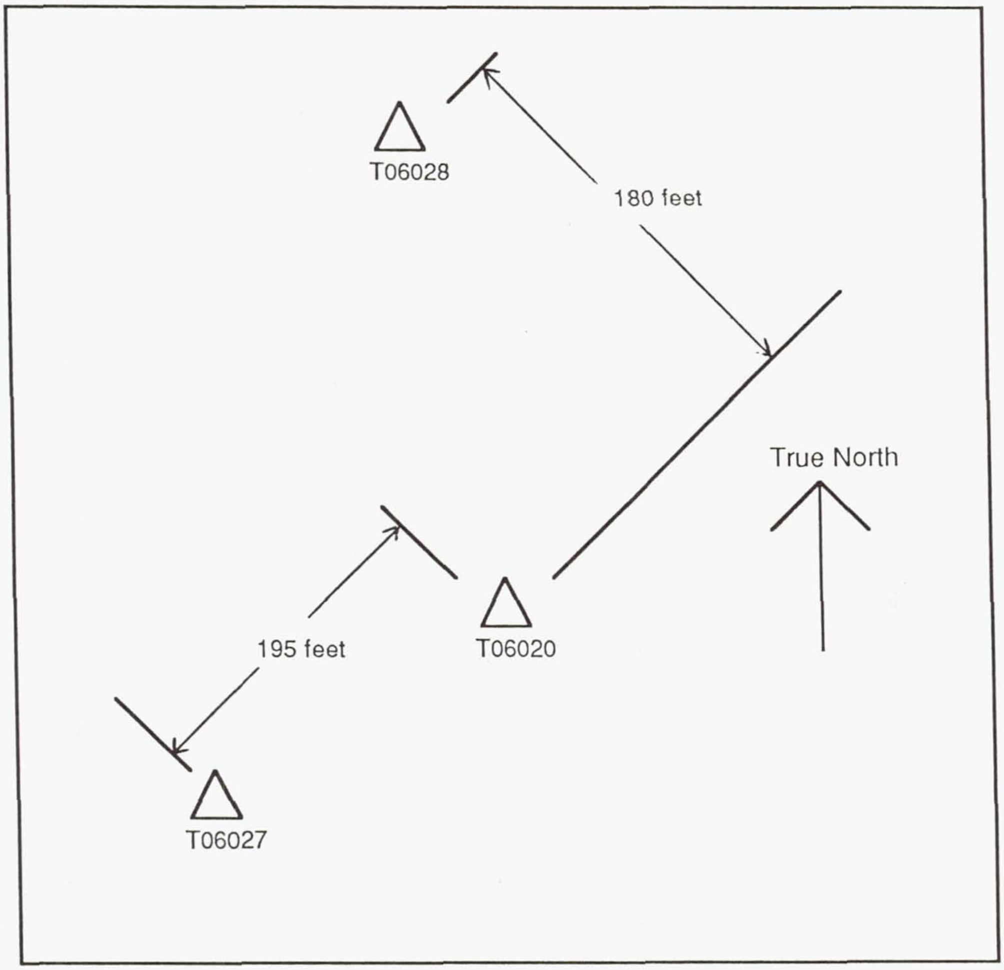
Target Area #5C



ARC inclination angles are 11 degrees.
ARC and trihedral look directions are due South.
Trihedrals with RAM and grids sit flush on the ground.

Receive antenna of X4 found to be pointing at 187 degrees True upon takedown of equipment.

Figure A-2g.

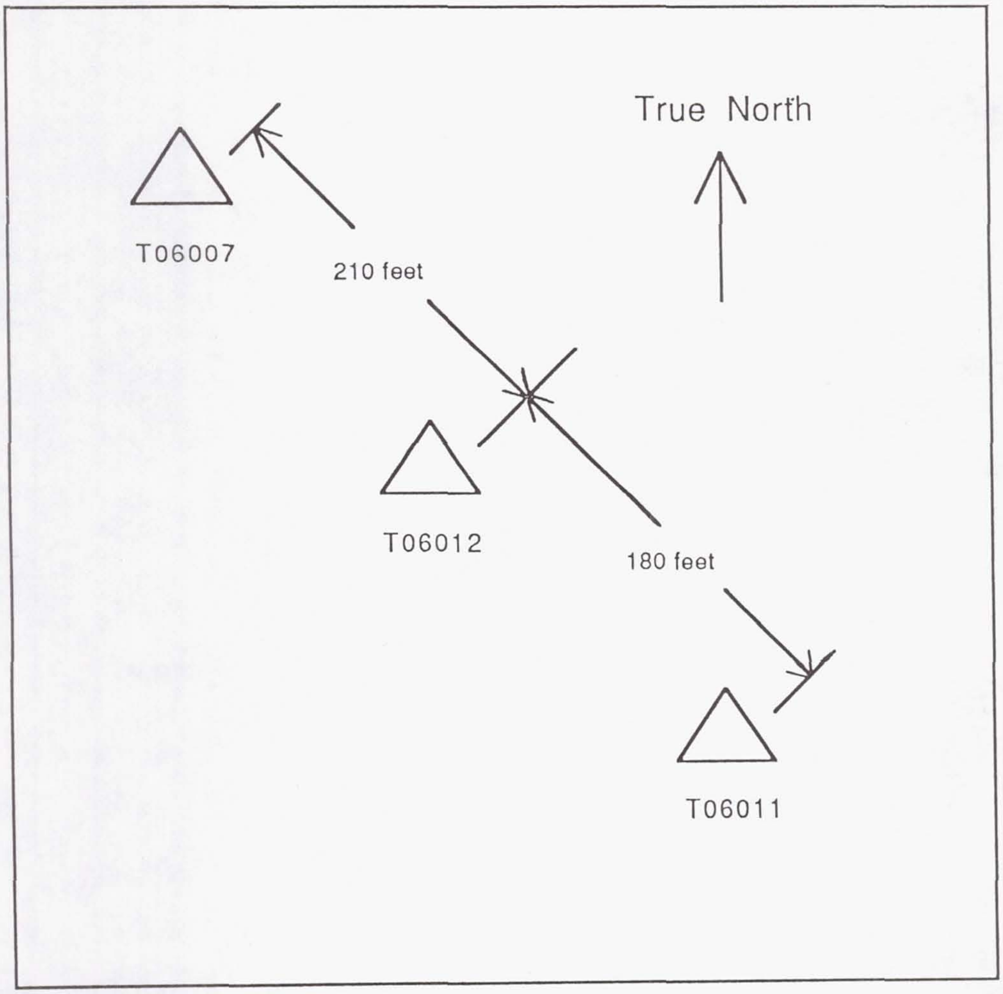


Target Area #6

Trihedral look direction is due South (180 degrees).
Trihedral inclination angle is 10 degrees.

Figure A-2h.

Target Area #7



Trihedral look direction is due South (180 degrees).

Trihedral inclination angle is 10 degrees.

Figure A-2i.

APPENDIX B

APPENDIX B

Figures B-1 through B-5 and Tables B-1 through B-5 areas which were used in the clutter analysis. The areas are coded by their clutter type. 'Re' is residential clutter, 'G' is grass, 'Ra' is runway, 'W' is water, 'U' is urban, 'C' is city, 'I' is industrial, 'H' is man-made, and 'M' is miscellaneous.

Table B-1. Clutter Statistics for the Denver Polarimetric Set , X-HH

Id	Region Type	# Pts	Incidence Angle	Min (dB)	Max(dB)	Mean (dB)	Variance	SDEV	Variation
Re1	Residential	90000	50.34	-44.08	15.79	-12.64	0.20761E+00	0.45565E+00	0.83765E-01
Re2	Residential	22500	56.21	-44.08	15.57	-12.75	0.28354E+00	0.53248E+00	0.10038E+02
Re3	Residential	90000	60.74	-44.08	18.89	-12.23	0.46259E+00	0.68014E+00	0.11375E+02
Re4	Residential	135000	62.74	-44.08	21.50	-10.75	0.13277E+01	0.11523E+01	0.13699E+02
Re5	Residential	45000	64.88	-44.08	21.37	-7.98	0.33587E+01	0.18327E+01	0.11504E+02
Re6	Residential	45000	64.92	-44.08	19.95	-9.45	0.11434E+01	0.10693E+01	0.94185E-01
Re7	Residential	45000	68.14	-44.08	19.69	-8.64	0.13667E+01	0.11691E+01	0.85456E+01
Re8	Residential	45000	68.21	-44.08	15.13	-13.02	0.81518E-01	0.28551E+00	0.57287E-01
Re9	Residential	45000	68.03	-44.08	22.48	-5.81	0.54702E+01	0.23388E+01	0.89135E-01
Re10	Residential	37500	70.58	-44.08	18.61	-8.67	0.12753E+01	0.11293E+01	0.83209E-01
Re11	Residential	22500	73.82	-44.08	18.28	-9.02	0.76250E+00	0.87321E+00	0.69674E+01
Re12	Residential	2500	79.55	-44.08	18.95	-1.94	0.95066E+01	0.30833E+01	0.48207E-01
Re13	Residential	2500	79.69	-44.08	-1.53	-19.46	0.13398E-02	0.36603E-01	0.32312E-01
Re14	Residential	40000	79.82	-44.08	18.54	-14.86	0.30884E+00	0.55574E+00	0.17022E-02
Re15	Residential	40000	80.06	-44.08	19.98	-12.28	0.92143E+00	0.95991E+00	0.16240E-02
Re16	Residential	20000	80.38	-44.08	23.95	-12.63	0.45174E+01	0.21254E+01	0.38965E-02
Re17	Residential	20000	80.67	-44.08	2.87	-22.12	0.18189E-02	0.42649E-01	0.69454E-01
Re18	Residential	20000	80.88	-44.08	9.10	-23.00	0.61432E-02	0.78379E-01	0.15633E-02
Re19	Residential	20000	81.08	-44.08	5.05	-23.23	0.17610E-02	0.41964E-01	0.88237E-01
Re20	Residential	20000	81.27	-44.08	12.52	-19.19	0.43622E-01	0.20886E+00	0.17344E-02
Re21	Residential	20000	81.46	-44.08	10.24	-16.08	0.53133E-01	0.23051E+00	0.93521E-01
Re22	Residential	20000	81.63	-44.08	14.78	-13.78	0.22005E+00	0.46910E+00	0.11205E-02
Re23	Residential	60000	51.25	-44.08	19.12	-10.28	0.58751E+00	0.76649E+00	0.81699E-01
Re24	Residential	30000	62.64	-44.08	19.44	-13.09	0.44651E+00	0.66822E+00	0.13617E-02
M1	Grass/Trees	2500	47.59	-44.08	-7.53	-16.70	0.44948E-03	0.21201E-01	0.99077E-00
M2	Grass/Trees	2500	52.31	-44.08	-9.10	-19.14	0.14065E-03	0.11860E-01	0.97256E-00
M3	Grass/Trees	2500	54.90	-44.08	-9.50	-20.27	0.90901E-04	0.95342E-02	0.10143E-01
H1	Building	1710	64.51	-25.46	12.72	-0.79	0.30213E+01	0.17382E+01	0.20872E+01
G1	Grass	10000	75.91	-44.08	-16.07	-28.23	0.29268E-05	0.17108E-02	0.11379E-01
G2	Grass	10000	77.42	-44.08	-17.31	-30.55	0.19100E-05	0.13820E-02	0.15701E+01
G3	Grass	10000	78.14	-44.08	-17.71	-30.75	0.25600E-05	0.16000E-02	0.19029E+01
M4	Gold Course	25000	75.93	-44.08	-3.30	-24.42	0.13606E-03	0.11664E-01	0.32250E-01
Re25	Residential	10000	77.35	-44.08	10.70	-15.14	0.43264E-01	0.20800E+00	0.67897E+01
G4	Grass	10000	51.33	-44.08	-6.64	-19.68	0.15965E-03	0.12635E-01	0.11735E+01
G5	Grass	5625	55.72	-44.08	-9.70	-20.82	0.69315E-04	0.83256E-02	0.10062E-01
G6	Grass	10000	78.98	-44.08	-15.56	-30.47	0.72185E-05	0.26867E-02	0.29940E+01
G7	Grass	10000	79.45	-44.08	-13.09	-31.58	0.89005E-05	0.29834E-02	0.42897E-01
G8	Grass	10000	80.03	-44.08	-11.51	-29.23	0.23422E-04	0.48397E-02	0.40563E-01
G9	Grass	10000	80.47	-44.08	-11.47	-28.74	0.35837E-04	0.59864E-02	0.44763E-01
G10	Grass	10000	80.84	-44.08	-9.85	-29.25	0.48482E-04	0.69629E-02	0.58610E-01
G11	Grass	10000	81.14	-44.08	-7.65	-26.61	0.11788E-03	0.10857E-01	0.49722E-01
G12	Grass	10000	81.50	-44.08	-8.31	-26.36	0.16590E-03	0.12880E-01	0.55645E-01
G13	Grass	10000	81.81	-44.08	-3.60	-27.16	0.22783E-03	0.15094E-01	0.78462E-01
G14	Grass	5625	59.97	-44.08	-8.30	-25.95	0.14192E-04	0.37673E-02	0.14827E-01
Ru1	Runway	1500	76.69	-44.08	-19.96	-34.45	0.76008E-06	0.87183E-03	0.24276E-01
Ru2	Runway	1500	76.69	-44.08	-22.97	-36.22	0.24743E-06	0.49742E-03	0.20823E-01
Ru3	Runway	1500	76.68	-44.08	-24.57	-41.28	0.32166E-07	0.17935E-03	0.24059E-01
Ru4	Runway	1125	77.46	-44.08	-22.18	-39.18	0.15198E-06	0.38985E-03	0.32255E-01
Ru5	Runway	1125	77.44	-44.08	-18.87	-36.53	0.76366E-06	0.87388E-03	0.39296E-01
G16	Grass	2250	76.52	-44.08	-14.71	-31.33	0.21267E-05	0.14583E-02	0.19795E-01
G17	Grass	2250	76.11	-44.08	-18.48	-29.25	0.23876E-05	0.15452E-02	0.13013E-01
G18	Grass	2250	77.31	-44.08	-17.95	-31.86	0.13754E-05	0.11728E-02	0.18010E-01
H2	Terminal	2400	77.65	-27.53	25.61	6.98	0.33518E+03	0.18308E+02	0.36676E-01
H3	Terminal	2400	78.04	-44.08	25.29	5.83	0.24121E+03	0.15531E+02	0.40579E+01
W1	Water	100	77.31	-44.08	-23.10	-36.38	0.47631E-06	0.69015E-03	0.29969E-01
W2	Water	100	77.83	-44.08	-44.08	-44.08	-0.43924E-16	0.00000E+00	0.00000E-00
H4	Building	1250	80.23	-44.08	24.78	5.02	0.35945E+03	0.18959E+02	0.59691E-01
H5	Building	2000	80.37	-44.08	27.30	2.41	0.49901E+03	0.22339E+02	0.12811E-02
M5	Park Lot-Full	1800	79.57	-44.08	13.12	-4.20	0.14378E+01	0.11991E+01	0.31564E-01

Table B-1. Cont.

Ru6	Runway	225	81.33	-44.08	-12.92	-33.41	0.19505E-04	0.44165E-02	0.96934E+01
U1	Urban	45000	64.89	-44.08	23.59	-5.66	0.67139E+01	0.25911E+01	0.95377E+01
U2	Urban	67500	67.69	-44.08	22.28	-4.71	0.79247E+01	0.28151E+01	0.83349E+01
U3	Urban	67500	70.99	-44.08	20.61	-8.01	0.19106E+01	0.13823E+01	0.87488E+01
U4	Urban	67500	72.33	-44.08	20.77	-7.10	0.27270E+01	0.16514E+01	0.84683E+01
U5	Urban	45000	73.44	-44.08	19.38	-10.42	0.89370E+00	0.94536E+00	0.10419E+02
U6	Urban	45000	74.45	-44.08	22.33	-8.13	0.31579E+01	0.17770E+01	0.11555E+02
U7	Urban	45000	75.24	-44.08	21.83	-9.59	0.22027E+01	0.14842E+01	0.13508E+02
U8	Urban	45000	75.76	-44.08	22.31	-9.59	0.24400E+01	0.15621E+01	0.14205E+02
U9	Urban	45000	76.82	-44.08	24.28	-10.17	0.41138E+01	0.20283E+01	0.21073E-02
U10	Urban	45000	77.23	-44.08	24.62	-8.76	0.68241E+01	0.26123E+01	0.19622E+02
U11	Urban	45000	77.62	-44.08	21.74	-11.74	0.95960E+00	0.97959E+00	0.14608E+02
U12	Urban	45000	78.11	-44.08	29.92	-6.68	0.40137E+02	0.63354E+01	0.29502E+02
U13	Urban	15000	78.50	-44.08	28.46	-2.37	0.20871E+03	0.14447E+02	0.24954E+02
U14	Urban	15000	78.85	-44.08	25.46	-5.38	0.19997E+02	0.44717E+01	0.15420E+02
U15	Urban	15000	78.10	-44.08	29.92	-0.85	0.15097E+03	0.12287E+02	0.14927E+02
C1	City	10000	79.07	-44.08	30.06	4.99	0.74416E+03	0.27279E+02	0.86374E+01
C2	City	10000	79.21	-44.08	29.05	3.78	0.49710E+03	0.22296E+02	0.93391E-01
C3	City	10000	79.35	-44.08	34.63	7.49	0.46211E+04	0.67979E+02	0.12124E+02
C4	City	10000	79.49	-44.08	30.73	4.96	0.72282E+03	0.26885E+02	0.85739E-01
C5	City	10000	79.62	-44.08	30.60	1.19	0.38563E+03	0.19637E+02	0.14924E+02
C6	City	10000	79.96	-44.08	31.59	5.97	0.13650E+04	0.36946E+02	0.93354E+01
C7	City	10000	80.09	-44.08	35.77	6.45	0.44918E+04	0.67021E+02	0.15168E+02
C8	City	10000	80.23	-44.08	34.14	2.73	0.12503E+04	0.35359E+02	0.18841E+02
C9	City	10000	80.38	-44.08	33.41	4.61	0.19540E+04	0.44204E+02	0.15302E-02
H6	Building	600	78.29	-22.86	16.27	2.83	0.14188E+02	0.37667E+01	0.19611E+01
H7	Warehouse	850	78.38	-44.08	20.53	1.53	0.33934E+02	0.58253E+01	0.40998E-01
H8	Warehouse	850	78.47	-44.08	18.79	-2.63	0.13741E+02	0.37069E+01	0.67934E+01
H9	Warehouse	500	78.53	-44.08	17.35	1.35	0.20769E+02	0.45573E+01	0.33435E+01
H10	Warehouse	850	78.60	-44.08	17.63	-2.23	0.10685E+02	0.32687E+01	0.54630E+01
U16	Urban	30000	75.40	-44.08	21.10	-7.27	0.29841E+01	0.17275E+01	0.92083E+01
U17	Urban	30000	75.40	-44.08	21.26	-7.35	0.37187E+01	0.19284E+01	0.10476E+02
U18	Urban	30000	75.40	-44.08	18.74	-10.71	0.65449E+00	0.80901E+00	0.95289E+01
I1	Industrial	7500	79.03	-44.08	26.41	2.56	0.25650E+03	0.16016E+02	0.88759E-01
I2	Industrial	7500	79.08	-44.08	29.28	1.55	0.24536E+03	0.15664E+02	0.10960E+02
I3	Industrial	5000	79.10	-44.08	27.28	2.32	0.14834E+03	0.12179E+02	0.71318E-01
I4	Industrial	5000	79.57	-44.08	28.28	6.36	0.89589E+03	0.29931E+02	0.69193E+01
I5	Industrial	5000	80.84	-44.08	27.79	0.23	0.23443E+03	0.15311E+02	0.14517E+02
I6	Industrial	5000	81.59	-44.08	20.20	-4.76	0.86128E+01	0.29348E+01	0.87760E-01
U19	Urban	10000	73.46	-44.08	14.06	-10.57	0.35754E+00	0.59795E+00	0.68245E-01
U20	Urban	16000	72.87	-44.08	20.45	-5.29	0.48227E+01	0.21961E+01	0.74262E+01

Table B-2. Clutter Statistics for the First Denver 'Step West'

ID	Region Type	# Pts	Incidence Angle	Min (dB)	Max(dB)	Mean (dB)	Variance	SDEV	Variation
W1	Water	1500	78.38	-38.71	-17.26	-37.57	0.39690E-06	0.63000E-03	0.36004E+01
W2	Water	2800	79.30	-38.71	-20.46	-38.61	0.27979E-07	0.16727E-03	0.12137E+01
G1	Grass	30000	41.80	-38.71	-4.66	-18.60	0.45201E-03	0.21260E-01	0.15401E+01
G2	Grass	30000	55.72	-38.71	-11.55	-24.44	0.11801E-04	0.34352E-02	0.95442E+00
G3	Grass	30000	63.20	-38.71	-10.50	-22.24	0.38870E-04	0.62346E-02	0.10438E+01
G4	Grass	30000	68.07	-38.71	-8.30	-23.84	0.23947E-04	0.48936E-02	0.11834E+01
G5	Grass	30000	71.65	-38.71	-10.26	-25.25	0.11210E-04	0.33481E-02	0.11216E+01
G6	Grass	30000	73.96	-38.71	-12.95	-23.38	0.15034E-04	0.38774E-02	0.84437E+00
G7	Grass	30000	75.51	-38.71	-12.99	-24.55	0.10204E-04	0.31944E-02	0.91093E+00
G8	Grass	30000	76.48	-38.71	-10.12	-24.59	0.12262E-04	0.35017E-02	0.10074E+01
Re1	Residential	10000	75.44	-38.71	4.65	-16.68	0.40062E-02	0.63294E-01	0.29484E+01
Re2	Residential	10000	79.16	-38.71	9.37	-15.75	0.19947E-01	0.14123E+00	0.53124E+01
H1	Terminal	2800	82.51	-38.71	21.97	0.63	0.59941E+02	0.77422E+01	0.66972E+01
H2	Terminal	2800	82.49	-38.71	15.85	-8.47	0.11789E+01	0.10858E+01	0.76262E+01
H3	Terminal	2800	82.54	-38.71	10.27	-13.84	0.10371E+00	0.32204E+00	0.77991E+01
M1	ParkingLot	4000	82.36	-38.71	8.15	-13.14	0.11848E+00	0.34421E+00	0.70868E+01
U1	Urban	30000	80.18	-38.71	12.85	-14.68	0.68217E-01	0.26118E+00	0.76718E+01
U2	Urban	30000	81.05	-38.71	23.72	-11.66	0.43056E+01	0.20750E+01	0.30383E+02
U3	Urban	30000	81.73	-38.71	17.84	-15.65	0.20394E+00	0.45159E+00	0.16585E+02
U4	Urban	30000	83.32	-38.71	10.18	-22.51	0.13507E-01	0.11622E+00	0.20715E+02
U5	Urban	30000	83.97	-38.71	7.99	-25.68	0.82248E-02	0.90691E-01	0.33549E+02
H4	Warehouse	300	79.56	-38.71	16.43	-3.50	0.92285E+01	0.30378E+01	0.68022E+01
H5	Warehouse	300	79.56	-38.71	8.99	-5.63	0.81714E+00	0.90396E+00	0.33083E+01
H6	Warehouse	300	79.56	-38.71	9.75	-7.94	0.48676E+00	0.69768E+00	0.43450E+01
H7	Warehouse	300	79.56	-38.71	3.17	-9.09	0.89906E-01	0.29984E+00	0.24312E+01
G9	Grass	10000	78.21	-38.71	-7.45	-28.93	0.22393E-04	0.47321E-02	0.36980E+01
Re3	Residential	10000	80.28	-38.71	9.72	-18.46	0.30731E-01	0.17530E+00	0.12296E+02
Re4	Residential	25500	71.22	-38.71	6.96	-15.63	0.11561E-01	0.10752E+00	0.39313E+01
H8	Building	1520	70.10	-38.71	3.61	-14.84	0.17118E-01	0.13084E+00	0.39846E+01
Re5	Residential	10000	55.66	-38.71	3.20	-19.03	0.15607E-02	0.39505E-01	0.31565E+01
Re6	Residential	10000	68.19	-38.71	15.06	-11.59	0.31647E+00	0.56255E+00	0.81161E+01
Re7	Residential	2500	83.24	-38.71	2.73	-24.60	0.31120E-02	0.55785E-01	0.16088E+02
Re8	Residential	15000	78.48	-38.71	2.75	-17.48	0.24802E-02	0.49801E-01	0.27883E+01
Re9	Residential	12500	77.65	-38.71	5.28	-16.83	0.42610E-02	0.65277E-01	0.31478E+01
Re10	Residential	30000	79.16	-38.71	19.34	-14.52	0.34867E+00	0.59048E+00	0.16719E+02
Re11	Residential	30000	78.49	-38.71	4.25	-18.46	0.18770E-02	0.43324E-01	0.30410E+01
Re12	Residential	12000	77.47	-38.71	7.47	-18.16	0.60775E-02	0.77959E-01	0.51040E+01
Re13	Residential	7000	76.58	-38.71	1.72	-18.98	0.25691E-02	0.50686E-01	0.40117E+01
Re14	Residential	15000	76.81	-38.71	2.14	-17.15	0.21997E-02	0.46901E-01	0.24310E+01
Re15	Residential	26250	75.53	-38.71	11.89	-16.99	0.29824E-01	0.17270E+00	0.86282E+01
Re16	Residential	12500	76.65	-38.71	9.97	-18.88	0.10724E-01	0.10356E+00	0.80027E+01
Re17	Residential	7000	77.37	-38.71	5.90	-16.81	0.97616E-02	0.98801E-01	0.47384E+01
I1	Industrial	5600	75.98	-38.71	9.20	-17.15	0.24545E-01	0.15667E+00	0.81298E+01
H9	Building	800	76.12	-38.71	0.67	-16.08	0.10091E-01	0.10045E+00	0.40708E+01
H10	Building	800	76.12	-38.71	0.70	-17.14	0.67417E-02	0.82108E-01	0.42530E+01
H11	Building	1000	76.55	-38.71	-0.48	-21.08	0.10957E-02	0.33101E-01	0.42485E+01
H12	Building	300	78.42	-20.89	1.87	-6.21	0.58227E-01	0.24130E+00	0.10078E+01
I2	Industrial	10000	78.70	-38.71	13.16	-12.03	0.25876E+00	0.50868E+00	0.81148E+01
I3	Industrial	12500	79.51	-38.71	17.33	-8.01	0.10713E+01	0.10351E+01	0.65397E+01
I4	Industrial	15000	80.09	-38.71	24.71	-4.17	0.26515E+02	0.51493E+01	0.13456E+02
I5	Industrial	15000	80.90	-38.71	26.27	-7.54	0.18102E+02	0.42546E+01	0.24140E+02
I6	Industrial	15000	80.83	-38.71	20.38	-4.40	0.10840E+02	0.32925E+01	0.90656E+01
G10	Grass	30000	51.04	-38.71	-13.39	-23.82	0.12472E-04	0.35316E-02	0.85132E+00
G11	Grass	20000	49.52	-38.71	-13.42	-23.46	0.16664E-04	0.40822E-02	0.90631E+00
G12	Grass	12500	59.81	-38.71	-12.12	-26.34	0.65129E-05	0.25520E-02	0.10997E+01
G13	Grass	20000	63.98	-38.71	-8.89	-19.49	0.98164E-04	0.99078E-02	0.88034E+00
G14	Grass	20000	65.74	-38.71	-8.03	-18.63	0.14384E-03	0.11993E-01	0.87568E+00
G15	Grass	30000	68.49	-38.71	-13.21	-23.85	0.14200E-04	0.37683E-02	0.91461E+00
G16	Grass	30000	73.92	-38.71	-8.04	-26.03	0.99671E-05	0.31571E-02	0.12644E+01

Table B-2. Cont.

G17	Grass	12500	70.79	-38.71	-18.71	-30.02	0.15545E-05	0.12468E-02	0.12537E+01
G18	Grass	10000	71.30	-38.71	-17.21	-30.82	0.14856E-05	0.12189E-02	0.14720E+01
G19	Grass	10000	67.77	-38.71	-10.58	-21.81	0.37557E-04	0.61284E-02	0.92993E+00
G20	Grass	10000	71.15	-38.71	-16.89	-28.76	0.29539E-05	0.17187E-02	0.12932E+01
G21	Grass	20000	73.14	-38.71	-6.42	-23.25	0.18295E-04	0.42773E-02	0.90459E+00
G22	Grass	12500	74.29	-38.71	-14.96	-24.36	0.97223E-05	0.31181E-02	0.85004E+00
G23	Grass	30000	78.69	-38.71	-6.81	-31.71	0.70983E-05	0.26643E-02	0.39520E+01
G24	Grass	30000	79.37	-38.71	-9.39	-32.53	0.80079E-05	0.28298E-02	0.50638E+01
G25	Grass	30000	80.18	-38.71	-10.10	-32.85	0.11511E-04	0.33927E-02	0.65322E+01
G26	Grass	30000	80.68	-38.71	-9.00	-35.06	0.82706E-05	0.28759E-02	0.92241E+01
G27	Grass	30000	81.75	-38.71	-8.50	-36.36	0.82507E-05	0.28724E-02	0.12430E+02
G28	Grass	15000	76.57	-38.71	-11.29	-23.84	0.19828E-04	0.44529E-02	0.10783E+01
G29	Grass	11250	75.99	-38.71	-14.39	-24.73	0.83022E-05	0.28813E-02	0.85633E+00
G30	Grass	5625	76.00	-38.71	-13.55	-23.98	0.12143E-04	0.34847E-02	0.87217E+00
G31	Grass	30000	46.84	-38.71	-7.54	-20.12	0.14178E-03	0.11907E-01	0.12229E+01
G32	Grass	4000	59.71	-38.71	-21.81	-30.69	0.59125E-06	0.76892E-03	0.90048E+00
G33	Grass	1500	53.05	-38.71	-18.79	-27.62	0.24600E-05	0.15684E-02	0.90607E+00
G34	Grass	7500	56.50	-38.71	-15.72	-25.52	0.57926E-05	0.24068E-02	0.85848E+00
G35	Grass	20000	56.09	-38.71	-6.60	-24.69	0.11752E-04	0.34282E-02	0.10093E+01
G36	Grass	15000	62.29	-38.71	-12.18	-28.53	0.42521E-05	0.20621E-02	0.14694E+01
G37	Grass	15000	63.42	-38.71	-10.19	-20.91	0.59243E-04	0.76969E-02	0.94905E+00
W3	Water	225	67.16	-38.71	-27.90	-38.50	0.97788E-08	0.98888E-04	0.70000E+00
W4	Water	225	73.59	-38.71	-31.82	-38.58	0.18696E-08	0.43239E-04	0.31172E+00
G38	Grass	20000	71.09	-38.71	-12.94	-23.40	0.14128E-04	0.37587E-02	0.82310E+00
G39	Grass	20000	56.09	-38.71	-13.52	-23.26	0.14041E-04	0.37471E-02	0.79375E+00
G40	Grass	20000	64.52	-38.71	-9.60	-18.81	0.13083E-03	0.11438E-01	0.87013E+00
G41	Grass	20000	65.56	-38.71	-8.99	-19.64	0.10056E-03	0.10028E-01	0.92235E+00
Re18	Residential	2500	56.03	-38.71	3.58	-15.73	0.11847E-01	0.10884E+00	0.40762E+01
Re19	Residential	2500	54.17	-38.71	3.09	-18.75	0.35624E-02	0.59686E-01	0.44784E+01
Re20	Residential	1400	45.89	-38.71	8.81	-10.58	0.15123E+00	0.38888E+00	0.44430E+01
G42	Grass	20000	65.34	-38.71	-10.43	-21.32	0.70338E-04	0.83867E-02	0.11367E+01
G43	Grass	20000	62.79	-38.71	-9.11	-22.16	0.49079E-04	0.70056E-02	0.11530E+01
G44	Grass	20000	57.13	-38.71	-9.04	-25.39	0.75136E-05	0.27411E-02	0.94903E+00
G45	Grass	10000	71.39	-38.71	-13.91	-24.15	0.14565E-04	0.38164E-02	0.99175E+00
G46	Grass	10000	71.39	-38.71	-10.44	-25.90	0.91493E-05	0.30248E-02	0.11771E+01
G47	Grass	10000	71.39	-38.71	-8.79	-27.35	0.98714E-05	0.31419E-02	0.17053E+01
G48	Grass	20000	71.18	-38.71	-14.01	-24.52	0.12101E-04	0.34786E-02	0.98601E+00
G49	Grass	7500	44.66	-38.71	-5.69	-17.29	0.56798E-03	0.23832E-01	0.12779E+01
G50	Grass	7500	46.10	-38.71	-5.02	-18.91	0.33189E-03	0.18218E-01	0.14158E+01
G51	Grass	7500	53.69	-38.71	-12.92	-23.83	0.11801E-04	0.34352E-02	0.83034E+00
G52	Grass	20000	56.44	-38.71	-15.09	-25.70	0.55641E-05	0.23588E-02	0.87539E+00
Re21	Residential	3600	43.71	-38.71	2.69	-13.80	0.11828E-01	0.10876E+00	0.26103E+01
Re22	Residential	10000	75.18	-38.71	6.07	-16.19	0.10162E-01	0.10081E+00	0.41965E+01
Re23	Residential	20000	78.70	-38.71	9.98	-17.19	0.10621E-01	0.10306E+00	0.53970E+01
Re24	Residential	20000	78.08	-38.71	3.92	-17.77	0.40187E-02	0.63393E-01	0.37949E+01
Re25	Residential	16000	78.86	-38.71	3.01	-17.99	0.25066E-02	0.50066E-01	0.31486E+01
Re26	Residential	10000	76.13	-38.71	10.07	-18.26	0.13768E-01	0.11734E+00	0.78590E+01
U6	Urban	12000	82.85	-38.71	16.11	-11.22	0.74051E+00	0.86053E+00	0.11390E+02
U7	Urban	30000	82.29	-38.71	10.99	-16.78	0.57992E-01	0.24081E+00	0.11475E+02
U8	Urban	30000	82.79	-38.71	13.78	-18.53	0.62119E-01	0.24924E+00	0.17787E+02
U9	Urban	30000	83.12	-38.71	16.03	-19.19	0.14202E+00	0.37685E+00	0.31257E+02
I7	Industrial	10000	80.04	-38.71	13.32	-10.31	0.30085E+00	0.54849E+00	0.58972E+01
I8	Industrial	10000	80.28	-38.71	23.75	-7.60	0.99269E+01	0.31507E+01	0.18127E+02
I9	Industrial	10000	80.52	-38.71	13.32	-10.97	0.25114E+00	0.50114E+00	0.62617E+01
I10	Industrial	10000	81.03	-38.71	15.53	-10.72	0.58426E+00	0.76437E+00	0.90220E+01
H13	Warehouse	2550	80.44	-38.71	7.21	-13.31	0.70592E-01	0.26569E+00	0.56981E+01
H14	Warehouse	2550	80.48	-38.71	8.10	-12.55	0.94250E-01	0.30700E+00	0.55288E+01
G53	Grass	5000	80.84	-38.71	-12.06	-34.21	0.94236E-05	0.30698E-02	0.80939E+01
G54	Grass	5000	79.07	-38.71	-4.33	-27.67	0.69687E-04	0.83479E-02	0.48841E+01
G55	Grass	5000	81.98	-38.71	-7.41	-35.98	0.15773E-04	0.39716E-02	0.15752E+02
G56	Grass	5000	82.59	-38.71	-6.06	-34.28	0.49031E-04	0.70022E-02	0.18767E+02
U10	Urban	15000	78.13	-38.71	11.42	-14.39	0.44610E-01	0.21121E+00	0.57982E+01
U11	Urban	10000	77.11	-38.71	9.06	-15.08	0.25071E-01	0.15834E+00	0.51055E+01
M2	Golf Course	20000	79.41	-38.71	0.24	-21.74	0.83740E-03	0.28938E-01	0.43164E+01

Table B-2. Cont.

G57	Grass	2500	78.45	-38.71	-19.87	-33.71	0.12481E-05	0.11172E-02	0.26270E+01
G58	Grass	2500	79.05	-38.71	-16.91	-33.94	0.29308E-05	0.17120E-02	0.42431E+01
U12	Urban	10000	76.76	-38.71	11.14	-13.39	0.46314E-01	0.21521E+00	0.46991E+01
G59	Grass	2500	70.75	-38.71	-17.16	-25.67	0.52597E-05	0.22934E-02	0.84671E+00
I11	Industrial	3750	74.15	-38.71	4.33	-12.89	0.20306E-01	0.14250E+00	0.27703E+01
I12	Industrial	3750	76.10	-38.71	1.44	-17.55	0.21228E-02	0.46074E-01	0.26191E+01
M3	Unknown	875	78.62	-38.71	-5.74	-18.16	0.93243E-03	0.30536E-01	0.19999E+01
M4	Unknown	875	78.89	-38.71	-0.30	-16.81	0.26657E-02	0.51630E-01	0.24781E+01
C1	City	10000	84.51	-38.71	13.27	-15.05	0.37120E+00	0.60926E+00	0.19496E+02
C2	City	10000	84.24	-38.71	24.06	-6.99	0.16092E+02	0.40115E+01	0.20082E+02
C3	City	5000	83.57	-38.71	15.22	-8.84	0.14541E+01	0.12059E+01	0.92283E+01
C4	City	5000	83.78	-38.71	15.14	-8.92	0.13742E+01	0.11722E+01	0.91505E+01
C5	City	5000	83.37	-38.71	19.32	-10.23	0.22521E+01	0.15007E+01	0.15836E+02
C6	City	10000	83.48	-38.71	13.60	-10.34	0.48334E+00	0.69523E+00	0.75106E+01
I13	Industrial	7500	83.22	-38.71	15.96	-12.63	0.50643E+00	0.71164E+00	0.13049E+02
I14	Industrial	7500	83.40	-38.71	10.07	-15.16	0.65913E-01	0.25674E+00	0.84252E+01
H15	Plane	49	82.35	-38.71	-8.29	-18.72	0.15610E-02	0.39509E-01	0.29444E+01
H16	Plane	105	82.36	-38.71	-4.13	-19.75	0.25868E-02	0.50861E-01	0.48060E+01
H17	Plane	105	82.45	-38.71	-4.21	-14.70	0.73472E-02	0.85716E-01	0.25295E+01

Table B-3. Clutter Statistics for the Second Denver 'Step West'

Id	Region Type	# Pts	Incidence Angle	Min (dB)	Max(dB)	Mean (dB)	Variance	SDEV	Variation
W1	Water	900	65.08	-39.89	-17.08	-37.18	0.97671E-06	0.98829E-03	0.51663E+01
W2	Water	1800	67.30	-39.89	-23.85	-38.95	0.61799E-07	0.24859E-03	0.19527E+01
W3	Water	1800	68.70	-39.89	-16.76	-34.38	0.15701E-05	0.12530E-02	0.34319E+01
G1	Grass	30000	48.05	-39.89	-16.83	-28.54	0.27265E-05	0.16512E-02	0.11793E+01
G2	Grass	30000	56.00	-39.89	-10.94	-27.93	0.32482E-05	0.18023E-02	0.11185E+01
G3	Grass	30000	61.61	-39.89	-10.24	-24.89	0.13786E-04	0.37129E-02	0.11457E+01
Re1	Residential	10000	49.53	-39.89	0.40	-21.09	0.42346E-03	0.20578E-01	0.26443E+01
Re2	Residential	10000	56.94	-39.89	-5.38	-21.98	0.14669E-03	0.12111E-01	0.19112E+01
Re3	Residential	10000	62.17	-39.89	5.32	-17.41	0.35853E-02	0.59877E-01	0.32965E+01
Re4	Residential	30000	67.30	-39.89	20.21	-14.46	0.48908E+00	0.69934E+00	0.19548E+02
H1	Warehouse	2550	72.46	-39.89	9.32	-11.64	0.10031E+00	0.31671E+00	0.46220E+01
H2	Warehouse	300	69.62	-39.89	1.98	-11.99	0.34087E-01	0.18463E+00	0.29186E+01
H3	Warehouse	300	69.62	-39.89	12.40	-8.55	0.11288E+01	0.10624E+01	0.76031E+01
H4	Warehouse	300	69.62	-39.89	1.34	-13.59	0.12707E-01	0.11273E+00	0.25741E+01
H5	Warehouse	300	69.62	-39.89	7.14	-13.14	0.94918E-01	0.30809E+00	0.63505E+01
G4	Grass	1500	75.33	-39.89	-12.22	-26.80	0.10366E-04	0.32196E-02	0.15405E+01
G5	Grass	1500	77.32	-39.89	-14.92	-27.45	0.15743E-04	0.39677E-02	0.22072E+01
Ru1	Runway	500	74.66	-39.89	-39.89	-39.89	-0.14382E-15	0.00000E+00	0.00000E+00
Ru2	Runway	500	77.61	-39.89	-39.89	-39.89	-0.14382E-15	0.00000E+00	0.00000E+00
H6	Terminal	2800	78.39	-39.89	21.98	-1.78	0.26153E+02	0.51140E+01	0.77090E+01
H7	Terminal	2800	78.36	-39.89	15.09	-6.04	0.13381E+01	0.11568E+01	0.46476E+01
H8	Terminal	2800	78.51	-39.89	9.75	-10.33	0.18126E+00	0.42575E+00	0.45985E+01
M1	Park Lot	2500	78.02	-39.89	12.59	-8.95	0.25041E+00	0.50041E+00	0.39301E+01
U1	Urban	30000	72.05	-39.89	16.34	-13.28	0.11659E+00	0.34146E+00	0.72671E+01
U2	Urban	30000	73.46	-39.89	16.36	-13.66	0.83486E-01	0.28894E+00	0.67155E+01
U3	Urban	30000	74.73	-39.89	5.77	-14.54	0.81683E-02	0.90379E-01	0.25723E+01
U4	Urban	30000	75.81	-39.89	4.77	-14.66	0.77279E-02	0.87908E-01	0.25709E+01
U5	Urban	30000	77.85	-39.89	12.56	-13.65	0.69779E-01	0.26416E+00	0.61206E+01
U6	Urban	30000	78.95	-39.89	13.91	-12.98	0.10143E+00	0.31847E+00	0.63268E+01
U7	Urban	30000	79.82	-39.89	19.65	-10.51	0.17728E+01	0.13315E+01	0.14967E+02
U8	Urban	30000	80.61	-39.89	16.82	-13.95	0.23364E+00	0.48337E+00	0.12009E+02
U9	Urban	30000	81.29	-39.89	10.24	-18.87	0.13521E-01	0.11628E+00	0.89614E+01
Re5	Residential	6400	58.50	-39.89	1.80	-20.28	0.11441E-02	0.33824E-01	0.36035E+01
Re6	Residential	20000	63.80	-39.89	11.00	-13.39	0.19475E-01	0.13955E+00	0.30451E+01
Re7	Residential	16000	66.85	-39.89	5.11	-14.48	0.53943E-02	0.73446E-01	0.20604E+01
Re8	Residential	20000	66.41	-39.89	9.06	-14.72	0.11715E-01	0.10823E+00	0.32080E+01
Re9	Residential	20000	73.10	-39.89	3.26	-16.64	0.27842E-02	0.52765E-01	0.24337E+01
Re10	Residential	17500	72.29	-39.89	8.22	-16.15	0.96423E-02	0.98195E-01	0.40457E+01
Re11	Residential	17500	70.51	-39.89	0.56	-17.41	0.17509E-02	0.41844E-01	0.23072E+01
Re12	Residential	17500	65.45	-39.89	7.72	-14.43	0.11692E-01	0.10813E+00	0.29993E+01
H9	Warehouse	1050	74.67	-39.89	8.20	-10.05	0.16597E+00	0.40739E+00	0.41239E+01
I1	Industrial	10000	71.71	-39.89	15.90	-10.16	0.48980E+00	0.69986E+00	0.72667E+01
I2	Industrial	10000	72.50	-39.89	10.98	-12.38	0.12237E+00	0.34982E+00	0.60476E+01
I3	Industrial	10000	73.28	-39.89	22.28	-4.99	0.14103E+02	0.37554E+01	0.11860E+02
I4	Industrial	10000	73.95	-39.89	16.76	-12.45	0.32325E+00	0.56855E+00	0.99914E+01
I5	Industrial	7500	64.31	-39.89	17.90	-10.04	0.12027E+01	0.10967E+01	0.11060E+02
I6	Industrial	7500	65.93	-39.89	6.39	-14.08	0.17974E-01	0.13407E+00	0.34277E+01
I7	Industrial	7500	67.30	-39.89	15.40	-11.41	0.39917E+00	0.63180E+00	0.87416E+01
I8	Industrial	7500	68.51	-39.89	15.19	-12.04	0.42573E+00	0.65248E+00	0.10428E+02
I9	Industrial	7500	69.69	-39.89	14.79	-13.48	0.34381E+00	0.58635E+00	0.13075E+02
Re13	Residential	10000	45.81	-39.89	8.59	-17.59	0.12260E-01	0.11072E+00	0.63606E+01
Re14	Residential	10000	52.97	-39.89	1.03	-21.70	0.65304E-03	0.25555E-01	0.37771E+01
G6	Grass	5000	44.70	-39.89	-13.37	-25.05	0.11811E-04	0.34367E-02	0.11005E+01
G7	Grass	5000	49.70	-39.89	-15.22	-26.06	0.60913E-05	0.24681E-02	0.99553E+00
G8	Grass	5000	53.61	-39.89	-15.55	-27.22	0.46008E-05	0.21449E-02	0.11307E+01
G9	Grass	5000	56.77	-39.89	-18.93	-28.62	0.14232E-05	0.11930E-02	0.86757E+00
G10	Grass	5000	59.39	-39.89	-13.13	-27.17	0.40081E-05	0.20020E-02	0.10427E+01
G11	Grass	5000	61.61	-39.89	-12.22	-25.23	0.93502E-05	0.30578E-02	0.10186E+01
G12	Grass	5000	68.26	-39.89	-10.95	-23.67	0.19351E-04	0.43990E-02	0.10243E+01

Table B-3. Cont.

G13	Grass	5000	70.97	-39.89	-9.84	-23.79	0.17588E-04	0.41938E-02	0.10044E+01
G14	Grass	5000	73.70	-39.89	-8.16	-23.53	0.21396E-04	0.46255E-02	0.10432E+01
G15	Grass	5000	74.45	-39.89	-12.30	-23.74	0.16885E-04	0.41092E-02	0.97227E+00
G16	Grass	5000	75.84	-39.89	-13.95	-28.92	0.56291E-05	0.23726E-02	0.18493E+01
G17	Grass	5000	76.90	-39.89	-17.19	-27.68	0.73327E-05	0.27079E-02	0.15861E+01
G18	Grass	5000	77.50	-39.89	-15.49	-25.95	0.12840E-04	0.35833E-02	0.14108E+01
G19	Grass	5000	78.48	-39.89	-13.57	-24.69	0.34547E-04	0.58776E-02	0.17293E+01
G20	Grass	5000	79.44	-39.89	-10.11	-24.47	0.13736E-03	0.11720E-01	0.32831E+01
C1	City	5000	80.23	-39.89	15.57	-5.95	0.20006E+01	0.14144E+01	0.55663E+01
C2	City	10000	80.46	-39.89	19.82	-2.99	0.11322E+02	0.33648E+01	0.66913E+01
C3	City	10000	80.68	-39.89	27.62	-4.43	0.76839E+02	0.87658E+01	0.24323E+02
C4	City	5000	80.66	-39.89	18.27	-5.16	0.47338E+01	0.21757E+01	0.71355E+01
C5	City	5000	80.89	-39.89	23.20	-4.63	0.15225E+02	0.39020E+01	0.11331E+02
C6	City	7500	81.11	-39.89	17.08	-5.68	0.24797E+01	0.15747E+01	0.58217E+01
C7	City	7500	81.41	-39.89	23.59	-6.07	0.12435E+02	0.35263E+01	0.14253E+02
C8	City	7500	81.83	-39.89	22.03	-3.73	0.16773E+02	0.40954E+01	0.96606E+01
I10	Industrial	7500	80.03	-39.89	21.06	-3.80	0.98166E+01	0.31331E+01	0.75163E+01
I11	Industrial	7500	80.35	-39.89	14.65	-7.79	0.97930E+00	0.98960E+00	0.59546E+01
I12	Industrial	7500	80.83	-39.89	15.65	-7.94	0.11803E+01	0.10864E+01	0.67594E+01
I13	Industrial	7500	81.39	-39.89	17.10	-6.99	0.16097E+01	0.12688E+01	0.63486E+01
I14	Industrial	7500	81.76	-39.89	16.87	-7.53	0.16661E+01	0.12908E+01	0.73049E+01
I15	Industrial	7500	82.06	-39.89	18.00	-7.85	0.18148E+01	0.13471E+01	0.82067E+01
Re15	Residential	10000	80.21	-39.89	9.24	-14.92	0.35260E-01	0.18778E+00	0.58242E+01
Re16	Residential	10000	80.66	-39.89	9.91	-13.99	0.56072E-01	0.23679E+00	0.59331E+01
C9	City	10000	82.38	-39.89	31.08	0.73	0.48242E+03	0.21964E+02	0.18580E+02
C10	City	10000	82.08	-39.89	28.09	-1.01	0.97138E+02	0.98559E+01	0.12430E+02
C11	City	10000	83.08	-39.89	23.38	-2.70	0.23967E+02	0.48957E+01	0.91136E+01
C12	City	10000	83.11	-39.89	21.55	-4.17	0.12068E+02	0.34739E+01	0.90837E+01
C13	City	10000	82.50	-39.89	22.94	-2.43	0.29589E+02	0.54396E+01	0.95125E+01
G21	Grass	10000	82.11	-39.89	-2.00	-30.23	0.38104E-03	0.19520E-01	0.20604E+02
U10	Urban	10000	80.81	-39.89	16.37	-10.05	0.58730E+00	0.76636E+00	0.77442E+01
U11	Urban	10000	80.87	-39.89	12.43	-12.53	0.11145E+00	0.33384E+00	0.59776E+01
U12	Urban	20000	81.09	-39.89	11.28	-14.86	0.33357E-01	0.18264E+00	0.55986E+01
U13	Urban	20000	81.09	-39.89	8.27	-17.20	0.21710E-01	0.14734E+00	0.77318E+01
Re17	Residential	20000	81.82	-39.89	14.08	-16.87	0.10385E+00	0.32225E+00	0.15671E+02
Re18	Residential	20000	81.82	-39.89	7.67	-23.13	0.51715E-02	0.71913E-01	0.14787E+02
Re19	Residential	10000	81.00	-39.89	7.07	-18.18	0.14481E-01	0.12034E+00	0.79079E+01
U14	Urban	12000	78.17	-39.89	13.91	-10.94	0.31846E+00	0.56432E+00	0.69989E+01

Table B-4. Clutter Statistics for the Third Denver 'Step West'

Id	Region Type	# Pts	Incidence Angle	Min (dB)	Max(dB)	Mean (dB)	Variance	SDEV	Variation
Ru1	Runway	500	47.84	-39.69	-26.72	-36.67	0.49020E-07	0.22140E-03	0.10280E+01
Ru2	Runway	500	61.73	-39.69	-29.93	-38.52	0.83701E-08	0.91488E-04	0.65036E+00
Ru3	Runway	500	69.71	-39.69	-28.67	-38.49	0.12324E-07	0.11101E-03	0.78411E+00
G1	Grass	1500	44.66	-39.69	-14.74	-23.81	0.17795E-04	0.42185E-02	0.10135E+01
G2	Grass	1500	55.72	-39.69	-20.67	-31.53	0.38856E-06	0.62334E-03	0.88595E+00
G3	Grass	1500	63.98	-39.69	-14.17	-23.09	0.15086E-04	0.38841E-02	0.79183E+00
G4	Grass	1500	71.15	-39.69	-19.23	-27.56	0.26681E-05	0.16334E-02	0.93036E+00
H1	Terminal	2625	67.90	-35.92	11.81	-8.60	0.51853E+00	0.72009E+00	0.52204E+01
H2	Terminal	2800	67.82	-39.69	12.61	-8.92	0.34393E+00	0.58646E+00	0.45692E+01
H3	Terminal	2100	68.33	-39.69	5.36	-12.50	0.40003E-01	0.20001E+00	0.35595E+01
M1	Parklot	2000	66.60	-39.69	1.91	-13.50	0.60616E-02	0.77856E-01	0.17442E+01
Re13	Residential	10000	45.34	-39.69	8.87	-16.44	0.22954E-01	0.15151E+00	0.66780E+01
W1	Water	4000	65.68	-39.69	-18.18	-33.93	0.38814E-06	0.62301E-03	0.15413E+01
Re1	Residential	30000	73.56	-39.69	8.48	-17.20	0.80312E-02	0.89617E-01	0.47048E+01
Re2	Residential	30000	76.19	-39.69	5.06	-18.85	0.16211E-02	0.40263E-01	0.30876E+01
U1	Urban	22500	31.32	-39.69	24.70	2.38	0.62137E+02	0.78827E+01	0.45587E+01
U2	Urban	22500	54.70	-39.69	5.64	-21.72	0.19617E-02	0.44291E-01	0.65758E+01
U3	Urban	22500	64.12	-39.69	14.12	-14.00	0.73685E-01	0.27145E+00	0.68256E+01
U4	Urban	22500	69.47	-39.69	9.95	-15.48	0.16630E-01	0.12896E+00	0.45578E+01
U5	Urban	22500	72.95	-39.69	7.73	-15.07	0.15782E-01	0.12563E+00	0.40357E+01
Re3	Residential	22500	74.29	-39.69	1.58	-17.44	0.13406E-02	0.36614E-01	0.20328E+01
Re4	Residential	22500	76.40	-39.69	0.61	-18.52	0.82704E-03	0.28758E-01	0.20433E+01
Re5	Residential	22500	78.01	-39.69	2.78	-19.05	0.16935E-02	0.41152E-01	0.33085E+01
Re6	Residential	22500	79.28	-39.69	4.71	-17.12	0.28592E-02	0.53472E-01	0.27559E+01
U6	Urban	22500	80.80	-39.69	19.02	-15.63	0.31773E+00	0.56368E+00	0.20619E+02
C1	City	10000	75.31	-39.69	9.75	-14.17	0.53885E-01	0.23213E+00	0.60699E+01
C2	City	10000	77.24	-39.69	6.70	-14.09	0.32480E-01	0.18022E+00	0.46170E+01
C3	City	10000	75.19	-39.69	13.71	-13.49	0.12410E+00	0.35228E+00	0.78768E+01
G5	Grass	5000	39.83	-39.69	-12.55	-23.07	0.28726E-04	0.53596E-02	0.10879E+01
G6	Grass	5000	45.56	-39.69	-15.34	-25.80	0.61974E-05	0.24895E-02	0.94729E+00
G7	Grass	5000	50.80	-39.69	-15.06	-28.33	0.21813E-05	0.14769E-02	0.10061E+01
G8	Grass	5000	57.08	-39.69	-21.61	-31.37	0.42119E-06	0.64899E-03	0.88923E+00
G9	Grass	1000	60.27	-39.69	-24.84	-32.02	0.25445E-06	0.50443E-03	0.80253E+00
G10	Grass	5000	62.41	-39.69	-12.20	-27.92	0.43385E-05	0.20829E-02	0.12911E+01
G11	Grass	5000	64.84	-39.69	-14.37	-23.33	0.17458E-04	0.41783E-02	0.89954E+00
G12	Grass	5000	67.08	-39.69	-13.90	-24.77	0.12122E-04	0.34817E-02	0.10449E+01
G13	Grass	5000	68.40	-39.69	-15.42	-27.22	0.35875E-05	0.18941E-02	0.99760E+00
G14	Grass	5000	70.39	-39.69	-17.36	-25.79	0.48705E-05	0.22069E-02	0.83681E+00
G15	Grass	5000	71.96	-39.69	-16.97	-28.66	0.16644E-05	0.12901E-02	0.94755E+00
I1	Industrial	5000	38.93	-39.69	21.74	-1.90	0.13470E+02	0.36702E+01	0.56894E+01
I2	Industrial	2550	48.42	-39.69	-18.57	-29.04	0.12747E-05	0.11290E-02	0.90608E+00
C4	City	5000	73.85	-39.69	7.47	-13.20	0.33687E-01	0.18354E+00	0.38364E+01
C5	City	7500	74.50	-39.69	17.20	-13.08	0.50829E+00	0.71294E+00	0.14480E+02
C6	City	7500	75.07	-39.69	16.47	-13.99	0.37034E+00	0.60856E+00	0.15262E+02
C7	City	7500	75.56	-39.69	8.42	-14.80	0.44042E-01	0.20986E+00	0.63350E+01
C8	City	7500	76.15	-39.69	11.19	-13.75	0.53590E-01	0.23149E+00	0.54835E+01
C9	City	7500	76.73	-39.69	16.39	-14.20	0.39405E+00	0.62773E+00	0.16508E+02
C10	City	7500	77.92	-39.69	13.94	-13.47	0.29942E+00	0.54719E+00	0.12161E+02
C11	City	7500	79.07	-39.69	7.35	-14.14	0.26468E-01	0.16269E+00	0.42208E+01
G16	Grass	10000	78.36	-39.69	-7.76	-26.81	0.31402E-04	0.56038E-02	0.26899E+01
U7	Urban	5000	79.72	-39.69	5.56	-13.04	0.23010E-01	0.15169E+00	0.30513E+01
U8	Urban	11250	68.65	-39.69	10.24	-12.94	0.73889E-01	0.27182E+00	0.53507E+01
U9	Urban	9000	75.41	-39.69	7.08	-15.52	0.16091E-01	0.12685E+00	0.45215E+01
U10	Urban	9000	75.41	-39.69	0.12	-17.19	0.17891E-02	0.42298E-01	0.22153E+01
U11	Urban	9000	75.40	-39.69	2.64	-17.04	0.22997E-02	0.47955E-01	0.24274E+01
U12	Urban	11000	75.43	-39.69	0.79	-17.54	0.14532E-02	0.38121E-01	0.21650E+01
U13	Urban	19000	77.20	-39.69	3.92	-17.88	0.35384E-02	0.59485E-01	0.36509E+01
U14	Urban	20000	76.93	-39.69	8.24	-16.97	0.59225E-02	0.76958E-01	0.38273E+01
U15	Urban	52500	77.69	-39.69	8.83	-18.28	0.54177E-02	0.73605E-01	0.49561E+01

Table B-4. Cont.

M2	City/Indus	10000	79.14	-39.69	13.13	-9.35	0.35865E+00	0.59888E+00	0.51545E+01
M3	City/Indus	10000	80.25	-39.69	15.95	-9.89	0.78973E+00	0.88867E+00	0.86554E+01
U16	Urban	37500	80.08	-39.69	10.93	-16.43	0.13739E-01	0.11721E+00	0.51515E+01
Re7	Residential	22500	78.02	-39.69	-1.33	-19.09	0.71604E-03	0.26759E-01	0.21693E+01
Re8	Residential	45000	77.79	-39.69	5.78	-19.22	0.15723E-02	0.39652E-01	0.33136E+01
Re9	Residential	45000	79.74	-39.69	9.69	-17.55	0.44851E-02	0.66971E-01	0.38081E+01
M4	City/Indus	10000	78.73	-39.69	9.94	-14.33	0.47966E-01	0.21901E+00	0.59345E+01
M5	City/Indus	10000	78.96	-39.69	16.38	-10.59	0.59682E+00	0.77254E+00	0.88480E+01
M6	City/Indus	10000	78.13	-39.69	14.11	-13.42	0.21522E+00	0.46392E+00	0.10198E+02
U17	Urban	15000	75.63	-39.69	7.40	-16.94	0.42151E-02	0.64924E-01	0.32117E+01
W2	Water	1500	64.18	-39.69	-17.67	-32.35	0.12586E-05	0.11219E-02	0.19284E+01
W3	Water	4000	65.86	-39.69	-18.18	-34.27	0.34354E-06	0.58613E-03	0.15684E+01
W4	Water	900	67.19	-39.69	-23.77	-34.57	0.15777E-06	0.39720E-03	0.11377E+01
G17	Grass	2100	69.92	-39.69	-16.67	-24.62	0.74195E-05	0.27239E-02	0.78915E+00
G18	Grass	2100	65.56	-39.69	-13.47	-21.51	0.31034E-04	0.55708E-02	0.78895E+00
Re10	Residential	20000	32.63	-39.69	30.89	3.72	0.45599E+03	0.21354E+02	0.90571E+01
Re11	Residential	15000	39.98	-39.69	27.25	-2.31	0.73298E+02	0.85614E+01	0.14581E+02
G19	Grass	4200	67.42	-39.69	-13.79	-23.30	0.15136E-04	0.38904E-02	0.83194E+00
Re12	Residential	37500	74.67	-39.69	5.96	-17.04	0.48956E-02	0.69968E-01	0.35385E+01
U18	Urban	10000	74.88	-39.69	3.70	-17.90	0.18623E-02	0.43155E-01	0.26602E+01
I3	Industrial	10000	73.40	-39.69	8.96	-13.76	0.41571E-01	0.20389E+00	0.48514E+01
I4	Industrial	7500	75.60	-39.69	5.74	-15.90	0.12356E-01	0.11116E+00	0.43257E+01
I5	Industrial	7500	76.72	-39.69	10.79	-15.24	0.39846E-01	0.19962E+00	0.66735E+01
I6	Industrial	10500	77.35	-39.69	13.50	-11.09	0.22844E+00	0.47796E+00	0.61495E+01
I7	Industrial	10500	78.11	-39.69	17.53	-11.10	0.48762E+00	0.69829E+00	0.90053E+01
I8	Industrial	10000	78.90	-39.69	9.35	-13.66	0.60129E-01	0.24521E+00	0.56951E+01
I9	Industrial	14000	79.43	-39.69	16.29	-9.12	0.39563E+00	0.62899E+00	0.51341E+01
U19	Urban	13000	73.98	-39.69	6.09	-15.59	0.69981E-02	0.83655E-01	0.30279E+01
U20	Urban	10000	75.94	-39.69	3.73	-16.10	0.63329E-02	0.79579E-01	0.32384E+01
I10	Industrial	10000	78.48	-39.69	17.08	-12.20	0.47975E+00	0.69264E+00	0.11493E+02
I11	Industrial	10500	80.26	-39.69	19.36	-9.10	0.15976E+01	0.12640E+01	0.10267E+02
I12	Industrial	10500	81.25	-39.69	21.54	-6.74	0.57073E+01	0.23890E+01	0.11282E+02
I13	Industrial	10500	81.21	-39.69	14.38	-11.09	0.28379E+00	0.53272E+00	0.68507E+01
I14	Industrial	7000	81.32	-39.69	9.32	-10.49	0.12335E+00	0.35122E+00	0.39353E+01
I15	Industrial	7000	82.10	-39.69	12.68	-11.24	0.27320E+00	0.52268E+00	0.69614E+01
U21	Urban	15000	80.84	-39.69	26.96	-7.69	0.28418E+02	0.53308E+01	0.31347E+02
H4	Plane	49	66.23	-33.83	2.16	-5.81	0.13331E+00	0.36512E+00	0.13928E+01
G20	Grass	1050	63.70	-39.69	-15.10	-22.28	0.21503E-04	0.46372E-02	0.78311E+00
Ru4	Runway	560	64.32	-39.69	-24.53	-35.35	0.11148E-06	0.33389E-03	0.11433E+01
Ru5	Runway	420	62.83	-39.69	-28.50	-38.54	0.12619E-07	0.11234E-03	0.80311E+00
G21	Grass	2100	65.68	-39.69	-15.55	-23.98	0.12838E-04	0.35831E-02	0.89568E+00
G22	Grass	15000	57.13	-39.69	-14.79	-30.96	0.70559E-06	0.83999E-03	0.10483E+01
G23	Grass	7200	57.58	-39.69	-21.35	-31.41	0.39298E-06	0.62688E-03	0.86813E+00
Ru6	Runway	420	61.69	-39.69	-35.48	-39.65	0.99199E-10	0.99599E-05	0.91784E-01
Ru7	Runway	240	64.58	-39.69	-21.49	-36.03	0.34160E-06	0.58447E-03	0.23433E+01
Ru8	Runway	240	64.39	-39.69	-29.08	-37.60	0.22829E-07	0.15109E-03	0.87023E+00
G24	Grass	1400	62.37	-39.69	-18.42	-27.36	0.26624E-05	0.16317E-02	0.88802E+00
C12	City	10000	83.54	-39.69	20.47	-5.54	0.39431E+01	0.19857E+01	0.71083E+01
C13	City	10000	83.04	-39.69	16.76	-9.74	0.50664E+00	0.71179E+00	0.66992E+01
C14	City	10000	83.17	-39.69	19.50	-8.10	0.22645E+01	0.15048E+01	0.97249E+01
C15	City	20000	82.88	-39.69	20.96	-9.70	0.13347E+01	0.11553E+01	0.10778E+02
C16	City	20000	82.19	-39.69	29.64	-2.70	0.75443E+02	0.86858E+01	0.16175E+02
C17	City	20000	82.17	-39.69	29.64	-2.82	0.72439E+02	0.85111E+01	0.16304E+02
C18	City	20000	81.81	-39.69	14.96	-11.08	0.34842E+00	0.59027E+00	0.75731E+01
C19	City	20000	82.60	-39.69	17.22	-7.64	0.16665E+01	0.12909E+01	0.74923E+01
C20	City	15000	83.00	-39.69	19.43	-6.61	0.28028E+01	0.16741E+01	0.76622E+01
C21	City	15000	82.64	-39.69	20.85	-7.98	0.31042E+01	0.17619E+01	0.11054E+02
C22	City	20000	83.40	-39.69	23.82	-8.41	0.65730E+01	0.25638E+01	0.17795E+02
H5	Building	900	70.22	-39.69	8.81	-10.31	0.21894E+00	0.46791E+00	0.50259E+01
H6	Building	1050	70.77	-39.69	11.39	-11.15	0.23475E+00	0.48451E+00	0.63136E+01
H7	Building	625	70.88	-39.69	16.97	-6.60	0.46522E+01	0.21569E+01	0.98488E+01
H8	Building	1000	66.54	-39.69	7.04	-12.98	0.67711E-01	0.26021E+00	0.51645E+01
H9	Building	300	68.40	-39.69	8.37	-10.46	0.20144E+00	0.44882E+00	0.49938E+01
H10	Building	300	67.99	-39.69	7.36	-12.12	0.10519E+00	0.32433E+00	0.52818E+01

Table B-4. Cont.

H11	Building	800	67.87	-39.69	9.95	-10.62	0.16824E+00	0.41017E+00	0.47333E+01
H12	Building	500	65.10	-39.69	2.68	-13.20	0.17650E-01	0.13285E+00	0.27760E+01
H13	Warehouse	1750	62.60	-39.69	-0.02	-19.28	0.19916E-02	0.44627E-01	0.37784E+01
H14	Building	450	76.61	-39.69	7.64	-10.78	0.12171E+00	0.34888E+00	0.41707E+01
H15	Plane	150	66.51	-39.69	-9.68	-22.39	0.18522E-03	0.13610E-01	0.23613E+01
H16	Plane	130	66.46	-39.69	-5.24	-20.64	0.11267E-02	0.33566E-01	0.38933E+01
H17	Plane	120	67.21	-39.69	-1.57	-14.12	0.14329E-01	0.11970E+00	0.30904E+01
H18	Plane	50	67.87	-31.25	2.40	-10.40	0.66893E-01	0.25864E+00	0.28385E+01
H19	Plane	80	67.72	-39.69	-6.00	-15.82	0.23526E-02	0.48504E-01	0.18516E+01
H20	Plane	80	66.76	-39.69	-3.79	-15.65	0.38285E-02	0.61875E-01	0.22733E+01
H21	Plane	50	68.26	-39.69	-0.83	-13.28	0.20368E-01	0.14272E+00	0.30354E+01
H22	Plane	50	68.04	-27.00	1.61	-8.38	0.72601E-01	0.26945E+00	0.18561E+01
H23	Plane	50	67.37	-28.25	-0.16	-10.88	0.24550E-01	0.15668E+00	0.19186E+01

Table B-5. Clutter Statistics for the Fourth Denver 'Step West'

ID	Region Type	# Pts	Incidence Angle	Min (dB)	Max(dB)	Mean (dB)	Variance	SDEV	Variation
G1	Grass	10000	68.27	-39.53	0.14	-19.01	0.90317E-03	0.30053E-01	0.23936E+01
U1	Urban	10000	56.70	-39.53	8.08	-15.21	0.18465E-01	0.13589E+00	0.45067E+01
U2	Urban	10000	56.70	-39.53	7.37	-14.21	0.22634E-01	0.15045E+00	0.39700E+01
U3	Urban	20000	59.68	-39.53	8.88	-15.50	0.11880E-01	0.10899E+00	0.38701E+01
Re1	Residential	20000	67.01	-39.53	11.72	-10.17	0.10580E+00	0.32526E+00	0.33828E+01
U4	Urban	20000	59.68	-39.53	14.80	-14.67	0.63903E-01	0.25279E+00	0.74123E+01
Re2	Residential	20000	67.01	-39.53	12.79	-10.59	0.99232E-01	0.31501E+00	0.36076E+01
U5	Urban	30000	61.59	-39.53	12.18	-14.61	0.37106E-01	0.19263E+00	0.55677E+01
C1	City	10000	70.84	-39.53	8.22	-10.56	0.10922E+00	0.33048E+00	0.37604E+01
C2	City	10000	74.17	-39.53	9.95	-12.69	0.92417E-01	0.30400E+00	0.56479E+01
C3	City	5000	46.73	-39.53	11.18	-11.78	0.12613E+00	0.35515E+00	0.53510E+01
C4	City	10000	51.29	-39.53	9.01	-14.50	0.33015E-01	0.18170E+00	0.51236E+01
C5	City	10000	54.96	-39.53	6.41	-15.98	0.15154E-01	0.12310E+00	0.48762E+01
C6	City	5000	52.94	-39.53	12.58	-12.92	0.19012E+00	0.43603E+00	0.85505E+01
C7	City	5000	56.18	-39.53	9.13	-13.23	0.83049E-01	0.28818E+00	0.60561E+01
C8	City	7500	59.06	-39.53	10.54	-14.09	0.11315E+00	0.33637E+00	0.86257E+01
C9	City	7500	63.01	-39.53	17.35	-9.59	0.87790E+00	0.93696E+00	0.85238E+01
C10	City	7500	66.12	-39.53	15.78	-9.16	0.62405E+00	0.78997E+00	0.65165E+01
I1	Industrial	7500	45.14	-39.53	16.51	-6.26	0.22104E+01	0.14867E+01	0.62799E+01
I2	Industrial	7500	51.91	-39.53	14.40	-13.19	0.26190E+00	0.51176E+00	0.10672E+02
I3	Industrial	7500	56.12	-39.53	16.88	-14.47	0.36215E+00	0.60179E+00	0.16858E+02
I4	Industrial	7500	61.95	-39.53	13.56	-13.82	0.16197E+00	0.40245E+00	0.97096E+01
I5	Industrial	7500	64.93	-39.53	13.46	-9.17	0.34908E+00	0.59083E+00	0.48811E+01
I6	Industrial	7500	66.80	-39.53	20.24	-4.48	0.72185E+01	0.26867E+01	0.75439E+01
U6	Urban	30000	46.93	-39.53	27.34	-6.66	0.25085E+02	0.50085E+01	0.23197E+02
Re3	Residential	30000	70.73	-39.53	11.72	-11.77	0.63452E-01	0.25190E+00	0.37846E+01
Re4	Residential	30000	58.21	-39.53	9.47	-19.66	0.72904E-02	0.85384E-01	0.78985E+01
U7	Urban	11250	59.11	-39.53	2.77	-18.72	0.18343E-02	0.42829E-01	0.31900E+01
U8	Urban	5000	54.96	-39.53	6.02	-13.90	0.23720E-01	0.15401E+00	0.37773E+01
I7	Industrial	6250	64.87	-39.53	18.64	-4.41	0.52769E+01	0.22971E+01	0.63347E+01
U9	Urban	7500	61.91	-39.53	2.40	-14.63	0.44939E-02	0.67036E-01	0.19459E+01
I8	Industrial	6000	65.05	-39.53	20.03	-7.43	0.38961E+01	0.19739E+01	0.10919E+02
U10	Urban	2500	56.00	-39.53	7.73	-12.17	0.61772E-01	0.24854E+00	0.40974E+01
I9	Industrial	6250	76.55	-39.53	5.94	-18.93	0.86564E-02	0.93040E-01	0.72713E+01
G2	Grass	6250	72.94	-39.53	-13.79	-24.85	0.89226E-05	0.29871E-02	0.91204E+00
W1	Water	2500	70.30	-39.53	-27.17	-39.49	0.15278E-08	0.39087E-04	0.34738E+00
I10	Industrial	6250	77.36	-39.53	9.89	-14.42	0.79217E-01	0.28145E+00	0.77908E+01
U11	Urban	15000	72.73	-39.53	8.70	-13.83	0.14332E-01	0.11972E+00	0.28892E+01
U12	Urban	30000	75.27	-39.53	3.75	-20.10	0.93120E-03	0.30516E-01	0.31252E+01
C11	City	10000	78.56	-39.53	21.64	-10.88	0.32384E+01	0.17996E+01	0.22048E+02
Re5	Residential	20000	76.12	-39.53	-2.61	-23.33	0.10192E-03	0.10096E-01	0.21743E+01
I11	Industrial	2500	75.92	-39.53	2.82	-16.99	0.66050E-02	0.81271E-01	0.40650E+01
I12	Industrial	7000	76.45	-39.53	4.28	-17.12	0.50391E-02	0.70987E-01	0.36596E+01
I13	Industrial	7500	78.47	-39.53	-2.13	-21.89	0.68276E-03	0.26130E-01	0.40347E+01
I14	Industrial	5625	79.00	-39.53	2.17	-18.21	0.26041E-02	0.51031E-01	0.33795E+01
C12	City	7500	79.13	-39.53	10.13	-12.95	0.10004E+00	0.31629E+00	0.62314E+01
U13	Urban	20000	71.21	-39.53	9.61	-12.82	0.18964E-01	0.13771E+00	0.26340E+01
H1	Building	1000	80.28	-39.53	8.55	-12.33	0.12481E+00	0.35329E+00	0.60479E+01
H2	Building	1000	80.12	-39.53	7.77	-13.90	0.11951E+00	0.34571E+00	0.84786E+01
H3	Building	1000	80.12	-39.53	-0.05	-21.24	0.31399E-02	0.56035E-01	0.74615E+01
H4	Building	600	81.92	-39.53	-4.64	-20.78	0.17105E-02	0.41358E-01	0.49471E+01
H5	Building	600	82.54	-39.53	10.19	-10.22	0.34678E+00	0.58888E+00	0.61979E+01
H6	Building	600	82.80	-39.53	9.94	-9.31	0.49112E+00	0.70080E+00	0.59826E+01
H7	Building	300	81.68	-39.53	1.22	-14.35	0.25804E-01	0.16064E+00	0.43746E+01
H8	Building	450	82.00	-39.53	7.31	-10.29	0.25505E+00	0.50502E+00	0.53995E+01
H9	Building	500	81.80	-39.53	-0.47	-18.33	0.55537E-02	0.74523E-01	0.50696E+01
H10	Building	300	82.05	-39.53	5.83	-13.95	0.76659E-01	0.27687E+00	0.68753E+01
H11	Building	300	82.09	-39.53	-0.61	-17.14	0.77184E-02	0.87855E-01	0.45444E+01
H12	Building	300	81.23	-39.53	-3.10	-18.62	0.26850E-02	0.51817E-01	0.37741E+01

Table B-5. Cont.

H13	Building	300	82.42	-39.53	-1.44	-18.37	0.52156E-02	0.72219E-01	0.49582E+01
H14	Building	300	82.23	-39.53	0.77	-15.97	0.10841E-01	0.10412E+00	0.41120E+01
H15	Building	3750	81.55	-39.53	10.13	-11.52	0.17051E+00	0.41293E+00	0.58604E+01
H16	Building	500	81.94	-39.53	9.55	-9.28	0.41388E+00	0.64334E+00	0.54524E+01
H17	Building	500	81.48	-39.53	14.15	-8.02	0.17112E+01	0.13081E+01	0.82963E+01
H18	Building	500	81.47	-39.53	10.27	-4.15	0.13864E+01	0.11775E+01	0.30607E+01
H19	Building	500	83.21	-39.53	7.09	-10.65	0.23441E+00	0.48415E+00	0.56189E+01
H20	Building	500	83.18	-39.53	8.77	-9.92	0.32738E+00	0.57217E+00	0.56221E+01
H21	Building	300	83.87	-39.53	17.18	-3.20	0.12877E+02	0.35884E+01	0.74920E+01
H22	Building	300	83.87	-39.53	8.19	-10.30	0.38187E+00	0.61796E+00	0.66190E+01
H23	Building	300	83.93	-39.53	9.05	-8.92	0.56395E+00	0.75097E+00	0.58575E+01
H24	Building	300	84.03	-39.53	16.59	-1.26	0.16648E+02	0.40801E+01	0.54553E+01
H25	Building	600	84.83	-39.53	14.02	-4.70	0.48776E+01	0.22085E+01	0.65156E+01
H26	Building	1800	84.08	-39.53	15.66	-7.71	0.20662E+01	0.14374E+01	0.84906E+01
H27	Building	100	84.58	-39.53	11.87	0.58	0.12530E+02	0.35397E+01	0.30967E+01
Re6	Residential	30000	68.13	-39.53	10.63	-10.50	0.53969E-01	0.23231E+00	0.26054E+01
U14	Urban	25000	56.98	-39.53	9.42	-15.86	0.21103E-01	0.14527E+00	0.55963E+01
Re7	Residential	15625	67.40	-39.53	10.74	-10.45	0.51485E-01	0.22690E+00	0.25183E+01
U15	Urban	30000	64.39	-39.53	9.45	-12.67	0.29648E-01	0.17219E+00	0.31827E+01
U16	Urban	30000	70.71	-39.53	15.86	-11.71	0.93829E-01	0.30632E+00	0.45416E+01
Re8	Residential	30000	76.63	-39.53	3.65	-23.75	0.56267E-03	0.23721E-01	0.56241E+01
G3	Grass	2500	71.43	-39.53	-9.74	-24.42	0.26633E-04	0.51607E-02	0.14290E+01
T1	Tree	100	70.51	-39.53	-6.38	-19.61	0.79403E-03	0.28179E-01	0.25785E+01
T2	Tree	100	70.40	-39.53	-3.76	-16.23	0.40994E-02	0.64026E-01	0.26861E+01
T3	Tree	100	73.24	-39.53	-5.83	-17.05	0.18839E-02	0.43404E-01	0.21981E+01
T4	Tree	100	73.13	-39.53	-5.39	-21.37	0.98395E-03	0.31368E-01	0.42977E+01
T5	Tree	225	70.03	-39.53	-6.50	-19.38	0.85401E-03	0.29223E-01	0.25315E+01
T6	Tree	225	70.89	-39.53	-2.51	-19.29	0.19647E-02	0.44325E-01	0.37678E+01
T7	Tree	225	67.94	-39.53	-4.24	-17.38	0.17977E-02	0.42399E-01	0.23207E+01
T8	Tree	225	68.17	-39.53	-0.07	-15.83	0.94687E-02	0.97307E-01	0.37279E+01
T9	Tree	225	68.49	-39.53	-2.82	-16.07	0.41960E-02	0.64777E-01	0.26236E+01
T10	Tree	225	68.17	-39.53	-3.64	-15.55	0.33619E-02	0.57982E-01	0.20804E+01
G4	Grass	1600	74.31	-39.53	-11.88	-26.46	0.21645E-04	0.46524E-02	0.20587E+01
G5	Grass	900	73.41	-39.53	-15.46	-24.91	0.10459E-04	0.32340E-02	0.10007E+01
T11	Tree	100	74.70	-39.53	-12.52	-24.69	0.55470E-04	0.74478E-02	0.21905E+01
T12	Tree	100	74.77	-39.53	-9.42	-21.38	0.45160E-03	0.21251E-01	0.29178E+01
W2	Water	900	73.82	-39.53	-19.90	-30.28	0.18092E-05	0.13451E-02	0.14342E+01
G6	Grass	1000	71.17	-39.53	-13.96	-22.85	0.20970E-04	0.45793E-02	0.88326E+00
G7	Grass	1000	71.61	-39.53	-15.65	-23.47	0.12327E-04	0.35110E-02	0.78059E+00
W3	Water	1500	70.95	-39.53	-22.62	-36.24	0.16302E-06	0.40375E-03	0.16975E+01

Table B-6. Clutter Statistics for the Polarimetric Set, X-VV

Id	Region Type	# Pts	Incidence Angle	Min (dB)	Max(dB)	Mean (dB)	Variance	SDEV	Variation
Re1	Residential	90000	50.34	-43.57	16.61	-16.74	0.58259E-01	0.24137E+00	0.11405E+0
Re2	Residential	22500	56.21	-43.57	15.49	-12.60	0.16871E+00	0.41074E+00	0.74688E+01
Re3	Residential	90000	60.74	-43.57	12.53	-14.02	0.64170E-01	0.25332E+00	0.63997E+01
Re4	Residential	135000	62.74	-43.57	12.53	-15.86	0.39890E-01	0.19973E+00	0.77066E+01
Re5	Residential	45000	64.88	-43.57	9.59	-19.63	0.89599E-02	0.94657E-01	0.86990E+01
Re6	Residential	45000	64.92	-43.57	6.95	-20.46	0.26977E-02	0.51939E-01	0.57752E+01
Re7	Residential	45000	68.14	-43.57	13.28	-17.95	0.38337E-01	0.19580E+00	0.12207E+02
Re8	Residential	45000	68.21	-43.57	7.47	-21.24	0.17534E-02	0.41873E-01	0.55688E+01
Re9	Residential	45000	68.03	-43.57	11.60	-16.98	0.20550E-01	0.14335E+00	0.71592E+01
Re10	Residential	37500	70.58	-43.57	14.23	-15.34	0.63291E-01	0.25158E+00	0.85946E+01
Re11	Residential	22500	73.82	-43.57	7.51	-15.16	0.23189E-01	0.15228E+00	0.49987E+01
Re12	Residential	2500	79.55	-43.57	12.07	-6.84	0.74701E+00	0.86430E+00	0.41768E+01
Re13	Residential	2500	79.69	-43.57	-1.94	-19.68	0.16050E-02	0.40062E-01	0.37252E+01
Re14	Residential	40000	79.82	-43.57	13.94	-16.18	0.72263E-01	0.26882E+00	0.11160E+02
Re15	Residential	40000	80.06	-43.57	15.99	-13.76	0.23964E+00	0.48953E+00	0.11649E+02
Re16	Residential	20000	80.38	-43.57	18.16	-14.55	0.66362E+00	0.81463E+00	0.23218E+02
Re17	Residential	20000	80.67	-43.57	7.22	-19.54	0.50656E-02	0.71173E-01	0.64020E+01
Re18	Residential	20000	80.88	-43.57	15.34	-18.92	0.68630E-01	0.26197E+00	0.20423E+02
Re19	Residential	20000	81.08	-43.57	7.39	-19.69	0.88465E-02	0.94056E-01	0.87571E+01
Re20	Residential	20000	81.27	-43.57	15.44	-16.47	0.23369E+00	0.48342E+00	0.21423E+02
Re21	Residential	20000	81.46	-43.57	13.37	-14.44	0.13151E+00	0.36265E+00	0.10072E+02
Re22	Residential	20000	81.63	-43.57	12.60	-13.43	0.12555E+00	0.35433E+00	0.78035E+01
Re23	Residential	60000	51.25	-43.57	17.15	-14.07	0.19778E+00	0.44472E+00	0.11354E+02
Re24	Residential	30000	62.64	-43.57	10.47	-17.66	0.13494E-01	0.11616E+00	0.67770E+01
M1	Grass/Trees	2500	47.59	-43.57	-12.92	-23.98	0.29038E-04	0.53886E-02	0.13486E+01
M2	Grass/Trees	2500	52.31	-43.57	-21.89	-30.17	0.88430E-06	0.94037E-03	0.97767E+00
M3	Grass/Trees	2500	54.90	-43.57	-11.50	-22.50	0.32714E-04	0.57196E-02	0.10175E+01
H1	Building	1710	64.51	-35.11	2.69	-10.08	0.31569E-01	0.17768E+00	0.18082E+01
G1	Grass	10000	75.91	-43.57	-19.34	-29.80	0.11269E-05	0.10615E-02	0.10146E+01
G2	Grass	10000	77.42	-43.57	-18.76	-31.52	0.87697E-06	0.93647E-03	0.13290E+01
G3	Grass	10000	78.14	-43.57	-16.71	-30.98	0.15588E-05	0.12485E-02	0.15629E+01
M4	Golf Course	25000	75.93	-43.57	-7.49	-26.51	0.51727E-04	0.71922E-02	0.32194E+01
Re25	Residential	10000	77.35	-43.57	6.56	-16.68	0.19296E-01	0.13891E+00	0.64679E+01
G4	Grass	10000	51.33	-43.57	-10.03	-25.87	0.15430E-04	0.39281E-02	0.15184E+01
G5	Grass	5625	55.72	-43.57	-14.89	-24.63	0.11389E-04	0.33747E-02	0.97928E+00
G6	Grass	10000	78.98	-43.57	-17.10	-32.85	0.18257E-05	0.13512E-02	0.26073E+01
G7	Grass	10000	79.45	-43.57	-16.57	-32.77	0.29725E-05	0.17241E-02	0.32649E+01
G8	Grass	10000	80.03	-43.57	-14.56	-29.91	0.10265E-04	0.32039E-02	0.31405E+01
G9	Grass	10000	80.47	-43.57	-14.39	-28.81	0.18692E-04	0.43234E-02	0.32850E+01
G10	Grass	10000	80.84	-43.57	-11.19	-27.11	0.39869E-04	0.63142E-02	0.32484E+01
G11	Grass	10000	81.14	-43.57	-12.04	-29.11	0.31795E-04	0.56387E-02	0.45919E+01
G12	Grass	10000	81.50	-43.57	-9.04	-29.09	0.48586E-04	0.69704E-02	0.56463E+01
G13	Grass	10000	81.81	-43.57	-0.88	-28.60	0.27091E-03	0.16459E-01	0.11910E+02
G14	Grass	5625	59.97	-43.57	-14.88	-27.20	0.40055E-05	0.20014E-02	0.10513E+01
Ru1	Runway	1500	76.69	-43.57	-24.42	-36.06	0.12501E-06	0.35357E-03	0.14260E+01
Ru2	Runway	1500	76.69	-43.57	-25.15	-36.06	0.10616E-06	0.32582E-03	0.13157E+01
Ru3	Runway	1500	76.68	-43.57	-26.96	-39.15	0.31000E-07	0.17607E-03	0.14473E+01
Ru4	Runway	1125	77.46	-43.57	-25.74	-39.08	0.73068E-07	0.27031E-03	0.21873E+01
Ru5	Runway	1125	77.44	-43.57	-26.13	-38.85	0.70658E-07	0.26582E-03	0.20390E+01
G16	Grass	2250	76.52	-43.57	-13.23	-32.21	0.29762E-05	0.17252E-02	0.28668E+01
G17	Grass	2250	76.11	-43.57	-19.56	-30.65	0.84324E-06	0.91828E-03	0.10655E+01
G18	Grass	2250	77.31	-43.57	-15.90	-31.95	0.11716E-05	0.10824E-02	0.16971E+01
H2	Terminal	2400	77.65	-29.27	18.69	1.92	0.26430E+02	0.51410E+01	0.33038E+01
H3	Terminal	2400	78.04	-43.57	18.48	0.45	0.17267E+02	0.41554E+01	0.37442E+01
W1	Water	100	77.31	-43.57	-27.20	-39.20	0.81449E-07	0.28539E-03	0.23720E+01
W2	Water	100	77.83	-43.57	-43.57	-43.57	-0.44514E-16	0.00000E+00	0.00000E+00
H4	Building	1250	80.23	-43.57	18.71	1.21	0.30025E+02	0.54796E+01	0.41427E+01
H5	Building	2000	80.37	-43.57	23.04	-2.87	0.39046E+02	0.62486E+01	0.12097E+02
M5	Park Lot-Full	1800	79.57	-43.57	8.60	-9.76	0.11055E+00	0.33248E+00	0.31447E+01

Table B-6. Cont.

Ru6	Runway	225	81.33	-43.57	-15.51	-35.33	0.69329E-05	0.26330E-02	0.89776E+01
U1	Urban	45000	64.89	-43.57	13.65	-16.85	0.32284E-01	0.17968E+00	0.87028E+01
U2	Urban	67500	67.69	-43.57	10.67	-16.35	0.22582E-01	0.15027E+00	0.64848E+01
U3	Urban	67500	70.99	-43.57	10.34	-15.91	0.17285E-01	0.13147E+00	0.51241E+01
U4	Urban	67500	72.33	-43.57	10.86	-15.06	0.31477E-01	0.17742E+00	0.56939E+01
U5	Urban	45000	73.44	-43.57	10.48	-16.77	0.15619E-01	0.12497E+00	0.59438E+01
U6	Urban	45000	74.45	-43.57	13.51	-14.18	0.95058E-01	0.30831E+00	0.80722E+01
U7	Urban	45000	75.24	-43.57	11.20	-15.18	0.38364E-01	0.19587E+00	0.64529E+01
U8	Urban	45000	75.76	-43.57	14.80	-14.55	0.78690E-01	0.28052E+00	0.79959E+01
U9	Urban	45000	76.82	-43.57	19.33	-12.94	0.36565E+00	0.60469E+00	0.11898E+02
U10	Urban	45000	77.23	-43.57	18.78	-11.79	0.58252E+00	0.76323E+00	0.11520E+02
U11	Urban	45000	77.62	-43.57	17.08	-14.00	0.15049E+00	0.38793E+00	0.97497E+01
U12	Urban	45000	78.11	-43.57	25.70	-10.98	0.46410E+01	0.21543E+01	0.26970E+02
U13	Urban	15000	78.50	-43.57	24.46	-8.37	0.14164E+02	0.37635E+01	0.25874E+02
U14	Urban	15000	78.85	-43.57	16.24	-11.99	0.33190E+00	0.57610E+00	0.91190E+01
U15	Urban	15000	78.10	-43.57	25.70	-5.71	0.16487E+02	0.40604E+01	0.15110E+02
C1	City	10000	79.07	-43.57	22.32	-2.41	0.16936E+02	0.41154E+01	0.71704E+01
C2	City	10000	79.21	-43.57	22.01	-3.18	0.17039E+02	0.41278E+01	0.85886E+01
C3	City	10000	79.35	-43.57	28.37	0.24	0.15834E+03	0.12583E+02	0.11900E+02
C4	City	10000	79.49	-43.57	22.02	-1.55	0.24869E+02	0.49869E+01	0.71263E+01
C5	City	10000	79.62	-43.57	22.33	-4.04	0.16506E+02	0.40628E+01	0.10291E+02
C6	City	10000	79.96	-43.57	26.95	1.59	0.15265E+03	0.12355E+02	0.85745E+01
C7	City	10000	80.09	-43.57	27.91	0.11	0.16203E+03	0.12729E+02	0.12406E+02
C8	City	10000	80.23	-43.57	28.27	-1.69	0.85845E+02	0.92653E+01	0.13677E+02
C9	City	10000	80.38	-43.57	30.76	1.07	0.43027E+03	0.20743E+02	0.16228E+02
H6	Building	600	78.29	-27.25	12.35	1.20	0.36564E+01	0.19122E+01	0.14518E+01
H7	Warehouse	850	78.38	-43.57	14.39	-3.39	0.29951E+01	0.17306E+01	0.37796E+01
H8	Warehouse	850	78.47	-43.57	16.91	-6.18	0.35416E+01	0.18819E+01	0.78037E+01
H9	Warehouse	500	78.53	-43.57	13.23	-2.22	0.43662E+01	0.20895E+01	0.34846E+01
H10	Warehouse	850	78.60	-43.57	10.40	-8.28	0.30171E+00	0.54928E+00	0.36934E+01
U16	Urban	30000	75.40	-43.57	18.81	-12.60	0.44768E+00	0.66909E+00	0.12178E+02
U17	Urban	30000	75.40	-43.57	13.24	-13.15	0.12329E+00	0.35113E+00	0.72446E+01
U18	Urban	30000	75.40	-43.57	10.68	-15.58	0.27047E-01	0.16446E+00	0.59441E+01
I1	Industrial	7500	79.03	-43.57	21.75	-3.98	0.13574E+02	0.36843E+01	0.92142E+01
I2	Industrial	7500	79.08	-43.57	18.68	-5.58	0.45736E+01	0.21386E+01	0.77257E+01
I3	Industrial	5000	79.10	-43.57	18.94	-4.46	0.62777E+01	0.25055E+01	0.69916E+01
I4	Industrial	5000	79.57	-43.57	23.39	-0.26	0.46511E+02	0.68199E+01	0.72488E+01
I5	Industrial	5000	80.84	-43.57	26.08	-1.14	0.82664E+02	0.90920E+01	0.11824E+02
I6	Industrial	5000	81.59	-43.57	16.20	-6.49	0.22652E+01	0.15050E+01	0.67133E+01
U19	Urban	10000	73.46	-43.57	9.53	-16.03	0.28331E-01	0.16832E+00	0.67399E+01
U20	Urban	16000	72.87	-43.57	12.89	-13.90	0.68029E-01	0.26082E+00	0.64037E+01

Table B-7. Clutter Statistics for the Polarimetric Set, X-VH

ID#	Region Type	# Pts	Incidence Angle	Min (dB)	Max(dB)	Mean (dB)	Variance	SDEV	Variation
Re1	Residential	90000	50.34	-47.09	0.44	-25.00	0.27547E-03	0.16597E-01	0.52441E+01
Re2	Residential	22500	56.21	-47.09	2.69	-27.42	0.30670E-03	0.17513E-01	0.96707E+01
Re3	Residential	90000	60.74	-47.09	-4.13	-29.25	0.32057E-04	0.56619E-02	0.47609E+01
Re4	Residential	135000	62.74	-47.09	6.91	-27.55	0.36136E-03	0.19009E-01	0.10805E+02
Re5	Residential	45000	64.88	-47.09	-2.99	-28.50	0.49652E-04	0.70464E-02	0.49877E+01
Re6	Residential	45000	64.92	-47.09	1.48	-28.52	0.77402E-04	0.87978E-02	0.62510E+01
Re7	Residential	45000	68.14	-47.09	-0.94	-26.12	0.10136E-03	0.10068E-01	0.41251E+01
Re8	Residential	45000	68.21	-47.09	-5.94	-27.23	0.23150E-04	0.48114E-02	0.25397E+01
Re9	Residential	45000	68.03	-47.09	-0.57	-27.11	0.10258E-03	0.10128E-01	0.52033E+01
Re10	Residential	37500	70.58	-47.09	1.17	-26.68	0.12216E-03	0.11052E-01	0.51468E+01
Re11	Residential	22500	73.82	-47.09	-3.63	-27.65	0.66290E-04	0.81419E-02	0.47379E+01
Re12	Residential	2500	79.55	-47.09	-9.20	-28.96	0.31114E-04	0.55780E-02	0.43878E+01
Re13	Residential	2500	79.69	-47.09	-18.64	-36.32	0.82661E-06	0.90918E-03	0.38954E+01
Re14	Residential	40000	79.82	-47.09	-7.35	-34.99	0.60393E-05	0.24575E-02	0.77573E+01
Re15	Residential	40000	80.06	-47.09	1.77	-32.35	0.12605E-03	0.11227E-01	0.19288E+02
Re16	Residential	20000	80.38	-47.09	-7.60	-32.78	0.10905E-04	0.33023E-02	0.62648E+01
Re17	Residential	20000	80.67	-47.09	-11.76	-36.60	0.16006E-05	0.12652E-02	0.57774E+01
Re18	Residential	20000	80.88	-47.09	-2.33	-36.25	0.20944E-04	0.45765E-02	0.19280E+02
Re19	Residential	20000	81.08	-47.09	-12.25	-36.91	0.19597E-05	0.13999E-02	0.68695E+01
Re20	Residential	20000	81.27	-47.09	-9.71	-35.95	0.41392E-05	0.20345E-02	0.80027E+01
Re21	Residential	20000	81.46	-47.09	-2.41	-34.75	0.30984E-04	0.55663E-02	0.16610E+02
Re22	Residential	20000	81.63	-47.09	-11.72	-35.09	0.44073E-05	0.20993E-02	0.67843E+01
Re23	Residential	60000	51.25	-47.09	11.73	-23.21	0.77352E-02	0.87950E-01	0.18424E+02
Re24	Residential	30000	62.64	-47.09	-0.41	-27.69	0.49488E-04	0.70348E-02	0.41298E+01
M1	Grass/Trees	2500	47.59	-47.09	-21.42	-30.98	0.83987E-06	0.91644E-03	0.11496E+01
M2	Grass/Trees	2500	52.31	-47.09	-26.34	-34.80	0.10652E-06	0.32637E-03	0.98573E+00
M3	Grass/Trees	2500	54.90	-47.09	-22.47	-33.06	0.26566E-06	0.51543E-03	0.10426E+01
H1	Building	1710	64.51	-47.09	-15.98	-27.05	0.71663E-05	0.26770E-02	0.13559E+01
G1	Grass	10000	75.91	-47.09	-30.80	-41.39	0.65366E-08	0.80849E-04	0.11145E+01
G2	Grass	10000	77.42	-47.09	-28.48	-42.37	0.11065E-07	0.10519E-03	0.18172E+01
G3	Grass	10000	78.14	-47.09	-27.55	-41.71	0.19380E-07	0.13921E-03	0.20648E+01
M4	GolfCourse	25000	75.93	-47.09	-15.07	-35.77	0.95005E-06	0.97471E-03	0.36790E+01
Re25	Residential	10000	77.35	-47.09	-5.41	-31.87	0.21161E-04	0.46001E-02	0.70692E+01
G4	Grass	10000	51.33	-47.09	-17.49	-33.67	0.37056E-06	0.60874E-03	0.14184E+01
G5	Grass	5625	55.72	-47.09	-21.75	-32.50	0.33211E-06	0.57629E-03	0.10237E+01
G6	Grass	10000	78.98	-47.09	-25.38	-42.94	0.32457E-07	0.18016E-03	0.35468E+01
G7	Grass	10000	79.45	-47.09	-24.30	-43.11	0.46499E-07	0.21564E-03	0.44120E+01
G8	Grass	10000	80.03	-47.09	-22.95	-41.13	0.14577E-06	0.38180E-03	0.49560E+01
G9	Grass	10000	80.47	-47.09	-21.19	-41.06	0.25095E-06	0.50095E-03	0.63905E+01
G10	Grass	10000	80.84	-47.09	-19.10	-38.59	0.66857E-06	0.81766E-03	0.59162E+01
G11	Grass	10000	81.14	-47.09	-18.21	-37.90	0.10829E-05	0.10406E-02	0.64191E+01
G12	Grass	10000	81.50	-47.09	-17.31	-37.33	0.17566E-05	0.13254E-02	0.71621E+01
G13	Grass	10000	81.81	-47.09	-16.17	-39.16	0.14145E-05	0.11893E-02	0.98115E+01
G14	Grass	5625	59.97	-47.09	-14.27	-36.89	0.60390E-06	0.77711E-03	0.37931E+01
Ru1	Runway	1500	76.69	-47.09	-36.88	-46.68	0.19797E-09	0.14070E-04	0.65436E+00
Ru2	Runway	1500	76.69	-47.09	-37.14	-46.64	0.21613E-09	0.14701E-04	0.67883E+00
Ru3	Runway	1500	76.68	-47.09	-37.72	-46.70	0.14895E-09	0.12204E-04	0.57097E+00
Ru4	Runway	1125	77.46	-47.09	-35.78	-46.69	0.31540E-09	0.17760E-04	0.82921E+00
Ru5	Runway	1125	77.44	-47.09	-35.10	-46.63	0.41126E-09	0.20280E-04	0.93350E+00
G16	Grass	2250	76.52	-47.09	-33.24	-44.73	0.19789E-08	0.44485E-04	0.13209E+01
G17	Grass	2250	76.11	-47.09	-31.02	-43.26	0.35022E-08	0.59179E-04	0.12533E+01
G18	Grass	2250	77.31	-47.09	-32.57	-44.89	0.23110E-08	0.48073E-04	0.14812E+01
H2	Terminal	2400	77.65	-47.09	0.30	-16.90	0.55532E-02	0.74520E-01	0.36537E+01
H3	Terminal	2400	78.04	-47.09	-2.20	-20.41	0.10730E-02	0.32756E-01	0.35965E+01
W1	Water	100	77.31	-47.09	-32.65	-43.73	0.80778E-08	0.89876E-04	0.21232E+01
W2	Water	100	77.83	-47.09	-47.09	-47.09	-0.92667E-17	0.00000E+00	0.00000E+00
H4	Building	1250	80.23	-47.09	-9.50	-27.22	0.70905E-04	0.84205E-02	0.44402E+01
H5	Building	2000	80.37	-47.09	-2.71	-27.03	0.41454E-03	0.20360E-01	0.10281E+02
M5	Parklot/Full	1800	79.57	-47.09	-13.98	-29.35	0.82535E-05	0.28729E-02	0.24720E+01

Table B-7. Cont.

Ru6	Runway	225	81.33	-47.09	-19.68	-37.88	0.11785E-05	0.10856E-02	0.66682E+01
U1	Urban	45000	64.89	-47.09	2.90	-27.13	0.20477E-03	0.14310E-01	0.73877E+01
U2	Urban	67500	67.69	-47.09	0.48	-26.99	0.84865E-04	0.92122E-02	0.46073E+01
U3	Urban	67500	70.99	-47.09	-3.00	-27.31	0.34713E-04	0.58918E-02	0.31712E+01
U4	Urban	67500	72.33	-47.09	2.31	-27.43	0.10307E-03	0.10152E-01	0.56239E+01
U5	Urban	45000	73.44	-47.09	-9.20	-28.92	0.86017E-05	0.29329E-02	0.22872E+01
U6	Urban	45000	74.45	-47.09	-0.62	-28.58	0.12235E-03	0.11061E-01	0.79811E+01
U7	Urban	45000	75.24	-47.09	-10.09	-30.50	0.53875E-05	0.23211E-02	0.26017E+01
U8	Urban	45000	75.76	-47.09	-9.44	-30.91	0.55521E-05	0.23563E-02	0.29027E+01
U9	Urban	45000	76.82	-47.09	-4.92	-31.27	0.17461E-04	0.41786E-02	0.55950E+01
U10	Urban	45000	77.23	-47.09	-3.37	-31.20	0.25114E-04	0.50114E-02	0.66061E+01
U11	Urban	45000	77.62	-47.09	5.07	-30.79	0.39332E-03	0.19832E-01	0.23796E+02
U12	Urban	45000	78.11	-47.09	-1.51	-31.38	0.24592E-04	0.49591E-02	0.68152E+01
U13	Urban	15000	78.50	-47.09	-3.58	-30.63	0.51100E-04	0.71484E-02	0.82652E+01
U14	Urban	15000	78.85	-47.09	-4.33	-29.19	0.64622E-04	0.80388E-02	0.66669E+01
U15	Urban	15000	78.10	-47.09	-1.51	-28.58	0.11956E-03	0.10934E-01	0.78895E+01
C1	City	10000	79.07	-47.09	-5.35	-25.82	0.14036E-03	0.11847E-01	0.45255E+01
C2	City	10000	79.21	-47.09	0.42	-25.32	0.47809E-03	0.21865E-01	0.74397E+01
C3	City	10000	79.35	-47.09	3.04	-22.77	0.18301E-02	0.42780E-01	0.80889E+01
C4	City	10000	79.49	-47.09	0.14	-23.76	0.76080E-03	0.27583E-01	0.65588E+01
C5	City	10000	79.62	-47.09	3.28	-26.00	0.78546E-03	0.28026E-01	0.11155E+02
C6	City	10000	79.96	-47.09	-0.13	-23.30	0.94856E-03	0.30799E-01	0.65843E+01
C7	City	10000	80.09	-47.09	1.56	-23.20	0.97807E-03	0.31274E-01	0.65332E+01
C8	City	10000	80.23	-47.09	4.83	-24.77	0.23016E-02	0.47975E-01	0.14395E+02
C9	City	10000	80.38	-47.09	0.95	-24.28	0.15792E-02	0.39739E-01	0.10656E+02
H6	Building	600	78.29	-47.09	-7.43	-20.74	0.21662E-03	0.14718E-01	0.17449E+01
H7	Warehouse	850	78.38	-47.09	-6.87	-25.46	0.11525E-03	0.10736E-01	0.37744E+01
H8	Warehouse	850	78.47	-47.09	-7.74	-29.46	0.47398E-04	0.68847E-02	0.60734E+01
H9	Warehouse	500	78.53	-47.09	-11.00	-25.24	0.90914E-04	0.95349E-02	0.31839E+01
H10	Warehouse	850	78.60	-47.09	-13.76	-30.20	0.69564E-05	0.26375E-02	0.27632E+01
U16	Urban	30000	75.40	-47.09	-0.34	-27.85	0.11922E-03	0.10919E-01	0.66611E+01
U17	Urban	30000	75.40	-47.09	-5.51	-28.18	0.44232E-04	0.66507E-02	0.43760E+01
U18	Urban	30000	75.40	-47.09	-11.45	-30.40	0.39858E-05	0.19964E-02	0.21915E+01
I1	Industrial	7500	79.03	-47.09	1.74	-23.49	0.14696E-02	0.38335E-01	0.85679E+01
I2	Industrial	7500	79.08	-47.09	-1.80	-27.08	0.18576E-03	0.13629E-01	0.69609E+01
I3	Industrial	5000	79.10	-47.09	-2.13	-23.93	0.60457E-03	0.24588E-01	0.60822E+01
I4	Industrial	5000	79.57	-47.09	2.78	-21.46	0.23653E-02	0.48634E-01	0.68053E+01
I5	Industrial	5000	80.84	-47.09	-2.55	-28.55	0.16760E-03	0.12946E-01	0.92792E+01
I6	Industrial	5000	81.59	-47.09	-3.17	-25.79	0.18534E-03	0.13614E-01	0.51675E+01
U19	Urban	10000	73.46	-47.09	-10.93	-28.99	0.85898E-05	0.29308E-02	0.23245E+01
U20	Urban	16000	72.87	-47.09	-4.53	-27.93	0.67550E-04	0.82189E-02	0.50971E+01

Table B-8. Clutter Statistics for the Polarimetric Set, X-HV

Id	Region Type	# Pts	Incidence Angle	Min (dB)	Max(dB)	Mean (dB)	Variance	SDEV	Variation
Re1	Residential	90000	50.34	-45.26	0.88	-24.38	0.33054E-03	0.18181E-01	0.49831E+01
Re2	Residential	22500	56.21	-45.26	3.17	-26.90	0.39455E-03	0.19863E-01	0.97301E+01
Re3	Residential	90000	60.74	-45.26	-3.20	-28.30	0.47107E-04	0.68634E-02	0.46396E+01
Re4	Residential	135000	62.74	-45.26	7.81	-26.38	0.55087E-03	0.23471E-01	0.10188E+02
Re5	Residential	45000	64.88	-45.26	-2.64	-27.31	0.73053E-04	0.85471E-02	0.45989E+01
Re6	Residential	45000	64.92	-45.26	2.65	-27.26	0.13062E-03	0.11429E-01	0.60784E+01
Re7	Residential	45000	68.14	-45.26	0.15	-24.99	0.16492E-03	0.12842E-01	0.40519E+01
Re8	Residential	45000	68.21	-45.26	-4.74	-26.01	0.39649E-04	0.62968E-02	0.25101E+01
Re9	Residential	45000	68.03	-45.26	0.78	-25.88	0.17606E-03	0.13269E-01	0.51385E+01
Re10	Residential	37500	70.58	-45.26	2.18	-25.79	0.18632E-03	0.13650E-01	0.51726E+01
Re11	Residential	22500	73.82	-45.26	-2.59	-26.70	0.10147E-03	0.10073E-01	0.47105E+01
Re12	Residential	2500	79.55	-45.26	-7.62	-27.64	0.58353E-04	0.76389E-02	0.44369E+01
Re13	Residential	2500	79.69	-45.26	-17.27	-34.74	0.15906E-05	0.12612E-02	0.37548E+01
Re14	Residential	40000	79.82	-45.26	-5.56	-33.30	0.14129E-04	0.37589E-02	0.80373E+01
Re15	Residential	40000	80.06	-45.26	3.17	-30.92	0.23817E-03	0.15433E-01	0.19085E+02
Re16	Residential	20000	80.38	-45.26	-5.76	-32.21	0.21872E-04	0.46768E-02	0.77841E+01
Re17	Residential	20000	80.67	-45.26	-9.00	-35.46	0.36632E-05	0.19140E-02	0.67332E+01
Re18	Residential	20000	80.88	-45.26	-0.27	-35.29	0.52139E-04	0.72207E-02	0.24391E+02
Re19	Residential	20000	81.08	-45.26	-8.96	-35.98	0.40009E-05	0.20002E-02	0.79348E+01
Re20	Residential	20000	81.27	-45.26	-6.91	-34.74	0.97321E-05	0.31196E-02	0.92848E+01
Re21	Residential	20000	81.46	-45.26	-0.83	-33.19	0.63873E-04	0.79920E-02	0.16649E+02
Re22	Residential	20000	81.63	-45.26	-8.15	-34.33	0.96643E-05	0.31088E-02	0.84339E+01
Re23	Residential	60000	51.25	-45.26	7.30	-23.15	0.22872E-02	0.47825E-01	0.98665E+01
Re24	Residential	30000	62.64	-45.26	0.68	-26.35	0.86425E-04	0.92965E-02	0.40075E+01
M1	Grass/Trees	2500	47.59	-45.26	-19.29	-29.20	0.19458E-05	0.13949E-02	0.11609E+01
M2	Grass/Trees	2500	52.31	-45.26	-23.83	-33.06	0.25002E-06	0.50002E-03	0.10106E+01
M3	Grass/Trees	2500	54.90	-45.26	-20.59	-31.36	0.56640E-06	0.75259E-03	0.10292E+01
H1	Building	1710	64.51	-45.26	-14.23	-26.20	0.11027E-04	0.33206E-02	0.13837E+01
G1	Grass	10000	75.91	-45.26	-29.79	-39.85	0.13341E-07	0.11550E-03	0.11165E+01
G2	Grass	10000	77.42	-45.26	-25.52	-41.12	0.21092E-07	0.14523E-03	0.18777E+01
G3	Grass	10000	78.14	-45.26	-27.40	-40.93	0.29647E-07	0.17218E-03	0.21317E+01
M4	Golf Course	25000	75.93	-45.26	-13.64	-34.12	0.19831E-05	0.14082E-02	0.36375E+01
Re25	Residential	10000	77.35	-45.26	-3.86	-30.20	0.43937E-04	0.66285E-02	0.69345E+01
G4	Grass	10000	51.33	-45.26	-17.28	-32.45	0.62358E-06	0.78967E-03	0.13867E+01
G5	Grass	5625	55.72	-45.26	-20.66	-30.98	0.66466E-06	0.81527E-03	0.10216E+01
G6	Grass	10000	78.98	-45.26	-24.36	-42.18	0.45860E-07	0.21415E-03	0.35409E+01
G7	Grass	10000	79.45	-45.26	-22.69	-42.65	0.54129E-07	0.23266E-03	0.42802E+01
G8	Grass	10000	80.03	-45.26	-21.67	-40.59	0.22220E-06	0.47138E-03	0.53998E+01
G9	Grass	10000	80.47	-45.26	-19.25	-39.95	0.41964E-06	0.64780E-03	0.63982E+01
G10	Grass	10000	80.84	-45.26	-18.03	-39.14	0.75746E-06	0.87032E-03	0.71322E+01
G11	Grass	10000	81.14	-45.26	-17.15	-36.94	0.19108E-05	0.13823E-02	0.68337E+01
G12	Grass	10000	81.50	-45.26	-14.38	-37.06	0.26842E-05	0.16383E-02	0.83314E+01
G13	Grass	10000	81.81	-45.26	-15.73	-38.18	0.24152E-05	0.15541E-02	0.10218E+02
G14	Grass	5625	59.97	-45.26	-12.73	-35.25	0.12782E-05	0.11306E-02	0.37858E+01
Ru1	Runway	1500	76.69	-45.26	-33.94	-44.73	0.60167E-09	0.24529E-04	0.72883E+00
Ru2	Runway	1500	76.69	-45.26	-34.34	-44.99	0.29509E-09	0.17178E-04	0.54215E+00
Ru3	Runway	1500	76.68	-45.26	-37.26	-45.15	0.10235E-09	0.10117E-04	0.33112E+00
Ru4	Runway	1125	77.46	-45.26	-34.28	-44.97	0.49671E-09	0.22287E-04	0.69978E+00
Ru5	Runway	1125	77.44	-45.26	-35.32	-45.05	0.34510E-09	0.18577E-04	0.59472E+00
G16	Grass	2250	76.52	-45.26	-31.70	-43.05	0.36806E-08	0.60668E-04	0.12254E+01
G17	Grass	2250	76.11	-45.26	-30.20	-41.49	0.71666E-08	0.84656E-04	0.11942E+01
G18	Grass	2250	77.31	-45.26	-30.53	-43.08	0.53678E-08	0.73265E-04	0.14888E+01
H2	Terminal	2400	77.65	-45.26	1.83	-15.57	0.10197E-01	0.10098E+00	0.36383E+01
H3	Terminal	2400	78.04	-45.26	-0.84	-18.91	0.20356E-02	0.45118E-01	0.35070E+01
W1	Water	100	77.31	-45.26	-30.04	-43.36	0.11400E-07	0.10677E-03	0.23170E+01
W2	Water	100	77.83	-45.26	-34.23	-44.78	0.11977E-08	0.34607E-04	0.10407E+01
H4	Building	1250	80.23	-45.26	-7.88	-25.50	0.16290E-03	0.12763E-01	0.45277E+01
H5	Building	2000	80.37	-45.26	-1.70	-25.75	0.68203E-03	0.26116E-01	0.98204E+01
M5	Park Lot-Full	1800	79.57	-45.26	-12.00	-27.70	0.18335E-04	0.42820E-02	0.25197E+01

Table B-8. Cont.

Ru6	Runway	225	81.33	-45.26	-17.95	-38.34	0.15955E-05	0.12631E-02	0.86143E+01
U1	Urban	45000	64.89	-45.26	3.96	-25.98	0.31285E-03	0.17688E-01	0.70073E+01
U2	Urban	67500	67.69	-45.26	1.70	-25.71	0.14563E-03	0.12068E-01	0.44987E+01
U3	Urban	67500	70.99	-45.26	-2.25	-26.37	0.50482E-04	0.71051E-02	0.30829E+01
U4	Urban	67500	72.33	-45.26	3.04	-26.68	0.13947E-03	0.11810E-01	0.54970E+01
U5	Urban	45000	73.44	-45.26	-8.20	-27.96	0.13057E-04	0.36135E-02	0.22570E+01
U6	Urban	45000	74.45	-45.26	0.30	-27.31	0.19408E-03	0.13931E-01	0.74976E+01
U7	Urban	45000	75.24	-45.26	-8.58	-28.98	0.10688E-04	0.32692E-02	0.25843E+01
U8	Urban	45000	75.76	-45.26	-7.97	-29.28	0.11663E-04	0.34152E-02	0.28954E+01
U9	Urban	45000	76.82	-45.26	-3.22	-29.62	0.37390E-04	0.61148E-02	0.56077E+01
U10	Urban	45000	77.23	-45.26	-1.54	-29.50	0.55603E-04	0.74568E-02	0.66417E+01
U11	Urban	45000	77.62	-45.26	6.77	-29.09	0.85027E-03	0.29159E-01	0.23628E+02
U12	Urban	45000	78.11	-45.26	0.12	-29.74	0.52254E-04	0.72287E-02	0.68053E+01
U13	Urban	15000	78.50	-45.26	-1.95	-28.99	0.10403E-03	0.10199E-01	0.80764E+01
U14	Urban	15000	78.85	-45.26	-2.96	-27.58	0.13521E-03	0.11628E-01	0.66563E+01
U15	Urban	15000	78.10	-45.26	0.12	-26.96	0.25443E-03	0.15951E-01	0.79125E+01
C1	City	10000	79.07	-45.26	-4.03	-24.28	0.29025E-03	0.17037E-01	0.45690E+01
C2	City	10000	79.21	-45.26	1.95	-23.63	0.10501E-02	0.32406E-01	0.74690E+01
C3	City	10000	79.35	-45.26	4.88	-21.11	0.41008E-02	0.64037E-01	0.82603E+01
C4	City	10000	79.49	-45.26	1.28	-22.07	0.16026E-02	0.40033E-01	0.64514E+01
C5	City	10000	79.62	-45.26	4.98	-24.49	0.16928E-02	0.41143E-01	0.11557E+02
C6	City	10000	79.96	-45.26	1.66	-21.69	0.19461E-02	0.44114E-01	0.65122E+01
C7	City	10000	80.09	-45.26	3.37	-21.51	0.21508E-02	0.46377E-01	0.65683E+01
C8	City	10000	80.23	-45.26	6.66	-23.08	0.50667E-02	0.71181E-01	0.14474E+02
C9	City	10000	80.38	-45.26	2.78	-22.64	0.33474E-02	0.57857E-01	0.10620E+02
H6	Building	600	78.29	-45.26	-6.14	-19.07	0.44782E-03	0.21162E-01	0.17064E+01
H7	Warehouse	850	78.38	-45.26	-5.11	-23.75	0.24841E-03	0.15761E-01	0.37342E+01
H8	Warehouse	850	78.47	-45.26	-5.84	-27.49	0.11588E-03	0.10765E-01	0.60368E+01
H9	Warehouse	500	78.53	-45.26	-9.31	-23.37	0.21334E-03	0.14606E-01	0.31745E+01
H10	Warehouse	850	78.60	-45.26	-11.90	-28.51	0.14991E-04	0.38718E-02	0.27469E+01
U16	Urban	30000	75.40	-45.26	1.03	-26.51	0.21224E-03	0.14569E-01	0.65228E+01
U17	Urban	30000	75.40	-45.26	-4.48	-26.93	0.75546E-04	0.86917E-02	0.42824E+01
U18	Urban	30000	75.40	-45.26	-9.62	-28.96	0.76933E-05	0.27737E-02	0.21812E+01
I1	Industrial	7500	79.03	-45.26	3.28	-21.90	0.31926E-02	0.56503E-01	0.87456E+01
I2	Industrial	7500	79.08	-45.26	-0.61	-25.40	0.39819E-03	0.19955E-01	0.69150E+01
I3	Industrial	5000	79.10	-45.26	-0.50	-22.49	0.12272E-02	0.35031E-01	0.62165E+01
I4	Industrial	5000	79.57	-45.26	4.42	-19.82	0.50907E-02	0.71349E-01	0.68485E+01
I5	Industrial	5000	80.84	-45.26	-1.46	-27.24	0.26819E-03	0.16376E-01	0.86791E+01
I6	Industrial	5000	81.59	-45.26	-1.39	-24.71	0.50317E-03	0.22431E-01	0.66328E+01
U19	Urban	10000	73.46	-45.26	-9.86	-27.99	0.13300E-04	0.36469E-02	0.22957E+01
U20	Urban	16000	72.87	-45.26	-3.95	-27.17	0.90693E-04	0.95233E-02	0.49605E+01

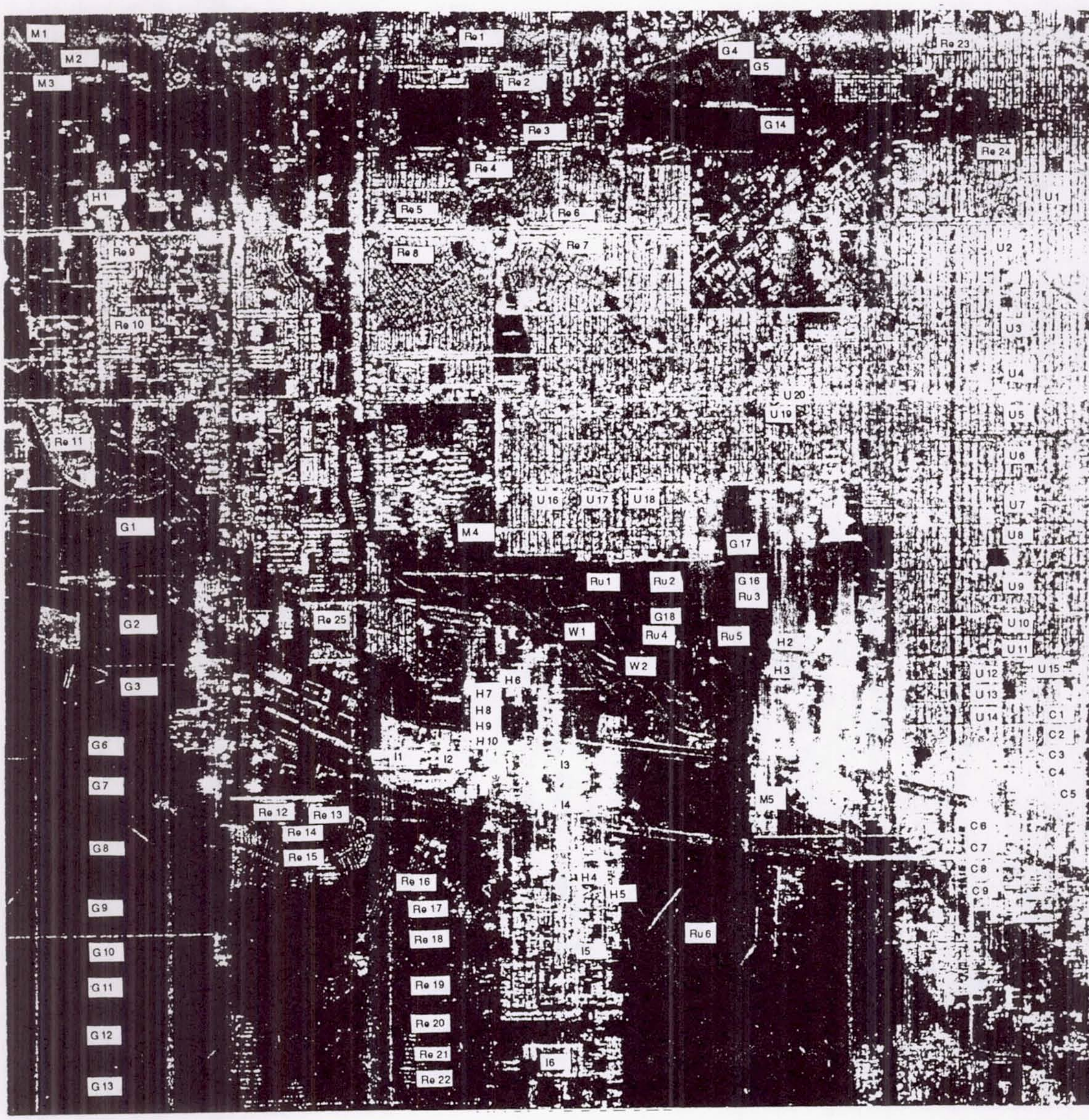


Figure B-1. The Denver Polarimetric Set, Near Range is at the Top of the Image.

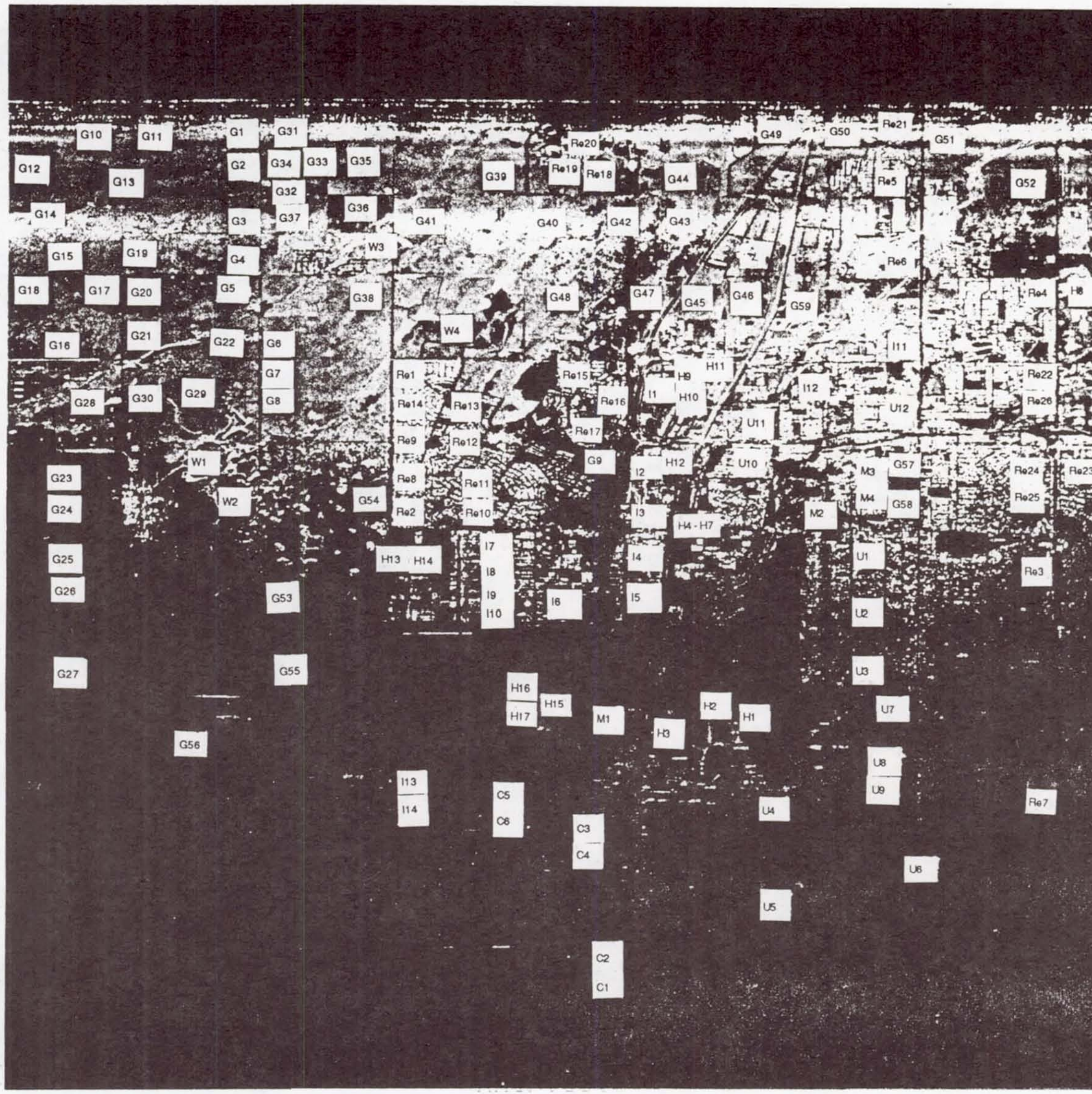


Figure B-2. First Denver 'Step West',
Near Range is at the Top of the Image.

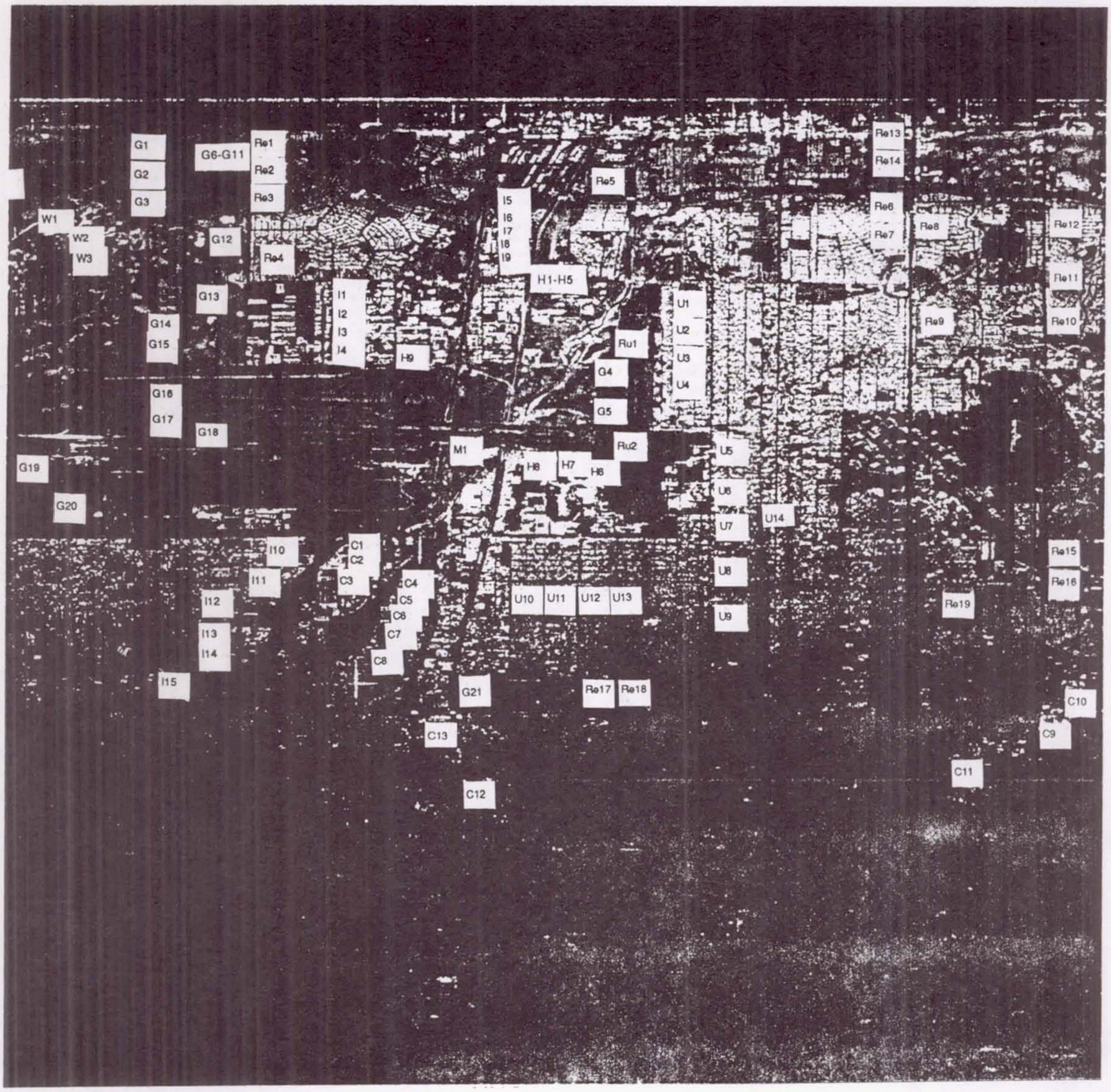


Figure B-3. Second Denver 'Step West',
Near Range is at the Top of the Image.

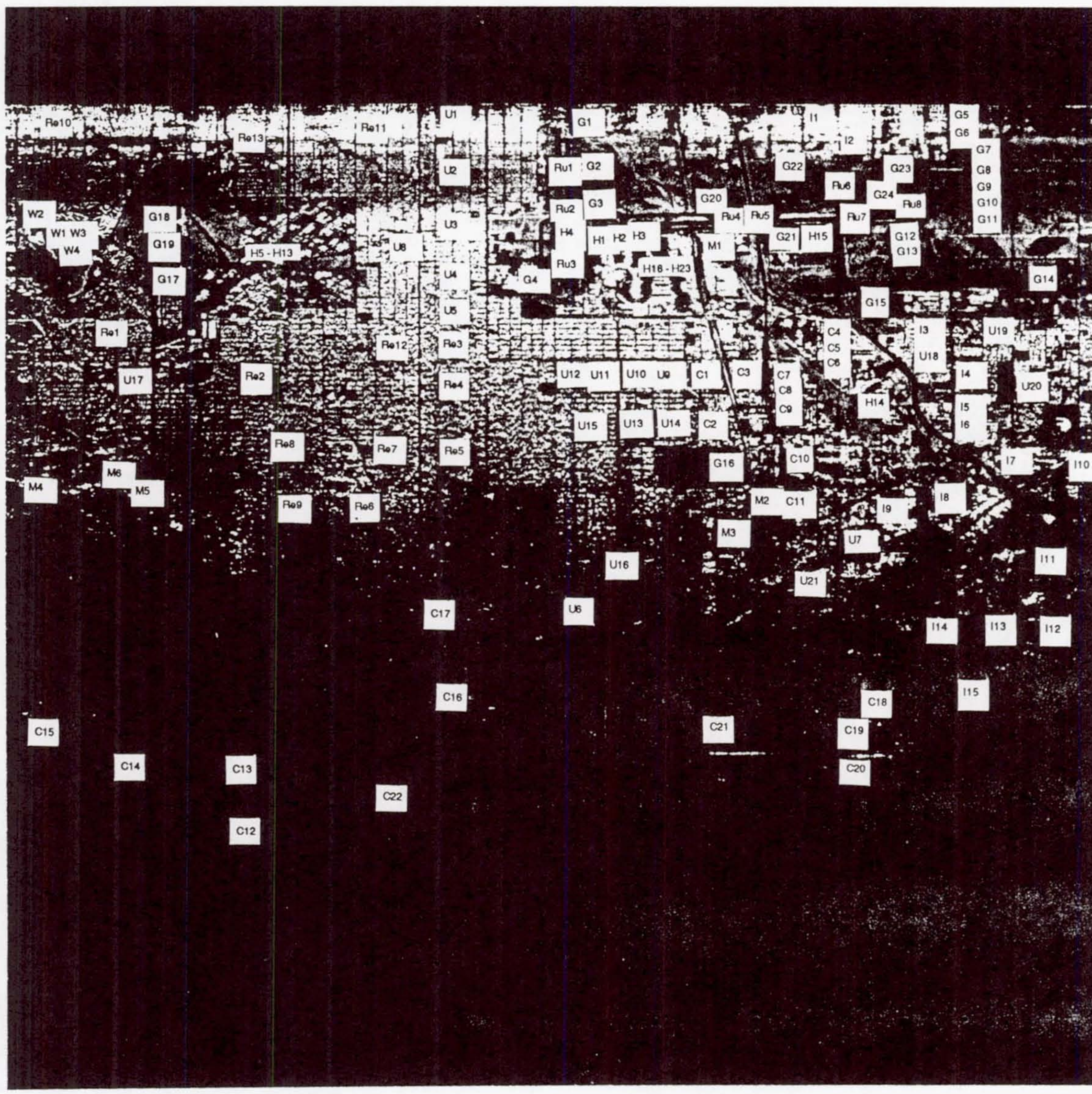


Figure B-4. Third Denver 'Step West', Mirror Image with Near Range at Top of the Image.

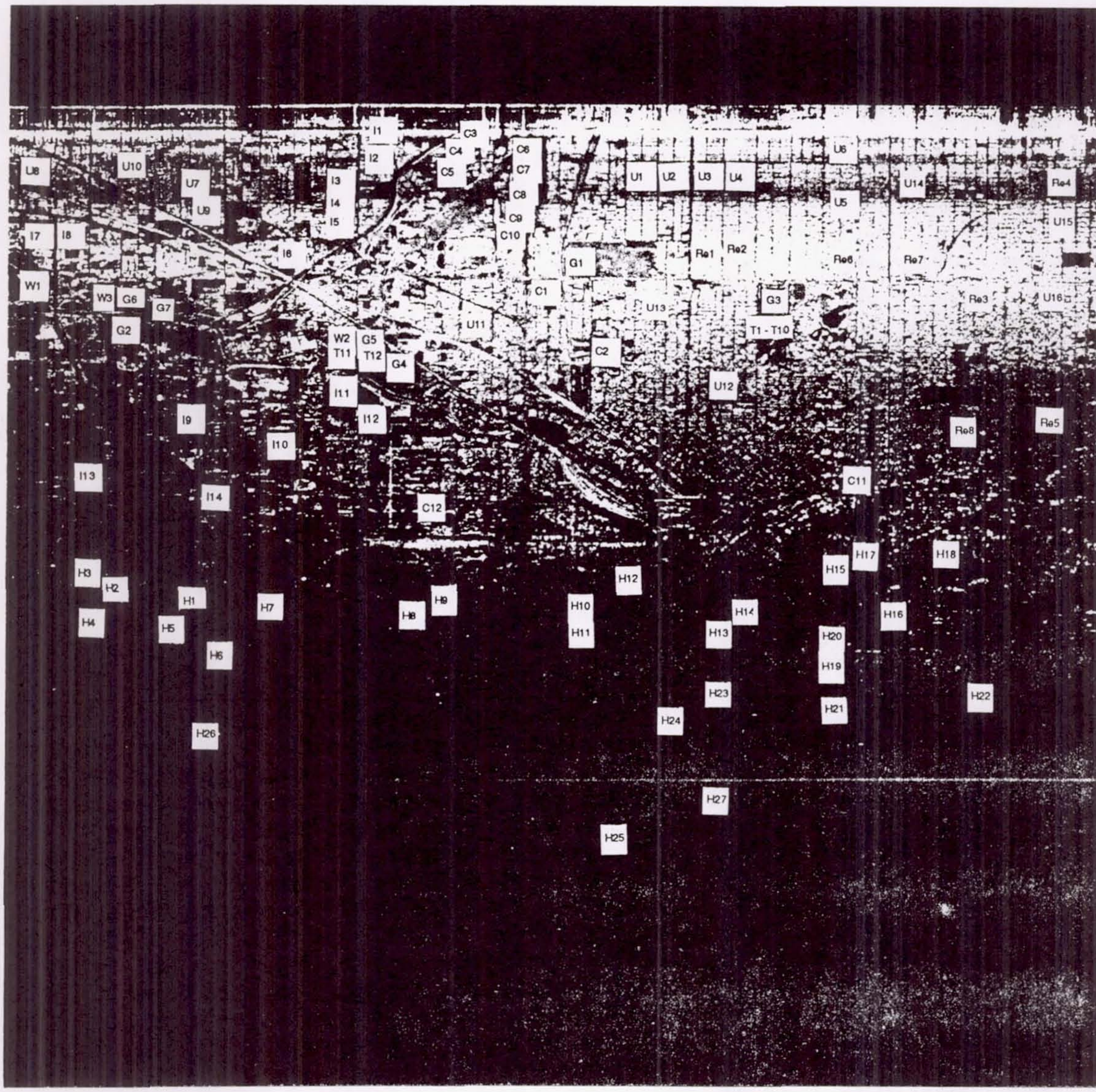


Figure B-5. Fourth Denver 'Step West',
Near Range is at the Top of the Image.

NASA National Aeronautics and Space Administration

Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-4305 DOT/FAA/DS-89/16		

4. Title and Subtitle	5. Report Date
Synthetic Aperture Radar Imagery of Airports and Surrounding Areas - Denver Stapleton International Airport	July 1990
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Robert G. Onstott and Denise J. Gineris	
	10. Work Unit No. 505-67-41-57
9. Performing Organization Name and Address Environmental Research Institute of Michigan (ERIM) 1975 Green Rd. Ann Arbor, Michigan 48105	11. Contract or Grant No. NAS1-18465
	13. Type of Report and Period Covered Contractor report 31 Aug. 87 - 30 Nov. 89
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Langley Research Center Hampton, Virginia 23665-5225	14. Sponsoring Agency Code

15. Supplementary Notes

Langley Technical Monitor: E. M. Bracalente
Phase III, Final Report

16. Abstract This report is the third in a series of three which address the statistical description of ground clutter at an airport and in the surrounding area. These data are being utilized in a program to detect microbursts. Synthetic aperture radar (SAR) data were collected at the Denver Stapleton Airport using a set of parameters which closely match those which are anticipated to be utilized by an aircraft on approach to an airport. This report describes these data and the results of the clutter study. Scenes of 13 km x 10 km were imaged at 9.38 GHz and HH-, VV-, and HV-polarizations, and contain airport grounds and facilities (up to 14%), cultural areas (more than 50%), and rural areas (up to 6%). Incidence angles range from 40° to 84°. At the largest depression angles the distributed targets, such as forest, fields, water, and residential, rarely had mean scattering coefficients greater than -10 dB. From 30% to 80% of an image had scattering coefficients less than -20 dB. About 1% to 10% of the scattering coefficients exceeded 0 dB, and from 0% to 1% above 10 dB. In examining the average backscatter coefficients at large angles, the clutter types cluster according to the following groups: (a) terminals (-3 dB), (b) city and industrial (-7 dB), (c) warehouse (-10 dB), (d) urban and residential (-14 dB), and (e) grass (-24 dB).

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Clutter, Backscatter, SAR, Microburst	Unclassified- Unlimited Subject Category 03

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified	396	A17

NASA FORM 1626 OCT 86 For sale by the National Technical Information Service, Springfield, Virginia 22161-2171

NASA-Langley, 1990