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DISCRETE CLUTTER MEASUREMENTS PROGRAM: OPERATIONS IN THE METROPOLITAN BOSTON AREA

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FOREWORD

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REVIEW AND APPROVAL

Publication of this technical report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas

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13. ABSTRACT

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The MITRE Corporation has been conducting a clutter measurements program aimed primarily at providing data for use in the design of AWACS. A mobile experimental radar facility has been constructed which permits the study of the discrete clutter of various terrains. This report describes the results obtained in the metropolitan Boston area.

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SECTION I

INTRODUCTION

The MITRE Corporation has been conducting an experimental program under which data is being collected on discrete clutter. Such data will be utilized in the design of AWACS radars.

Initially, an S-band radar was located at the MITRE Boston Hill Field Station in North Andover, Massachusetts; data was collected which confirmed the existence of clutter discretes, i.e., large isolated point targets[1]. From the peculiar nature of the terrain it was recognized that it would be necessary to design experiments whereby both the type of terrain and the grazing angle at which the terrain is viewed could be varied.

To this end, a mobile experimental radar facility was constructed and operated in western Massachusetts[2]. In this experiment data was collected on urban and rural terrain at grazing angles up to about eleven degrees.

Subsequently, the radar was operated in the metropolitan Boston area, and the results of this effort are the subject matter of this report.

The emphasis in earlier experiments was placed on the identification of sources of discretes as well as measurement of radar cross section (RCS). However, the emphasis in the phase being reported here was on the acquisition of data to expand the data base by making measurements on a large urban center. Measurement of RCS and the approximate location was made on only the largest discretes. The numbers involved and the lack of accessibility generally precluded identification of sources. Experimental results obtained show the Boston area to be the source of discretes larger than 10^6 m^2, and a large number of discretes greater than 10^3 m^2 at low grazing angles.

SECTION II

DESCRIPTION OF EQUIPMENT

A. VEHICLE AND PHYSICAL FACILITIES

The mobile experimental radar facility has an entirely self-sustaining capability permitting it to be used at sites where only minimal quality access roads are available. Figures 1, 2, 3, and 4 are views of the equipment in its operational and transport configurations.

The vehicle, a two- and one-half ton, 6 x 6 combat cargo and troop carrier, was obtained as surplus property. An electronic operations shelter, supplied with the truck, was refurbished and fitted out as a laboratory with work bench and electronic tool and parts complements. A commercial gasoline-powered 5 KVA, 115V, 60 hertz generator was procured and mounted on a shelf over the cab. (Subsequently, a trailered heavy-duty generator was substituted after breakdown of the commercial unit in the field.) Since it was intended to make the truck a self-contained ground check-out facility for helicopter experiments, a surplus gasoline-powered 200 ampere, 28V dc generator was similarly mounted on the shelf over the cab in order to simulate a typical helicopter electrical bus. All power sources are "hard wired" through breakered distribution panels to service receptacles.

From the time of arrival at a site, the equipment can be made fully operational in about one hour when installed by two technicians. The facility has provision for leveling the antenna on inclines of about

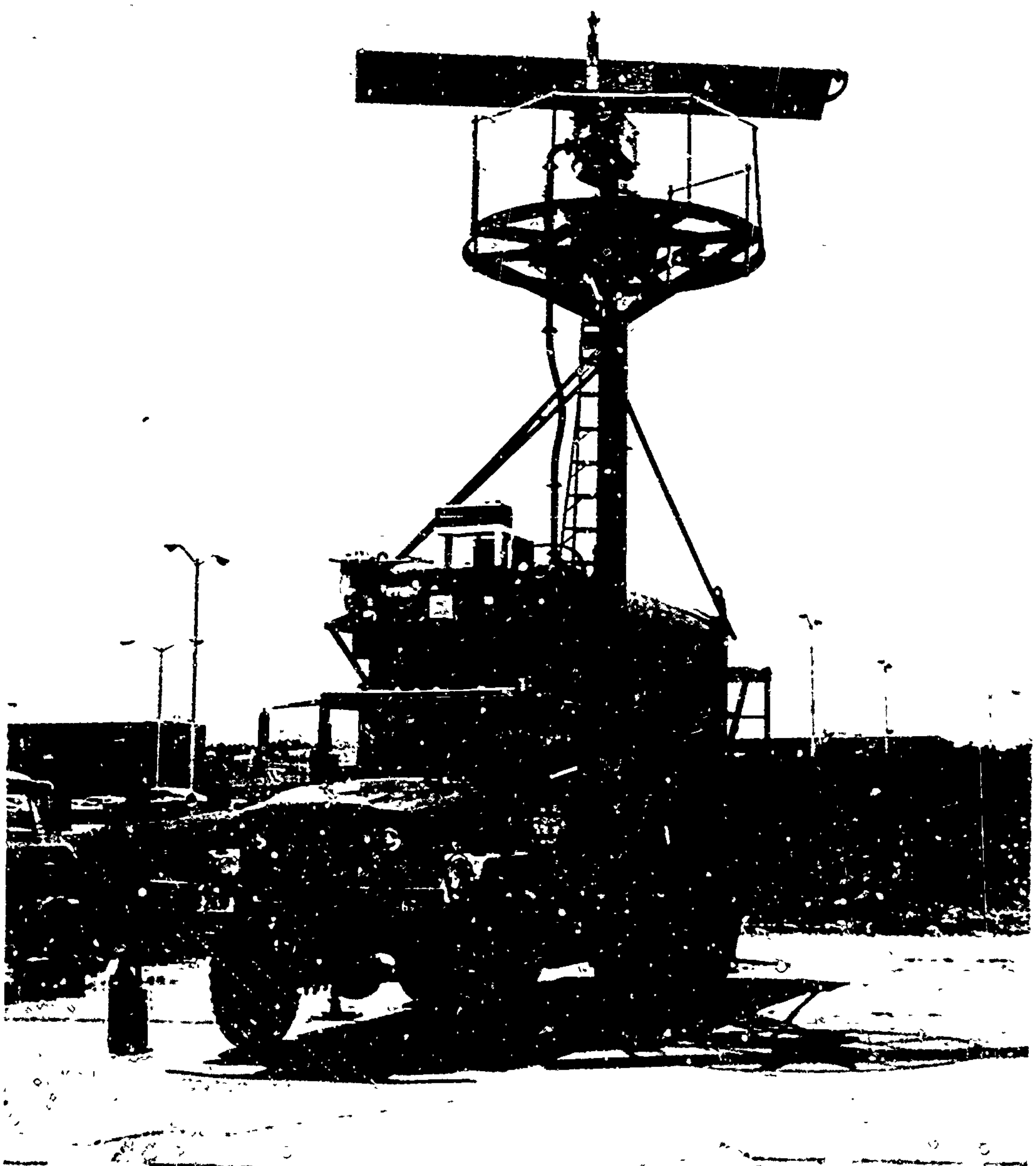


Figure 1 FRONT VIEW OF MOBILE RADAR FACILITY
IN THE OPERATIONAL CONFIGURATION

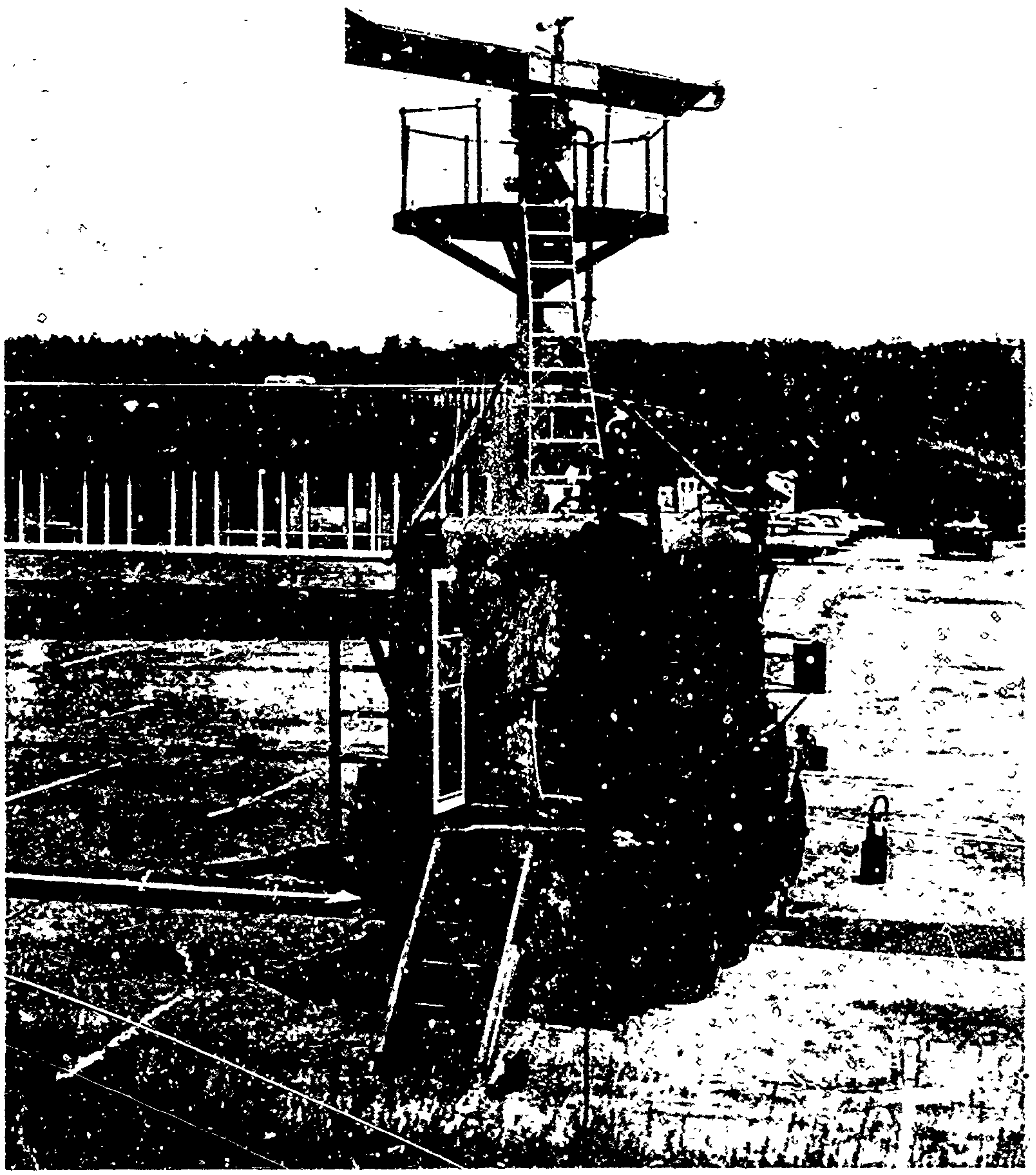


Figure 2 REAR VIEW OF MOBILE RADAR FACILITY IN THE OPERATIONAL CONFIGURATION

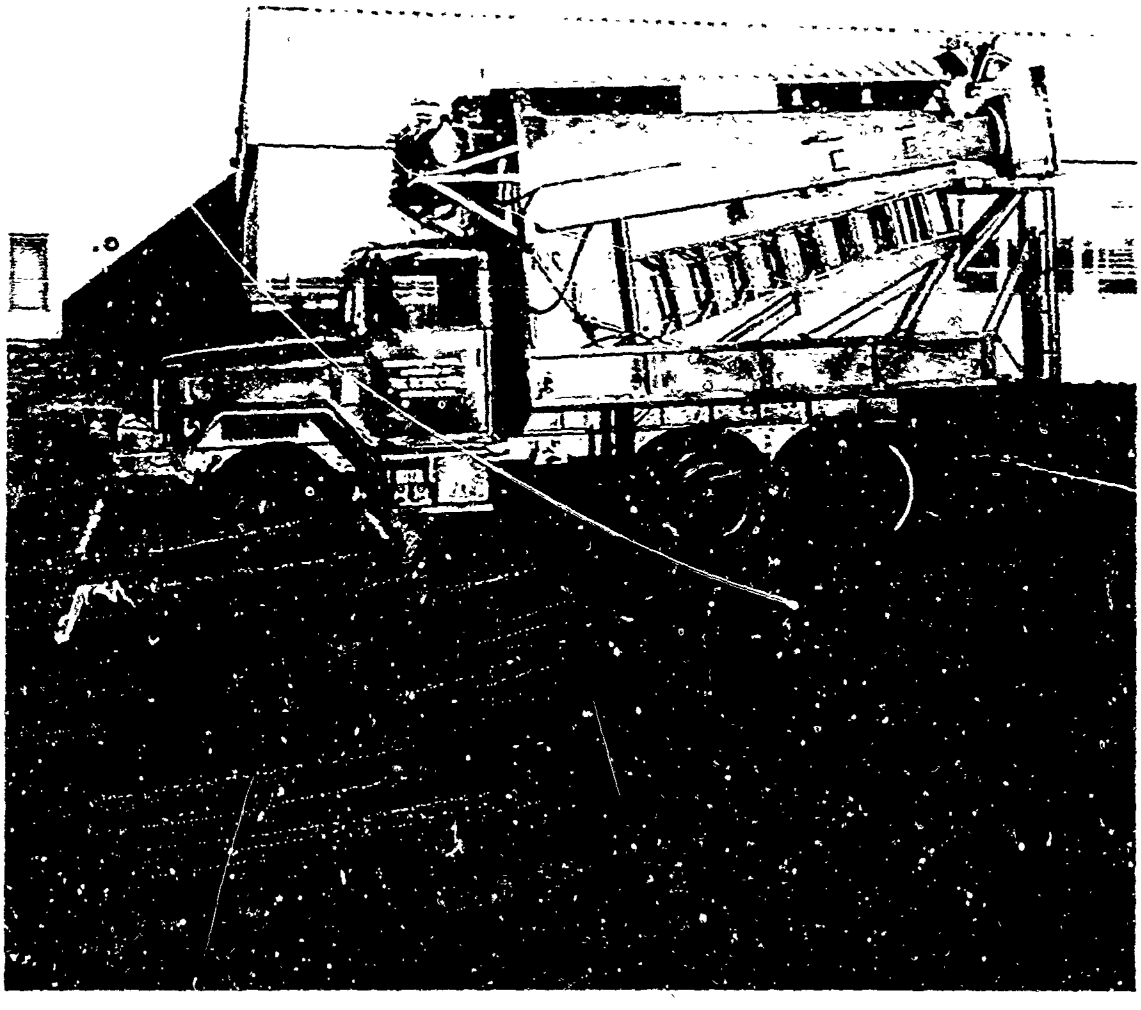


Figure 3 LEFT SIDE VIEW OF MOBILE RADAR FACILITY
IN THE TRAVELING CONFIGURATION

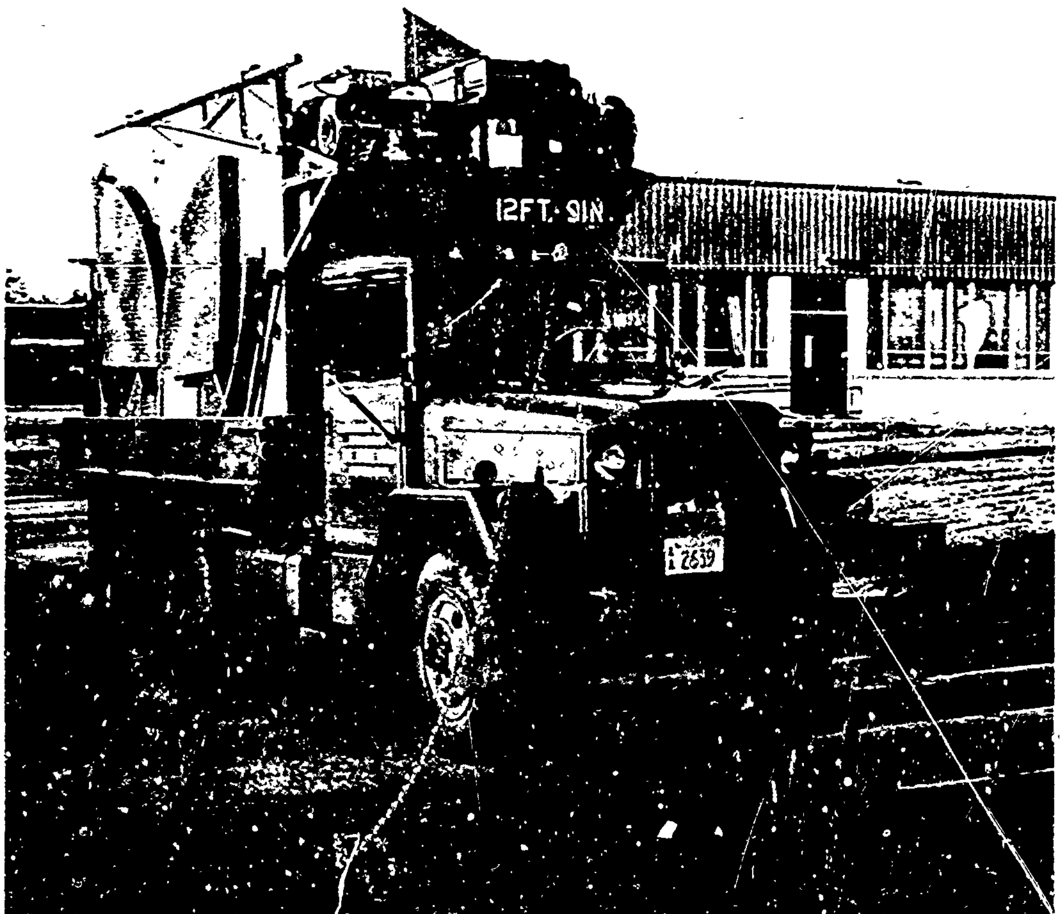


Figure 4 RIGHT SIDE VIEW OF MOBILE RADAR FACILITY IN THE TRAVELING CONFIGURATION

ten degrees from front to back, and about four degrees side to side. The antenna altitude above the ground is 25 feet, adequate for clearance above most obstructions, including tree lines. Stability of the antenna is provided by hydraulic jacks which take body weight off the truck springs.

The antenna, a twelve and one-half foot slotted waveguide array, is transported on the roof of the cabin. The pedestal, which contains the rotary joint and drive motor is permanently mounted on a "boom" which is lowered in transport to rest upon a carrying shelf. The boom is pivoted on the left front corner of the cabin, and is erected by means of a hydraulic piston after the personnel platform and antennas are assembled. Braces to the right front and left rear corners of the cabin lock the boom in a vertical position. Levels on the boom permit adjustment of the braces so that the antenna is horizontal in the event the truck is on a grade. The personnel platform, reached by ladder from the roof of the cabin, can accommodate two observers. Communications from the antenna to the cabin is by means of an "intercom".

B. INSTRUMENTATION

The mobile experimental radar facility contains essentially the same instrumentation as that utilized in the fixed installation at Boston Hill.[3] Consequently, only a brief discussion will be given here. Significant differences will be noted. Referring to Figure 5, the instrumentation system block diagram, three sections

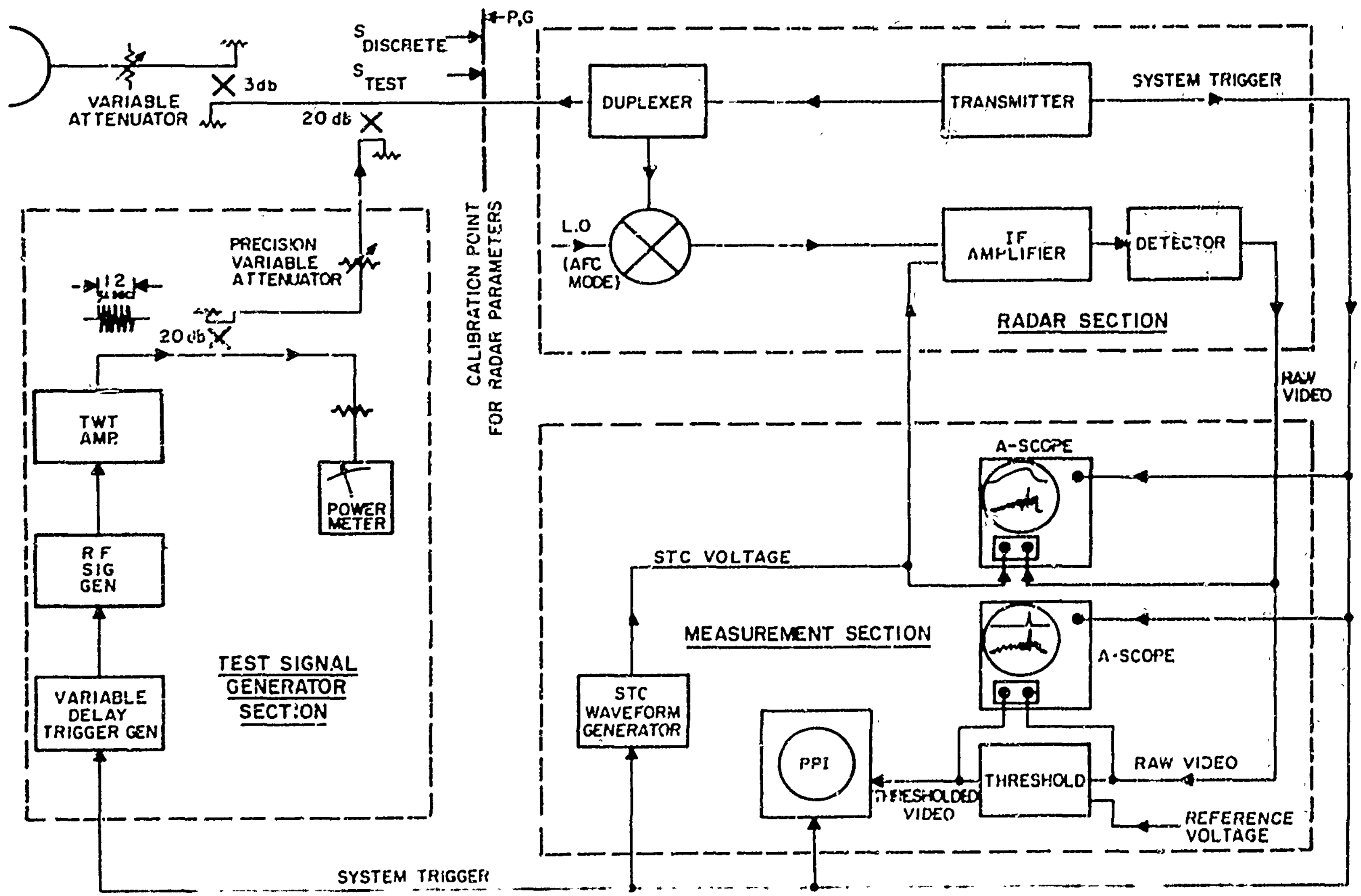


Figure 5 INSTRUMENTATION SYSTEM BLOCK DIAGRAM

of the instrumentation system are identified for convenience in discussion: "Radar Section", "Measurement Section", and "Test Signal Generator Section".

The radar section consists of an S-band non-coherent radar, RCA type CRM-N2C-30, with major parameters as given in Table I, and shown in block diagram form in Figure 6. The radar parameters of peak power and antenna gain were measured at the reference plane indicated in Figure 5 and include correction for wave guide loss. A fixed 3 db power divider reduces the transmitter power to a value within the rating of the variable attenuator, the need for which is described below. The range equation using measured radar parameters, and including the 3 db power divider loss, is plotted in Figure 7. Observe that a quantity σ_e, or "effective" cross section is defined. It is the product of the "true" radar cross section and the pattern propagation factor, F, a quantity which is explicitly unknown in all measurements. Thus, a measurement of S, the returned signal power from a discrete, and R, the range to the discrete, are used to measure a quantity σ_e unless otherwise stated.

The test signal generator section provides the ability to insert a test pulse of known power at any range of interest. Such a pulse is used primarily to calibrate the receiver from signal in to "raw video" out.

TABLE I

RADAR PARAMETERS

Frequency:	3052 Mhz
Peak Power:	23.5 Kw*
Pulse Length:	0.4μsec** (Range Resolution: 200 ft)
Pulse Repetition Rate:	1 Khz **
Antenna:	
Polarization -	Horizontal
Vertical Beamwidth -	20 degrees
Horizontal Beamwidth -	2 degrees
Gain -	28.4 db*
Side Lobes -	28 db, one-way (max)
Rotation Rate -	Variable to 13 r.p.m.
I.F. Amplifier:	
Type	Linear, with voltage controlled gain
Center Frequency	30 Mhz
Bandwidth	3 Mhz**

*See Figure 5 for definition of reference planes.

**The radar has an alternate mode with a 0.1 μsec pulse width and a 2 Khz repetition rate which was not utilized in the experiment.

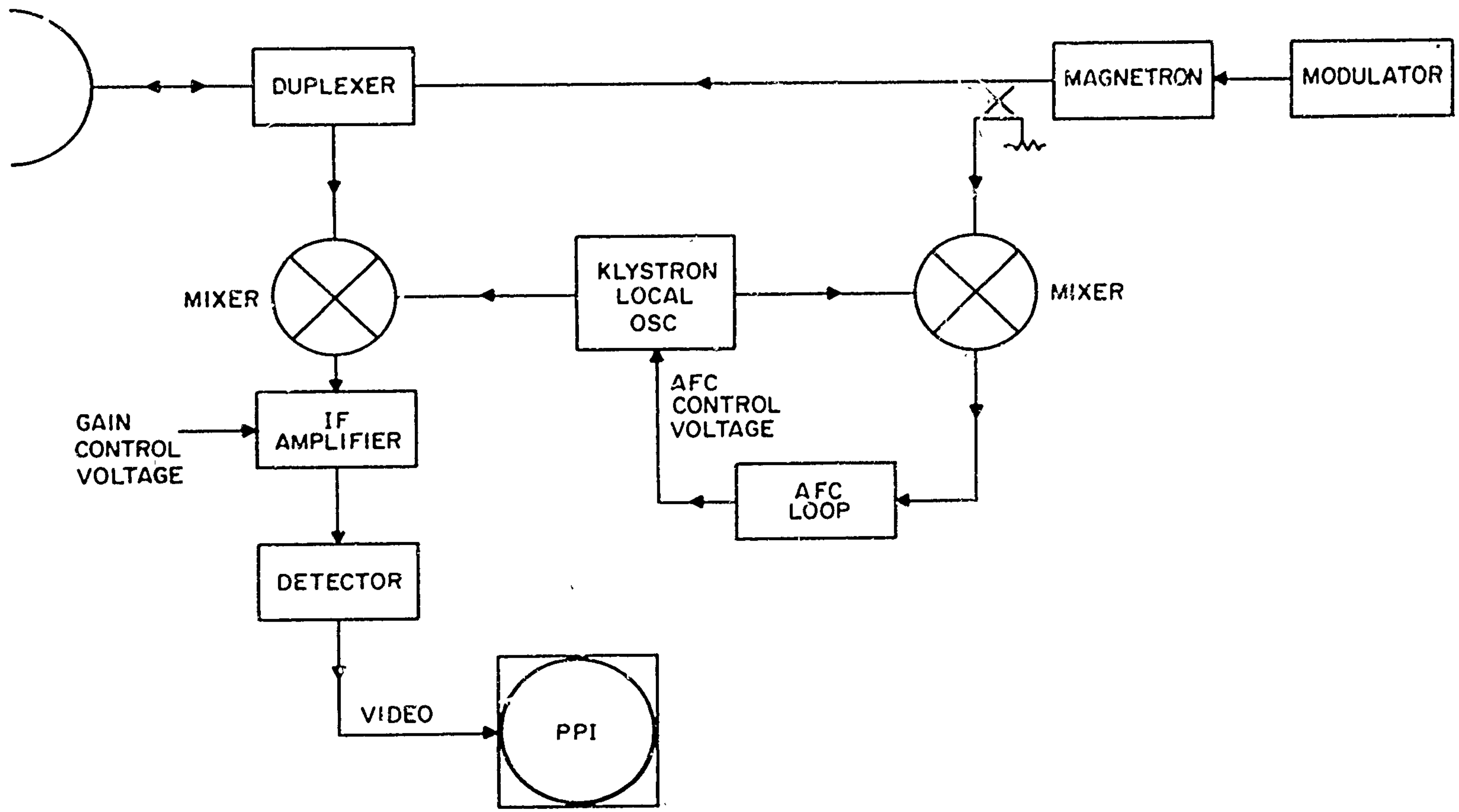


Figure 6 SIMPLIFIED RADAR BLOCK DIAGRAM

The measurement section provides the capability of (a) generating a sensitivity time control (STC) voltage which gain controls the I. F. amplifier, and (b) displaying radar outputs for measurement and observation.

An important feature of the operation of the radar is the removal of the range dependence of discrete returns. The STC generator produces a voltage waveform which, when applied to the gain control of the I. F. amplifier, increases the gain in direct proportion to the fourth power of range. In this way, the raw video signal level remains constant for a given size target independently of range. The STC waveform is obtained by integrating a sequence of equal-width, time-contiguous pulses whose amplitudes increase with range. Calibration is effected by first turning to zero the variable attenuator which precedes the antenna. Then test pulses corresponding to the power returned from a discrete of 1000 m^2 (from Figure 7) are injected into the radar sequentially at ranges of interest and the STC curve adjusted to produce a video voltage which just equals the reference voltage of the threshold. After calibration, a discrete which exceeds the threshold at any range is then known to be equal to or greater than 1000 m . By adjusting the variable attenuator, the threshold is automatically increased by twice the attenuator setting. During operation at Boston Hill, similar operation was obtained by an attenuator inserted between mixer and I. F. amplifier.

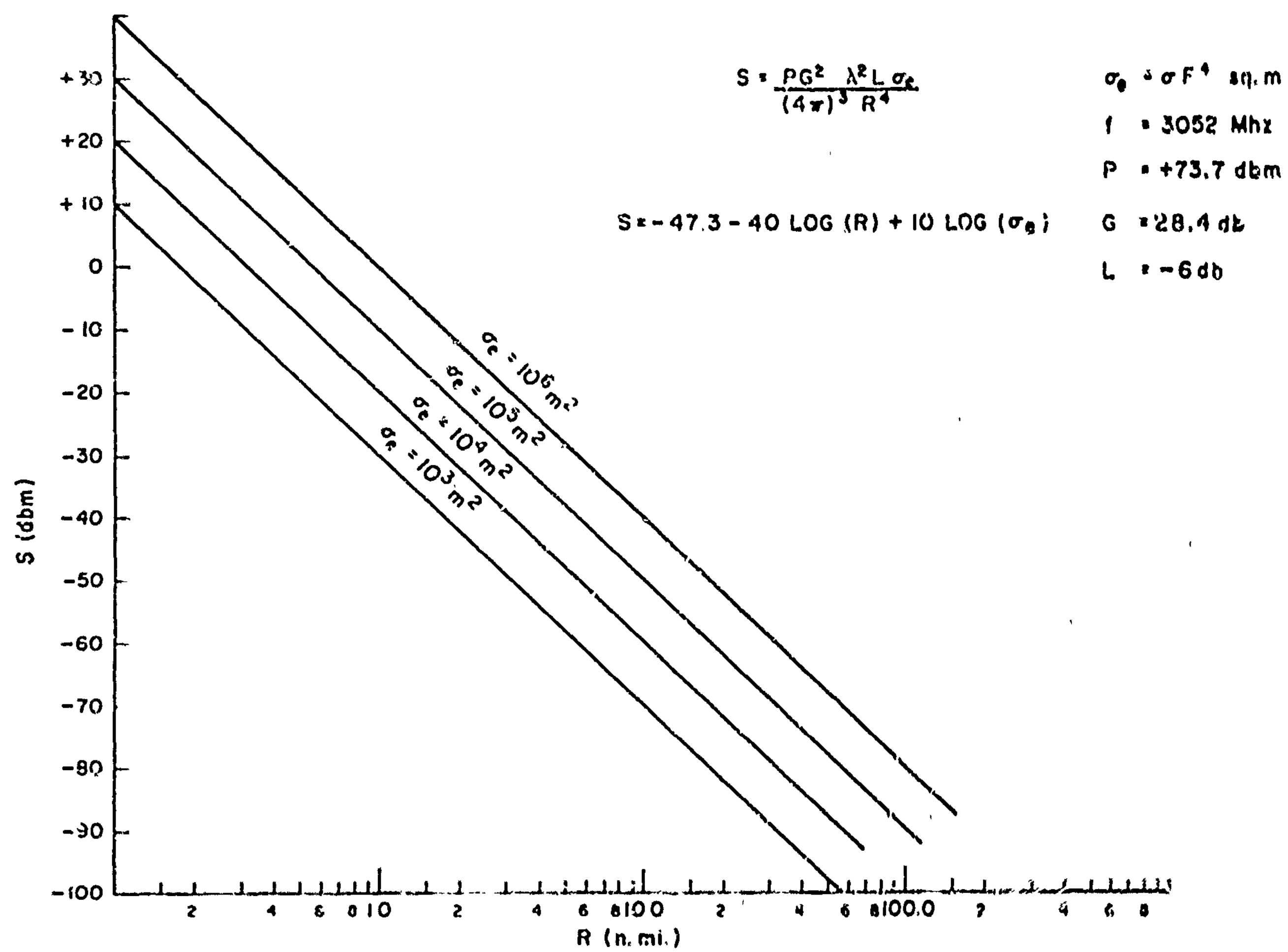


Figure 7 RECEIVED SIGNAL POWER vs. RANGE FOR VARIOUS RADAR CROSS SECTIONS (BASED UPON MEASURED RADAR PARAMETERS)

SECTION III

EXPERIMENTAL PROCEDURE

A. SITE SELECTION

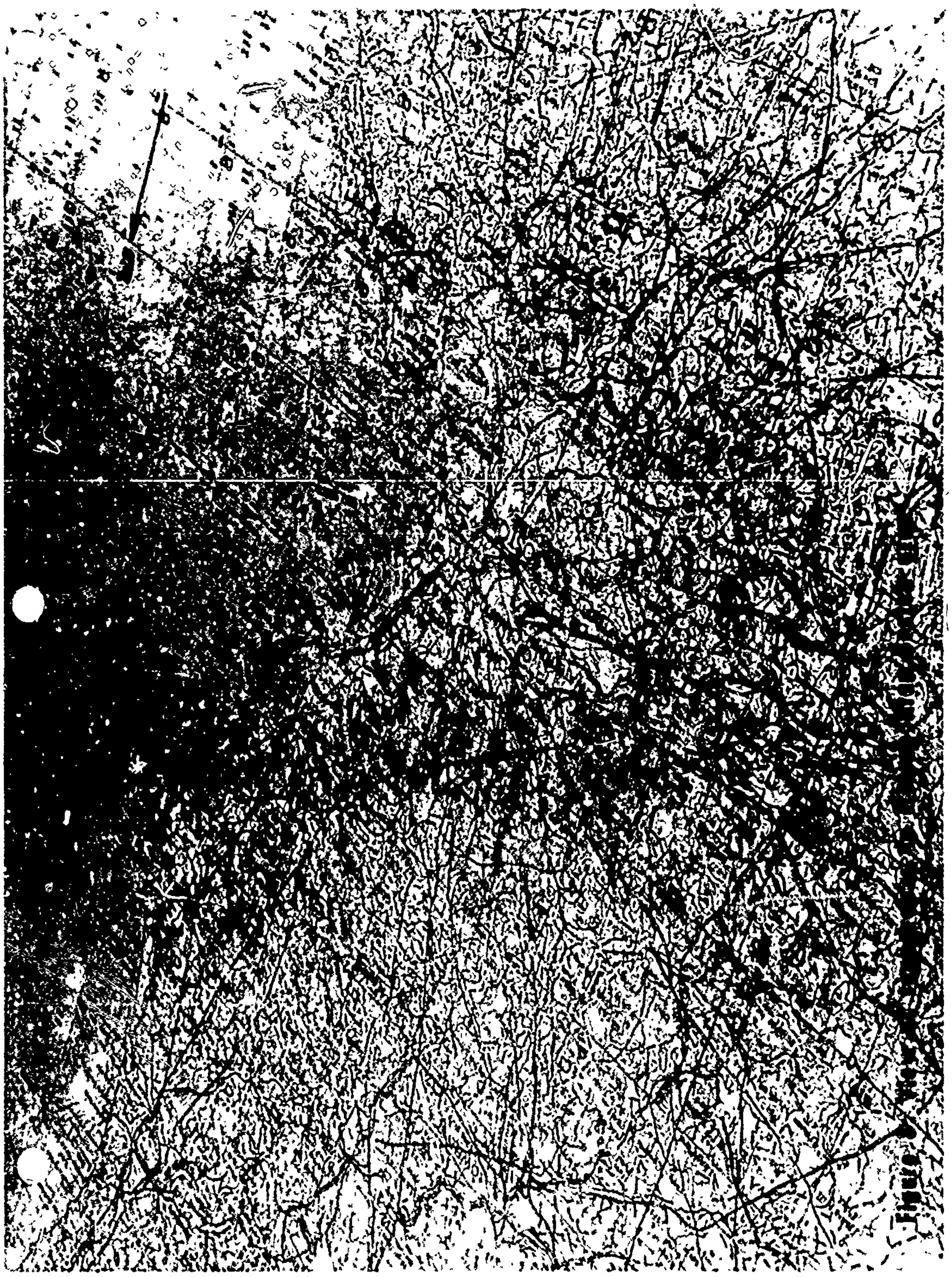
Figure 8 is a photograph of a portion of a three-dimensional map showing the area in eastern Massachusetts where the data was obtained. The vertical to horizontal exaggeration of the map scale is three to one (1:83,333 and 1:250,000 respectively). Three sites are indicated on the map: Robbins Park, Arlington (No. 1), Prospect Hill, Waltham (No. 2), and Great Blue Hill, Milton (No. 3). Black, red, and white pins, respectively, identify the sites. At site No. 3, the radar was operated at two positions at the same elevation, thereby permitting some variation of azimuth angle with constant grazing angle.

The area selected, the Boston metropolitan area, has a relatively small amount of shadowed terrain when viewed from outlying western hills.

Several cities comprise the Boston metropolitan area, as can be seen from Figure 8. A wide variety of commerce and industry are carried on within the component cities. In addition there are many residential sections.

B. PARAMETER MEASUREMENT

In this experiment no systematic effort was made to identify the sources of discretes. However, for the largest discretes at each



site, a range and azimuth measurement was made and their general location plotted (e.g., "downtown" Boston). While making azimuth measurements, some observations were made by telescope on probable sources of discretes. The exception to this is a series of observations made at site No. 3 on water towers. The water towers were selected for their location and isolation from other structures.

The measurement of (1) radar cross section, (2) range, and (3) azimuth are described below. After determining range and azimuth, U. S. Geological Survey topographic maps were used for plotting the locations of discretes.

1. Measurement of Radar Cross Section

Radar cross section was determined either by comparing the video levels of a discrete return and an R. F. test pulse on an A-scope, or by means of threshold adjustment using the attenuator in the waveguide to the antenna. Most measurements were made with the waveguide attenuator after it was established that the STC curve and attenuator scale gave appropriate accuracy; discrepancies of several tenths of a db were the largest observed when, from time to time, comparisons were made by the two methods.

2. Range Measurement

Range measurement was made using the time delay feature of an oscilloscope with a delayed sweep. Based upon an accurate scope calibration, and correlation with returns from isolated objects at locations obtained from U. S. Geological Survey topographic maps (scale of 1:24,000, "$7\frac{1}{2}$ minute" series), errors in absolute range measurement are believed not to have exceeded three hundred feet. Care was exercised in both the delay measurement and the subsequent plotting of the range measurement on topographic maps.

3. Measurement of Target Azimuth

As discussed in an earlier report[4] the antenna pedestal is fitted with an azimuth "ring," graduated in intervals of 0.5 degrees, and a pointer fitted to the antenna. Mounted on the antenna is a telescope previously boresighted with the beam. The telescope is focused on a known distant object. From the bearing to the distant object, scaled from a topographic map, true north on the azimuth ring and PPI can be deduced.

After north-referencing the beam, bearing measurements can be made on a target of interest by "hand cranking" the antenna till an electrical maximum is observed on an A-scope and noting the corresponding angle on the azimuth ring. Absolute accuracy is estimated to have been no worse than about 0.5 degrees or about 52 feet per mile of range.

SECTION IV

MEASURED RESULTS AND OBSERVATIONS

A. GENERAL

The general approach adopted for this phase of the experimental program was to view the metropolitan Boston area from as many different sites as practicable, and at each site to collect data on the number, general location, and RCS of discretes.

Grazing angle was essentially uncontrollable. Except for sites No. 3A and No. 3B, no control of azimuth angle was achieved. However, as can be seen from Figure 8, the sites are comparatively widely spaced on an arc of about one hundred degrees centered on downtown Boston.

No special attempt was made to identify the sources of discretes. In fact, position measurements were made on only the largest (approximately twenty-five at each site) in order to orient the data. An exception to this procedure was the study of selected water towers at site No. 3B, and described in detail below. However, the sources of certain discretes were obvious. For example, the Prudential Center, the tallest building in Boston, was the source of returns at all sites, but with varying RCS. In some cases, reference to detailed topographic maps showed the existence of gas or oil storage tanks sufficiently isolated to be recognized as the sources of returns. Several of the largest discretes repeated as among the largest, with different values of RCS, at two or more sites. It should be recognized that "largest" was an arbitrary definition which varied from values exceeding +16 to +20 db relative to 1000 m^2. Several among the singly observed discretes were observed at values below these size criteria from other sites.

The data presented below in Sections B, C, and D consist of (a) counts of discretes made from PPI displays of thresholded video by an operator, and (b) PPI photographs of thresholded video (except for site No. 1, where PPI photographic facilities were not operative). Reference to Figures 9, 10, 22, and 34, the cumulative distributions, shows that when the antenna is searchlighting, the operator/threshold combination is somewhat more sensitive. Consequently, at the lower values of RCS the numbers of discretes for the scanning antenna case should be regarded as low. In addition, as can be seen from PPI photos, targets close in range and azimuth, but probably resolveable by the radar itself, merge on the display and can only be counted as a single discrete. The manual count stopped when, in the judgement of the operator, the accuracy of the count was degraded. The possible error is difficult to estimate but is certainly less than 20% and probably less than 10%. The error in the count increases with decreasing threshold.

B. RESULTS AT SITE NO. 1

Site No. 1, Robbins Park in Arlington, is approximately six nautical miles from the state capitol area of Boston. The true bearing to Boston is about 120 degrees from this site, and its elevation is about 300 feet above mean sea level (MSL).

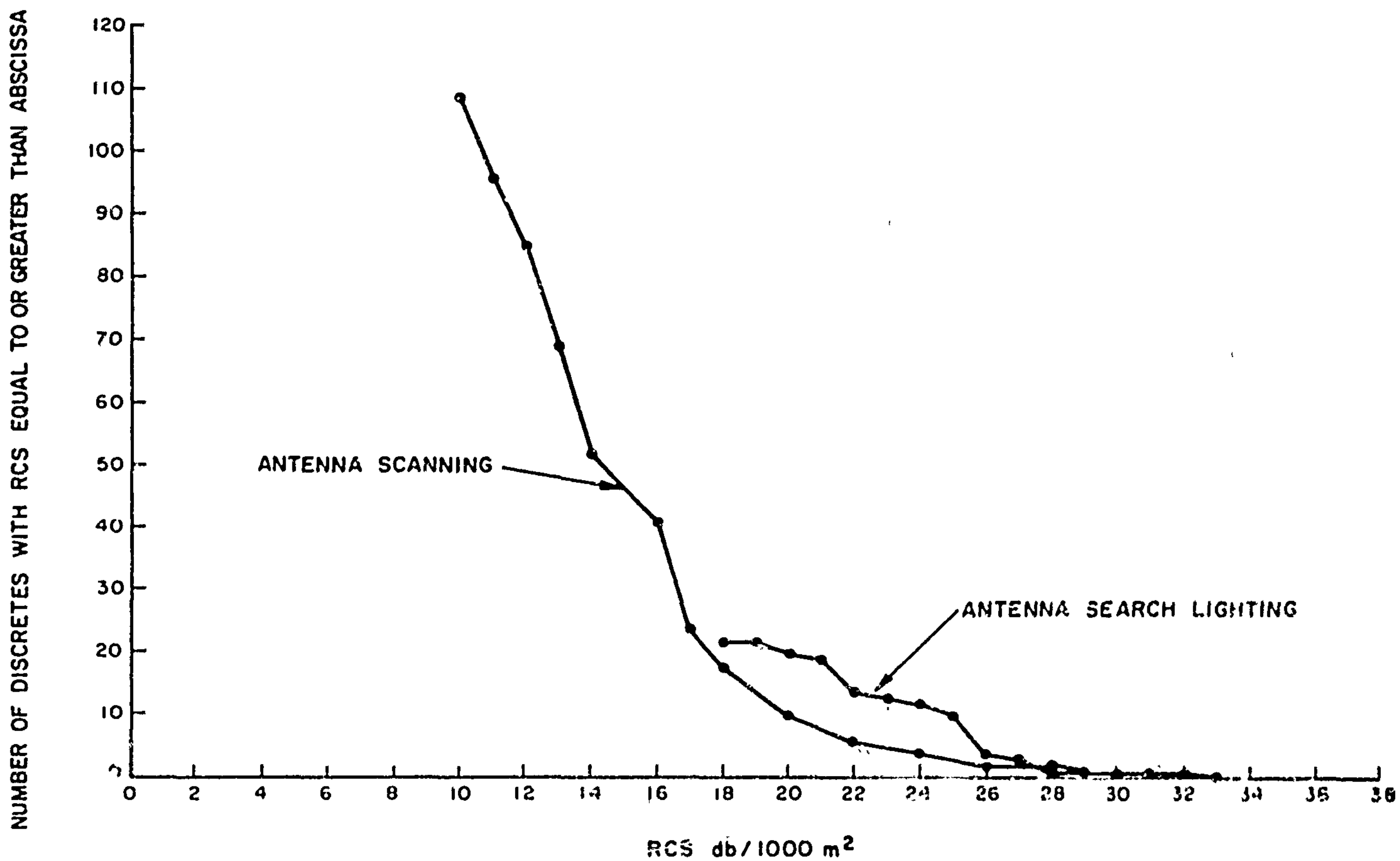


Figure 9 OBSERVED CUMULATIVE DISTRIBUTION OF DISCRETES AT SITE # 1

The largest discrete sources, located by searchlighting, were found to be in Somerville, Cambridge, Chelsea, Boston, and Brookline; the majority of the very largest were at the longest ranges. As the threshold was lowered, the target density increased toward the radar along an axis through Arlington, Somerville, and Cambridge. This area is more or less flat, though some low small hills exist, and is generally about 25 feet above MSL. From these considerations, it can be inferred that lower values of RCS are denser at higher grazing angles. This trend is better illustrated by reference to PPI photos taken at other sites. About 110 discretes of RCS greater than or equal to 10,000 m^2 were observed as can be noted from Figure 9. Note that one discrete of +32 db above 10^3 m^2 was observed. This was the first instance when a RCS above 10^6 m^2 was observed.

C. RESULTS AT SITE NO. 2

Site No. 2, Prospect Hill in Waltham, is approximately 8.5 nautical miles from the state capitol area of Boston. The true bearing to Boston is about 100 degrees from this site, and the elevation is about 480 feet above MSL.

Figures 11 through 21 show discrete detections in the range 10^5 m^2 to 10^3 m^2 in 2 db steps, within a range of 16 nautical miles. Figure 10 shows the upper end of a distribution at this site prepared from a count made by an operator.

The series of PPI photos illustrates two main features of this particular radar landscape. The largest discretes are in the commercial

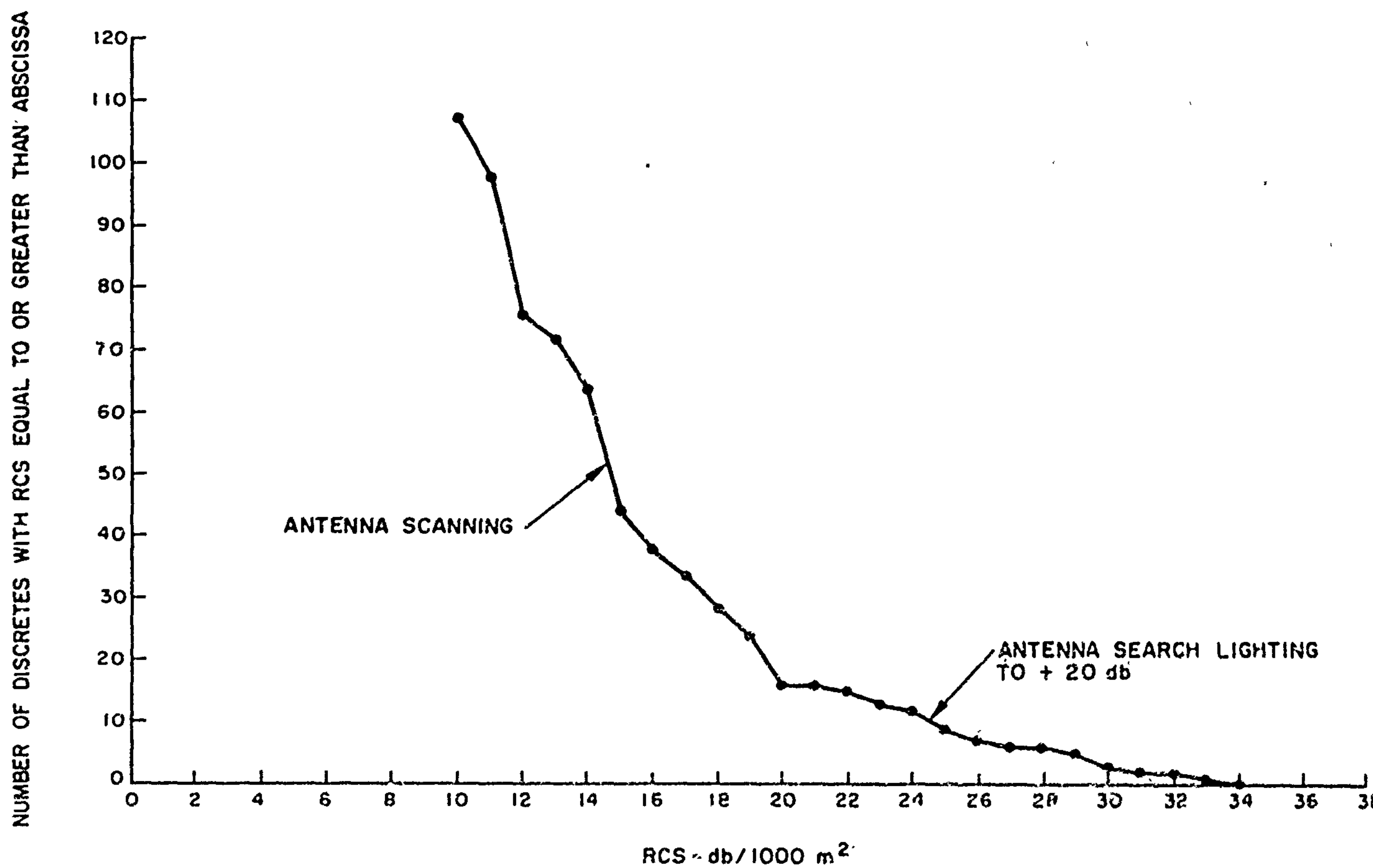


Figure 10 OBSERVED CUMULATIVE DISTRIBUTION OF DISCRETES FROM SITE # 2

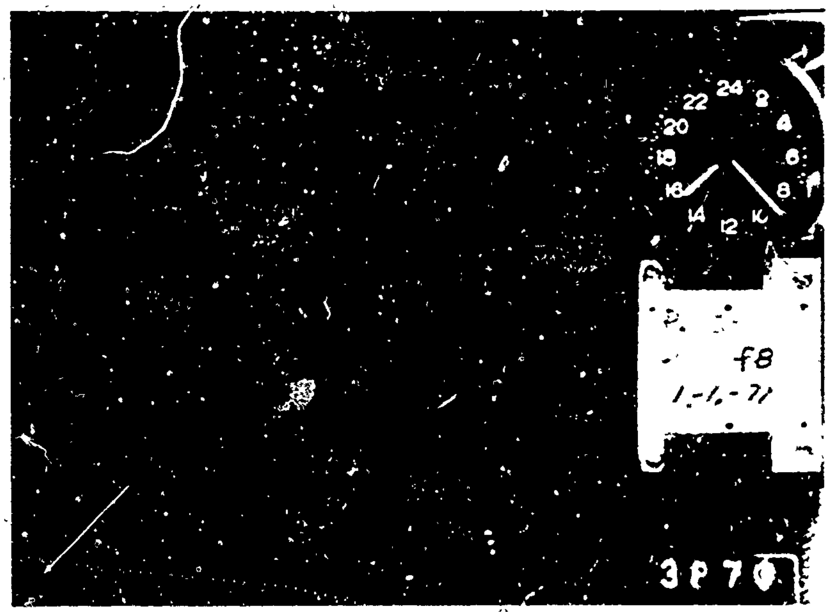


Figure 11 PPI DISPLAY OF THRESHOLDED VIDEO $\geq$ 50 db/m^2
WITHIN 16 MILES (SITE NO. 2)

Figure 12 PPI DISPLAY OF THRESHOLDED VIDEO $\geq$ 48 db/m^2
WITHIN 16 MILES (SITE NO. 2)

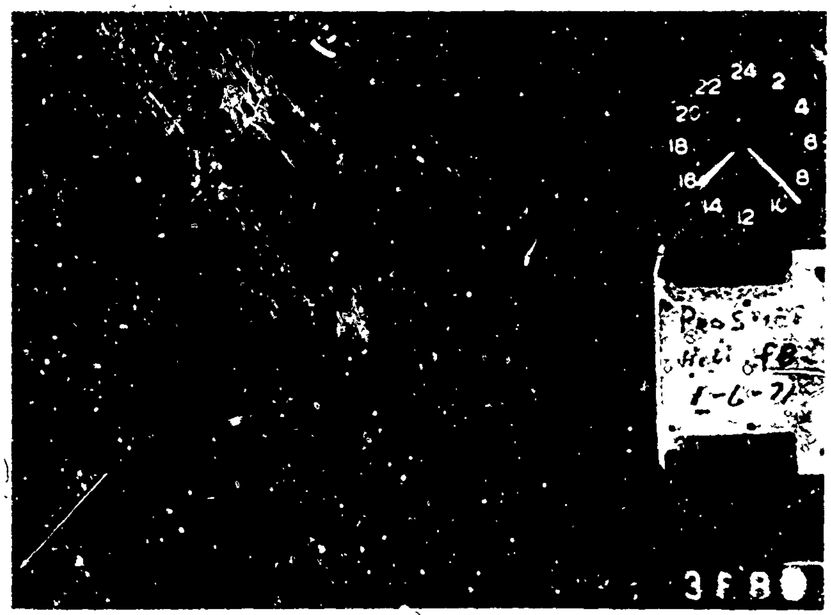


Figure 13 PPI DISPLAY OF THRESHOLDED VIDEO $\geq$ 46 db/m^2
WITHIN 16 MILES (SITE NO. 2)

Figure 14 PPI DISPLAY OF THRESHOLDED VIDEO $\geq$ 44 db/m^2
WITHIN 16 MILES (SITE NO. 2)

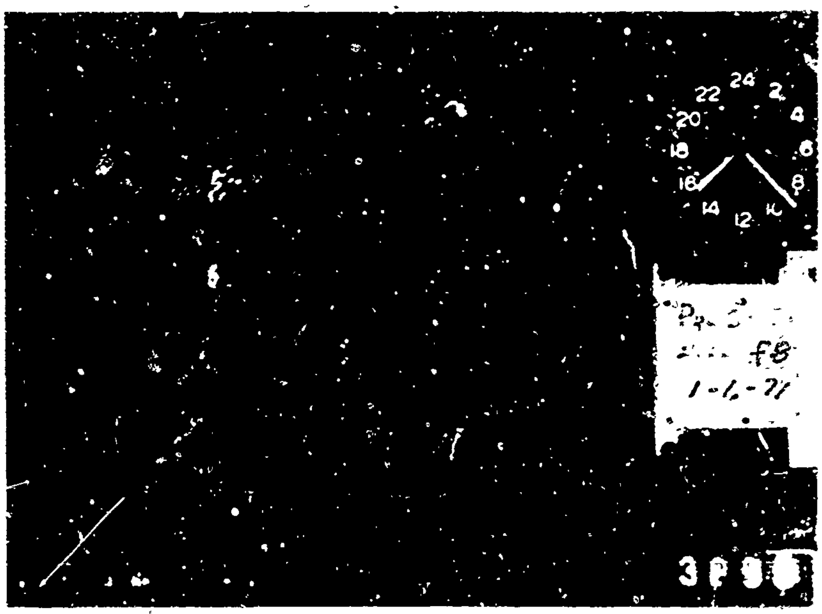


Figure 15 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 42 db/m^2 WITHIN 16 MILES (SITE NO. 2)

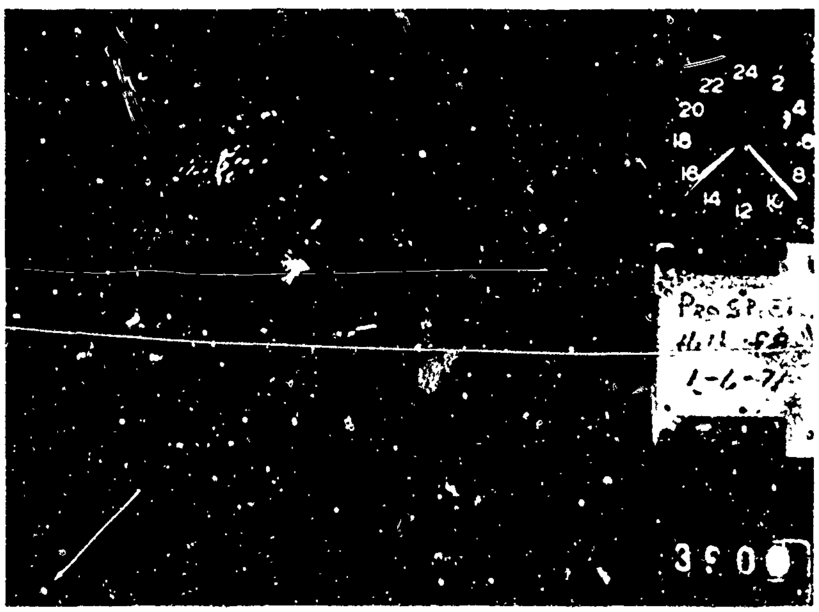


Figure 16 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 40 db/m^2 WITHIN 16 MILES (SITE NO. 2)

Figure 17 PPI DISPLAY OF THRESHOLDED VIDEO $\geq$ 38 db/m^2
WITHIN 16 MILES (SITE NO. 2)

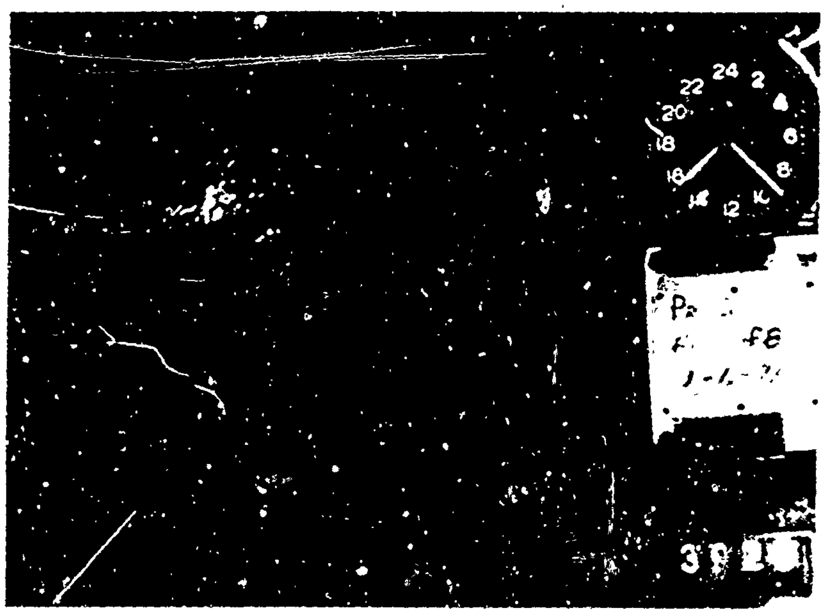


Figure 18 PPI DISPLAY OF THRESHOLDED VIDEO $\geq$ 36 db/m^2
WITHIN 16 MILES (SITE NO. 2)

Figure 19 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 34 db/m^2
WITHIN 16 MILES (SITE NO. 2)

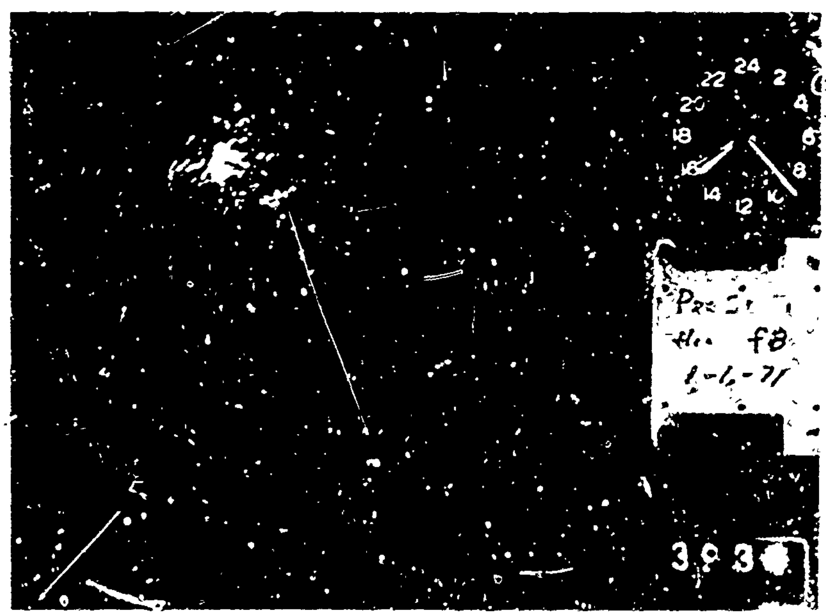


Figure 20 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 32 db/m^2
WITHIN 16 MILES (SITE NO. 2)

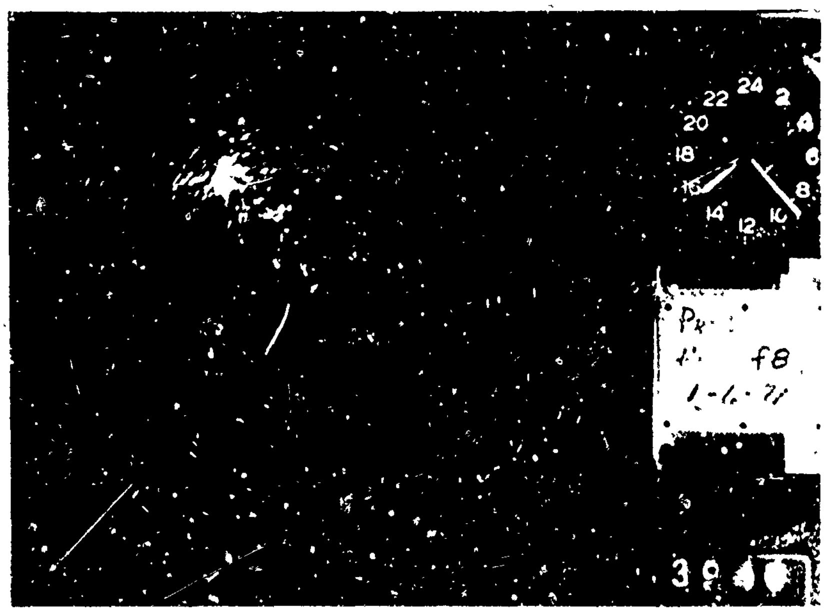


Figure 21 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 30 db/m^2
WITHIN 16 MILES (SITE NO. 2)

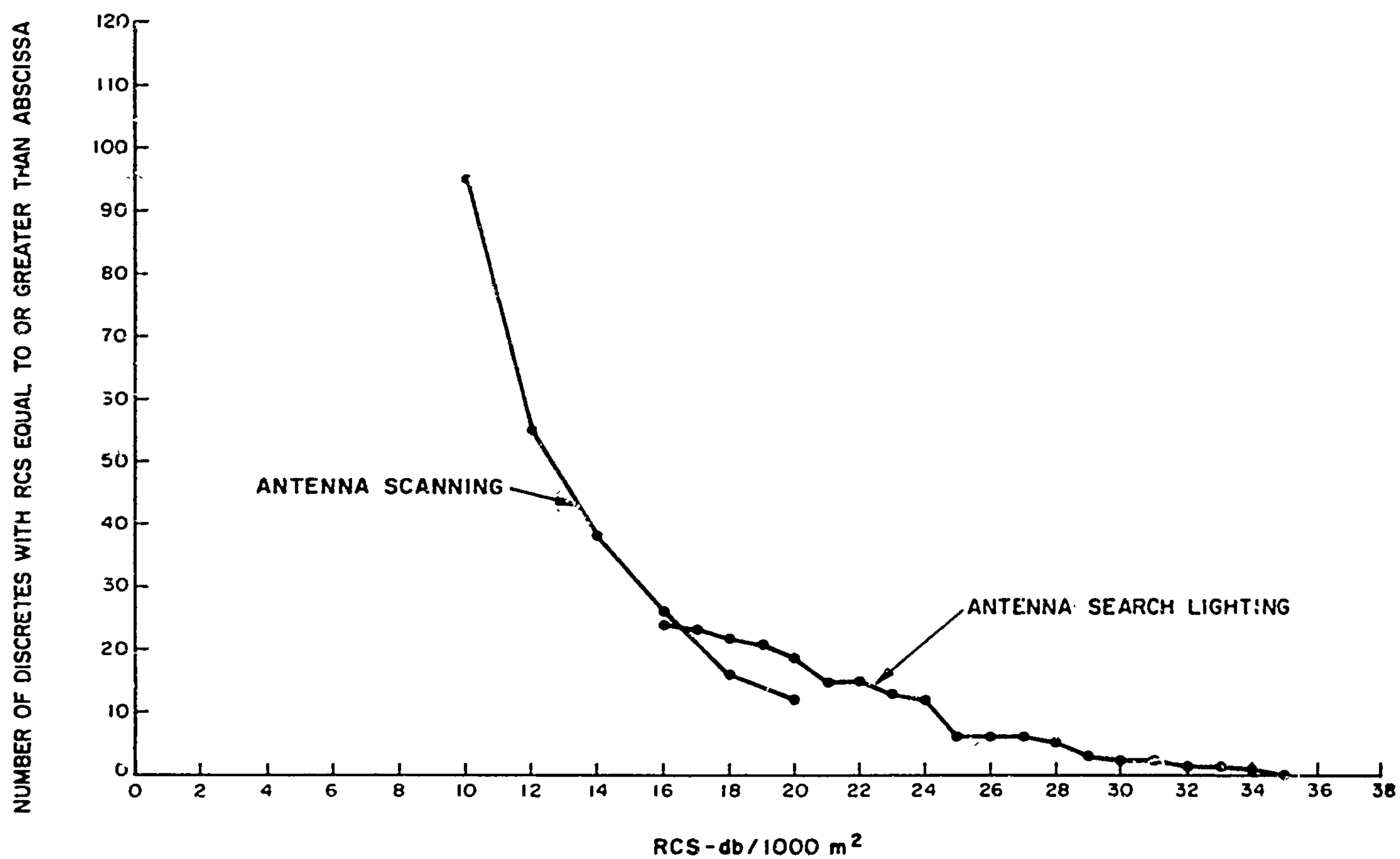


Figure 22 OBSERVED CUMULATIVE DISTRIBUTION OF DISCRETES AT SITE # 3A

and industrial district of Boston, slightly north of the "N" in "Boston" in Figure 8. As the threshold is reduced the density increases, and a corridor defined by low hills in Newton/Brookline to the south and Belmont/Arlington to the north becomes evident. As was also observed at site No. 1, the density increases radially inward toward the radar as the threshold is reduced. Since the terrain is comparatively flat and low, it is inferred that steeper grazing angles are associated with lower values of RCS. Of particular interest is the high areal-density associated with the Boston commercial district. After making allowance for the display resolution being less than the radar resolution, it is apparent that very closely spaced discretes exist. Many of the isolated returns at far ranges are water towers on hills.

D. RESULTS AT SITE NO. 3

Site No. 3 (A and B), Great Blue Hill in Milton, is approximately 10 nautical miles from the state capitol area of Boston. The true bearing to Boston is about 15 degrees from this site, and the elevation is about 635 feet above MSL. Positions 3A and 3B are separated by about 150 feet and are at the same elevation.

By referring to the two series of PPI photos for sites 3A and 3B, (Figures 23-33 & 35-45) it is apparent that in a gross sense the discrete densities are comparable for each location, and similar to results at the other two sites. Figures 22 and 34, the distributions, show about a two to one difference in density at 10^4 m^2. However, as the

Figure 23 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 50 db/m^2
WITHIN 16 MILES (SITE NO. 3A)

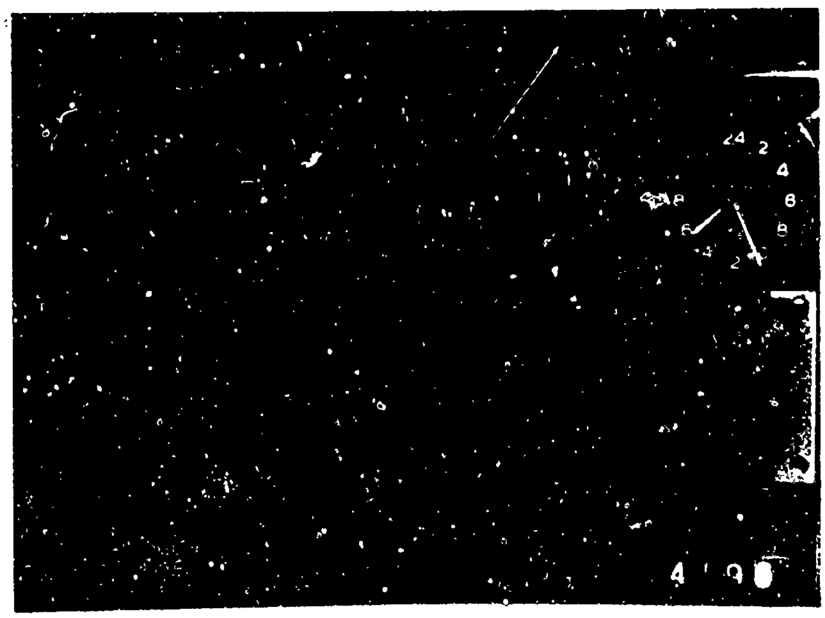


Figure 24 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 48 db/m^2
WITHIN 16 MILES (SITE NO. 3A)

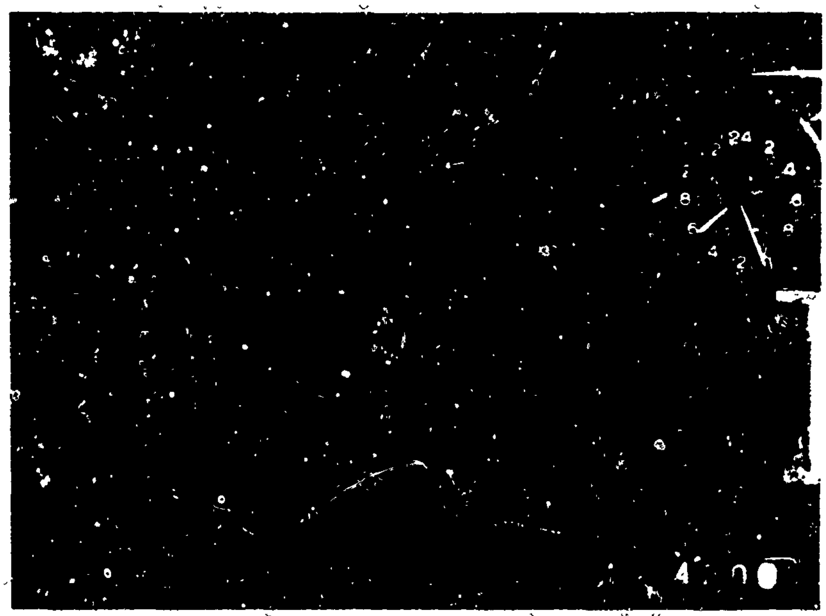


Figure 25 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 46 db/m^2
WITHIN 16 MILES (SITE NO. 3A)

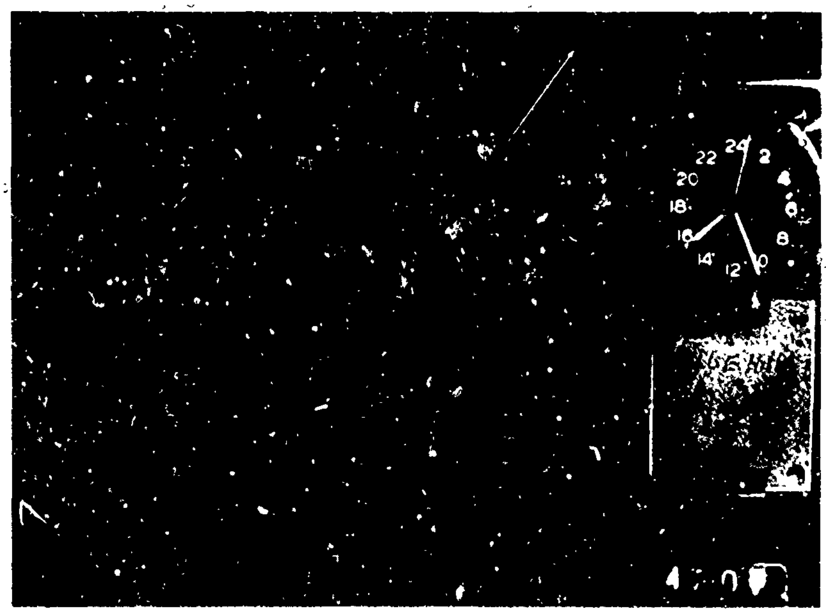


Figure 26 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 44 db/m^2
WITHIN 16 MILES (SITE NO. 3A)

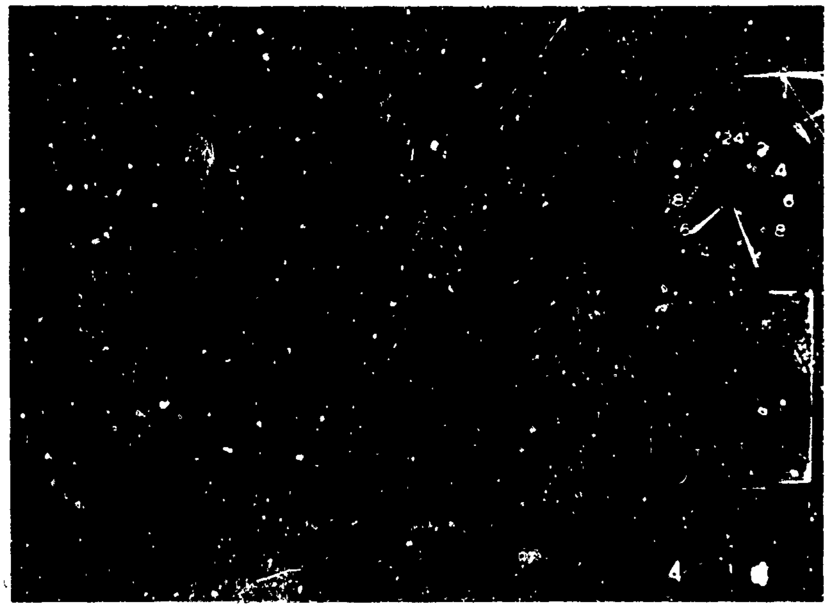


Figure 27 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 42 db/m^2 WITHIN 16 MILES (SITE NO. 3A)

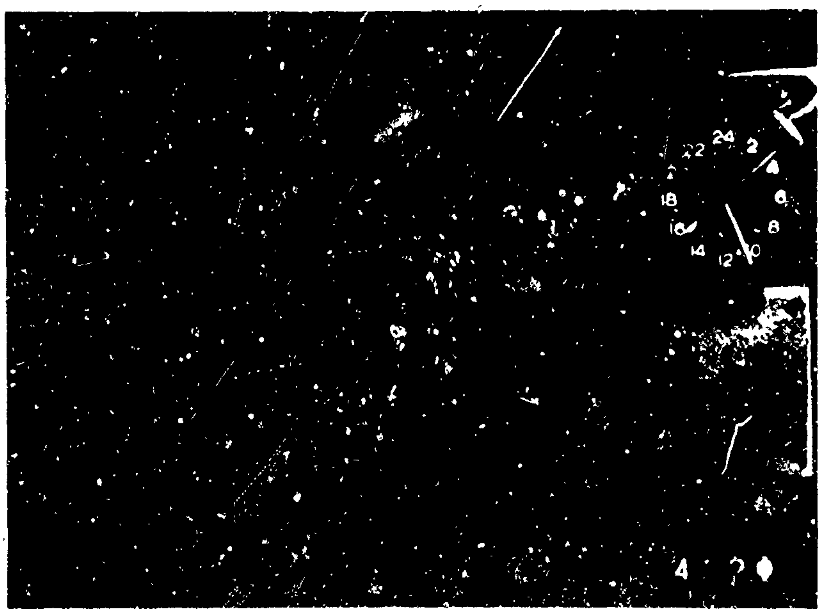


Figure 28 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 40 db/m^2 WITHIN 16 MILES (SITE NO. 3A)

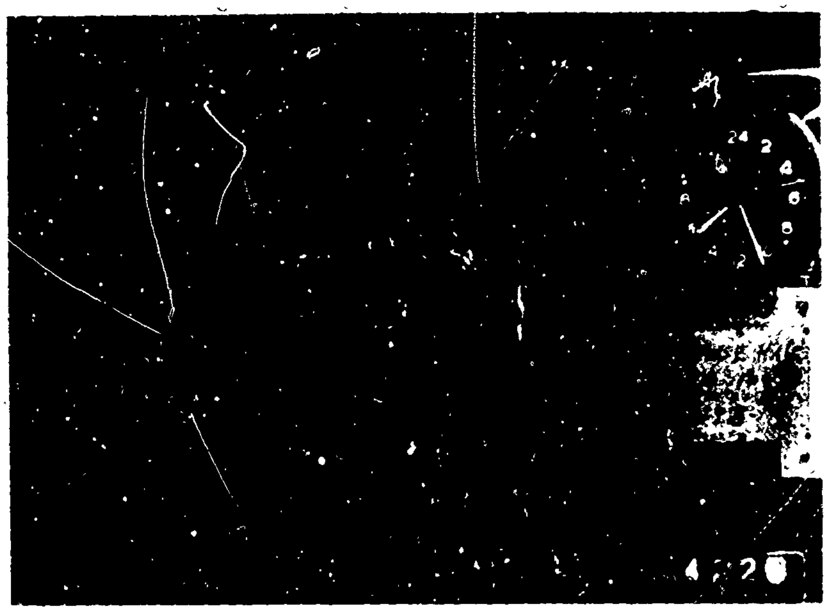


Figure 29 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 38 db/m^2
WITHIN 16 MILES (SITE NO. 3A)

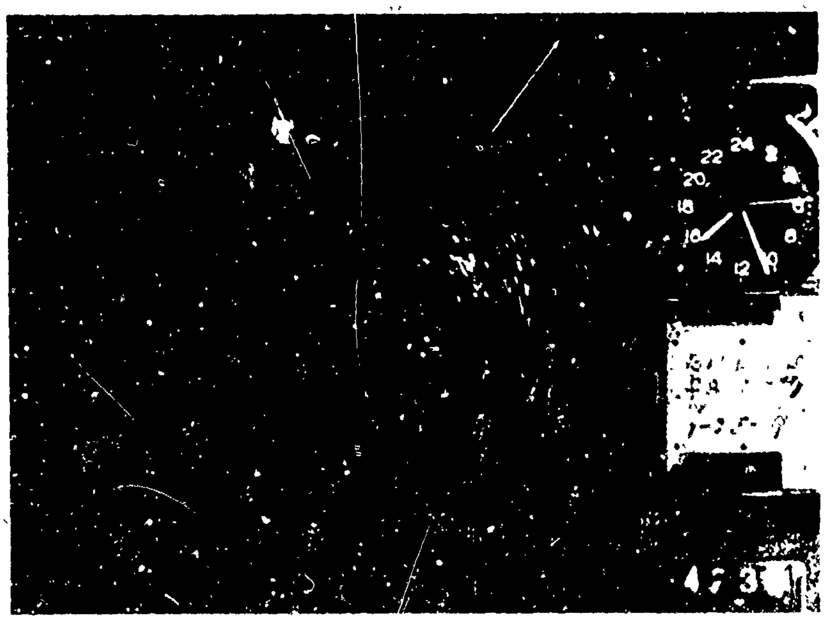


Figure 30 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 36 db/m^2
WITHIN 16 MILES (SITE NO. 3A)

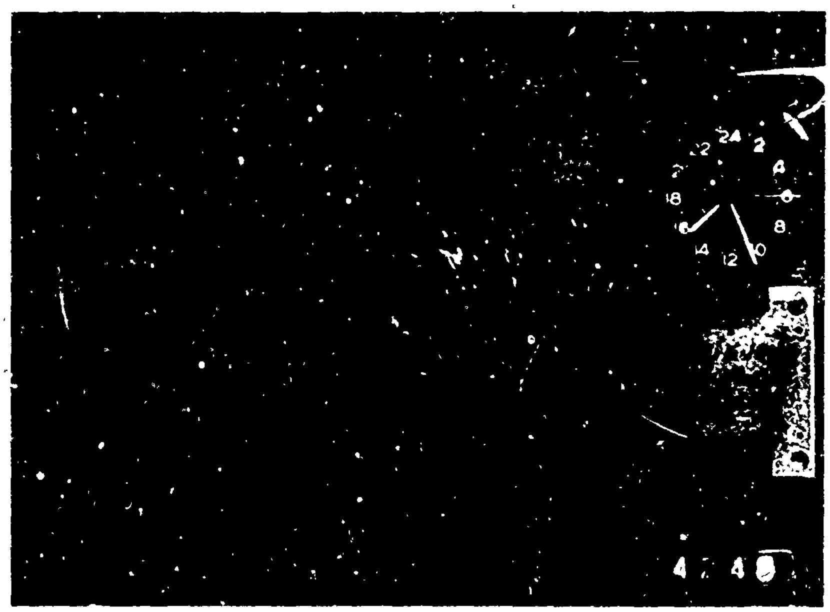


Figure 31 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 34 db/m^2 WITHIN 16 MILES (SITE NO. 3A)

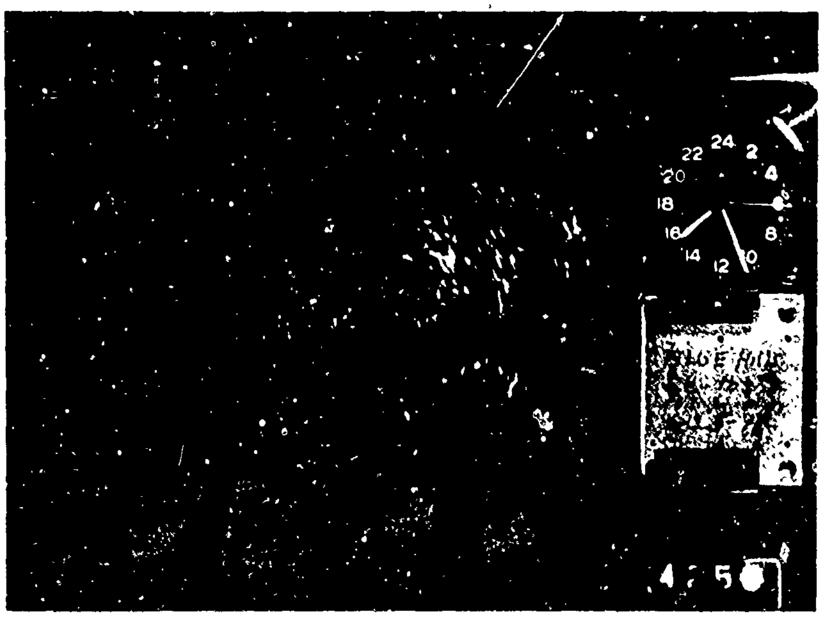


Figure 32 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 32 db/m^2 WITHIN 16 MILES (SITE NO. 3A)

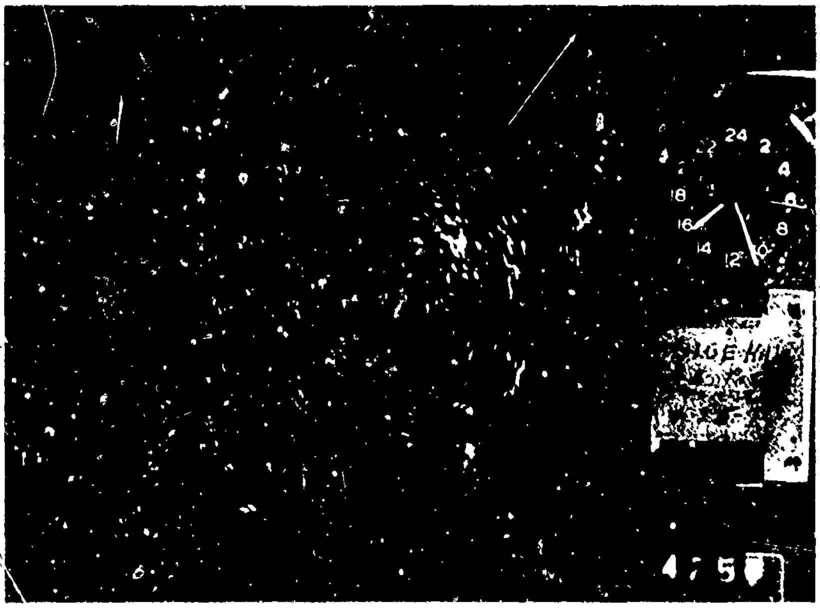


Figure 33 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 30 db/m^2
WITHIN 16 MILES (SITE NO. 3A)

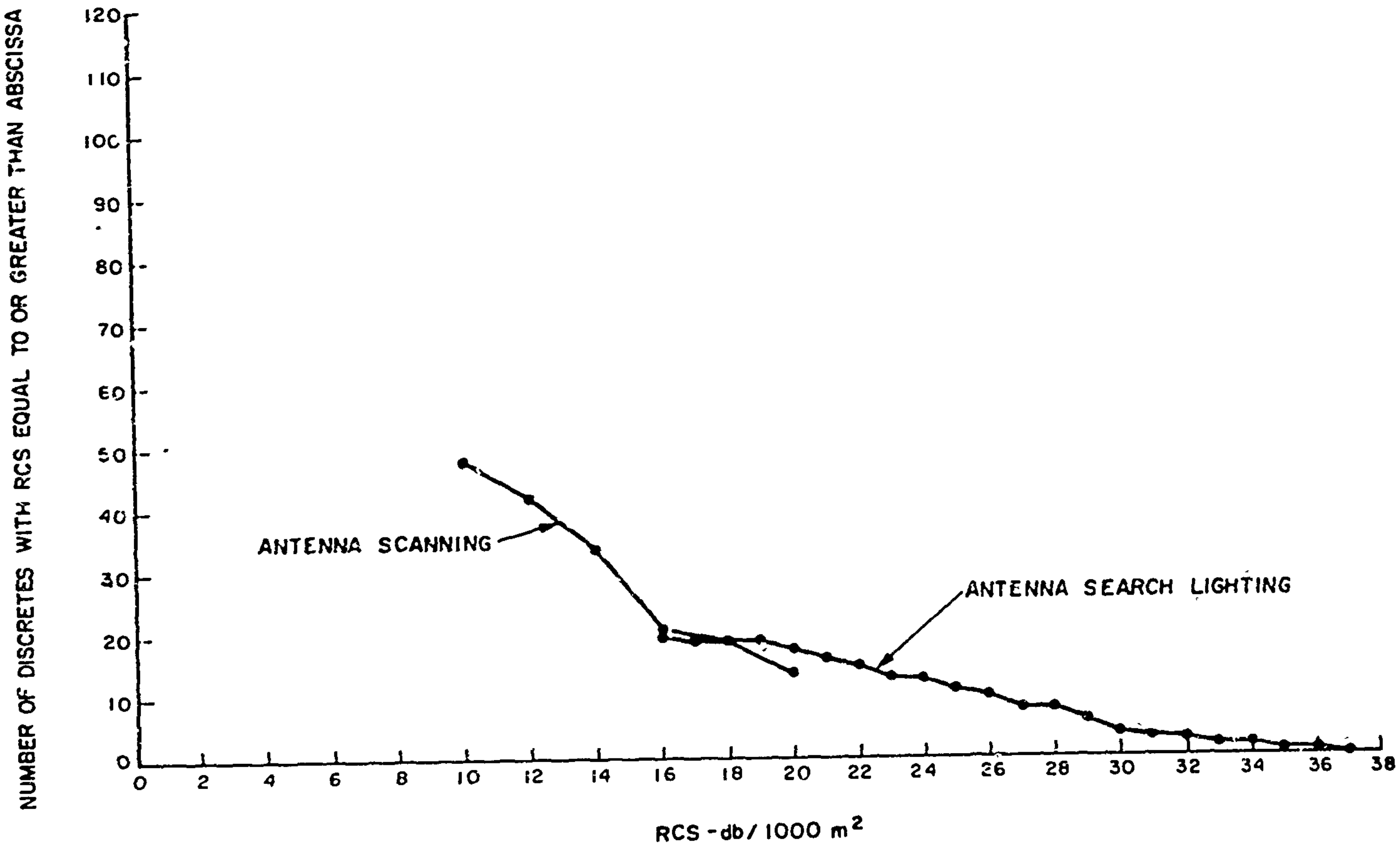


Figure 34 OBSERVED CUMULATIVE DISTRIBUTION OF DISCRETES AT SITE # 3D

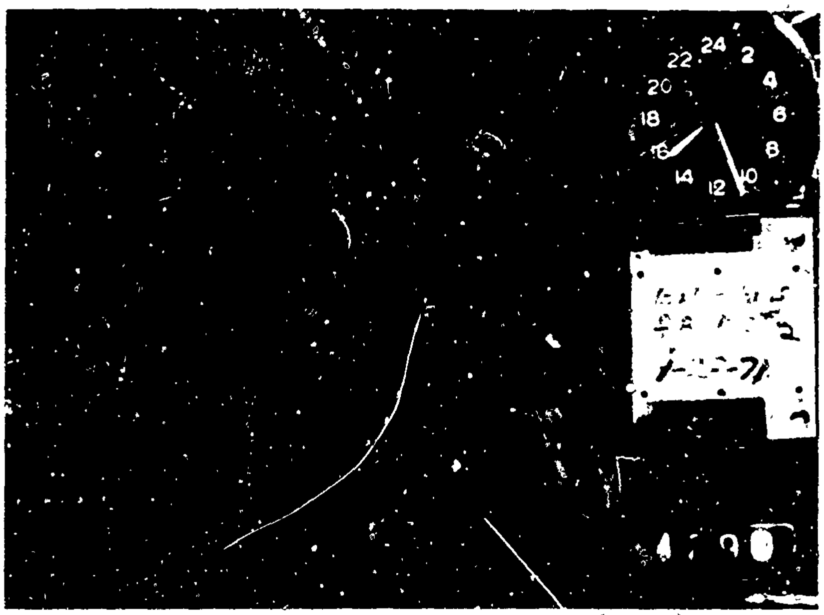


Figure 35 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 50 db/m^2
WITHIN 16 MILES (SITE NO. 3B)

Figure 36 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 48 db/m^2
WITHIN 16 MILES (SITE NO. 3B)

Figure 37 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 46 db/m^2 WITHIN 16 MILES (SITE NO. 3B)

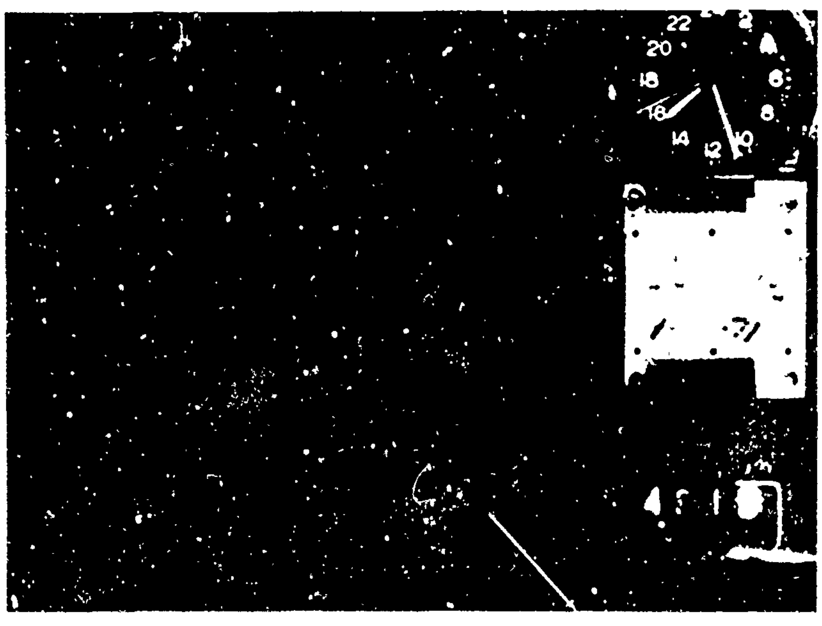


Figure 38 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 44 db/m^2 WITHIN 16 MILES (SITE NO. 3B)

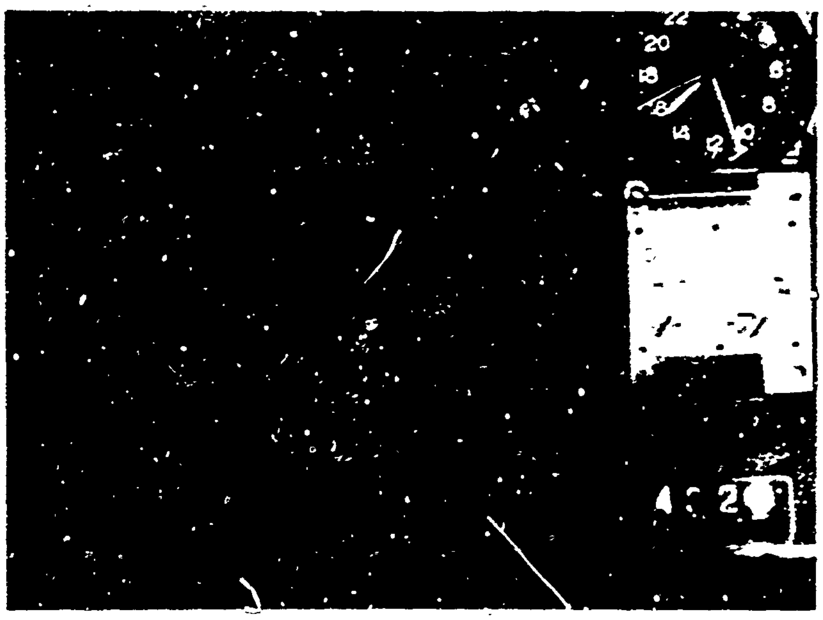


Figure 39 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 42 db/m^2
WITHIN 16 MILES (SITE NO. 3B)

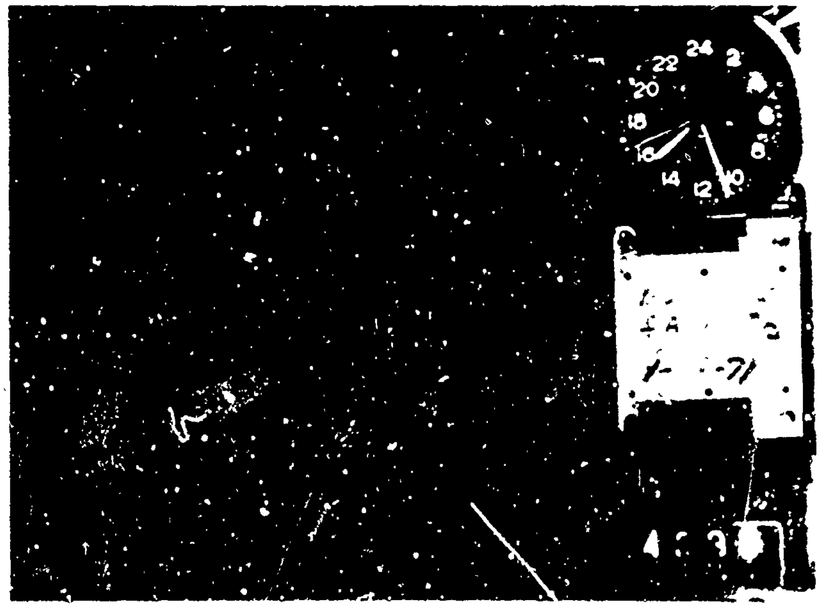


Figure 40 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 40 db/m^2
WITHIN 16 MILES (SITE NO. 3B)

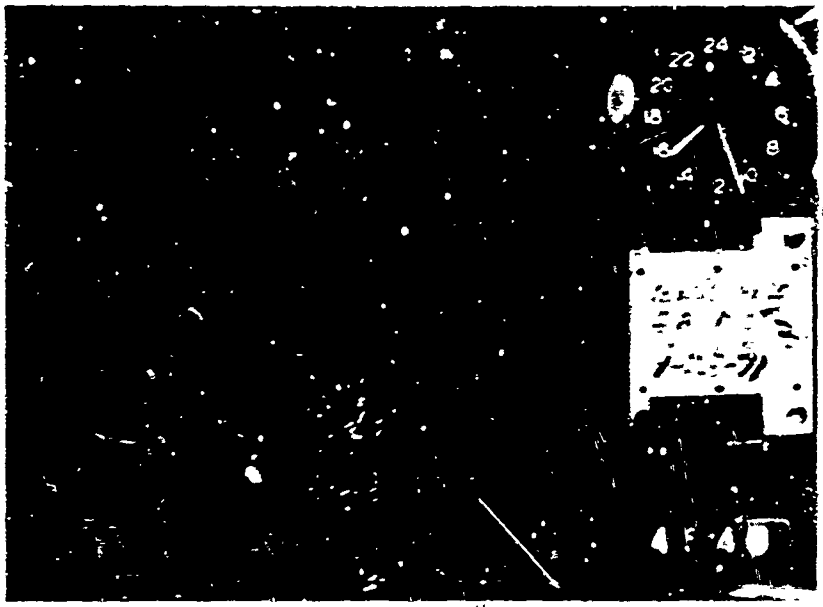


Figure 41 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 38 db/m^2 WITHIN 16 MILES (SITE NO. 3B)

Figure 42 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 36 db/m^2 WITHIN 16 MILES (SITE NO. 3B)

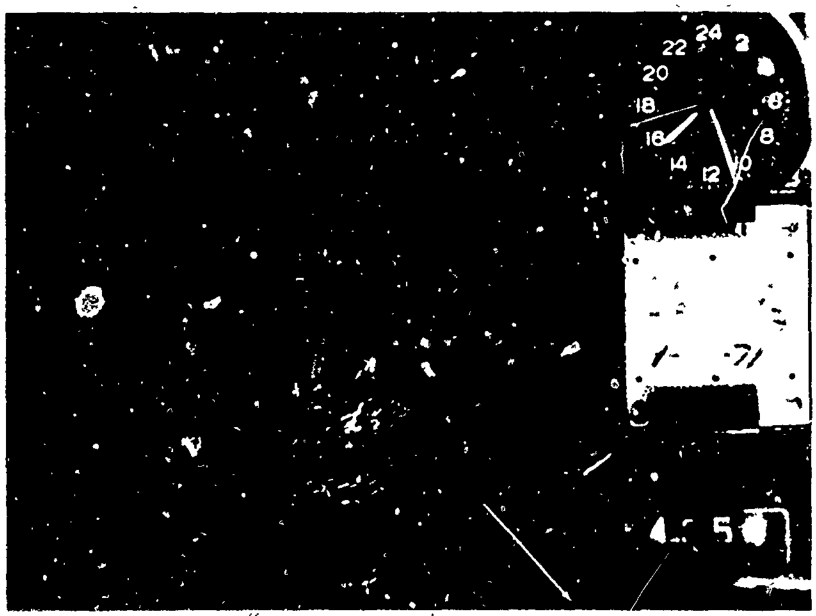


Figure 43 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 34 db/m^2
WITHIN 16 MILES (SITE NO. 3B)

Figure 44 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 32 db/m^2
WITHIN 16 MILES (SITE NO. 3B)

Figure 45 PPI DISPLAY OF THRESHOLDED VIDEO ≥ 30 db/m^2
WITHIN 16 MILES (SITE NO. 3B)

threshold is reduced below $10^4\ m^2$ the densities tends to become approximately equal. The detailed structure of the discrete return patterns from the two sites are different. This is particularly obvious when the photos of the highest RCS are compared. This demonstrates extreme azimuthal sensitivity as has been observed in other experiments.

Table II contains data on selected water towers. They were selected because of their proximity to the radar; the steepest grazing angle was desired. Of particular significance is the fact that these water towers are only somewhat over $10^3\ m^2$ but are types comparable to those observed at Boston Hill. There is about an order of magnitude decrease in RCS observed at Great Blue Hill for grazing angles of about 0.7 to 0.9 degrees. At Boston Hill the water towers were at long ranges and elevations comparable to the radar and were therefore illuminated very nearly at zero grazing angle. In searchlighting the antenna in the water tower study several close-in towers were observed below the $10^3\ m^2$ threshold.

TABLE II. DATA ON SELECTED WATER TOWERS VISIBLE FROM POSITIONS NO. 3

Target	True Bearing (degrees)	Range (n.mi.)	Elevation Difference (ft)	Grazing Angle (degrees)[1]	RCS (db/$10^3 m^2$)
1[2]	254° 30'	4.80	400	0.79	+5.5
2	339° 15'	4.10	330	0.76	+6
3	160	3.48	400	0.92	+8
4	254° 40'	3.64	500	0.78	+4
5	253° 20'	3.56	520	0.73	+2.4
6[2]	72° 20'	2.26	300	0.81	+3.5

NOTES: (1) Sine grazing angle equals elevation difference (from topographic maps) divided by slant range.

(2) Two water tanks unresolvable in azimuth (approximately one hundred feet separation.)

SECTION V

SUMMARY AND CONCLUSIONS

A large urban center has been studied at low grazing angles and the most significant results obtained are as follows:

(1) From each of four radar sites discretes greater than 10^6 m^2 have been observed. The sources of these discretes were found to be located in the commercial and industrial district of the metropolitan area.

(2) At each site, about 100 discretes greater than or equal to 10^4 m^2 were recorded. Discretes greater than 10^3 m^2 were too numerous to be accurately counted, using available equipment.

(3) A particularly hi . areal density of discretes was observed in the commercial/industrial districts. Although residential areas contain many discrete sources, a concentration of discretes was observed in the primarily commercial/industrial district.

(4) A sensitivity to grazing angle was observed. Density of discretes increased with decreasing RCS and at increasing grazing angle.

Several inferences are suggested by the results outlined above. The high density associated with the commercial/industrial district argues for a cluster type of discrete clutter model, particularly if the emphasis is to be on the largest discretes. There is then some general support for the cluster concept adopted by Carlson and Greenstein.[5] The density of the cluster seems to be related to population density or some other cultural phenomenon.

The generally similar results at the three locations on an arc centered on the state capital district may be due, at least in part, to the more or less semi-circular layout of the Boston metropolitan area. This would be consistent with the experience of radargrammetrists.[6]

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3. McCurley, E. P., McEvoy, W. J., p. 18 et seq.

4. Ibid, p. 25.

5. Carlson, R. and Greenstein, L., "A Distributed and Discrete Clutter Model for AWACS," Special Report No. 2, AWACS Radar Development Program; Illinois Institute of Technology Research Institute.

6. Levine, D., "Radargrammetry," McGraw-Hill Book Co., 1960, p. 216.