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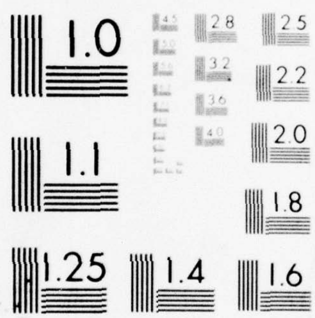

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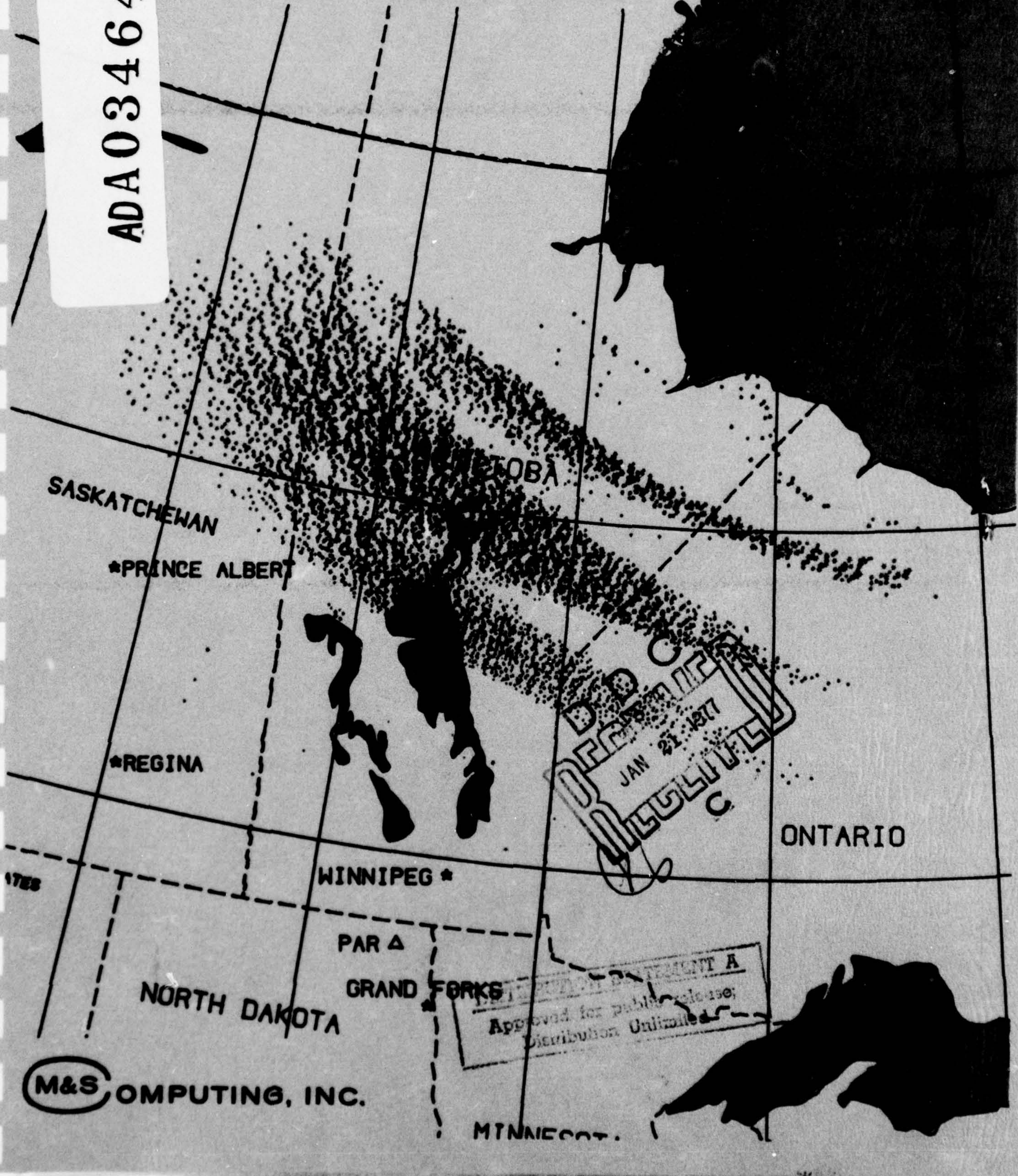
PAR AURORAL STUDY
VOLUME I



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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER Volume I	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PAR AURORAL STUDY. Volume I.		5. TYPE OF REPORT & PERIOD COVERED Interim – one of six volumes
		6. PERFORMING ORG. REPORT NUMBER 76-0013
7. AUTHOR(s) M. J. Mitchell		8. CONTRACT OR GRANT NUMBER(s) Army DASG60-74-C0026
9. PERFORMING ORGANIZATION NAME AND ADDRESS M&S Computing, Inc. P. O. Box 5183 Huntsville, AL 35805	236 p.	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Not applicable
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Ballistic Missile Defense Systems Command ATTN: BMDSC-WH, P. O. Box 1500 Huntsville, AL 35807		12. REPORT DATE 15 Mar 76
		13. NUMBER OF PAGES 231
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Same as above.		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE Not applicable

16. DISTRIBUTION STATEMENT (of this Report)

Unlimited Distribution

Vol 2, A034 503
3, A034 581
4, A034 504
5, A034 505

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Same.

18. SUPPLEMENTARY NOTES

This is one of six volumes of reports that present the aurora borealis data collected by a multi-megawatt phased array radar. The radar has excellent sensitivity and range resolution affording very precise aurora detail.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aurora borealis, radar/aurora effects, phased array radar, aurora maps, satellite track perturbation effects, off-perpendicular contours.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The report describes the data collected in connection with research of aurora borealis effects on the performance of a phased array radar. The primary objective of the study was to advance the understanding of the auroral phenomenon and of its interactions with radar. A multi-megawatt phased array radar was used to collect large quantities of high resolution auroral backscatter data with simultaneous tracking of a number of selected satellites. The report provides a detailed description of the data collection process and data reduction

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techniques in connection with Sep 75 auroral storms.

Volume I

PREFACE

This report describes the auroral borealis research effort being performed by M&S Computing, Inc. for the Army Ballistic Missile Defense Command in Huntsville, Alabama. The primary objective of the study is to advance the understanding of the auroral phenomenon, especially of its interactions with radar. The primary data gathering instrument is the Safeguard Perimeter Acquisition Radar in North Dakota. This radar has been used to collect large quantities of high resolution auroral backscatter data with the simultaneous tracking of a number of selected satellites.

The data presented here represents the initial results of the reduction of data collected on the two dates of September 17-18 and September 26-27, 1975. The report provides a detailed description of the data collection process and the data reduction techniques, as well as future auroral study efforts.

Prepared by:

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Approved by:

Dr. W. E. Salter

Report No. 76-0013

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1. INTRODUCTION

The purpose of this report is to describe the auroral experiments performed by BMDSCOM at the SAFEGUARD PAR Site in North Dakota during the fall of 1975. The objective was to gather a large quantity of high-resolution auroral data for in-depth analysis. The region of observation was very large and the data was gathered continuously from near the onset of auroral activity until it ended. In addition to the radar data tapes obtained at the PAR Site, a collection of video tapes, charts, graphs, and associated data were obtained from several outside agencies. This data includes geomagnetic and solar data, auroral radar data from Churchill, Canada, along with instrumentation and A-scope video tapes from PAR. M&S Computing is performing for BMDSCOM an initial reduction of this data including tape stripping, reformatting, and data management as well as the graphic presentation of numerous auroral backscatter maps. More advanced analysis of geomagnetic relationships, morphology, and tracking effects are also being performed. The volume and diversity of the gathered data precludes an exhaustive analysis of all its aspects. However, it will be made available to the scientific community so that additional analysis may be performed, if desired.

Section 2 describes the auroral test plan, the 1975 auroral test and the required hardware and software changes. Section 3 describes the activities and events during the two data gathering periods. Section 4 discusses the development and features of the aurora off-line data reduction and analysis software tools. This section also explains the basic data reduction process. Section 5 describes the data stripping and processing which has been performed. Included also are examples of the graphic presentations. Section 6 discusses the goals of analysis efforts being performed for BMDSCOM. This section includes a description of advanced analysis software tools being developed by M&S Computing. Section 7 outlines future auroral data gathering tasks to be performed at PAR and explains new special techniques being provided.

In this report, no attempt is made to describe the results of in-depth analysis of the data presented. The analysis is, in fact, just beginning. The main point is to describe the study, the data which has and will be collected, and the tools being used to analyze that data.

2. EVALUATION OF THE PAR AURORAL EXPERIMENTS

The aurora has been of concern to the PAR system designers and its military user since early in its development. Several factors contribute to this concern. Included are:

- the orientation of the phased array face which is pointed almost directly toward geomagnetic north,

- the UHF operating band, and

- the very high-power transmitted and the exceptional sensitivity of the receiver.

The net effect of these factors is that in the presence of even weak auroral activity, a significant amount of transmitted energy will be backscattered to the radar. For this reason, features were designed into the PAR hardware and software to minimize the effects of these echoes. It was especially desired to prevent the false reporting of offensive reentry vehicles. Later, during the PAR installation and testing phase, experiments were performed in the presence of aurora to test and optimize these protective features. The results have proven satisfactory. It was during these first auroral tests by Bell Telephone Laboratories in early 1974, that many of the auroral blocking features were temporarily disabled allowing a significant amount of auroral data to be recorded. Some of this data has been reduced and presented in both graphic form and as computer printout. However, it lacked the necessary experimental controls required for detailed scientific analysis. Moreover, some of the auroral blocking functions were still partially functional. The results of these first tests combined with the interest of the scientific community in the design of new and even more powerful long range radars prompted further auroral studies.

The PAR is particularly well-suited for auroral backscatter studies. Among its features are:

- An operating frequency in the 450 MHz band.

- Phased array steering, providing rapid wide angle scan capabilities.

- Exceptionally high-peak and average transmit powers allowing very long range coverage, well over 2000km.

- Excellent sensitivity and noise performance.

- Narrow receive beam $<1.5°$.

- o Excellent range resolution < 1.5 km coupled with very high transmit pulse energy, obtained by pulse compression.
- o Optimum face orientation to minimize distortion and steering loss in direction of maximum auroral backscatter.
- o High performance data processing and recording capabilities.
- o Capability to perform simultaneous measurements of auroral backscatter and satellite tracking.
- o Sidelobe suppression capabilities to minimize unwanted side-lobe returns.

These features undoubtedly made the PAR a potentially valuable tool for providing the data to get a new look at the aurora and to bolster and clarify the auroral data collected previously by the scientific community. It offered the capability to collect data in masses and with a resolution not possible previously.

In the spring of 1975, the requirement for performing these studies was provided in the SAFEGUARD Operational Experience Plan. This program consisted of a wide variety of experiments which would determine and provide for the documentation of a number of performance, reliability, and potential capabilities of the now fully operational SAFEGUARD System. Included in this plan was the general topic of auroral studies. M&S Computing was assigned the task of determining the goals for this study, developing the test plan, specifying special hardware and software requirements, and coordinating the implementation of all aspects of the plan. In addition to those responsibilities, M&S Computing was faced with the task of coordinating the scheduling of aurora data collection with the military user of the SAFEGUARD PAR Radar. Difficulty arose from the low reliability associated with the prediction of auroral events, a deficiency compounded by the current low levels of sunspot activity and subsequently infrequent and weak aurora.

Early in 1975, meetings were held at the Air Force Cambridge Research Laboratories in an attempt to more firmly establish realizable testing goals. A further meeting was held at the Air Force Global Weather Central at Offutt Air Force Base to determine the auroral prediction capabilities which could be provided. Also determined were the types of geomagnetic, satellite photographs, and solar data which would be available to support the radar data. As a result of this meeting, a channel of communications was opened with the USAF which would provide timely predictive data to PAR, preceding and during the data collection period. Long range predictions estimated a maximum of auroral activity near September 21, 1975. That date was chosen as the tentative time frame for the two nights of data collection which would be performed. Further tie-ins were made with Finley Air Station, a UHF radar just south of PAR, and with the Fort Churchill, Manitoba Research Range, operated by the Canadian National Research Council. These facilities provided additional capabilities for determining the approach or presence of auroral activity; a critical capability since PAR is so highly automated it lacks a plan position indicator.

By early April, 1975, the basic goals of the experiment had been established. Those goals are stated briefly below:

- Preparation of auroral echo maps to develop a more precise characterization of the structure and time variation of the aurora and to provide a better understanding of the requirements for the auroral exclusion region.
- Analysis of the tracking errors which result from signal propagation through an aurorally perturbed ionosphere.
- Analysis of the sidelobe blanking effectiveness in an auroral environment.
- Analysis of aurorally generated noise radiation.
- Correlation of radar auroral observations with forecasting and other predictive techniques.

It was determined that the radar would scan as rapidly as possible the region expected to produce auroral returns. This region is determined by the altitude of the ionospheric E layer and the location of the radar and its orientation with respect to the earth's geomagnetic field. It was decided that the best compromise between minimizing the time required to scan this region and still obtaining frequent full space observations would be provided by a sequence of nine consecutive scans up to 20° elevation followed by one scan of the entire region observable by the radar. This sequence would be initiated at the onset of auroral activity and maintained until the activity ceased. It was also determined that a number of satellite calibration spheres and Navy Transit satellites would be tracked during the auroral event. Analysis of this track data might provide valuable insight into the effects of ionospheric disturbances on tracking performance, especially in that it would be possible to spatially correlate these track data with the location of the aurora.

The development of a detailed test plan was quite involved in that many hardware and software modifications were required to collect the search and track data. It must be understood that the PAR is a military radar controlled by a tactical software process designed to detect and track only satellites and offensive reentry vehicles and to reject such interference as aurora. Software and hardware changes, even on a temporary basis, are thoroughly screened and controlled and must be exhaustively tested to assure that there is no impairment to the military capability. Implementation of these modifications is a lengthly and arduous task. After several meetings with Bell Telephone Laboratories, the SAFEGUARD prime contractor, a test requirements memorandum was prepared on May 28, 1975, stating the test philosophy and basic capabilities required as well as identifying the software and hardware modifications which would be needed. The major system changes are given in the following paragraphs.

The tactical software generates a range blanking gate which suppresses video responses from range intervals in the region where auroral backscatter is expected to occur. This gate and other constraints had to be modified to allow maximum observation of the aurora. The normal scanning raster is a complex irregular sequence designed to maximize reentry target detection. This pattern was changed to a regular non-interlacing television type raster. This facilitates off-line data reduction and maximizes time-space event correlation.

Target track initiation is normally automatic whenever a target meets certain criteria. The massive number of auroral echoes and their diverse characteristics create a high probability of attempted automatic tracking, an undesirable response in this experiment. For this reason, the radar was restricted from attempting any tracks except when manually directed. This manual control was reserved for the initiation of track on the special spheres and Transit satellites. A special search routine, normally a part of the tactical software, is used to locate special objects. By searching a small region, surrounding the desired target, it can be detected and brought in track. Software modifications were made to extend the region in which the satellites could be tracked and to keep the object in a high data rate track throughout the tracking sequence.

The PAR data processor records digitized events from the detected return signal. During search, three events are reported to the processor: the time at which the video signal exceeds the noise threshold, the amplitude of each video peak or zero slope, and the time at which the video falls below the noise blanking threshold. Each of these events is called a reply. These replies must be sent to the data processor where they normally undergo many levels of processing along with being recorded. In the presence of aurora, there are many video peaks, in fact, it has been observed that sometimes replies are generated at the maximum theoretical radar response rate. Both hardware and software techniques are built into the tactical system to prevent data overflow. The hardware limits the number of peaks which may occur between up and down threshold crossings while the software limits the total number of replies which can be generated during each search cycle. The search cycle consists of the transmitting and receiving of three pulses at three separate angles. This software and hardware limiting was modified for the auroral test creating a possibility of overloading the radar/data processor data buffer, the data processor, or the recording equipment. Overloading was alleviated by disabling one of the three beams generated each minor cycle. Disabling one beam is possible since there is a separate signal processor for each beam which permits the radar to sample three directions simultaneously. The gap created by the missing beam was closed by modifying the raster to generate a different beamstacking arrangement as shown in Figure 2-1. Since the radar functions are performed in timed sequence blocks, the number of potential radar replies was cut by one-third. In addition, all PAR software functions not needed for aurora data collection were disabled.

The PAR normally switches its operating frequency at regular periods. The range of the several frequencies employed covers a broad band. A technique was developed to constrain the radar to operate at one frequency at least 99% of the time.

The PAR receiver employs linear FM pulse compression with software selectable Doppler offset frequency generators which, through the mixers, compensate for target Doppler. Doppler compensation is impossible for unpredictable auroral measurements so modifications were made to hold the offset to zero.

The functions of the noise threshold control and the IF attenuator are dynamically controlled by the computer. Modifications were made to allow manual control of the IF attenuators and the noise threshold was set to a fixed value. Similarly, the sensitivity time control was disabled allowing full gain from minimum to maximum range.

The last modification allowed the antenna pattern of the sidelobe blanking system called a Q-Channel, to be modified by card reader input to facilitate convenient and rapid testing of the sidelobe blanking function.

Guidelines for a basic procedure for performing the test were published by M&S Computing on August 20, 1975. In response to this document, PAR Site personnel produced a detailed test procedure. One of its prime objectives was to establish the procedures for initiating data collection. That is, terminating the tactical functions of the PAR, loading the auroral software, installing the necessary hardware modifications, and setting up the special instrumentation and video recording equipment. One individual, a member of the PAR Site Engineering staff, was selected to act as Test Director. The Test Director was responsible for the entire data collection process including coordination with the military. Geomagnetic indices, auroral forecasts, radar observations, and visual observation data were to be provided via telephone or TWX to the Test Director. The Test Director used those data to decide whether to interrupt the tactical software and implement auroral data collection and later,

BEAM PACKING

ORIGINAL

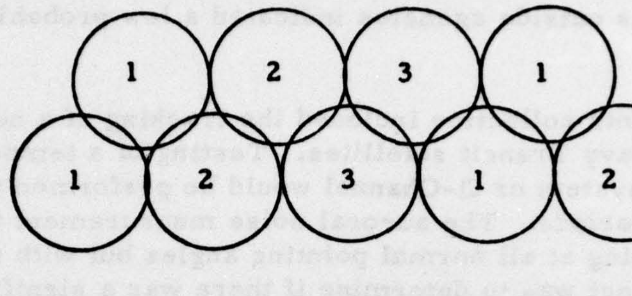

Figure 2-1a

MODIFIED

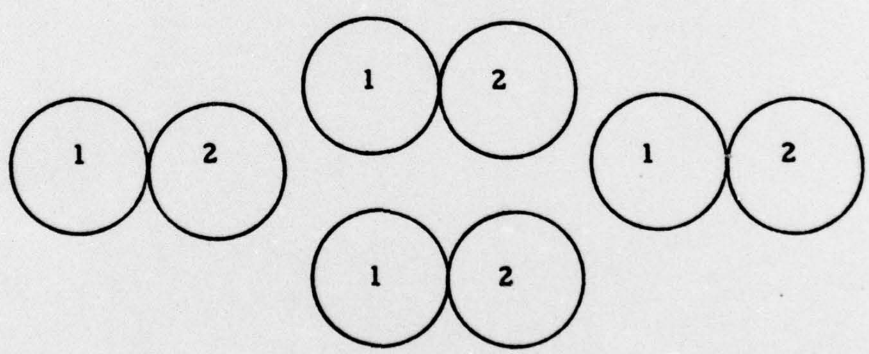

Figure 2-1b

to decide when to end the data collection. Once the data collection process was started, automatic recording was performed continuously until local indicators and instrumentation indicated that the auroral activity had subsided and that the various outside agencies indicated a low probability of a reoccurrence.

Special events collection included the tracking of a number of calibration spheres and Navy Transit satellites. Testing of a temporarily modifed sidelobe blanking system or Q-Channel would be performed twice during especially active periods. The auroral noise measurement test was planned to consist of scanning at all normal pointing angles but with the transmitters inhibited. The object was to determine if there was a significant increase in noise generated returns when the radar was pointed toward the aurorally active region.

3. GATHERING THE AURORAL DATA

Site checkout of the auroral software and hardware modifications was completed by September 13, 1975. Several runs were made in the presence of moderate aurora. The system was functioning as planned; also the data gathering procedures and alert scheme were being performed properly. The tie-ins to Global Weather Central, Fort Churchill, and the Finley Radar Station were reliable.

Global Weather Central had moved the expected auroral peak to the September 15-17, 1975, time frame. The schedule change required the that the installation of TV monitors and recording equipment be expedited, and the task was completed by the night of September 16, 1975. There were a number of video displays. One was from a wide angle low light level television camera mounted on the roof of the PAR. That camera was locked in place and oriented toward the geomagnetic north pole. A second camera monitored an oscilloscope which was set up to provide an A-scope presentation of the detected video. A third camera monitored a console Cathode Ray Tube (CRT) which displayed satellite ground tracks on a projected map of North America. A fourth camera monitored the saturation alarm counter which indicates input signal levels above the usable range of the signal processor. That signal would be used to alert the Test Director that more signal processor front-end attenuation should be added. The final camera monitored the highly accurate system clock. Using the split screen capability, this time was patched onto a section of each of the other displays, thus, providing a very accurate record of time for all recordings.

It had been observed at the PAR that generally if auroral activity was going to occur, it would first appear between 23:30 and 01:30 UT, or 18:30 and 20:30 local DST. This pattern is typical of the more common diffuse, quiet forms of auroral activity which occur in periods of low solar and geomagnetic activity. Each evening the auroral software was loaded and the A-scope was observed for the unmistakable signals telling of the presence of aurora.

3.1 First Recorded Occurrence

At midafternoon, on September 17, 1975, Global Weather Central predicted a rather low probability of aurora. At 22:00 UT, they indicated significant geomagnetic disturbances in Norway which increased the global A_p index. At 23:30, the auroral software was loaded into the PAR data processor, the A-scope presentation immediately showed the presence of weak auroral echoes. Unfortunately, it was cloudy so no visual aurora was observed. Fort Churchill, located about 1150 km from the PAR on a line almost directly between the PAR and the north geomagnetic pole, reported no visual or radar aurora. The radar at Fort Churchill, however, is capable of only 5kW peak output power.

As observation continued, peak backscattered signal strength as observed on the A-scope increased by about 11 dB by 23:54 UT, then steadily increased another 5 dB by 01:00 UT. The intensity of these peaks then began a rapid increase, gaining another 10 dB by 01:58 UT and remained strong until about 02:30. When it began to fall off, by 03:15 no echoes could be observed.

At this time, Global Weather Central reported intense auroral activity over Norway. The A_p index was up to 41. Fort Churchill reported radar auroral activity and noted their peak intensity occurred about 34 minutes before the peak at the PAR.

At the PAR, a few weak echoes were observed at 03:50. These had subsided by 04:00. At 04:30, the intensity slowly increased. At 05:05, a more rapid buildup was observed, but these levels were still far below the earlier peak. A steady buildup occurred until the second peak at about 07:00 UT. The aurora then gradually decreased in intensity with frequent secondary peaks until 10:45 UT or 5:45 local when all activity ceased. Fort Churchill was at this time, experiencing a buildup of aurora probably due to the poleward motion of the receding auroral oval.

The auroral data collection was terminated at 10:45 UT. Two major peaks had occurred, 21 different satellite tracks had been performed, and 31 reels of 2400 feet data tapes had been generated. The intensity of the auroral echoes was, however, much lower than had been hoped for. The auroral echoes failed to exceed the dynamic range of the signal processor. The aurora, which was producing 55-65 dB s/n signals during the most intense aurora, could not have produced a significant number of detectable sidelobe returns, so the sidelobe blanking test was not performed.

3.2 Second Auroral Occurrence

The same daily procedure of receiving auroral predictions and early evening radar observations was made with no avail until the night of September 26, 1975. On this evening, fairly strong (+40 dB s/n) peaks were observed as soon as the auroral process was loaded at 23:23 UT (18:23 local), recording was begun immediately. A rapid buildup in intensity was experienced and there were at least four cycles of auroral buildup and drop-off before the major peak occurred near 08:30 UT. That peak yielded a number of echoes well above 75 dB s/n. There was also a much more pronounced north/south movement of the southern edge of the reflecting region. At 01:45, surface atmospheric measurements were made to be used for lower tropospheric refraction calculations. At 02:15, the PAR was experiencing strong auroral echoes. Fort Churchill reported only mild auroral activity and mild echoes with a steady magnetic field. Clouds obscurred any visual aurora at the Canadian site. At PAR, the sky was clear enough to see stars but no visual aurora was observed at any time during the night. At 03:30 UT, Fort Churchill reported significant magnetic disturbances, especially in the Z-component. They reported that these levels are usually associated with a magnetic storm. The riometer also showed a higher absorption level. At 04:00, Churchill reported similar conditions with moderate auroral activity. PAR was observing only moderate backscatter levels. At 04:10, Global Weather Central predicted an $A_p \geq 30$ for the next three hours. At 05:00, they predicted an A_p of approximately 40 for the next six hours. The intensity of the auroral returns was steadily increasing, a broad fluctuating plateau of strong returns was experienced from 06:00 until 07:50 when the intensity began to climb rapidly. At 07:15, the Finley Radar Station reported that it was observing strong auroral returns from 130 km to their maximum range in a sector between 35° and 350° north. That meant that the southern edge of the aurora had moved behind the PAR. An intense peak was observed at PAR at about 08:30 followed by a slight drop-off with another broad peak at 08:49, followed by a steady fluctuating condition until 10:00, at which time the data collection was terminated. Thirty-one data tapes were produced. Sidelobe blanking tests were run from 07:56:32 until 08:20:05 and again from 08:22:10 until 08:32:10. The radar transmitters were inhibited from 7:48:31 until 7:49:31 in an attempt to measure auroral noise. It should be noted, however, that the noise threshold was not lowered for this test, and unless the auroral noise level was very strong, probably very few noise returns would be detected. A significant amount of satellite track data was taken the night of September 26, 1975.

4. DEVELOPMENT OF AURORAL DATA REDUCTION TOOLS

The post-processing of the data from the two data collection periods is being done at M&S Computing, Inc., in Huntsville, Alabama. Development of auroral data reduction and analysis tools began several weeks before the data was collected. In the planning stage, it was obvious that the storage and retrieval of such a mass of data, as produced by the auroral test, would require a special data management system. Tapes originating at PAR contain a large amount of redundant data and the format is not suitable for production processing. Furthermore, the data is not organized in sets, comprising single scans of the observed region providing this reorganization was one of the prime functions in the initial data reduction. Another requirement was to provide a technique so that the stripping and re-reformatting operation could be made in spite of occasional parity errors on the original tapes.

The auroral post-processing functions can be divided into three major blocks: stripping of the original data tapes, the mathematical processing functions, and the graphics display processor. A block diagram of these functions is shown in Figure 4-1.

4.1 Tape Stripping Operation

The upper section of Figure 4-1 illustrates the overall functions of this program. Auroral tapes from PAR are read, track data is separated from search data, redundant data is eliminated, and tape errors are corrected. Search data is organized into scans. The stripping program numbers these scans, generates scan characterization data by recording the start and end times, the number of replies in the scan, and the peak and the mean intensity. The reformatted search data is then stored on a second magnetic tape. The stripping program then stores the scan characterization data on a magnetic disk. Also recorded are reel identification number and logical record number of the tape on which the reformatted search data was stored. Figure 4-2 shows a sample printout of the data in the search catalog. The catalog also contains a code indicating that errors may have been present on the original PAR tapes.

Satellite track stripping and cataloging are accomplished in a similar manner. The reformatted track data is stored on a separate set of tapes than the search data. An example of the track catalog is shown in Figure 4-3.

4.2 Data Retrieval

Data retrieval is accomplished in the following manner. When the user has determined the scan(s) or track(s) to be processed, the scan (track) number is input through the desired mathematical preprocessor which accesses

OVERALL AURORAL DATA REDUCTION PROCESS

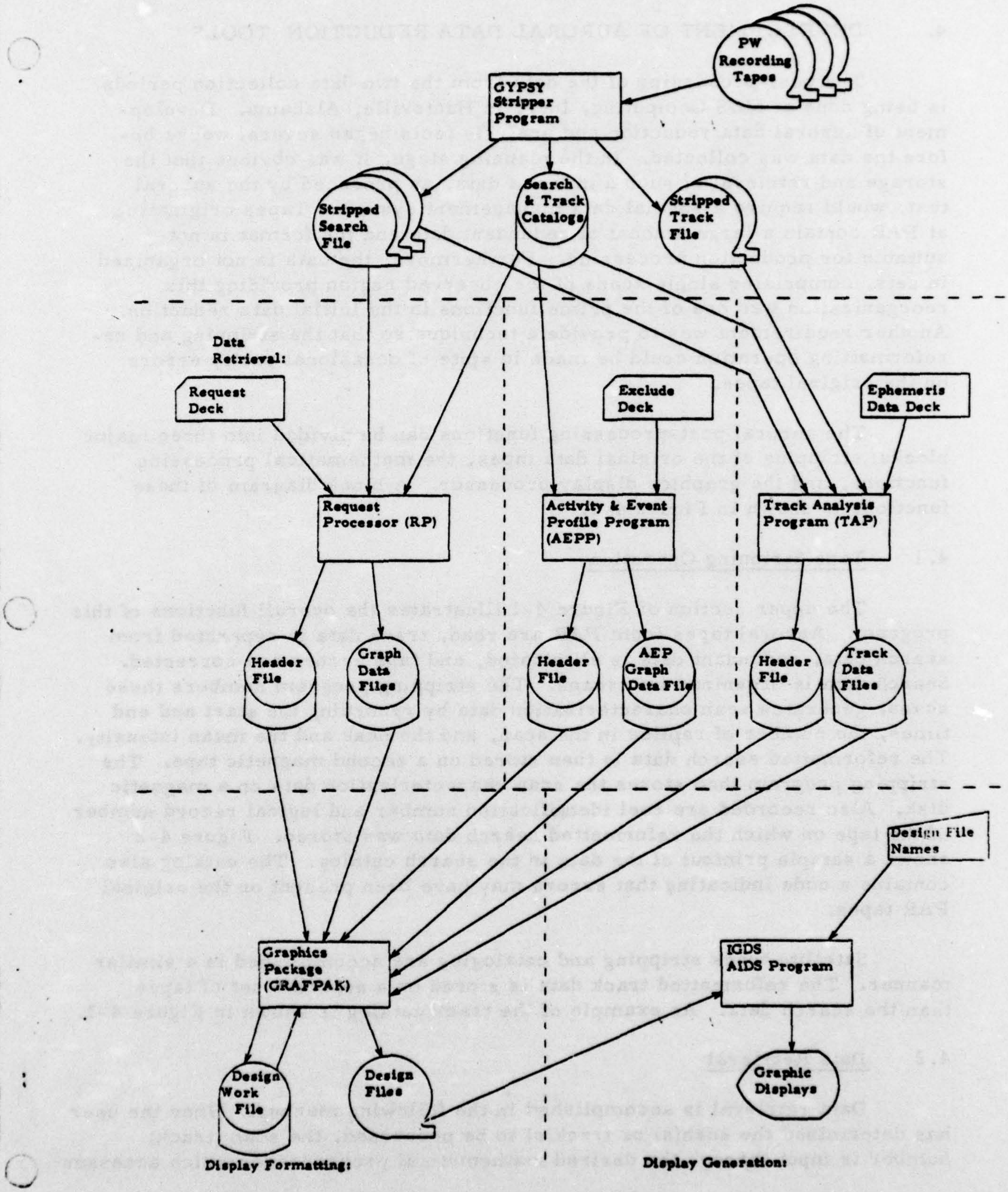

Figure 4-1

SEARCH CATALOG DIRECTORY PAGE NO. 1

SCAN NO	START TIME	NO RETURNS	PEAK AMPLITUDE	MEAN AMPLITUDE	RECORD NO	REEL ID	FLAG WORD
1	260/23/43/24.00	5280.	170	89.39	8	SFG001	0
2	260/23/43/42.00	5176.	187	89.84	58	SFG001	0
3	260/23/44/ 2.00	5177.	243	89.42	108	SFG001	0
4	260/23/44/22.00	5094.	158	89.42	149	SFG001	0
5	260/23/44/40.00	5581.	162	90.14	192	SFG001	0
6	260/23/45/ 0.00	5268.	200	89.87	244	SFG001	0
7	260/23/45/20.00	5024.	240	88.31	296	SFG001	0
8	260/23/45/38.00	5822.	168	88.17	341	SFG001	0
9	260/23/45/58.00	4400.	173	87.53	388	SFG001	0
10	260/23/46/18.00	4517.	196	84.95	428	SFG001	1
11	260/23/47/ 6.00	3363.	214	87.22	520	SFG001	0
12	260/23/47/20.00	3935.	199	87.82	556	SFG001	0
13	260/23/47/40.00	3527.	186	89.50	594	SFG001	0
14	260/23/47/58.00	4013.	167	91.32	628	SFG001	0
15	260/23/48/18.00	4283.	152	91.00	668	SFG001	0
16	260/23/48/38.00	4964.	158	89.72	708	SFG001	0
17	260/23/48/56.00	4863.	152	90.72	752	SFG001	0
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19	260/23/49/36.00	4661.	152	91.83	830	SFG001	0
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23	260/23/51/18.00	4181.	147	90.23	1022	SFG001	0
24	260/23/51/36.00	3770.	152	91.56	1060	SFG001	0
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33	260/23/54/54.00	4860.	166	91.65	1433	SFG001	0
34	260/23/55/14.00	4728.	178	92.40	1478	SFG001	0
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37	260/23/56/12.00	5234.	156	93.14	1601	SFG001	0
38	260/23/56/32.00	6034.	162	92.04	1644	SFG001	0
39	260/23/56/52.00	5859.	157	93.60	1694	SFG001	0
40	260/23/57/16.00	5994.	202	91.43	1738	SFG001	1
41	260/23/57/54.00	4450.	152	93.13	1817	SFG001	0
42	260/23/58/14.00	4431.	156	93.13	1854	SFG001	0
43	260/23/58/32.00	4050.	162	92.73	1894	SFG001	0
44	260/23/58/52.00	3910.	161	92.95	1934	SFG001	0
45	260/23/59/12.00	4467.	172	94.76	1972	SFG001	0
46	260/23/59/30.00	4635.	156	94.79	2009	SFG001	0
47	260/23/59/50.00	4985.	172	93.28	2047	SFG001	0
48	261/ 0/ 0/10.00	5738.	165	94.63	2087	SFG001	0
49	261/ 0/ 0/28.00	4539.	156	94.56	2129	SFG001	0
50	261/ 0/ 0/48.00	4805.	154	88.89	2170	SFG001	1

Figure 4-2

TRACK CATALOG DIRECTORY PAGE NO. 1

TRACK NO.	CLUSTER NUMBER	START TIME	END TIME	REEL ID	PR NUMBER	SCAN NUMBER	TRACK TYPE
1	0	261/ 0/ 0/48.92	261/ 0/ 6/ 4.33	SFG040	46	49	1000
2	1	261/ 0/ 0/49.70	261/ 0/ 7/34.73	SFG040	57	50	7000
3	2	261/ 0/20/ 3.19	261/ 0/20/18.73	SFG040	6223	100	1000
4	3	261/ 0/20/ 4.07	261/ 0/25/57.78	SFG040	6235	100	7000
5	5	261/ 0/20/ 4.07	261/ 0/25/57.78	SFG040	6239	100	7000
6	4	261/ 0/20/39.21	261/ 0/25/45.35	SFG040	7776	101	3000
7	0	261/ 1/28/45.55	261/ 1/29/ 1.09	SFG040	17234	214	1000
8	1	261/ 1/28/46.43	261/ 1/34/14.48	SFG040	17246	214	7000
9	3	261/ 1/28/46.43	261/ 1/34/14.48	SFG040	17250	214	7000
10	2	261/ 1/29/21.57	261/ 1/34/12.71	SFG040	18788	215	3000
11	6	261/ 2/ 9/16.87	261/ 2/ 9/28.51	SFG041	42	1414	1000
12	8	261/ 2/ 9/17.74	261/ 2/11/51.32	SFG041	55	1414	7000
13	9	261/ 2/ 9/17.74	261/ 2/11/51.31	SFG041	58	1414	7000
14	7	261/ 2/ 9/52.89	261/ 2/11/45.10	SFG041	1596	1415	3000
15	10	261/ 2/56/20.96	261/ 3/ 1/36.47	SFG041	5234	275	1000
16	11	261/ 2/56/21.84	261/ 2/56/21.84	SFG041	5246	275	7000
17	13	261/ 2/56/21.84	261/ 2/56/21.84	SFG041	5250	275	7000
18	12	261/ 2/56/56.99	261/ 3/ 1/ 5.78	SFG041	6788	275	3000
19	14	261/ 3/ 5/52.28	261/ 3/ 6/ 7.82	SFG041	15779	289	1000
20	15	261/ 3/ 5/53.16	261/ 3/11/16.08	SFG041	15791	289	7000
21	17	261/ 3/ 5/53.16	261/ 3/11/16.08	SFG041	15795	289	7000
22	16	261/ 3/ 6/28.30	261/ 3/11/ 4.43	SFG041	17304	291	3000
23	22	261/ 4/26/ 7.14	261/ 4/30/37.65	SFG042	45	476	1000
24	23	261/ 4/26/ 8.02	261/ 4/26/ 8.02	SFG042	57	476	7000
25	25	261/ 4/26/ 8.02	261/ 4/26/ 8.02	SFG042	61	476	7000
26	24	261/ 4/26/43.16	261/ 4/30/ 3.60	SFG042	1602	478	3000
27	26	261/ 4/35/19.90	261/ 4/35/35.44	SFG042	9076	500	1000
28	27	261/ 4/35/20.78	261/ 4/41/ 9.36	SFG042	9089	500	7000
29	29	261/ 4/35/20.78	261/ 4/41/ 9.36	SFG042	9093	500	7000
30	28	261/ 4/35/55.92	261/ 4/41/ 2.06	SFG042	10630	502	3000
31	30	261/ 4/44/ 5.92	261/ 4/48/36.42	SFG042	20149	523	1000
32	31	261/ 4/44/ 6.79	261/ 4/48/48.66	SFG042	20161	523	7000
33	33	261/ 4/44/ 6.79	261/ 4/48/48.66	SFG042	20165	523	7000
34	32	261/ 4/44/41.94	261/ 4/48/16.59	SFG042	21704	524	3000
35	34	261/ 4/53/58.05	261/ 4/54/13.60	SFG045	44	548	1000
36	36	261/ 4/53/58.93	261/ 4/58/10.01	SFG045	57	548	7000
37	37	261/ 4/53/58.93	261/ 4/58/10.01	SFG045	60	548	7000
38	35	261/ 4/54/34.08	261/ 4/58/10.21	SFG045	1596	549	3000
39	38	261/ 5/49/ 4.15	261/ 5/52/49.56	SFG045	8193	701	1000
40	40	261/ 5/49/ 5.03	261/ 5/49/ 5.03	SFG045	8206	701	7000
41	41	261/ 5/49/ 5.03	261/ 5/49/ 5.03	SFG045	8209	701	7000
42	39	261/ 5/49/40.17	261/ 5/52/16.10	SFG045	9751	703	3000
43	42	261/ 6/ 7/51.88	261/ 6/ 9/37.18	SFG045	15731	750	1000
44	44	261/ 6/ 7/52.76	261/ 6/ 9/50.40	SFG045	15744	750	7000
45	45	261/ 6/ 7/52.76	261/ 6/ 9/50.40	SFG045	15747	750	7000
46	43	261/ 6/ 8/27.90	261/ 6/ 9/22.47	SFG045	17287	751	3000
47	46	261/ 6/18/ 0.40	261/ 6/18/15.94	SFG045	20036	778	1000
48	48	261/ 6/18/ 1.28	261/ 6/18/ 1.28	SFG045	20049	778	7000
49	49	261/ 6/18/ 1.28	261/ 6/18/ 1.28	SFG045	20052	778	7000
50	0	0/ 0/ 0/ 0.00	0/ 0/ 0/ 0.00		0	0	0

Figure 4-3

the search (track) catalog. The preprocessor determines from the catalog the basic information concerning the storage of the pertinent data. The program then requests the computer operator to mount the proper tape reels. The desired data is then transferred from the tape to a disk drive for access by the computer.

4.3 Graphics Processing

Graphics presentation was used whenever possible as a means to output the results of the data reduction process. This technique was chosen because of the immediate clarity and insight which may be realized upon examination of these graphical forms. Graphical data also is self-documenting which is a real advantage when the data is to be distributed.

One prime factor in the choice of this media was the existence of a sophisticated Interactive Graphics Design System (IGDS) at M&S Computing. The extensive capabilities of IGDS greatly simplified the task of providing auroral data in a sophisticated graphical form.

The IGDS, which is shown in Figure 4-4, allows the operator to communicate with the system by simple manual selections of commands on a menu. Selection of these commands initiates the execution of complex programs but eliminates the need for time-consuming card input. The terminal keyboard is used when completely new data is to be processed.

Key to the operation of the system are the 19" storage Cathode Ray Tubes (CRT's). These modified Tektronix 4014 graphics terminals have an exceptional number of built-in capabilities and can be controlled to produce complex plots at a very high speed. Dual screens are employed so that different plots can be compared easily. Data can be quickly exchanged between the two screens. Permanent copies can be made rapidly using the hard copy unit. If larger, multicolored or even higher quality copies are required, output can be directed to the high-speed CalComp plotter.

IGDS is an exceptional analysis tool in that it allows the displays to be instantly blown up or reduced to any scale. Another important feature is that the system provides 32 overlay levels on each plot. Any combination of these overlay levels can be observed at one time. This capability is used to generate the various altitude and azimuth slices which will be described later.

The IGDS Data Management System will automatically store and catalog all plots on mass storage devices so that any item of processed auroral data is available for near instant recall.

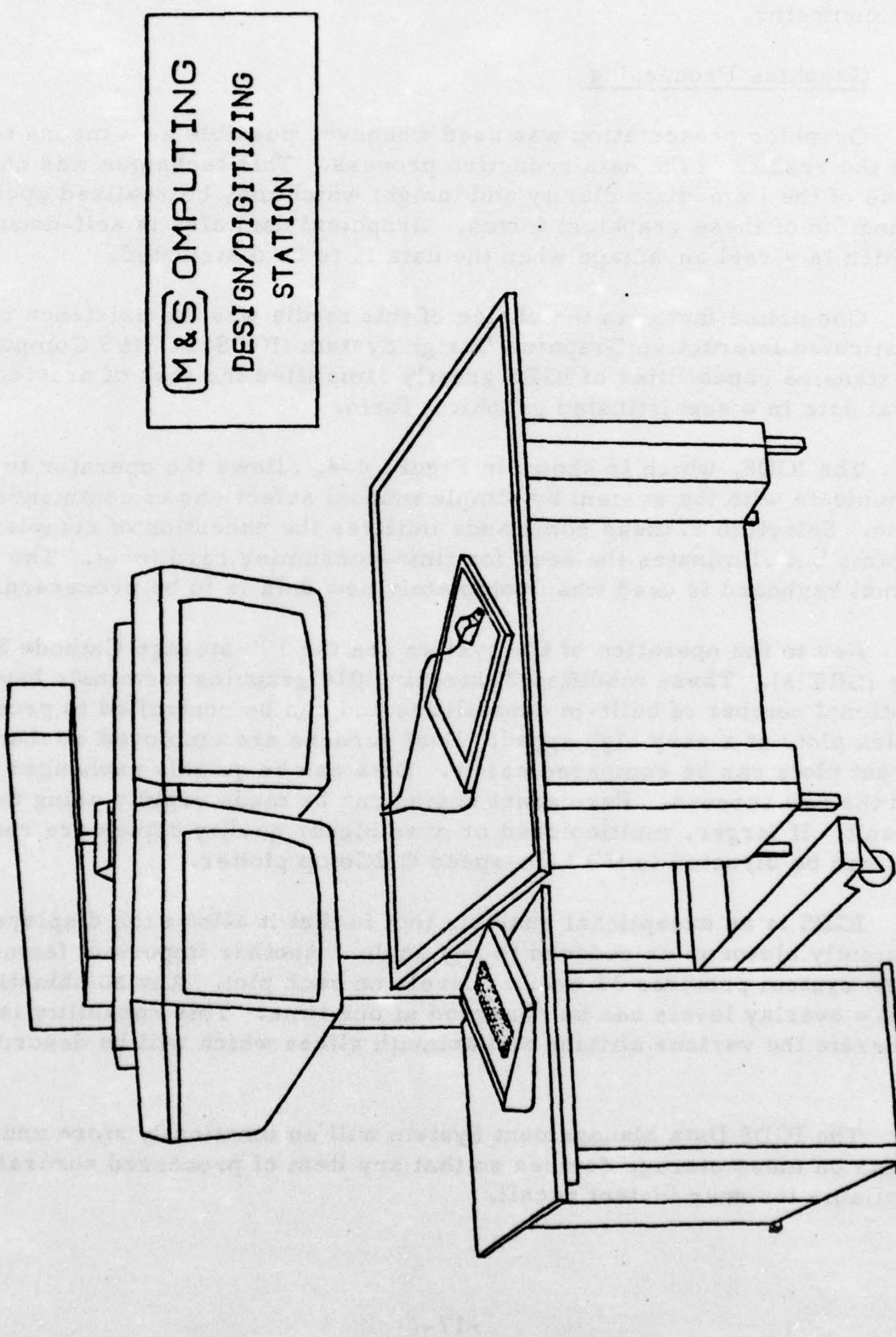


Figure 4-4

The auroral post-processing effort has benefited greatly from the availability of this IGDS, especially in the expense of software development. The Auroral Graphics Processor does the basic data preparation, layout, and scaling as well as supplying headers and scale information. From that point, this data is handled completely by the IGDS.

4.4 Data Preprocessing

Preprocessing involves the various, mathematical, statistical, and sorting operations, which must be accomplished before the data can be prepared for graphical presentation. There are three types of preprocessors, as shown in the middle section of Figure 4-1. These are, from left to right, the Search Reply Request Processor, the Activity and Event Profile (AEP), and the Track Analysis Program.

4.5 Activity and Event Profile

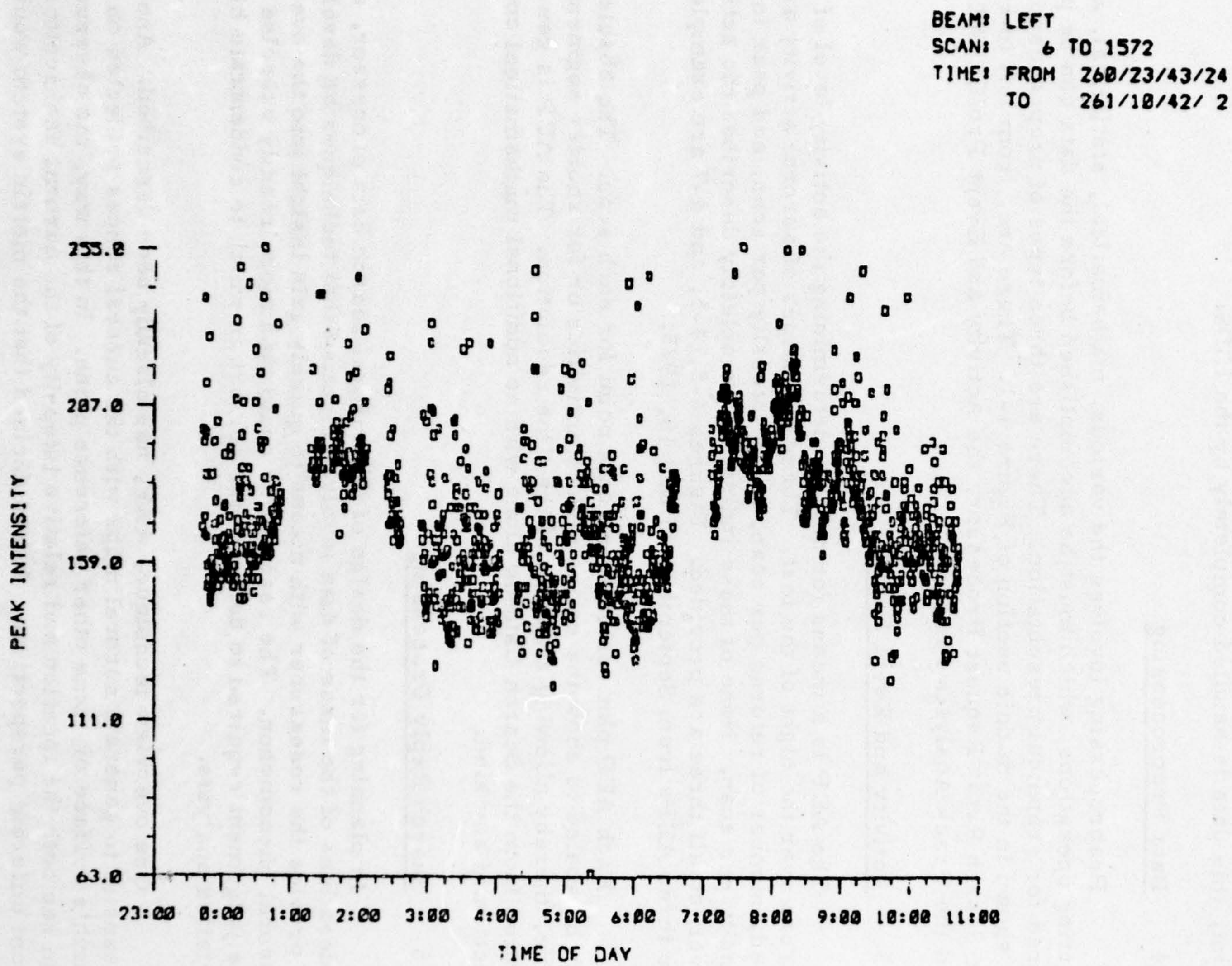
The AEP is a means for quickly determining the activity level of the aurora over the night of the test. Three indicators of auroral activity are used, number of returns per scan, mean intensity per scan, and peak intensity per scan. None of these indicators completely describes the activity level; so all three are provided. Figures 4-5, 4-6, and 4-7 are examples of the three AEPs from September 17 and 18, 1975.

Each AEP plot contains one data point for each scan. The abscissa can be scaled to show the entire night's activities or for shorter segments of time, thereby allowing a choice of the time resolution. The AEP is generated from the Search Catalog alone with no additional mathematical correction of any kind.

4.6 Search Reply Processing

In planning for the design of the auroral search data processor, considerations of the mass of data involved dictated that techniques be developed to provide the researcher with means to quickly gain insight into the overall auroral phenomenon. The researcher could then more readily exercise the the judgement required to define those periods in which to concentrate his detailed analysis.

One overview technique, AEP, has already been described. Another means is to generate auroral maps with the auroral echoes projected on the earth's surface or some other reference plane. In this way, the observer can see both the location and relative intensity of the auroral backscattering from different perspectives. It was decided that the metric system would be



ACTIVITY AND EVENT PROFILE

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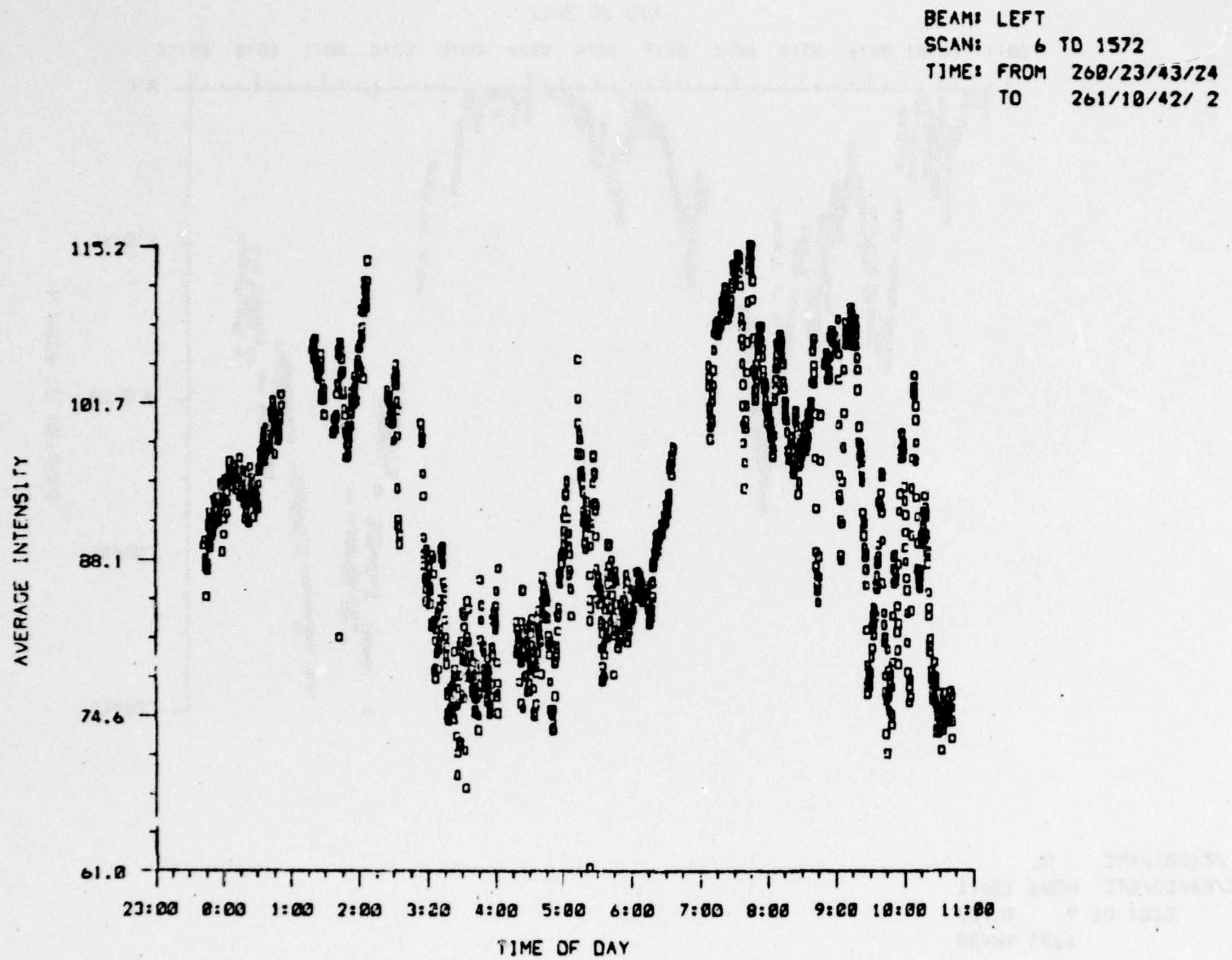
Figure 4-5



ACTIVITY AND EVENT PROFILE

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Figure 4-6

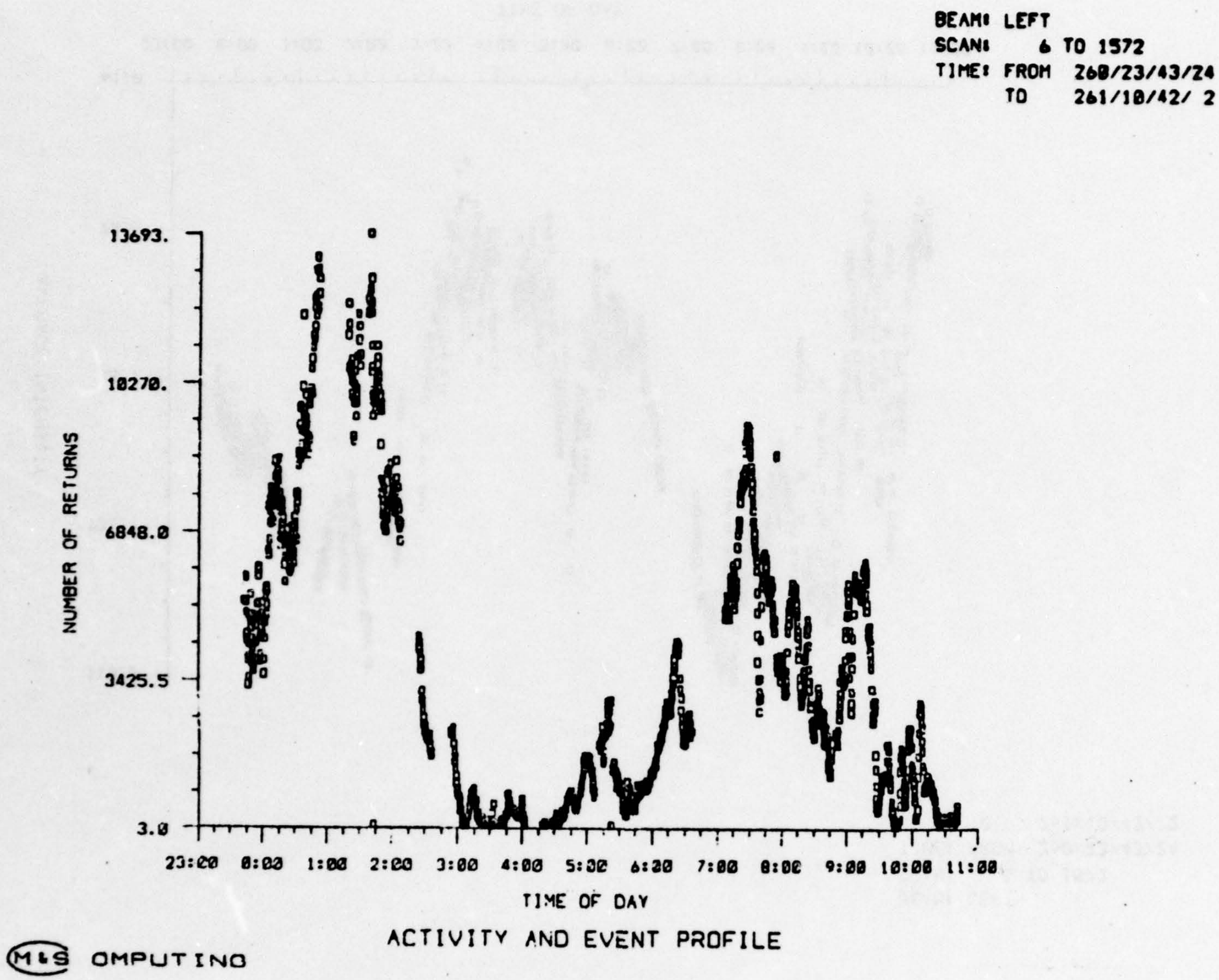
BEAM: LEFT
SCAN: 6 TO 1572
TIME: FROM 260/23/43/24
TO 261/10/42/ 2
13693.
10270.
6848.0
3425.5
3.0
NUMBER OF RETURNS
23:20 0:00 1:00 2:00 3:00 4:00 5:30 6:20 7:00 8:00 9:00 10:00 11:00
TIME OF DAY
ACTIVITY AND EVENT PROFILE
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Figure 4-7

used exclusively. The different types of auroral maps will be described in the next sections, but some general explanations will be made here.

The PAR records only certain portions of the detected video signal. Recorded data are known as replies. The three types of events recorded are noise blanking threshold upcrossings, video peaks, and noise threshold downcrossings. The time of each event is also recorded as is the log amplitude. Figure 4-8 illustrates these events.

In all of the auroral maps shown in this report, aurora is represented by placing a character at the projected location of each video peak. For each plot, the characters are quantized into eight sizes indicating eight bands of log video amplitude. Quantization intervals are determined using the minimum and maximum reply on each scan. This technique provides maximum resolution of echo strengths on each scan but does not permit direct comparisons of absolute echo strengths of different scans.

Data for all types of search reply processing must undergo certain preliminary processing including: conversion of the radar processor bit code into recognizable power level and target range. The power level term is corrected for a number of factors including transmit and receive antenna element pattern factor and antenna aperture area projected in the direction of the beam. A range to the fourth power factor has been applied to correct for range attenuation. This correction will be changed to range/squared when volume reflection properties are calculated. Two other factors are also applied to the signal. These are sensitivity corrections determined every 12 seconds during the radar self-calibration or Class A tests. One calibration factor corrects for changes in peak transmitted power level, the other for receiver sensitivity. Separate calculations are made for the right- and left-hand beam in each pair as separate signal processors are used for each one. Search processing may be performed on either or both beams so that comparisons may be made.

Another function performed to all search data is coordinate conversion. This process converts the data from the radar face coordinate systems to N-S, E-W projections or longitude and latitude with spherical altitude.

One of the capabilities of the basic search preprocessor is spatial data filtering. Filtering may be performed to reduce data point density to relieve congestion on graphical auroral maps, to reduce computer processing time, and to select data only from special regions in space. The ability to select data from special regions provides a powerful tool for scientific analysis of auroral data. The technique in which this filtering approach was implemented makes the overall processing of small regions very efficient in that it allows undesired data to be bypassed with very little handling (a much desired capability when each scan contains as many as 27,000 replies).

GENERATION OF PAR REPLY DATA

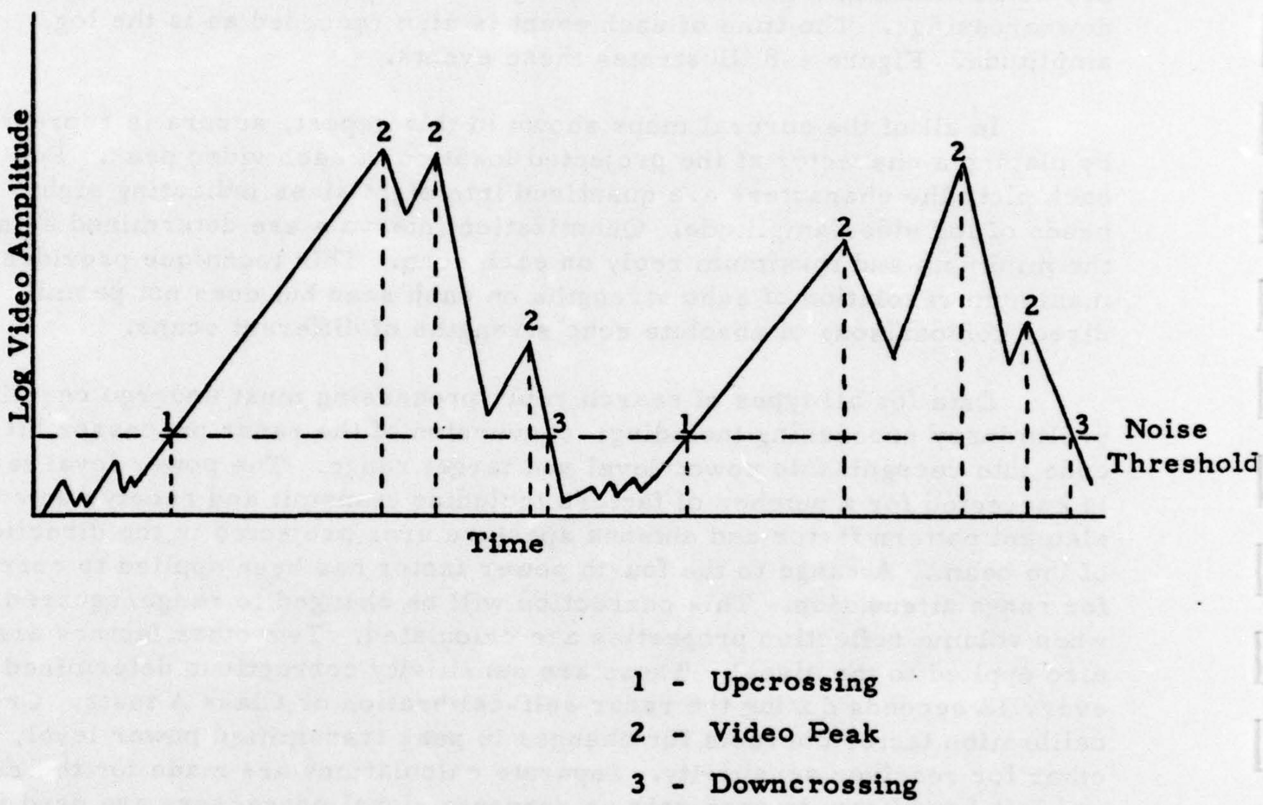

Figure 4-8

The filter allows the user to define a volume of space outside of which no data will be processed. In addition to this regional filter, it is possible to select only data from predetermined range intervals at any number of selected steering angles. Efficient filtering is possible because all recorded data is stored in the same chronological order it came from the radar. Radar scanning is a TV-like raster and replies are time (range) ordered. The spatial filter boundaries are converted to basic radar bit code so that comparisons will require no correction or conversion. Furthermore, the sorting operation takes advantage of the time-space organizations of the input data to quickly eliminate unwanted data.

It is often desirable to sort data from different geomagnetic off-perpendicular contours. One of the critical factors in the auroral backscatter mechanism is the angle made between the radar beam and the earth's magnetic field lines at the reflecting point shown in Figure 4-9. Only when this angle is near 0° (perpendicular) does strong reflection take place. It is often desirable to study the relationship of the off-perpendicular-to-received signal strength. The spatial filter can thus be used to sort data according to its relationship with the earth's magnetic field if supplied with the proper angles and range intervals. Information is supplied by another program which has generated and stored this data in tables. The program generates each of the discrete steering angles used while the PAR is in the search mode. Then using a 42-term sperhical harmonic solution of the International Geomagnetic Reference field, the program generates the ranges to each point where the beam meets the desired aspect conditions.

As a point of interest, the family of all space points where a radar makes the same degree of off-perpendicular angle, forms a dome-like surface (open side toward the earth). The set of domes for all aspect angles is stacked one inside the other like mixing bowls with the 0° off-perpendicular surface on the inside. As can be seen in Figure 4-9, the aspect angle $(90^{\circ} - \delta)$ can be both positive and negative. Because of their location, most radars cannot make negative aspect angles because these contours are stacked inside the 0° surface and are observable only at very low elevations. The earth's curvature, then, usually blocks observation of these regions. In fact, the PAR can never make less than $+1.0^{\circ}$ off-perpendicular in the altitude region where aurora occurs.

The tables generated by the geomagnetic model can be directly accessed by the spatial filter to select data which corresponds to each off-perpendicular contour. The data can then be used for various analytical processing.

RADAR/MAGNETIC FIELD ASPECT ANGLE

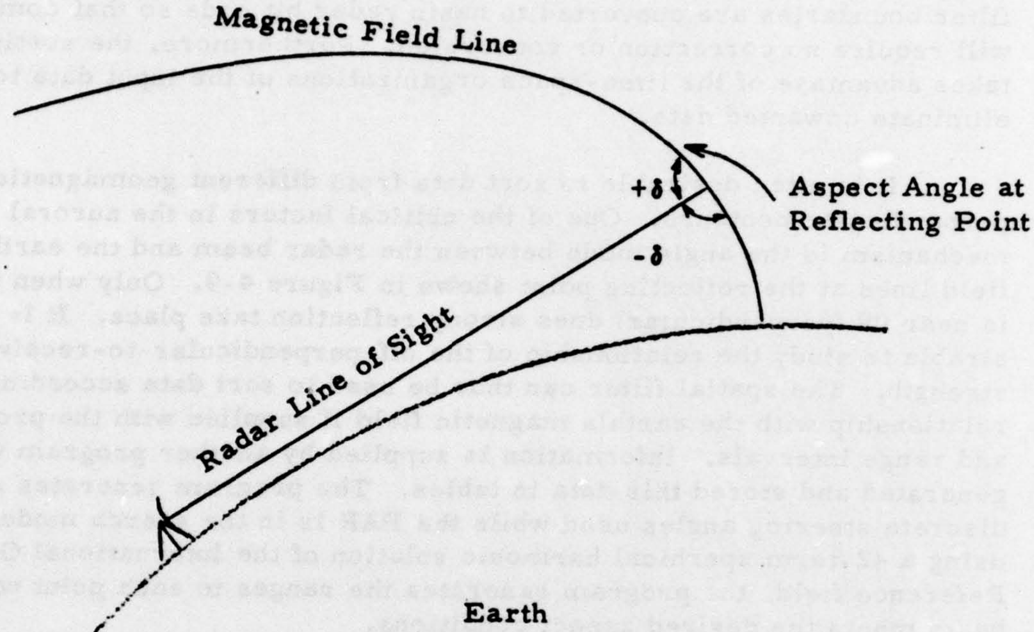

Figure 4-9

Several specific search data processing capabilities have been planned, developed, and are being used. Some capabilities are still in development and a few are still in the preliminary design stage. The next sections describe those programs which are either fully operational or are near completion.

4.7 Auroral Maps

Three types of auroral maps are provided: top-down views, profile, and sine space views. These maps are presented on M&S Computing's IGDS. All auroral plot data is stored on magnetic tape for rapid recall. Selected plots are maintained on disk files for immediate access.

4.7.1 Top-Down Views

Top-down views provide a picture of auroral reflections as seen looking down from above the aurora toward the center of the earth with the reflection points projected onto the earth's surface. The surface is represented as either a map of North America or a rectangular projection in N-S, E-W coordinates. The auroral reflections are represented by a character of size proportioned to the logarithm of the corrected echo intensity. Figure 4-10 is an example of a top-down view with the N-S, E-W projection. Lines extend outward from the point where the PAR is located, the dashed-line points toward the geomagnetic north pole, the vertical solid line is true-north, and the solid lines are separated by 15°. Top-downs are generated in sets of 10 on each plot corresponding to different slices in altitude. Once generated, these slices are on separate levels and can be observed singularly or in any combination. Figure 4-10 is a composite of all altitudes from 70 to 170 km.

Figure 4-11 shows an auroral top-down projected on a map of North America. The map, data, scales, coordinates, geographic locations, etc., are each on separate levels so they can be put together in any combination.

4.7.2 Profile Views

The profile views involve a projection where the aurora is observed form an angle perpendicular to the bisector of the azimuth slice(s). The data points on the projection are shown with their true range because the data points in the slice are folded into the projection plane at the bisector. Figure 4-12 is a composite of all azimuths from -30° to +60°.

4.7.3 Sine Space

Sine space is a coordinate system used to represent radar pointing angles using direction cosines. Sine α is an azimuth-like coordinate and sine β is an elevation-like coordinate. Those familiar with the technique will find the plots informative. Three types of sine space plots are provided with each level

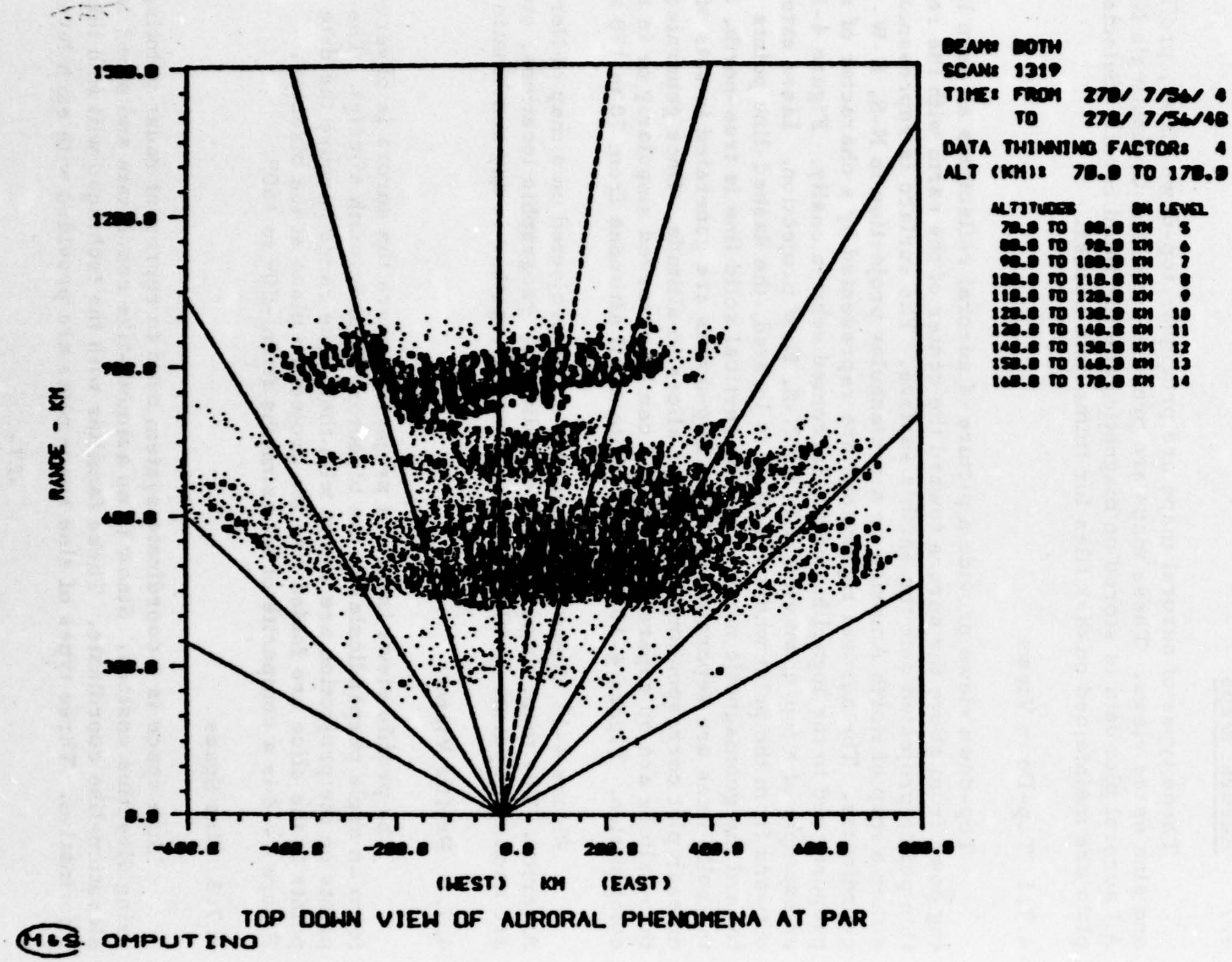
BEAM: BOTH
SCAN: 1319
TIME: FROM 270/ 7/56/ 4
TO 270/ 7/56/40
DATA THINNING FACTOR: 4
ALT (KM): 70.0 TO 170.0
ALTITUDES ON LEVEL
70.0 TO 80.0 KM 5
80.0 TO 90.0 KM 6
90.0 TO 100.0 KM 7
100.0 TO 110.0 KM 8
110.0 TO 120.0 KM 9
120.0 TO 130.0 KM 10
130.0 TO 140.0 KM 11
140.0 TO 150.0 KM 12
150.0 TO 160.0 KM 13
160.0 TO 170.0 KM 14
RANGE - KM
1500.0
1200.0
900.0
600.0
300.0
0.0
-600.0
-400.0
-200.0
0.0
200.0
400.0
600.0
800.0
(WEST) KM (EAST)
TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR
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Figure 4-10

TOP-DOWN VIEW OF AURORA PROJECTED ON MAP OF NORTH AMERICA

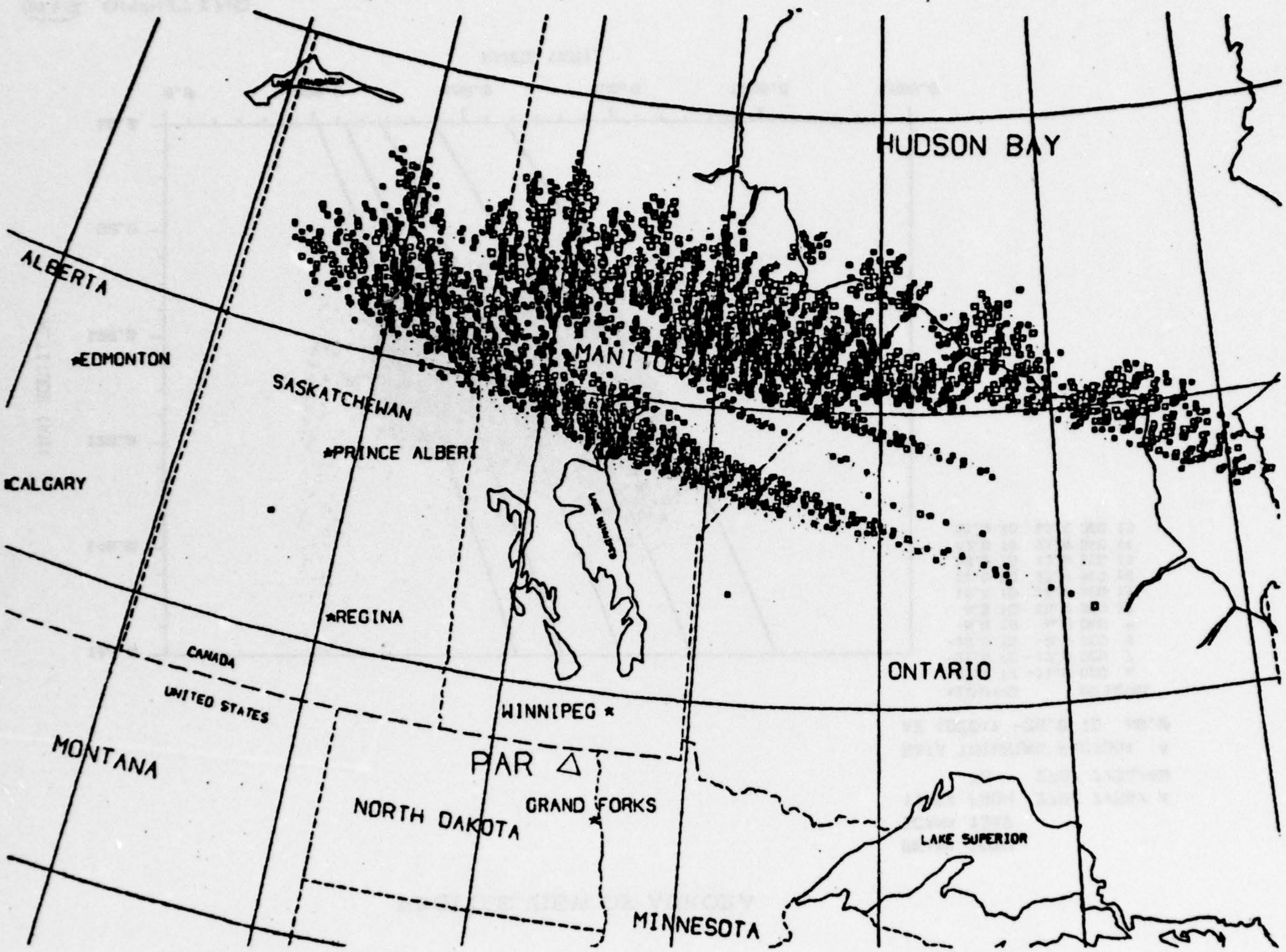

Figure 4-11

PROFILE VIEW OF AURORA

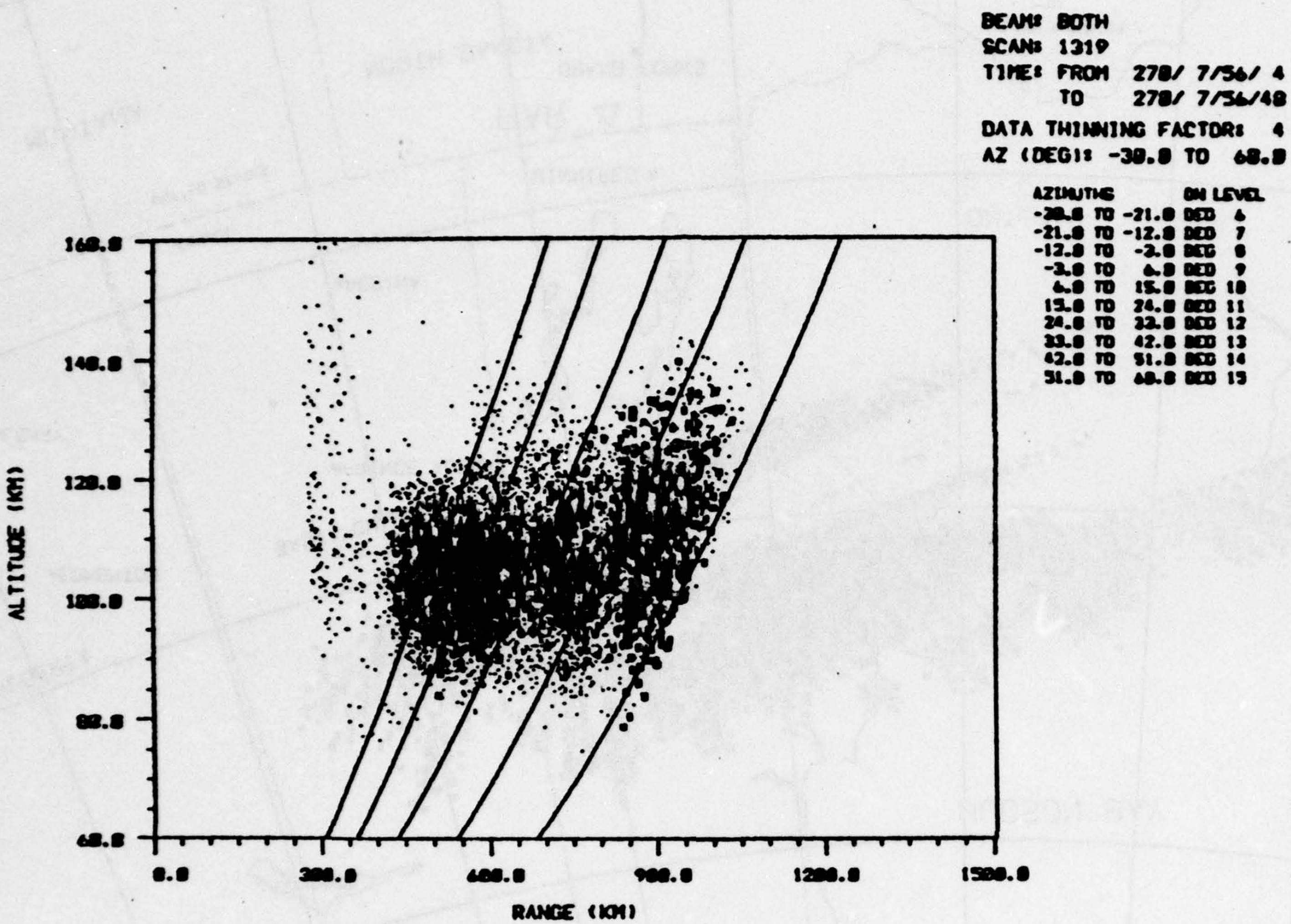

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Figure 4-12

displaying a different indicator of auroral intensity. A character is located at each beam position where at least one auroral echo was detected. The size of the character is proportional to either the number of peaks measured, the average of all peaks from that angle, or the maximum peak. Figure 4-13 shows a typical sine space plot.

In the upper right-hand corner of all maps is a legend telling whether the right- or left-hand beam is included, the scan number, and the Julian data (to one second resolution) of the start and end time of this scan.

4.7.4 Histograms

The histogram preprocessor does not generate maps, but will be discussed here. The histogram program generates frequency of occurrence statistics for various data. Almost any set of parameters could be processed by this program. Figure 4-14 shows a histogram of the corrected signal-to-noise ratio of all replies in scan 190.

4.8 Track Data Processing

There are a number of programs included in the track data processing package. Some require only the raw unsmoothed radar track data, others require the input of precise satellite trajectory information, known as ephemeris data. Two primary factors have been chosen in the study of aurora and tracking interactions. These are scintillation and refraction. Track processing software which is fully developed, is designed for the analysis of scintillation effects. There are plans, however, to extend the analysis to include refraction studies.

Scintillation appears as rapid fluctuation in signal power and apparent target position which can result from perturbations of the radar-to-satellite propagation path. It is generally accepted that these perturbations are caused by irregularities in the ionospheric F region. It is further apparent that the characteristics of these irregularities are related to the magnetic disturbances associated with auroral activity.

Scintillation may be studied in one way by analyzing the point-by-point fluctuations in signal strength and position. For this study, absolute target position is not important and radar biases and refraction errors are negligible because these factors change slowly and smoothly.

Two programs are presently available for the analysis of ionospheric scintillation. For these programs, equations have been defined which process the point-by-point raw unfiltered radar track data and produce index terms which are related to the fluctuations in the received signals.

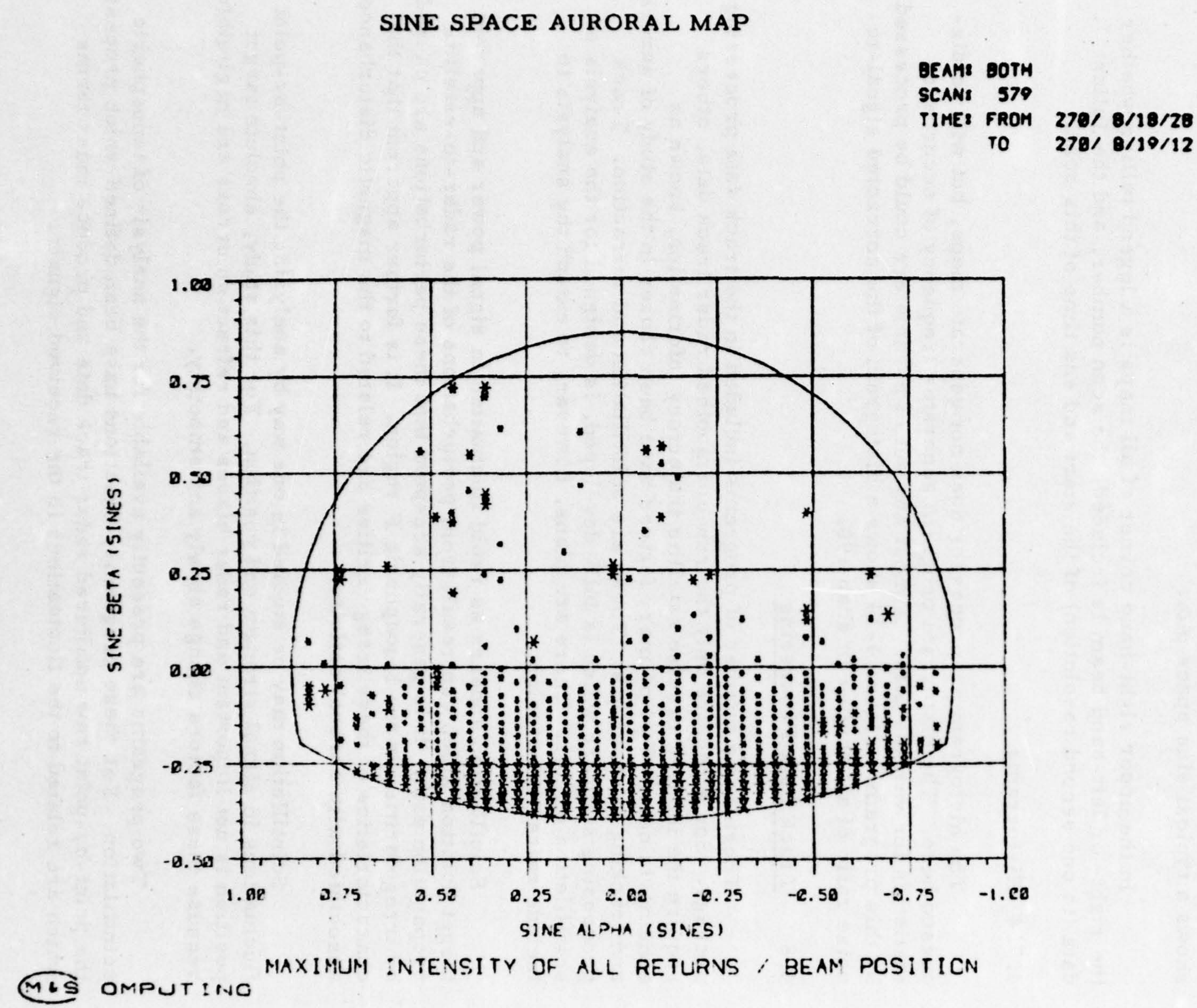
SINE SPACE AURORAL MAP
BEAM: BOTH
SCAN: 579
TIME: FROM 270/ 8/18/28
TO 270/ 8/19/12
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
SINE BETA (SINES)
1.00
0.75
0.52
0.25
0.00
-0.25
-0.50
-0.75
-1.00
SINE ALPHA (SINES)
MAXIMUM INTENSITY OF ALL RETURNS / BEAM POSITION
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Figure 4-13

HISTOGRAM SHOWING FREQUENCY OF OCCURRENCE OF CORRECTED S/N VALUES

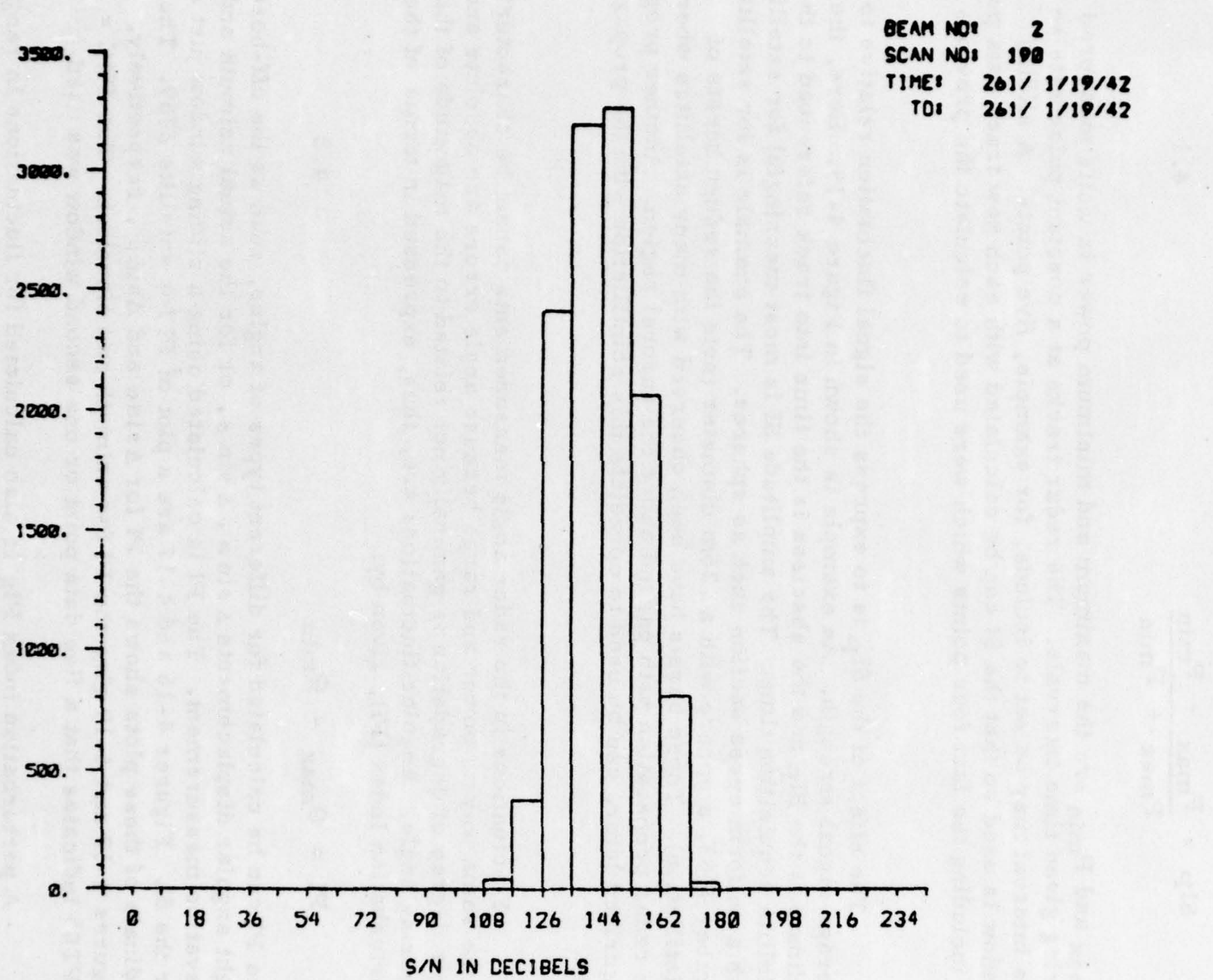

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Figure 4-14

Fluctuations in sum beam amplitude are characterized by the dimensionless Scintillation Index (SI), given by:

$$SI_P = \frac{P_{max} - P_{min}}{P_{max} + P_{min}} \qquad 4.1$$

P_{max} and P_{min} are the maximum and minimum power in watts measured during given time intervals. The radar tracks at a constant pulse rate so this interval may be set to include, for example, five points. A sliding window is used so that the SI can be calculated with each new track data point by including the last four points which were used to calculate the previous SI.

The effect of the SI_P is to express the signal fluctuation relative to the average signal strength. An example is shown in Figure 4-15. Here, the ordinate is the SI_P and the abscissa is the time into track referenced to the satellite acquisition time. The amplitude SI is most meaningful for satellites with a uniform cross section such as spheres. The example is for satellite number 4963, a sphere with a .26m diameter (note the sudden bursts of scintillation). These bursts have been observed with many satellites where the radar propagation path passed above the auroral region. Another program, described later, can be used to correlate this scintillation with the propagation path.

Fluctuations in the radar angle measurements cannot be characterized in the same way as power and range because angle errors are absolute and their degree of degradation is generally not related to the magnitude of the steering angle. Angular fluctuations are, thus, expressed in terms of their Perturbation Index (PI), given by:

$$PI = \Theta_{max} - \Theta_{min} \qquad 4.2$$

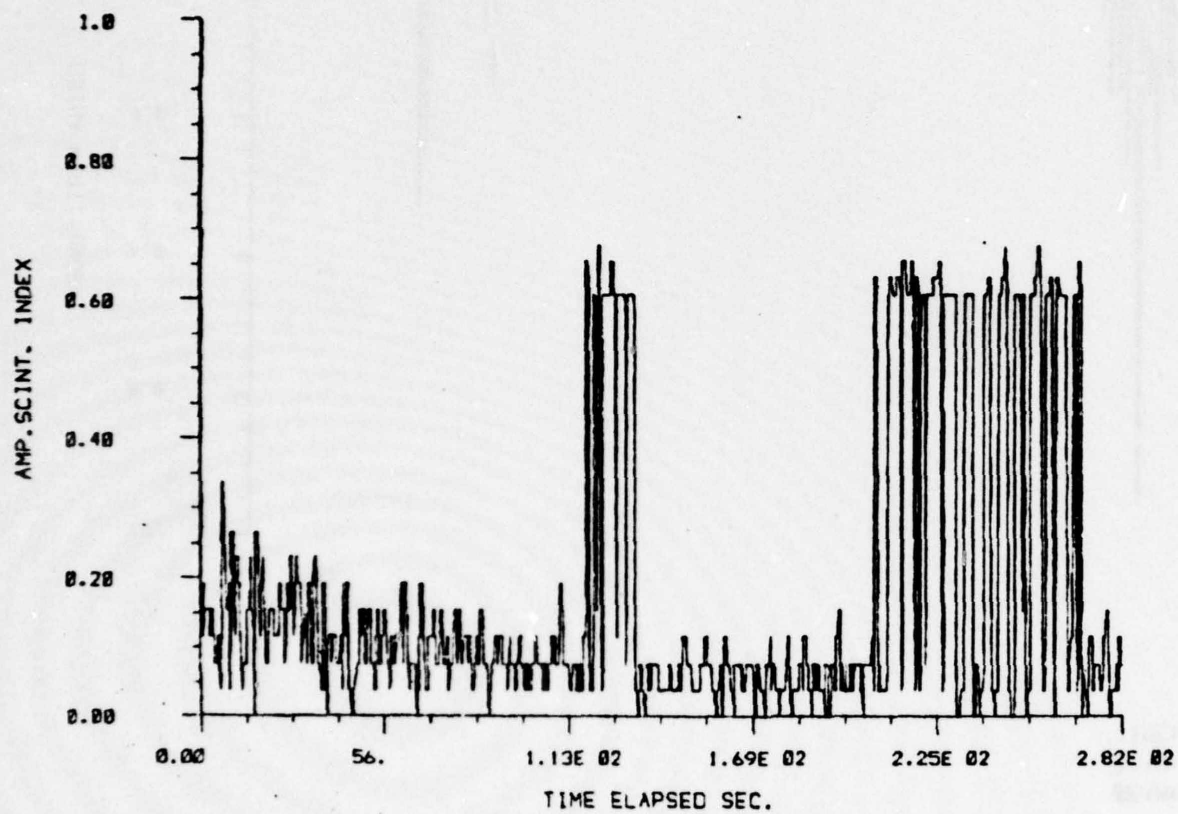
The PI can be calculated for different types of angles, such as the off-boresight angular displacements $\Delta \sin \alpha$, $\Delta \sin \beta$, or for the actual azimuth and elevation measurement. The PI is calculated using a sliding window just as for the SI. Figures 4-16 and 4-17 are a plot of PI for satellite 2759. The ordinate of these plots shows the PI for $\Delta \sin \alpha$ and $\Delta \sin \beta$, respectively. Figures 4-18 and 4-19 give the PI for azimuth and elevation. The PRC = SIPT05 indicates that a five data point or one second window was used.

A perturbation index PI_R is also calculated for fluctuations in range. The PI_R is given by:

$$PI_R = R_{max} - R_{min} \qquad 4.3$$

POWER SCINTILLATION INDEX

BEAM: CENTER
SCAN: 523
TIME: FROM 261/ 4/44/ 7
TO 261/ 4/48/48



TRACK # 0032 SAT ID 4963 PRC = SIPT05

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Figure 4-15

PERTURBATION INDEX FOR SINα ANGULAR ERROR

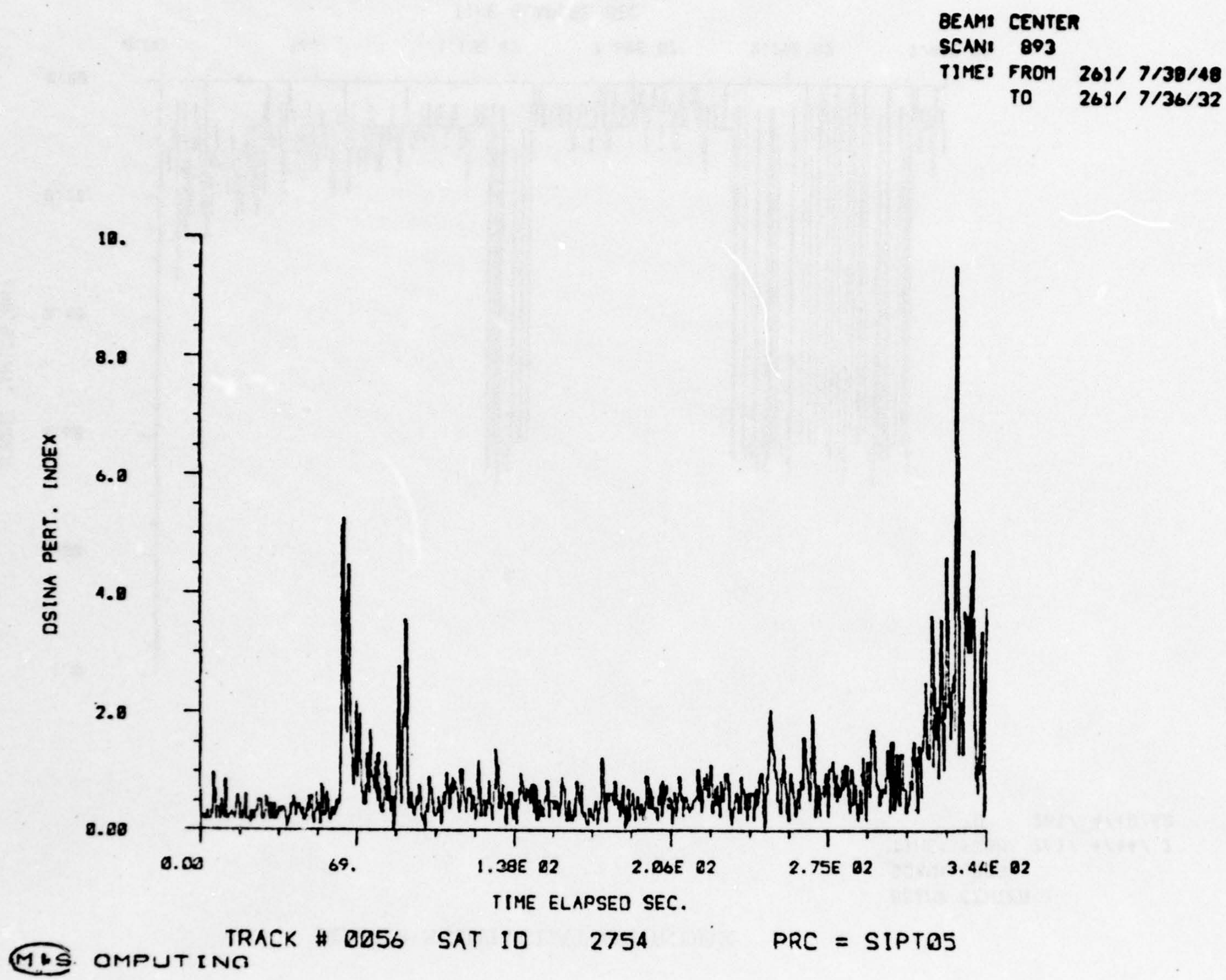


Figure 4-16

PERTURBATION INDEX FOR SIN β ANGULAR ERROR

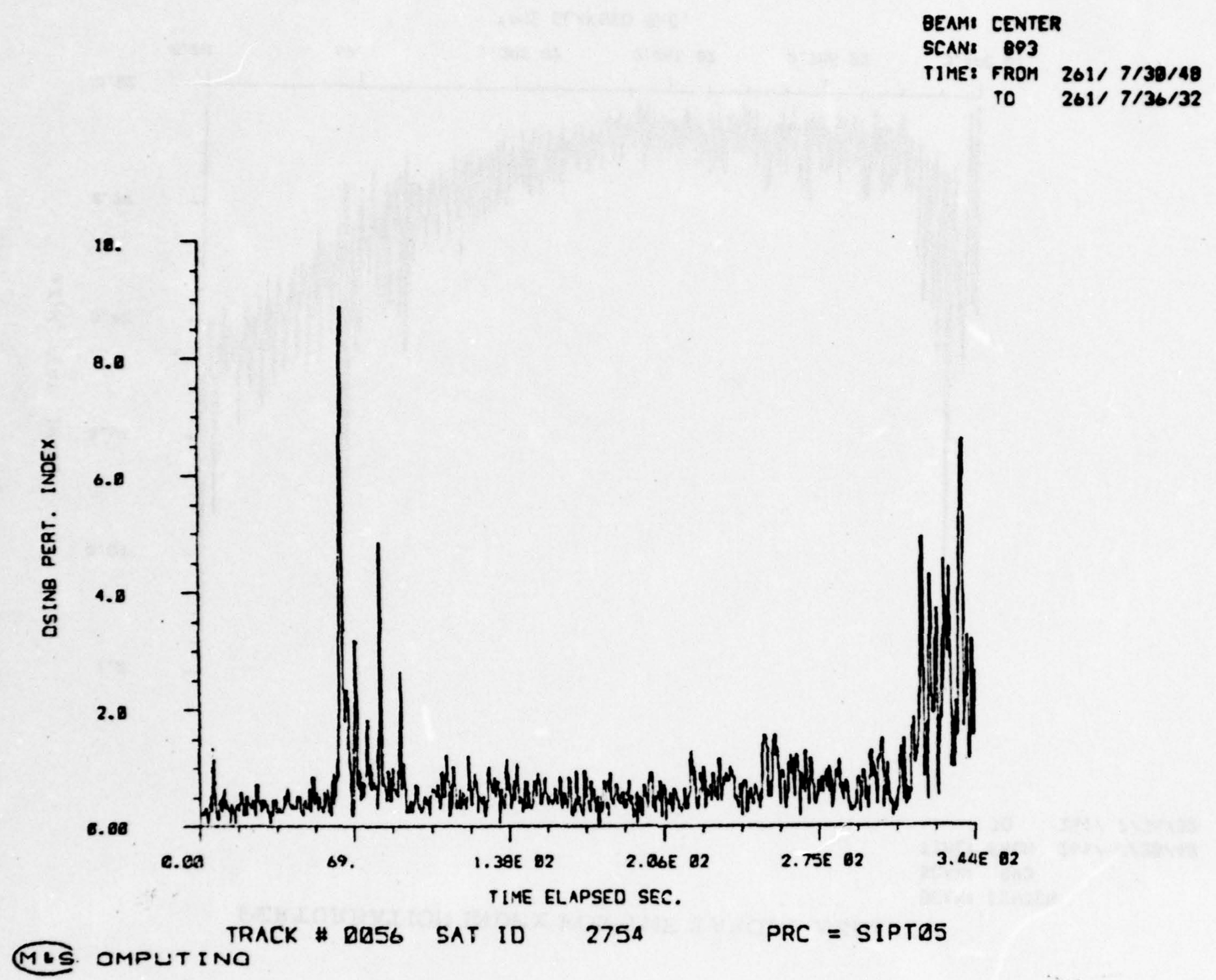
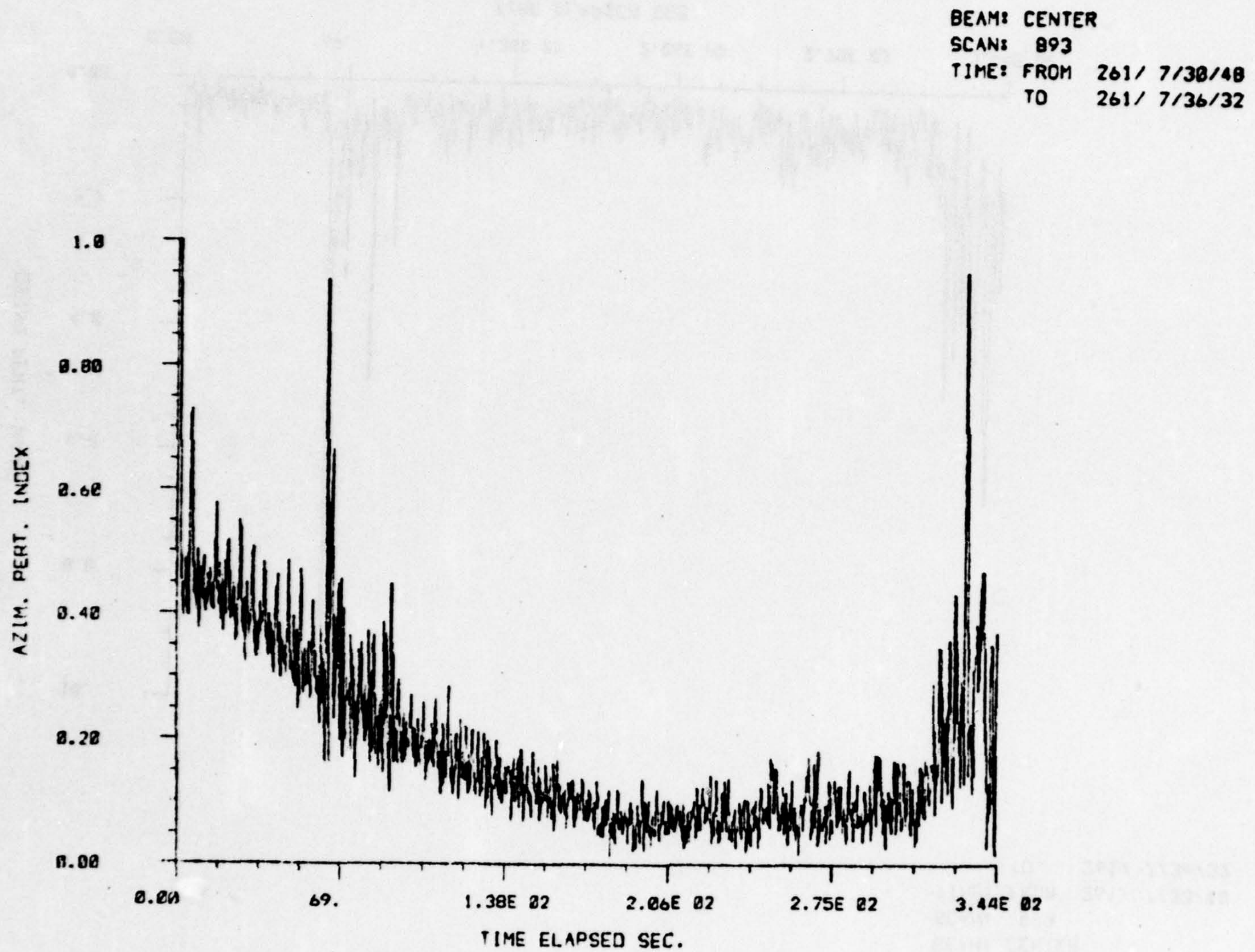


Figure 4-17

PERTURBATION INDEX FOR THE TARGET AZIMUTH

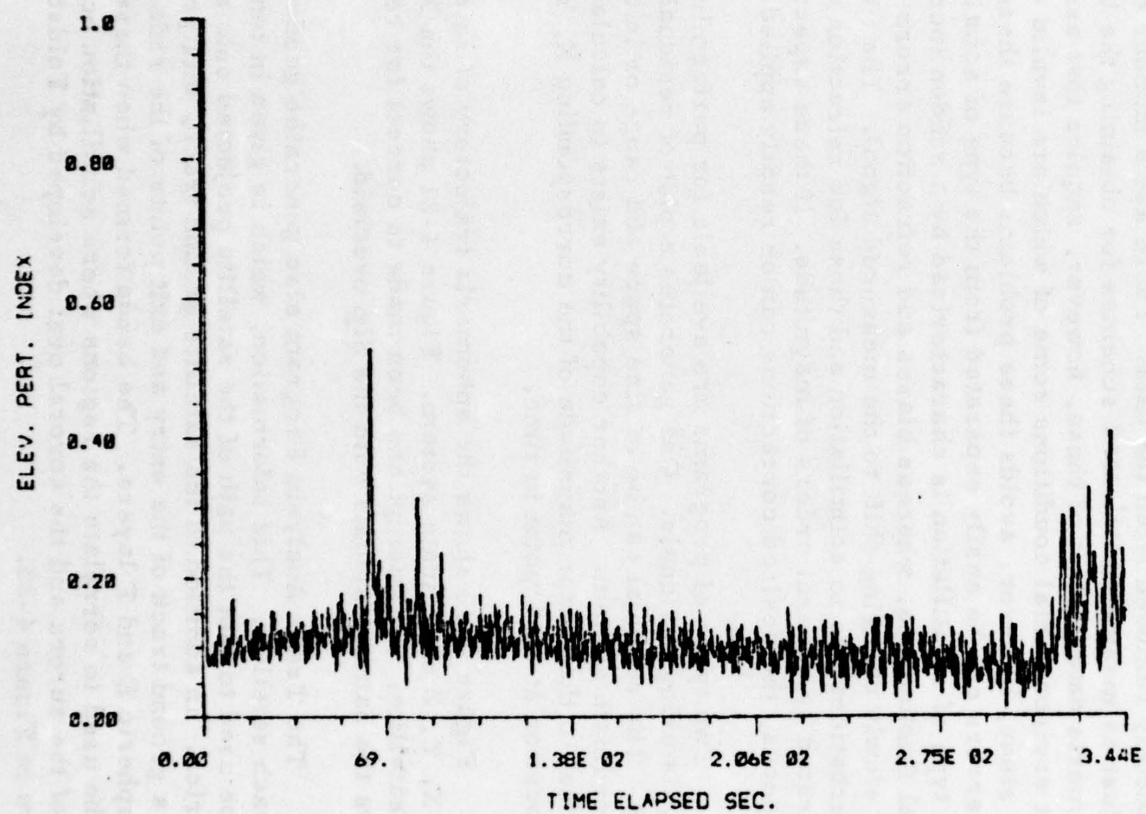


TRACK # 0056 SAT ID 2754 PRC = TIPTØ5

Figure 4-18

PERTURBATION INDEX FOR THE TARGET ELEVATION

BEAM: CENTER
SCAN: 893
TIME: FROM 261/ 7/30/48
TO 261/ 7/36/32



TRACK # 0056 SAT ID 2754 PRC = TIPT05

Figure 4-19

Another set of programs is available which compares raw radar data to either Kalman smoothed or to precise ephemeris data. The Track Analysis Program calculates residuals at each track data point. Residuals can be determined using either the Kalman smoothed radar data or the ephemeris data. Residuals not only show scintillation, but the effects of tropospheric and ionospheric refraction, biases in the radar equipment, and bias errors introduced by coordinate conversions due to inaccuracies in modeling the location and orientation of the radar face.

In this initial track data analysis, no attempt was made to correct for refraction and biases. In the best of circumstances, these effects can never be completely removed from the data. There are a number of conflicting opinions and just as many sophisticated schemes for obtaining the best fit to the ephemeris data. Most of these, however, require that assumptions be made about environmental conditions some of which are invalid during auroral activity. This study, however, avoids these problems because these biases and refraction errors can be easily separated from the type of scintillation being studied. This type of scintillation is characterized by a sudden increase in the level of signal fluctuations, whereas biases and refraction errors add either a constant or very slowly changing shift to the measured signal. The time scale involved with perturbations due to scintillation and those for refraction and bias errors are separated by several orders of magnitude. If these expectations should prove erroneous, the desired corrections can be readily applied.

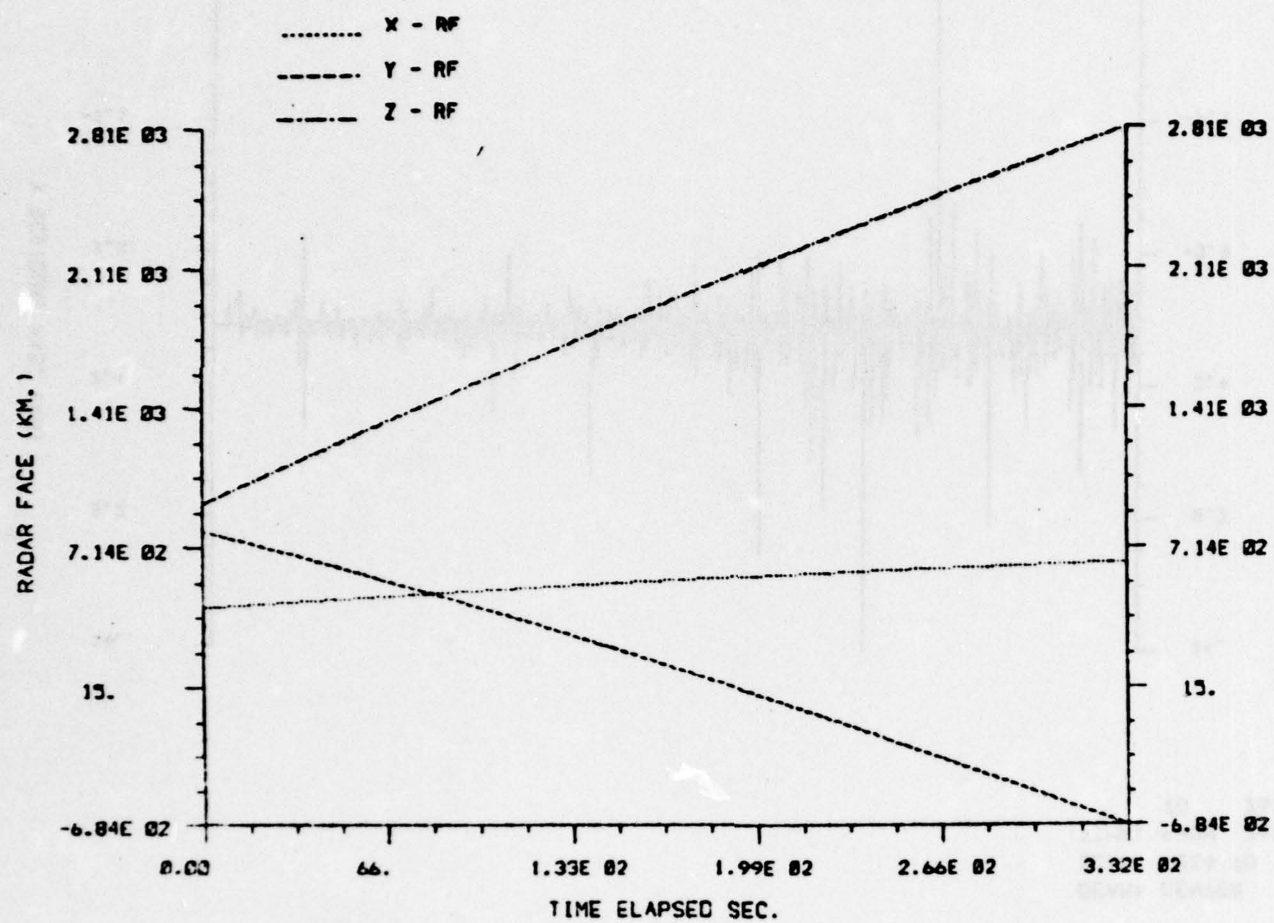
Two types of programs are available for performing scintillation analysis using residuals. One generates a plot of residuals versus time in track. The residual can be in sine space and range or in the radar face X, Y, Z coordinate system. Another capability exists to calculate the ratio of each residual to the vector magnitude of the corresponding X, Y, or Z component of its location at each point in time.

Figure 4-20 shows the ephemeris trajectory of satellite 3133 in the radar face X, Y, Z coordinate system. Figure 4-21 shows the X_{RF} track residuals for this satellite. No attempt has been made to correct for refraction. Figure 4-22 shows the same residuals with the SI_P overlaid.

The Track Analysis Program also generates geodetic ground track data for each satellite. This information, which is given in longitude and latitude, can be used to plot the path of the satellite projected onto a map of North America. In addition to the satellite ground track, this program also generates a ground track of the entry and exit points of the radar beam for both the ionospheric E and F layers. The bands formed when these points are plotted will be used to correlate the regions where scintillation occurred with the location of the aurora and the auroral oval developed by Feldstein. An example is shown in Figure 4-23.

EPHERMERIS TRAJECTORY IN RADAR FACE COORDINATES FOR SATELLITE 3133

BEAM: CENTER
SCAN: 214
TIME: FROM 261/ 1/28/41
TO 261/ 1/34/14



TRACK # TN03 SAT ID 3133 TP PRC = PROFIL

M&S OMPUTINO

Figure 4-20

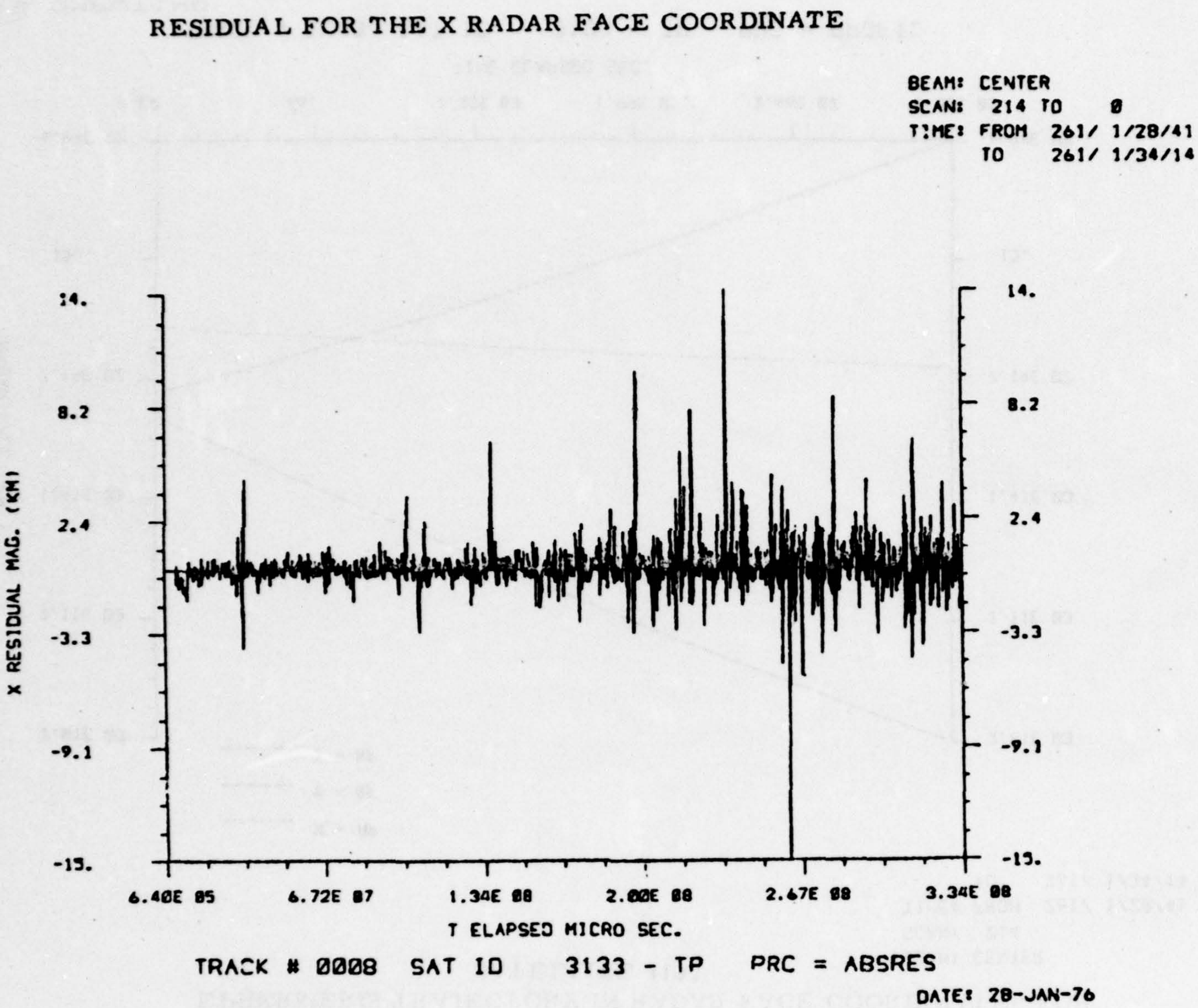

RESIDUAL FOR THE X RADAR FACE COORDINATE
BEAM: CENTER
SCAN: 214 TO 0
TIME: FROM 261/ 1/28/41
TO 261/ 1/34/14
14.
8.2
2.4
-3.3
-9.1
-15.
X RESIDUAL MAG. (KM)
6.40E 05
6.72E 07
1.34E 08
2.00E 08
2.67E 08
3.34E 08
T ELAPSED MICRO SEC.
TRACK # 0008 SAT ID 3133 - TP PRC = ABSRES
DATE: 28-JAN-76

Figure 4-21

RESIDUAL WITH SI_P OVERLAY

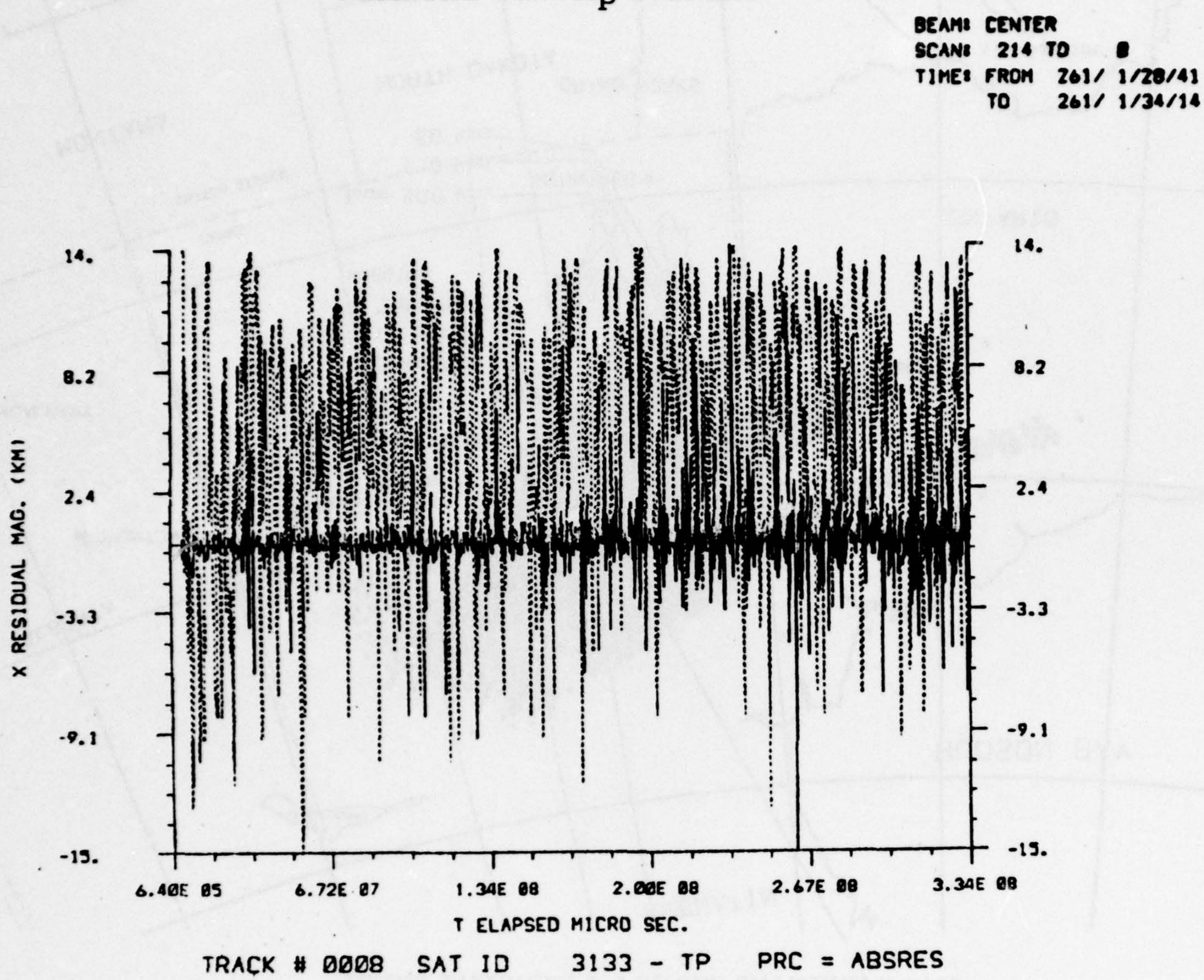


Figure 4-22

BEAM INTERCEPT TRACKS SATELLITE 4963

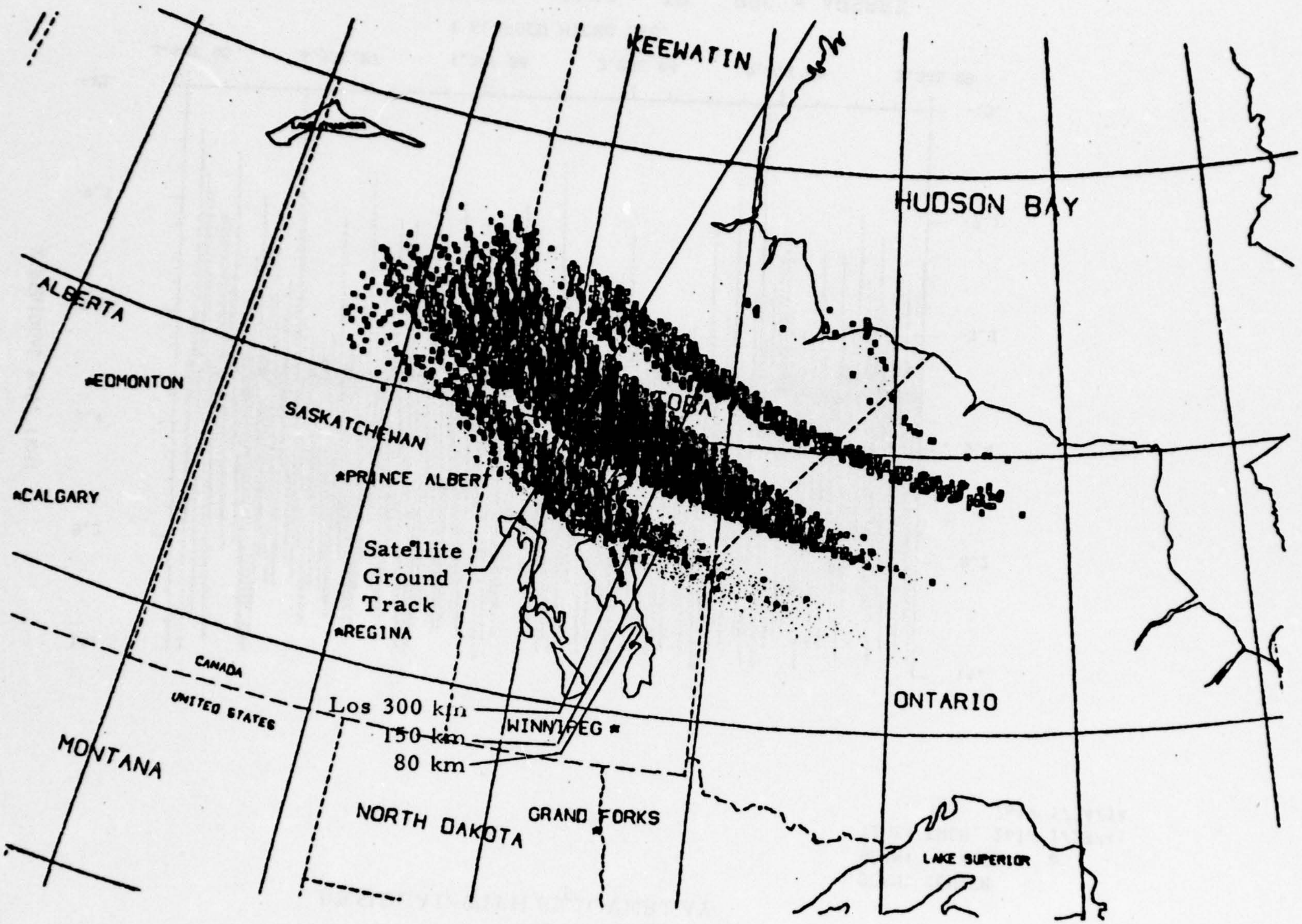


Figure 4.23

5. REDUCTION OF DATA FROM SEPTEMBER, 1975

The original PAR auroral tapes were copied on-site and mailed to Huntsville. Data reduction was started immediately upon their arrival.

5.1 Examples of Processing Data from September 17 and 18, 1975

This section includes a large set of self-explanatory plots. When examining them, it may be interesting to refer again to the AEP in Section 4.4.

A considerable amount of additional data of the type shown has been processed and is available upon request. All altitude and azimuth slices indicated on the plots are also available.

Some additional information about the operation of the radar and the nature of the auroral backscatter mechanism will be helpful in interpreting these plots. The auroral plots exhibit certain characteristic shapes especially noticeable in the profile views. Some of the outer limits of the auroral reflecting mass are truly defined by the structure of the aurora itself, but some of these boundaries result from radar scan limits or magnetic aspect. Figure 5-1 will be used to illustrate the mechanism responsible for these boundaries.

One boundary is established by the lowest elevation scanned by the radar. This forms the maximum observable range boundary. This lower scan limit also cuts off the outermost range extent in the top-down views. The upper altitude bound of auroral backscatter is limited by magnetic aspect which, in the case of the PAR, is no better than 5.5° at 150 km altitude and increases by roughly $.5^{\circ}$ per 10 km altitude in the upper region of observed radar aurora. The edge of the reflecting aurora facing the radar is bounded by both aspect and the lower edge of the aurora itself. The minimum radar range used in auroral mapping very seldom affects the data in any way.

In the top-down plots, the characteristic shape of the auroral reflecting region is determined primarily by the lower elevation limit and aspect. The far side of the aurora is limited by the elevation limits as is evident from Figure 5-2, the near side is limited by magnetic aspect.

Establishing these bounds is only a means for interpreting certain limiting criteria on the plots. In many cases, the edges of the aurora occur in regions where no limiting criteria should be of any significant effect. The plot in Figure 5-2 is an example. In this case, the backside of the aurora is scan-limited but at near $+8^{\circ}$ azimuth the near side of the aurora is only a few degrees off-$\perp$. At near 5° off-perpendicular the upper altitude region is still not severely affected by aspect. This example suggests that the near and topside

FACTORS LIMITING REGION OF RADAR AURORA

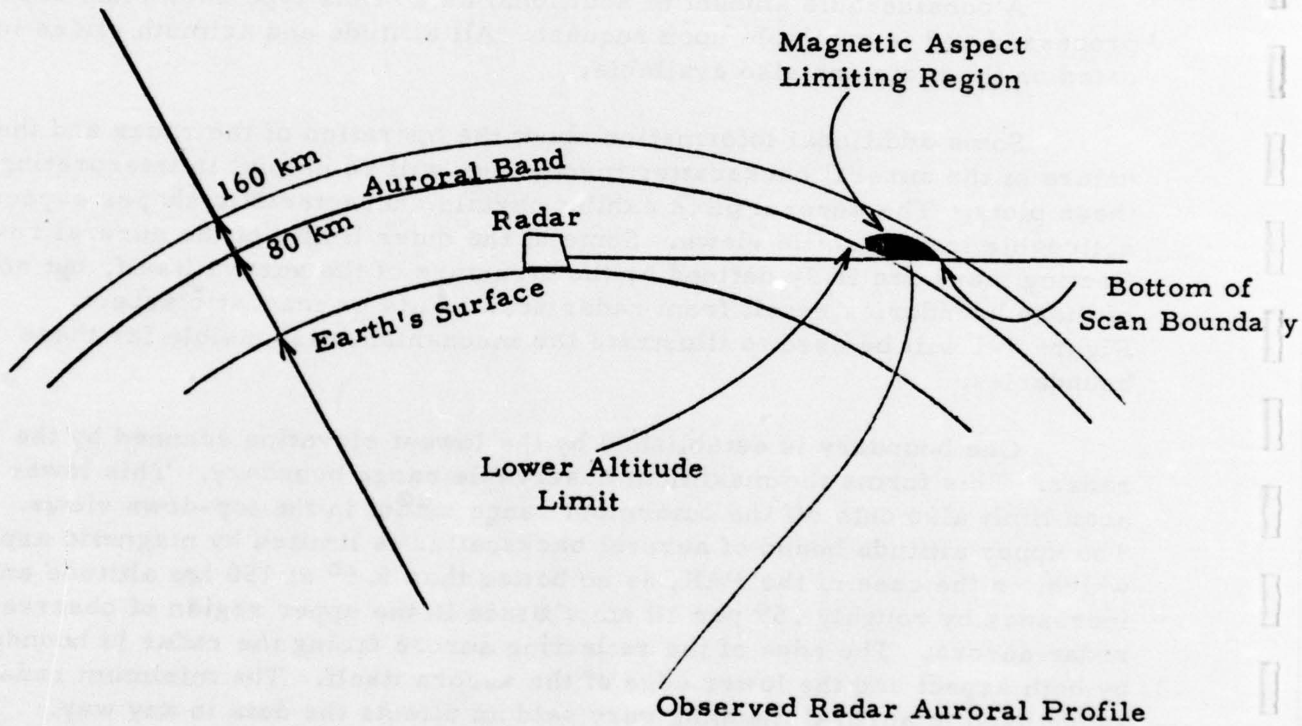
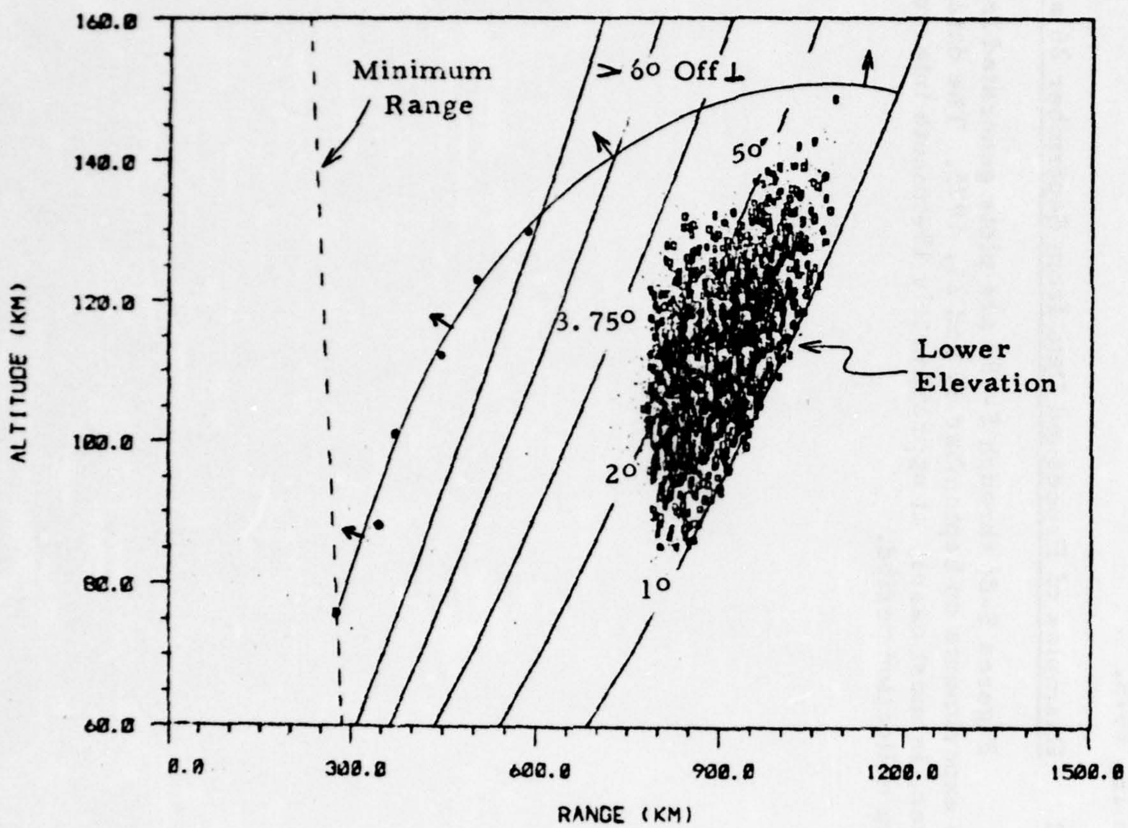


Figure 5-1

PROFILE ILLUSTRATING BOUNDARY CONSTRAINTS

BEAM: BOTH
SCAN: 47
TIME: FROM 260/23/59/50
TO 261/ 0/ 0/10
DATA THINNING FACTOR: 2
AZ (DEG): -30.0 TO 70.0

AZIMUTHS	ON LEVEL
-30.0 TO -20.0 DEG	6
-20.0 TO -10.0 DEG	7
-10.0 TO 0.0 DEG	8
0.0 TO 10.0 DEG	9
10.0 TO 20.0 DEG	10
20.0 TO 30.0 DEG	11
30.0 TO 40.0 DEG	12
40.0 TO 50.0 DEG	13
50.0 TO 60.0 DEG	14
60.0 TO 72.0 DEG	15



M&S COMPUTING

Figure 5-2

actually represent the physical limits of the ionospheric disturbance that causes the reflections.

Figure 5-3 illustrates the general affect of aspect. This set of off-perpendicular contours approximates those that would be expected for PAR at a constant 100 km altitude. In the top-down views, the forward swept near-side of the auroral reflections is a result of changes in aspect shown in the figure. Any banding effects or voids in the aurora normally truly represent the true physical phenomenon in that they appear to be unperturbed regions.

Figures 5-4 through 5-85 were generated from data taken September 17 and 18, 1975.

5.2 Examples of Processed Data from September 26 and 27, 1975

Figures 5-86 through 5-180 are plots generated from data taken during the experiments on September 26 and 27, 1975. The data represent samples taken, in most cases, at approximately 15-minute intervals throughout the data collection period.

OFF-PERPENDICULAR CONTOURS AT 100 KM ALTITUDE

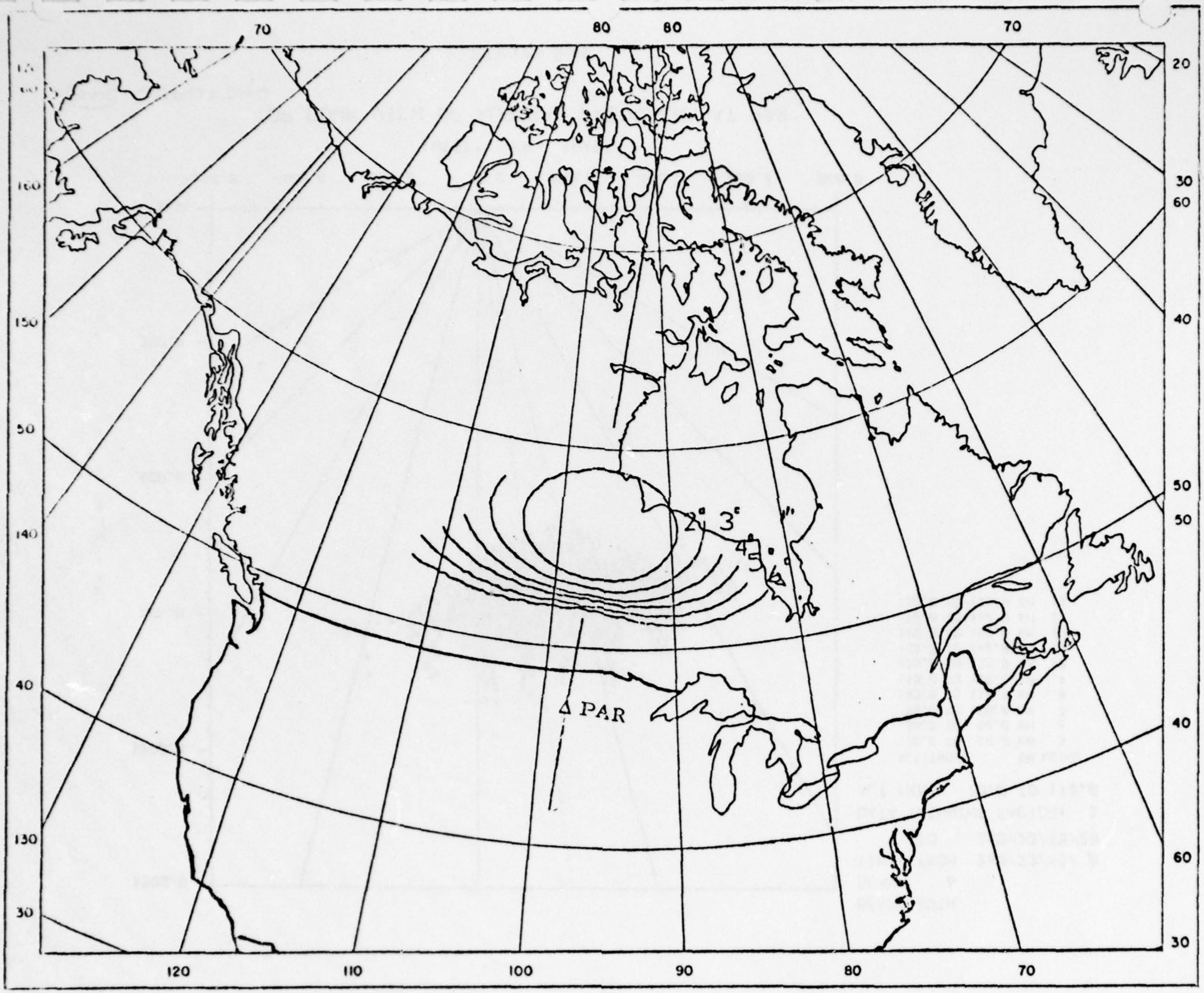
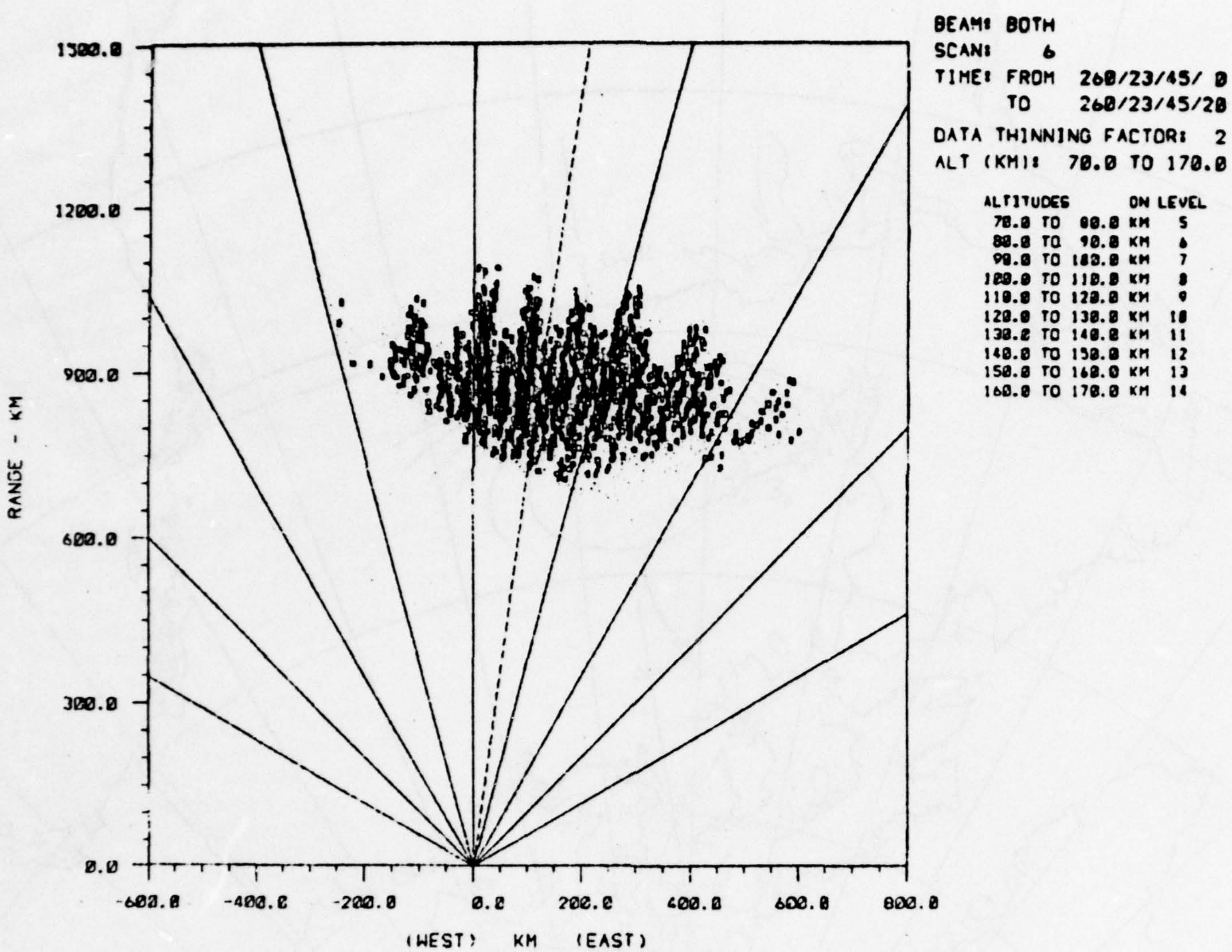


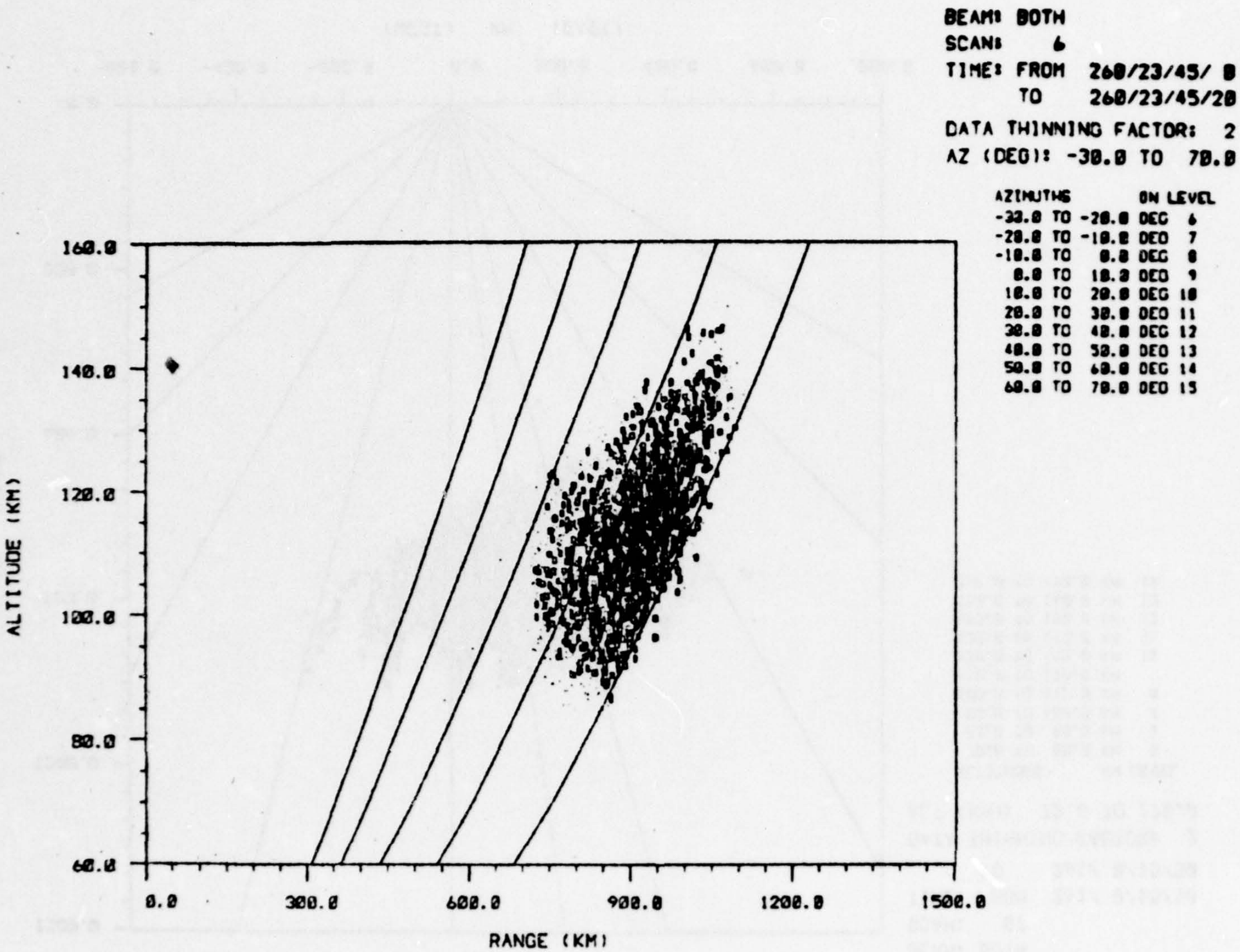
Figure 5-3



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

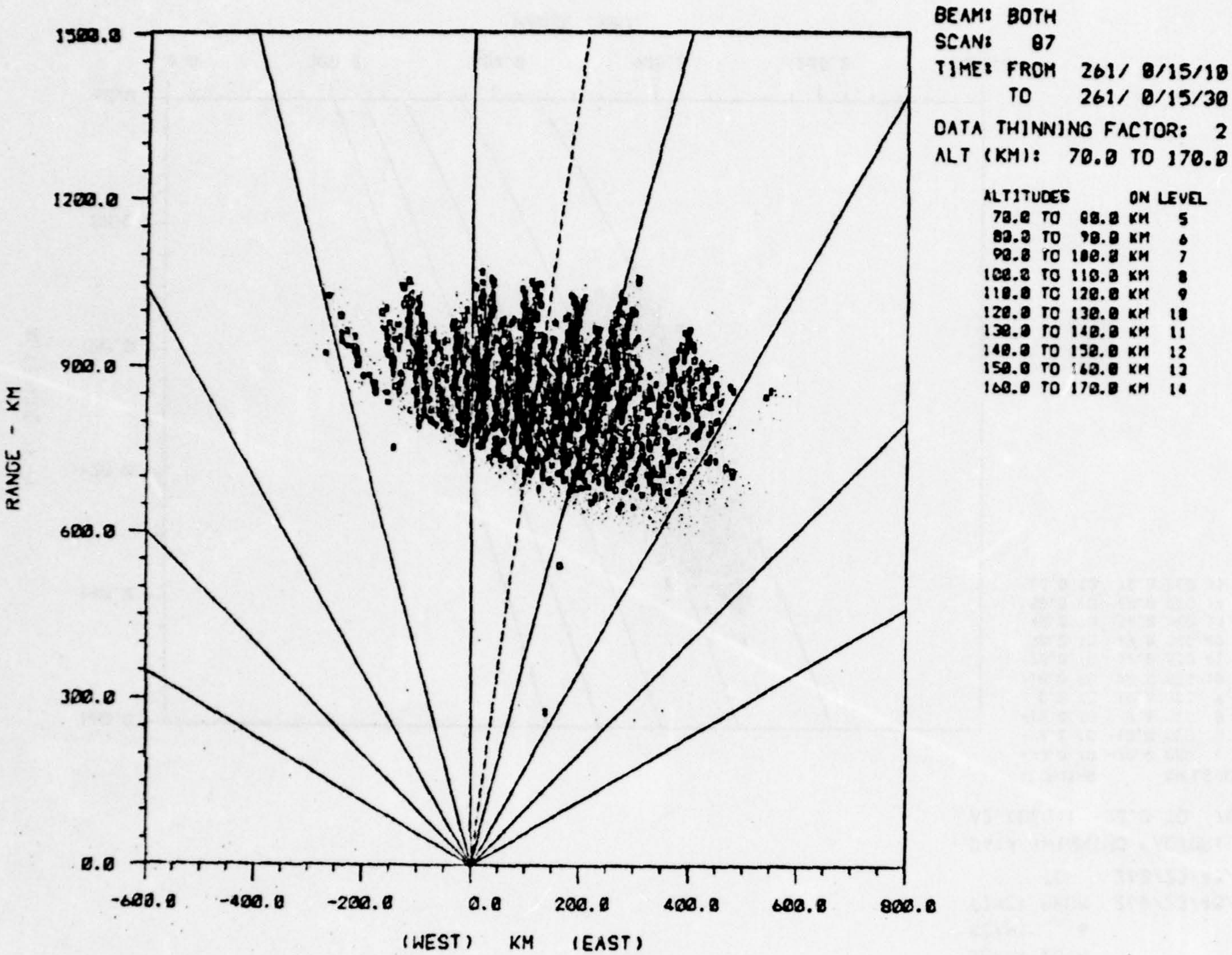
M&S COMPUTING

Figure 5-4



M&S COMPUTING

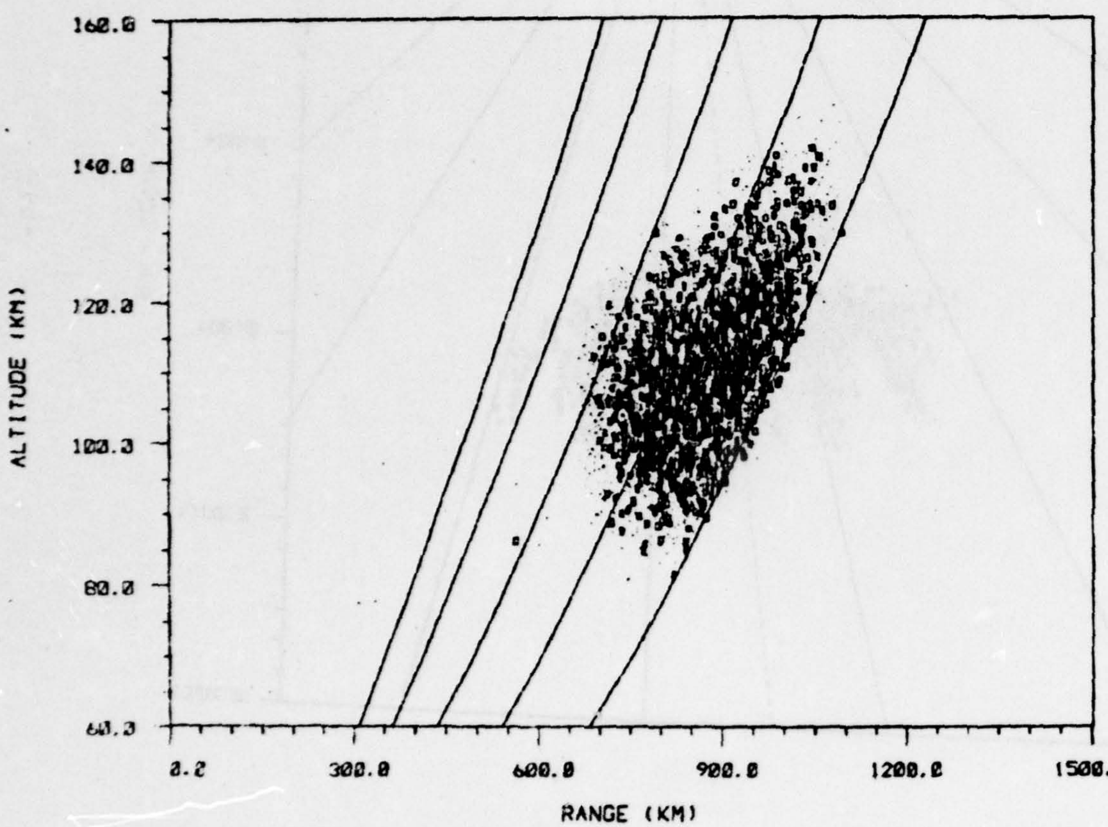
Figure 5-5



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

M&S OMPUTING

Figure 5-6



BEAM: BOTH
SCAN: 07
TIME: FROM 261/ 0/15/10
TO 261/ 0/15/30

DATA THINNING FACTOR: 2
AZ (DEG): -30.0 TO 70.0

AZIMUTHS	ON LEVEL
-30.0 TO -20.0 DEG	6
-20.0 TO -10.0 DEG	7
-10.0 TO 0.0 DEG	8
0.0 TO 10.0 DEG	9
10.0 TO 20.0 DEG	10
20.0 TO 30.0 DEG	11
30.0 TO 40.0 DEG	12
40.0 TO 50.0 DEG	13
50.0 TO 60.0 DEG	14
60.0 TO 70.0 DEG	15

M&S OMPUTING

Figure 5-7

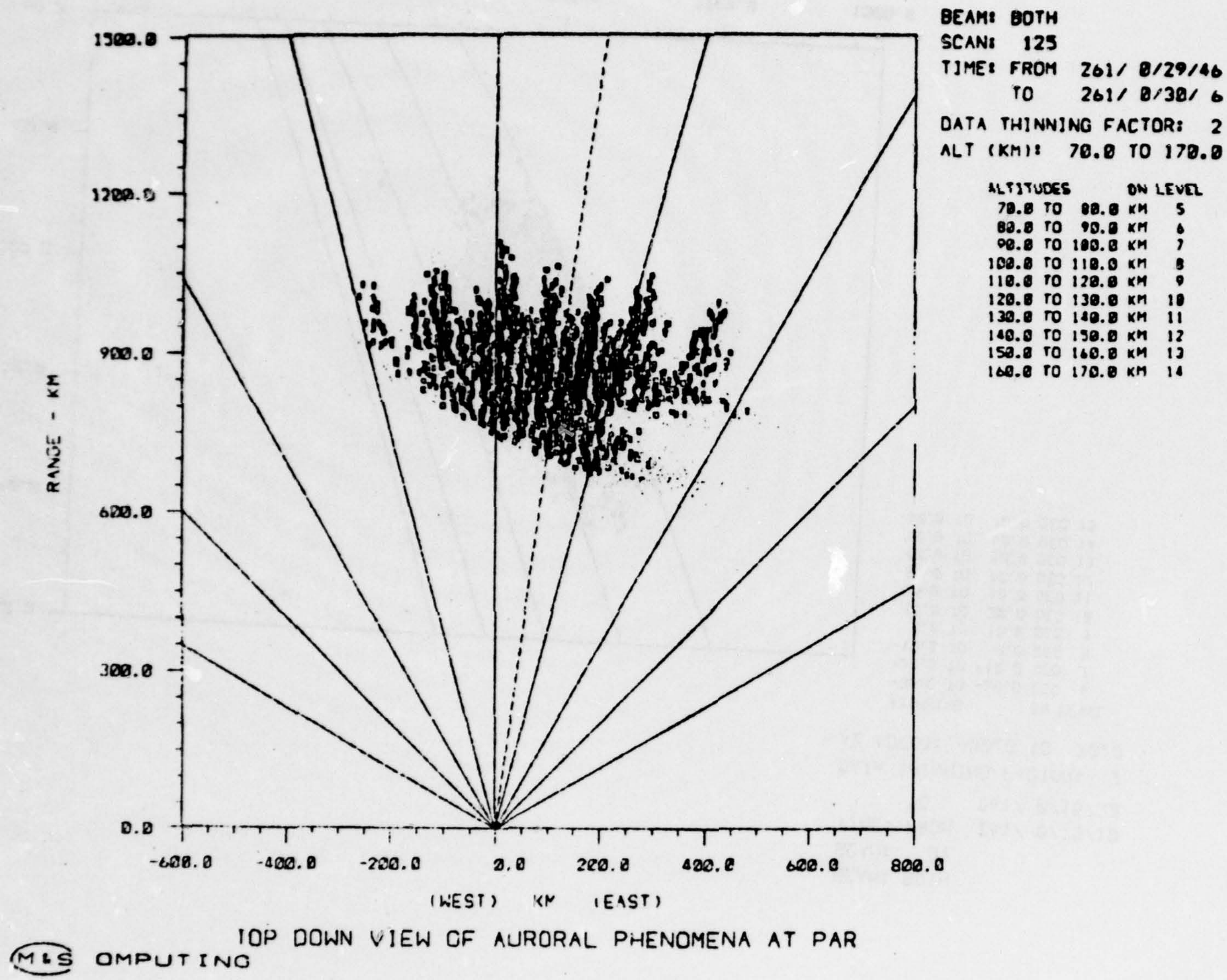
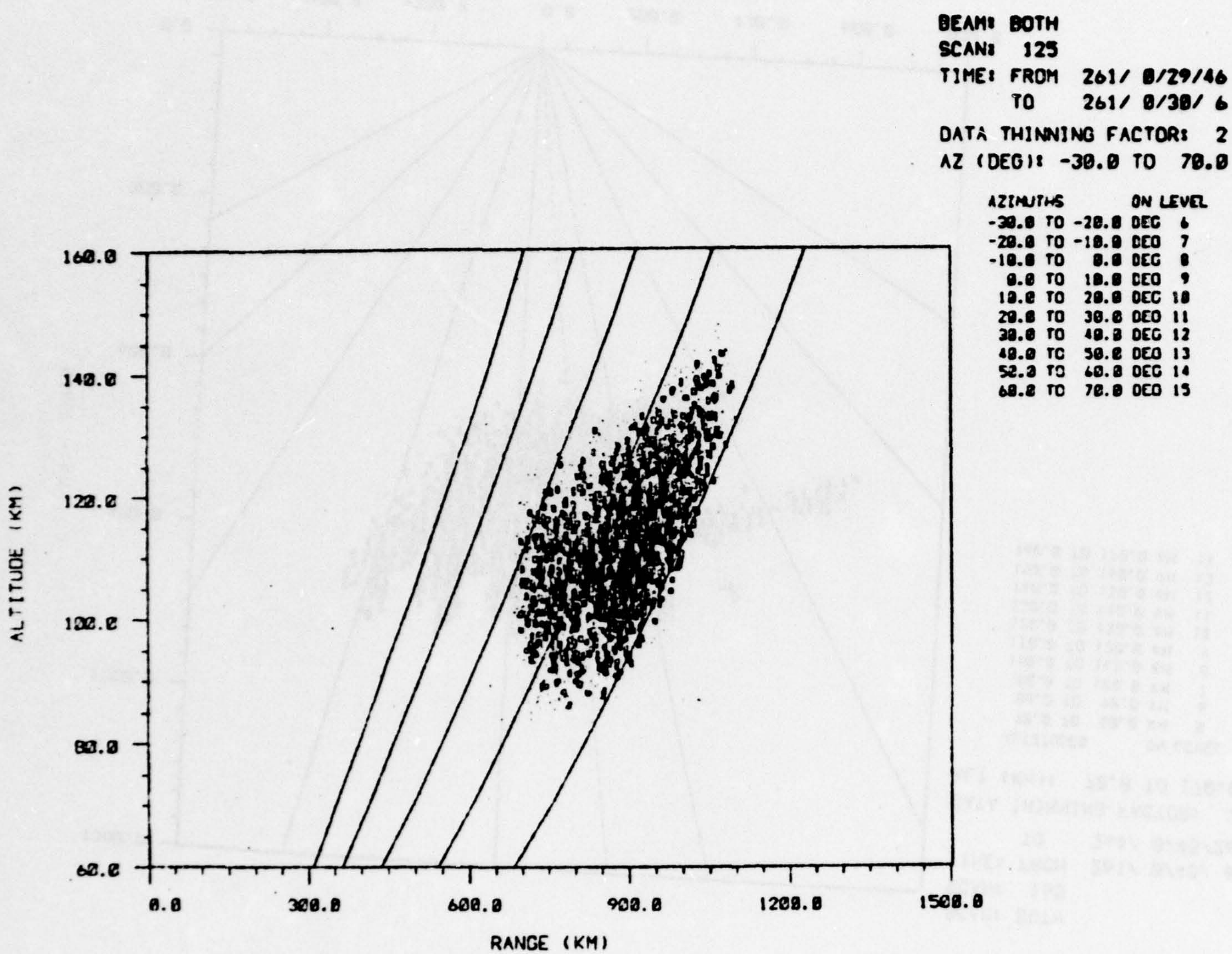
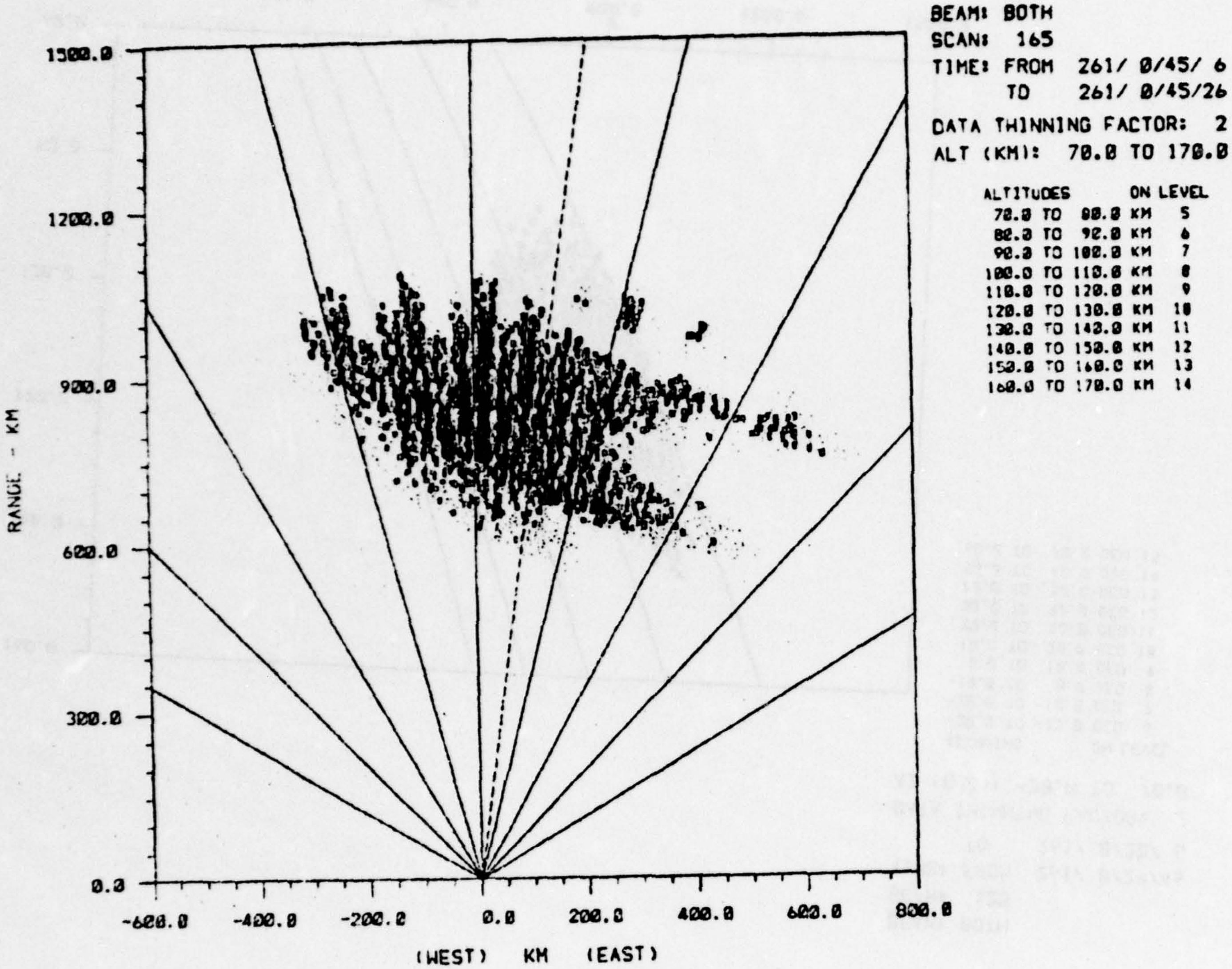

BEAM: BOTH
SCAN: 125
TIME: FROM 261/ 0/29/46
TO 261/ 0/30/ 6
DATA THINNING FACTOR: 2
ALT (KM): 70.0 TO 170.0
ALTITUDES ON LEVEL
70.0 TO 80.0 KM 5
80.0 TO 90.0 KM 6
90.0 TO 100.0 KM 7
100.0 TO 110.0 KM 8
110.0 TO 120.0 KM 9
120.0 TO 130.0 KM 10
130.0 TO 140.0 KM 11
140.0 TO 150.0 KM 12
150.0 TO 160.0 KM 13
160.0 TO 170.0 KM 14
RANGE - KM
1500.0
1200.0
900.0
600.0
300.0
0.0
-600.0
-400.0
-200.0
0.0
200.0
400.0
600.0
800.0
(WEST) KM (EAST)
TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR
M&S OMPUTING

Figure 5-8



M&S COMPUTING

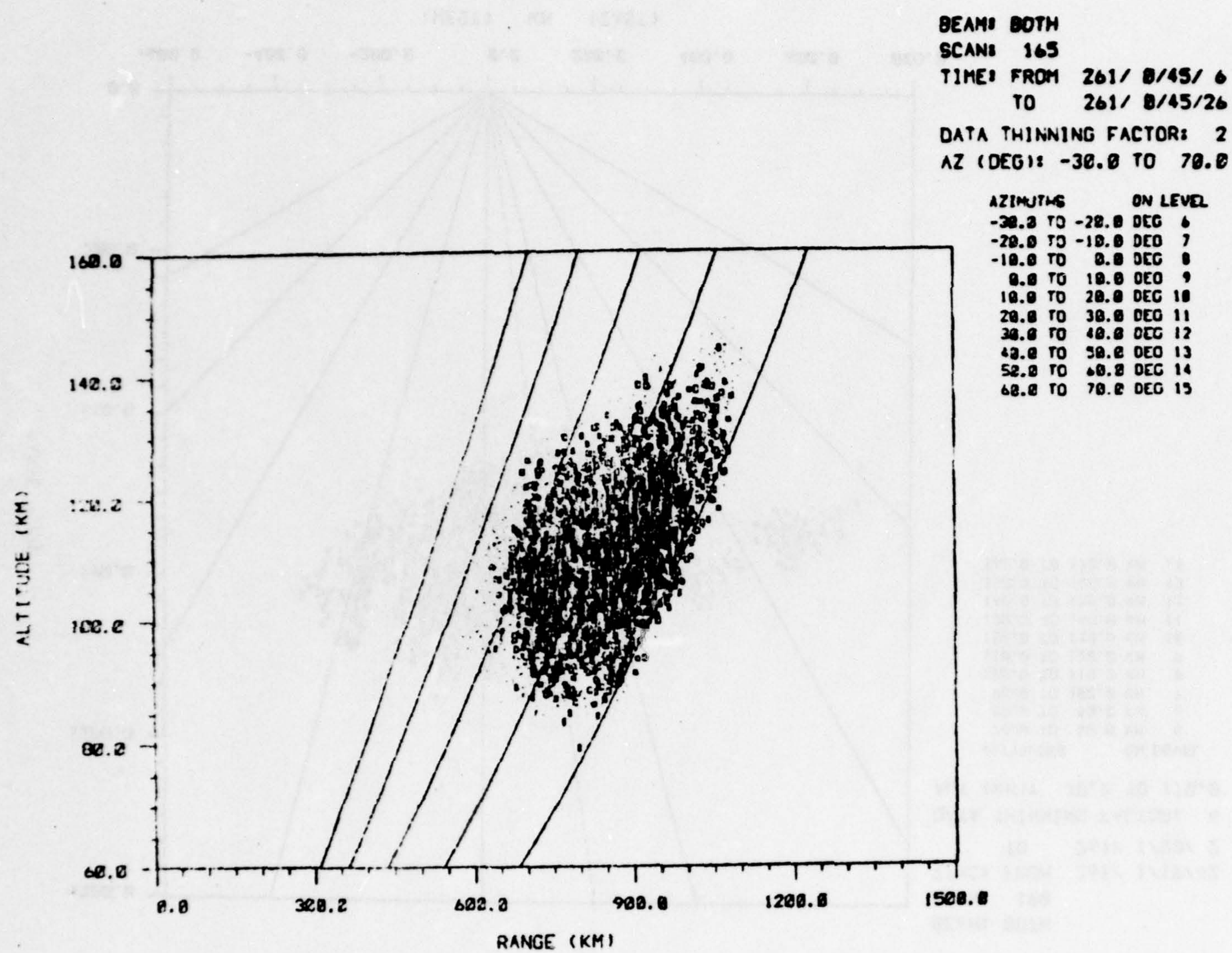
Figure 5-9



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

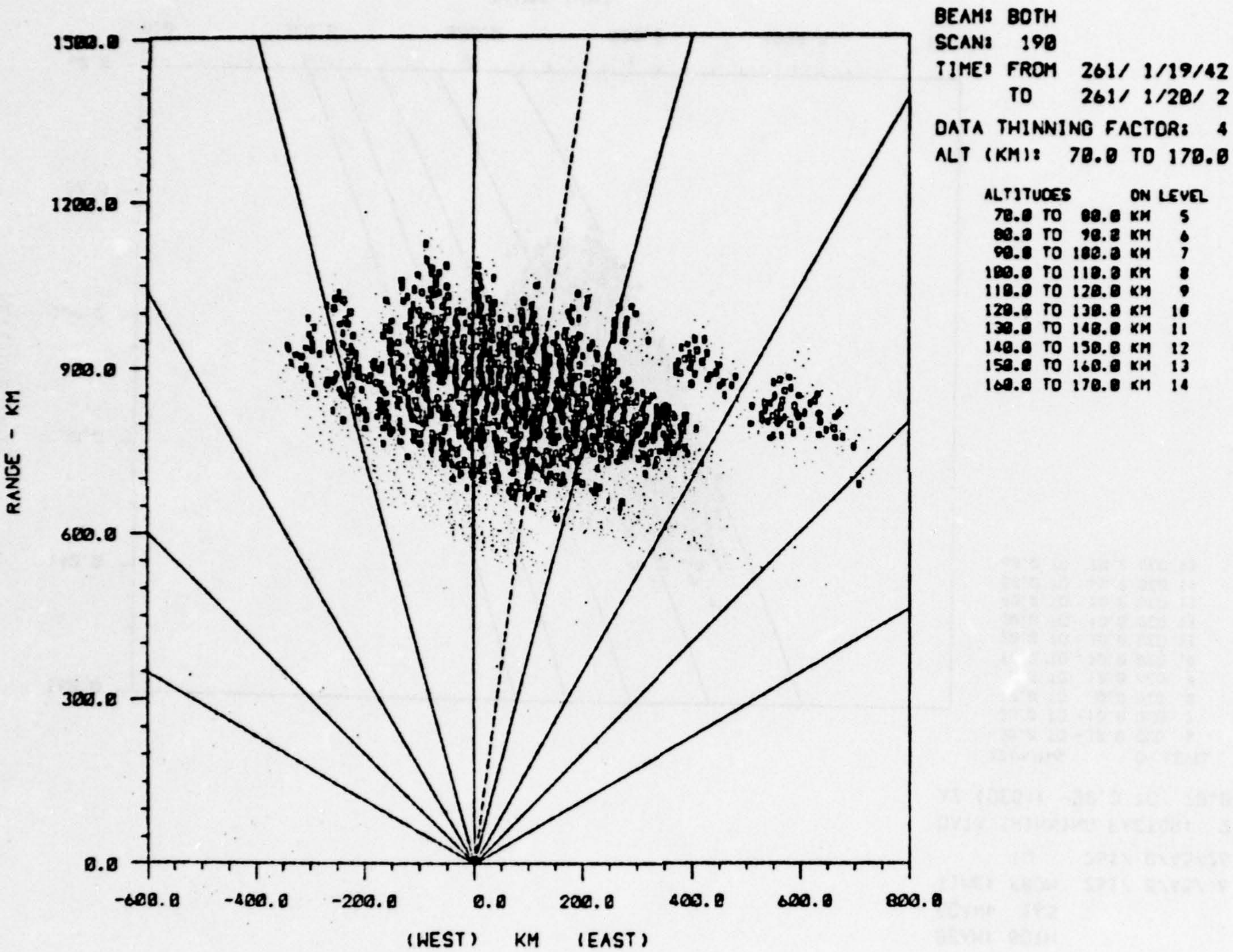
M&S OMPUTING

Figure 5-10



M&S COMPUTING

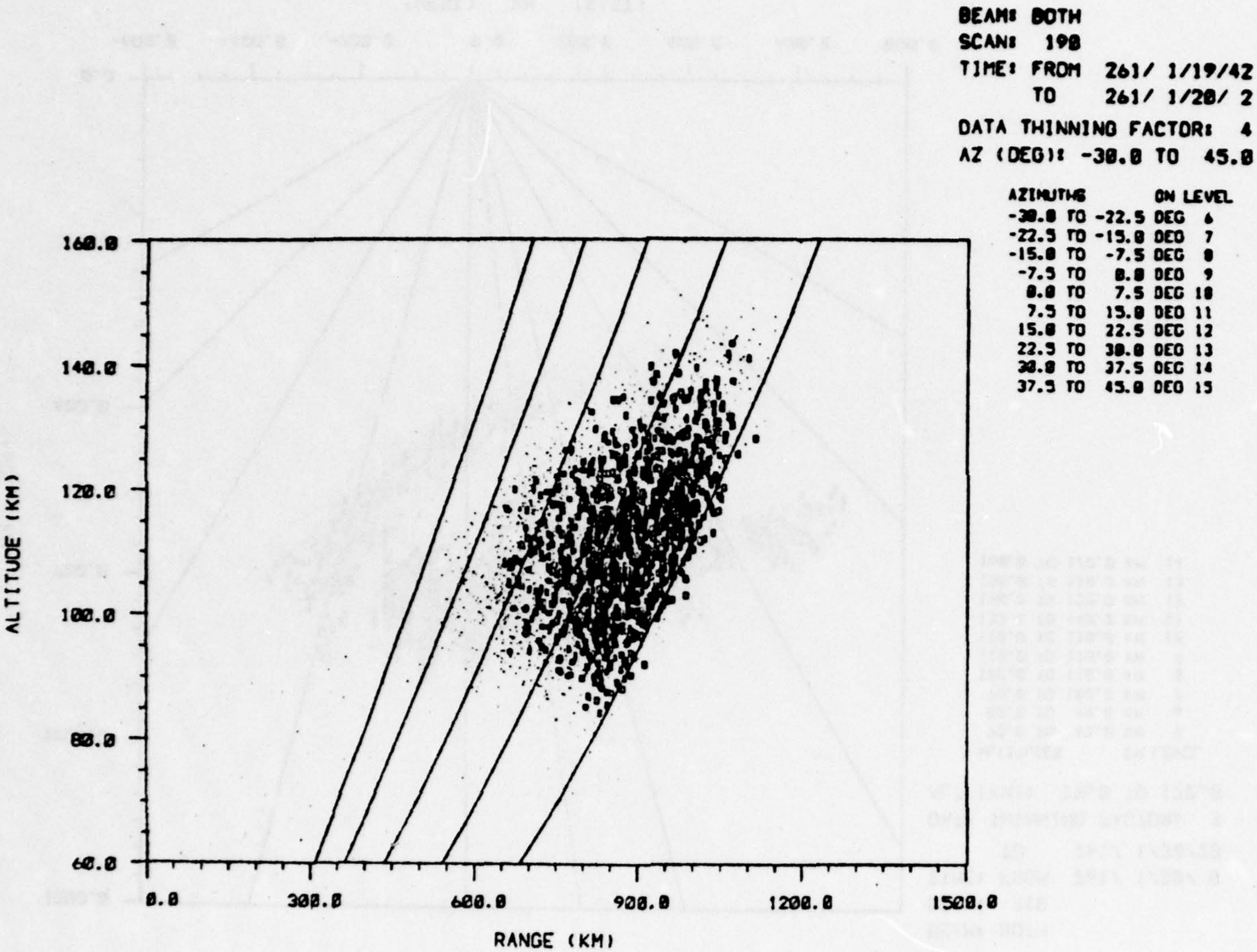
Figure 5-11



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

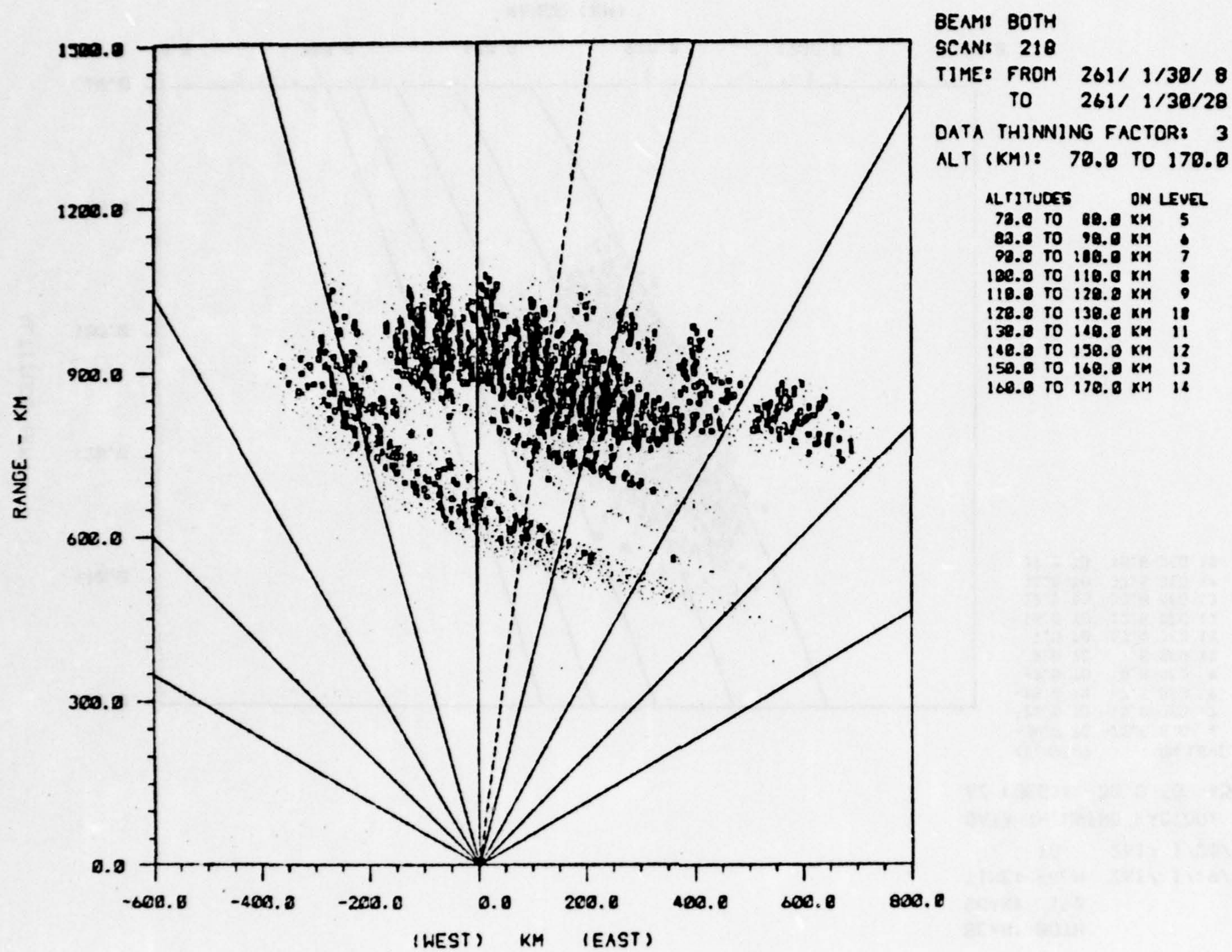
M&S COMPUTING

Figure 5-12



M&S COMPUTING

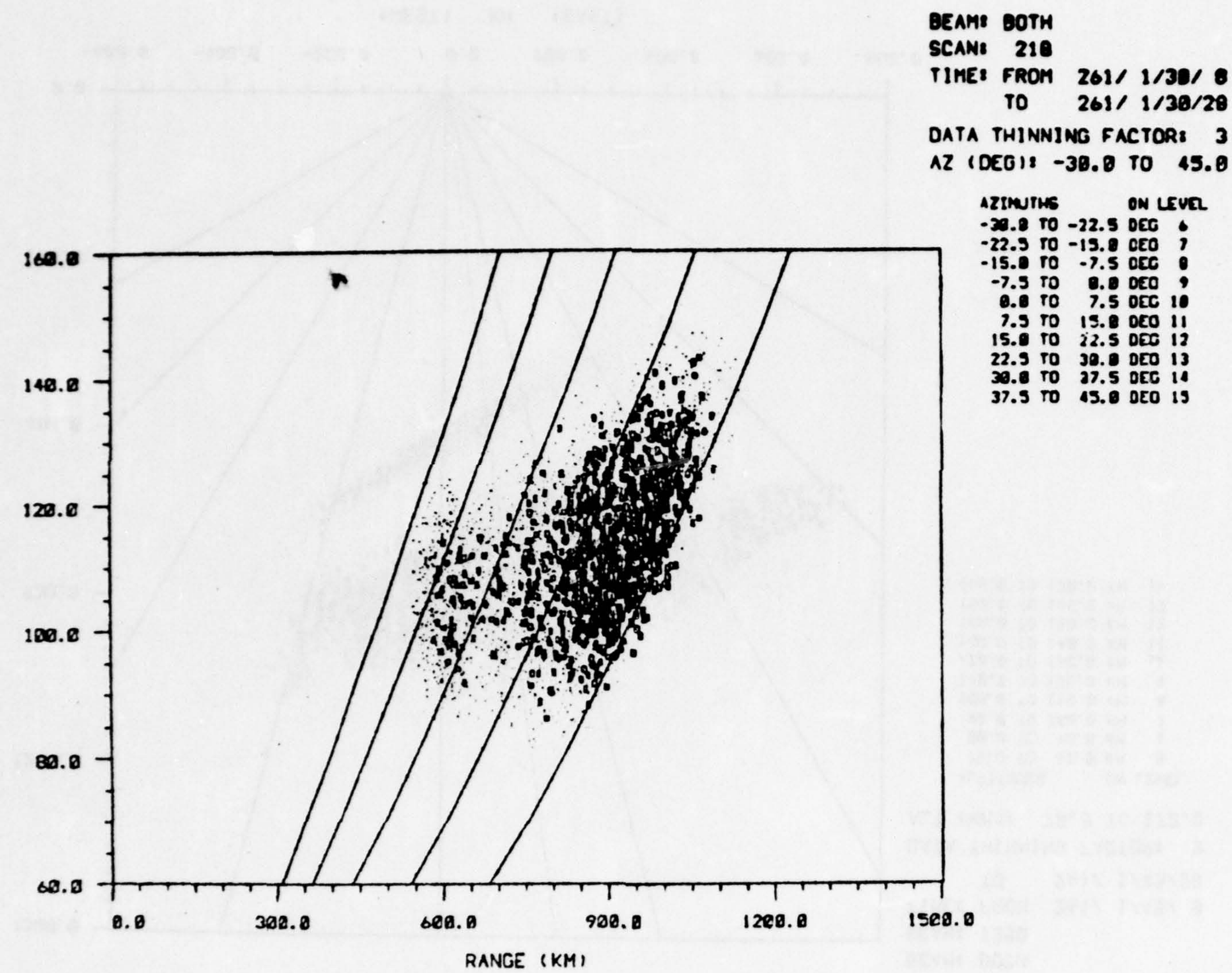
Figure 5-13



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

M&S COMPUTING

Figure 5-14



M&S COMPUTING

Figure 5-15

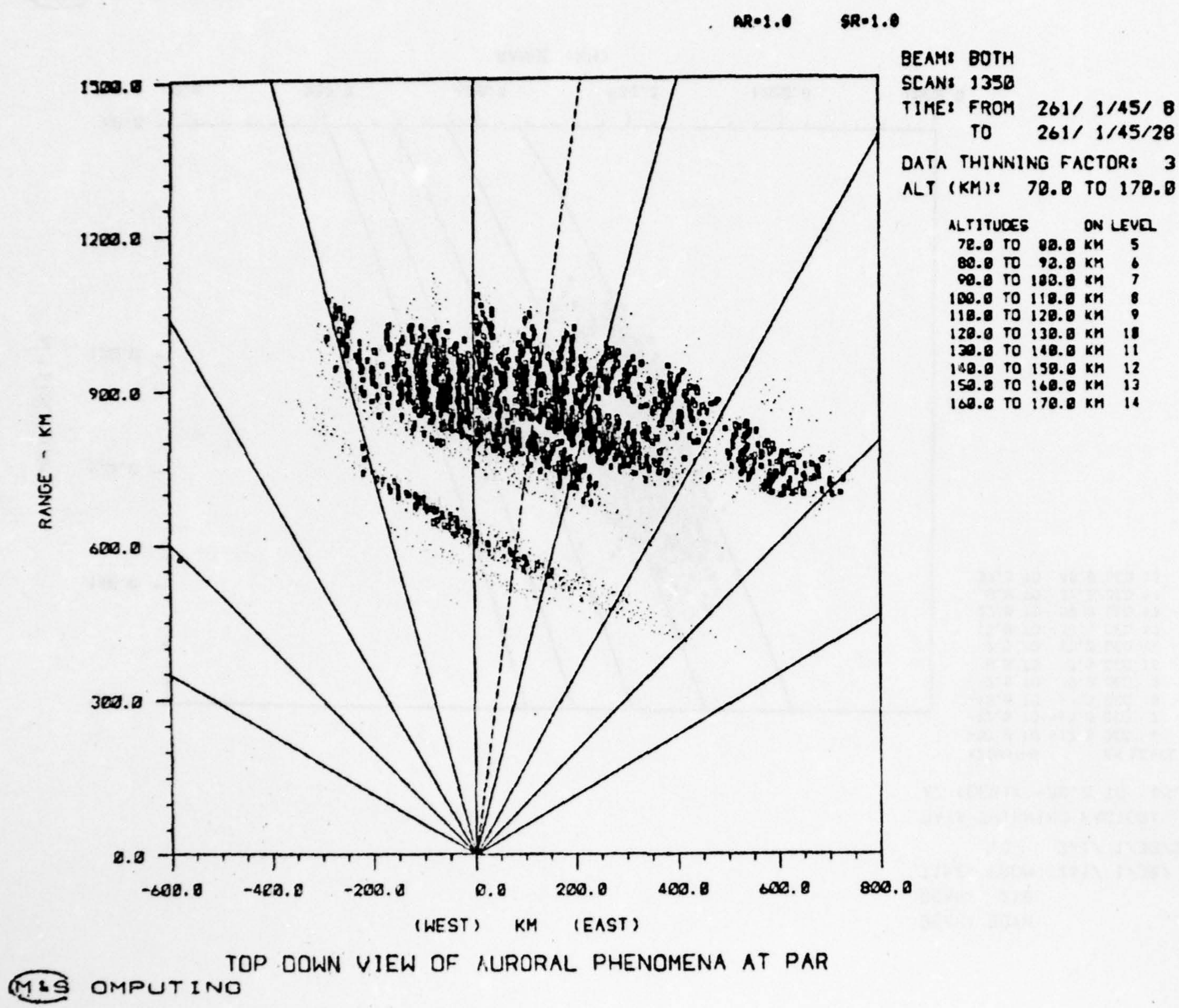
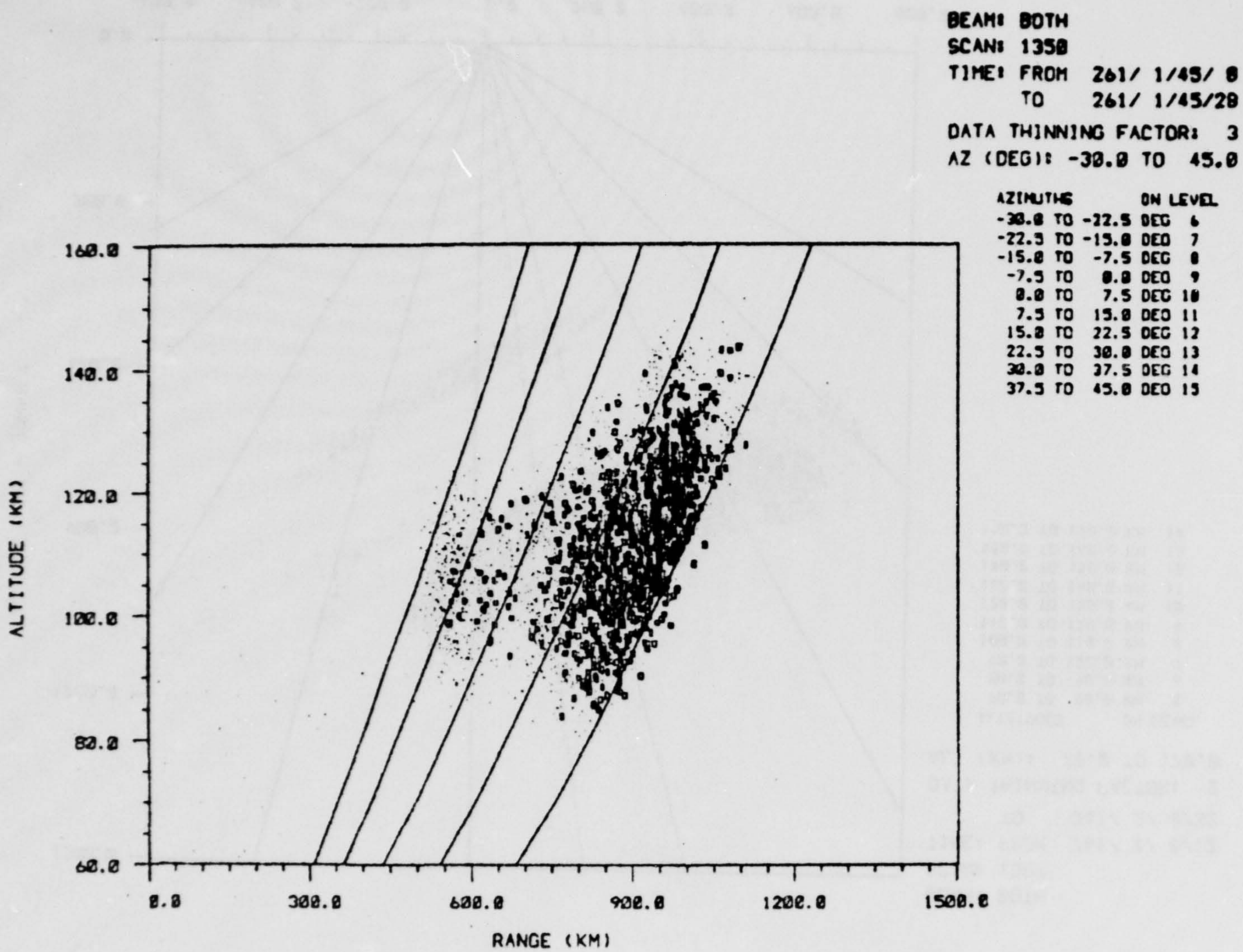
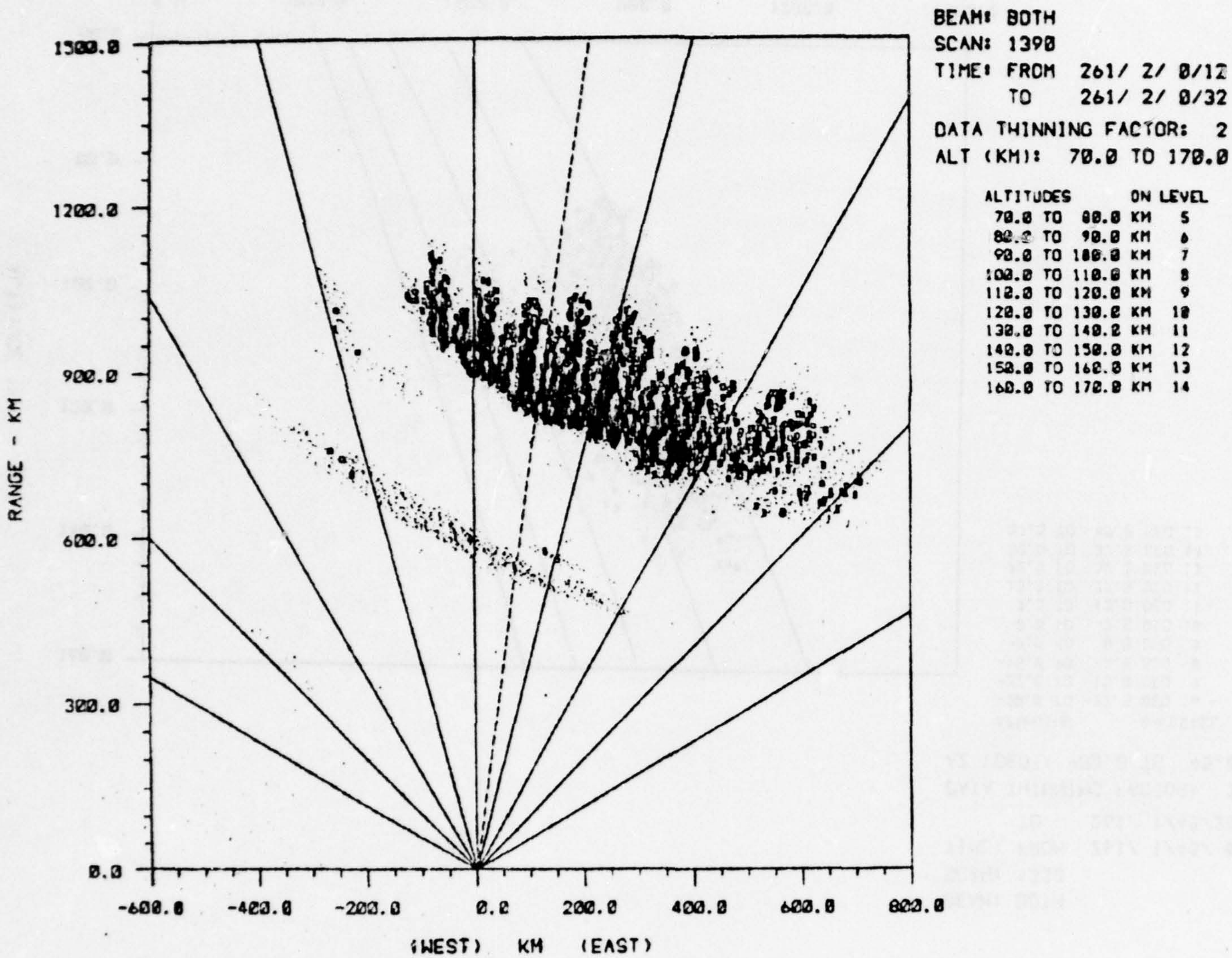

AR=1.0 SR=1.0
BEAM: BOTH
SCAN: 1350
TIME: FROM 261/ 1/45/ 8
TO 261/ 1/45/28
DATA THINNING FACTOR: 3
ALT (KM): 70.0 TO 170.0
ALTITUDES ON LEVEL
70.0 TO 80.0 KM 5
80.0 TO 90.0 KM 6
90.0 TO 100.0 KM 7
100.0 TO 110.0 KM 8
110.0 TO 120.0 KM 9
120.0 TO 130.0 KM 10
130.0 TO 140.0 KM 11
140.0 TO 150.0 KM 12
150.0 TO 160.0 KM 13
160.0 TO 170.0 KM 14
RANGE - KM
1500.0
1200.0
900.0
600.0
300.0
0.0
-600.0
-400.0
-200.0
0.0
200.0
400.0
600.0
800.0
(WEST) KM (EAST)
TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR
M&S OMPUTING

Figure 5-16



M&S OMPUTING

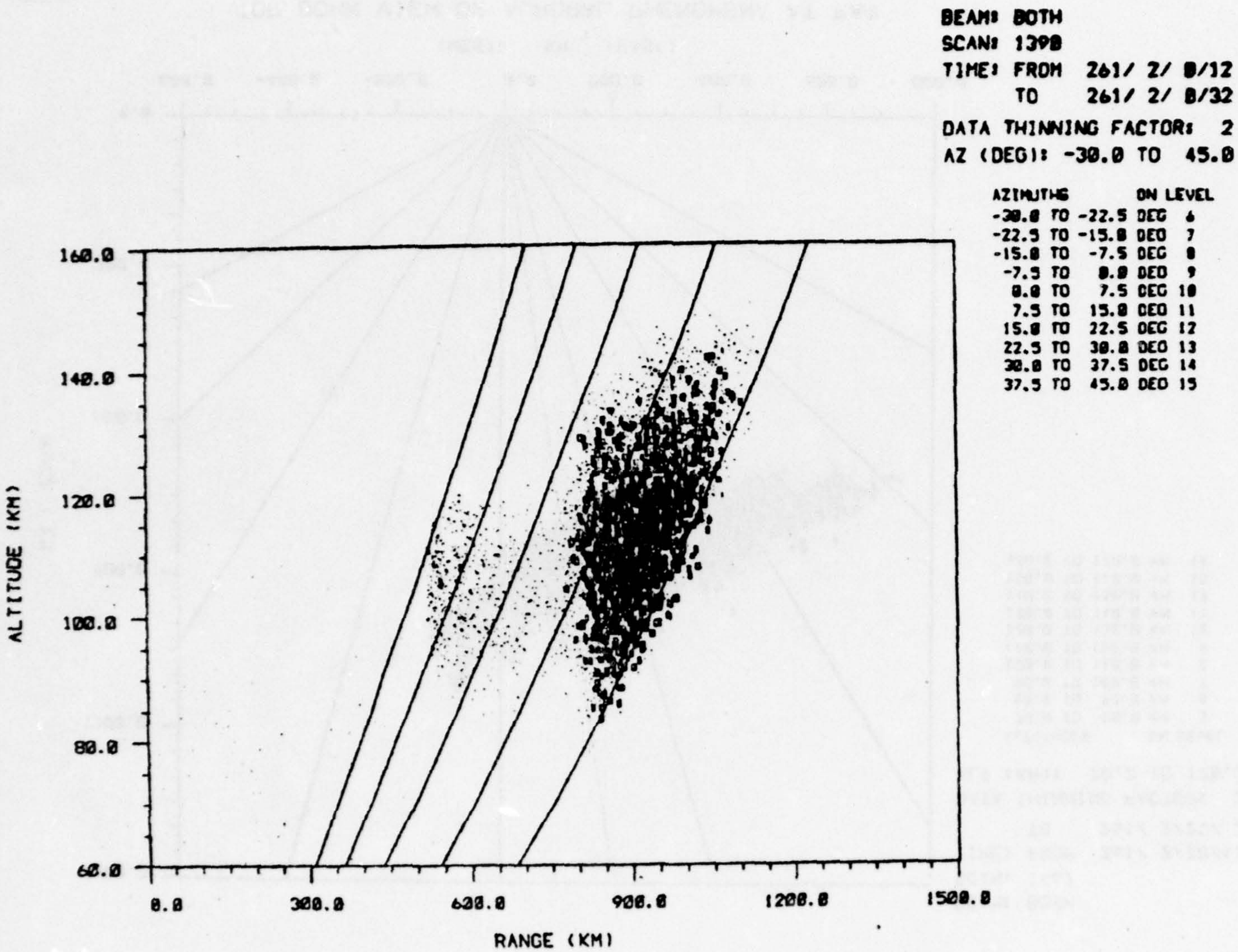
Figure 5-17



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

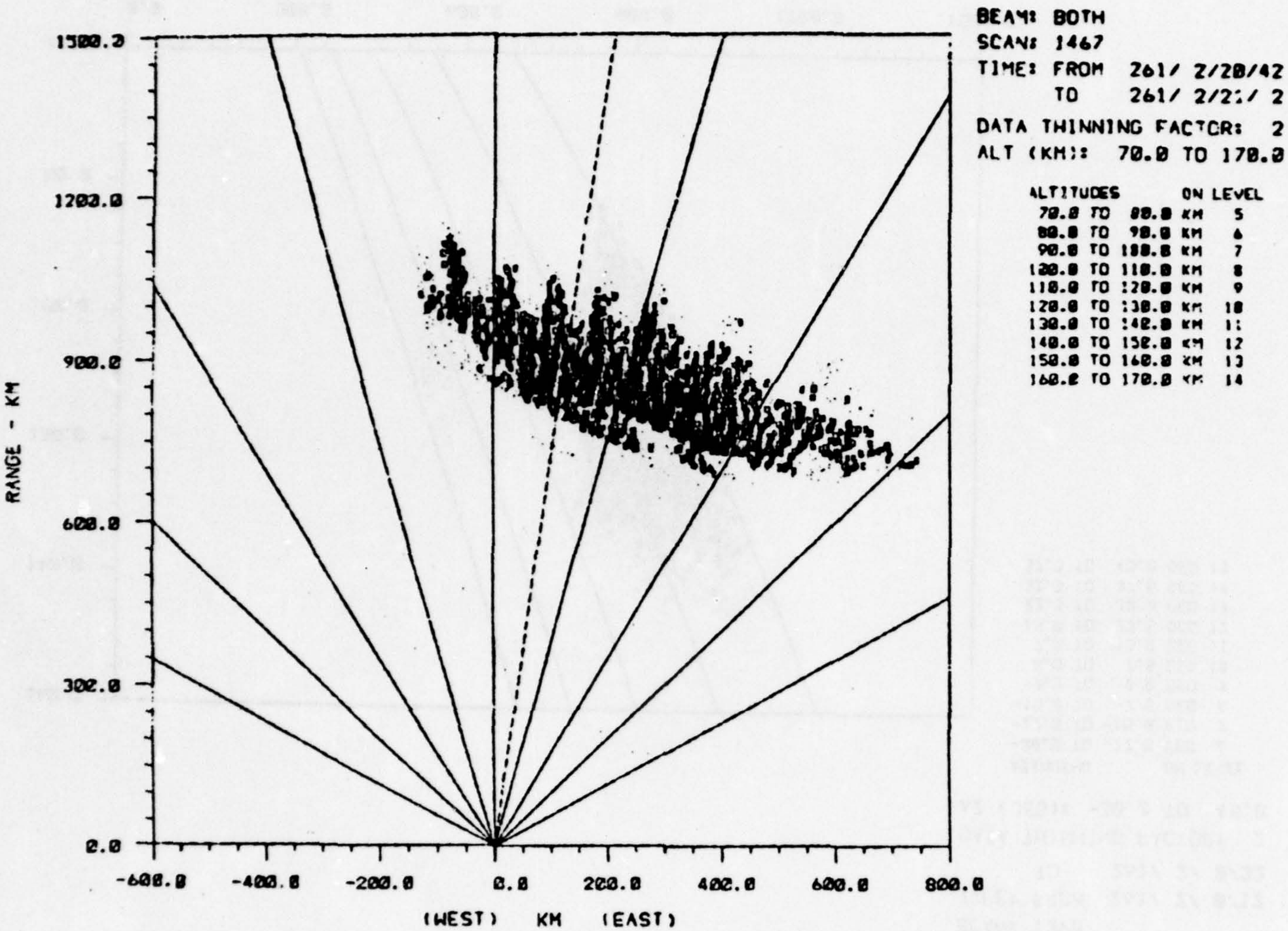
M&S OMPUTING

Figure 5-18



M&S OMPUTING

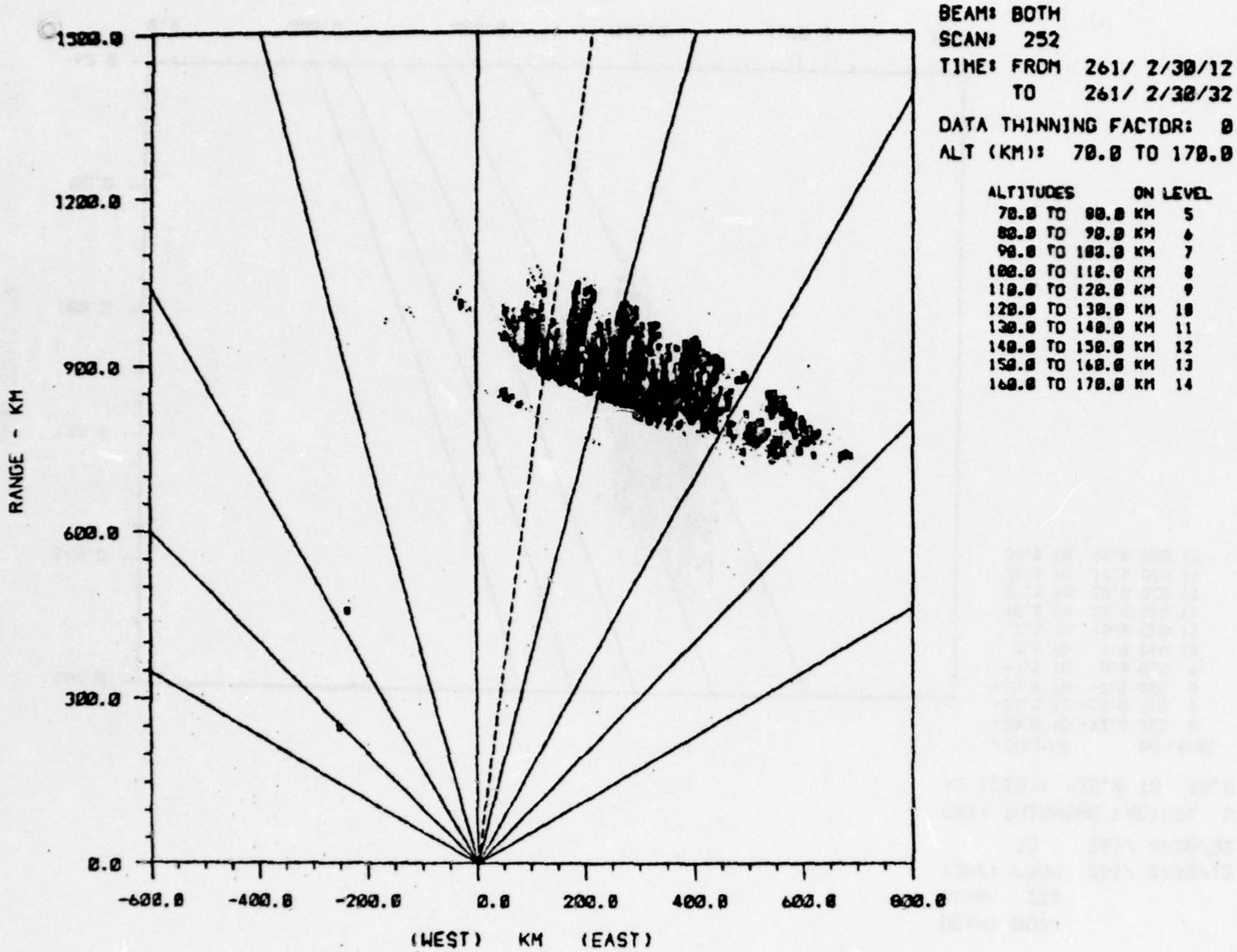
Figure 5-19



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

M&S OMPUTINO

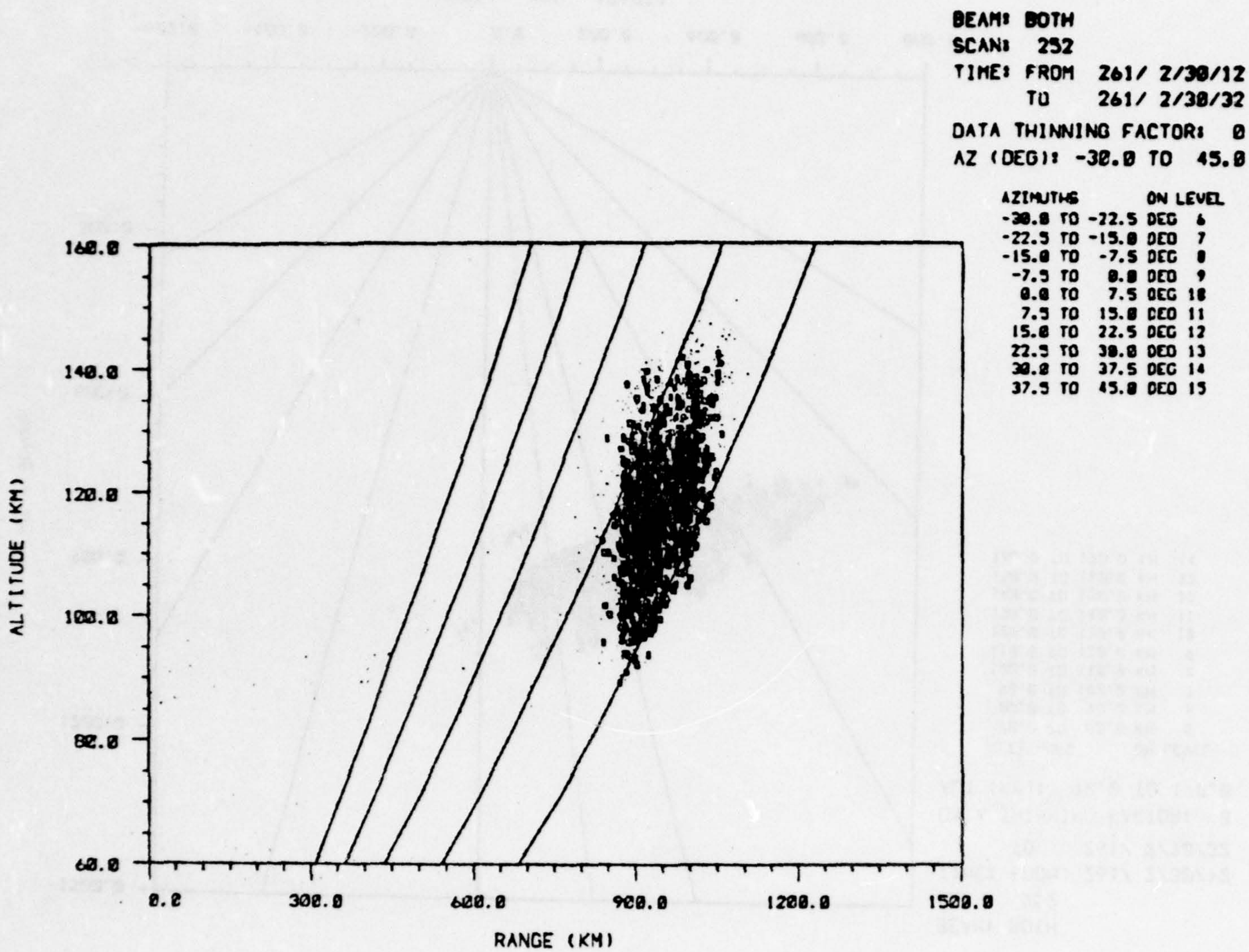
Figure 5-20



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

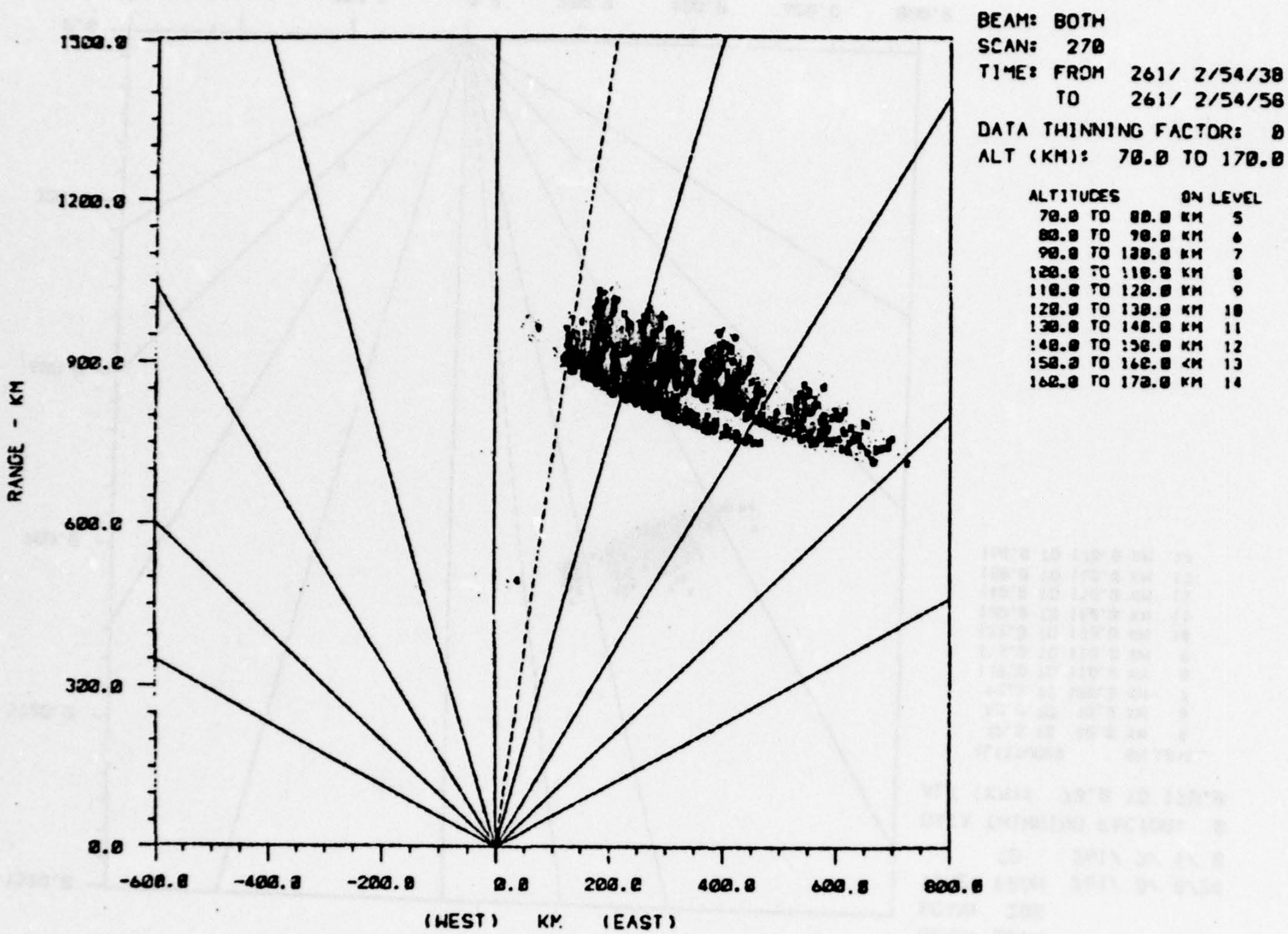
M&S OMPUTING

Figure 5-21



MLS OMPUTING

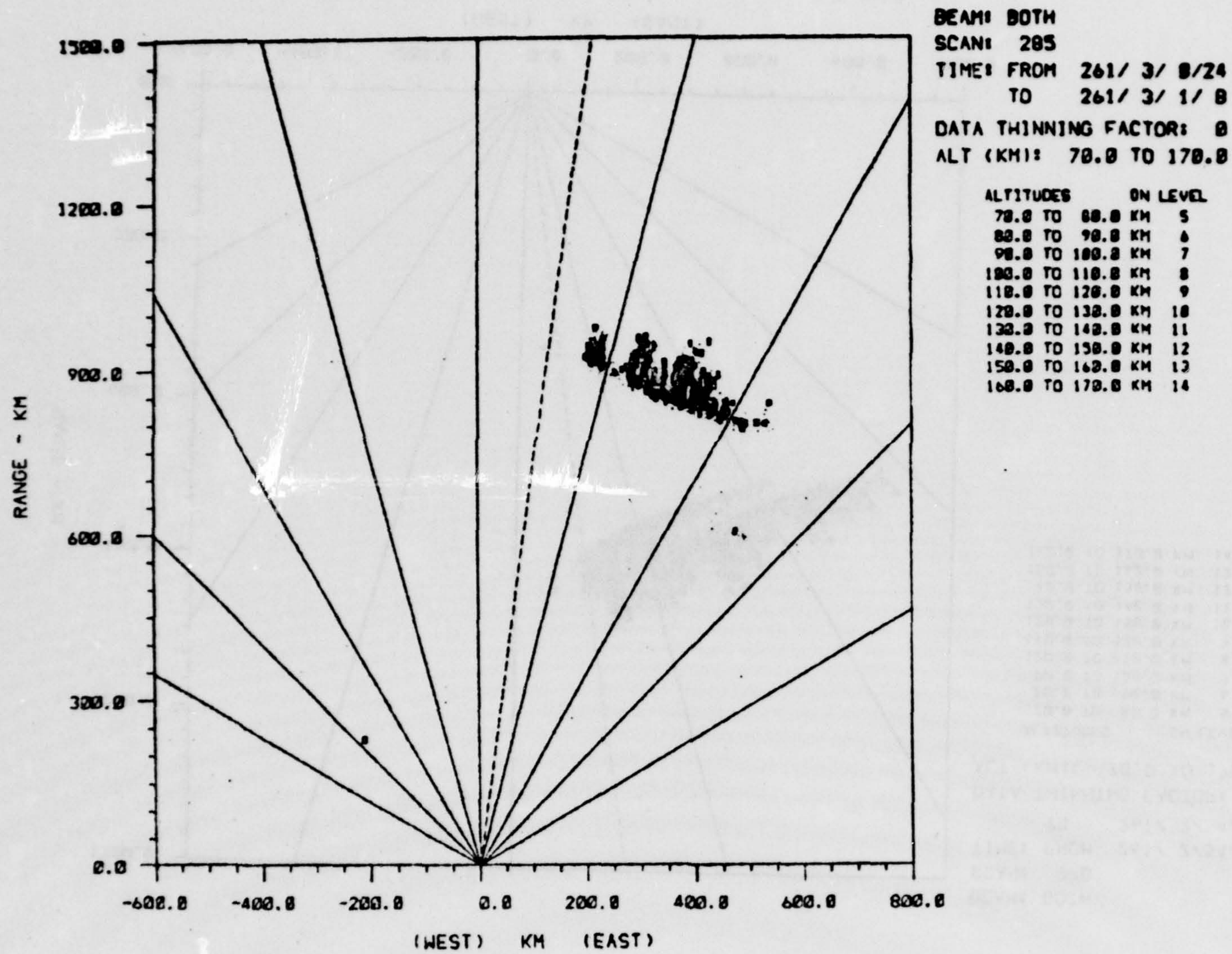
Figure 5-22



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

M&S OMPUTING

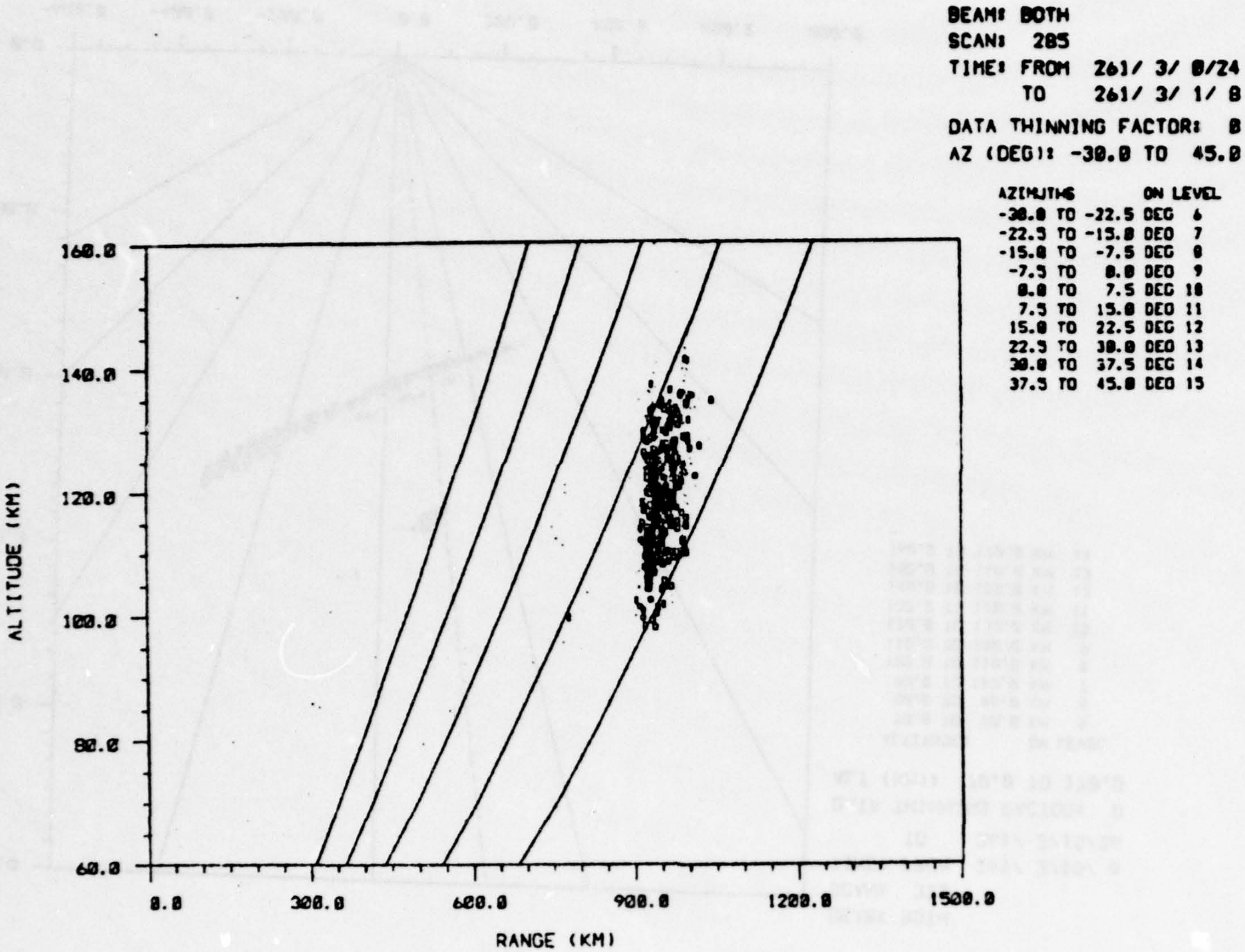
Figure 5-23



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

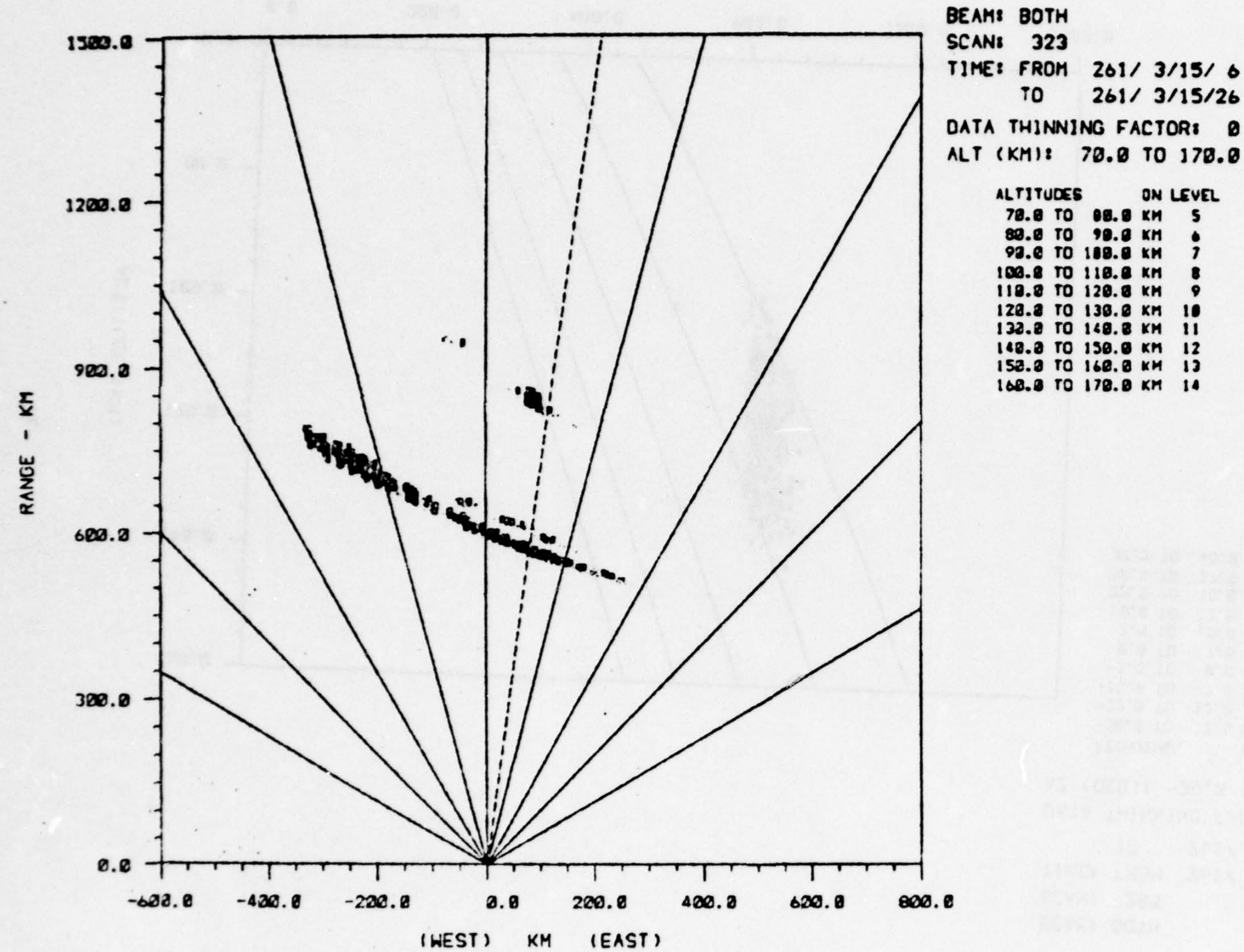
MRS COMPUTING

Figure 5-24



MTS OMPUTING

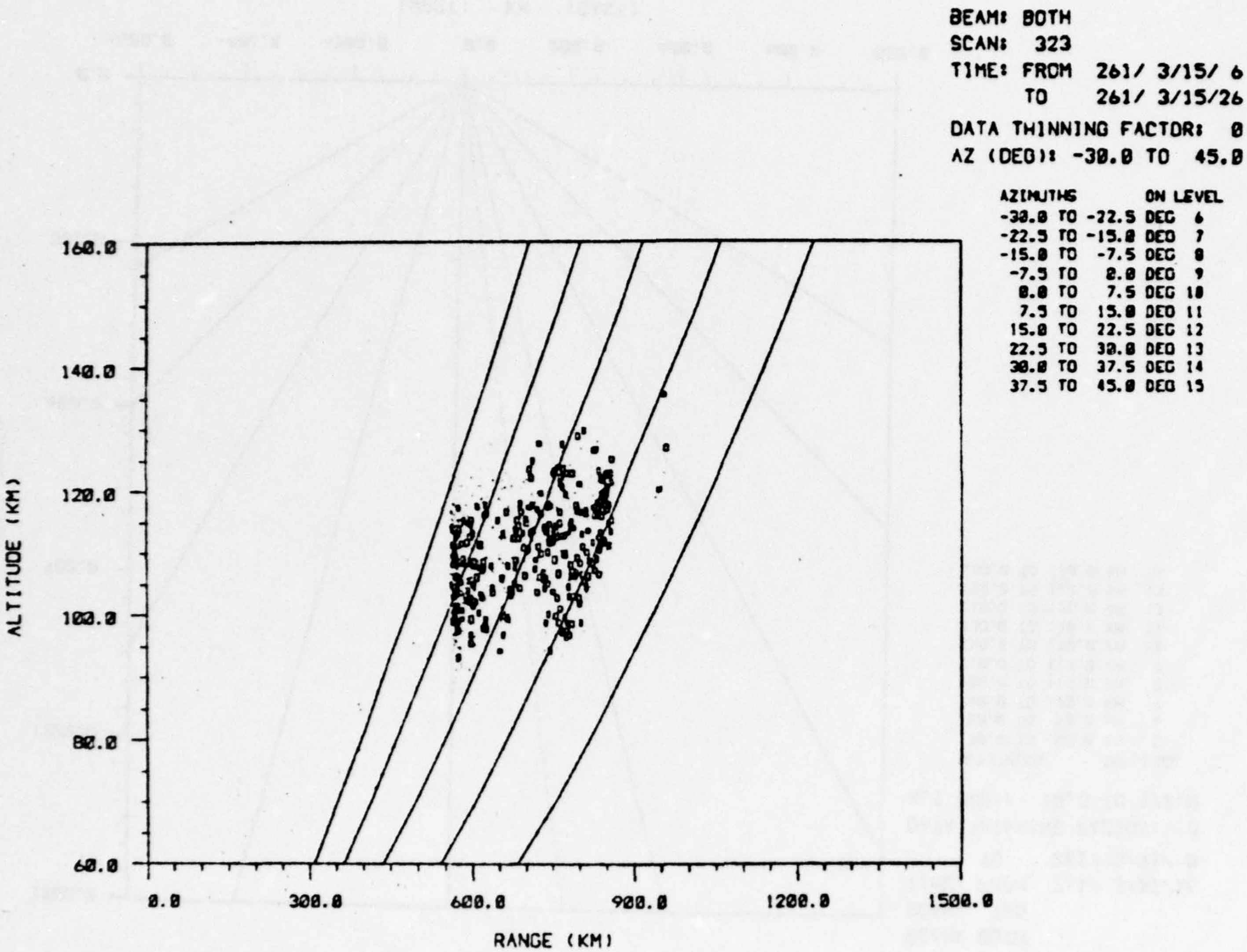
Figure 5-25



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

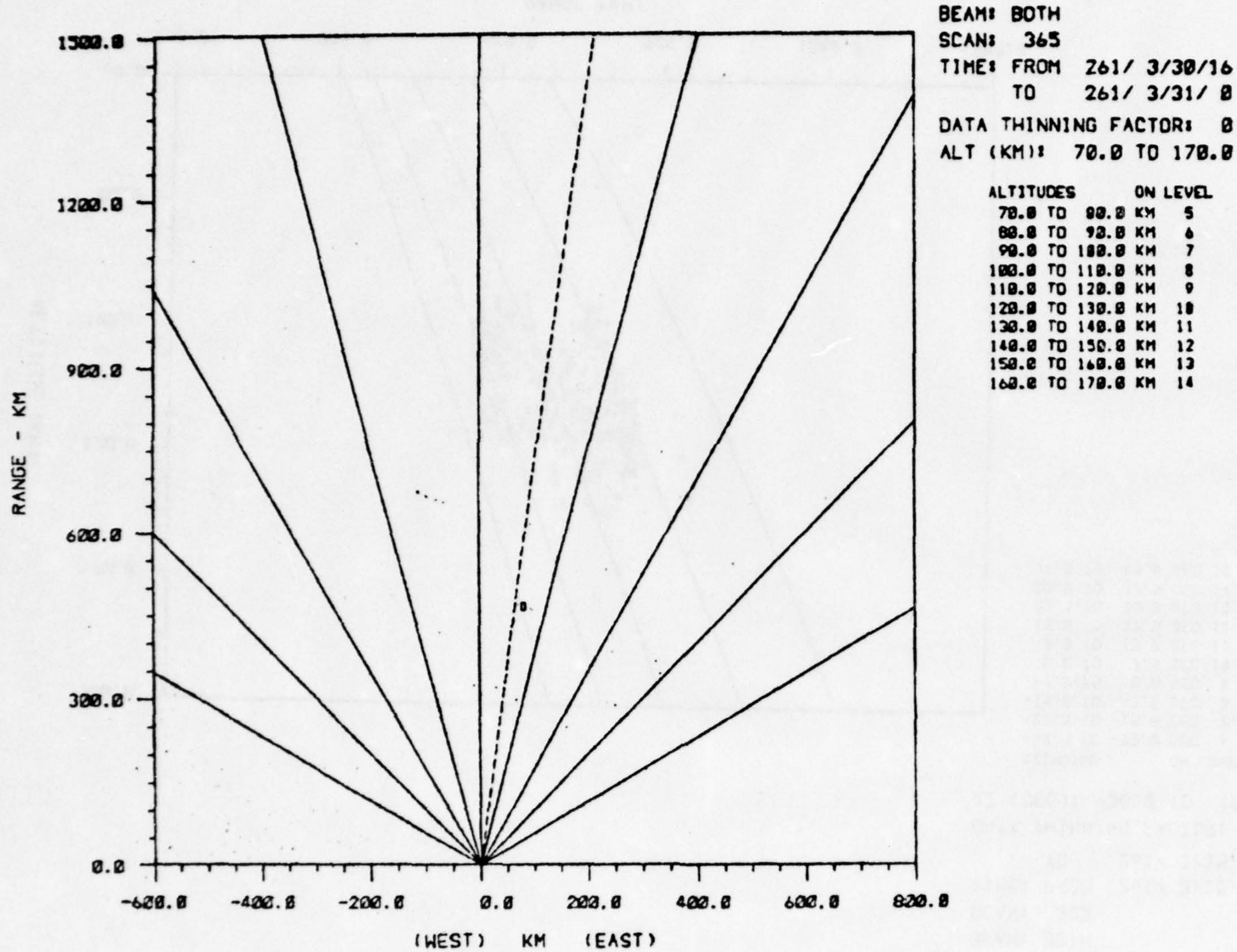
M&S OMPUTINO

Figure 5-26



M&S OMPUTINO

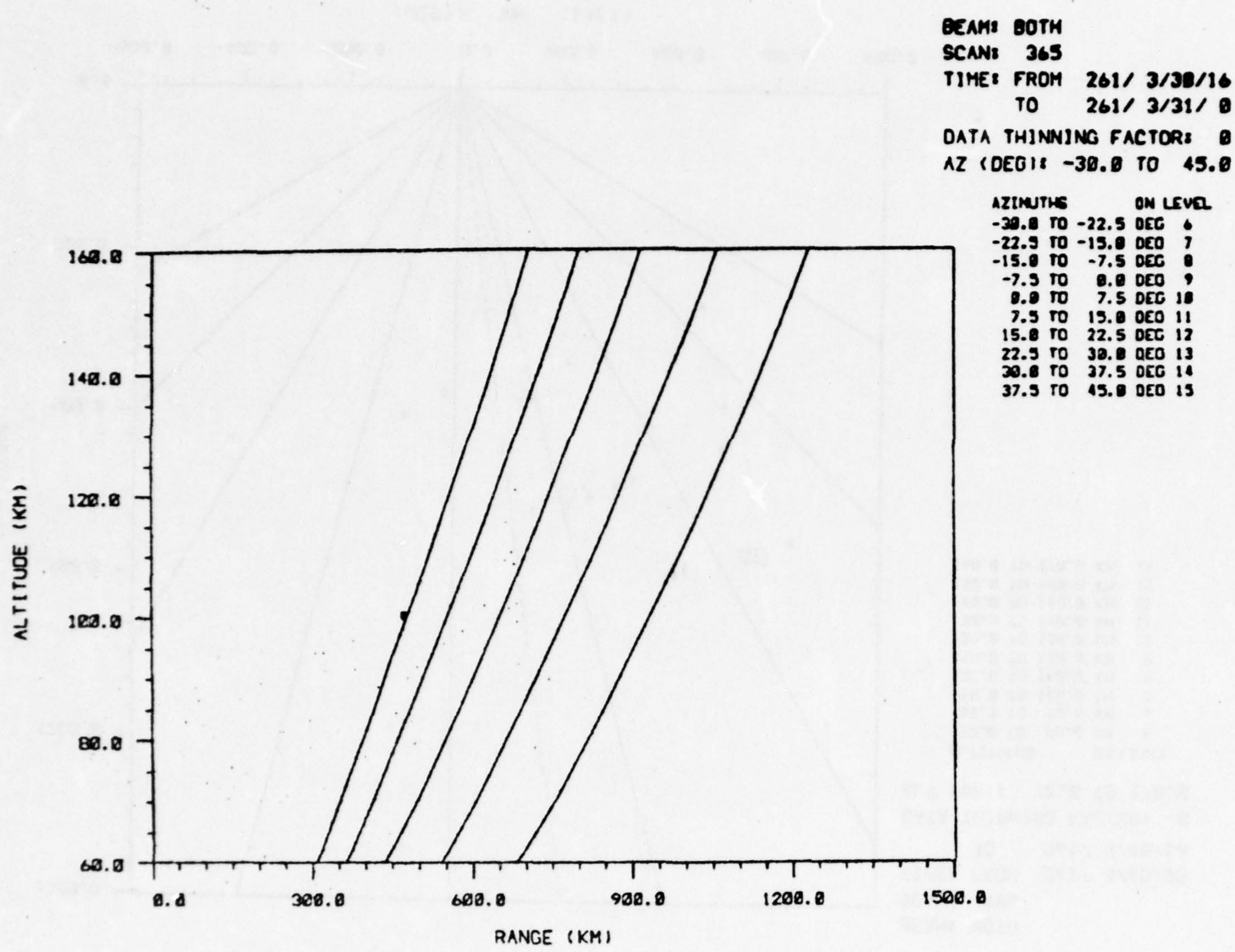
Figure 5-27



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

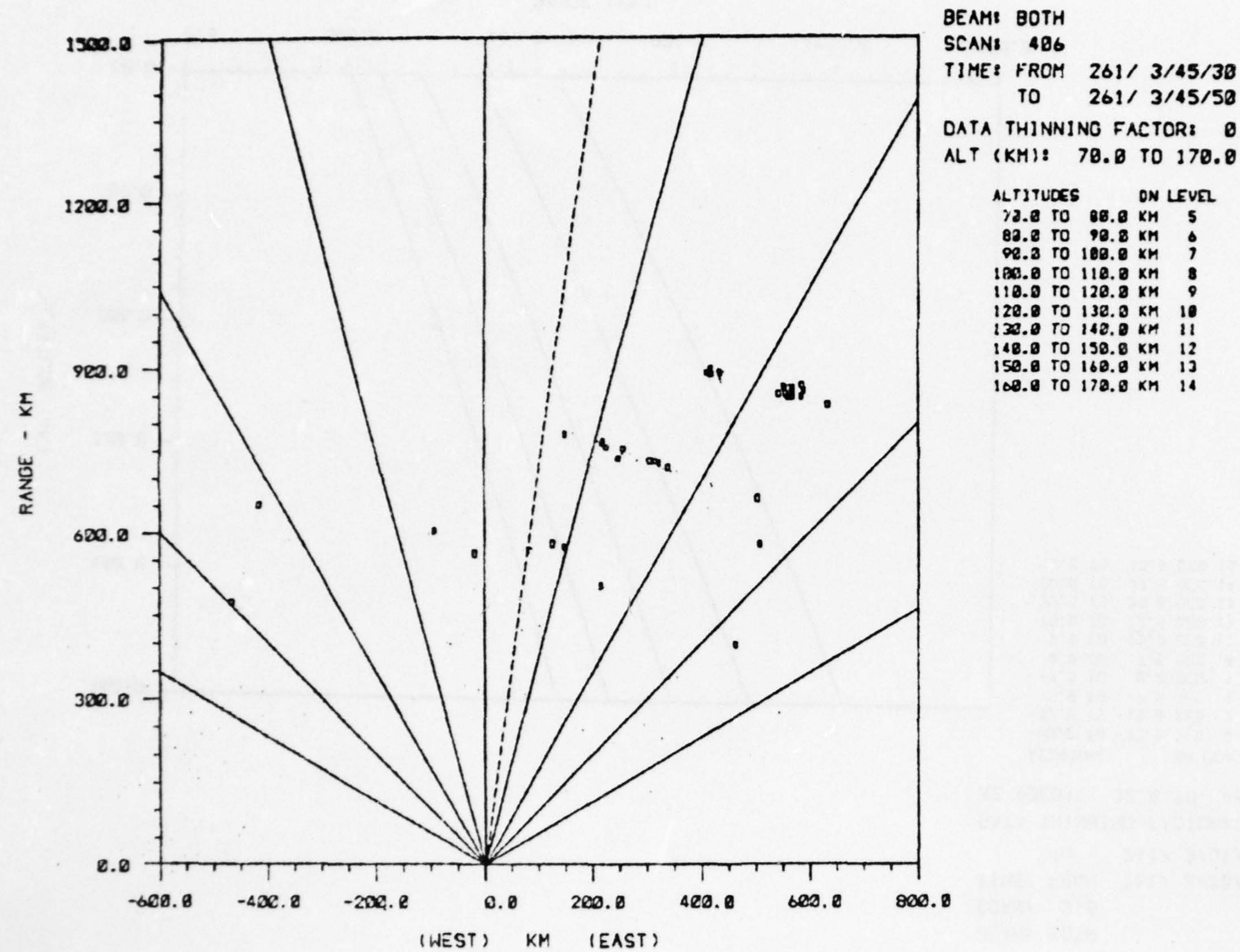
M&S OMPUTING

Figure 5-28



M&S OMPUTING

Figure 5-29



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

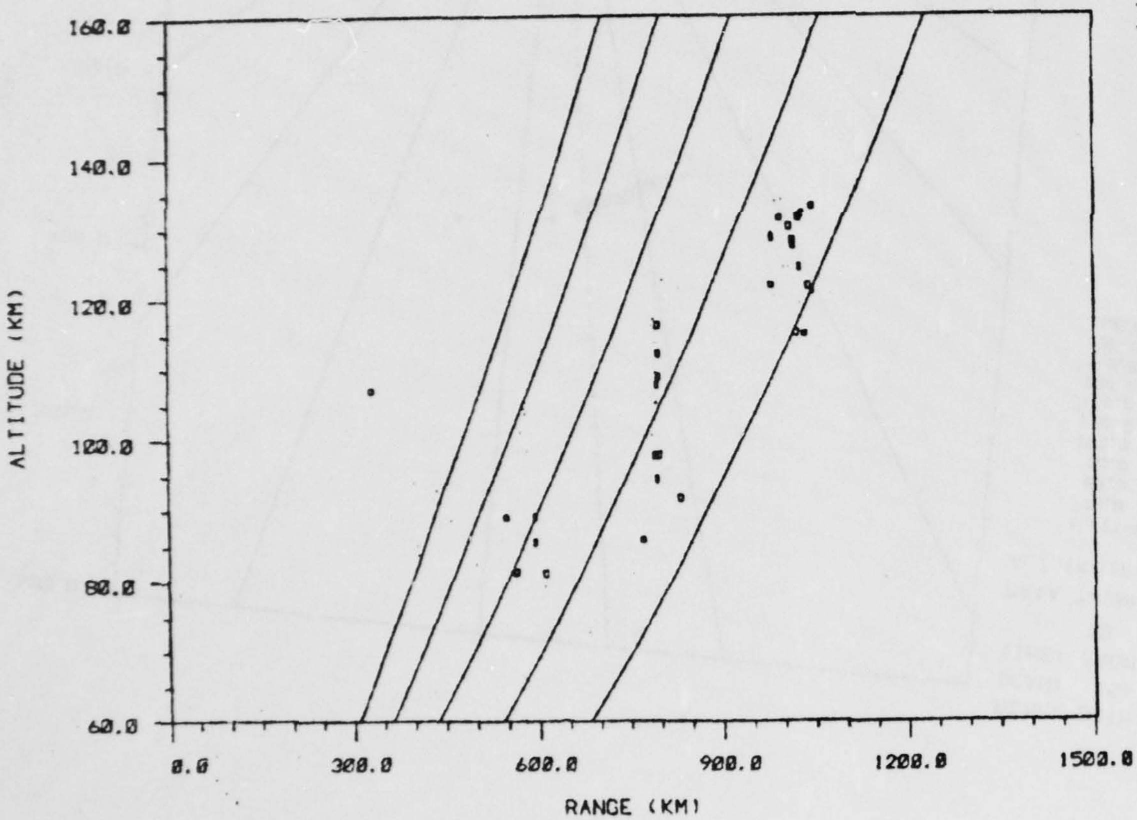
M&S COMPUTING

Figure 5-30

BEAM: BOTH
SCAN: 406
TIME: FROM 261/ 3/45/30
TO 261/ 3/45/50

DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 45.0

AZIMUTHS			ON LEVEL
-30.0 TO -22.5	DEG	6	
-22.5 TO -15.0	DEG	7	
-15.0 TO -7.5	DEG	8	
-7.5 TO 0.0	DEG	9	
0.0 TO 7.5	DEG	10	
7.5 TO 15.0	DEG	11	
15.0 TO 22.5	DEG	12	
22.5 TO 30.0	DEG	13	
30.0 TO 37.5	DEG	14	
37.5 TO 45.0	DEG	15	



M&S COMPUTING

Figure 5-31

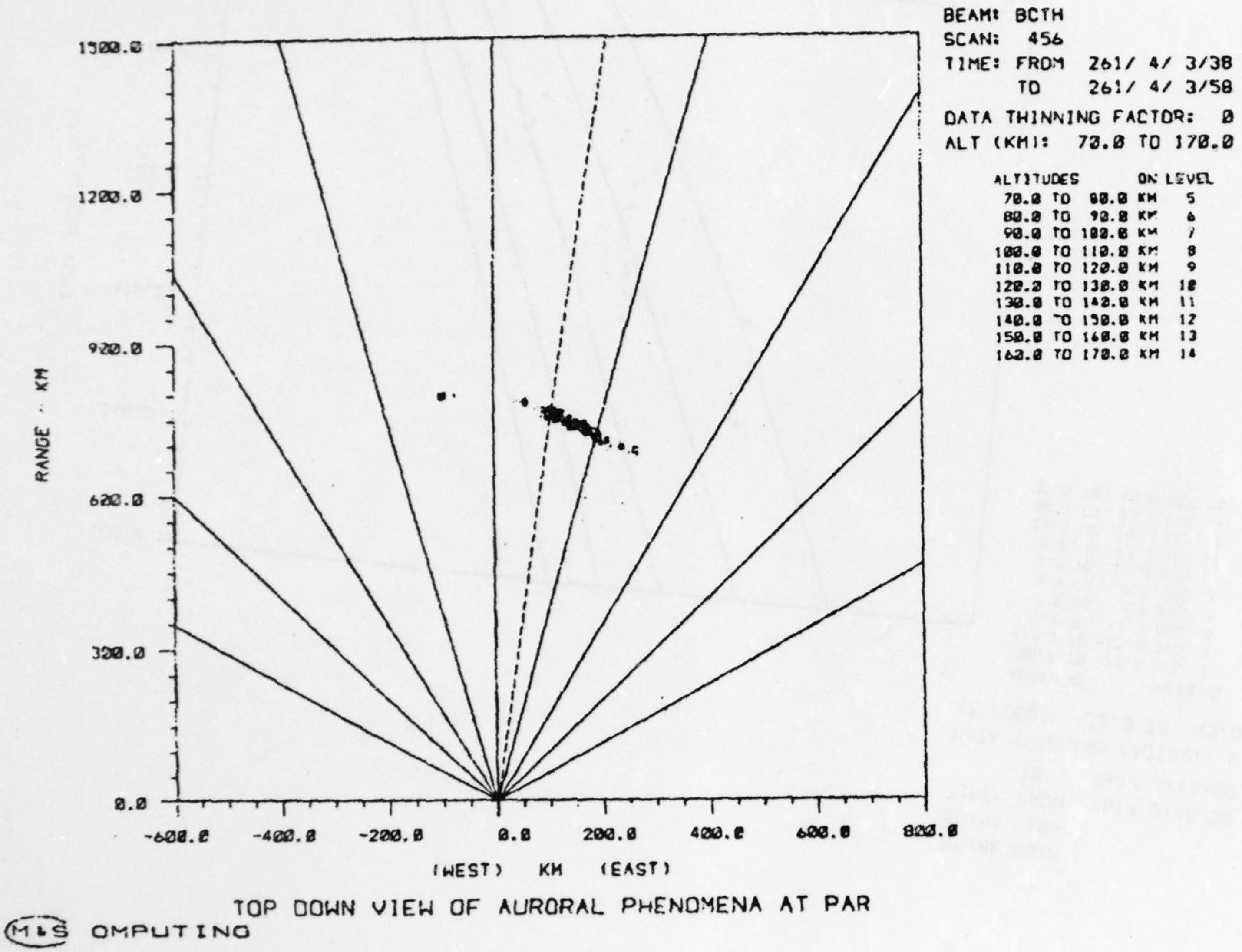
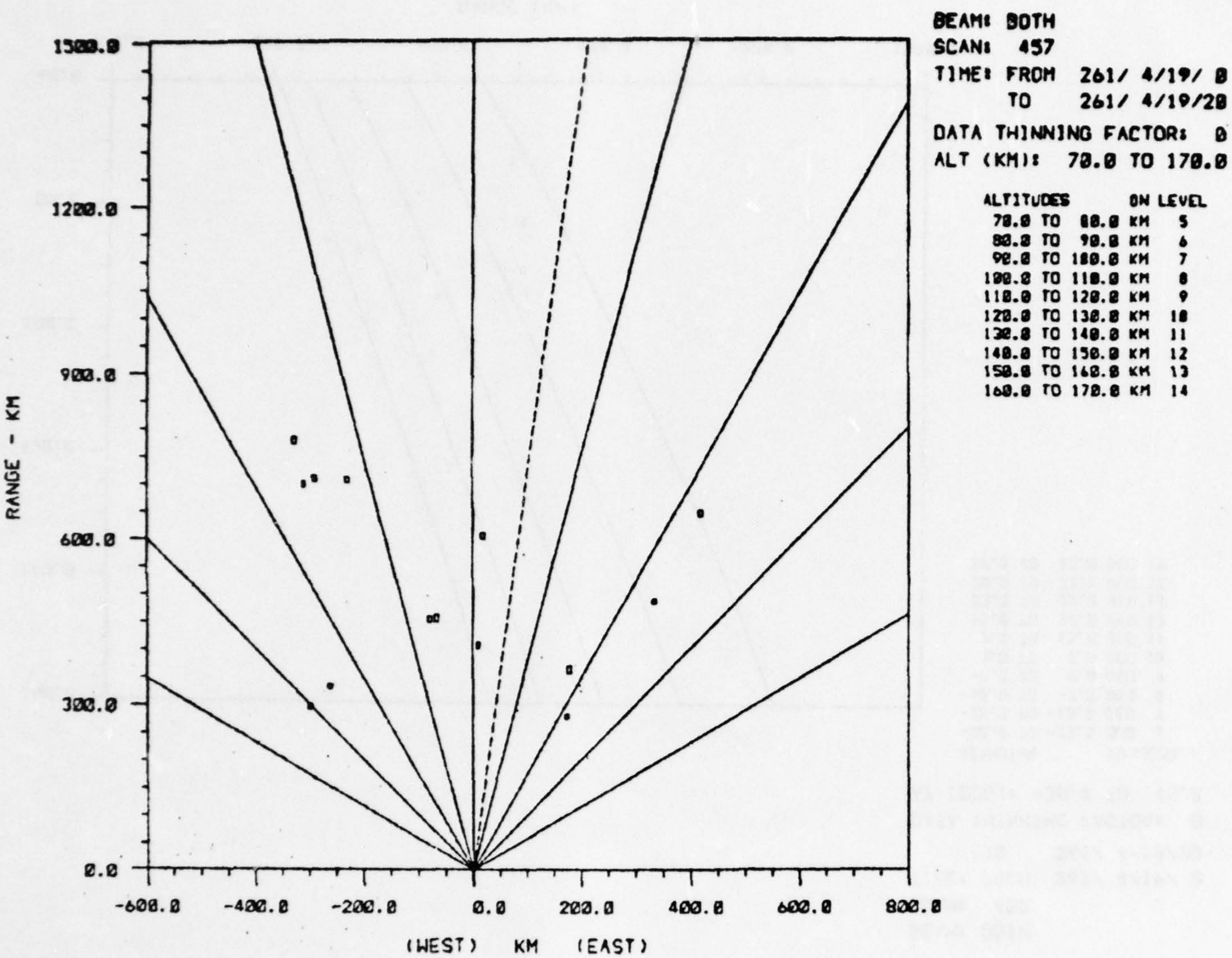

BEAM: BCTH
SCAN: 456
TIME: FROM 261/ 4/ 3/38
TO 261/ 4/ 3/58
DATA THINNING FACTOR: 0
ALT (KM): 70.0 TO 170.0
ALTITUDES ON LEVEL
70.0 TO 80.0 KM 5
80.0 TO 90.0 KM 6
90.0 TO 100.0 KM 7
100.0 TO 110.0 KM 8
110.0 TO 120.0 KM 9
120.0 TO 130.0 KM 10
130.0 TO 140.0 KM 11
140.0 TO 150.0 KM 12
150.0 TO 160.0 KM 13
160.0 TO 170.0 KM 14
1500.0
1200.0
900.0
600.0
300.0
0.0
RANGE - KM
-600.0
-400.0
-200.0
0.0
200.0
400.0
600.0
800.0
(WEST) KM (EAST)
TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR
M&S OMPUTING

Figure 5-32



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

OMPUTING

Figure 5-33

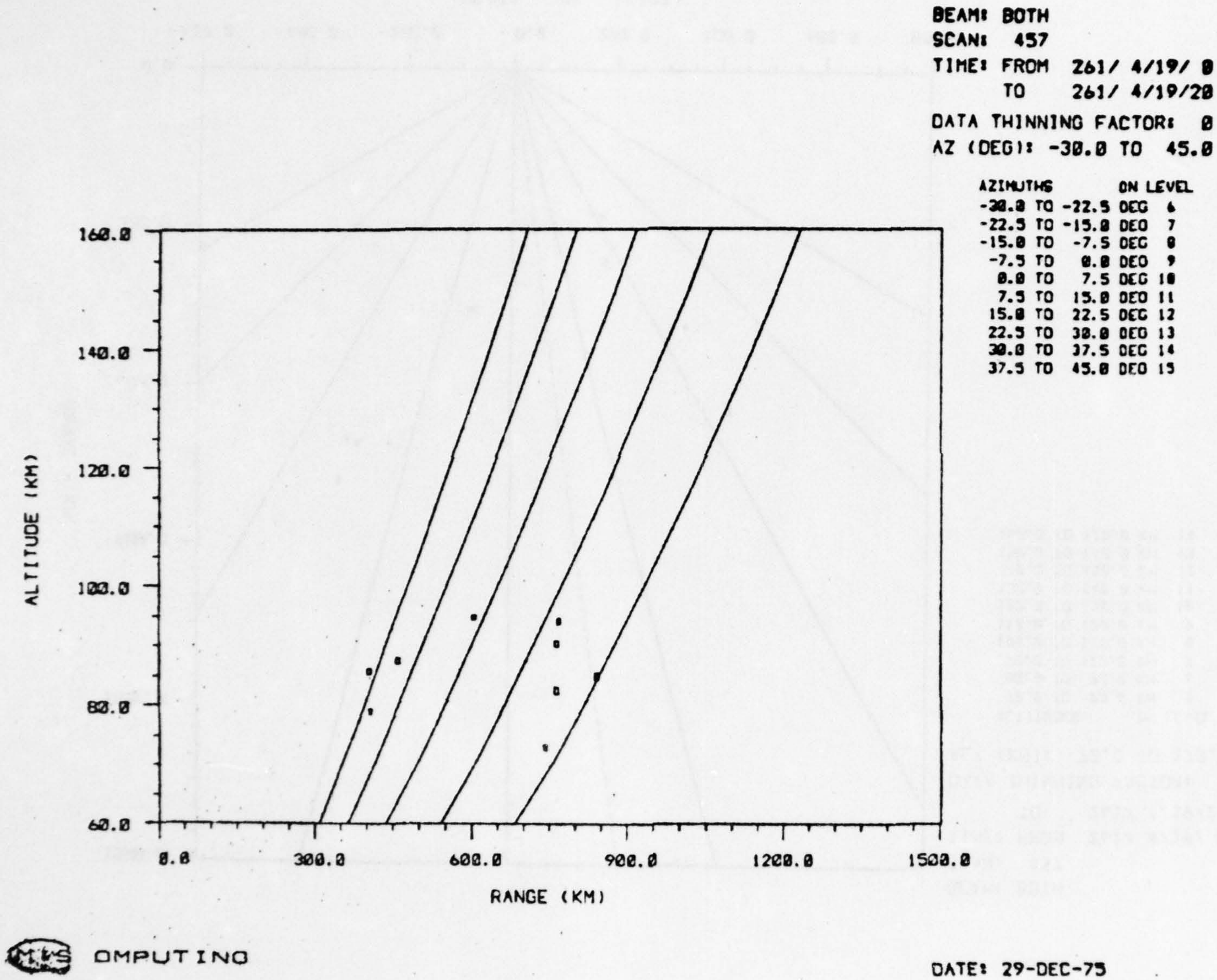
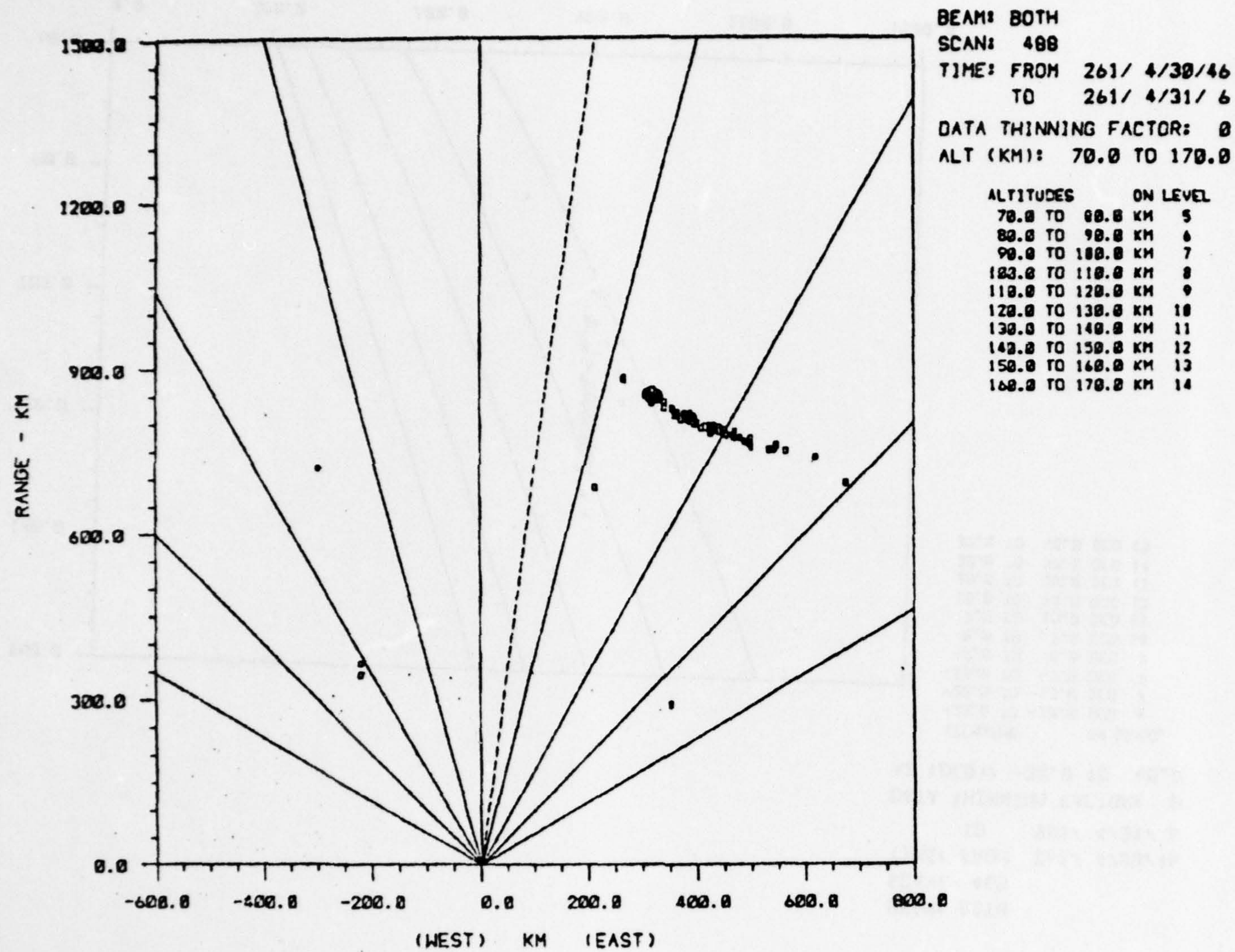

BEAM: BOTH
SCAN: 457
TIME: FROM 261/ 4/19/ 0
TO 261/ 4/19/20
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 45.0
AZIMUTHS ON LEVEL
-30.0 TO -22.5 DEG 6
-22.5 TO -15.0 DEG 7
-15.0 TO -7.5 DEG 8
-7.5 TO 0.0 DEG 9
0.0 TO 7.5 DEG 10
7.5 TO 15.0 DEG 11
15.0 TO 22.5 DEG 12
22.5 TO 30.0 DEG 13
30.0 TO 37.5 DEG 14
37.5 TO 45.0 DEG 15
160.0
140.0
120.0
100.0
80.0
60.0
ALTITUDE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)
OMPUTING
DATE: 29-DEC-75

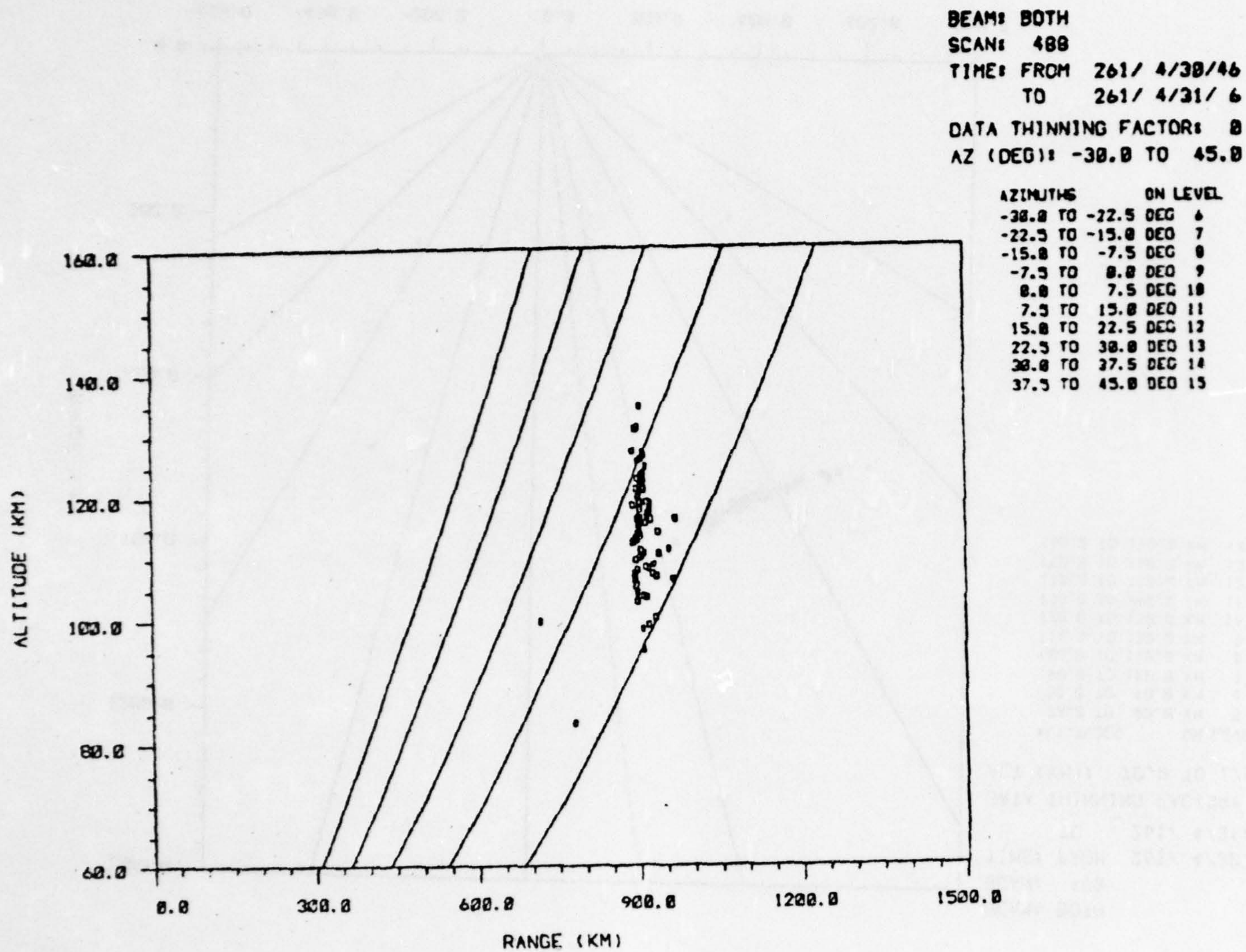
Figure 5-34



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

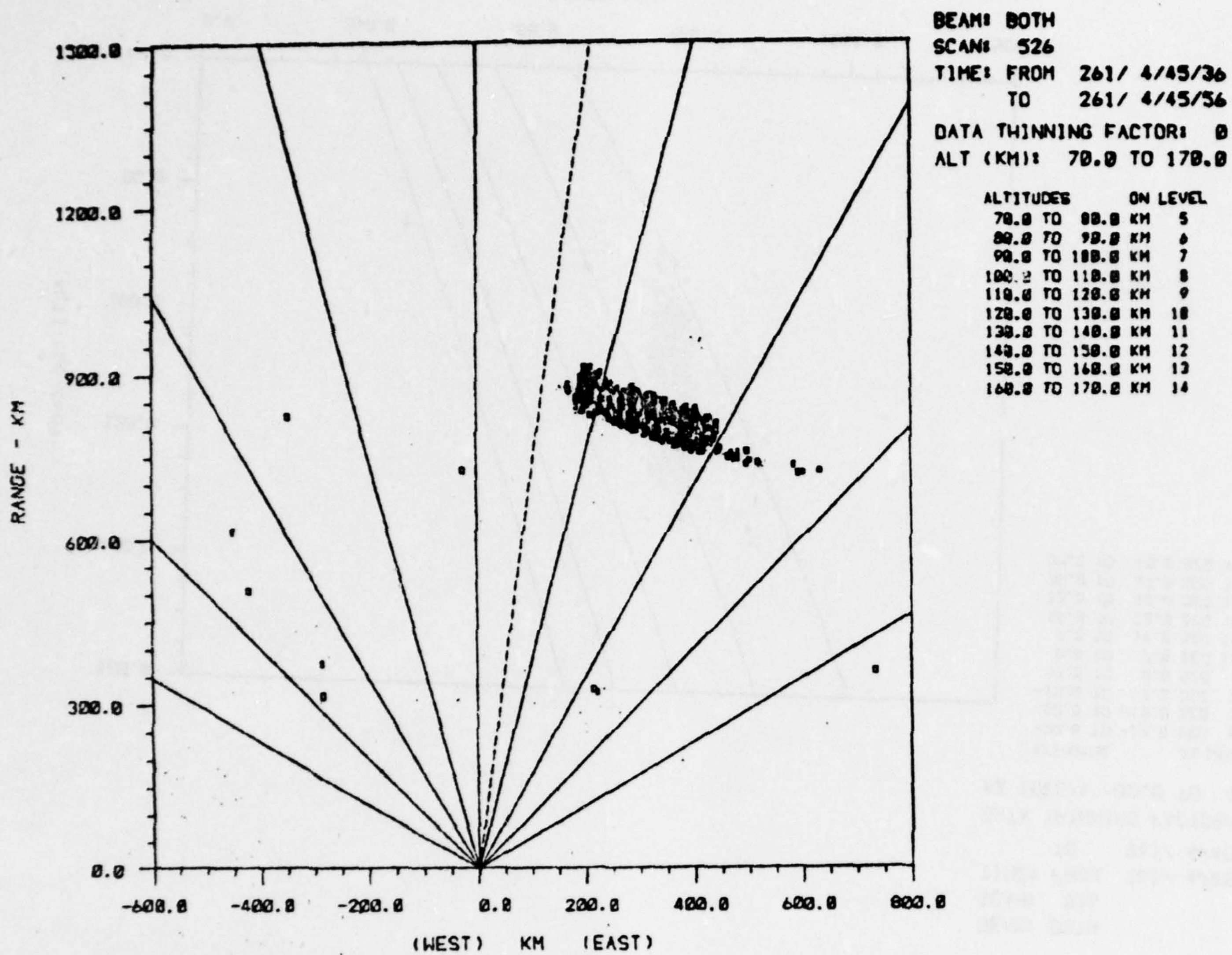
COMPUTING

Figure 5-35



MLS OMPUTINO

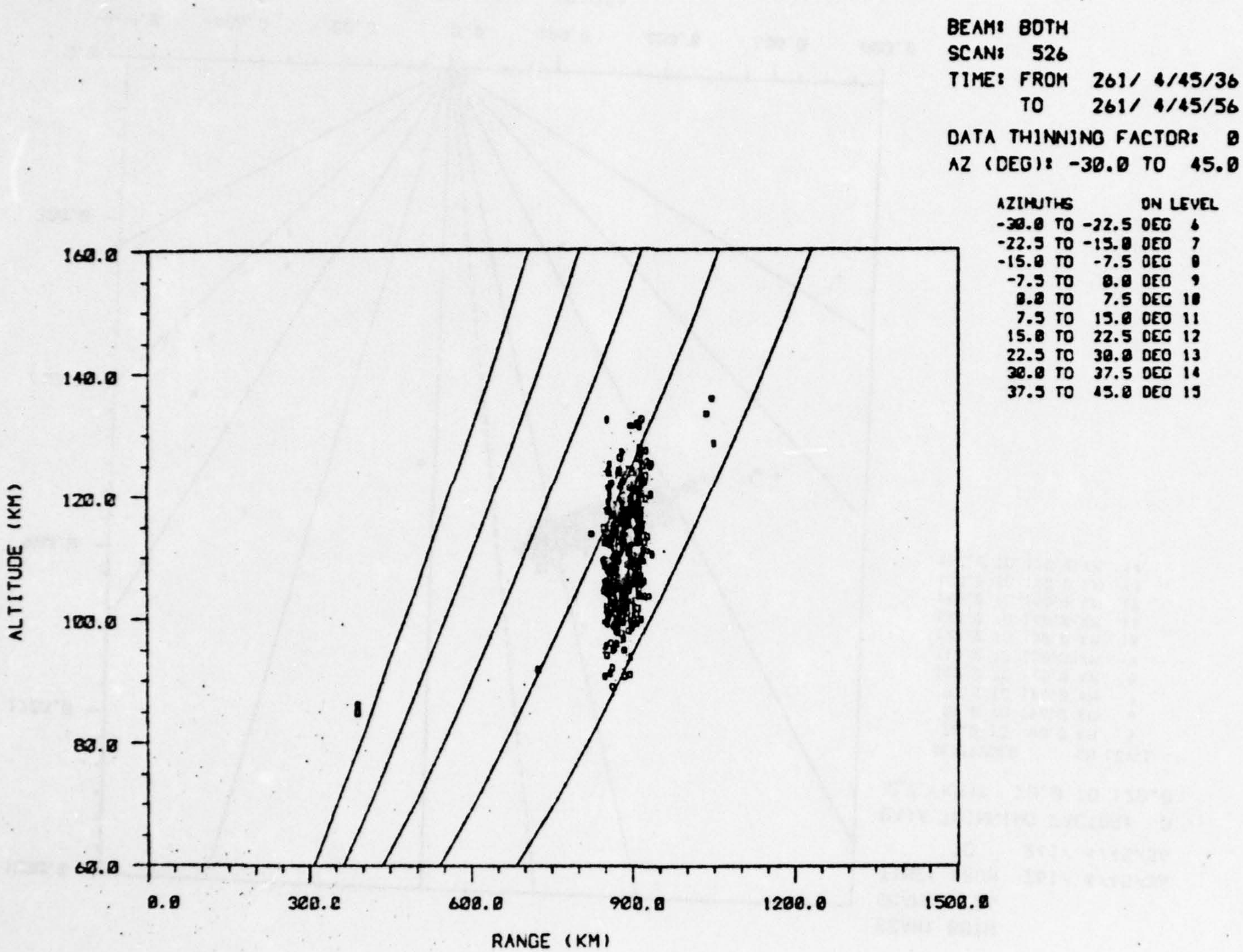
Figure 5-36



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

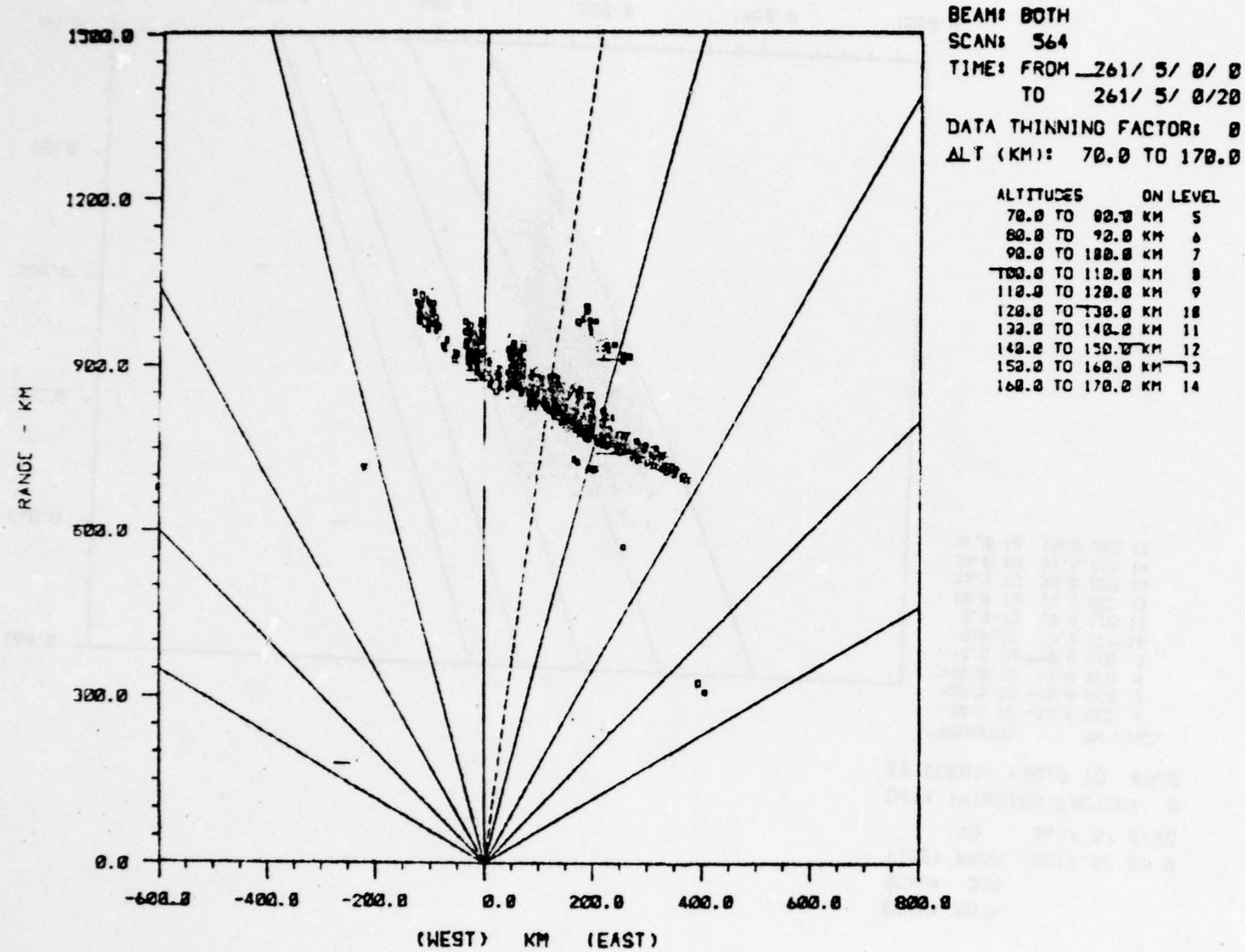
M&S COMPUTING

Figure 5-37



M&S OMPUTING

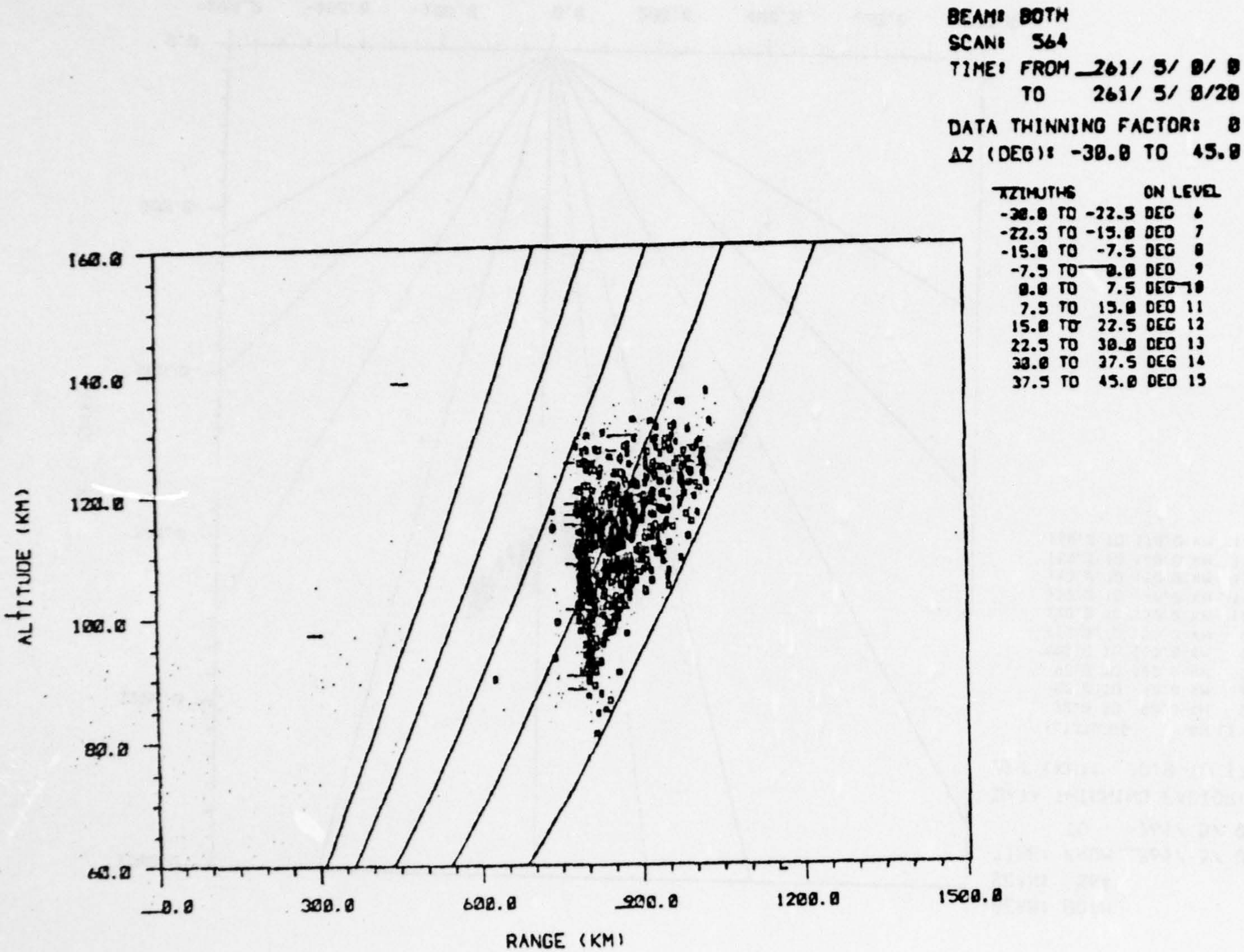
Figure 5-38



TOP DOWN VIEW OF AURORAL-PHENOMENA AT PAR

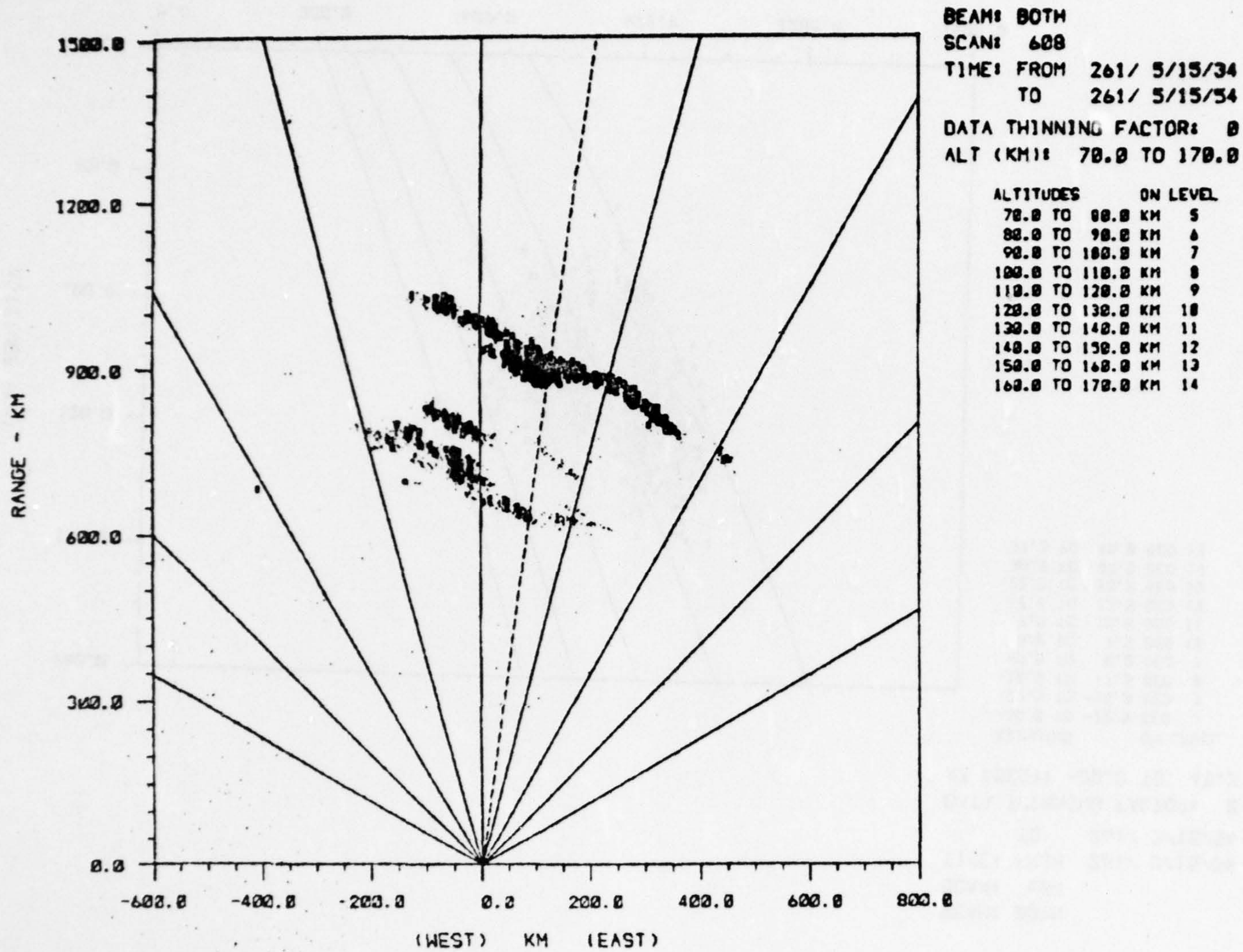
M&S COMPUTING

Figure 5-39



M&S COMPUTING

Figure 5-40



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

MKS OMPUTING

Figure 5-41

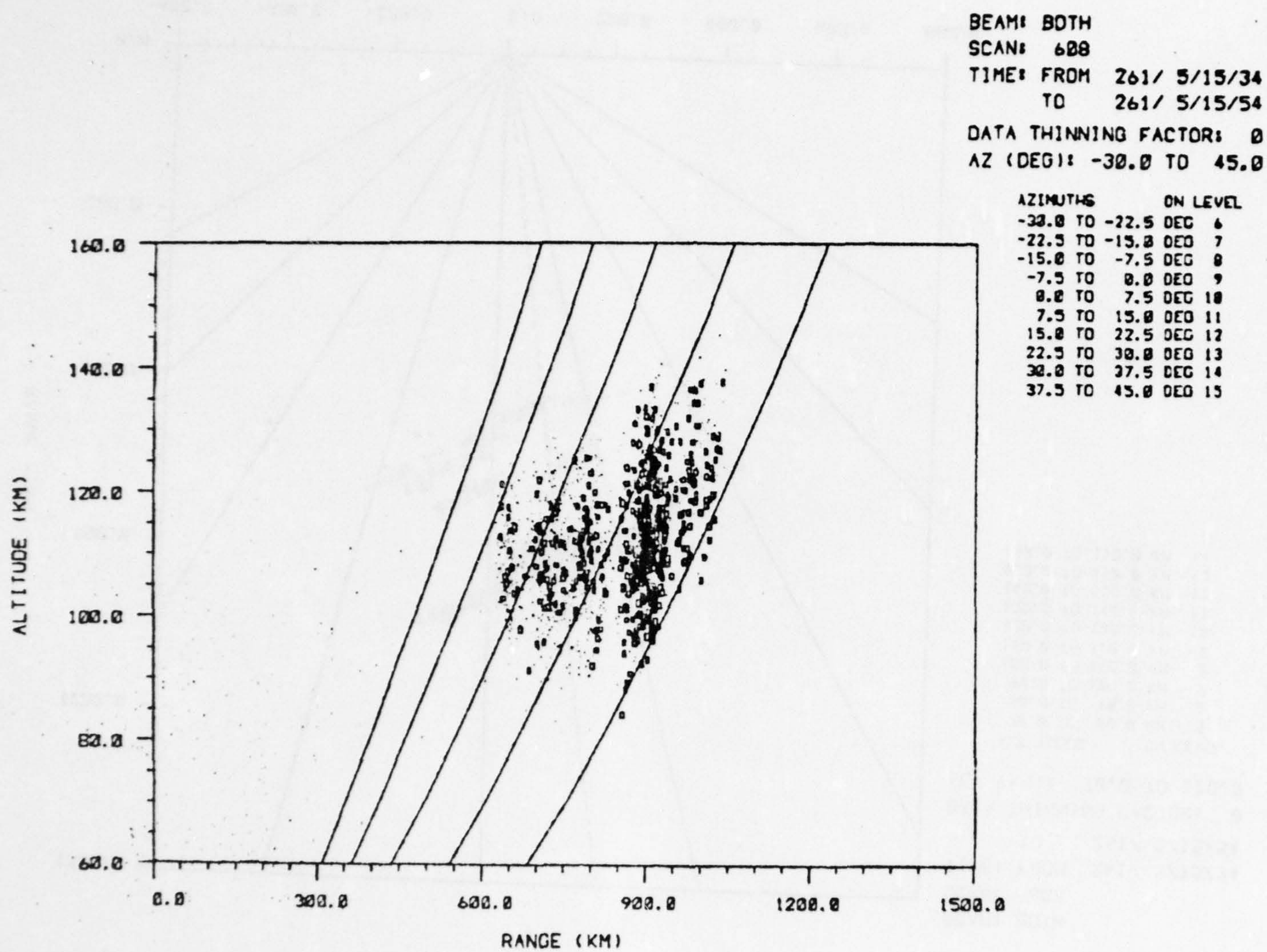
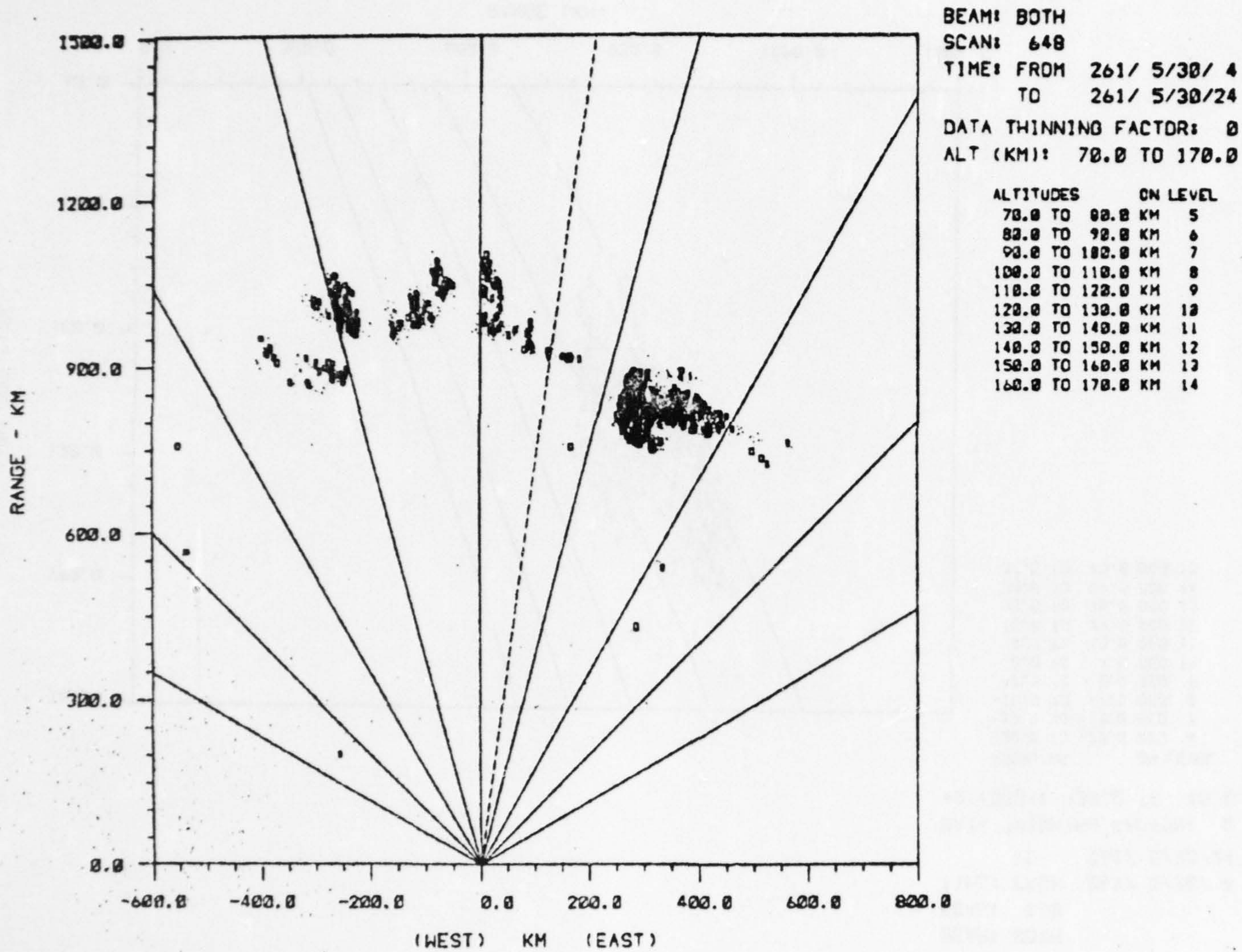

BEAM: BOTH
SCAN: 608
TIME: FROM 261/ 5/15/34
TO 261/ 5/15/54
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 45.0
AZIMUTHS ON LEVEL
-30.0 TO -22.5 DEG 6
-22.5 TO -15.0 DEG 7
-15.0 TO -7.5 DEG 8
-7.5 TO 0.0 DEG 9
0.0 TO 7.5 DEG 10
7.5 TO 15.0 DEG 11
15.0 TO 22.5 DEG 12
22.5 TO 30.0 DEG 13
30.0 TO 37.5 DEG 14
37.5 TO 45.0 DEG 15
160.0
140.0
120.0
100.0
80.0
60.0
ALTITUDE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

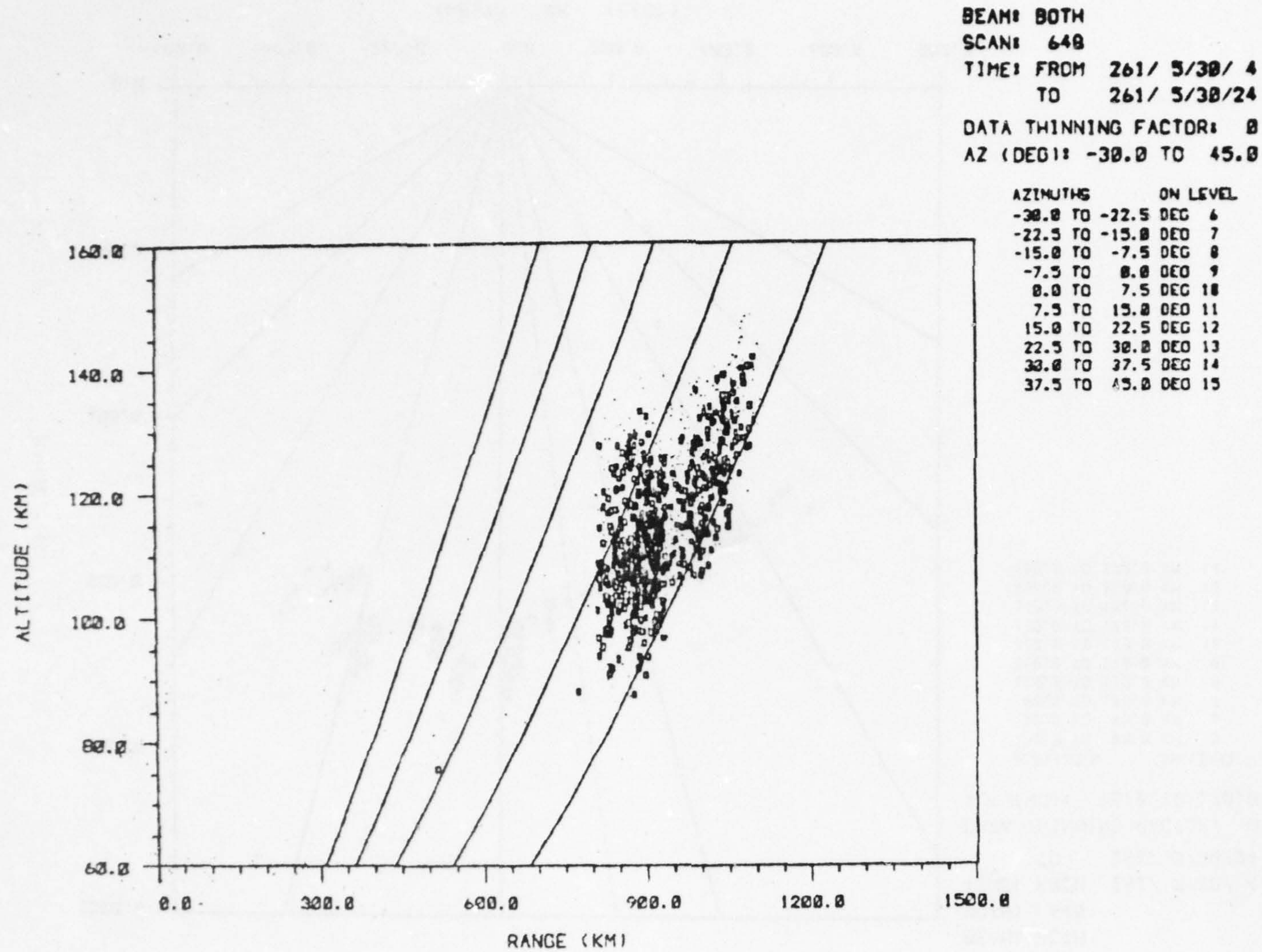
Figure 5-42



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

M&S COMPUTING

Figure 5-43



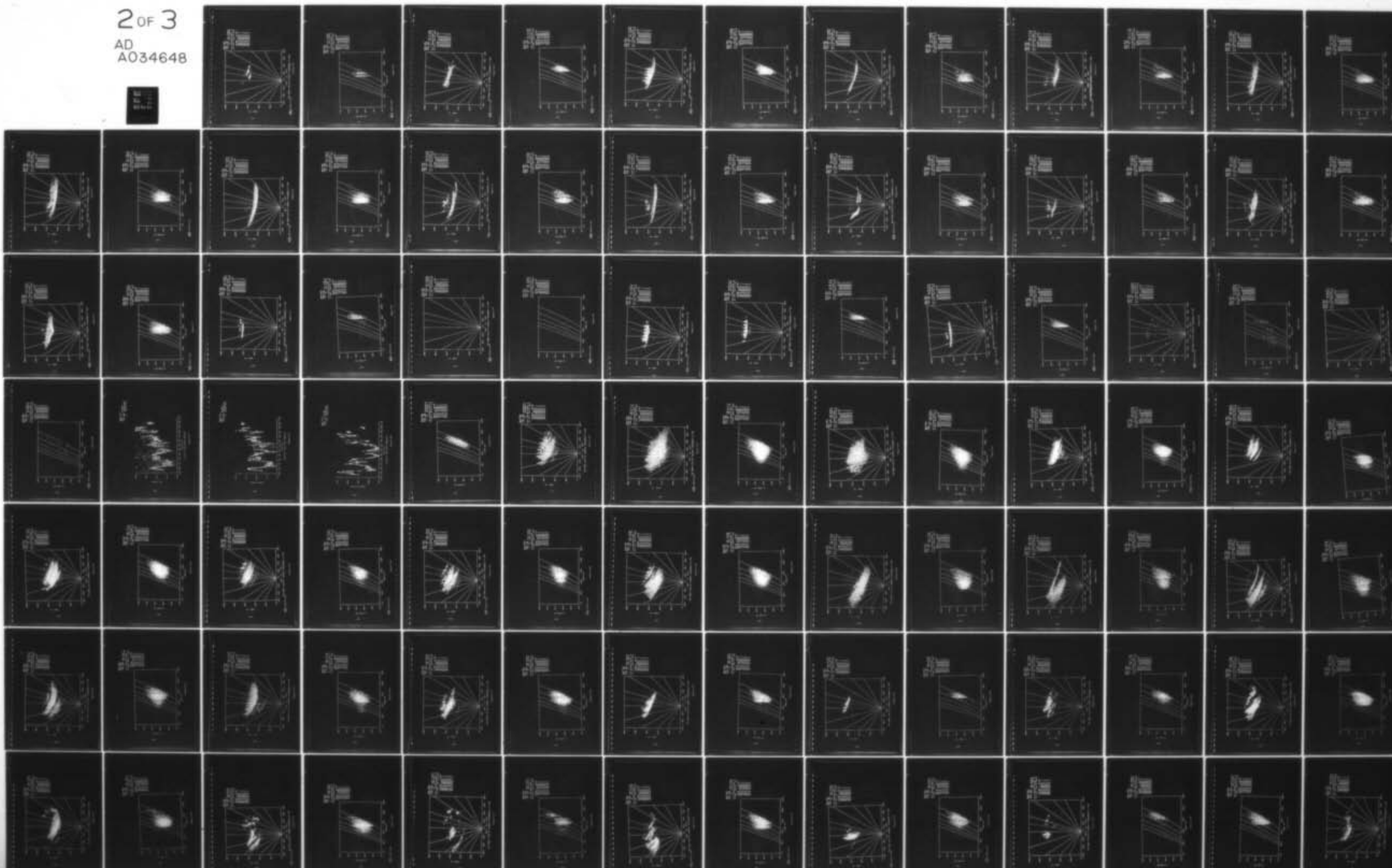
M&S COMPUTING

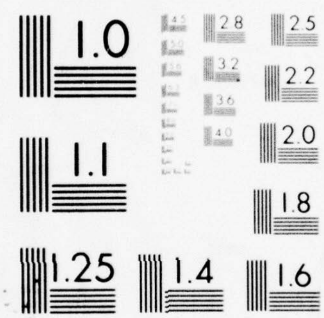
Figure 5-44

AD-A034 648   M AND S COMPUTING INC HUNTSVILLE ALA   F/G 4/1
PAR AURORAL STUDY. VOLUME I.(U)
MAR 76   M J MITCHELL   DASG60-74-C-0026

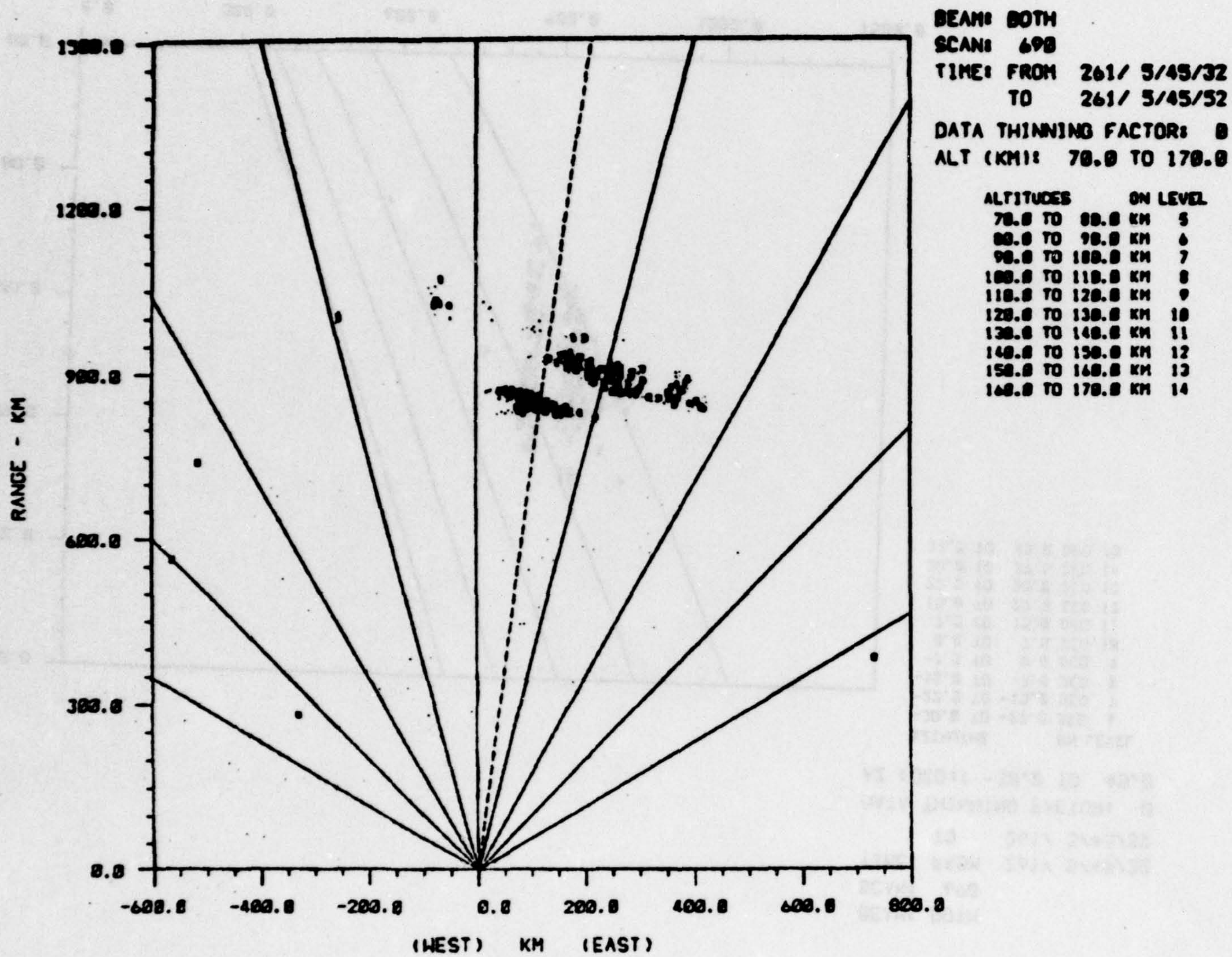
UNCLASSIFIED   76-0013   NL

2 OF 3
AD
A034648





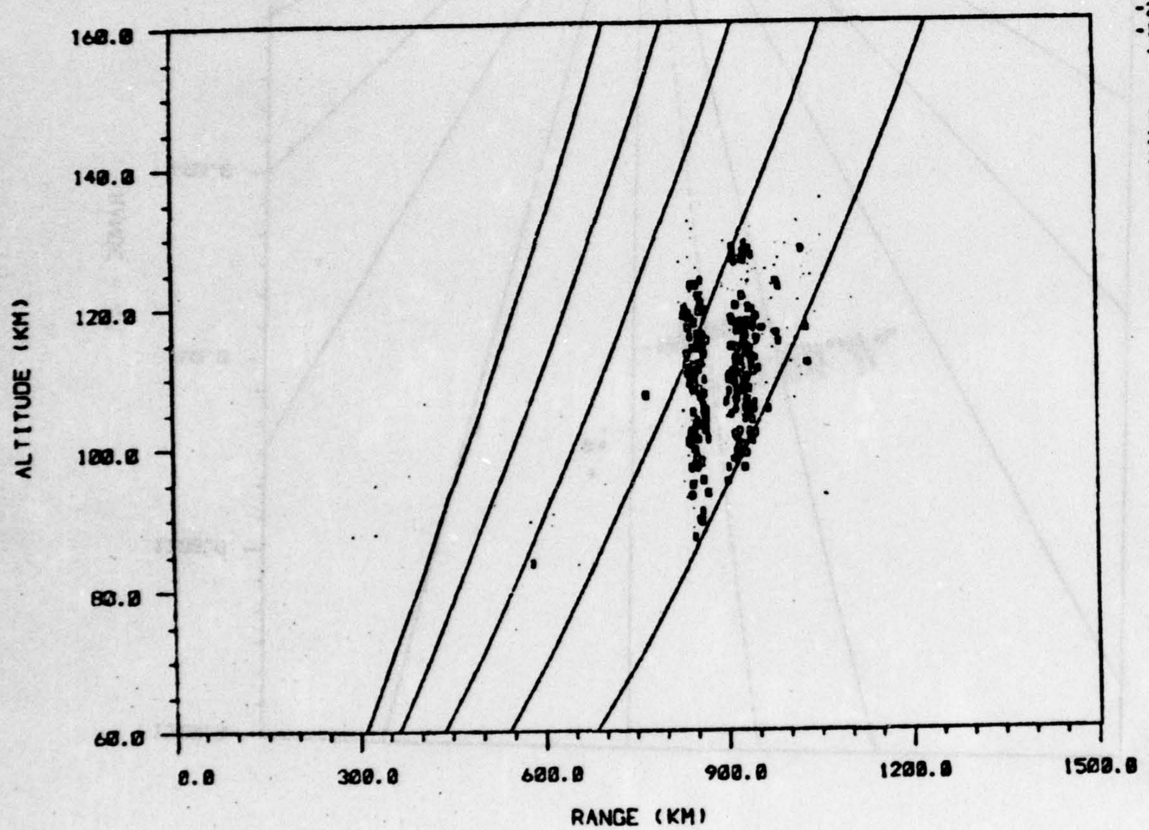
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

H&S COMPUTING

Figure 5-45



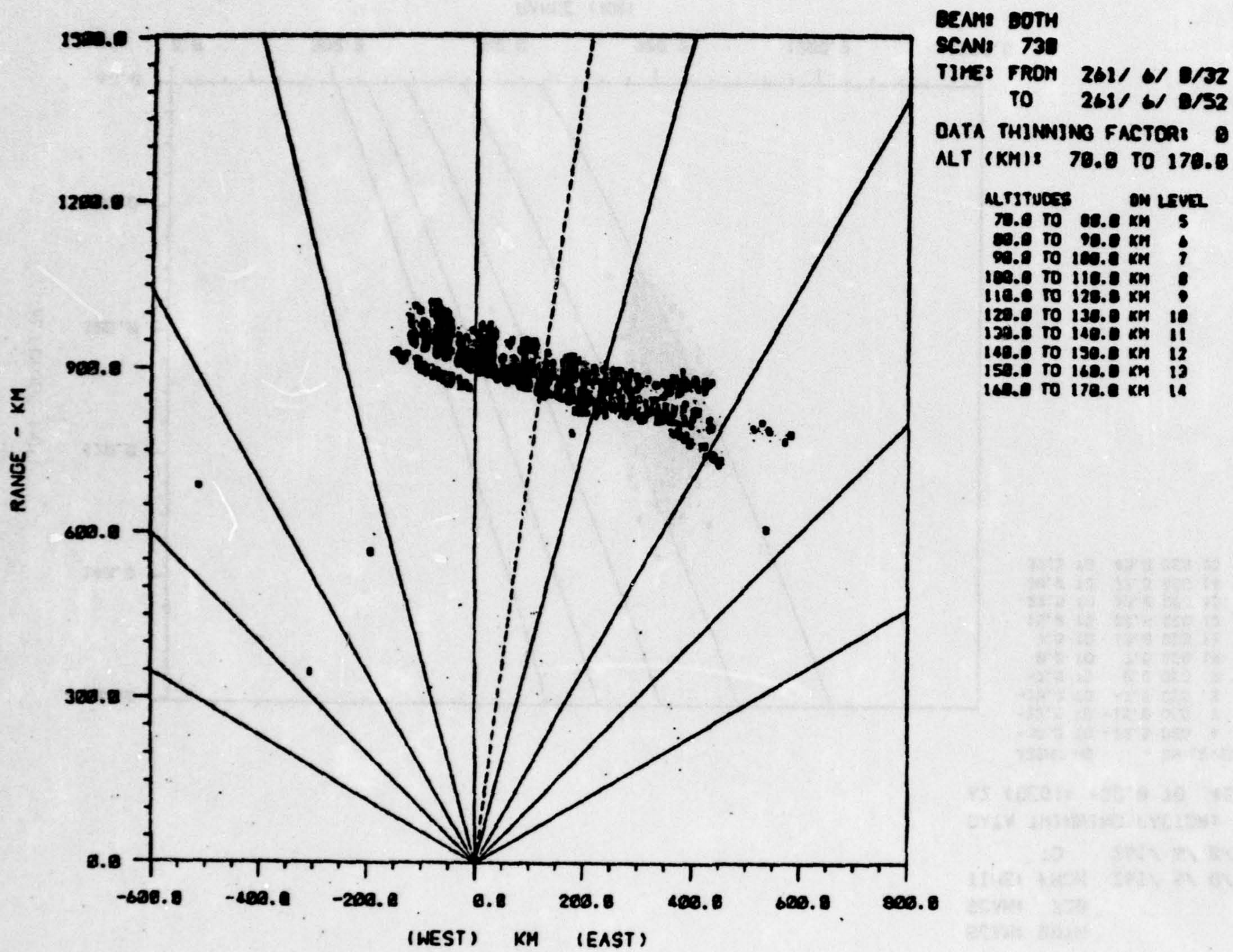
BEAM: BOTH
SCAN: 690
TIME: FROM 261/ 5/45/32
TO 261/ 5/45/52

DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 45.0

AZIMUTHS				ON LEVEL
-30.0	TO	-22.5	DEG	6
-22.5	TO	-15.0	DEG	7
-15.0	TO	-7.5	DEG	8
-7.5	TO	0.0	DEG	9
0.0	TO	7.5	DEG	10
7.5	TO	15.0	DEG	11
15.0	TO	22.5	DEG	12
22.5	TO	30.0	DEG	13
30.0	TO	37.5	DEG	14
37.5	TO	45.0	DEG	15

M+S OMPUTING

Figure 5-46



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

MIS COMPUTING

Figure 5-47

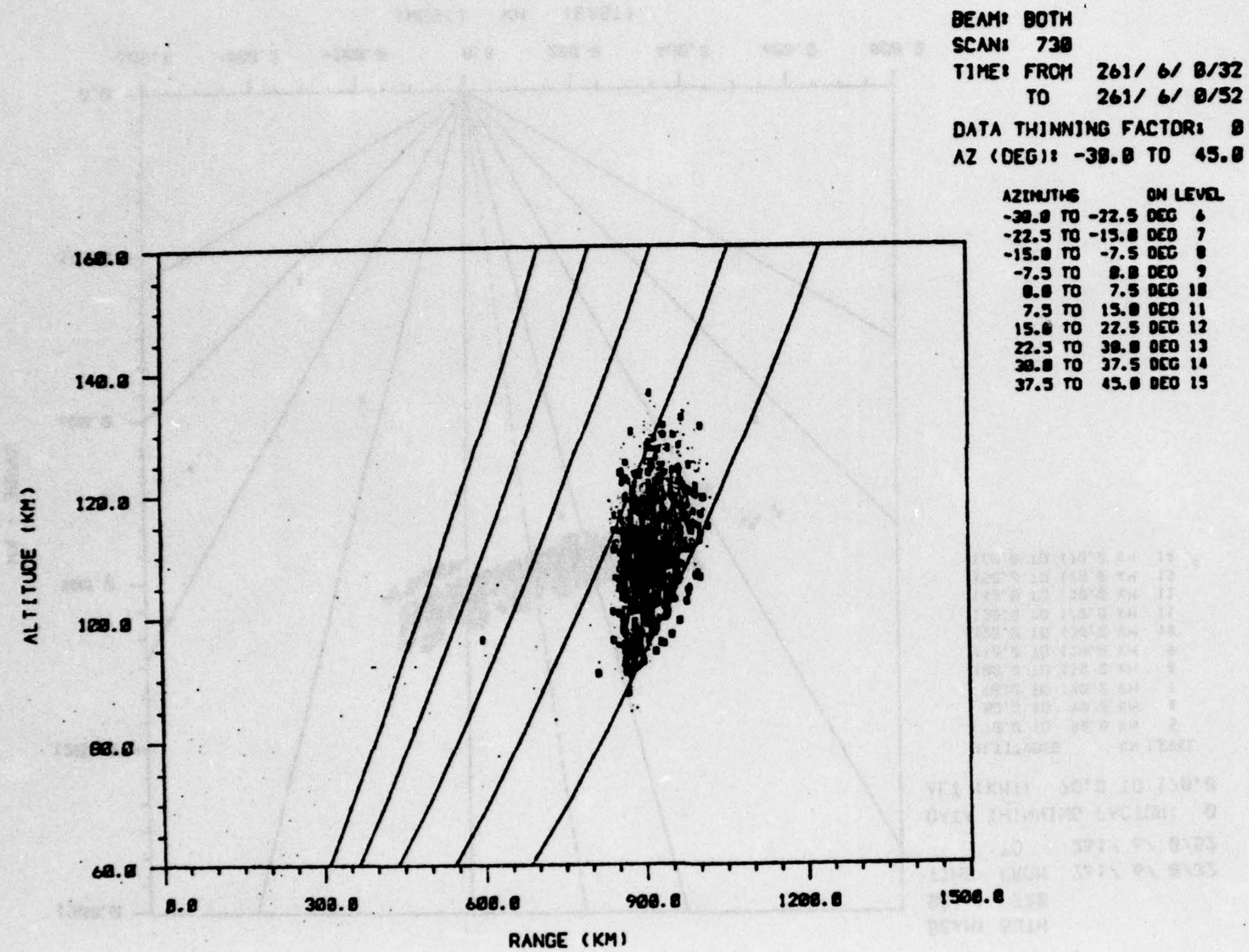
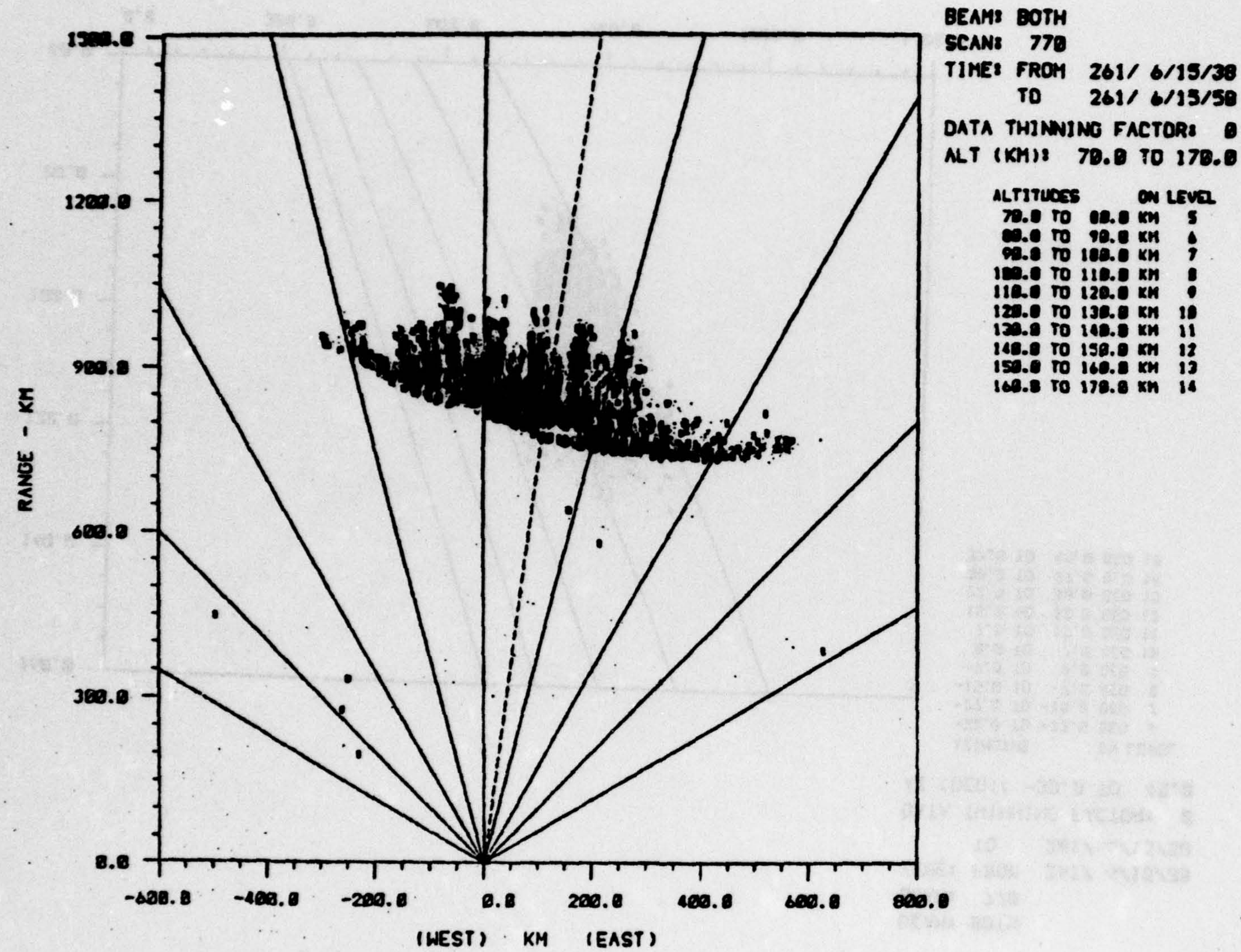

BEAM: BOTH
SCAN: 730
TIME: FROM 261/ 6/ 0/32
TO 261/ 6/ 0/52
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 45.0
AZIMUTHS ON LEVEL
-30.0 TO -22.5 DEG 6
-22.5 TO -15.0 DEG 7
-15.0 TO -7.5 DEG 8
-7.5 TO 0.0 DEG 9
0.0 TO 7.5 DEG 10
7.5 TO 15.0 DEG 11
15.0 TO 22.5 DEG 12
22.5 TO 30.0 DEG 13
30.0 TO 37.5 DEG 14
37.5 TO 45.0 DEG 15
ALTITUDE (KM)
160.0
140.0
120.0
100.0
80.0
60.0
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

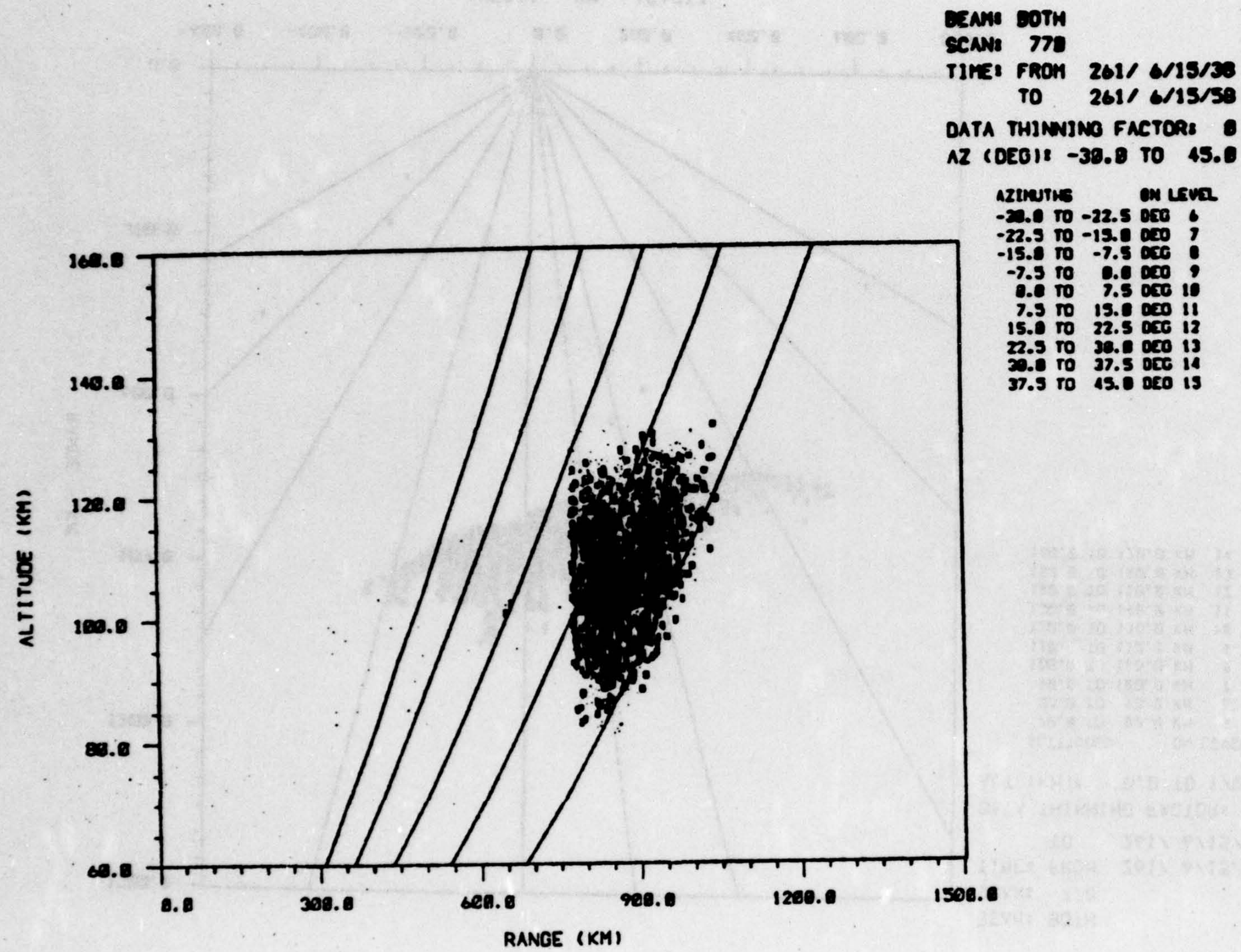
Figure 5-48



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

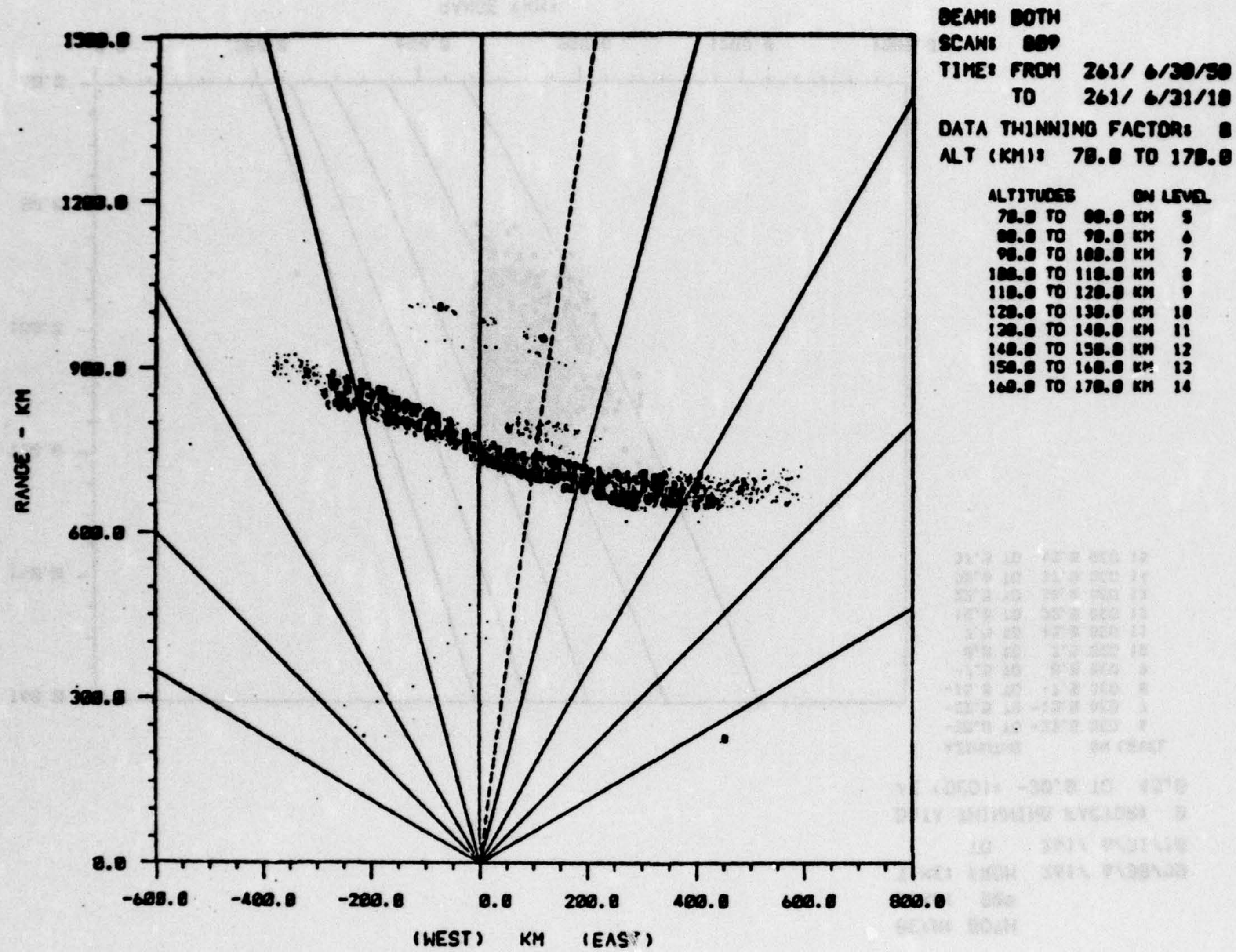
M&S COMPUTING

Figure 5-49



M&S OMPUTING

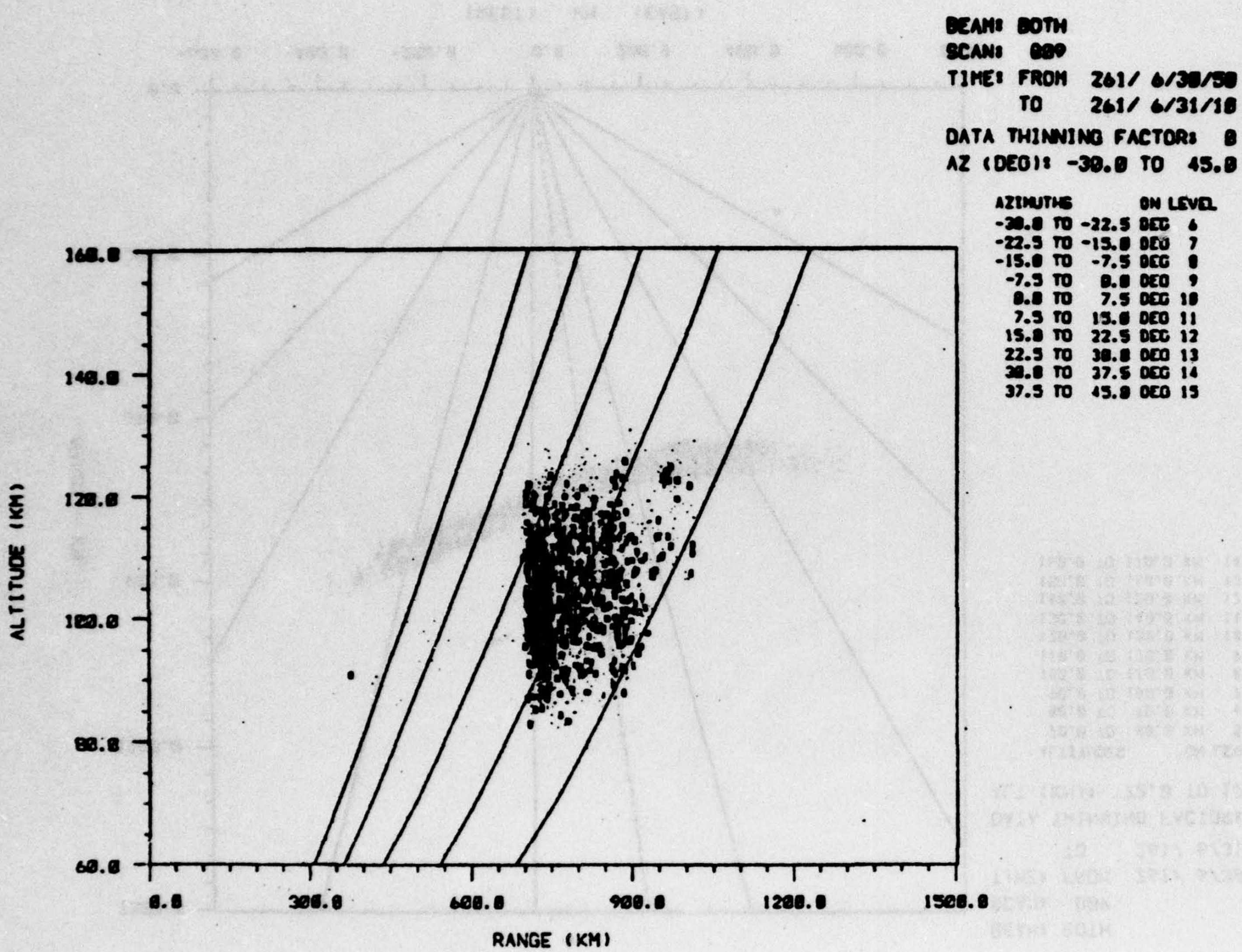
Figure 5-50



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

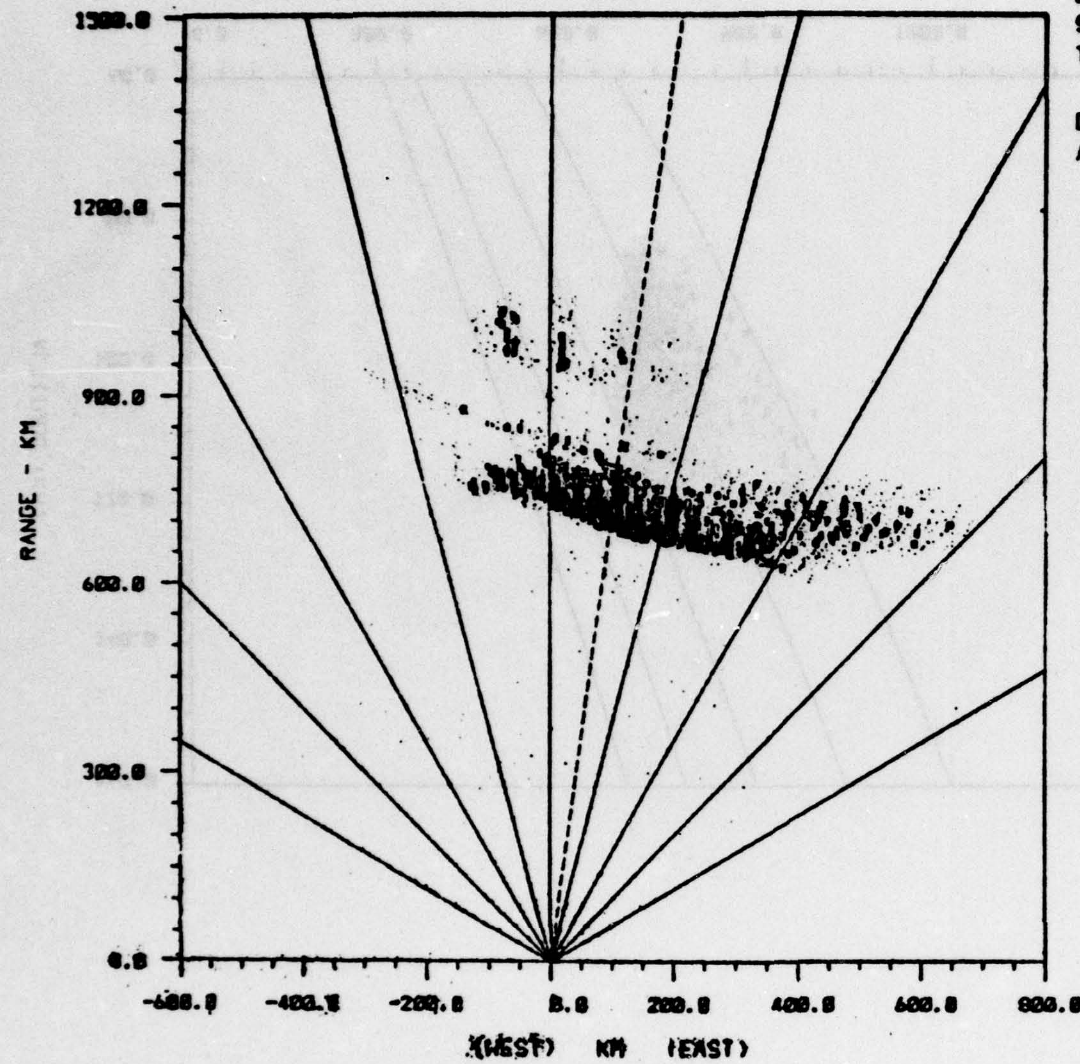
M&S OMPUTING

Figure 5-51



M&S OMPUTING

Figure 5-52



BEAM: BOTH
SCAN: 020
TIME: FROM 261/ 7/ 7/ 0
TO 261/ 7/ 7/20
DATA THINNING FACTOR: 2
ALT (KM): 70.0 TO 170.0

ALTITUDES	ON LEVEL
70.0 TO 80.0 KM	5
80.0 TO 90.0 KM	6
90.0 TO 100.0 KM	7
100.0 TO 110.0 KM	8
110.0 TO 120.0 KM	9
120.0 TO 130.0 KM	10
130.0 TO 140.0 KM	11
140.0 TO 150.0 KM	12
150.0 TO 160.0 KM	13
160.0 TO 170.0 KM	14

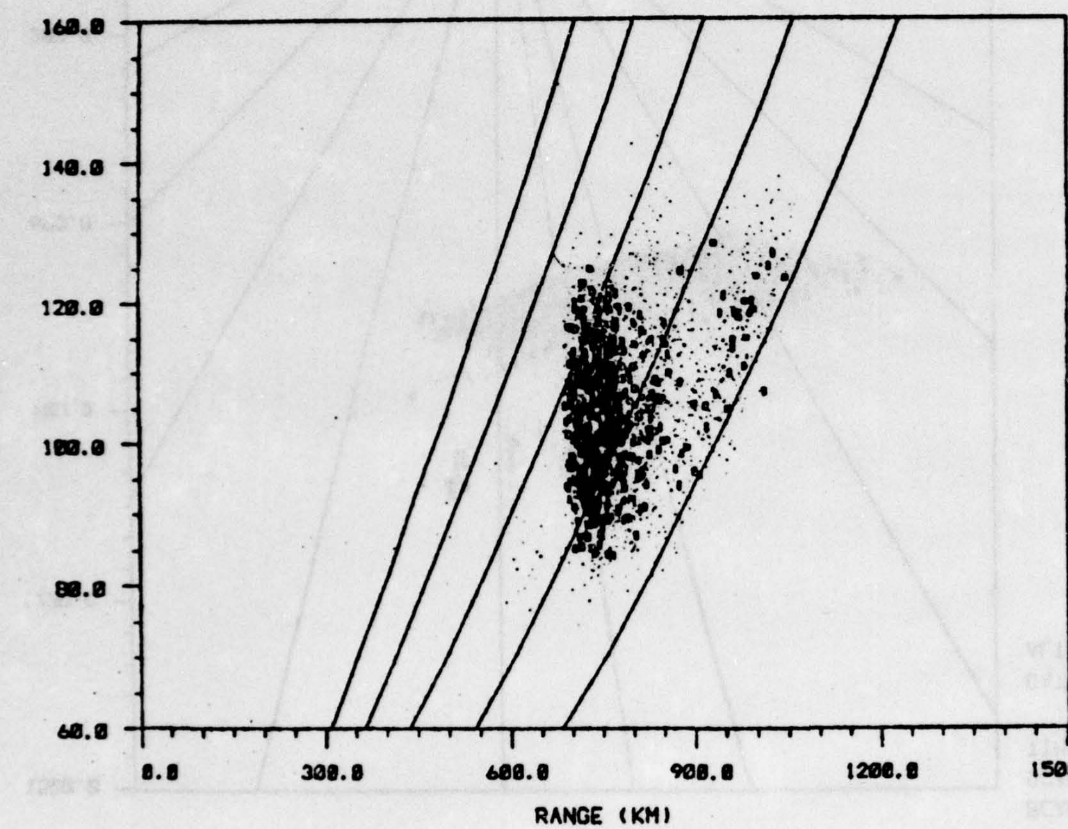
TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

M&S COMPUTING

Figure 5-53

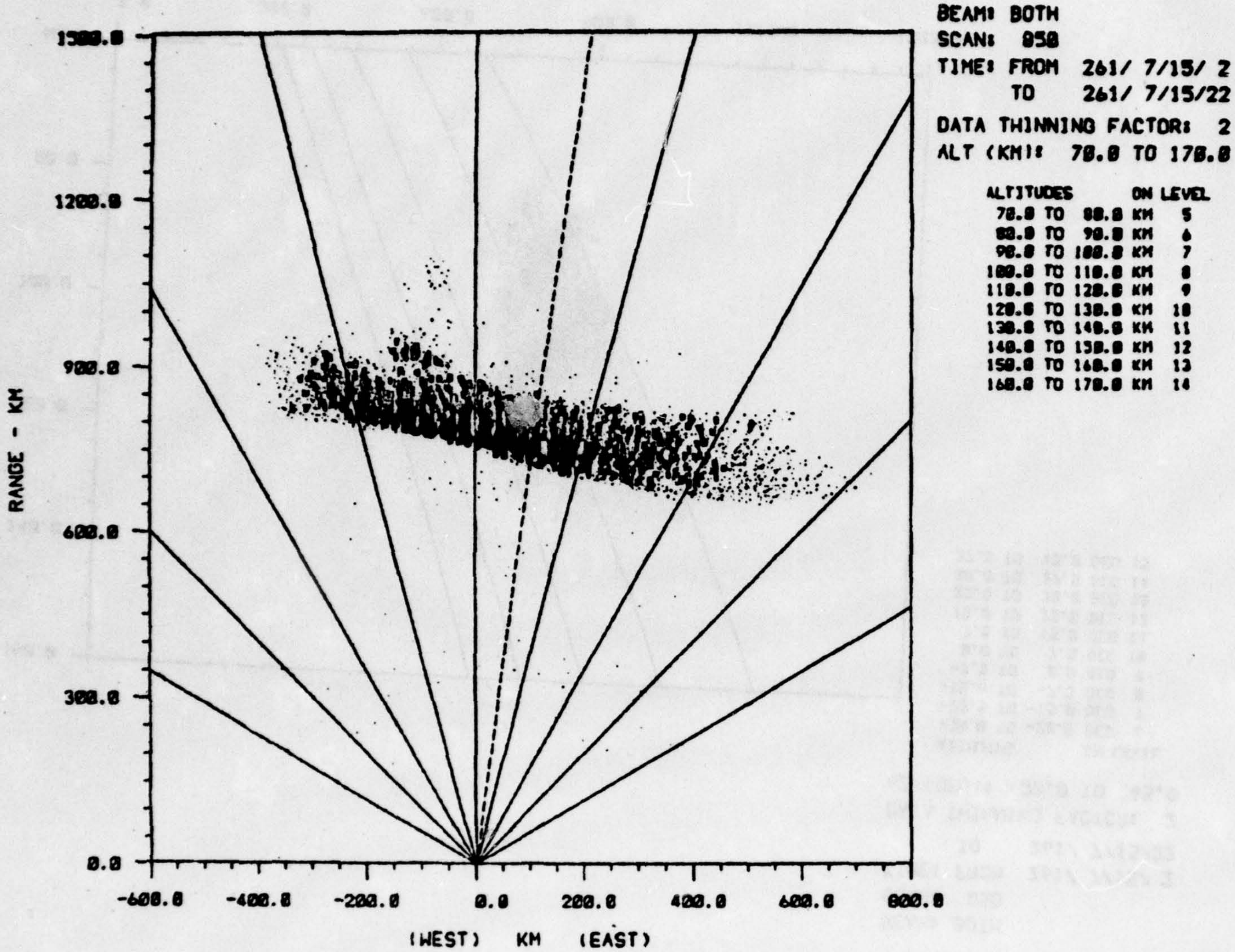
BEAM: BOTH
SCAN: 828
TIME: FROM 261/ 7/ 7/ 8
TO 261/ 7/ 7/28
DATA THINNING FACTOR: 2
AZ (DEG): -30.0 TO 45.0

AZIMUTHS	ON LEVEL
-30.0 TO -22.5 DEG	6
-22.5 TO -15.0 DEG	7
-15.0 TO -7.5 DEG	8
-7.5 TO 0.0 DEG	9
0.0 TO 7.5 DEG	10
7.5 TO 15.0 DEG	11
15.0 TO 22.5 DEG	12
22.5 TO 30.0 DEG	13
30.0 TO 37.5 DEG	14
37.5 TO 45.0 DEG	15



MCS OMPUTING

Figure 5-54



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

M+S OMPUTINO

Figure 5-55

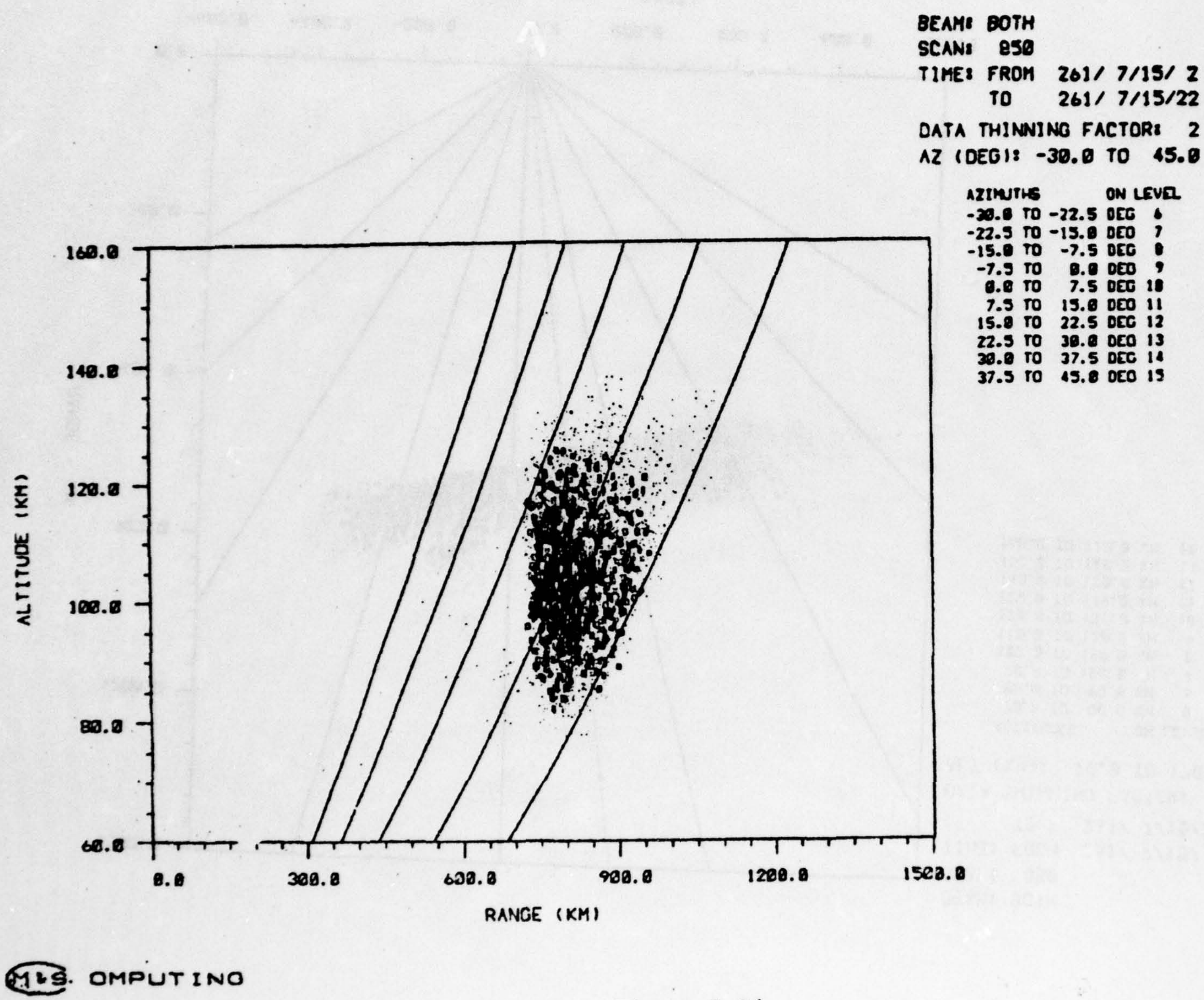
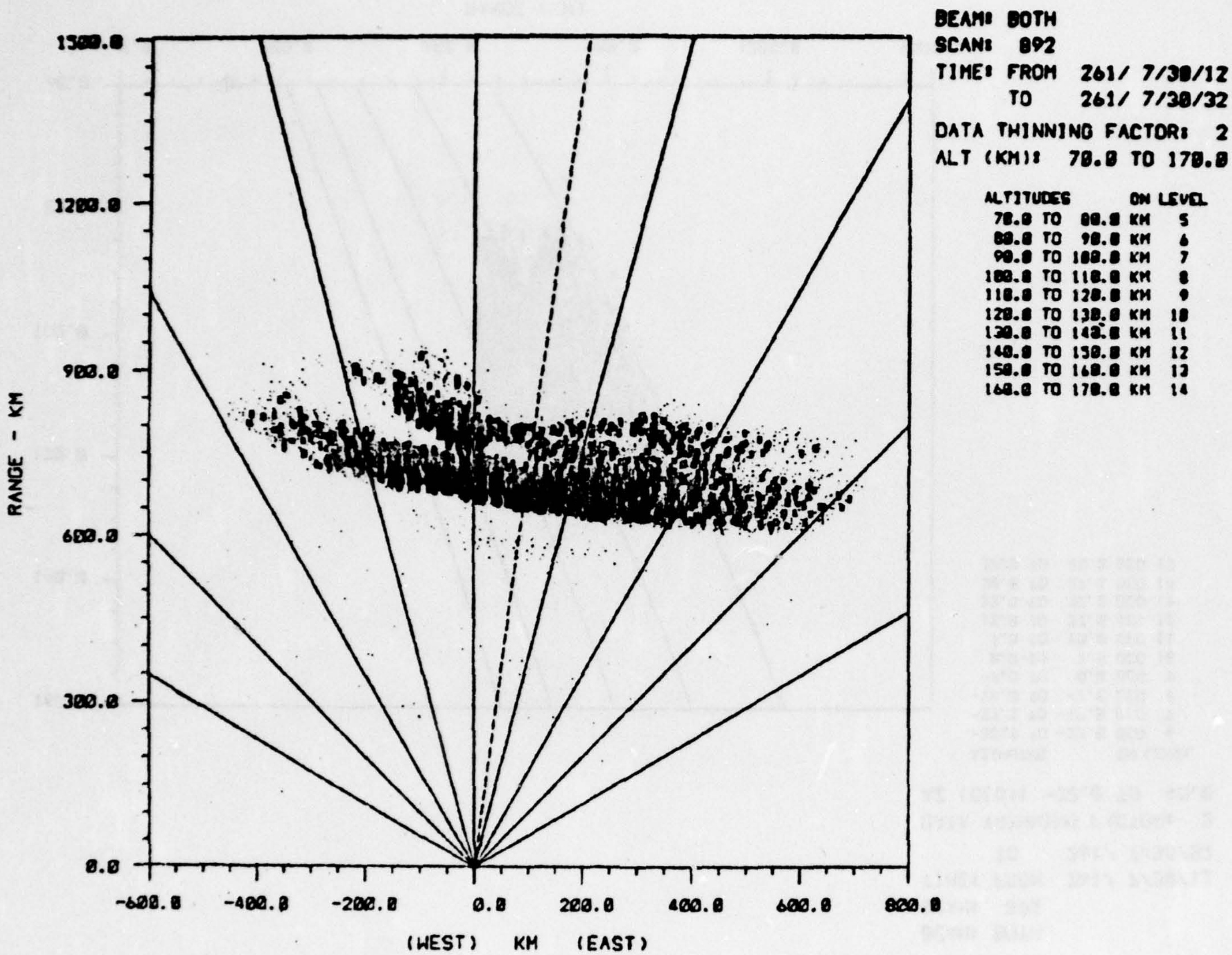

BEAM: BOTH
SCAN: 850
TIME: FROM 261/ 7/15/ 2
TO 261/ 7/15/22
DATA THINNING FACTOR: 2
AZ (DEG): -30.0 TO 45.0
AZIMUTHS ON LEVEL
-30.0 TO -22.5 DEG 6
-22.5 TO -15.0 DEG 7
-15.0 TO -7.5 DEG 8
-7.5 TO 0.0 DEG 9
0.0 TO 7.5 DEG 10
7.5 TO 15.0 DEG 11
15.0 TO 22.5 DEG 12
22.5 TO 30.0 DEG 13
30.0 TO 37.5 DEG 14
37.5 TO 45.0 DEG 15
ALTITUDE (KM)
160.0
140.0
120.0
100.0
80.0
60.0
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)
M&S. OMPUTING

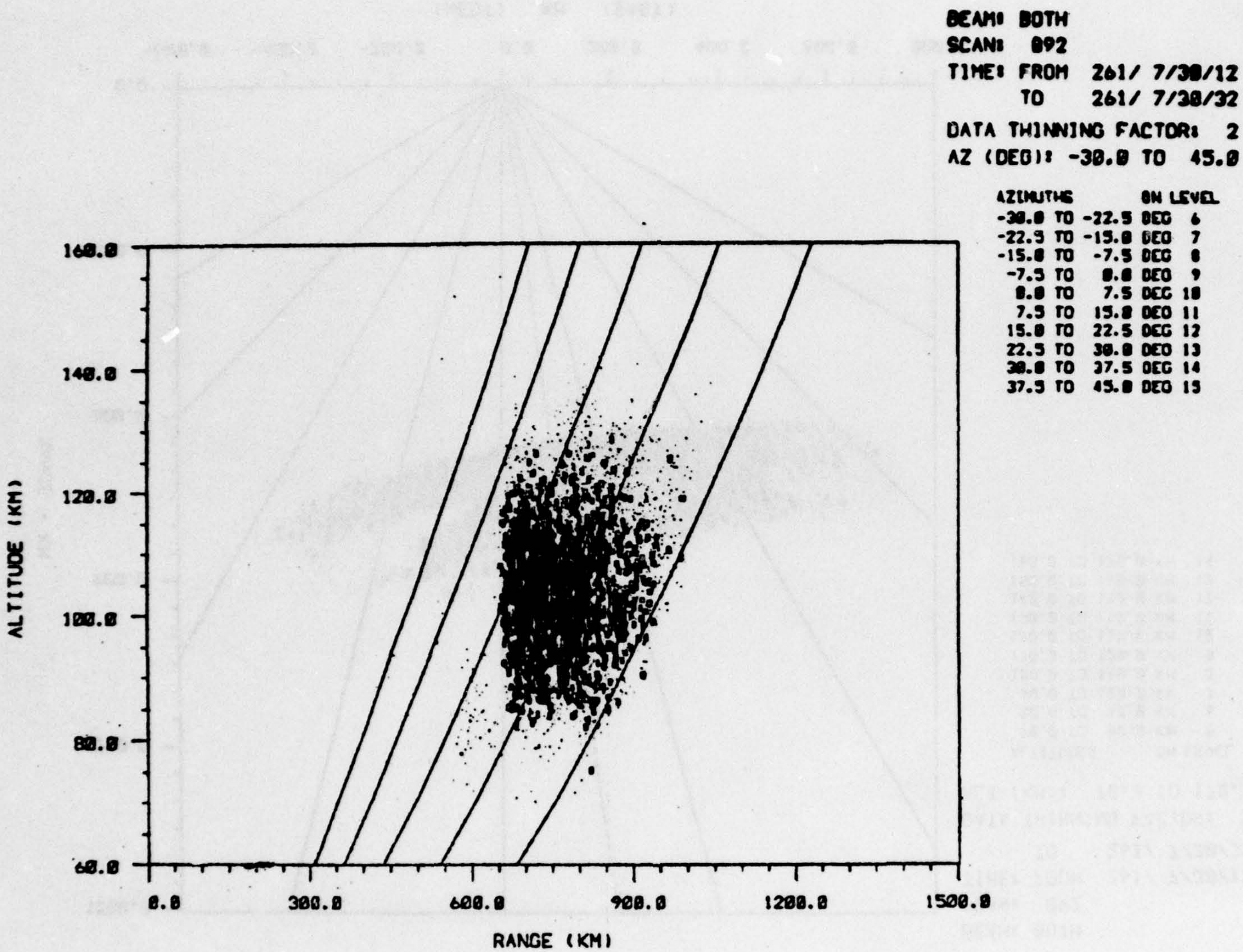
Figure 5-56



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

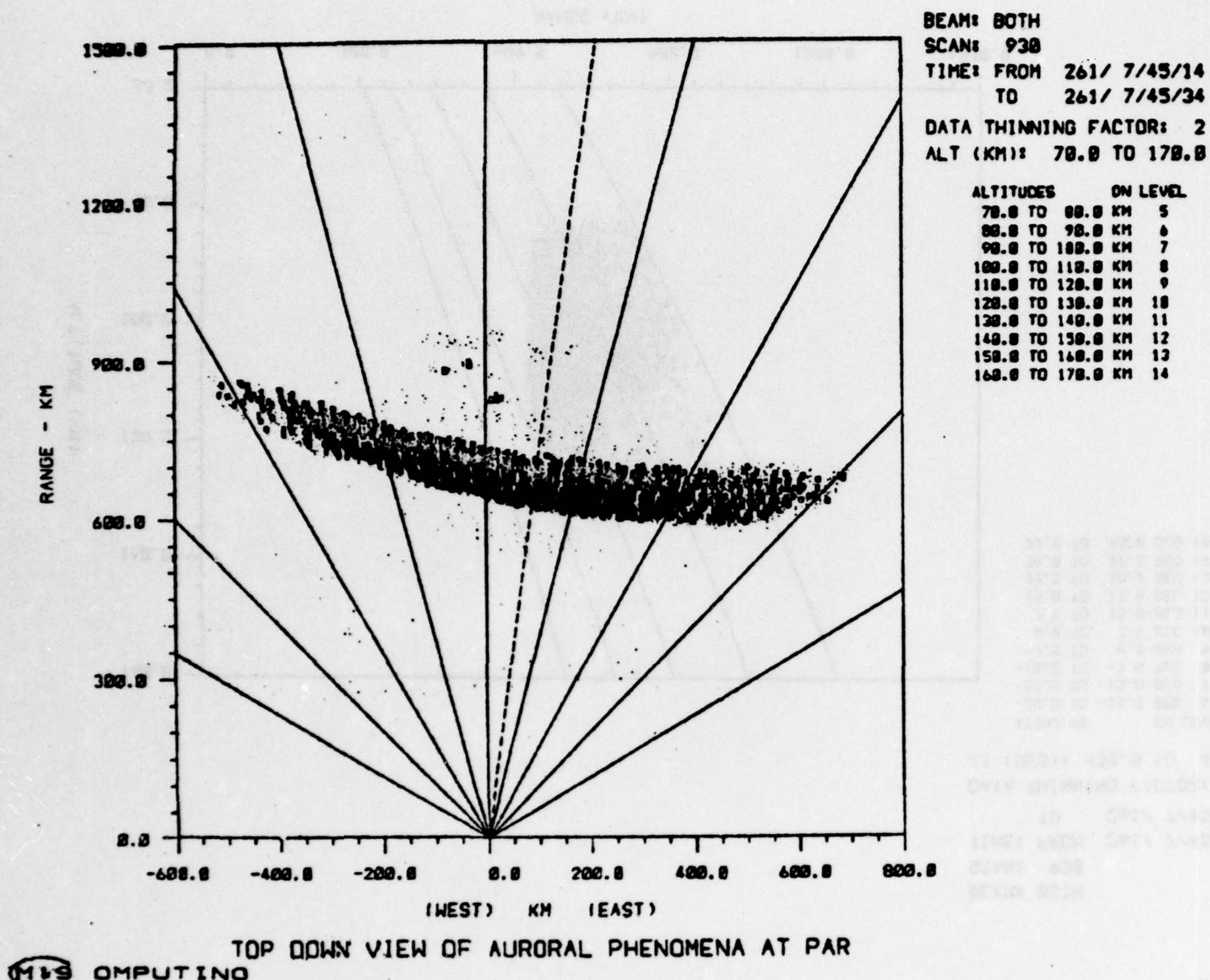
M&S OMPUTING

Figure 5-57



MtS OMPUTING

Figure 5-58



BEAM: BOTH
SCAN: 930
TIME: FROM 261/ 7/45/14
TO 261/ 7/45/34
DATA THINNING FACTOR: 2
ALT (KM): 70.0 TO 170.0
ALTITUDES ON LEVEL
70.0 TO 80.0 KM 5
80.0 TO 90.0 KM 6
90.0 TO 100.0 KM 7
100.0 TO 110.0 KM 8
110.0 TO 120.0 KM 9
120.0 TO 130.0 KM 10
130.0 TO 140.0 KM 11
140.0 TO 150.0 KM 12
150.0 TO 160.0 KM 13
160.0 TO 170.0 KM 14
RANGE - KM
1500.0
1200.0
900.0
600.0
300.0
0.0
-600.0
-400.0
-200.0
0.0
200.0
400.0
600.0
800.0
(WEST) KM (EAST)
TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR
M&S OMPUTING

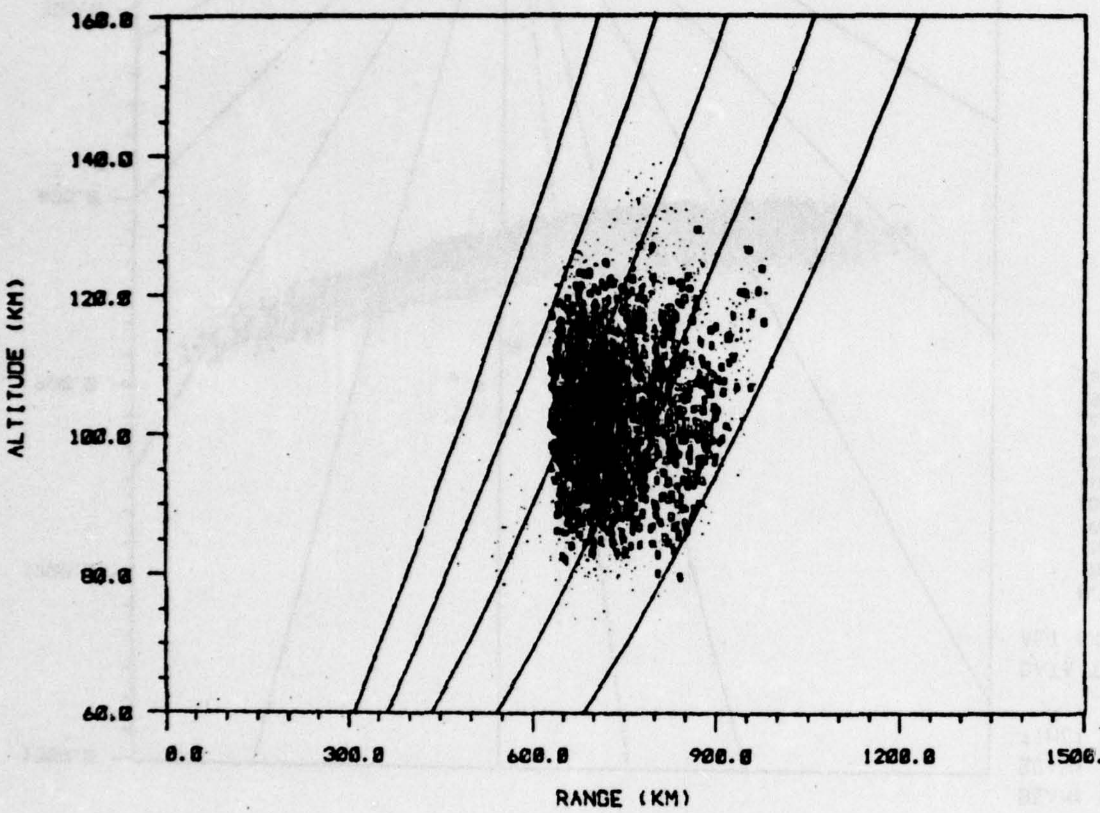
Figure 5-59

BEAM: BOTH
SCAN: 930
TIME: FROM 261/ 7/45/14
TO 261/ 7/45/34

DATA THINNING FACTOR: 2

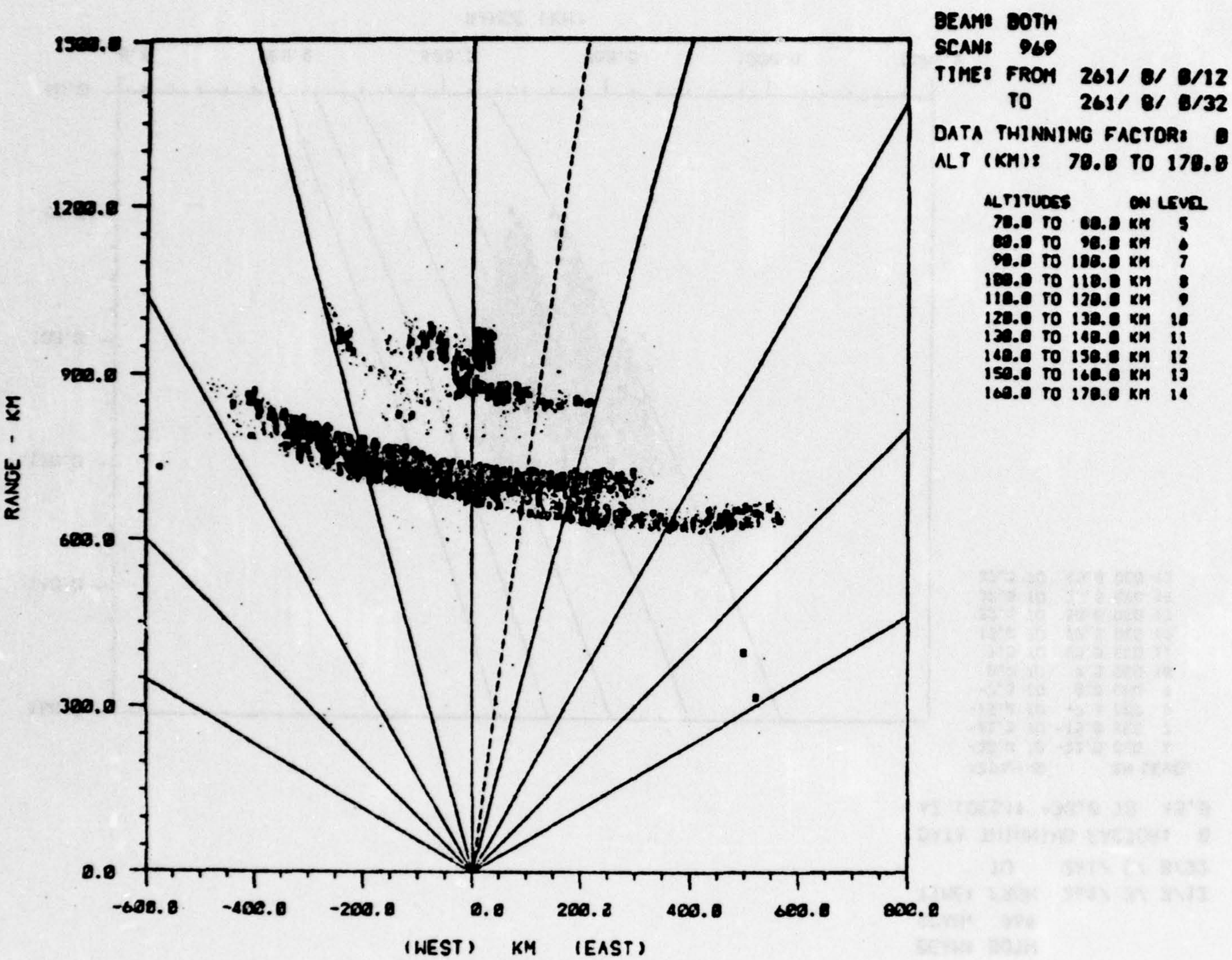
AZ (DEG): -30.0 TO 45.0

AZIMUTHS	ON LEVEL
-30.0 TO -22.5 DEG	6
-22.5 TO -15.0 DEG	7
-15.0 TO -7.5 DEG	8
-7.5 TO 0.0 DEG	9
0.0 TO 7.5 DEG	10
7.5 TO 15.0 DEG	11
15.0 TO 22.5 DEG	12
22.5 TO 30.0 DEG	13
30.0 TO 37.5 DEG	14
37.5 TO 45.0 DEG	15



M&S OMPUTING

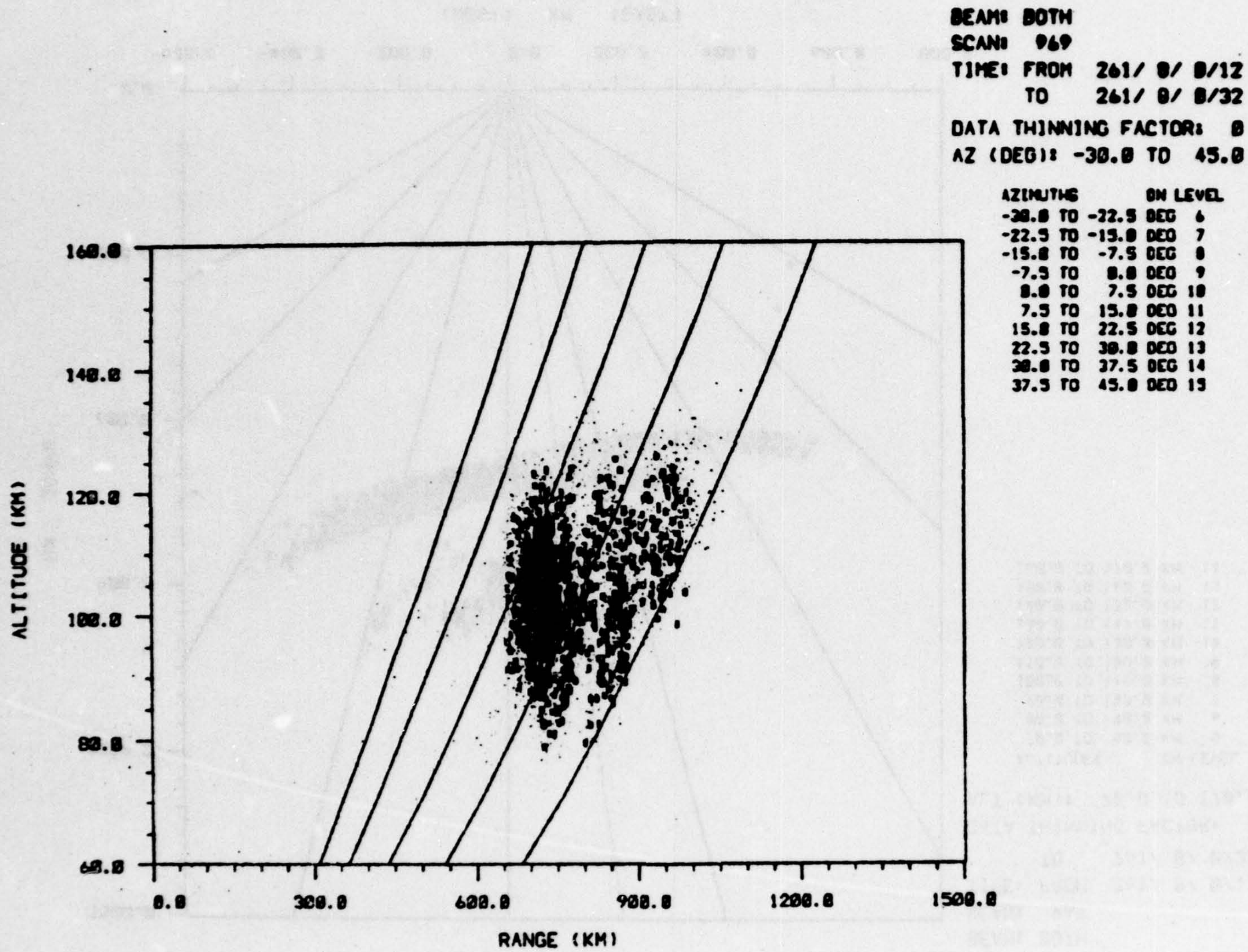
Figure 5-60



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

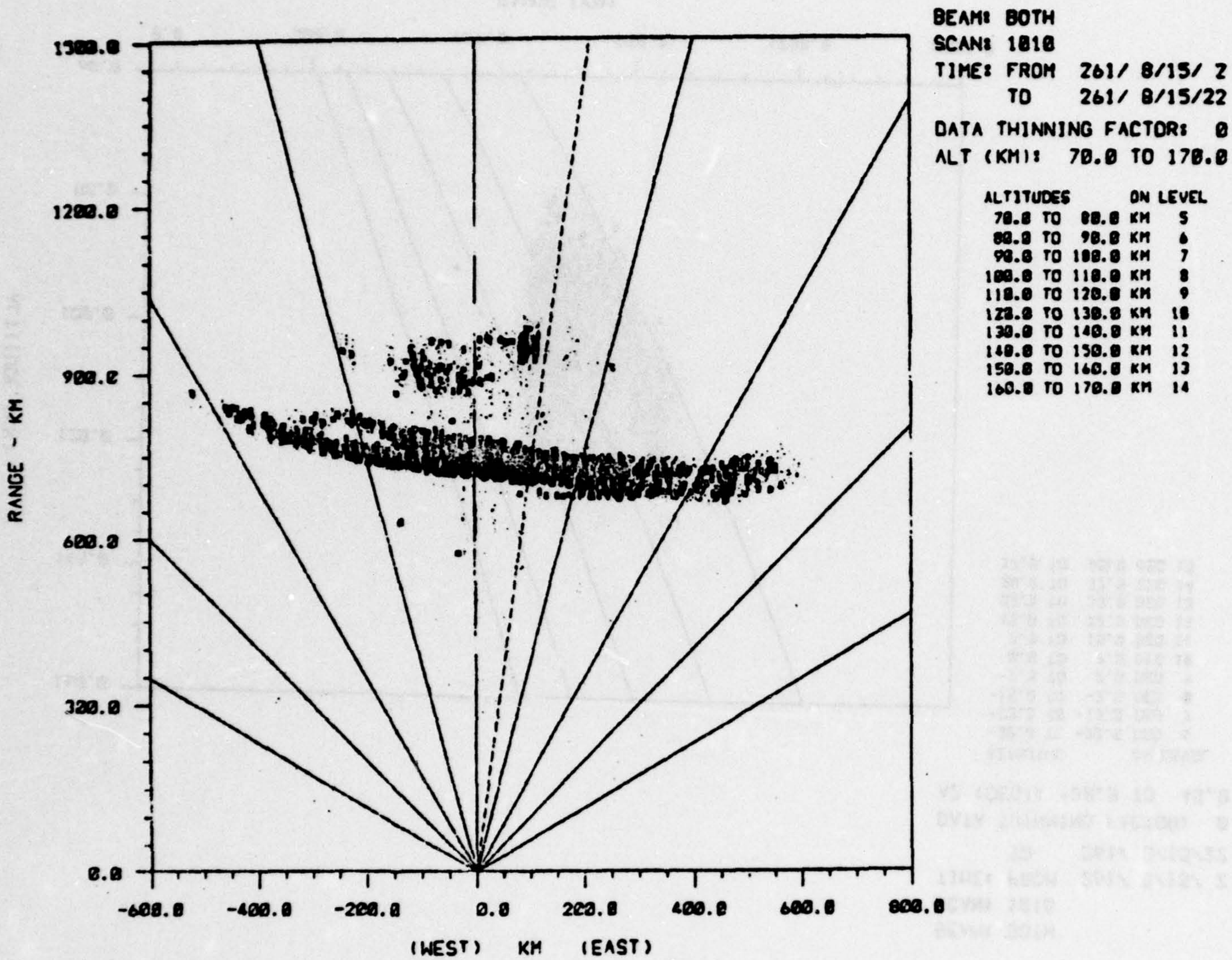
M&S OMPUTING

Figure 5-61



M&S COMPUTING

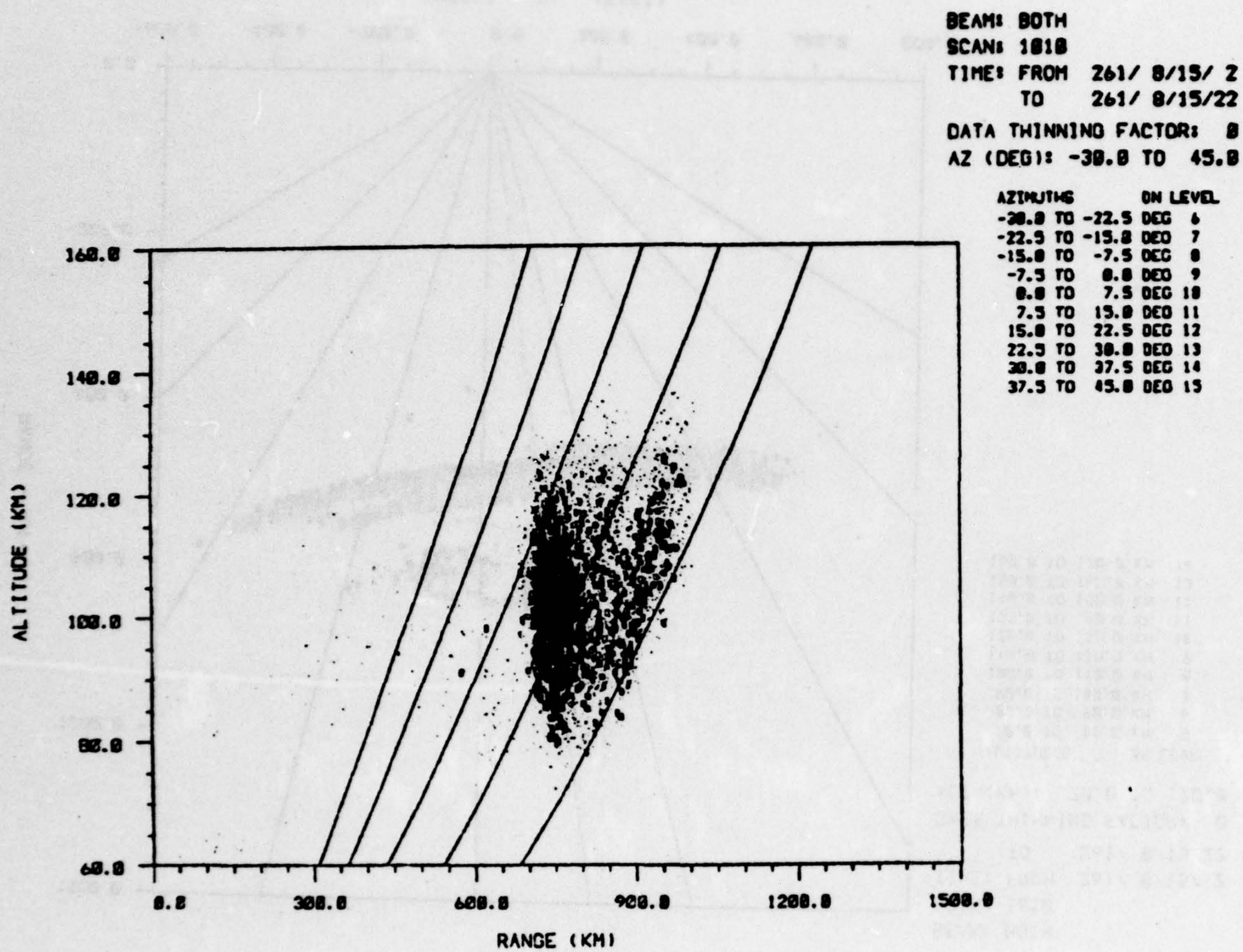
Figure 5-62



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

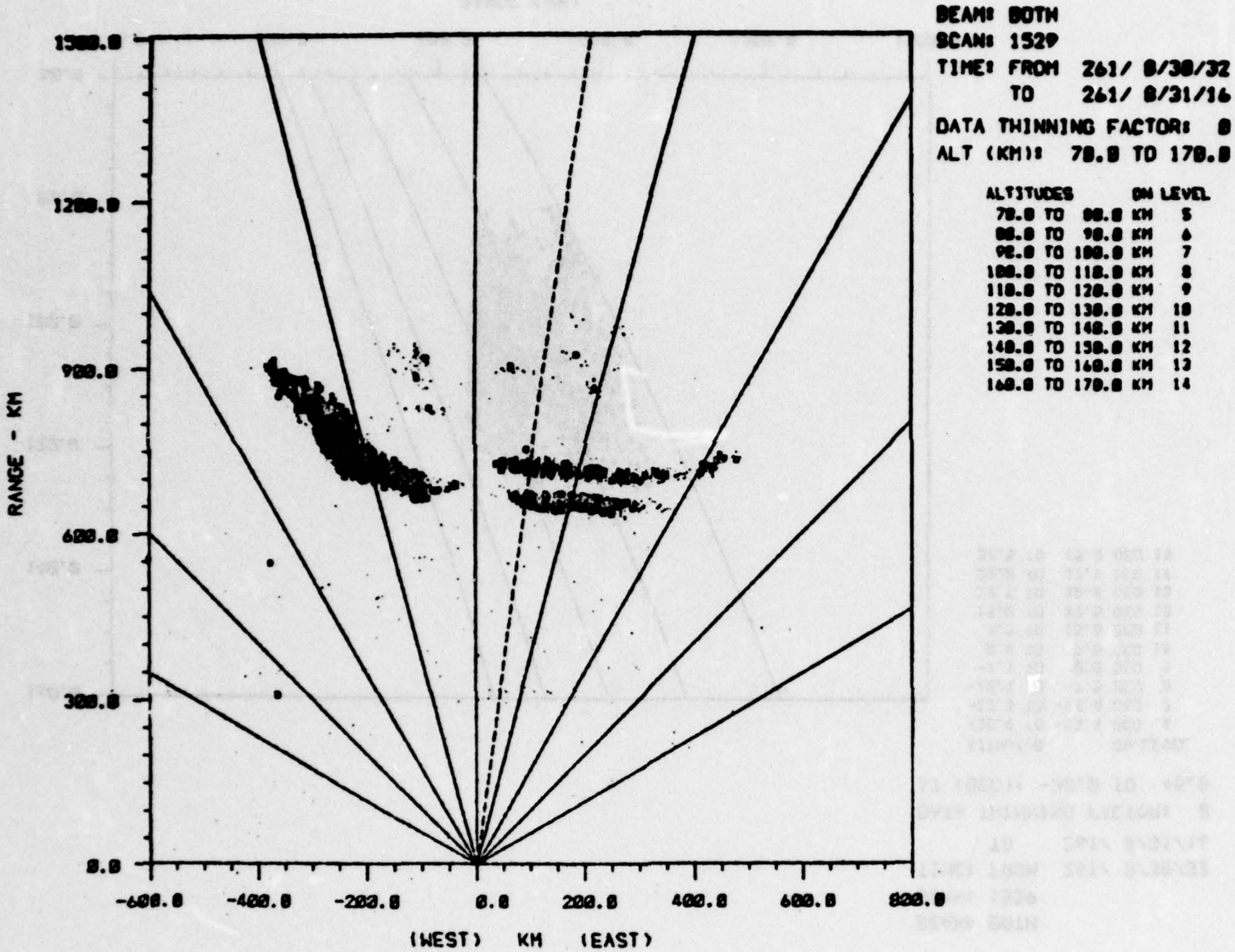
M&S COMPUTING

Figure 5-63



M&S COMPUTING

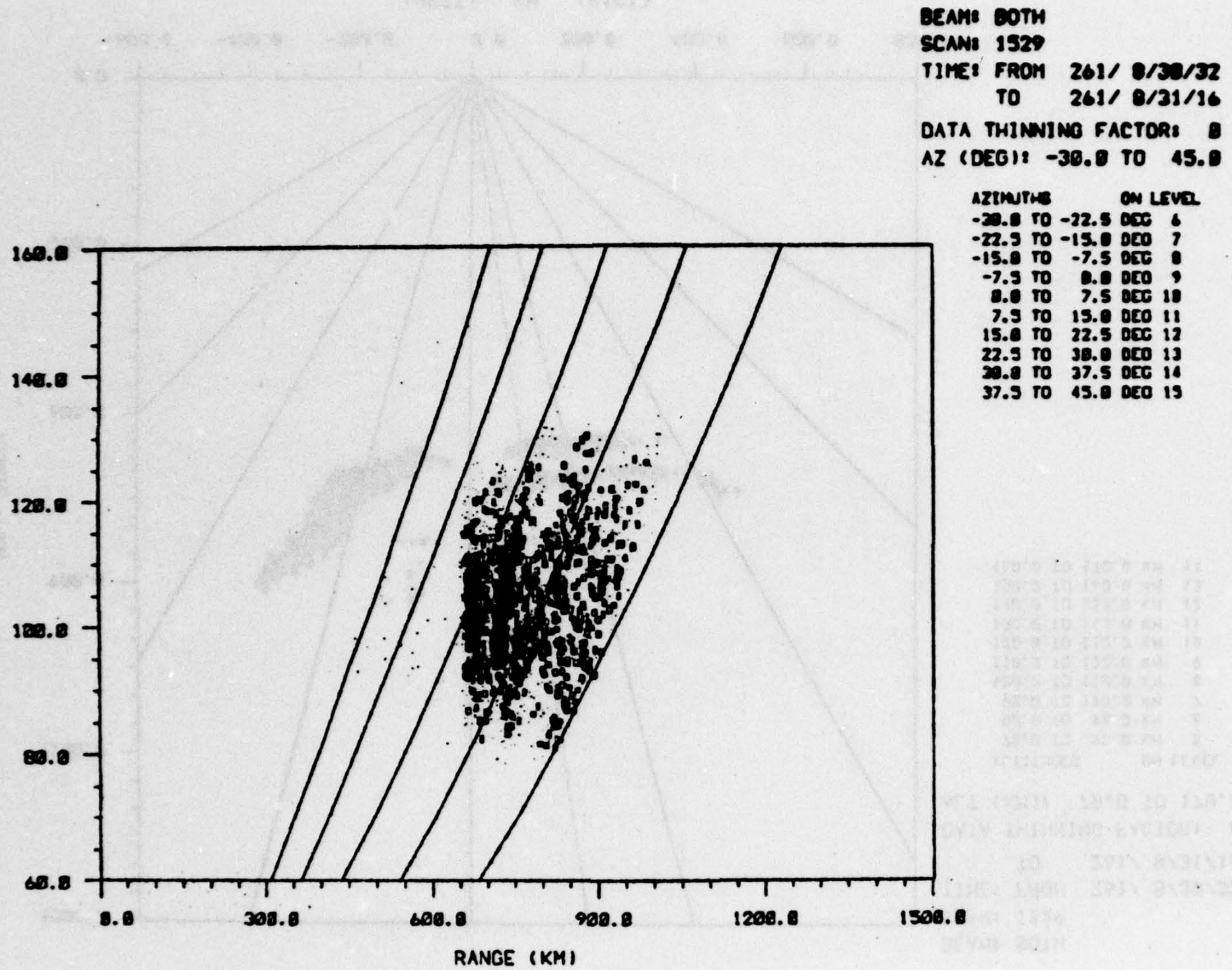
Figure 5-64



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

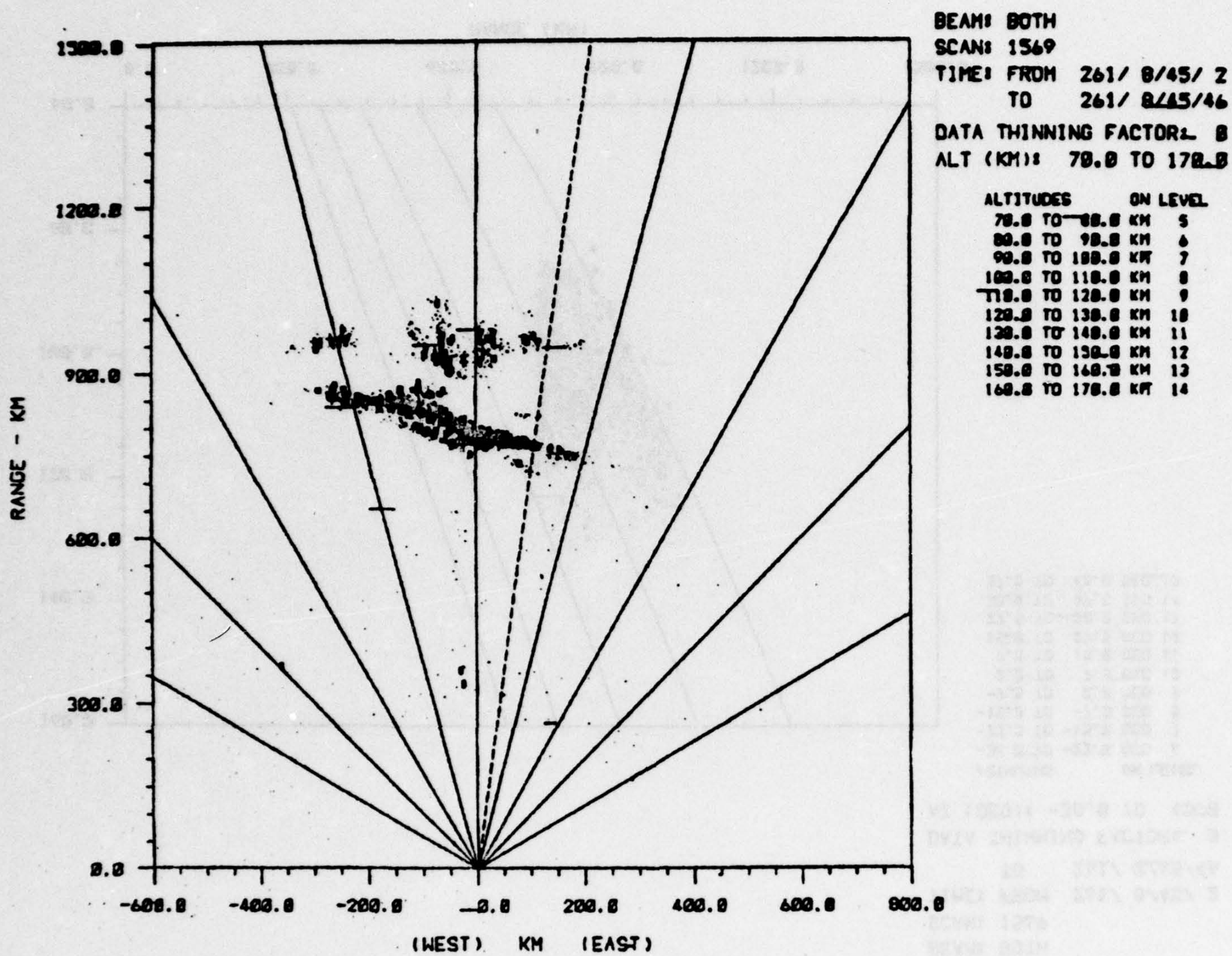
M&S OMPUTING

Figure 5-65



M&S COMPUTING

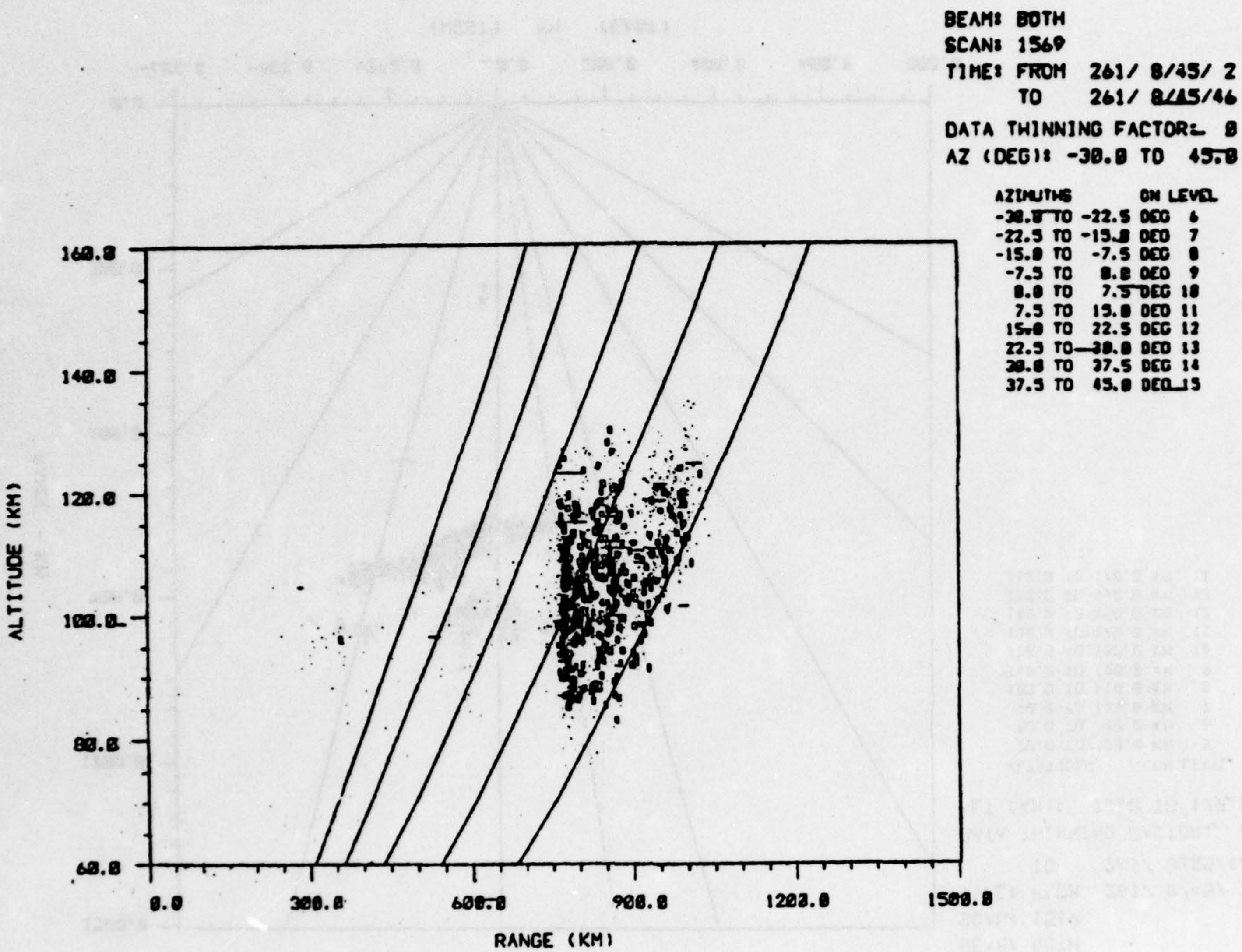
Figure 5-66



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

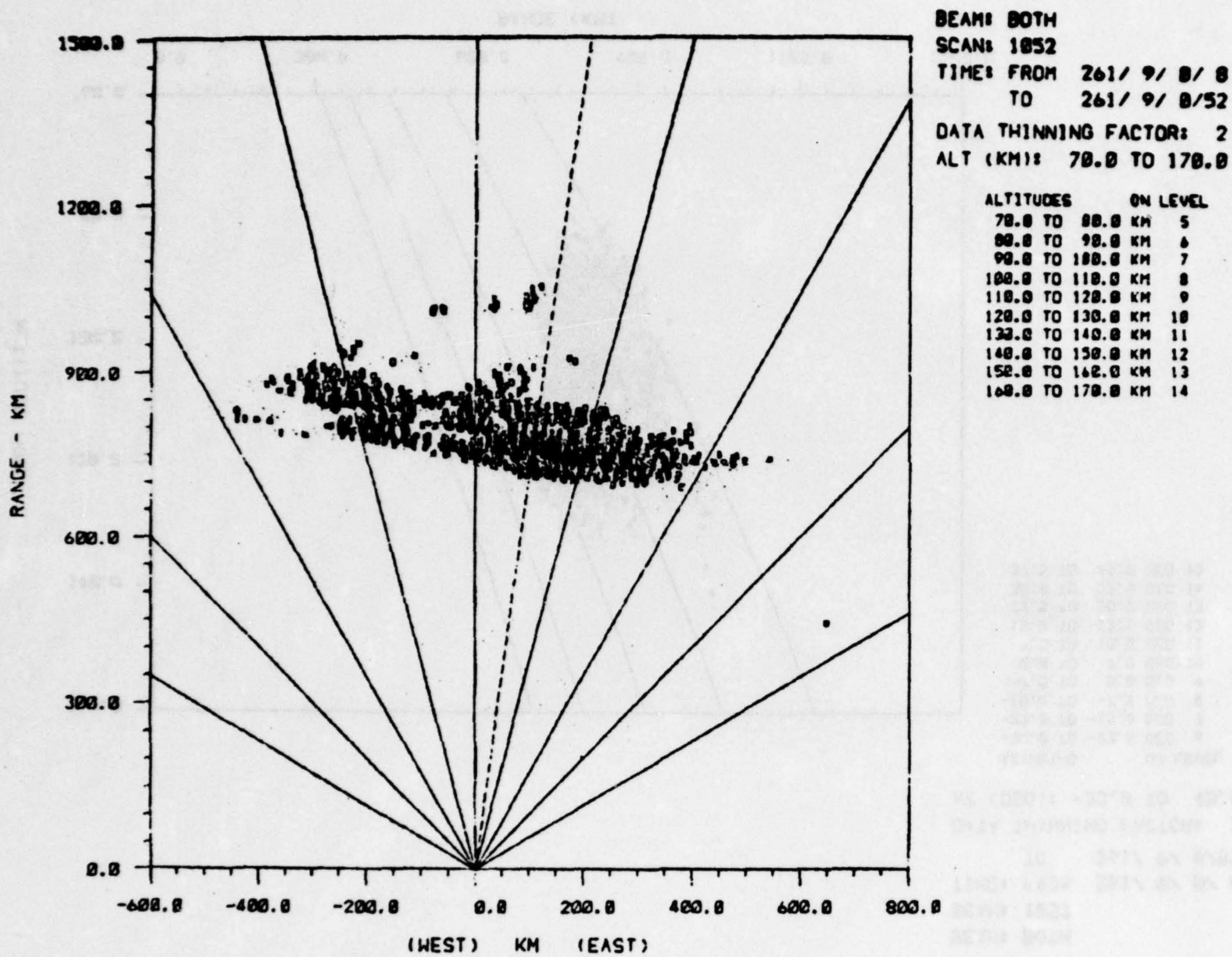
M&S COMPUTING

Figure 5-67



MRS COMPUTING

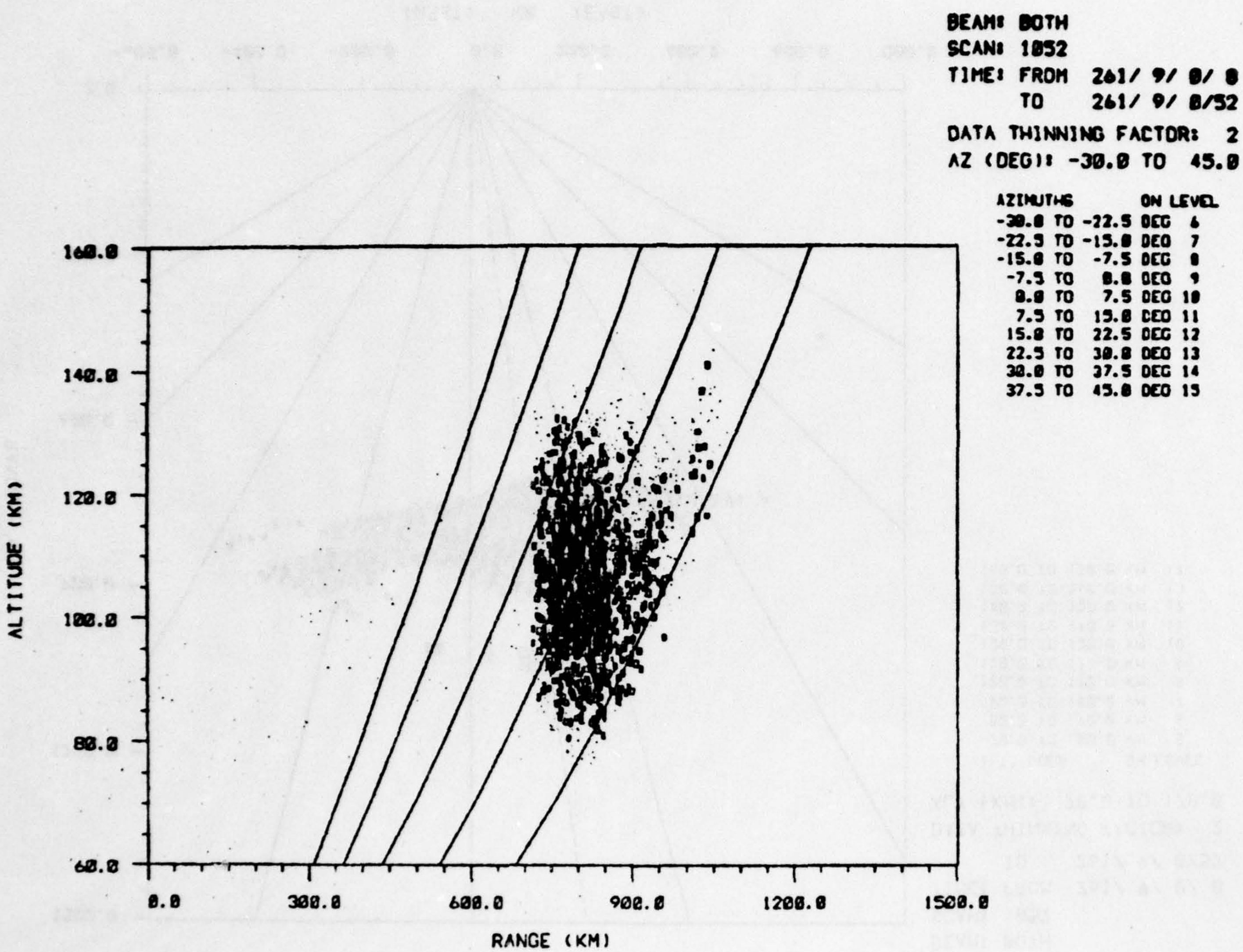
Figure 5-68



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

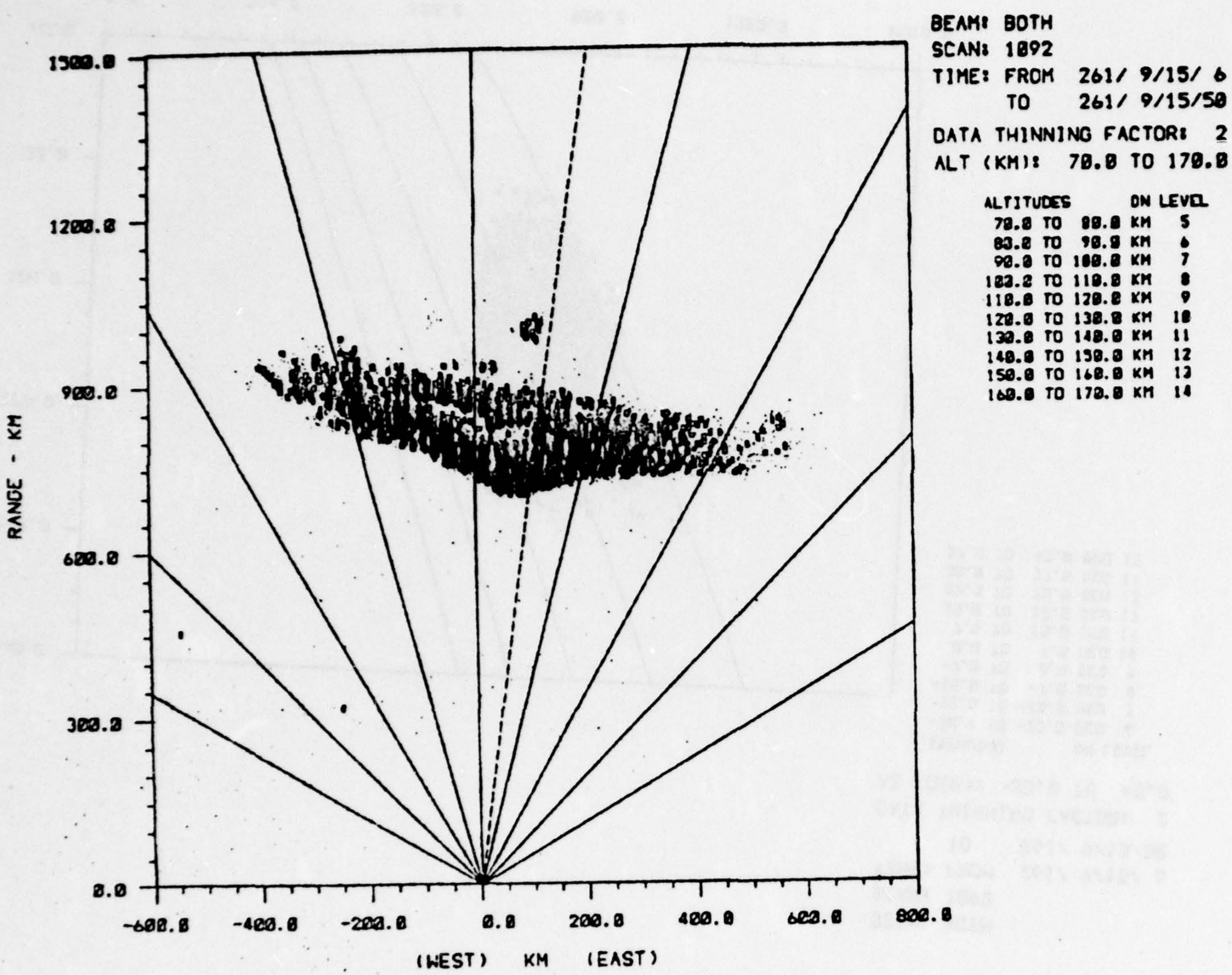
M&S COMPUTING

Figure 5-69



M&S COMPUTING

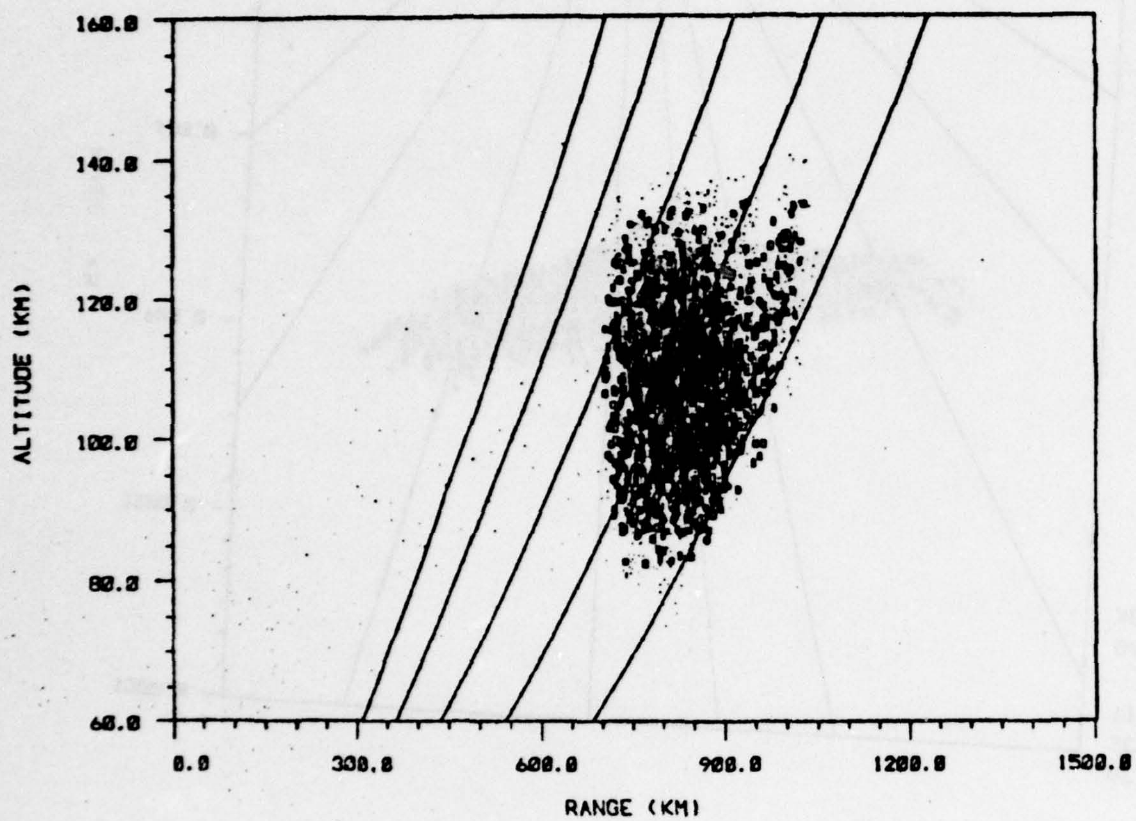
Figure 5-70



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

MRS COMPUTING

Figure 5-71

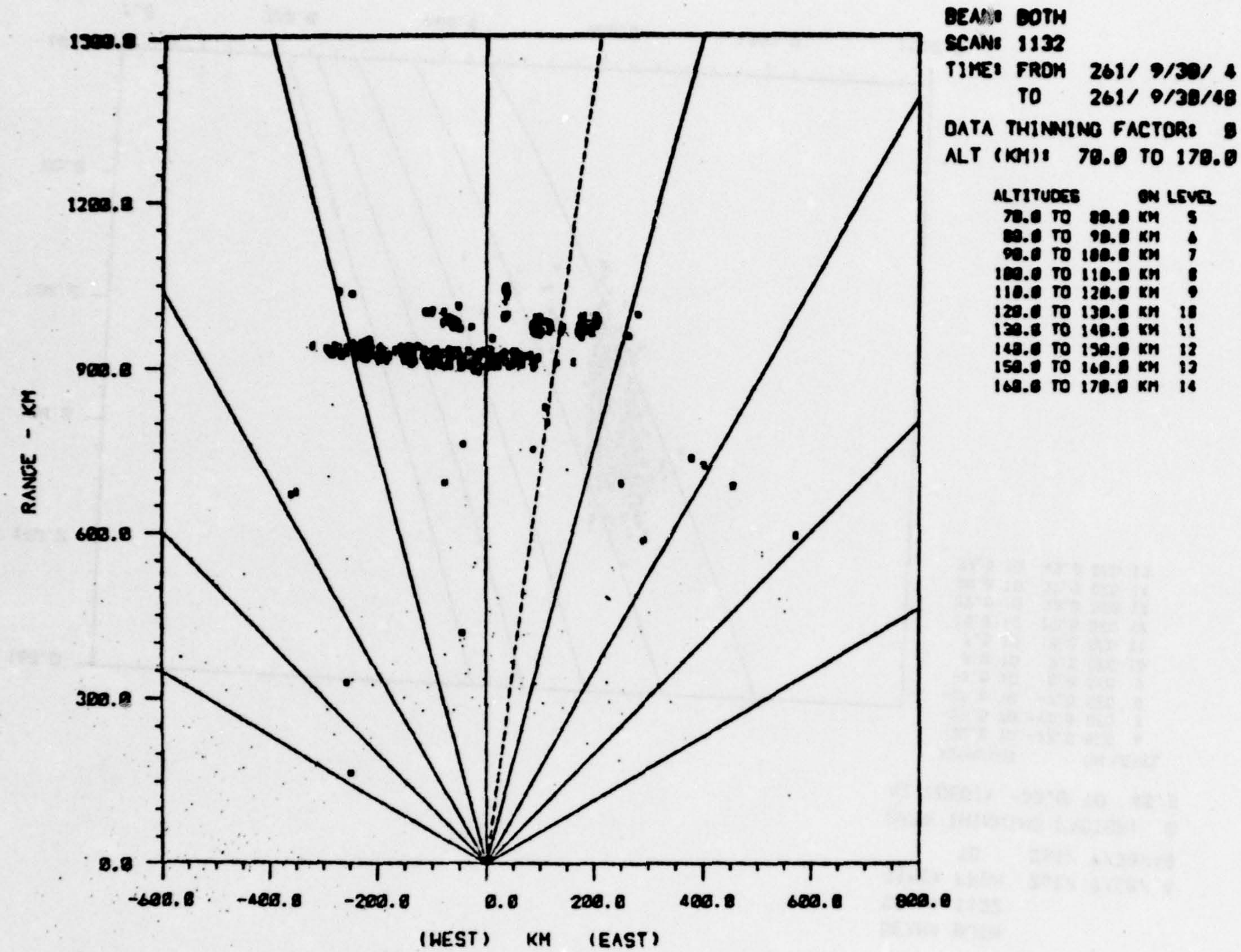


BEAM: BOTH
SCAN: 1092
TIME: FROM 261/ 9/15/ 6
TO 261/ 9/15/50
DATA THINNING FACTOR: 2
AZ (DEG): -30.0 TO 45.0

AZIMUTHS	ON LEVEL
-30.0 TO -22.5 DEG	6
-22.5 TO -15.0 DEG	7
-15.0 TO -7.5 DEG	8
-7.5 TO 0.0 DEG	9
0.0 TO 7.5 DEG	10
7.5 TO 15.0 DEG	11
15.0 TO 22.5 DEG	12
22.5 TO 30.0 DEG	13
30.0 TO 37.5 DEG	14
37.5 TO 45.0 DEG	15

M&S COMPUTING

Figure 5-72



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

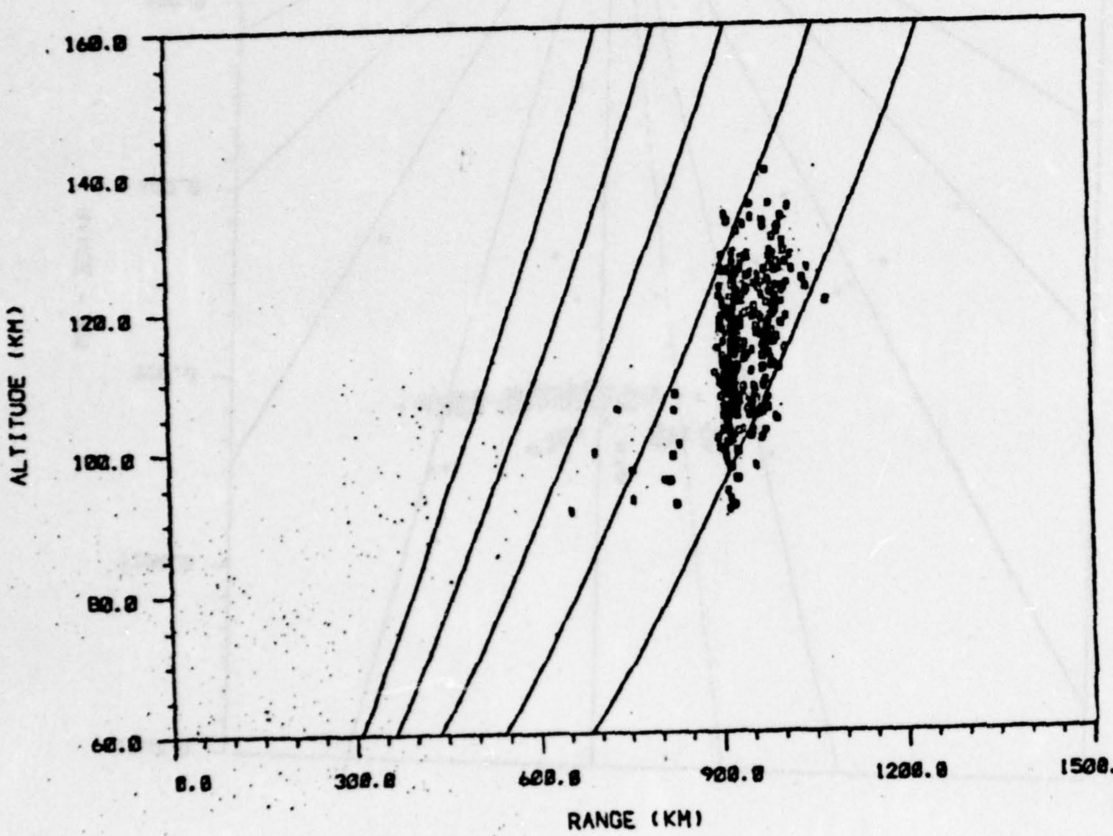
MIS OMPUTING

Figure 5-73

BEAM: BOTH
SCAN: 1132
TIME: FROM 261/ 9/30/ 4
TO 261/ 9/30/40

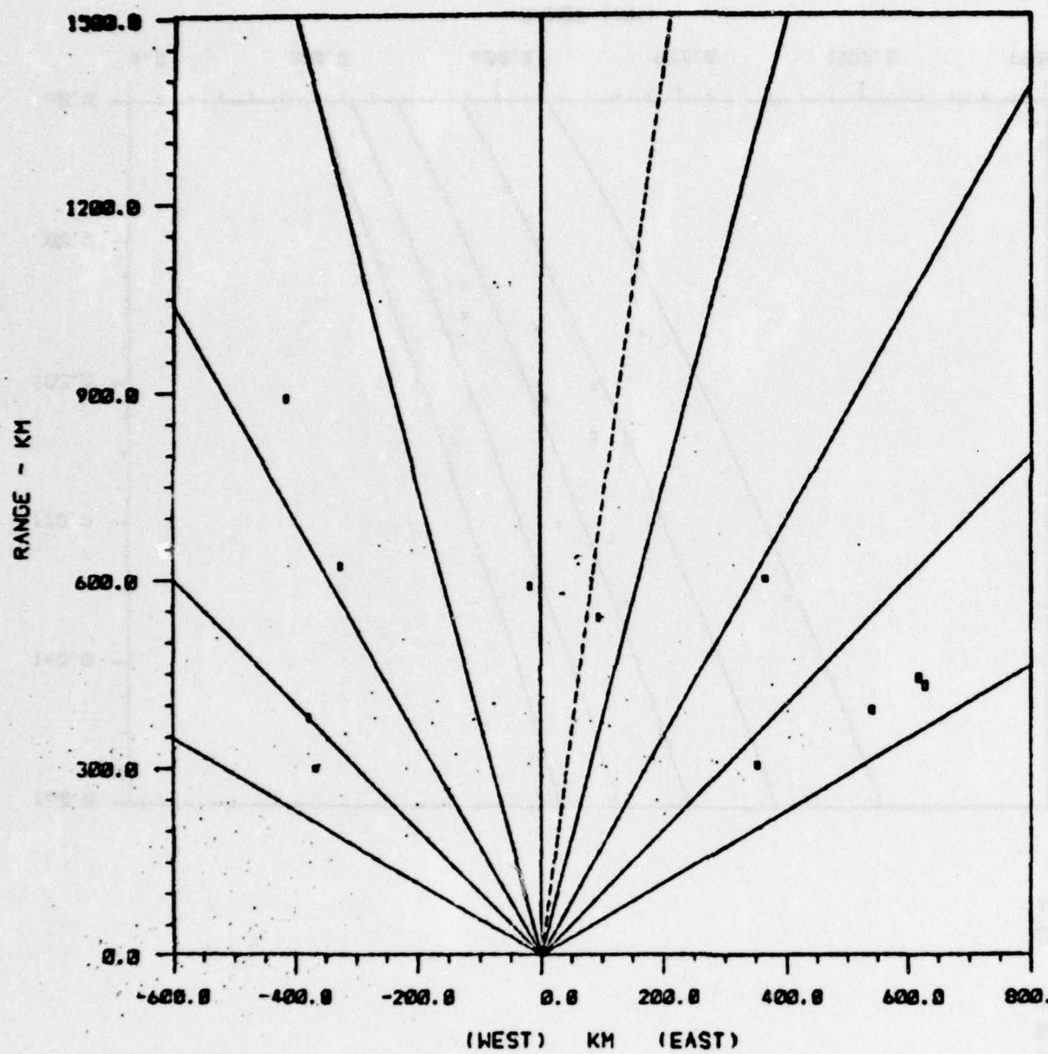
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 45.0

AZIMUTHS	ON LEVEL
-30.0 TO -22.5 DEG	6
-22.5 TO -15.0 DEG	7
-15.0 TO -7.5 DEG	8
-7.5 TO 0.0 DEG	9
0.0 TO 7.5 DEG	10
7.5 TO 15.0 DEG	11
15.0 TO 22.5 DEG	12
22.5 TO 30.0 DEG	13
30.0 TO 37.5 DEG	14
37.5 TO 45.0 DEG	15



M&S COMPUTING

Figure 5-74



BEAM: BOTH
SCAN: 1173
TIME: FROM 261/ 9/45/10
TO 261/ 9/45/30

DATA THINNING FACTOR: 0
ALT (KM): 70.0 TO 170.0

ALTITUDES	ON LEVEL
70.0 TO 80.0 KM	5
80.0 TO 90.0 KM	6
90.0 TO 100.0 KM	7
100.0 TO 110.0 KM	8
110.0 TO 120.0 KM	9
120.0 TO 130.0 KM	10
130.0 TO 140.0 KM	11
140.0 TO 150.0 KM	12
150.0 TO 160.0 KM	13
160.0 TO 170.0 KM	14

TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

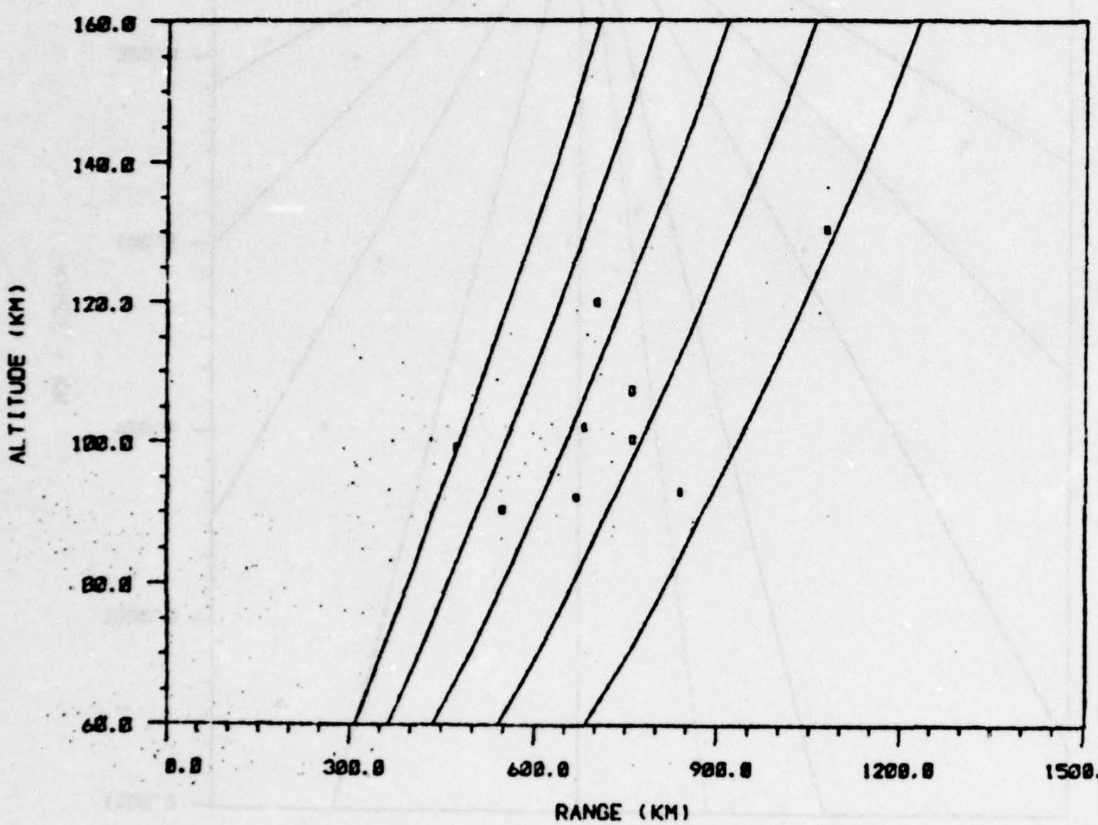
M&S COMPUTING

Figure 5-75

BEAM: BOTH
SCAN: 1173
TIME: FROM 261/ 9/45/18
TO 261/ 9/45/38

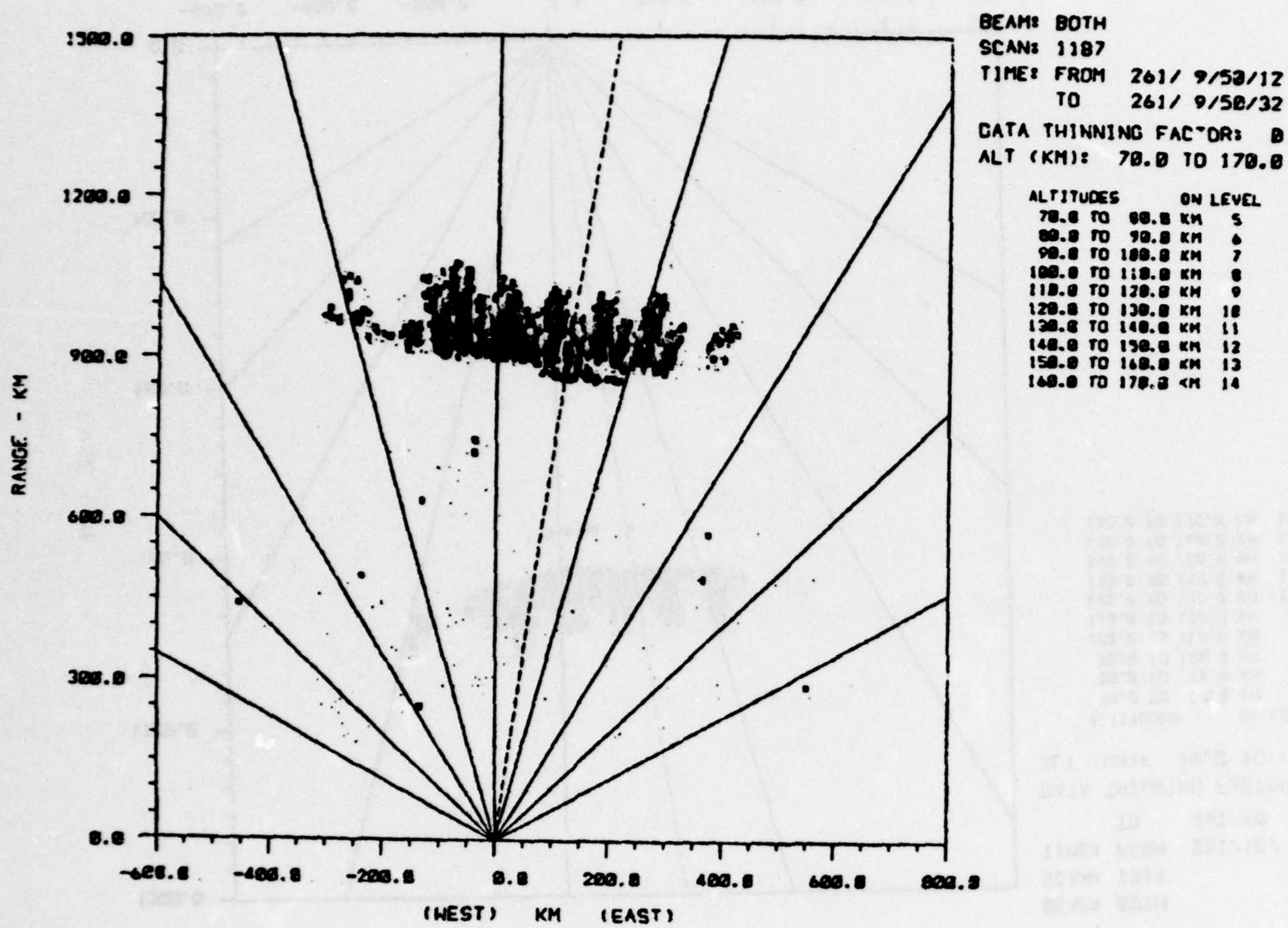
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 420.0

AZIMUTHS			ON LEVEL
-30.0 TO	15.0	DEG	6
15.0 TO	60.0	DEG	7
60.0 TO	105.0	DEG	8
105.0 TO	150.0	DEG	9
150.0 TO	195.0	DEG	10
195.0 TO	240.0	DEG	11
240.0 TO	285.0	DEG	12
285.0 TO	330.0	DEG	13
330.0 TO	375.0	DEG	14
375.0 TO	420.0	DEG	15



M&S OMPUTING

Figure 5-76



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

M&S COMPUTING

Figure 5-77

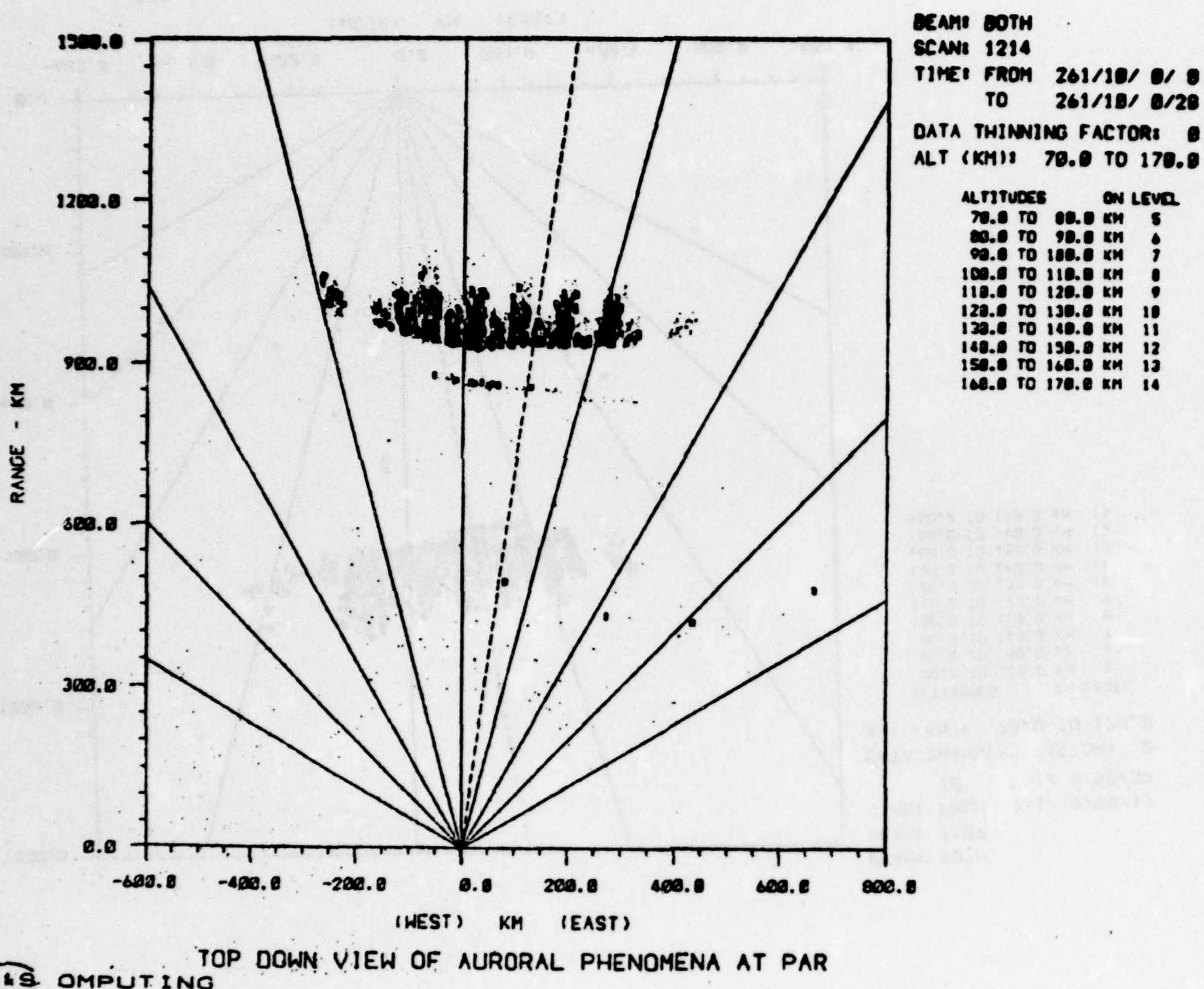
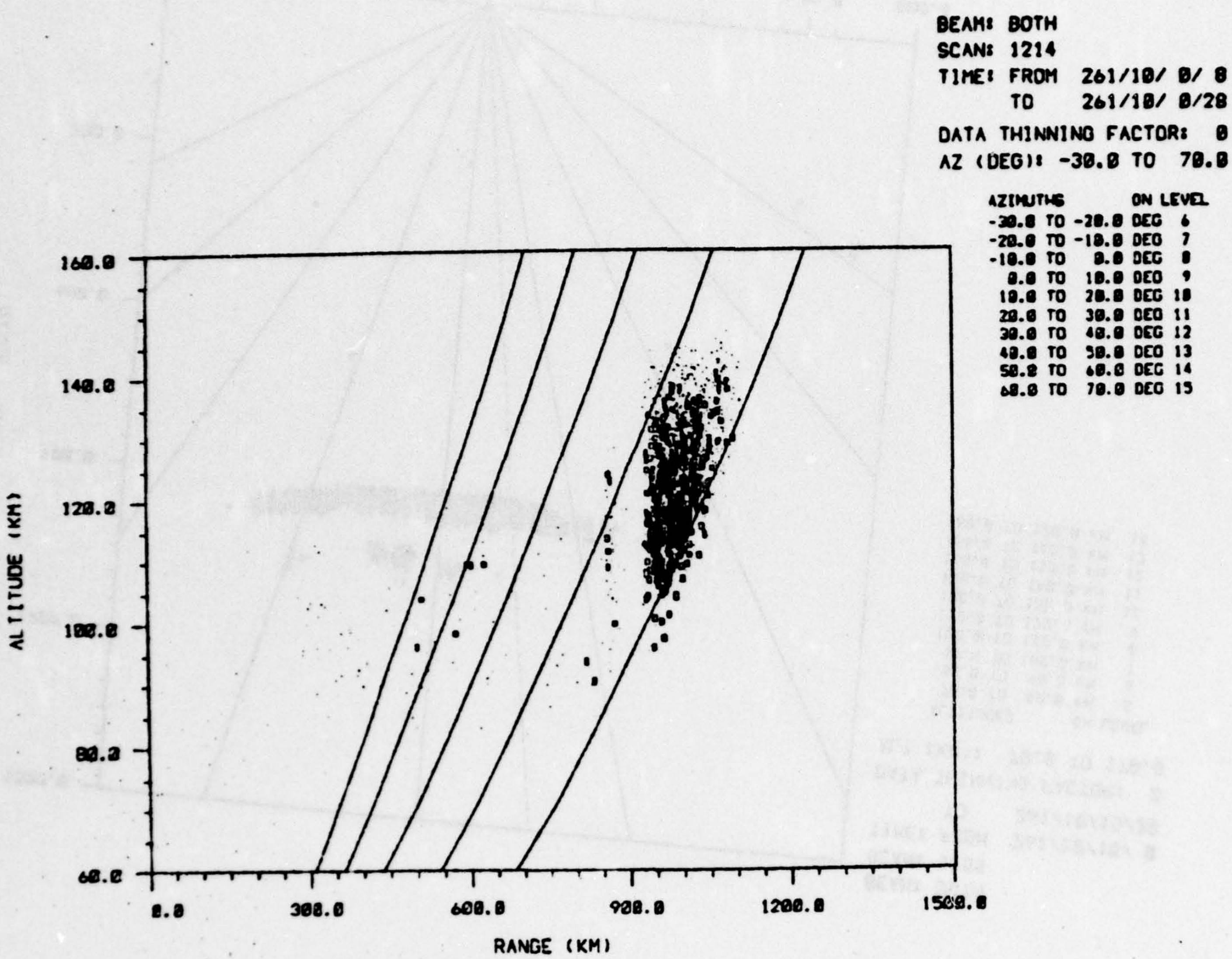
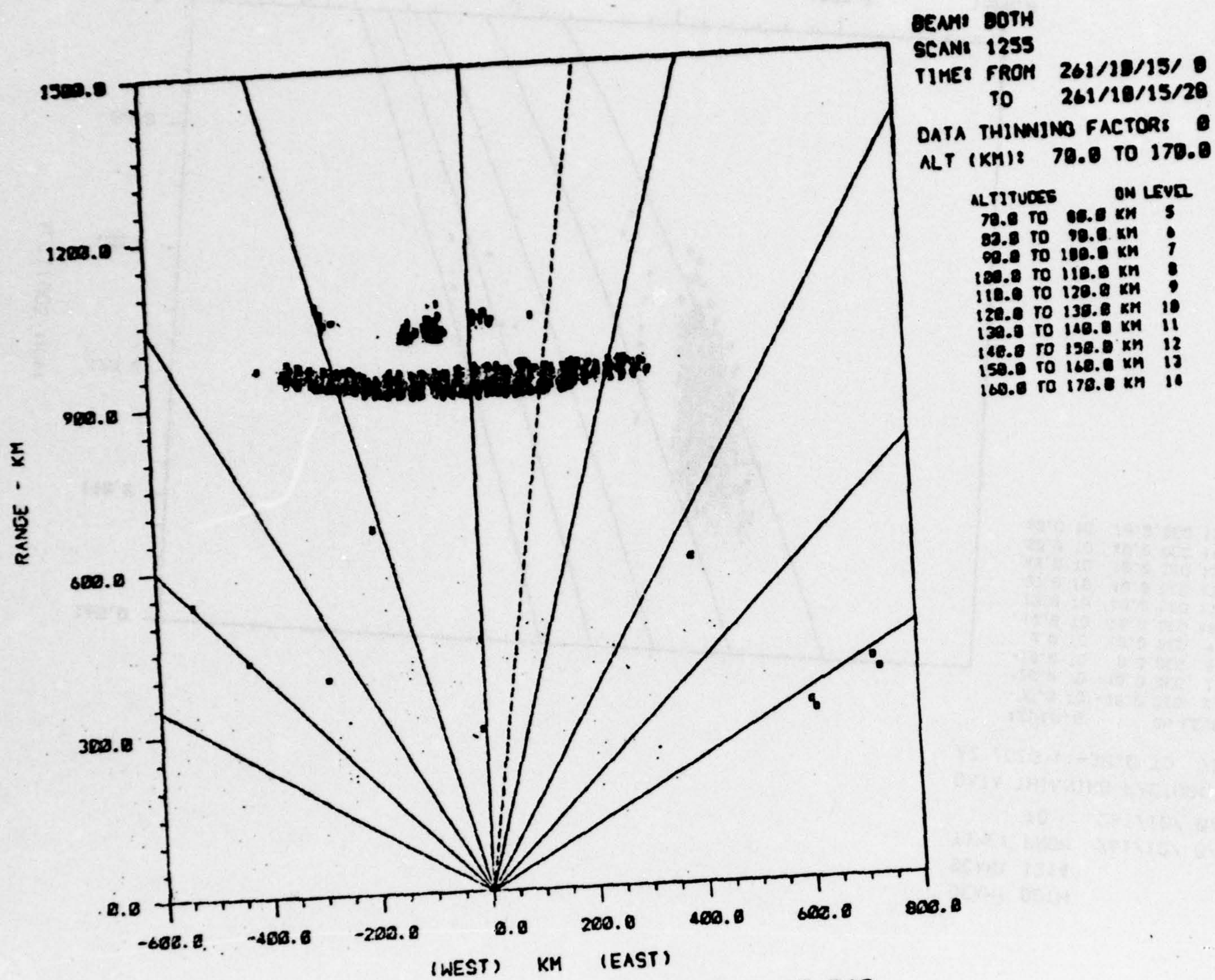

BEAM: BOTH
SCAN: 1214
TIME: FROM 261/18/ 0/ 0
TO 261/18/ 0/20
DATA THINNING FACTOR: 0
ALT (KM): 70.0 TO 170.0
ALTITUDES ON LEVEL
70.0 TO 80.0 KM 5
80.0 TO 90.0 KM 6
90.0 TO 100.0 KM 7
100.0 TO 110.0 KM 8
110.0 TO 120.0 KM 9
120.0 TO 130.0 KM 10
130.0 TO 140.0 KM 11
140.0 TO 150.0 KM 12
150.0 TO 160.0 KM 13
160.0 TO 170.0 KM 14
RANGE - KM
1500.0
1200.0
900.0
600.0
300.0
0.0
-600.0
-400.0
-200.0
0.0
200.0
400.0
600.0
800.0
(WEST) KM (EAST)
TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR
M&S OMPUTING

Figure 5-78



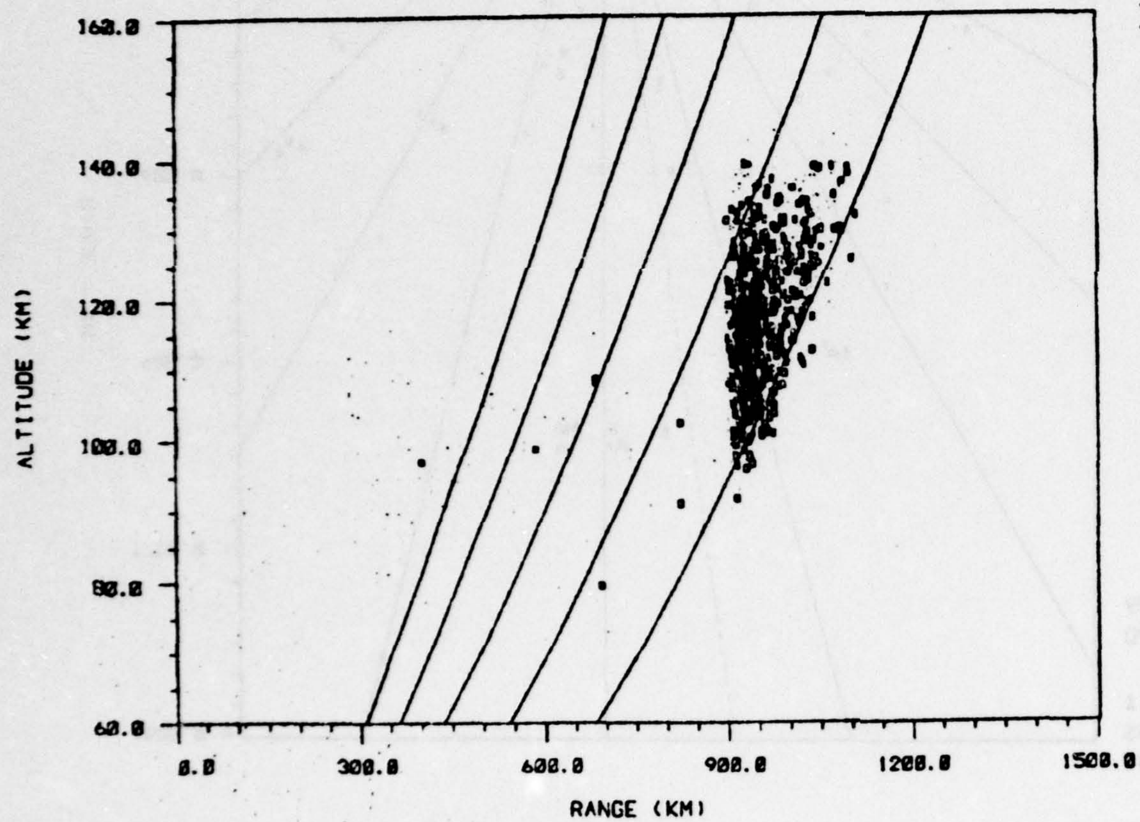
M&S COMPUTING

Figure 5-79



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 30

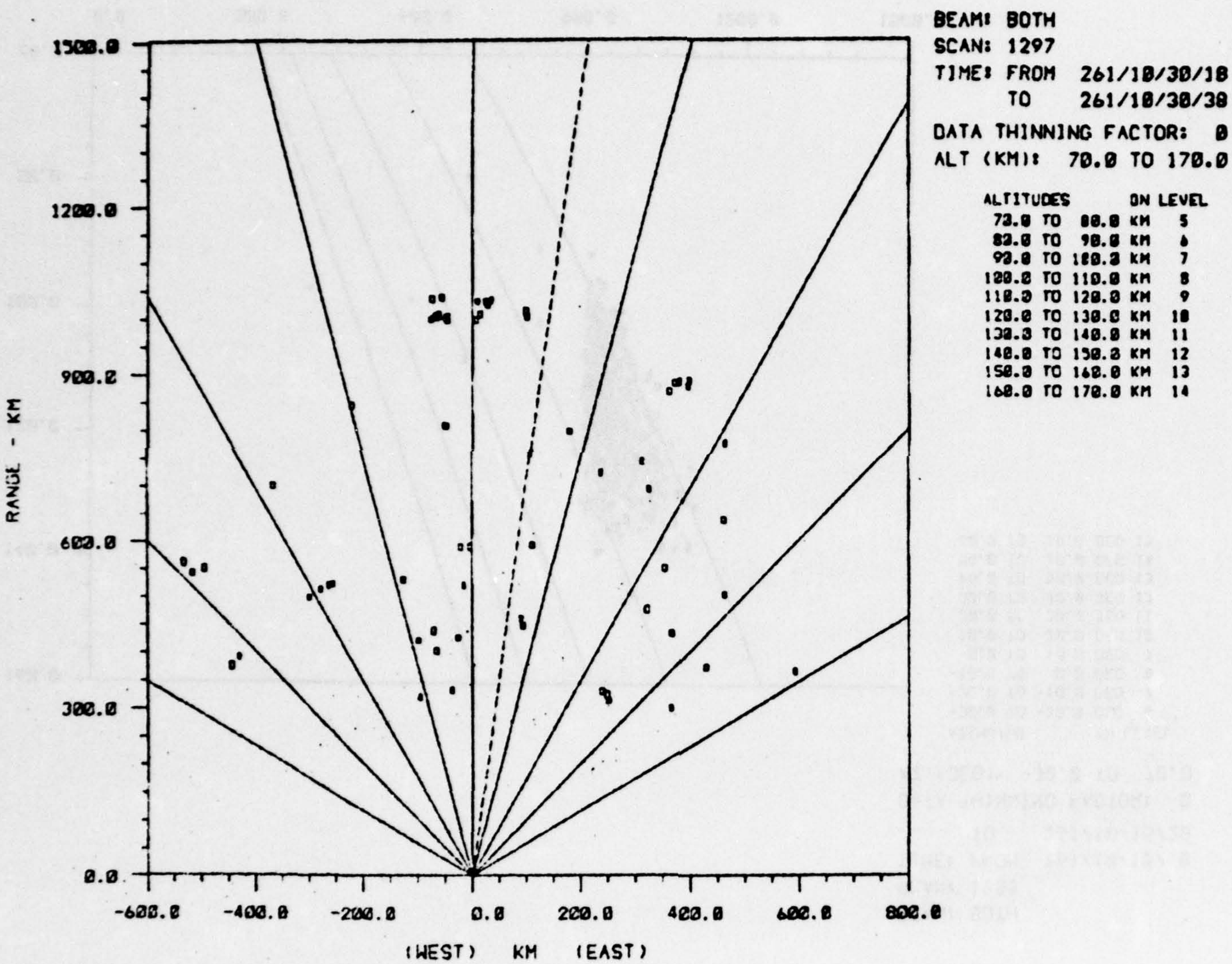


BEAM: BOTH
SCAN: 1255
TIME: FROM 261/10/15/ 0
TO 261/10/15/28
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 70.0

AZIMUTHS	ON LEVEL
-30.0 TO -20.0 DEG	6
-20.0 TO -10.0 DEG	7
-10.0 TO 0.0 DEG	8
0.0 TO 10.0 DEG	9
10.0 TO 20.0 DEG	10
20.0 TO 30.0 DEG	11
30.0 TO 40.0 DEG	12
40.0 TO 50.0 DEG	13
50.0 TO 60.0 DEG	14
60.0 TO 70.0 DEG	15

M&S COMPUTING

Figure 5-81



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

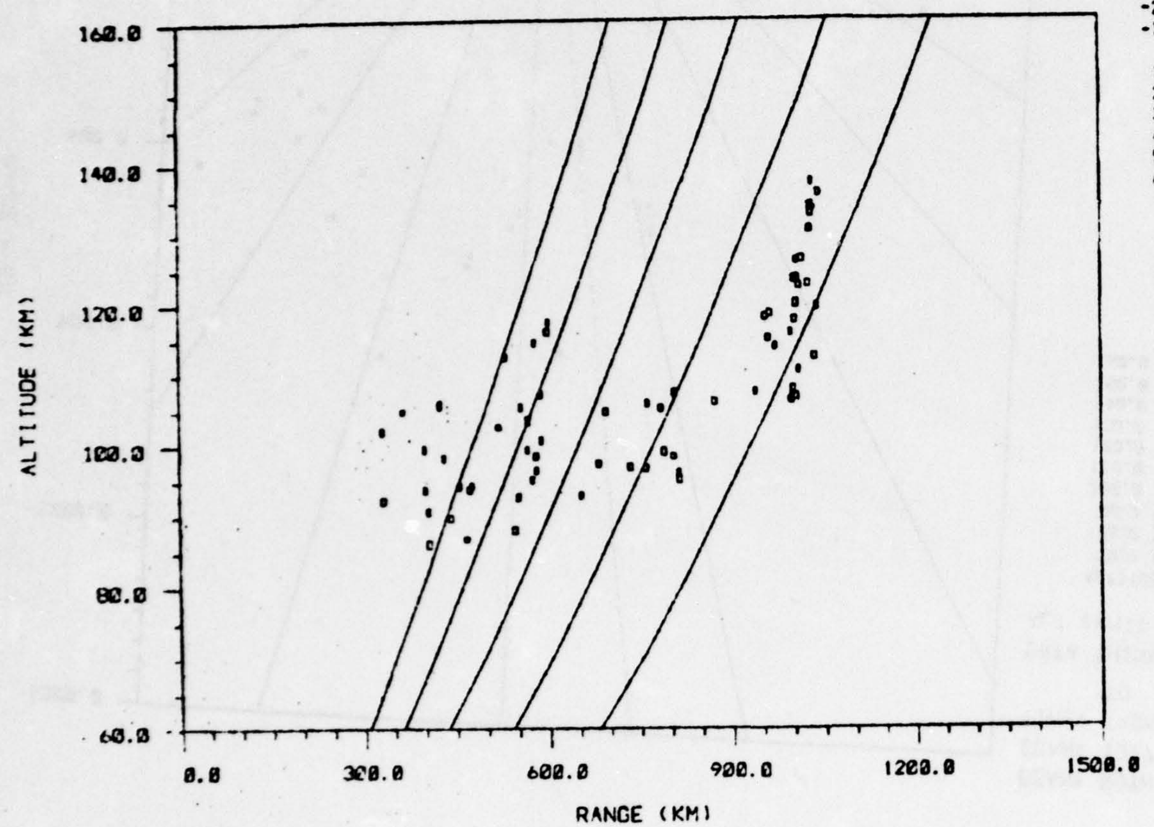
MRS OMPUTING

Figure 5-82

BEAM: BOTH
SCAN: 1297
TIME: FROM 261/10/30/18
TO 261/10/30/38

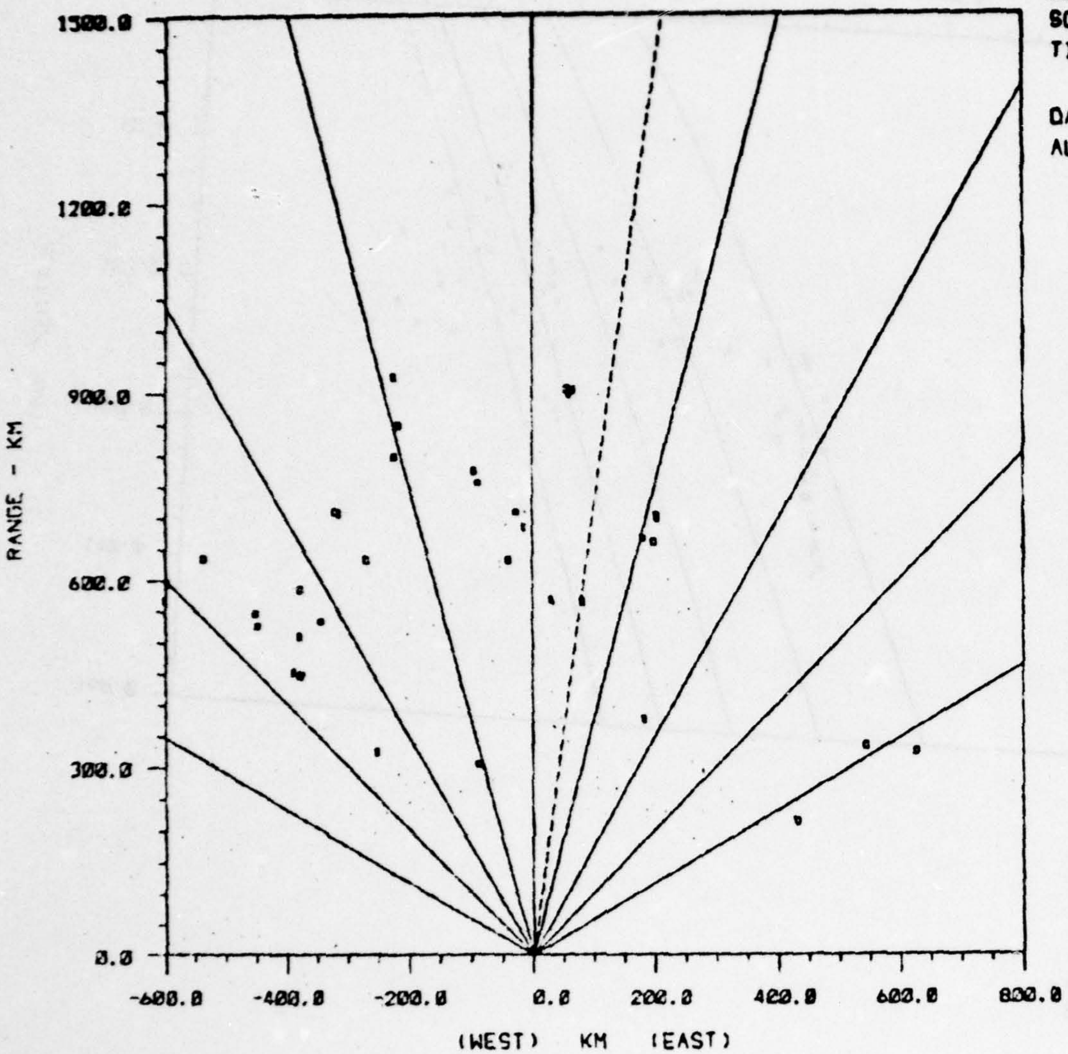
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 70.0

AZIMUTHS	CN LEVEL
-30.0 TO -20.0 DEG	6
-20.0 TO -10.0 DEG	7
-10.0 TO 0.0 DEG	8
0.0 TO 10.0 DEG	9
10.0 TO 20.0 DEG	10
20.0 TO 30.0 DEG	11
30.0 TO 40.0 DEG	12
40.0 TO 50.0 DEG	13
50.0 TO 60.0 DEG	14
60.0 TO 70.0 DEG	15



M+S OMPUTINO

Figure 5-83



BEAM: BOTH
SCAN: 1327
TIME: FROM 261/10/42/ 2
TO 261/10/42/22

DATA THINNING FACTOR: 0
ALT (KM): 70.0 TO 170.0

ALTITUDES	ON LEVEL
70.0 TO 80.0 KM	5
80.0 TO 90.0 KM	6
90.0 TO 100.0 KM	7
100.0 TO 110.0 KM	8
110.0 TO 120.0 KM	9
120.0 TO 130.0 KM	10
130.0 TO 140.0 KM	11
140.0 TO 150.0 KM	12
150.0 TO 160.0 KM	13
160.0 TO 170.0 KM	14

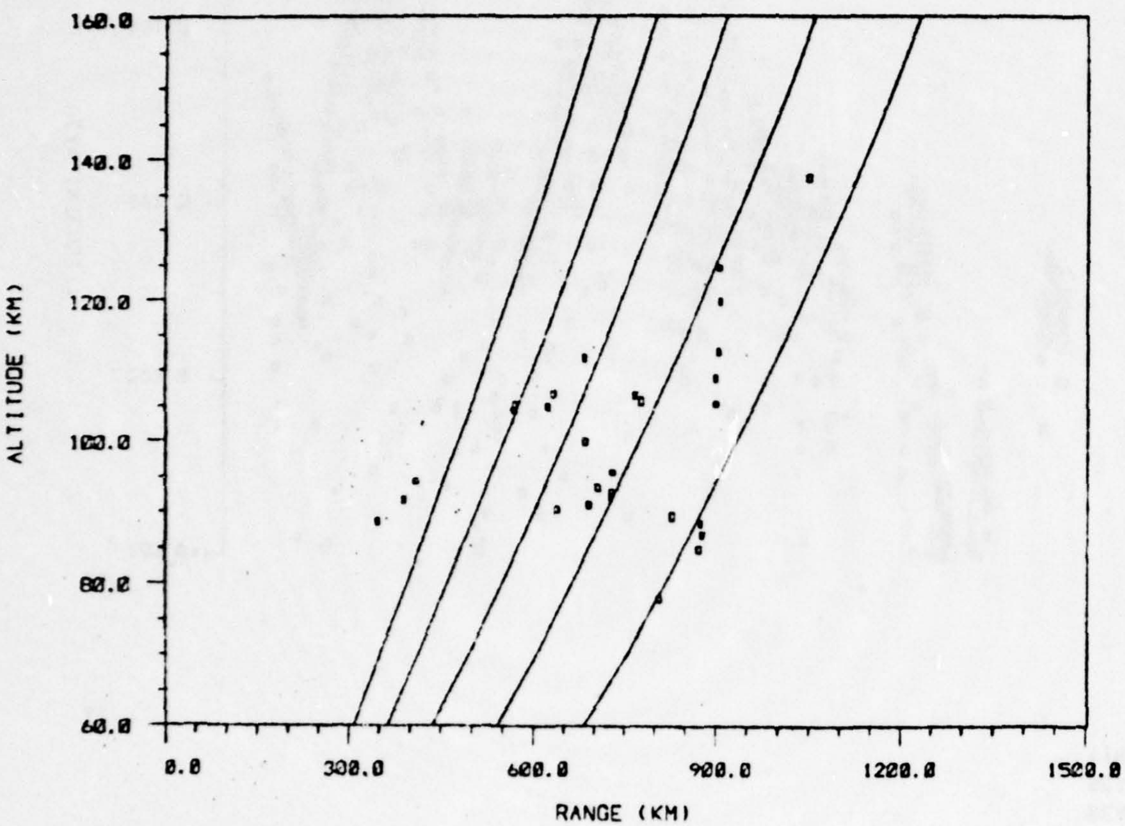
TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

MRS OMPUTING

Figure 5-84

BEAM: BOTH
SCAN: 1327
TIME: FROM 261/10/42/ 2
TO 261/10/42/22
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 70.0

AZIMUTHS	ON LEVEL
-30.0 TO -20.0 DEG	6
-20.0 TO -10.0 DEG	7
-10.0 TO 0.0 DEG	8
0.0 TO 10.0 DEG	9
10.0 TO 20.0 DEG	10
20.0 TO 30.0 DEG	11
30.0 TO 40.0 DEG	12
40.0 TO 50.0 DEG	13
50.0 TO 60.2 DEG	14
60.0 TO 70.0 DEG	15



M&S OMPUTING

Figure 5-85

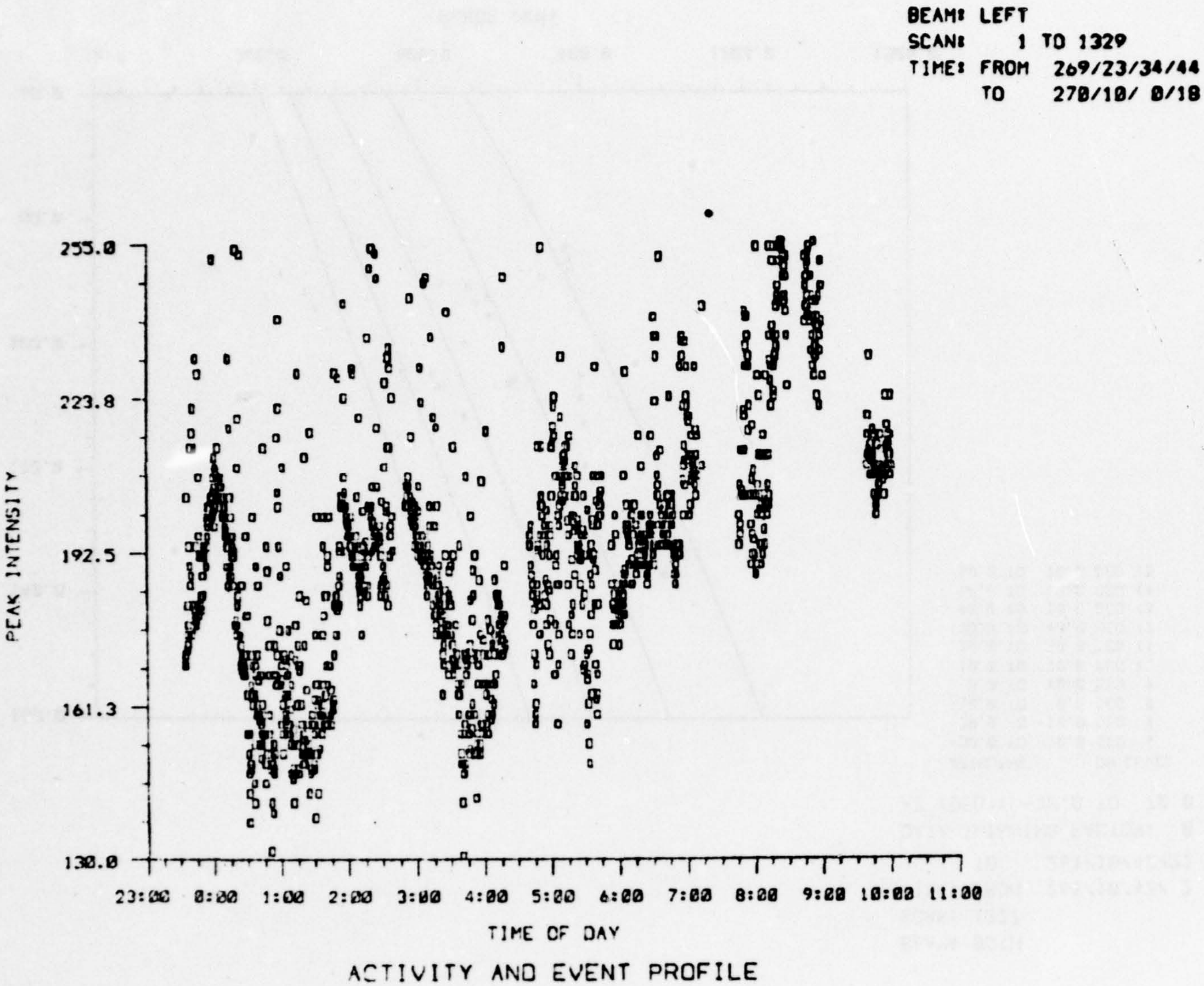
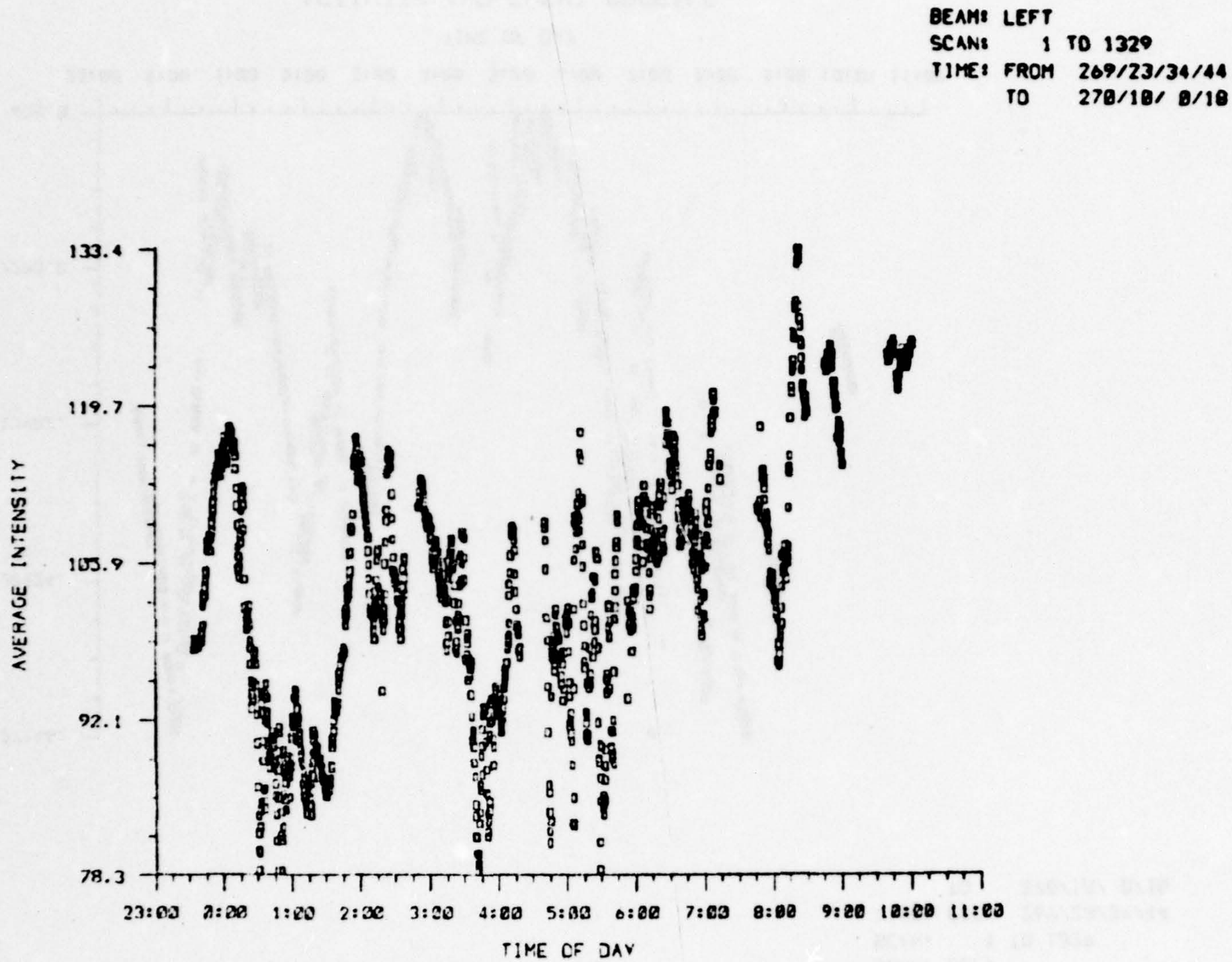

BEAM: LEFT
SCAN: 1 TO 1329
TIME: FROM 269/23/34/44
TO 270/10/ 0/18
PEAK INTENSITY
255.0
223.8
192.5
161.3
130.0
23:00
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
TIME OF DAY
ACTIVITY AND EVENT PROFILE

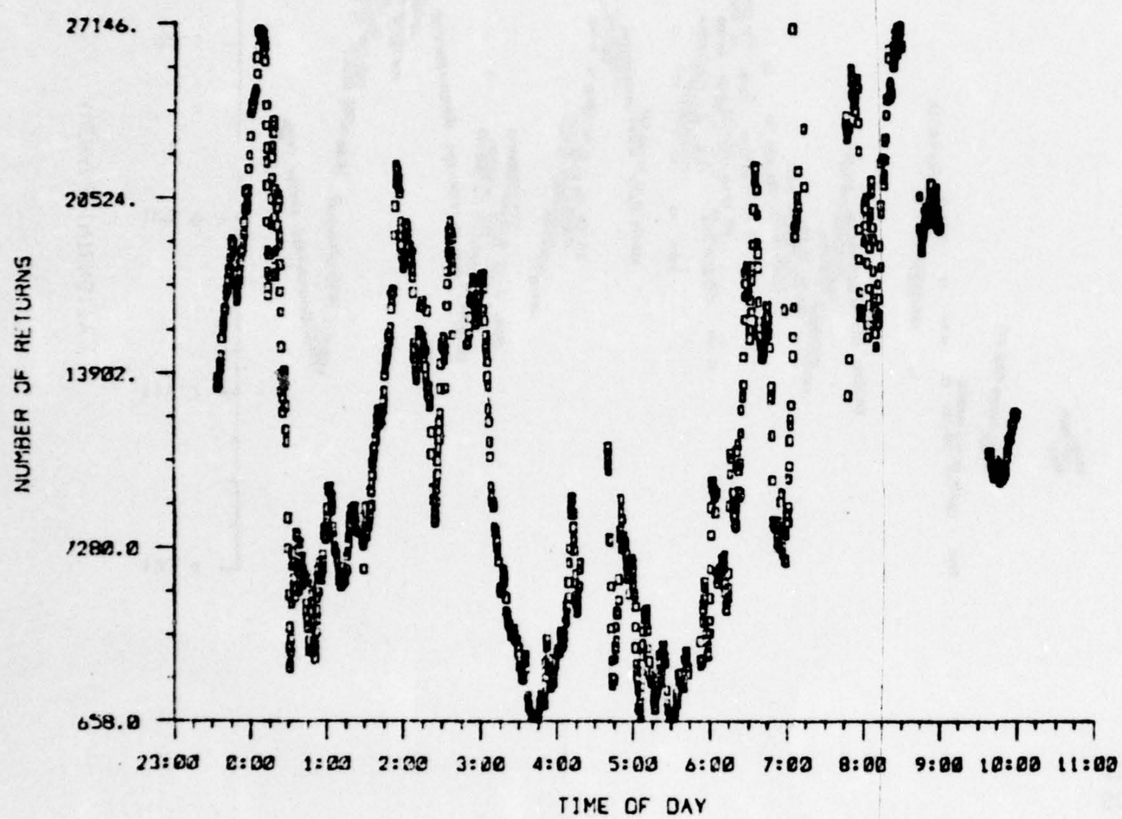
Figure 5-86



ACTIVITY AND EVENT PROFILE

Figure 5-87

BEAM: LEFT
SCAN: 1 TO 1329
TIME: FROM 269/23/34/44
TO 270/10/ 0/18



ACTIVITY AND EVENT PROFILE

Figure 5-88

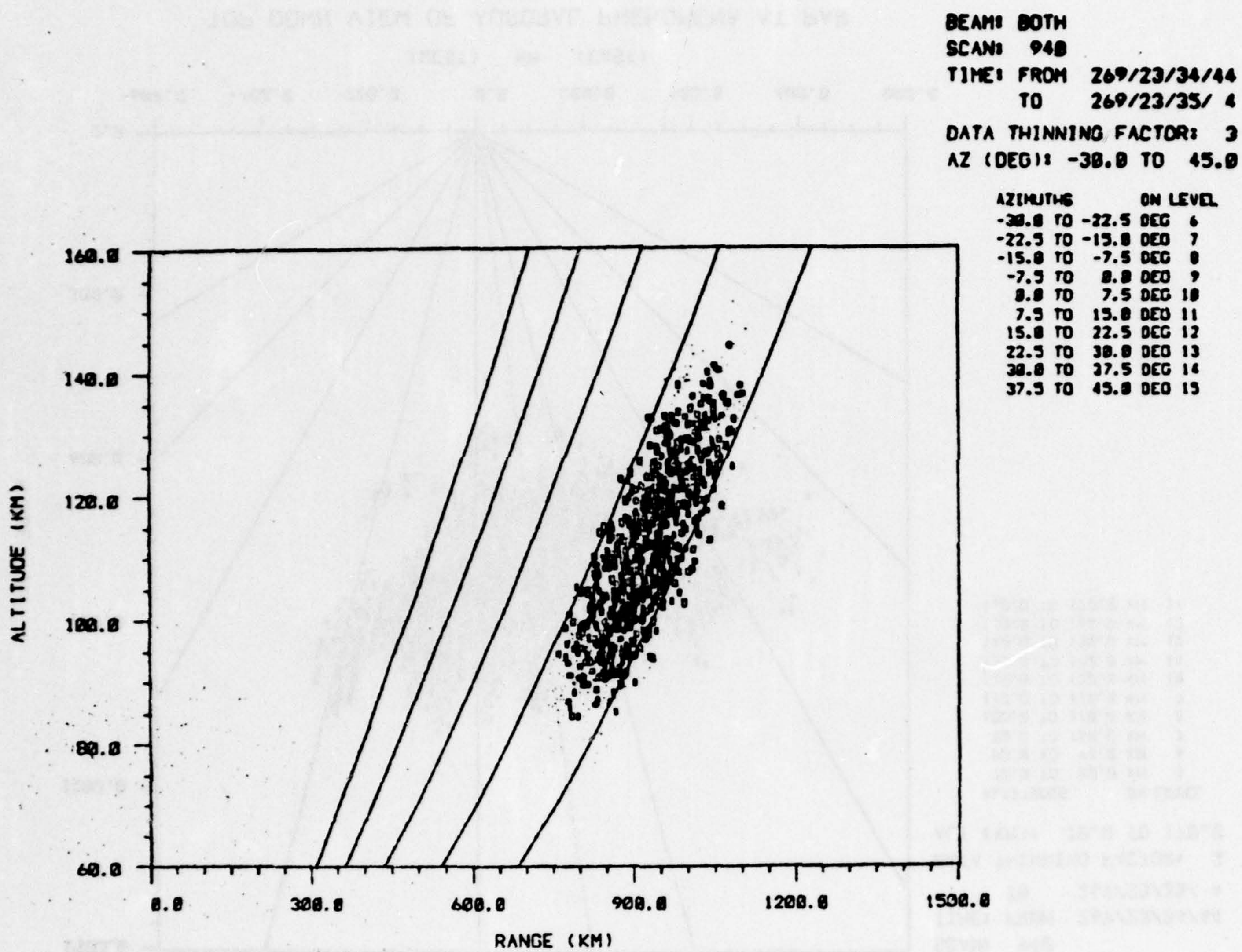
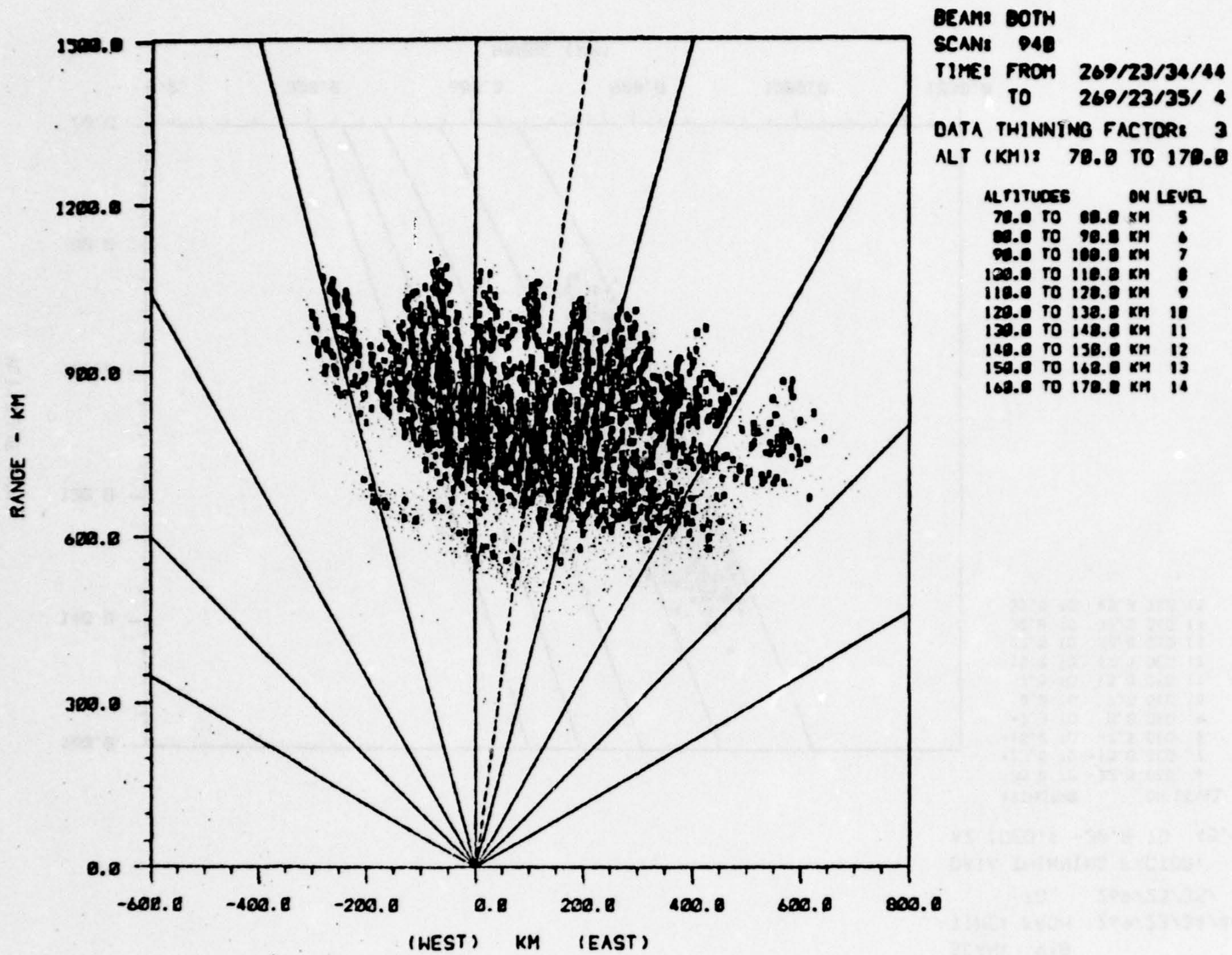
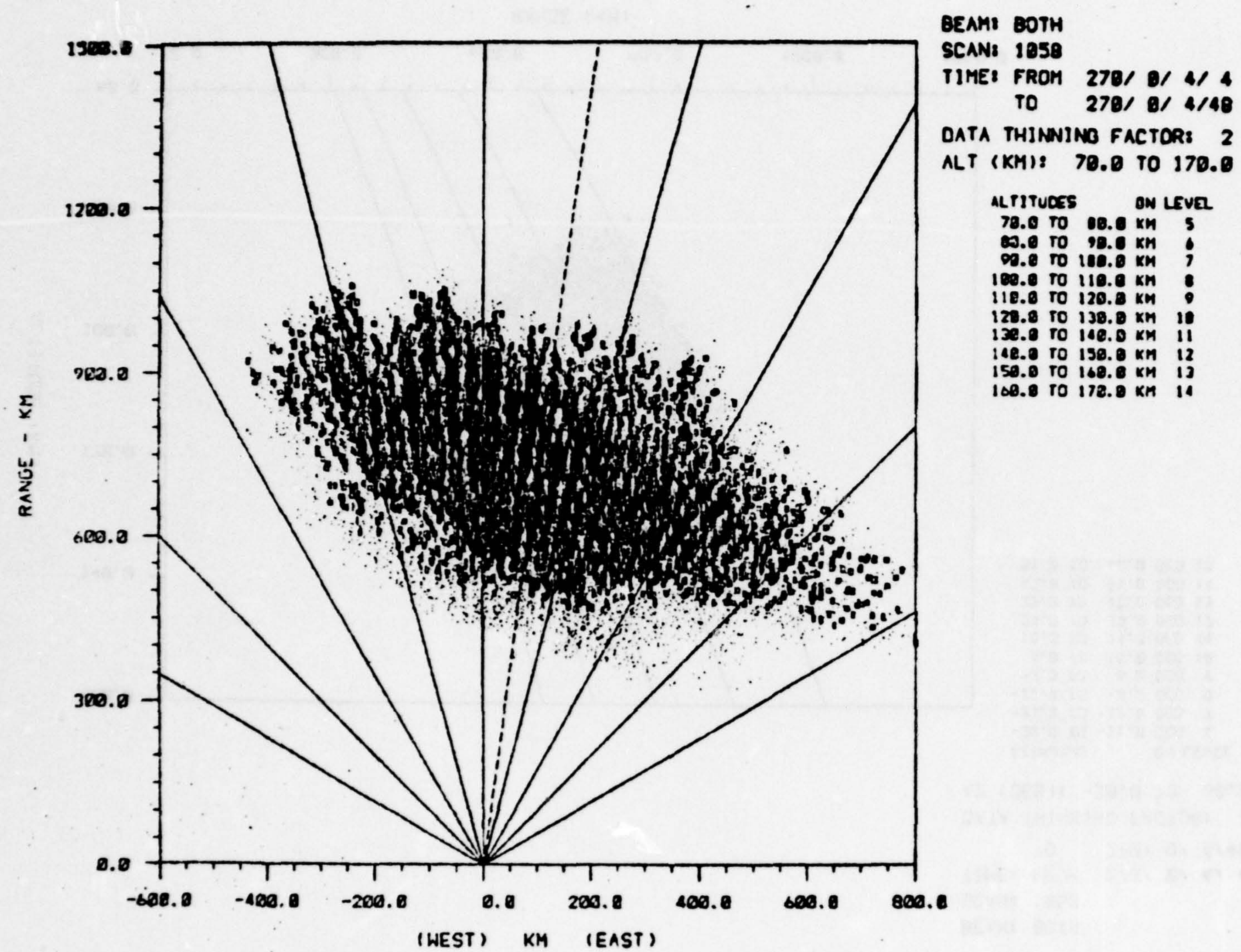

BEAM: BOTH
SCAN: 940
TIME: FROM 269/23/34/44
TO 269/23/35/ 4
DATA THINNING FACTOR: 3
AZ (DEG): -30.0 TO 45.0
AZIMUTHS ON LEVEL
-30.0 TO -22.5 DEG 6
-22.5 TO -15.0 DEG 7
-15.0 TO -7.5 DEG 8
-7.5 TO 0.0 DEG 9
0.0 TO 7.5 DEG 10
7.5 TO 15.0 DEG 11
15.0 TO 22.5 DEG 12
22.5 TO 30.0 DEG 13
30.0 TO 37.5 DEG 14
37.5 TO 45.0 DEG 15
160.0
140.0
120.0
100.0
80.0
60.0
ALTITUDE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

Figure 5-89



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

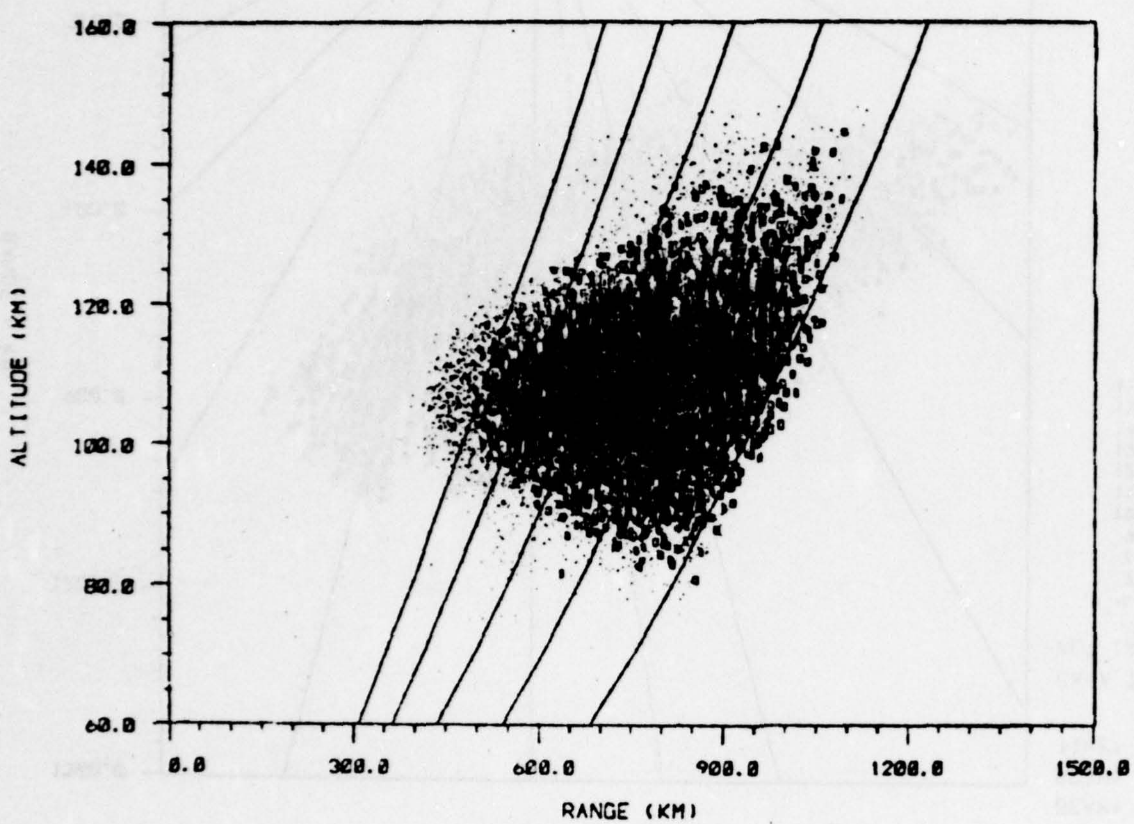
Figure 5-90



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

M&S COMPUTING

Figure 5-91

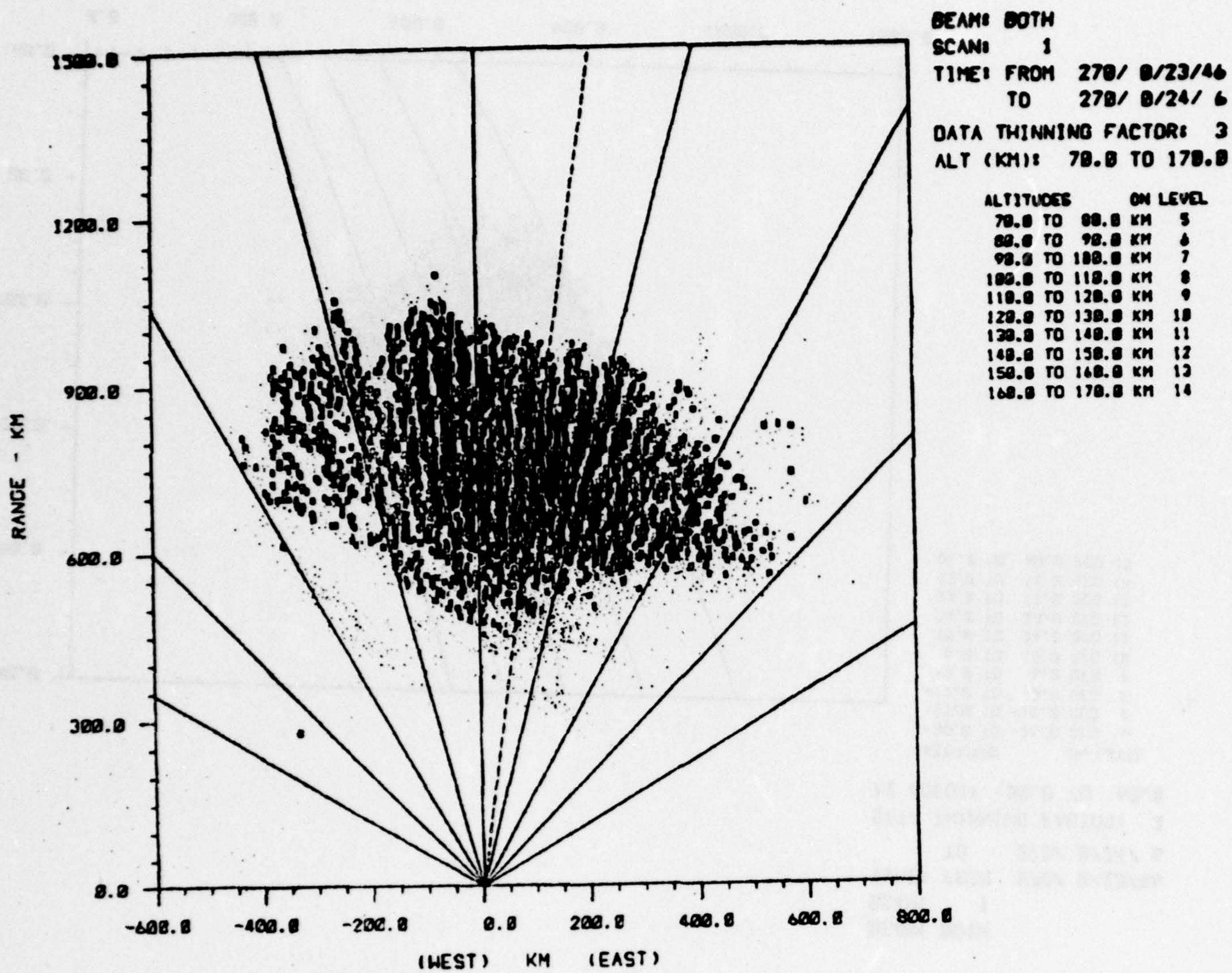


BEAM: BOTH
SCAN: 1058
TIME: FROM 270/ 0/ 4/ 4
TO 270/ 0/ 4/48
DATA THINNING FACTOR: 2
AZ (DEG): -30.0 TO 60.0

AZIMUTHS				ON LEVEL
-30.0	TO	-21.0	DEG	6
-21.0	TO	-12.0	DEG	7
-12.0	TO	-3.0	DEG	8
-3.0	TO	6.0	DEG	9
6.0	TO	15.0	DEG	10
15.0	TO	24.0	DEG	11
24.0	TO	33.0	DEG	12
33.0	TO	42.0	DEG	13
42.0	TO	51.0	DEG	14
51.0	TO	60.0	DEG	15

M&S OMPUTING

Figure 5-92



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-93

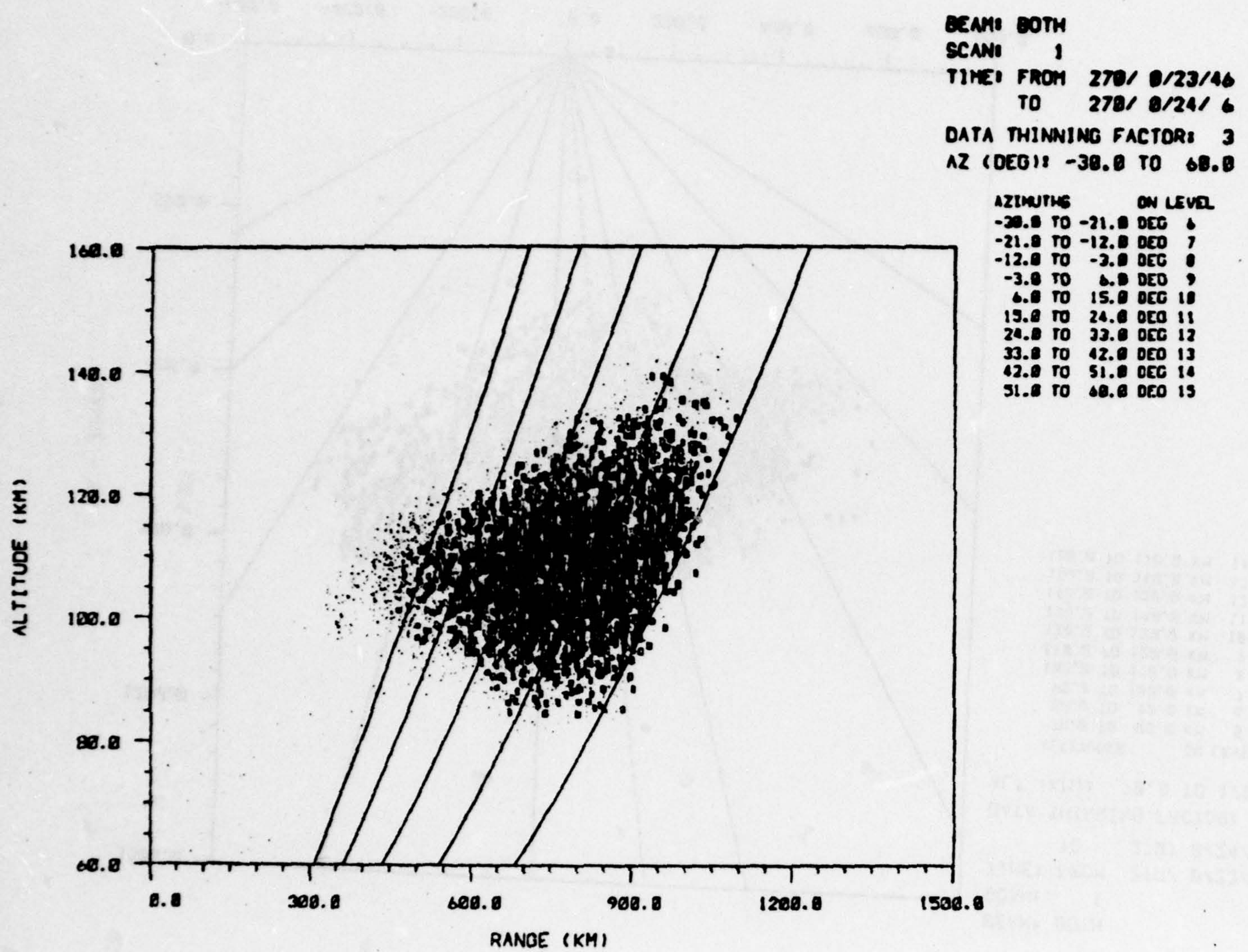
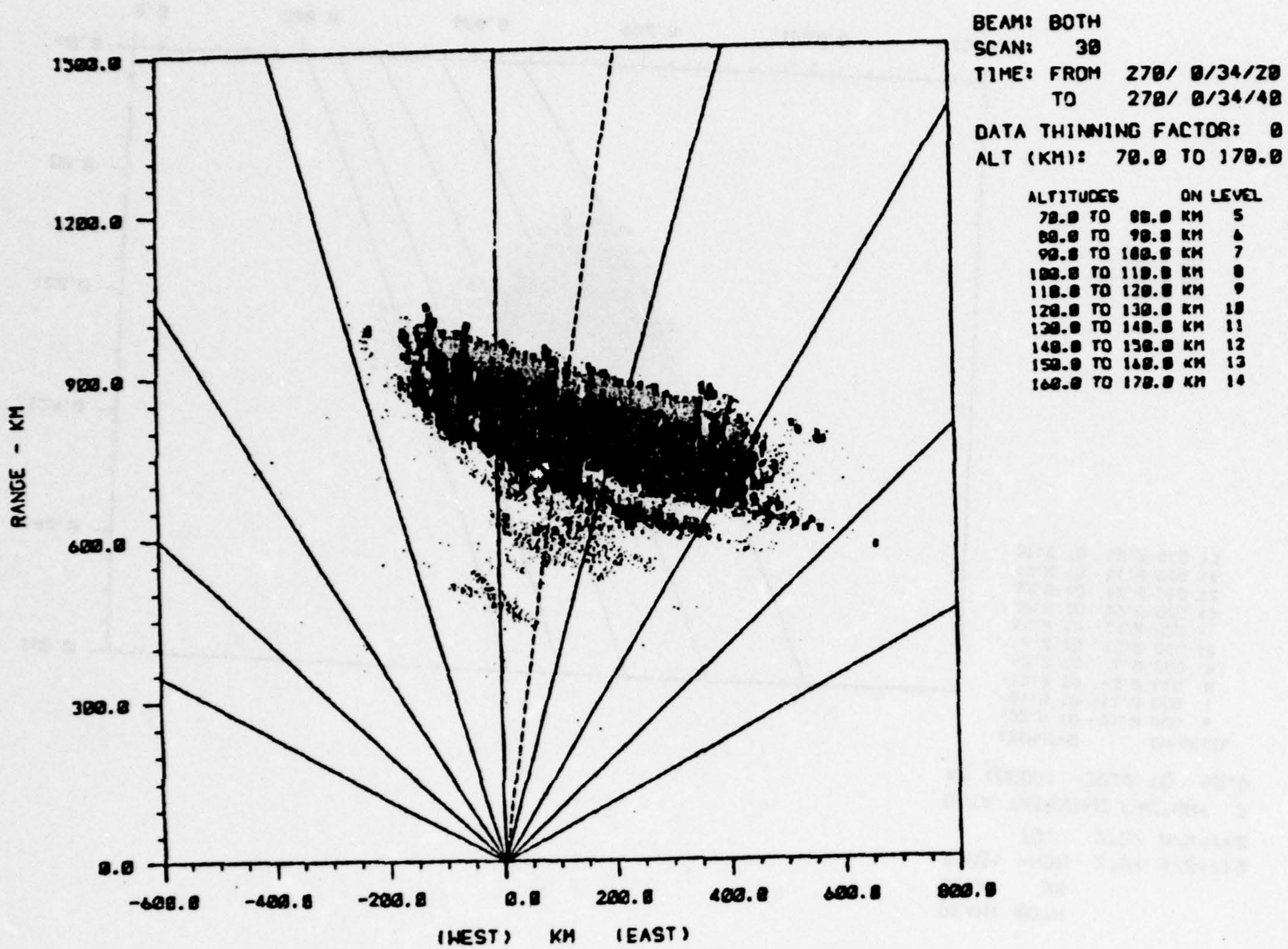

BEAM: BOTH
SCAN: 1
TIME: FROM 270/ 0/23/46
TO 270/ 0/24/ 6
DATA THINNING FACTOR: 3
AZ (DEG): -30.0 TO 60.0
AZIMUTHS ON LEVEL
-30.0 TO -21.0 DEG 6
-21.0 TO -12.0 DEG 7
-12.0 TO -3.0 DEG 8
-3.0 TO 6.0 DEG 9
6.0 TO 15.0 DEG 10
15.0 TO 24.0 DEG 11
24.0 TO 33.0 DEG 12
33.0 TO 42.0 DEG 13
42.0 TO 51.0 DEG 14
51.0 TO 60.0 DEG 15
ALTITUDE (KM)
160.0
140.0
120.0
100.0
80.0
60.0
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

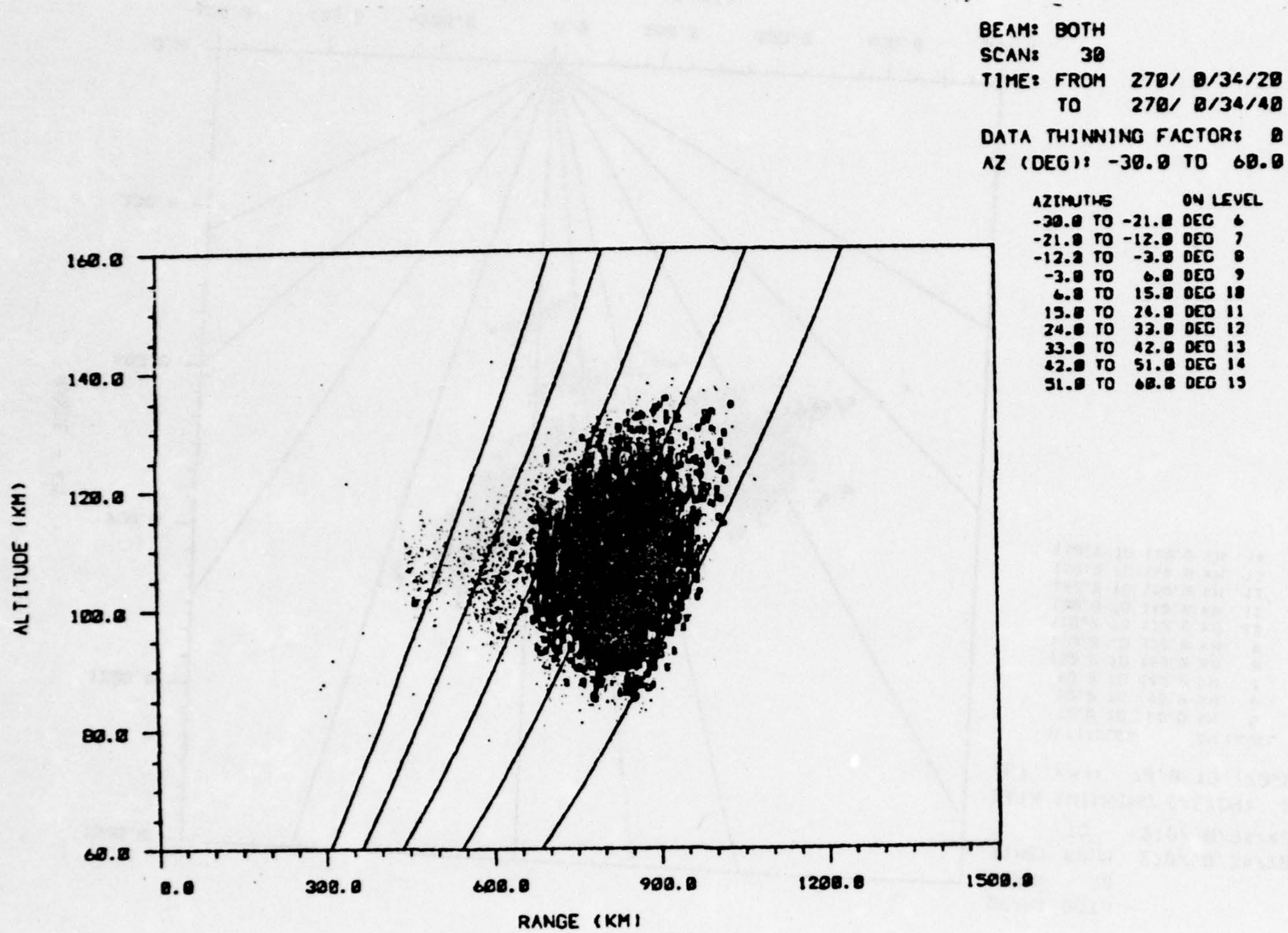
Figure 5-94



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

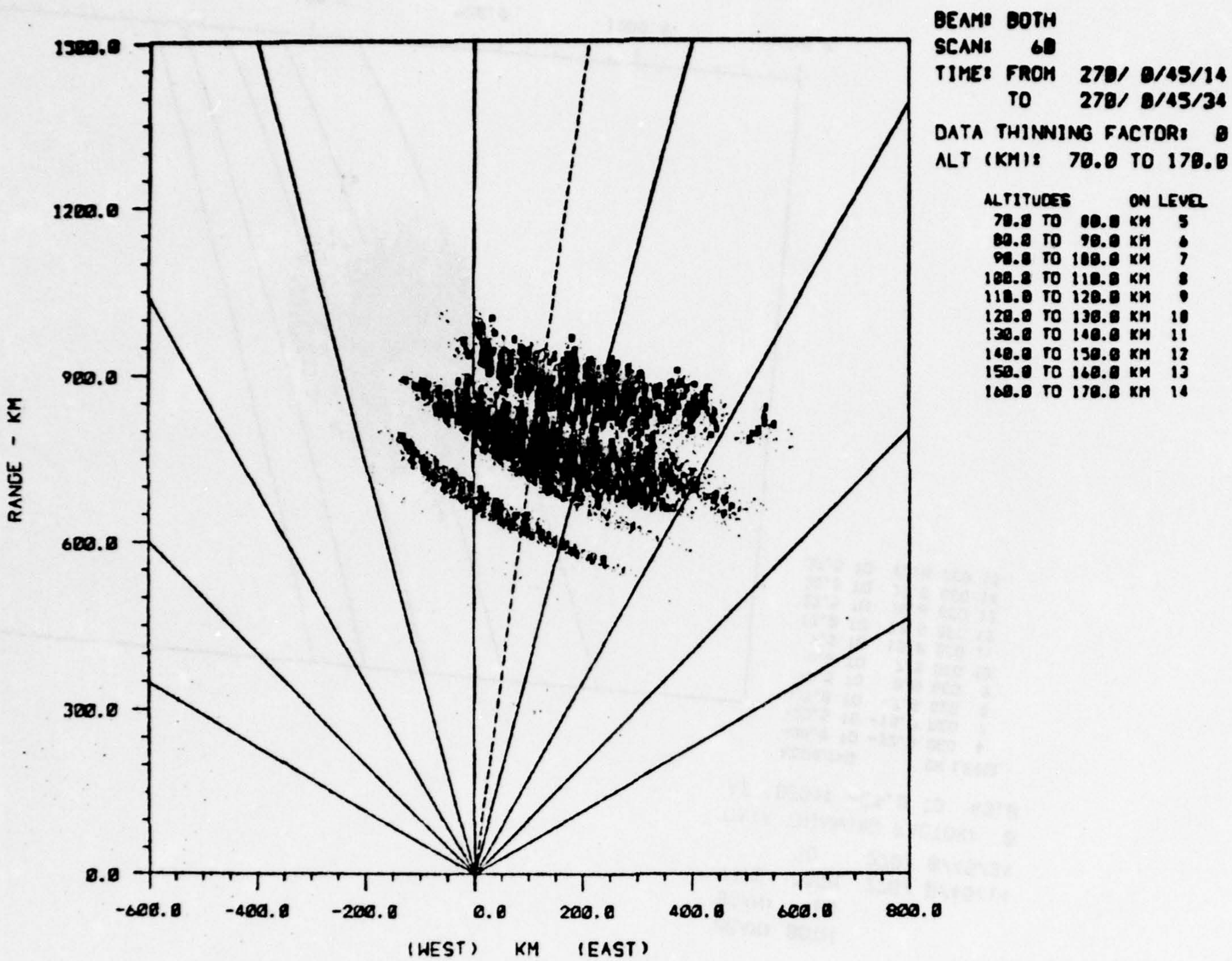
M&S OMPUTINO

Figure 5-95



M&S OMPUTING

Figure 5-96



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-97

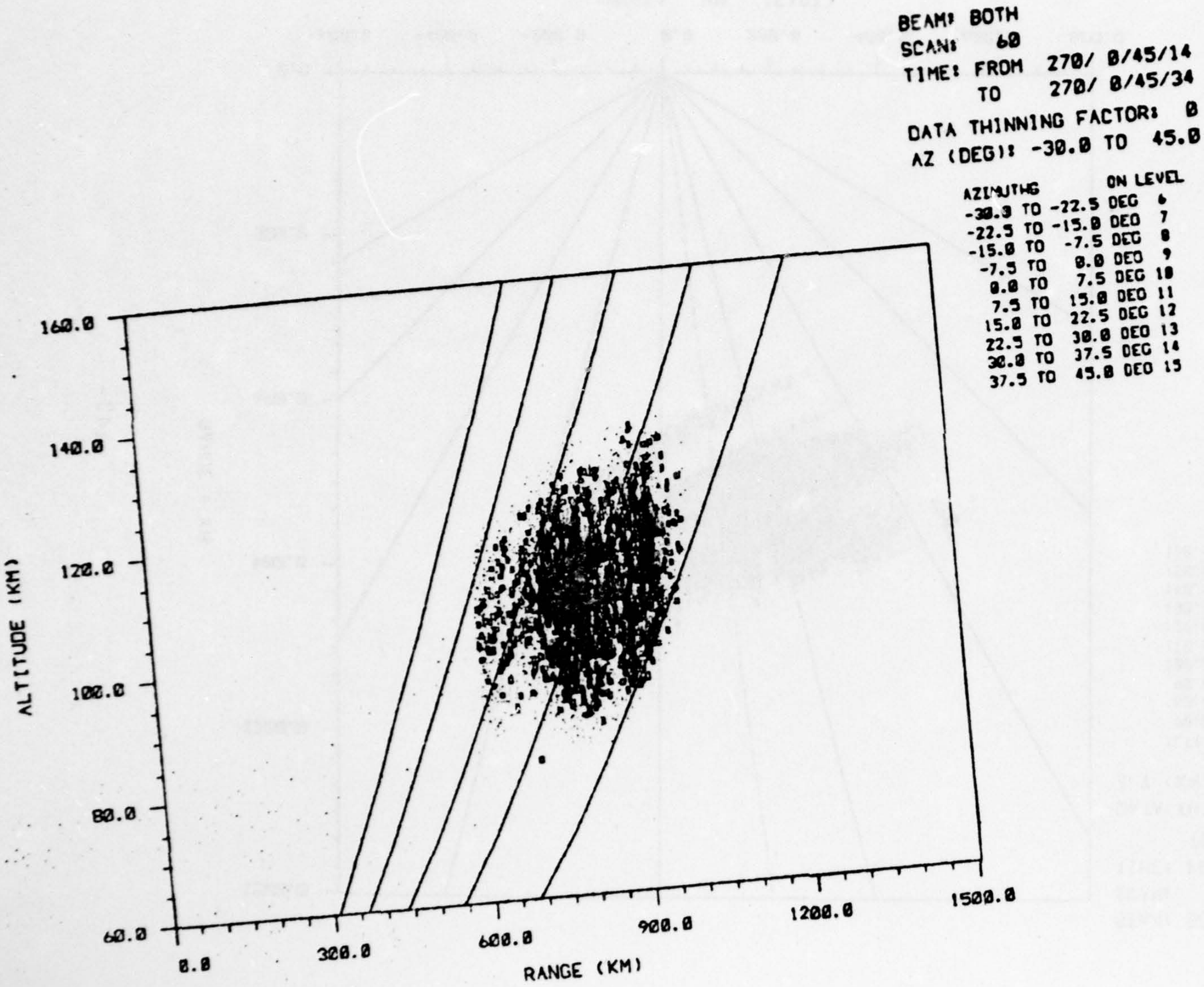
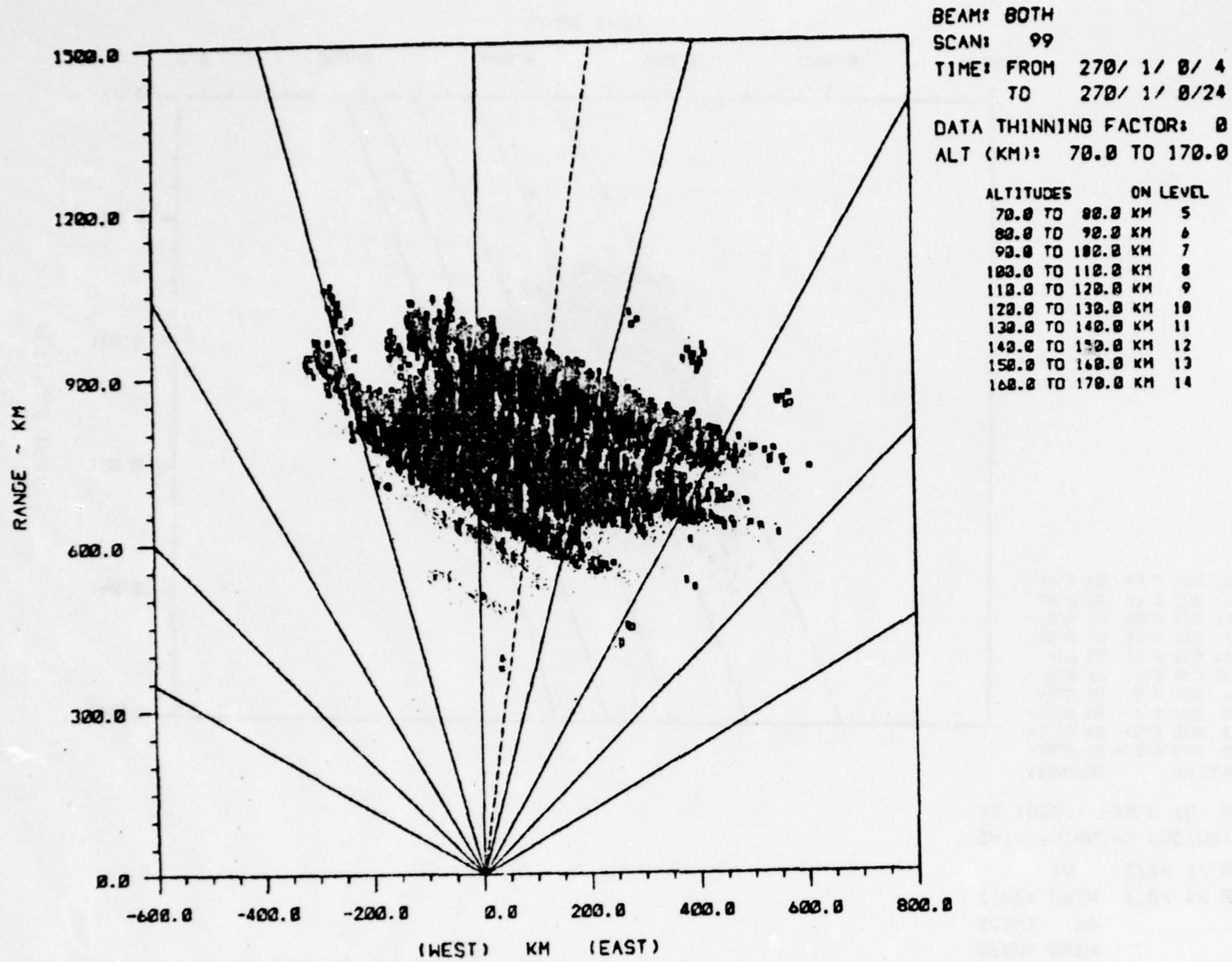

BEAM: BOTH
SCAN: 60
TIME: FROM 270/ 0/45/14
TO 270/ 0/45/34
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 45.0
AZIMUTHS ON LEVEL
-30.0 TO -22.5 DEG 6
-22.5 TO -15.0 DEG 7
-15.0 TO -7.5 DEG 8
-7.5 TO 0.0 DEG 9
0.0 TO 7.5 DEG 10
7.5 TO 15.0 DEG 11
15.0 TO 22.5 DEG 12
22.5 TO 30.0 DEG 13
30.0 TO 37.5 DEG 14
37.5 TO 45.0 DEG 15
160.0
140.0
120.0
100.0
80.0
60.0
ALTITUDE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

Figure 5-98



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-99

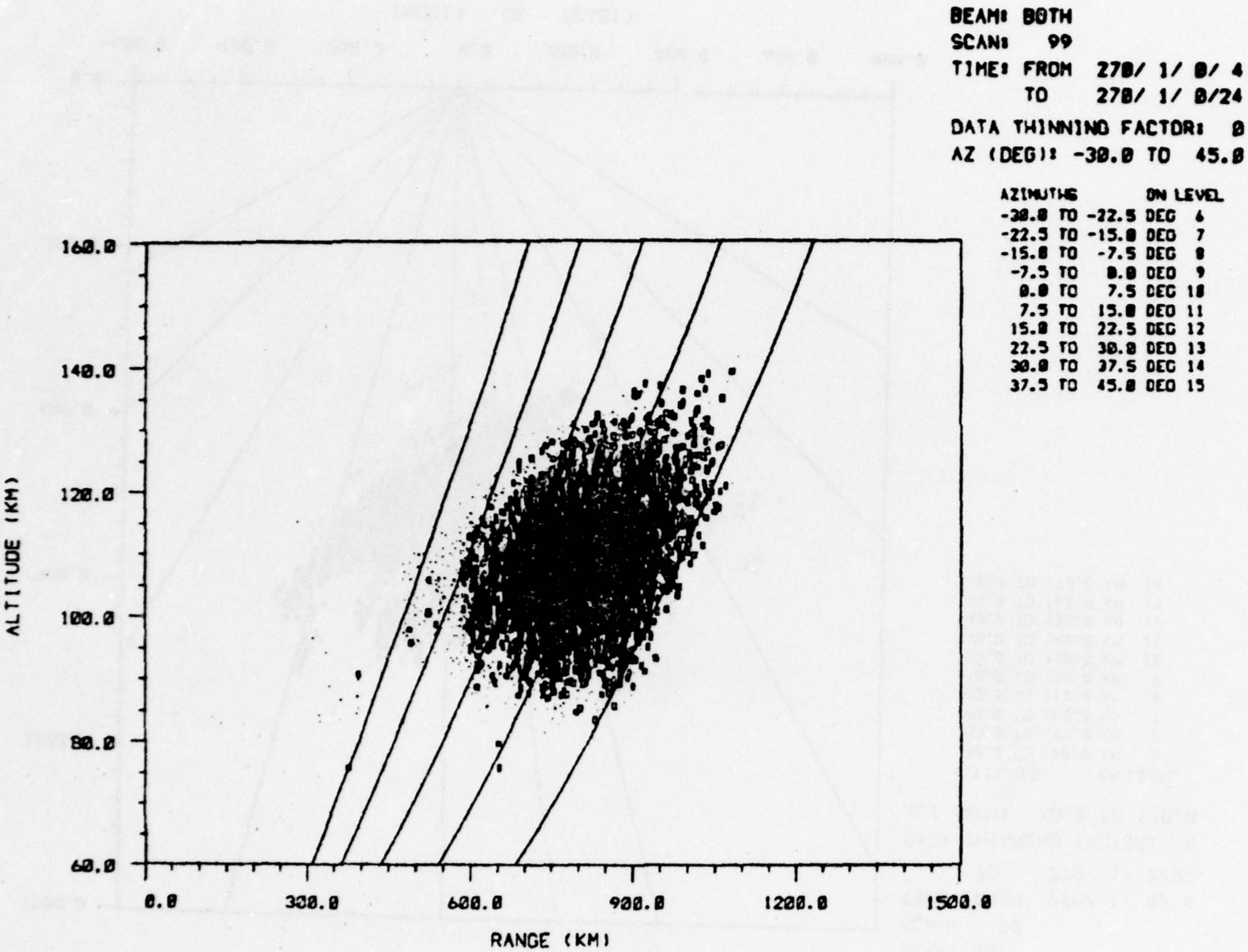
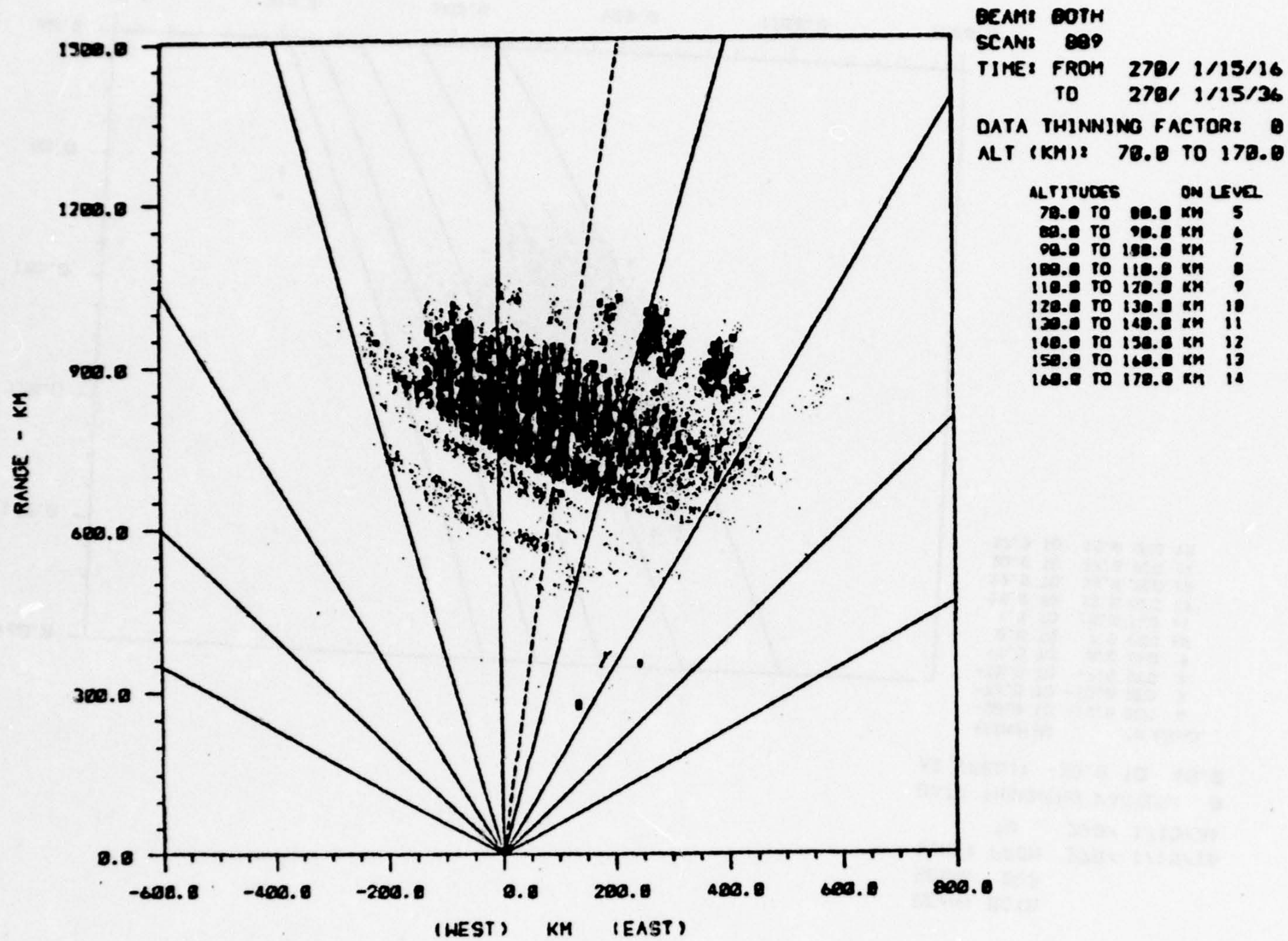

BEAM: BOTH
SCAN: 99
TIME: FROM 270/ 1/ 0/ 4
TO 270/ 1/ 0/24
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 45.0
AZIMUTHS ON LEVEL
-30.0 TO -22.5 DEG 6
-22.5 TO -15.0 DEG 7
-15.0 TO -7.5 DEG 8
-7.5 TO 0.0 DEG 9
0.0 TO 7.5 DEG 10
7.5 TO 15.0 DEG 11
15.0 TO 22.5 DEG 12
22.5 TO 30.0 DEG 13
30.0 TO 37.5 DEG 14
37.5 TO 45.0 DEG 15
ALTITUDE (KM)
160.0
140.0
120.0
100.0
80.0
60.0
RANGE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0

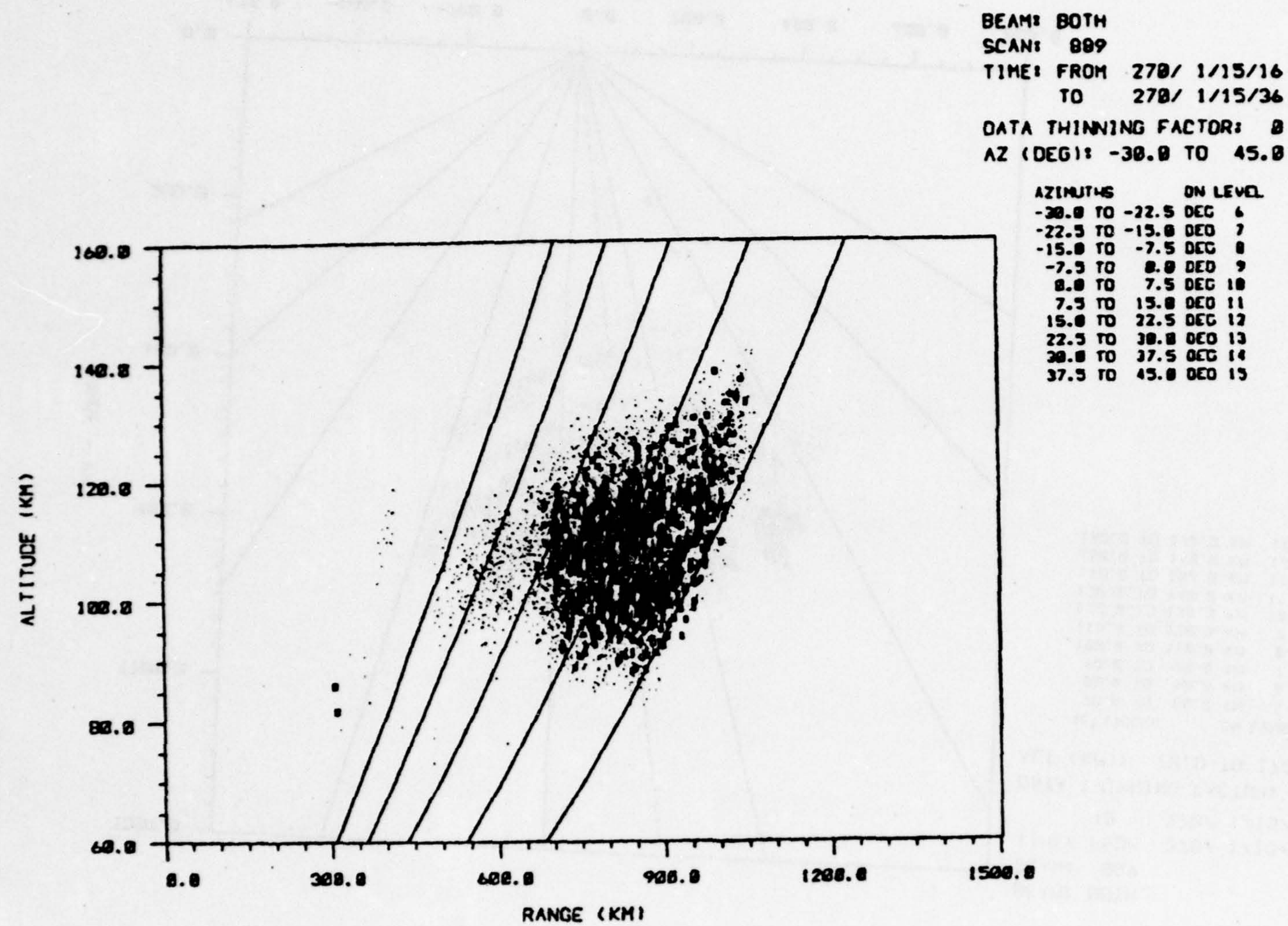
Figure 5-100



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

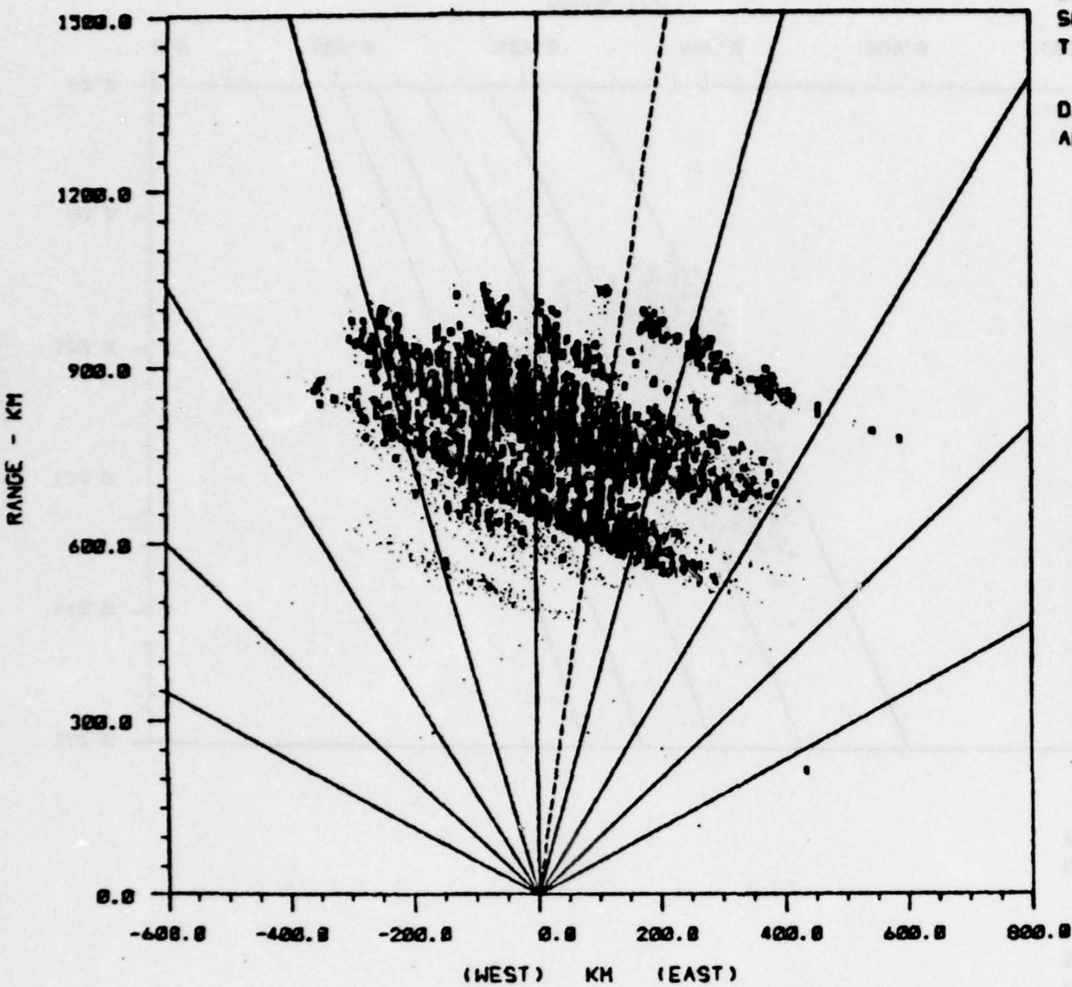
M&S OMPUTING

Figure 5-101



M&S COMPUTING

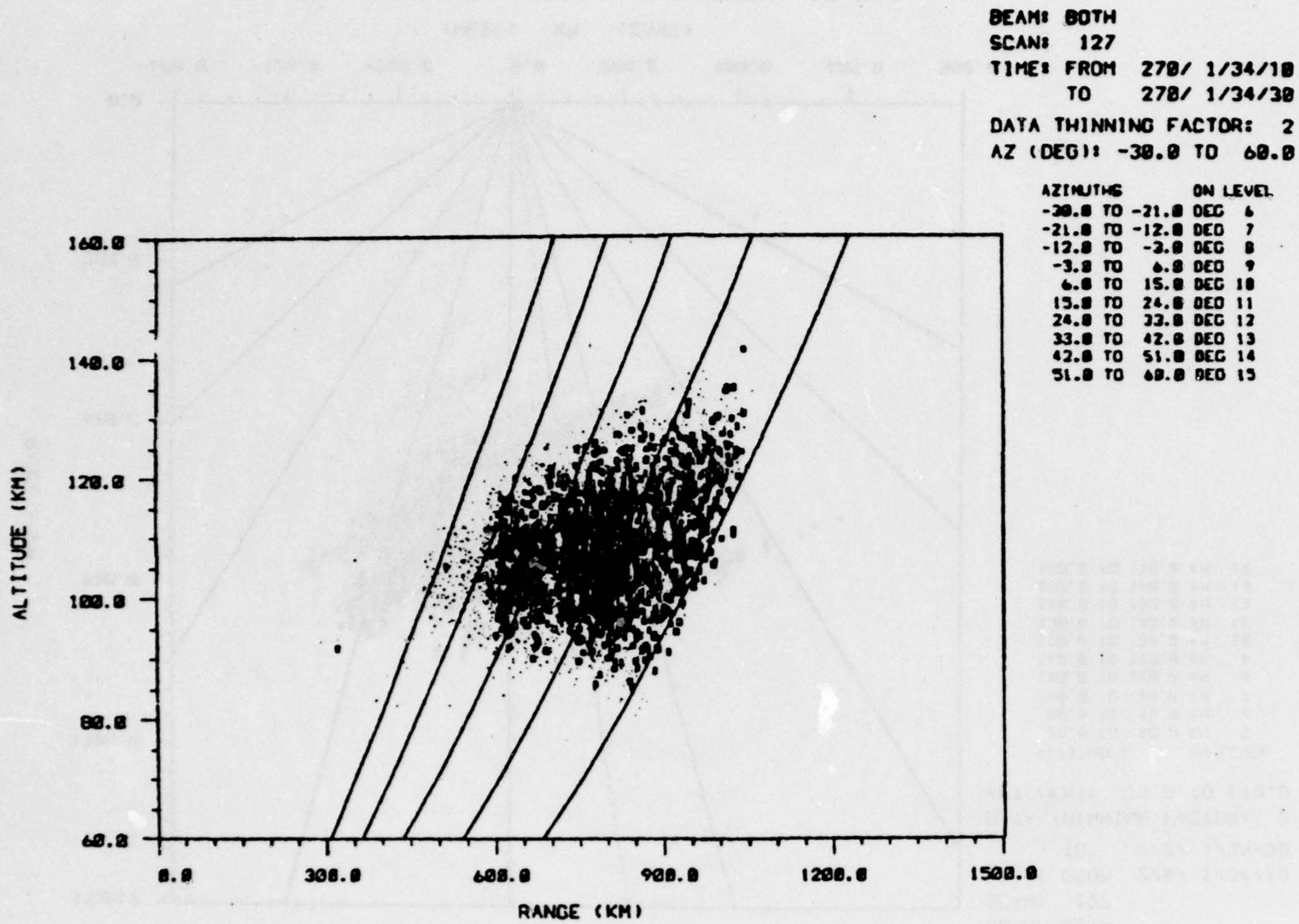
Figure 5-102



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

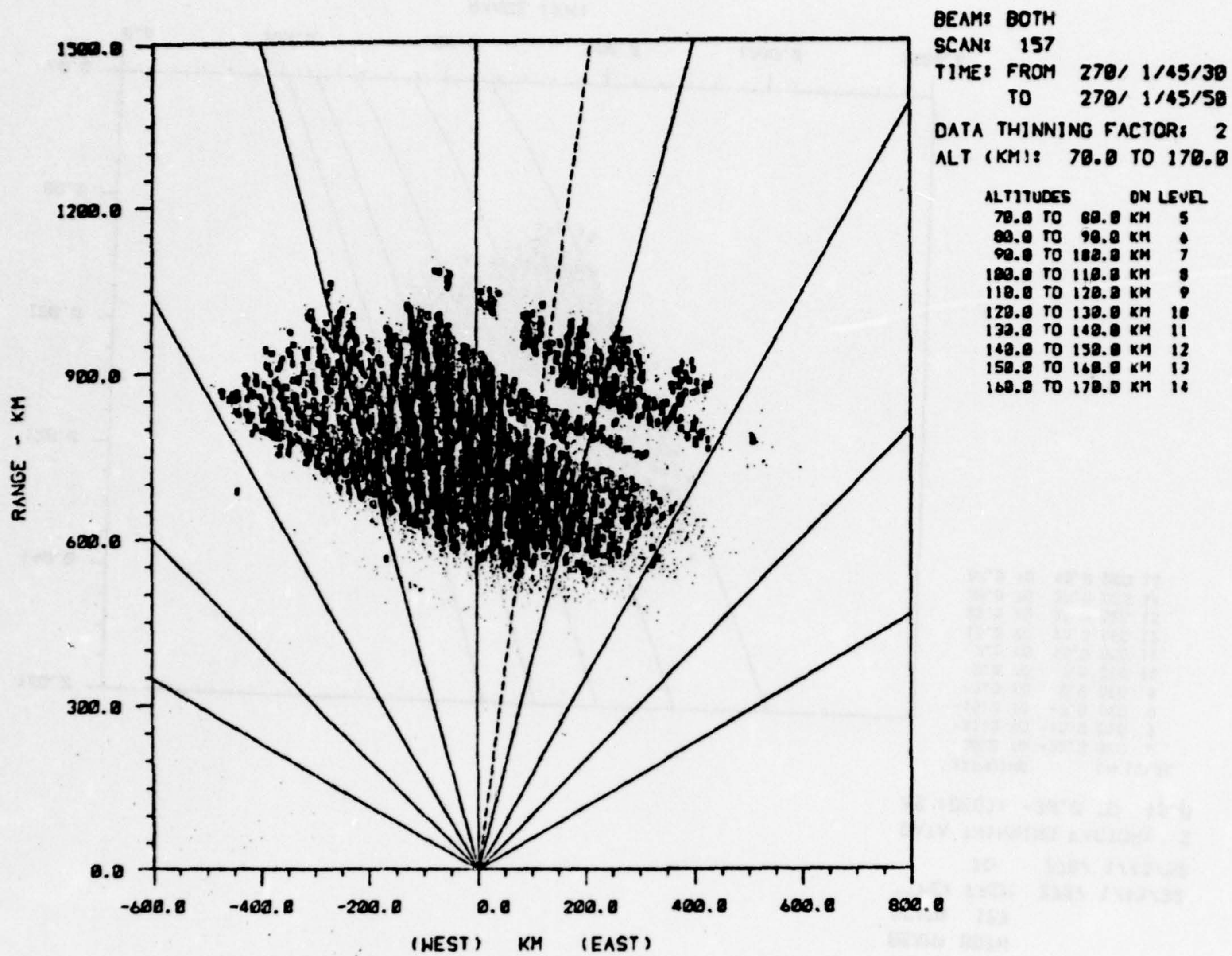
M&S OMPUTING

Figure 5-103



M&S COMPUTING

Figure 5-104



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-105

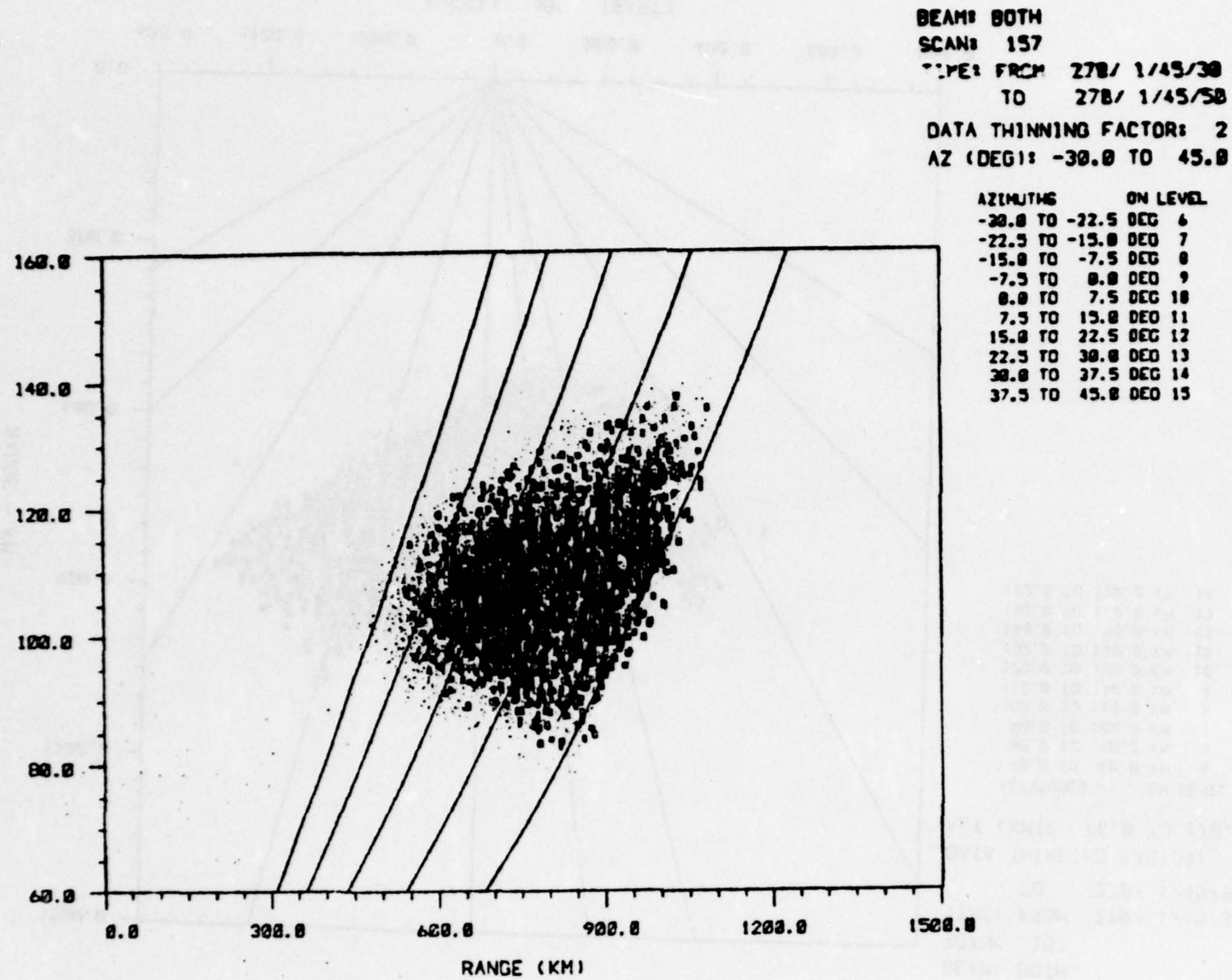
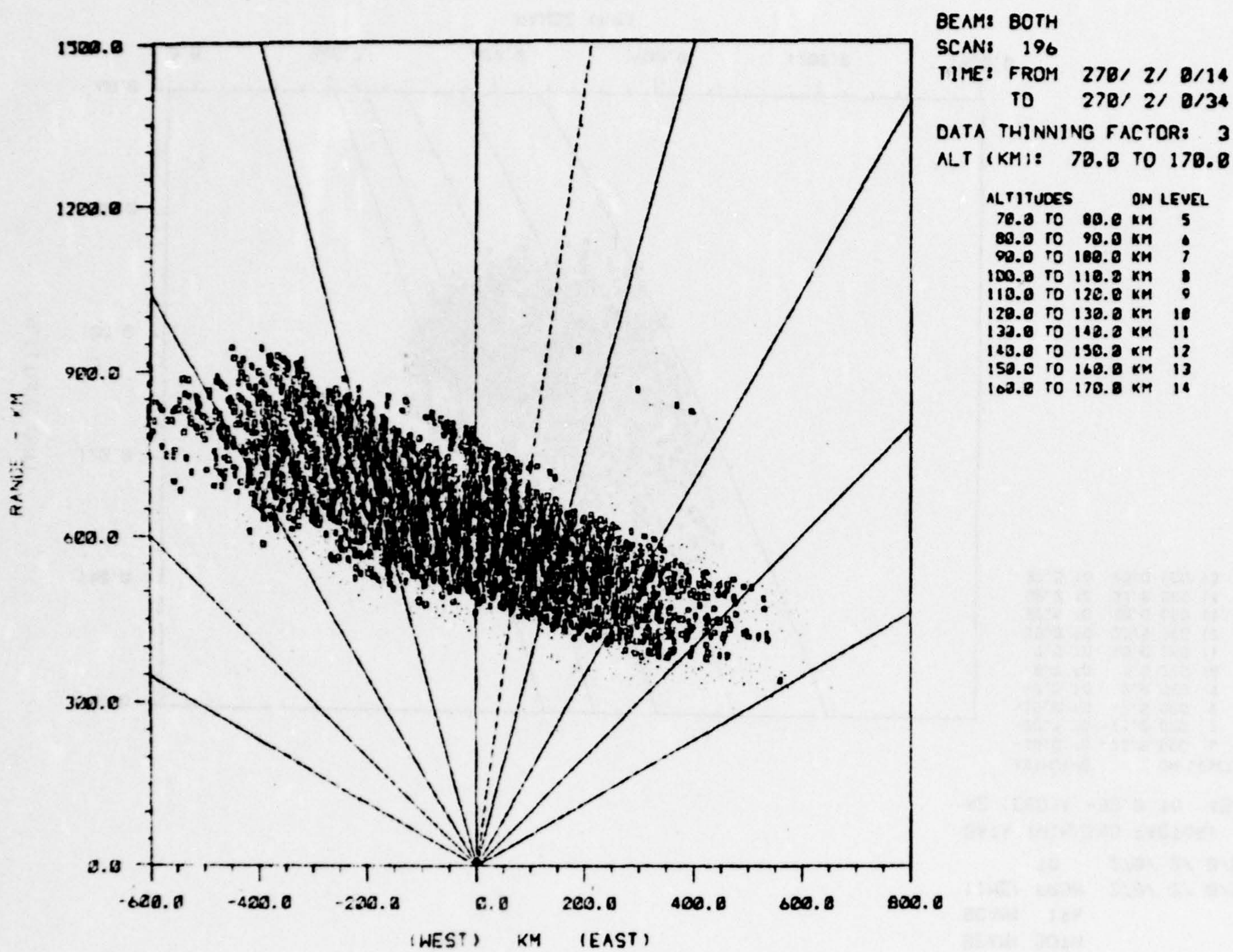

BEAM: BOTH
SCAN: 157
TIME: FROM 278/ 1/45/30
TO 278/ 1/45/50
DATA THINNING FACTOR: 2
AZ (DEG): -30.0 TO 45.0
AZIMUTHS ON LEVEL
-30.0 TO -22.5 DEG 6
-22.5 TO -15.0 DEG 7
-15.0 TO -7.5 DEG 8
-7.5 TO 0.0 DEG 9
0.0 TO 7.5 DEG 10
7.5 TO 15.0 DEG 11
15.0 TO 22.5 DEG 12
22.5 TO 30.0 DEG 13
30.0 TO 37.5 DEG 14
37.5 TO 45.0 DEG 15
160.0
140.0
120.0
100.0
80.0
60.0
ALTITUDE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

Figure 5-106



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-107

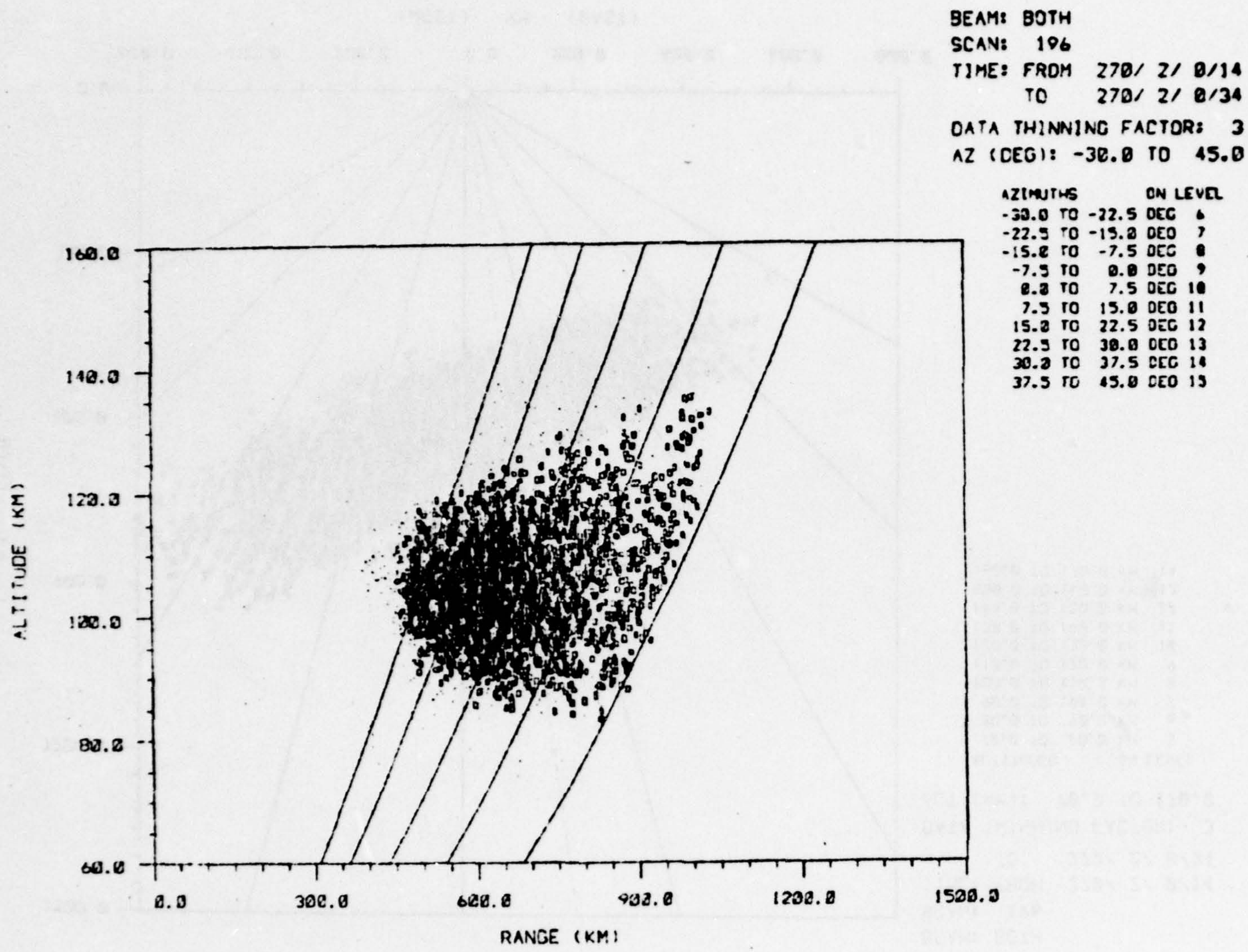
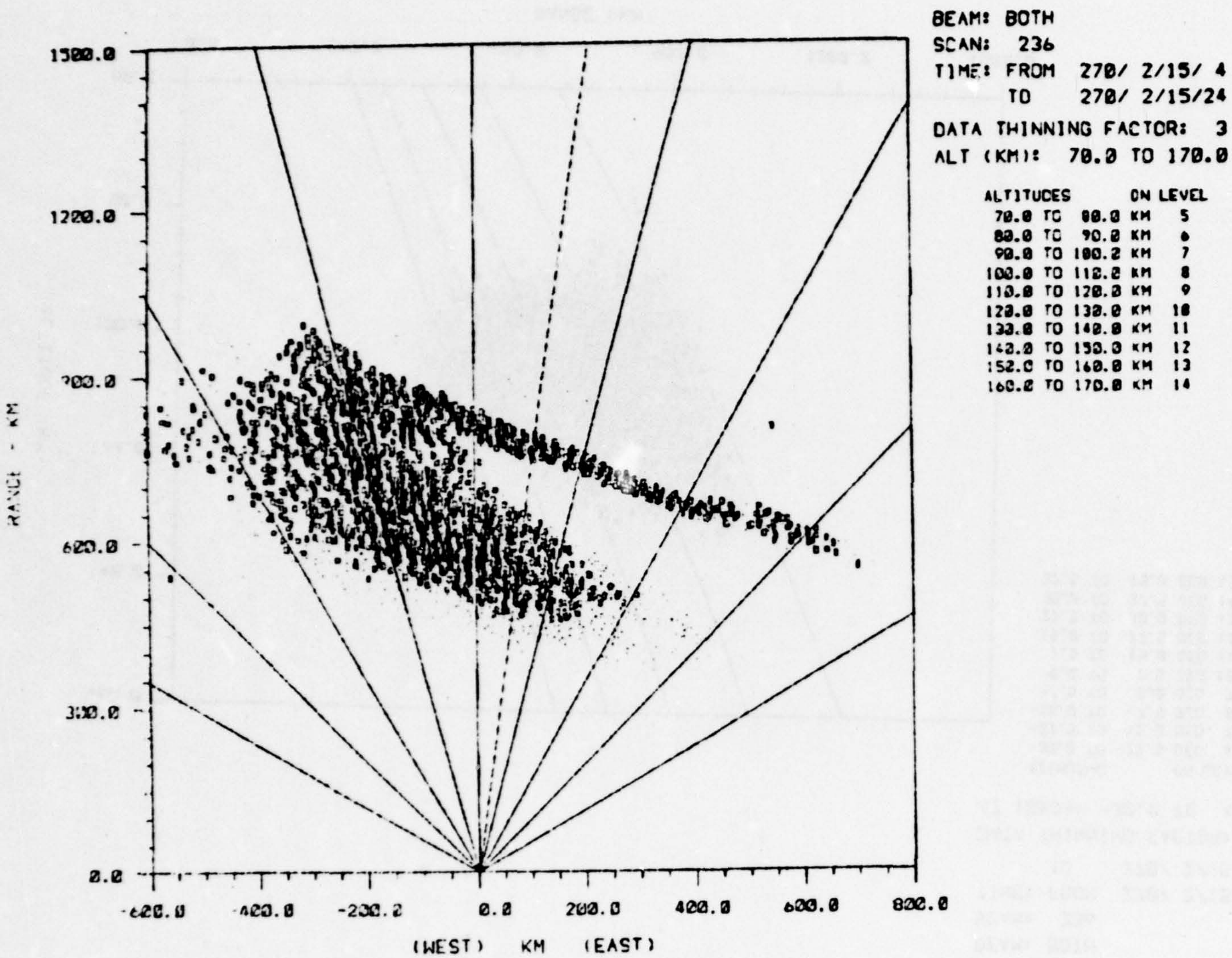

BEAM: BOTH
SCAN: 196
TIME: FROM 270/ 2/ 0/14
TO 270/ 2/ 0/34
DATA THINNING FACTOR: 3
AZ (DEG): -30.0 TO 45.0
AZIMUTHS ON LEVEL
-30.0 TO -22.5 DEG 6
-22.5 TO -15.0 DEG 7
-15.0 TO -7.5 DEG 8
-7.5 TO 0.0 DEG 9
0.0 TO 7.5 DEG 10
7.5 TO 15.0 DEG 11
15.0 TO 22.5 DEG 12
22.5 TO 30.0 DEG 13
30.0 TO 37.5 DEG 14
37.5 TO 45.0 DEG 15
160.0
140.0
120.0
100.0
80.0
60.0
ALTITUDE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

Figure 5-108



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-109

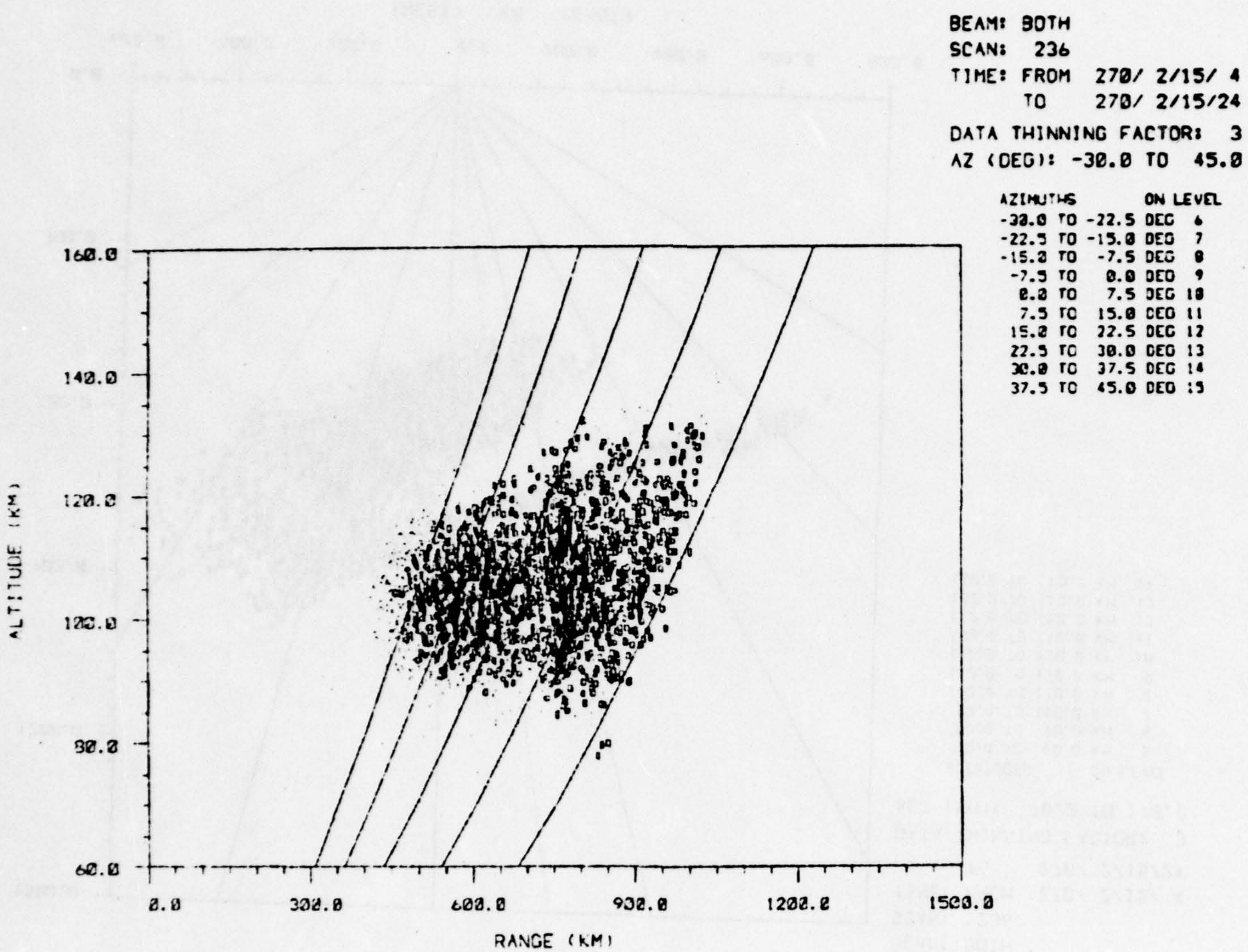

BEAM: BOTH
SCAN: 236
TIME: FROM 270/ 2/15/ 4
TO 270/ 2/15/24
DATA THINNING FACTOR: 3
AZ (DEG): -30.0 TO 45.0
AZIMUTHS ON LEVEL
-30.0 TO -22.5 DEG 6
-22.5 TO -15.0 DEG 7
-15.0 TO -7.5 DEG 8
-7.5 TO 0.0 DEG 9
0.0 TO 7.5 DEG 10
7.5 TO 15.0 DEG 11
15.0 TO 22.5 DEG 12
22.5 TO 30.0 DEG 13
30.0 TO 37.5 DEG 14
37.5 TO 45.0 DEG 15
160.0
140.0
120.0
100.0
80.0
60.0
ALTITUDE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

Figure 5-110

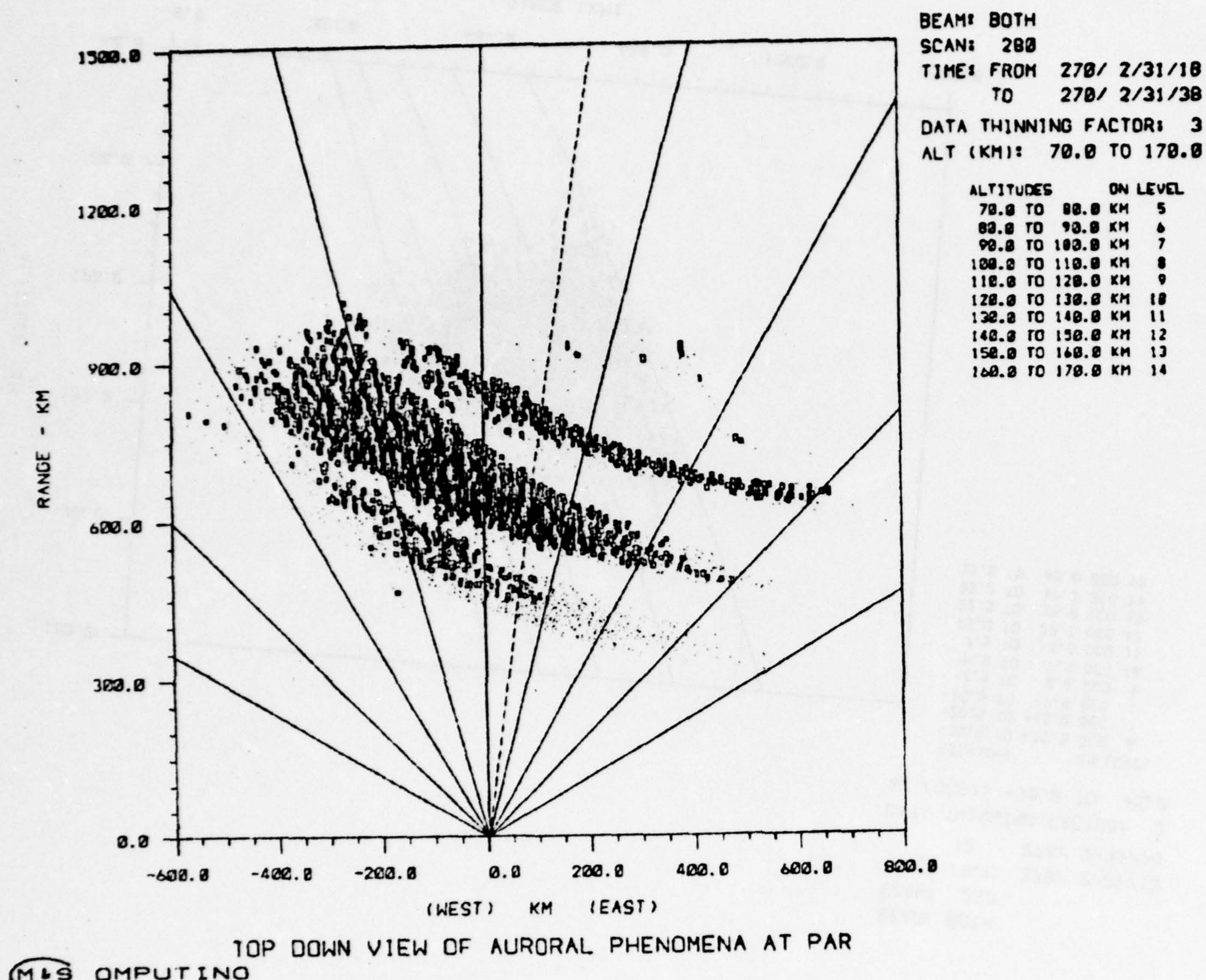

BEAM: BOTH
SCAN: 280
TIME: FROM 270/ 2/31/18
TO 270/ 2/31/38
DATA THINNING FACTOR: 3
ALT (KM): 70.0 TO 170.0
ALTITUDES ON LEVEL
70.0 TO 80.0 KM 5
80.0 TO 90.0 KM 6
90.0 TO 100.0 KM 7
100.0 TO 110.0 KM 8
110.0 TO 120.0 KM 9
120.0 TO 130.0 KM 10
130.0 TO 140.0 KM 11
140.0 TO 150.0 KM 12
150.0 TO 160.0 KM 13
160.0 TO 170.0 KM 14
RANGE - KM
1500.0
1200.0
900.0
600.0
300.0
0.0
-600.0
-400.0
-200.0
0.0
200.0
400.0
600.0
800.0
(WEST) KM (EAST)
TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR
M&S OMPUTINO

Figure 5-111

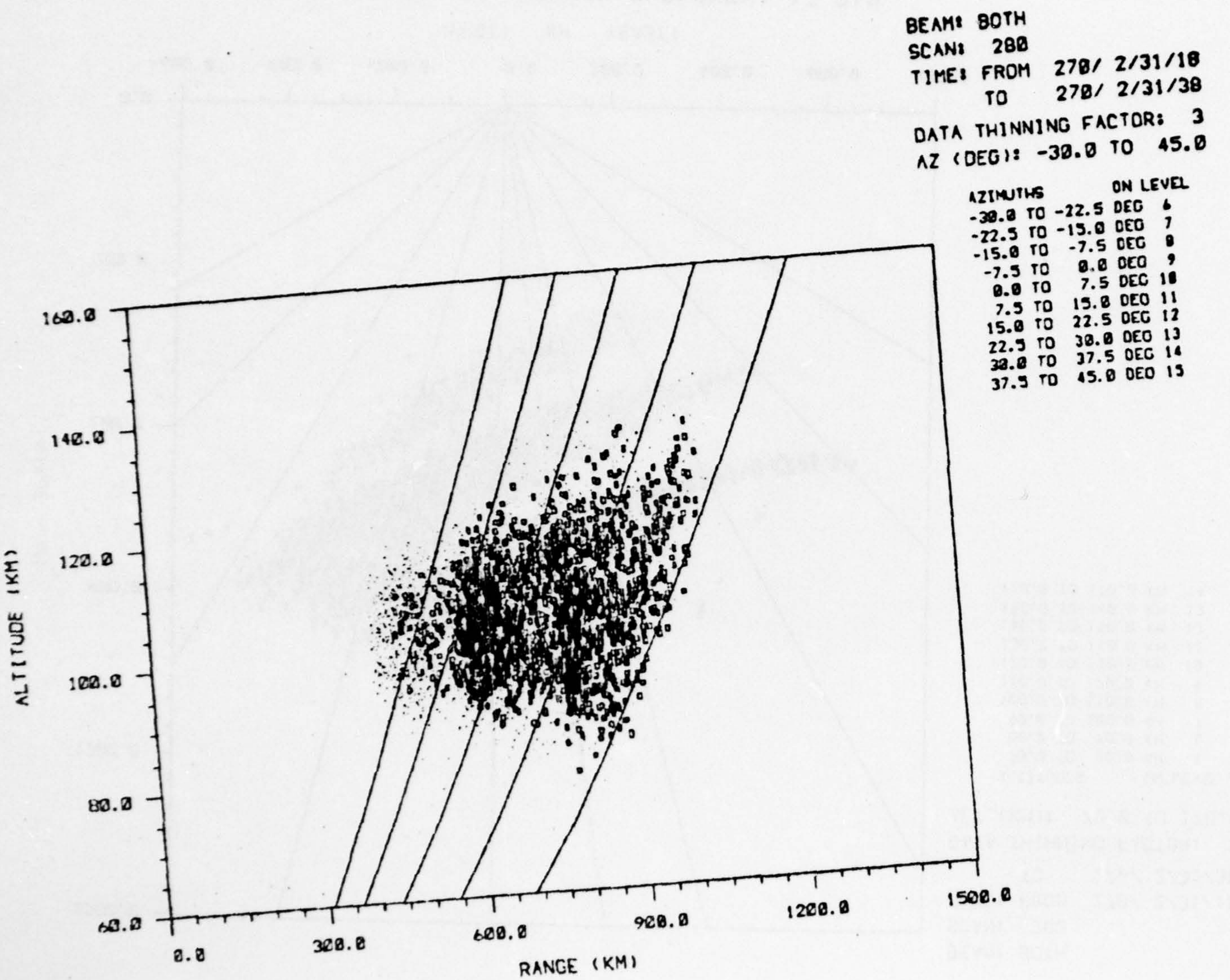
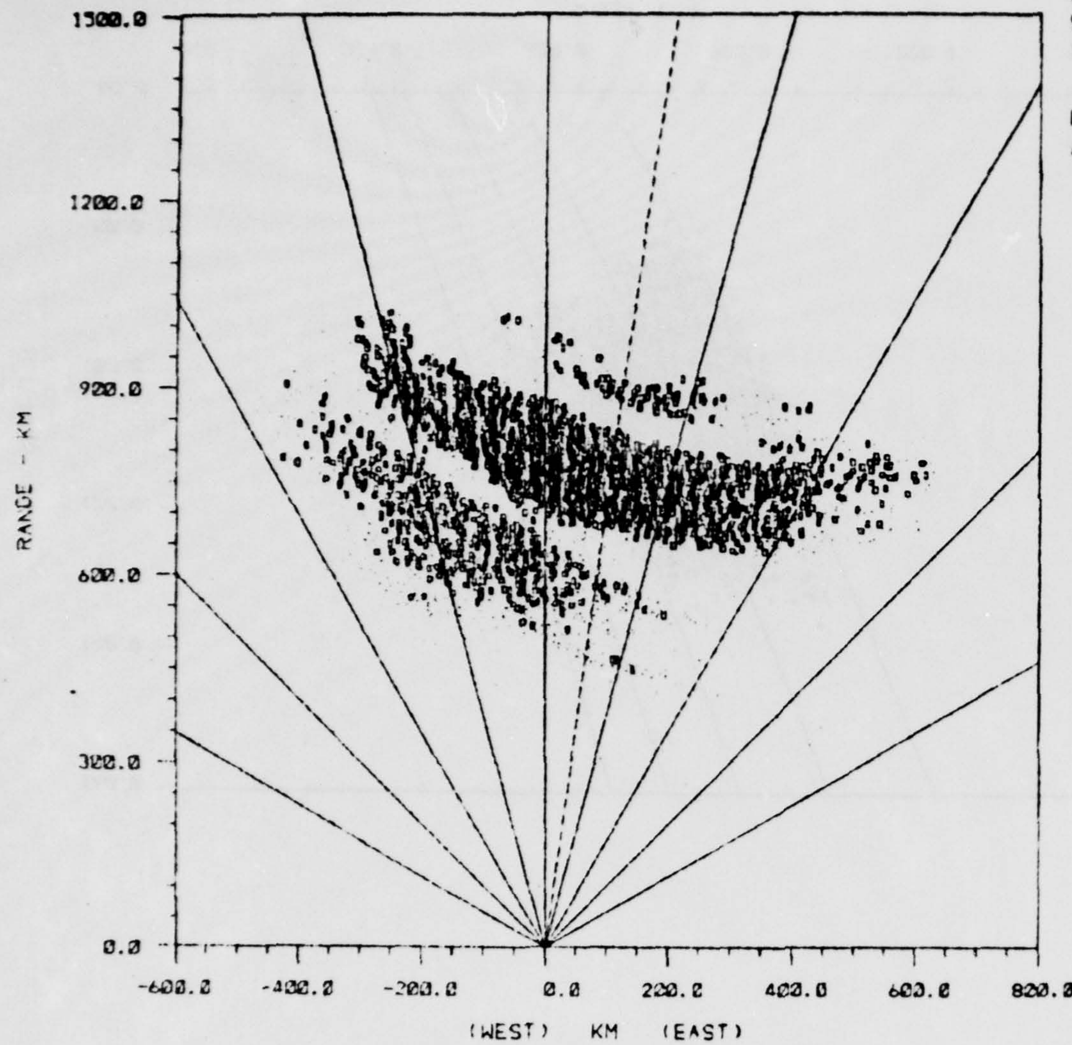


Figure 5-112

M&S OMPUTINO



BEAM: BOTH
SCAN: 282
TIME: FROM 270/ 2/51/ 2
TO 270/ 2/51/22
DATA THINNING FACTOR: 3
ALT (KM): 70.0 TO 170.0

ALTITUDES	ON LEVEL
70.0 TO 80.0 KM	5
80.0 TO 90.0 KM	6
90.0 TO 100.0 KM	7
100.0 TO 110.0 KM	8
110.0 TO 120.0 KM	9
120.0 TO 130.0 KM	10
130.0 TO 140.0 KM	11
140.0 TO 150.0 KM	12
150.0 TO 160.0 KM	13
160.0 TO 170.0 KM	14

TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-113

BEAM: BOTH
SCAN: 282
TIME: FROM 270/ 2/51/ 2
TO 270/ 2/51/22
DATA THINNING FACTOR: 3
AZ (DEG): -30.0 TO 45.0

AZIMUTHS	ON LEVEL
-30.0 TO -22.5 DEG	6
-22.5 TO -15.0 DEG	7
-15.0 TO -7.5 DEG	8
-7.5 TO 0.0 DEG	9
0.0 TO 7.5 DEG	10
7.5 TO 15.2 DEG	11
15.0 TO 22.5 DEG	12
22.5 TO 30.2 DEG	13
30.0 TO 37.5 DEG	14
37.5 TO 45.0 DEG	15

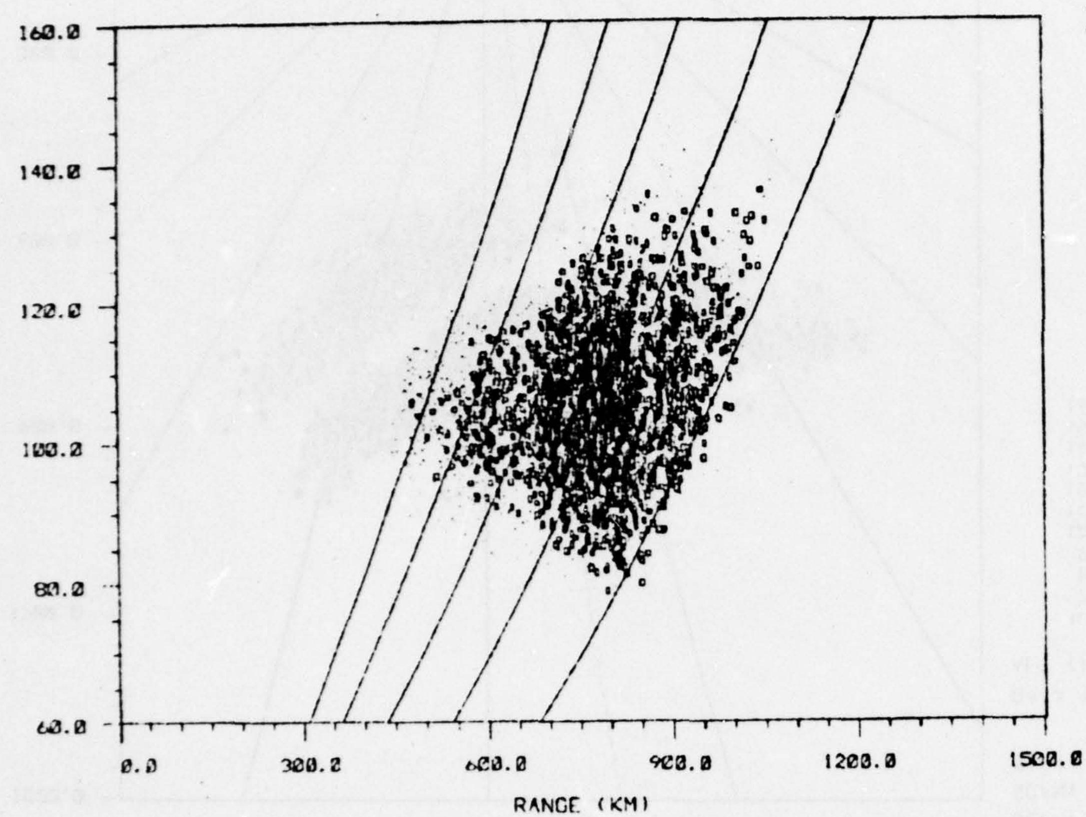
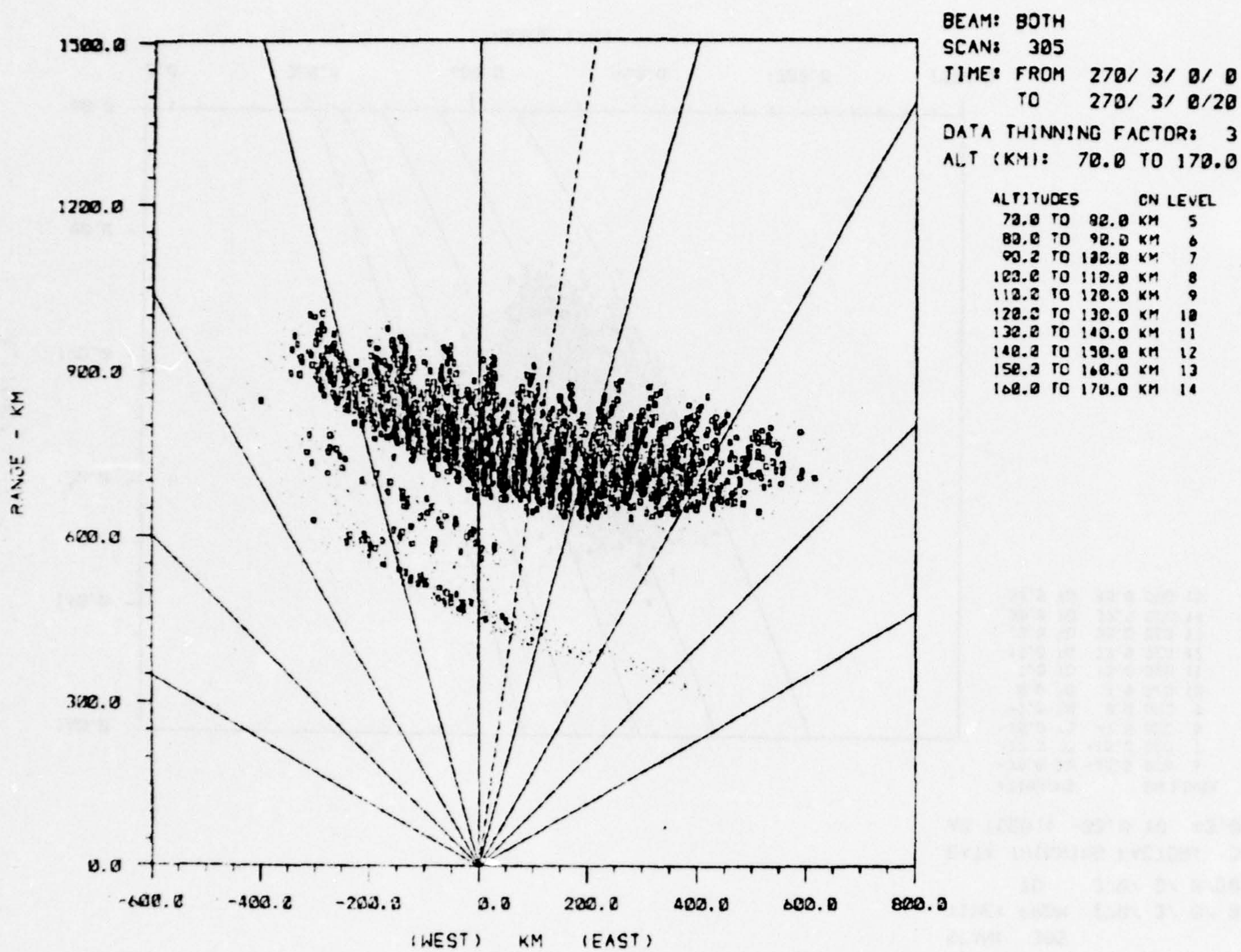


Figure 5-114



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-115

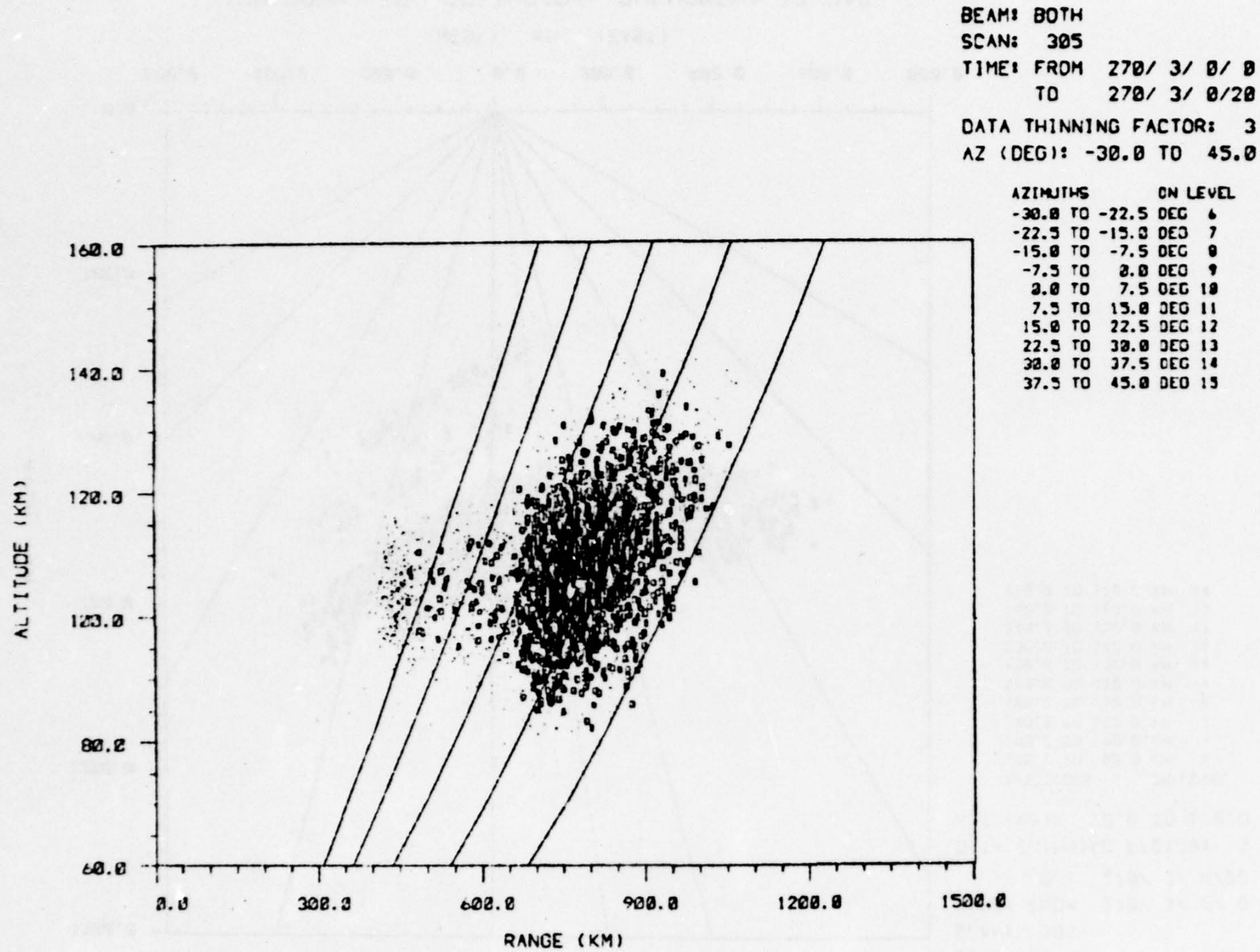
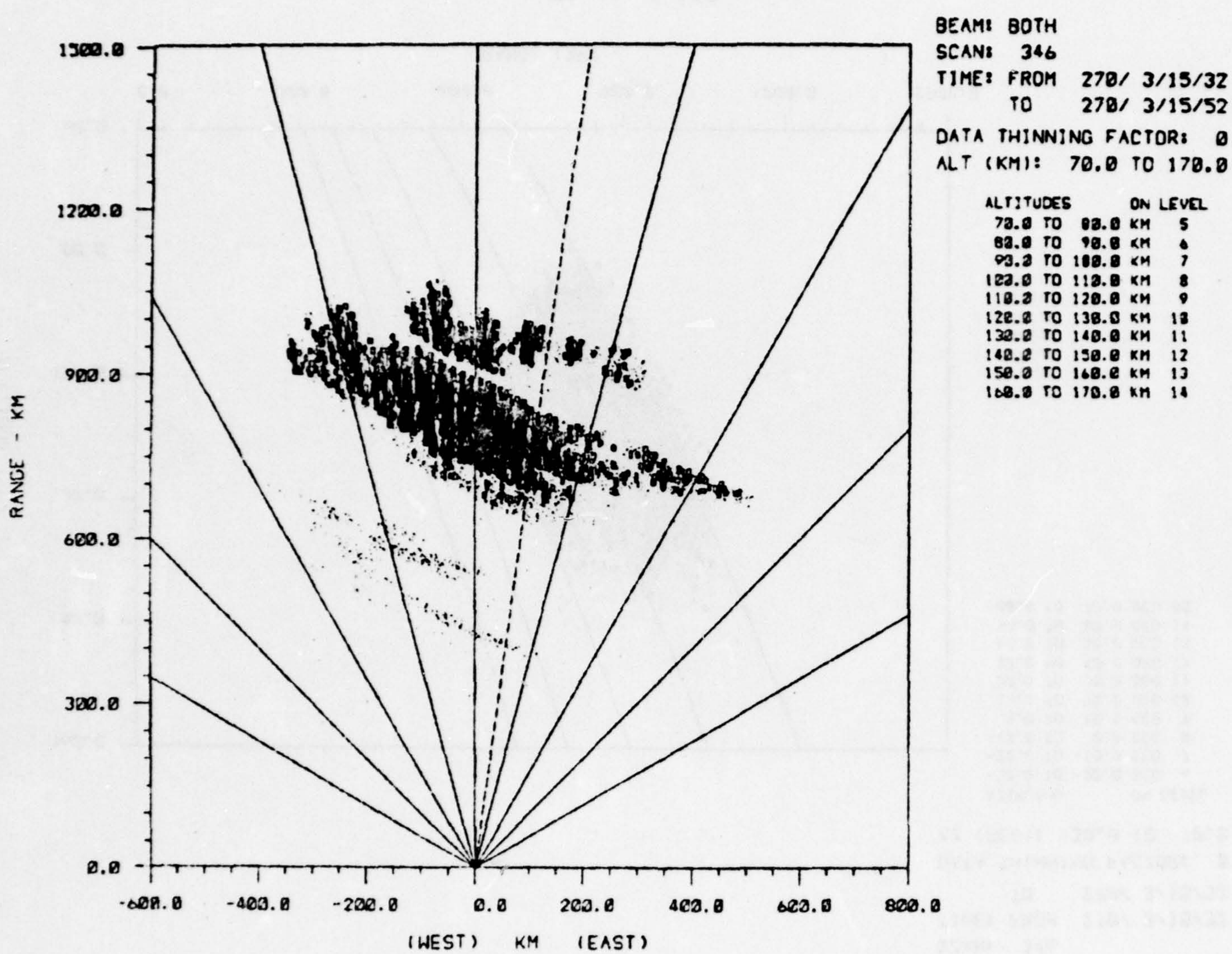

BEAM: BOTH
SCAN: 305
TIME: FROM 270/ 3/ 0/ 0
TO 270/ 3/ 0/20
DATA THINNING FACTOR: 3
AZ (DEG): -30.0 TO 45.0
AZIMUTHS ON LEVEL
-30.0 TO -22.5 DEG 6
-22.5 TO -15.0 DEG 7
-15.0 TO -7.5 DEG 8
-7.5 TO 0.0 DEG 9
0.0 TO 7.5 DEG 10
7.5 TO 15.0 DEG 11
15.0 TO 22.5 DEG 12
22.5 TO 30.0 DEG 13
30.0 TO 37.5 DEG 14
37.5 TO 45.0 DEG 15
ALTITUDE (KM)
160.0
140.0
120.0
100.0
80.0
60.0
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

Figure 5-116



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-117

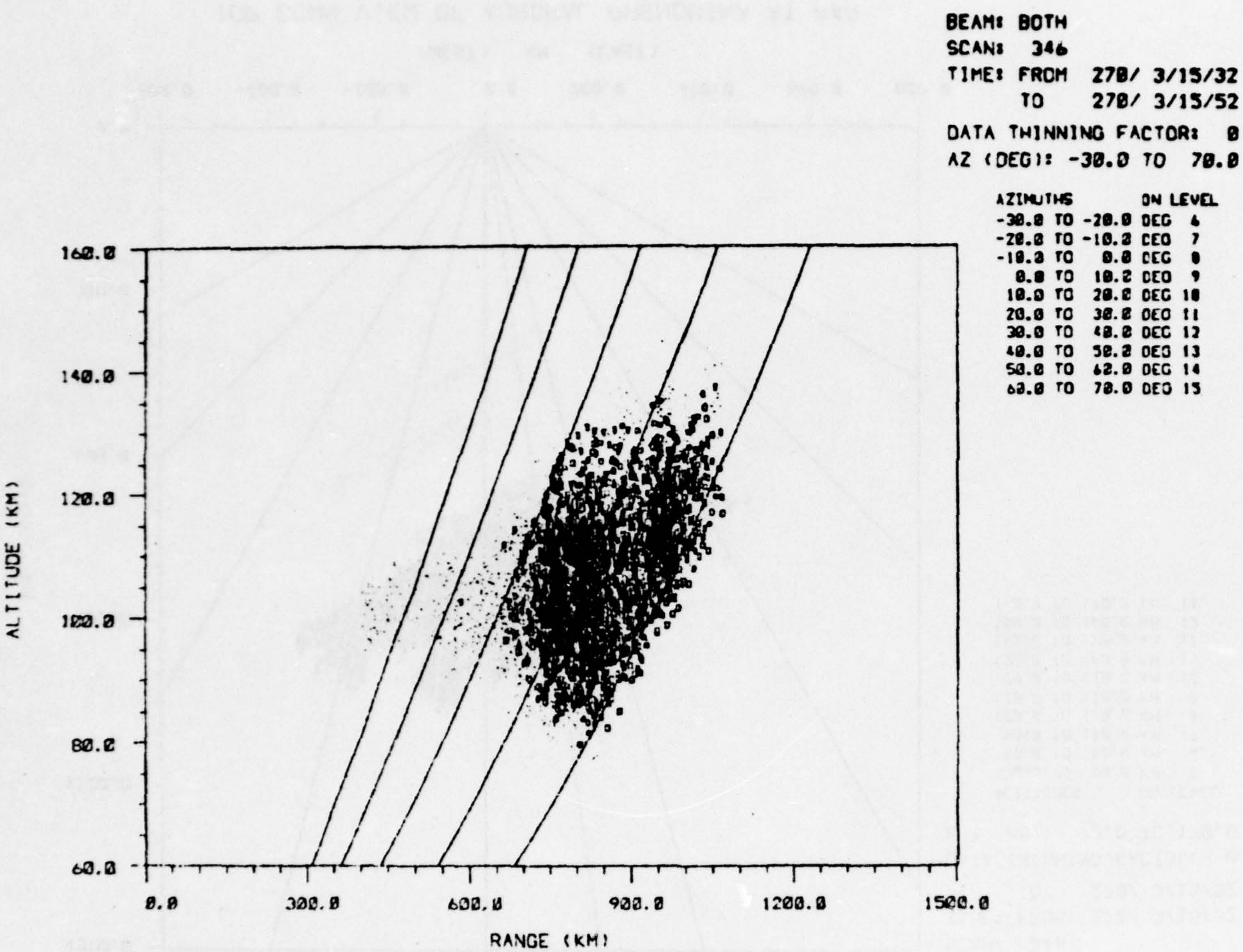
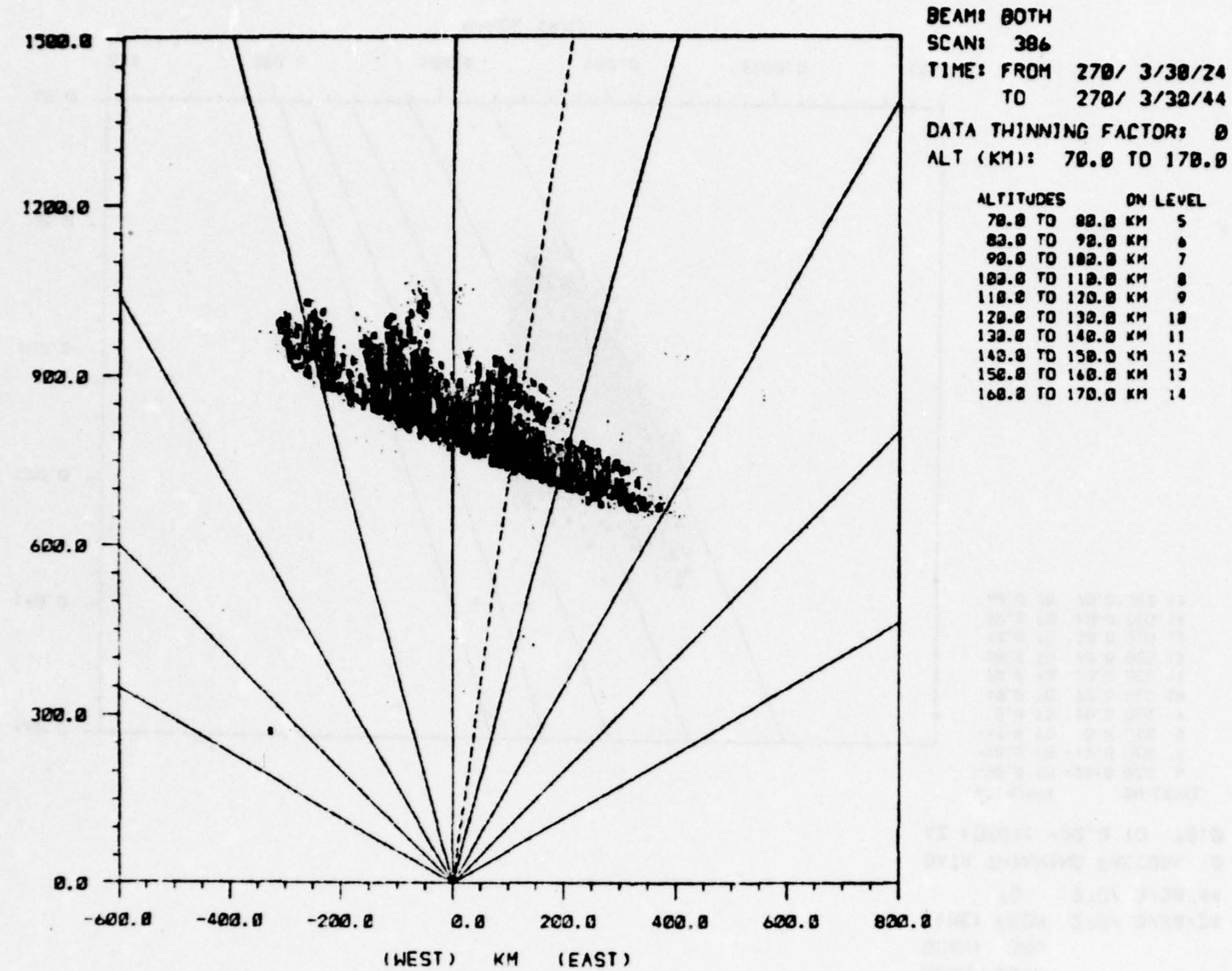

BEAM: BOTH
SCAN: 346
TIME: FROM 270/ 3/15/32
TO 270/ 3/15/52
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 70.0
AZIMUTHS ON LEVEL
-30.0 TO -20.0 DEG 6
-20.0 TO -10.0 DEG 7
-10.0 TO 0.0 DEG 8
0.0 TO 10.0 DEG 9
10.0 TO 20.0 DEG 10
20.0 TO 30.0 DEG 11
30.0 TO 40.0 DEG 12
40.0 TO 50.0 DEG 13
50.0 TO 60.0 DEG 14
60.0 TO 70.0 DEG 15
ALTITUDE (KM)
160.0
140.0
120.0
100.0
80.0
60.0
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

Figure 5-118



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-119

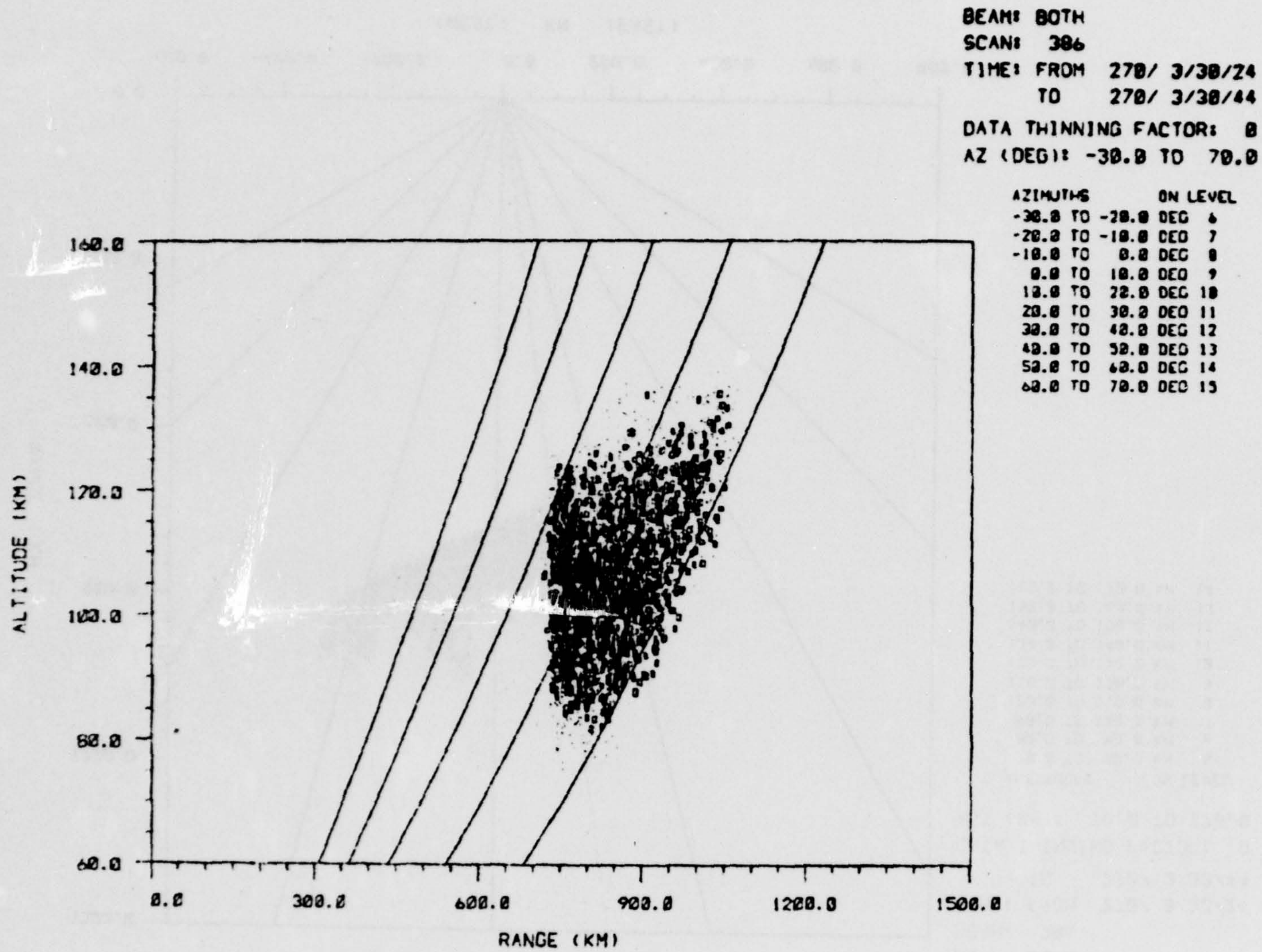
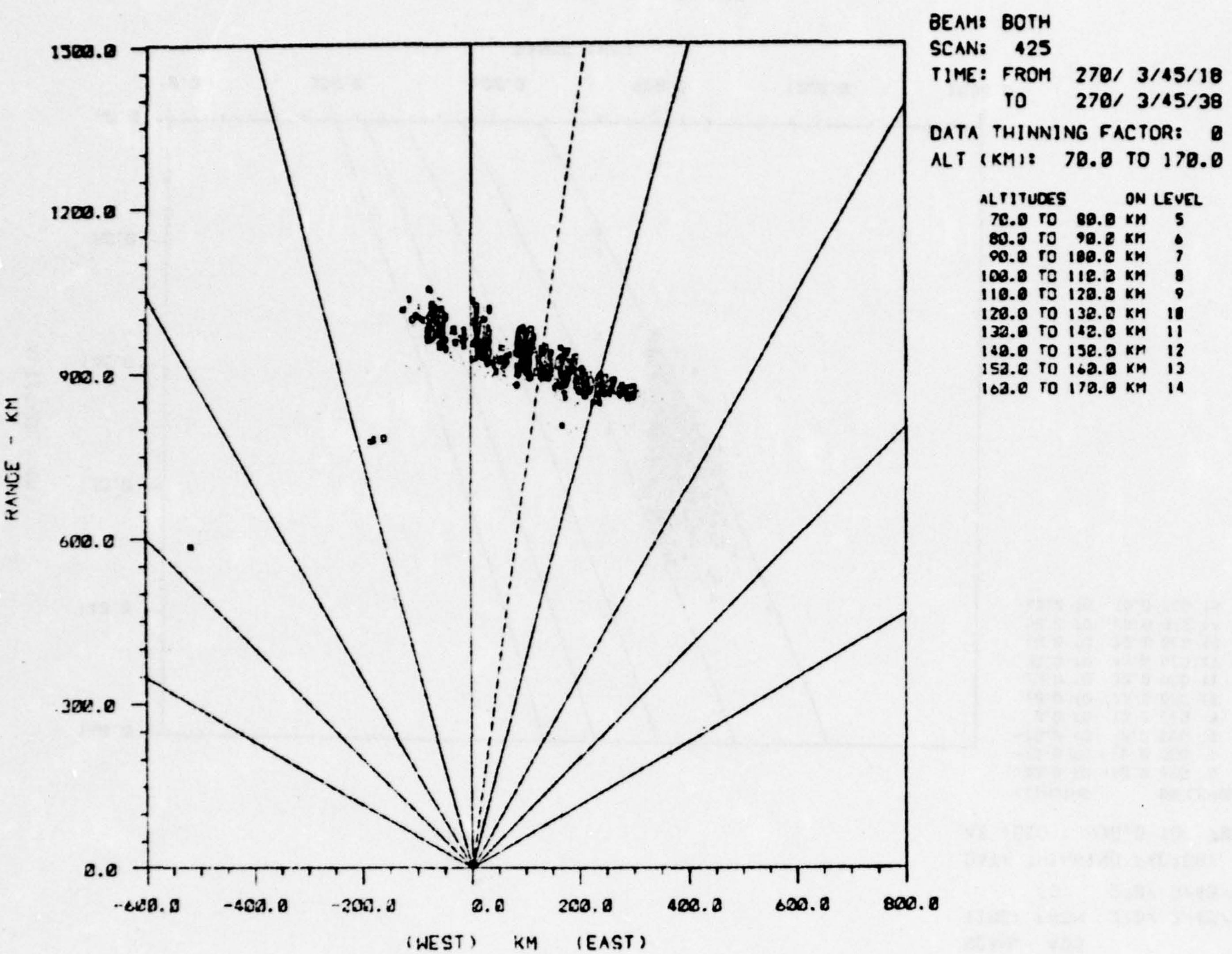

BEAM: BOTH
SCAN: 306
TIME: FROM 270/ 3/30/24
TO 270/ 3/30/44
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 70.0
AZIMUTHS ON LEVEL
-30.0 TO -20.0 DEG 6
-20.0 TO -10.0 DEG 7
-10.0 TO 0.0 DEG 8
0.0 TO 10.0 DEG 9
10.0 TO 20.0 DEG 10
20.0 TO 30.0 DEG 11
30.0 TO 40.0 DEG 12
40.0 TO 50.0 DEG 13
50.0 TO 60.0 DEG 14
60.0 TO 70.0 DEG 15
160.0
140.0
120.0
100.0
80.0
60.0
ALTITUDE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

Figure 5-120



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-121

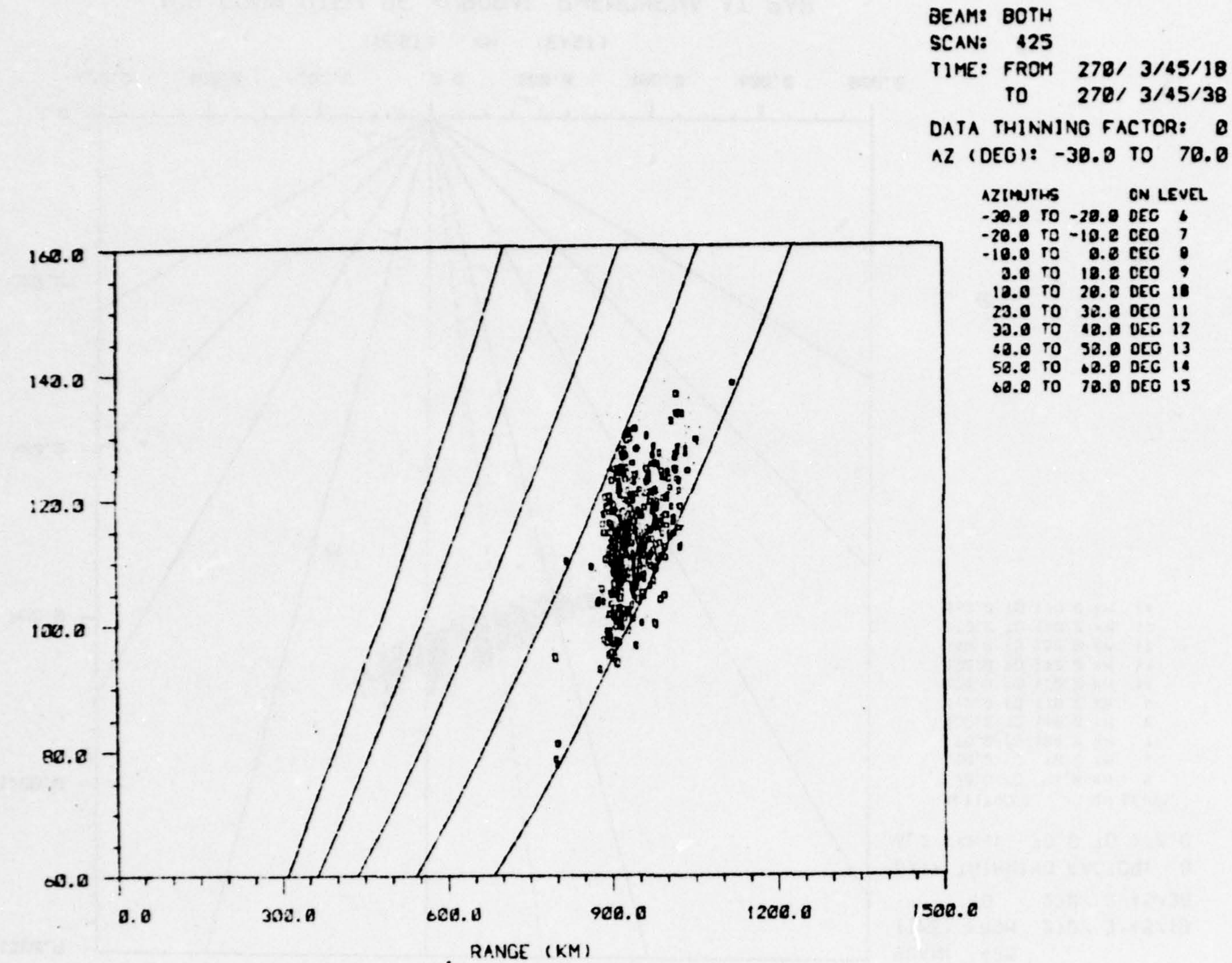
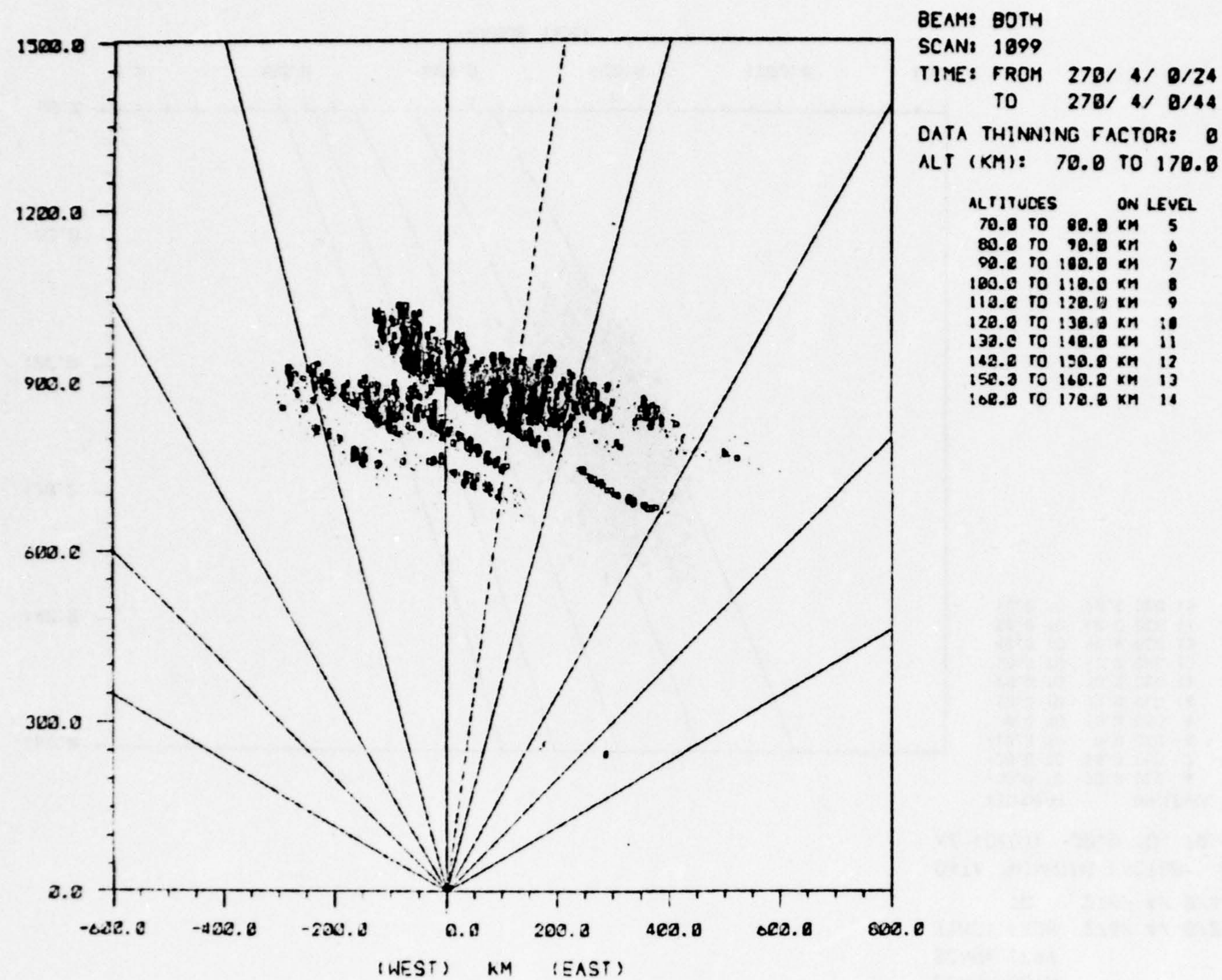
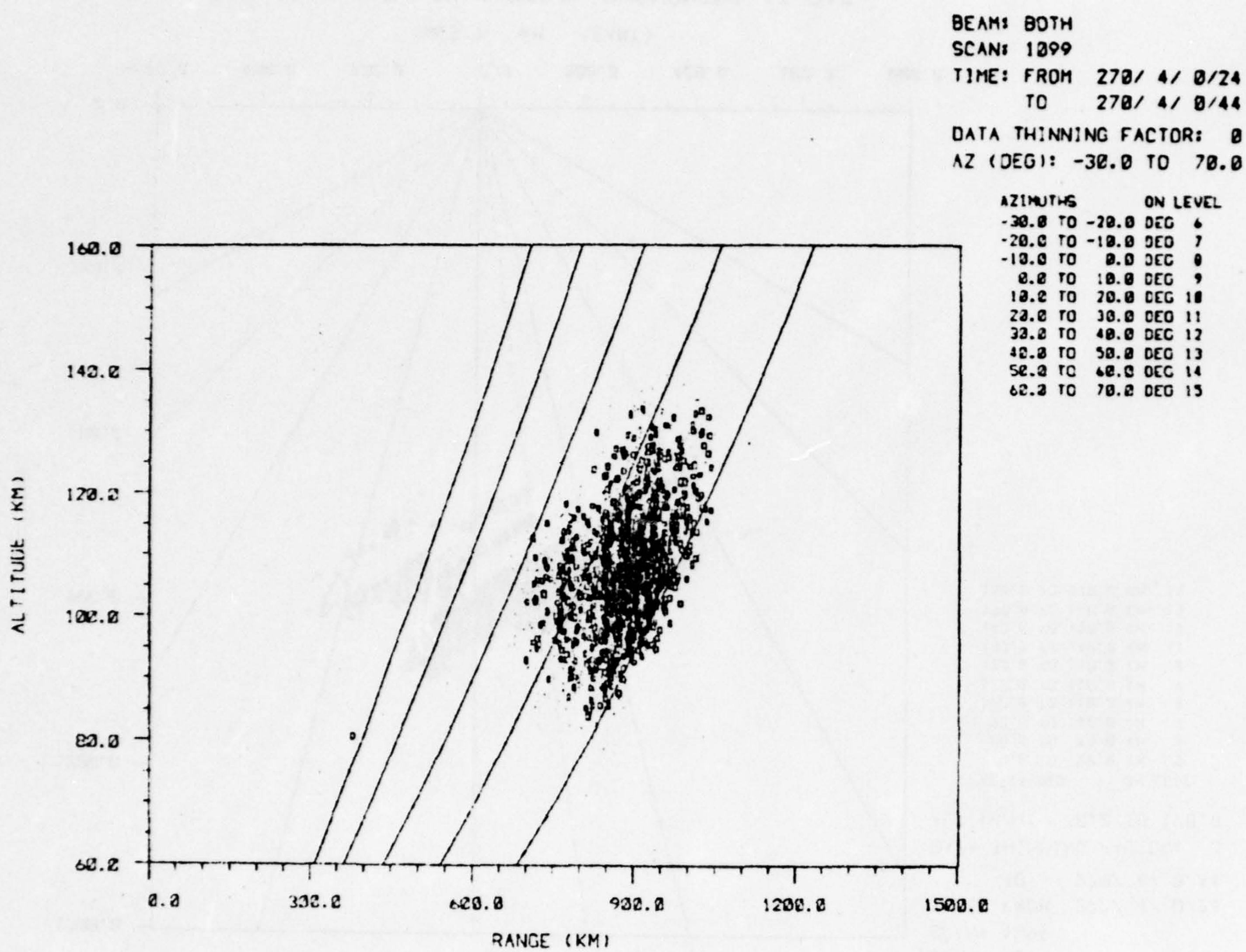

BEAM: BOTH
SCAN: 425
TIME: FROM 270/ 3/45/18
TO 270/ 3/45/38
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 70.0
AZIMUTHS ON LEVEL
-30.0 TO -20.0 DEG 6
-20.0 TO -10.0 DEG 7
-10.0 TO 0.0 DEG 8
0.0 TO 10.0 DEG 9
10.0 TO 20.0 DEG 10
20.0 TO 30.0 DEG 11
30.0 TO 40.0 DEG 12
40.0 TO 50.0 DEG 13
50.0 TO 60.0 DEG 14
60.0 TO 70.0 DEG 15
ALTITUDE (KM)
160.0
140.0
120.0
100.0
80.0
60.0
RANGE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0

Figure 5-122



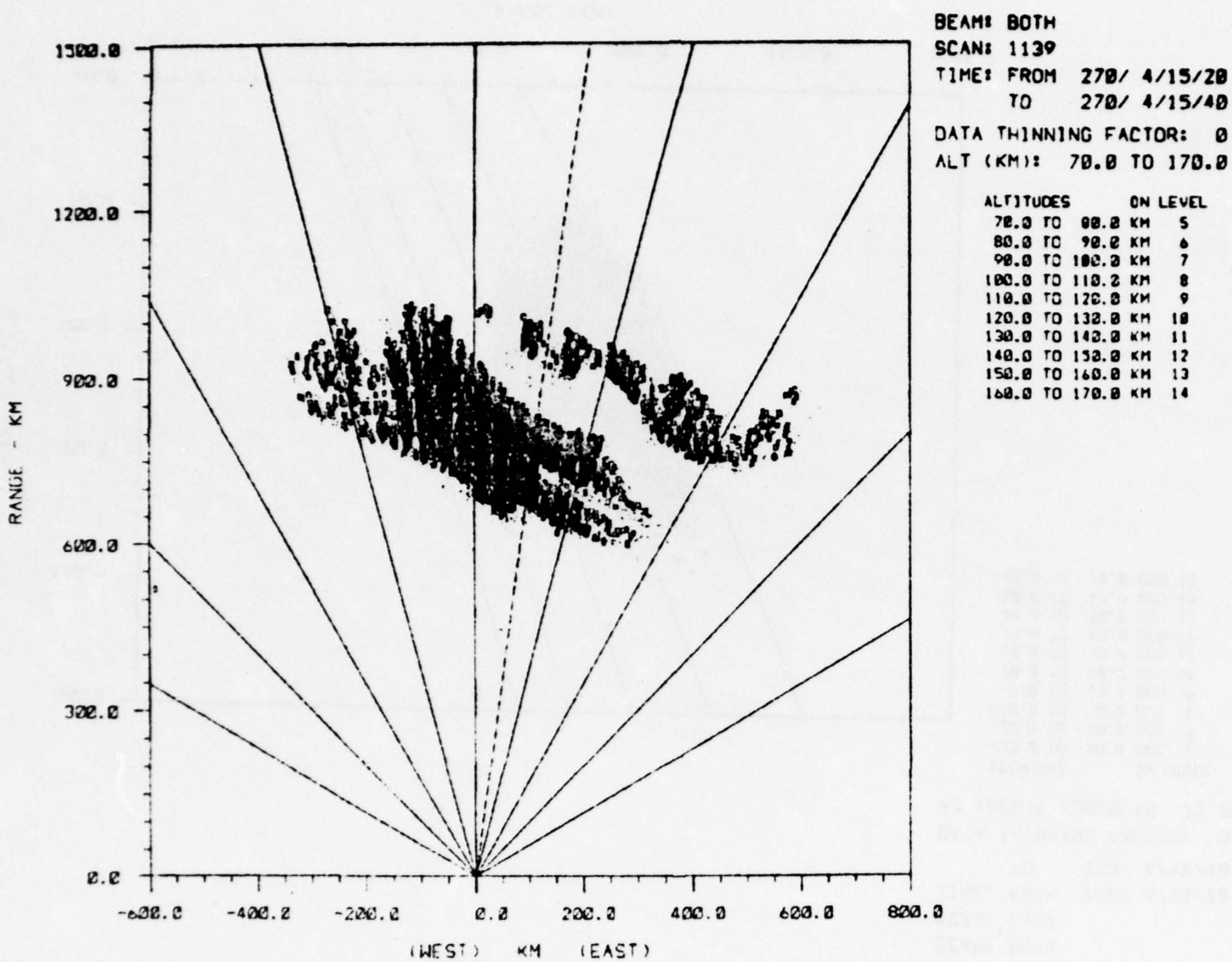
TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-123



BEAM: BOTH
SCAN: 1099
TIME: FROM 270/ 4/ 0/24
TO 270/ 4/ 0/44
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 70.0
AZIMUTHS ON LEVEL
-30.0 TO -20.0 DEG 6
-20.0 TO -10.0 DEG 7
-10.0 TO 0.0 DEG 8
0.0 TO 10.0 DEG 9
10.0 TO 20.0 DEG 10
20.0 TO 30.0 DEG 11
30.0 TO 40.0 DEG 12
40.0 TO 50.0 DEG 13
50.0 TO 60.0 DEG 14
60.0 TO 70.0 DEG 15
160.0
140.0
120.0
100.0
80.0
60.0
ALTITUDE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

Figure 5-124



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-125

BEAM: BOTH
SCAN: 1139
TIME: FROM 270/ 4/15/20
TO 270/ 4/15/40

DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 70.0

AZIMUTHS	ON LEVEL
-30.0 TO -20.0 DEG	6
-20.0 TO -10.0 DEG	7
-10.0 TO 0.0 DEG	8
0.0 TO 10.0 DEG	9
10.0 TO 20.0 DEG	10
20.0 TO 30.0 DEG	11
30.0 TO 40.0 DEG	12
40.0 TO 50.0 DEG	13
50.0 TO 60.0 DEG	14
60.0 TO 70.0 DEG	15

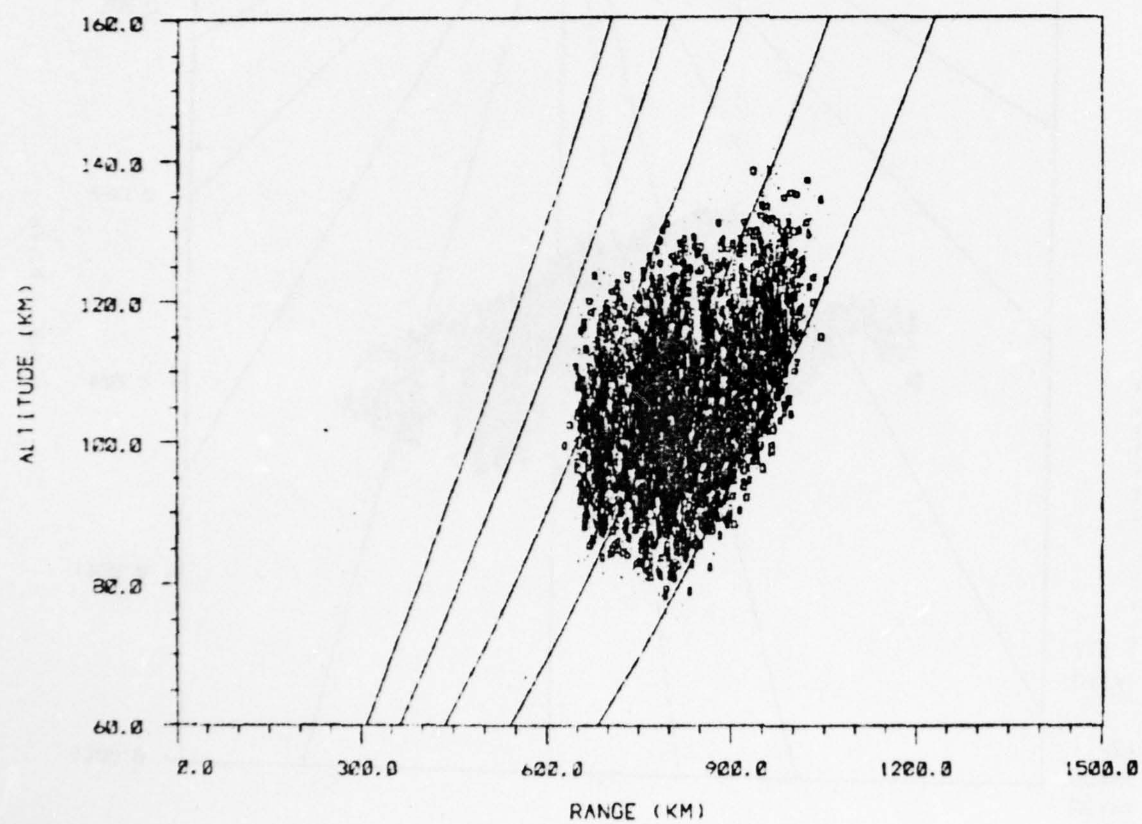
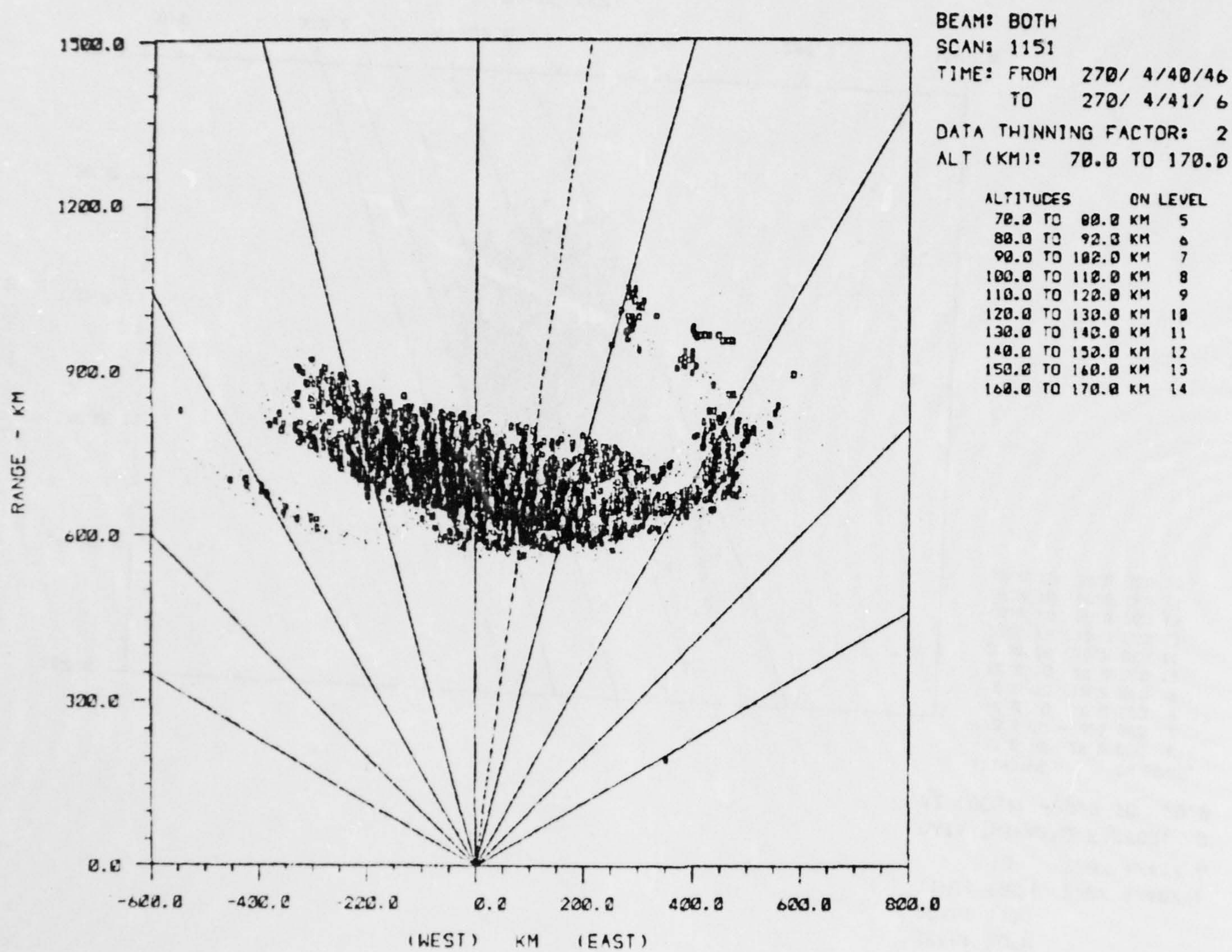
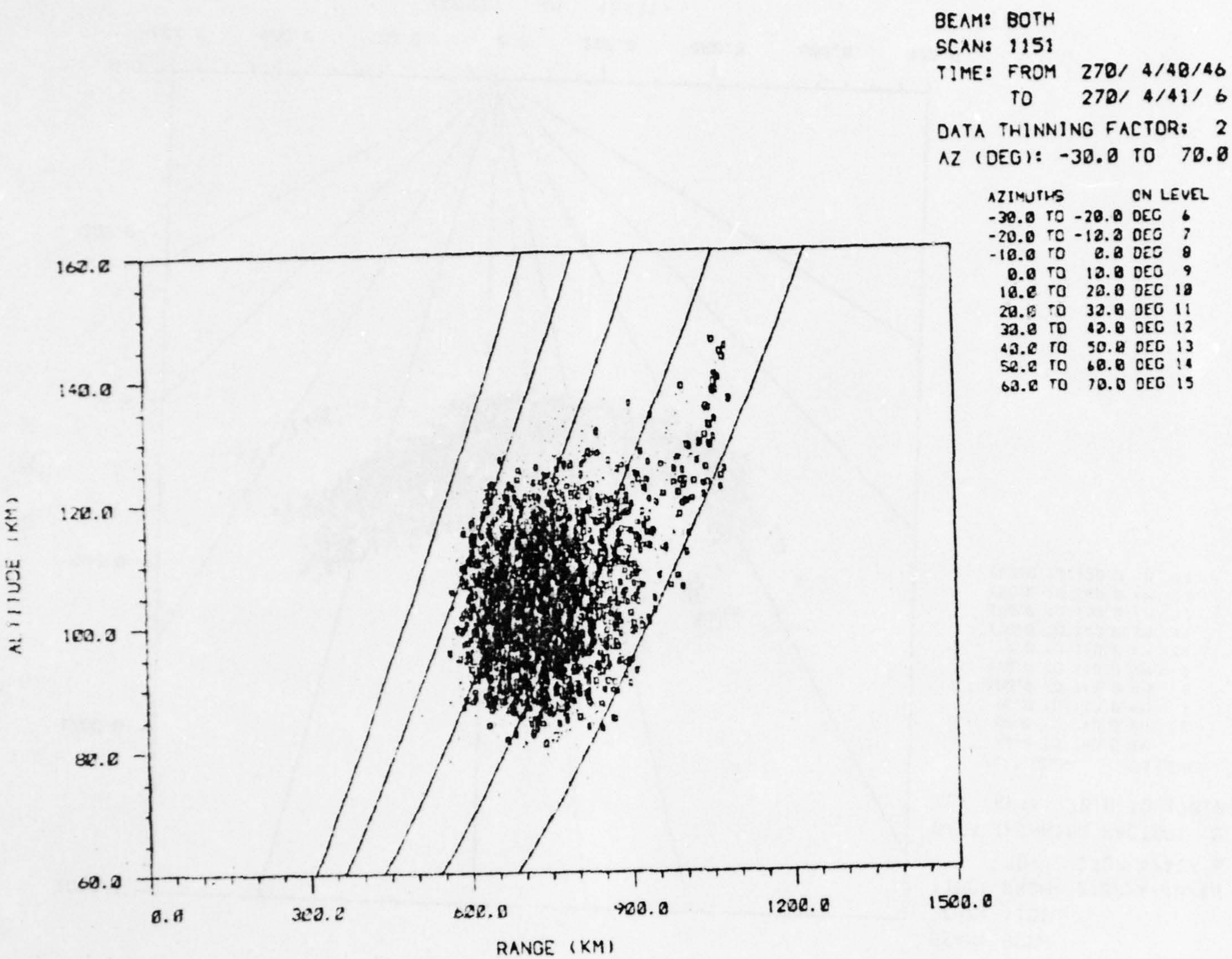


Figure 5-126



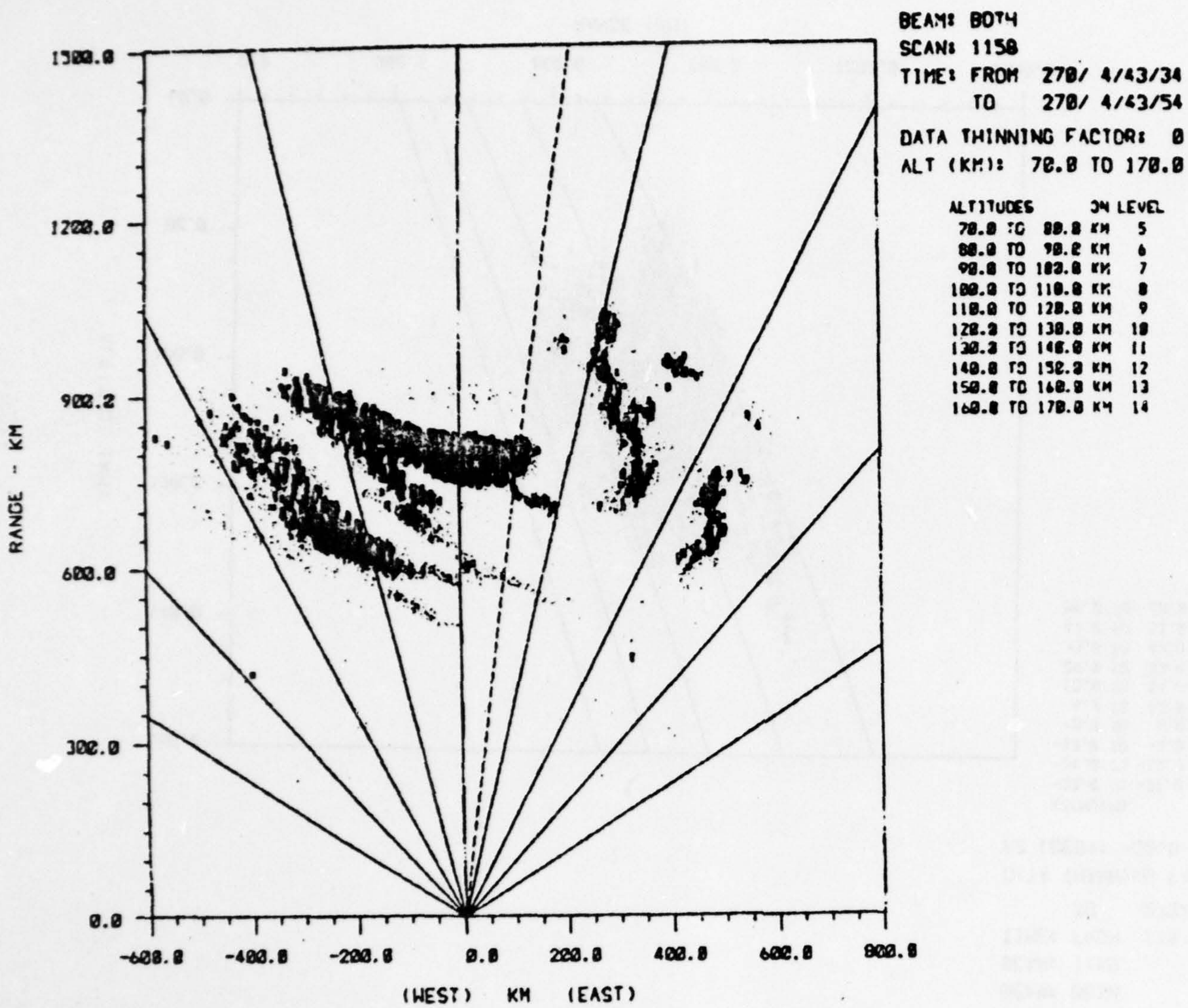
TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-127



BEAM: BOTH
SCAN: 1151
TIME: FROM 270/ 4/40/46
TO 270/ 4/41/ 6
DATA THINNING FACTOR: 2
AZ (DEG): -30.0 TO 70.0
AZIMUTHS ON LEVEL
-30.0 TO -20.0 DEG 6
-20.0 TO -10.0 DEG 7
-10.0 TO 0.0 DEG 8
0.0 TO 10.0 DEG 9
10.0 TO 20.0 DEG 10
20.0 TO 30.0 DEG 11
30.0 TO 40.0 DEG 12
40.0 TO 50.0 DEG 13
50.0 TO 60.0 DEG 14
60.0 TO 70.0 DEG 15
ALTITUDE (KM)
162.0
140.0
120.0
100.0
80.0
60.0
0.0
300.2
600.0
900.0
1200.0
1500.0
RANGE (KM)

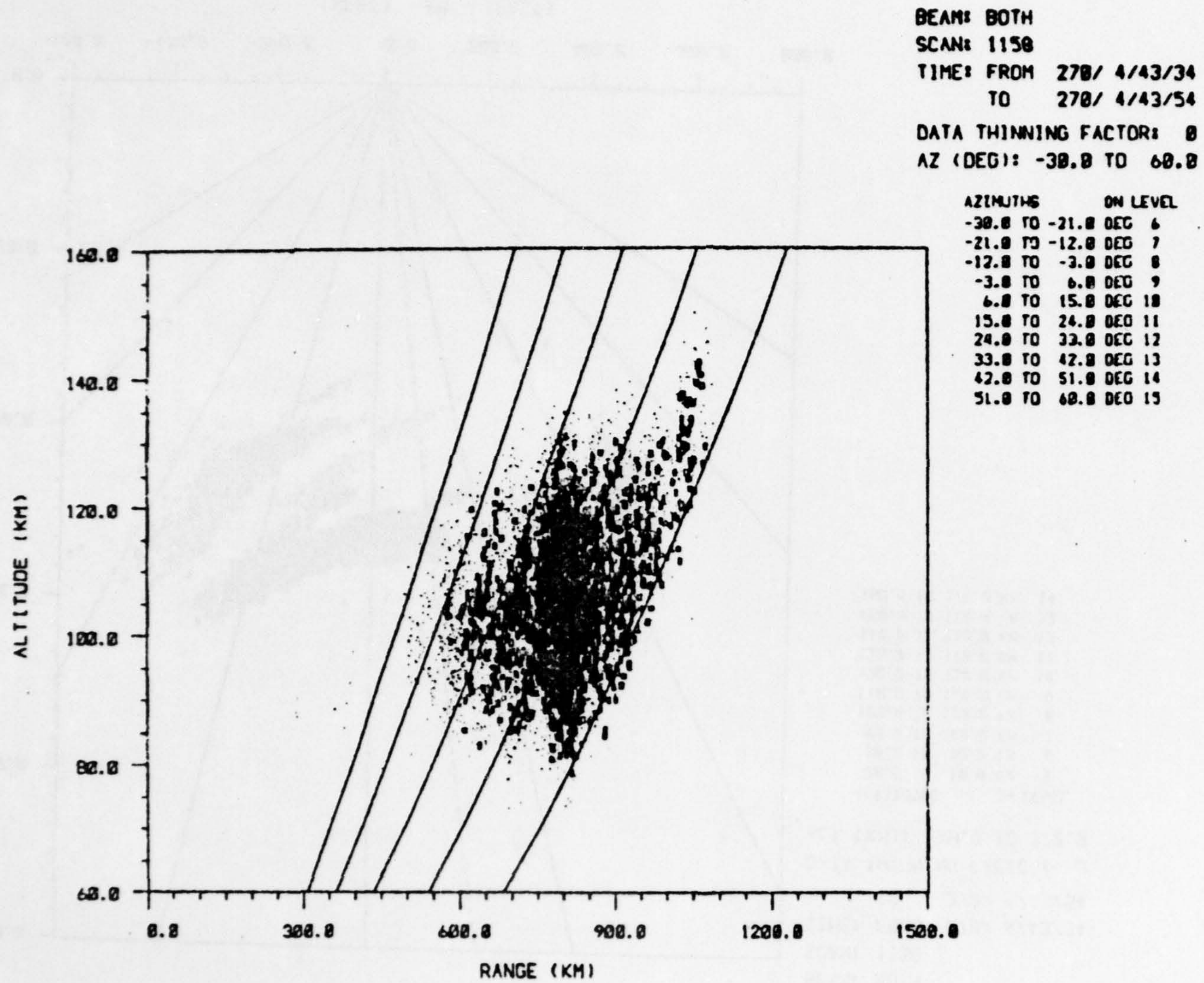
Figure 5-128



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

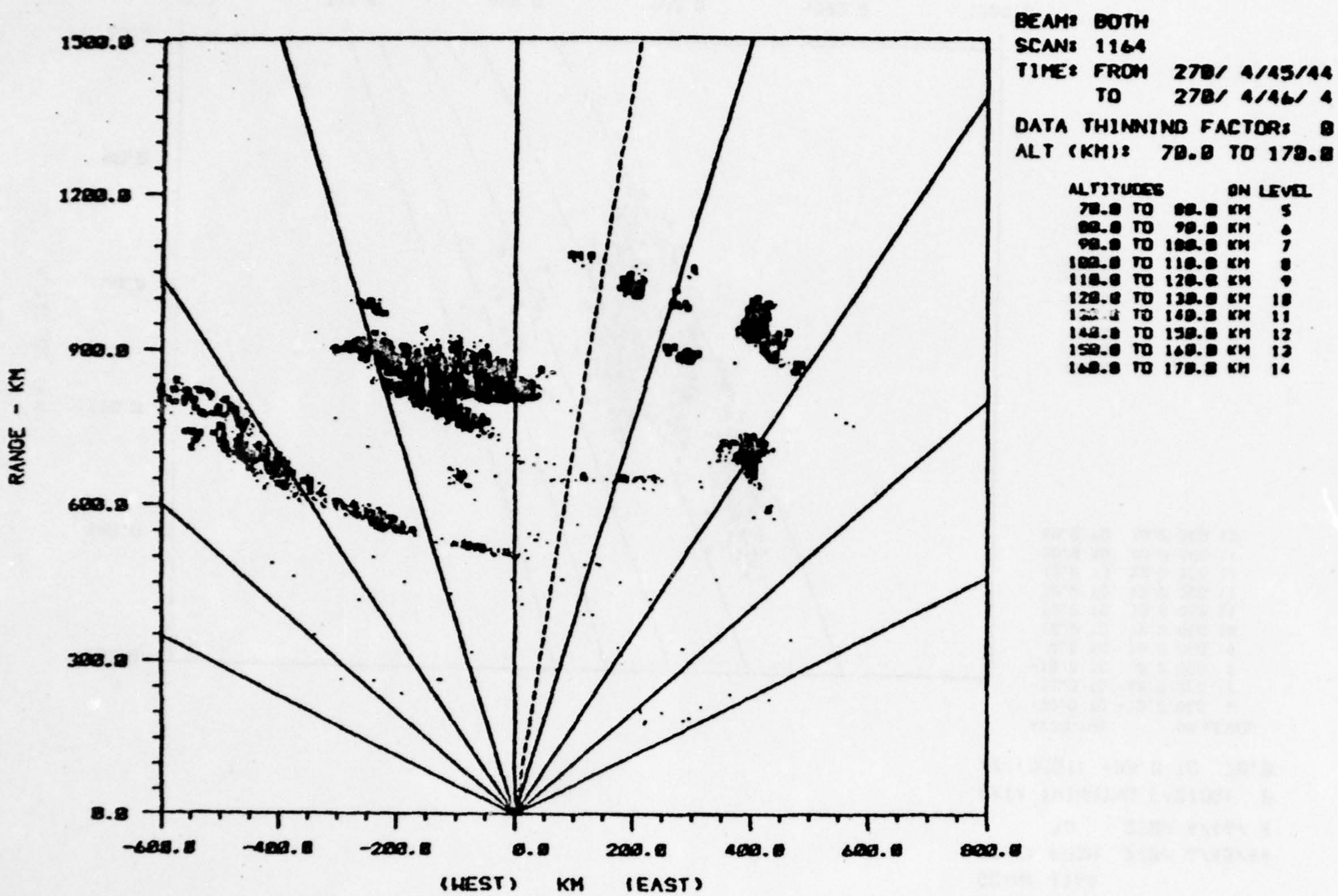
M&S OMPUTINO

Figure 5-129



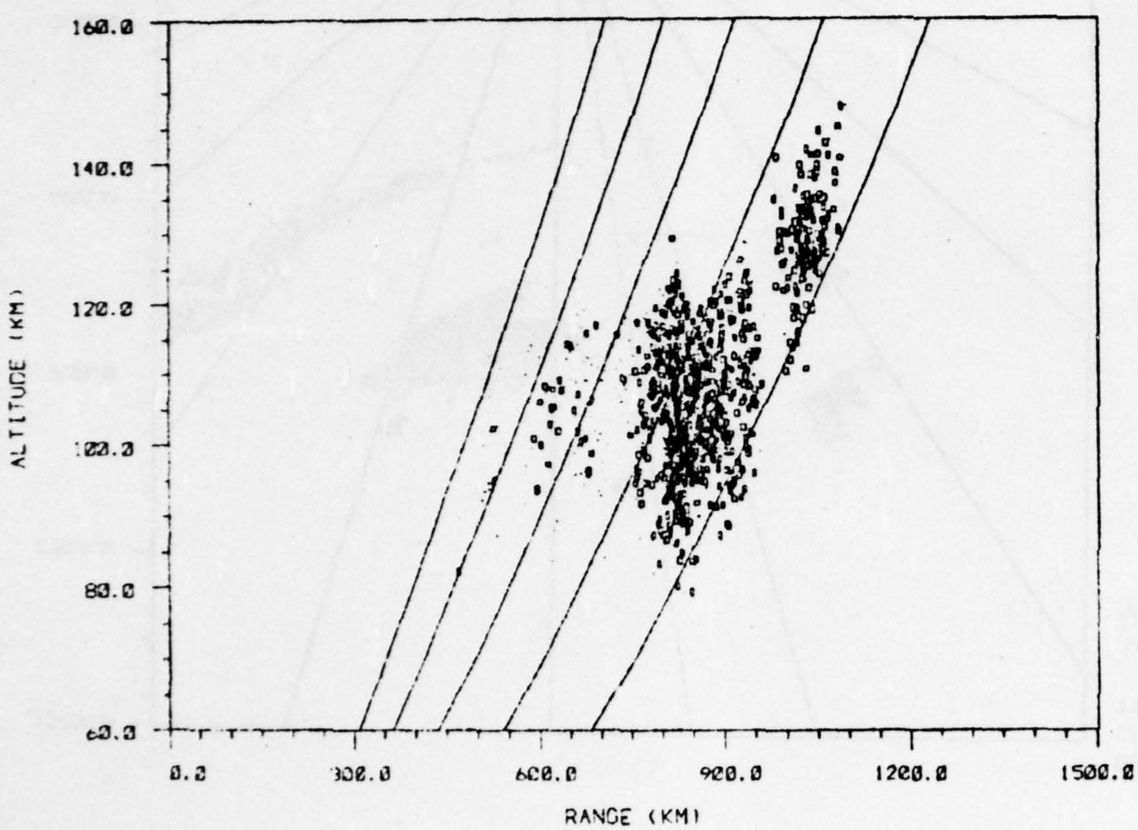
M&S OMPUTINO

Figure 5-130



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

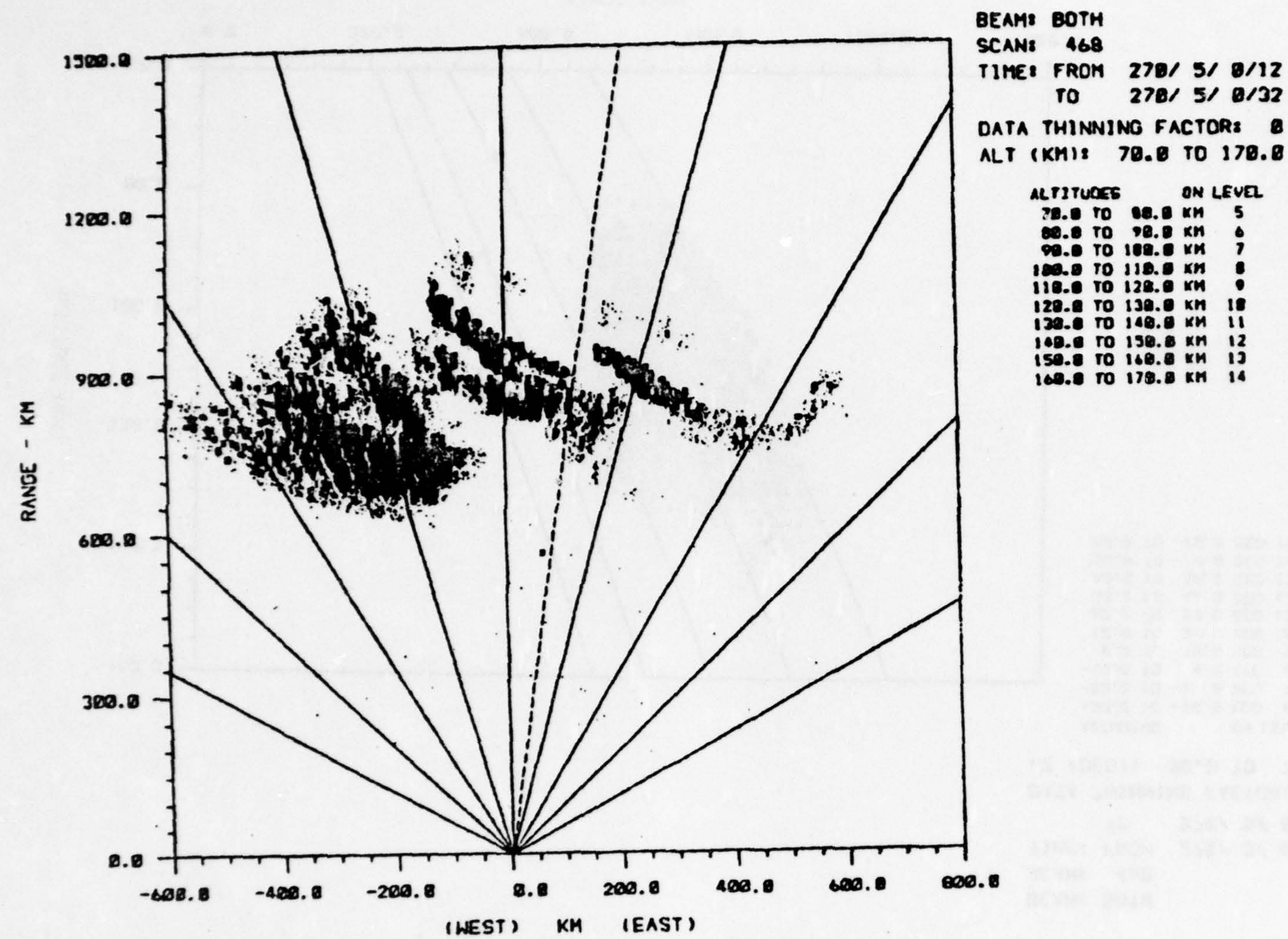
Figure 5-131



BEAM: BOTH
SCAN: 1164
TIME: FROM 270/ 4/45/44
TO 270/ 4/46/ 4
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 70.0

AZIMUTHS				ON LEVEL
-30.0	TO	-20.0	DEG	6
-20.0	TO	-10.0	DEG	7
-10.0	TO	0.0	DEG	8
0.0	TO	10.0	DEG	9
10.0	TO	20.0	DEG	10
20.0	TO	30.0	DEG	11
30.0	TO	40.0	DEG	12
40.0	TO	50.0	DEG	13
50.0	TO	60.0	DEG	14
60.0	TO	70.0	DEG	15

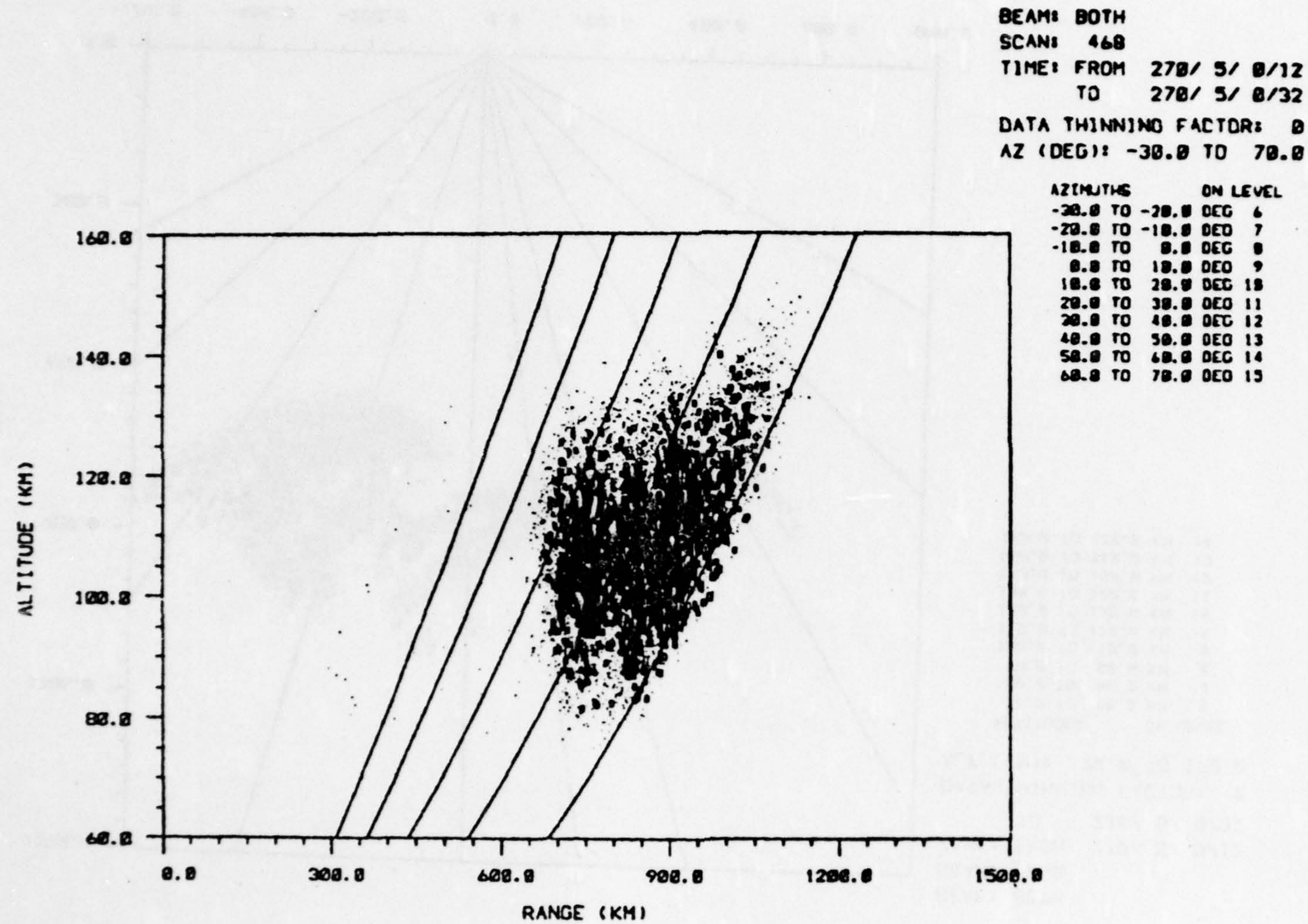
Figure 5-132



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

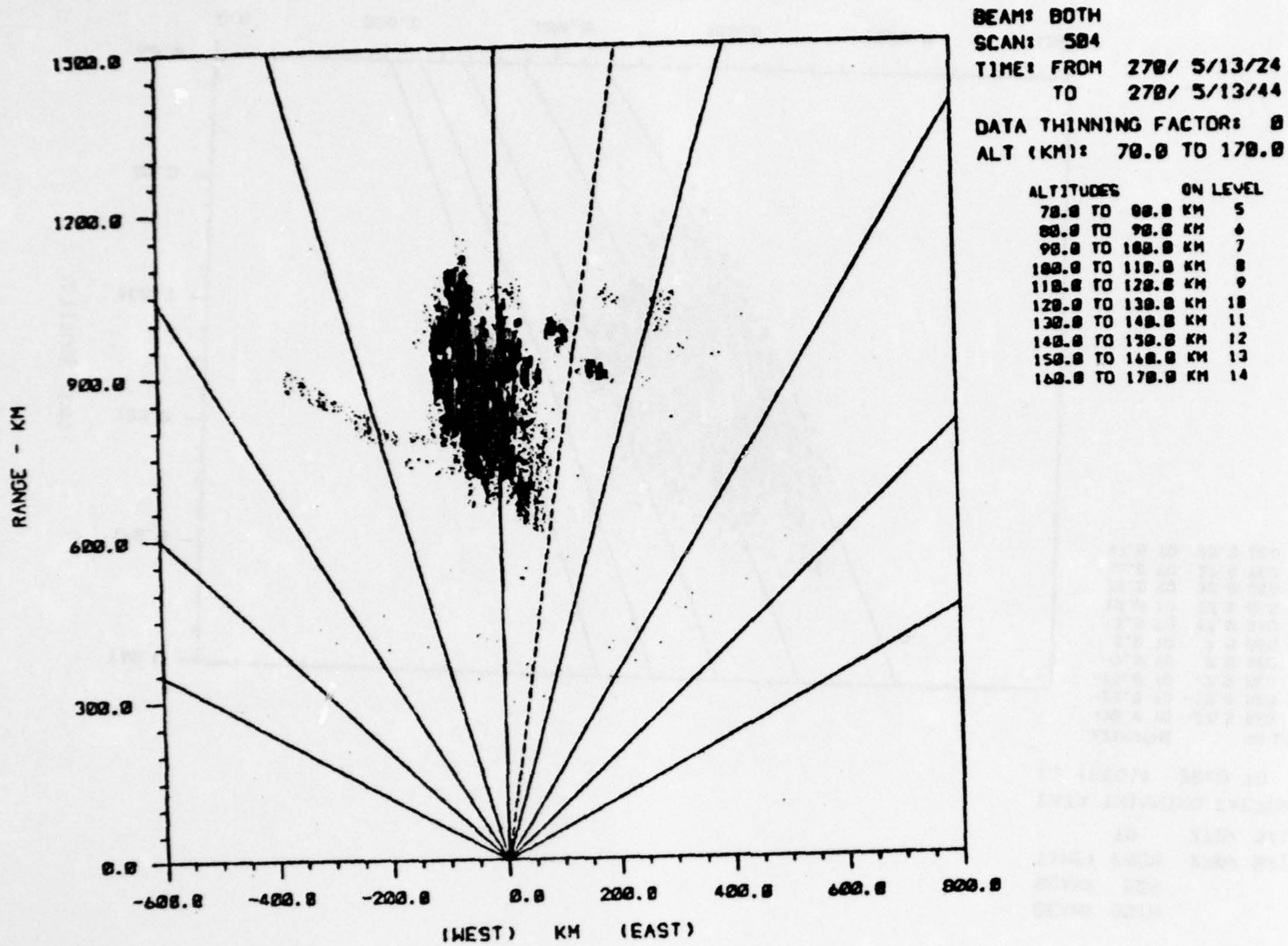
M&S OMPUTING

Figure 5-133



M&S COMPUTING

Figure 5-134



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

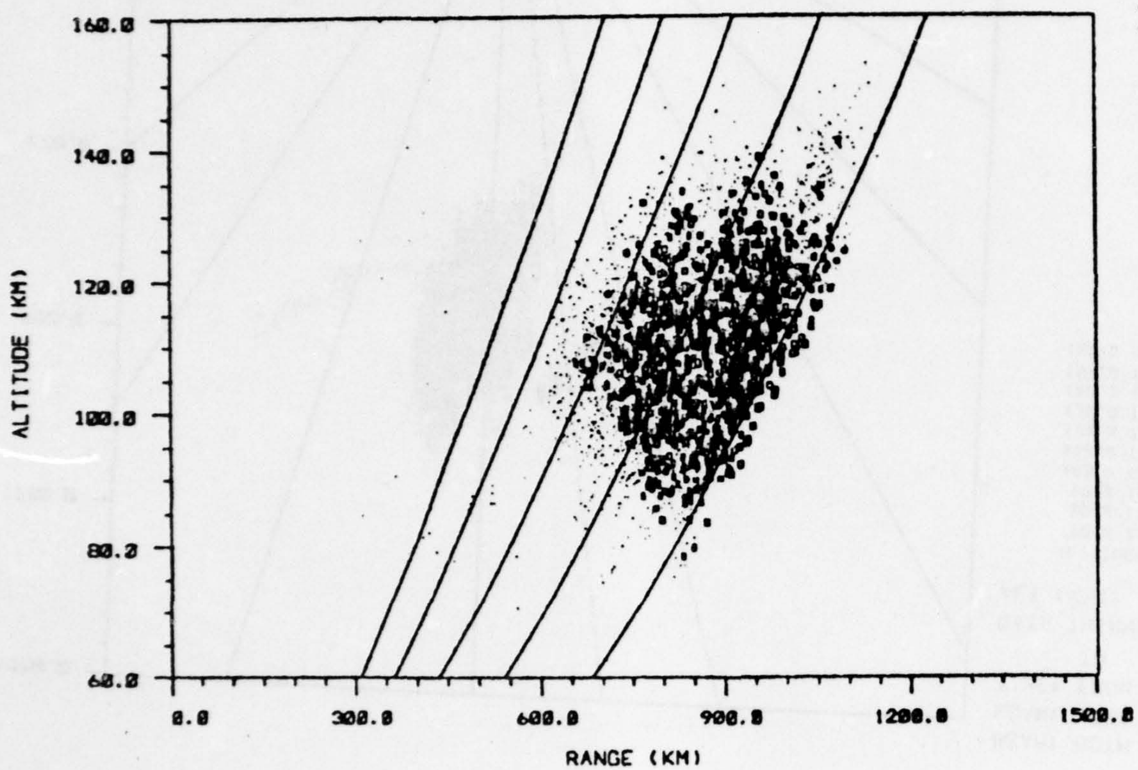
M&S COMPUTING

Figure 5-135

BEAM: BOTH
SCAN: 504
TIME: FROM 270/ 5/13/24
TO 270/ 5/13/44

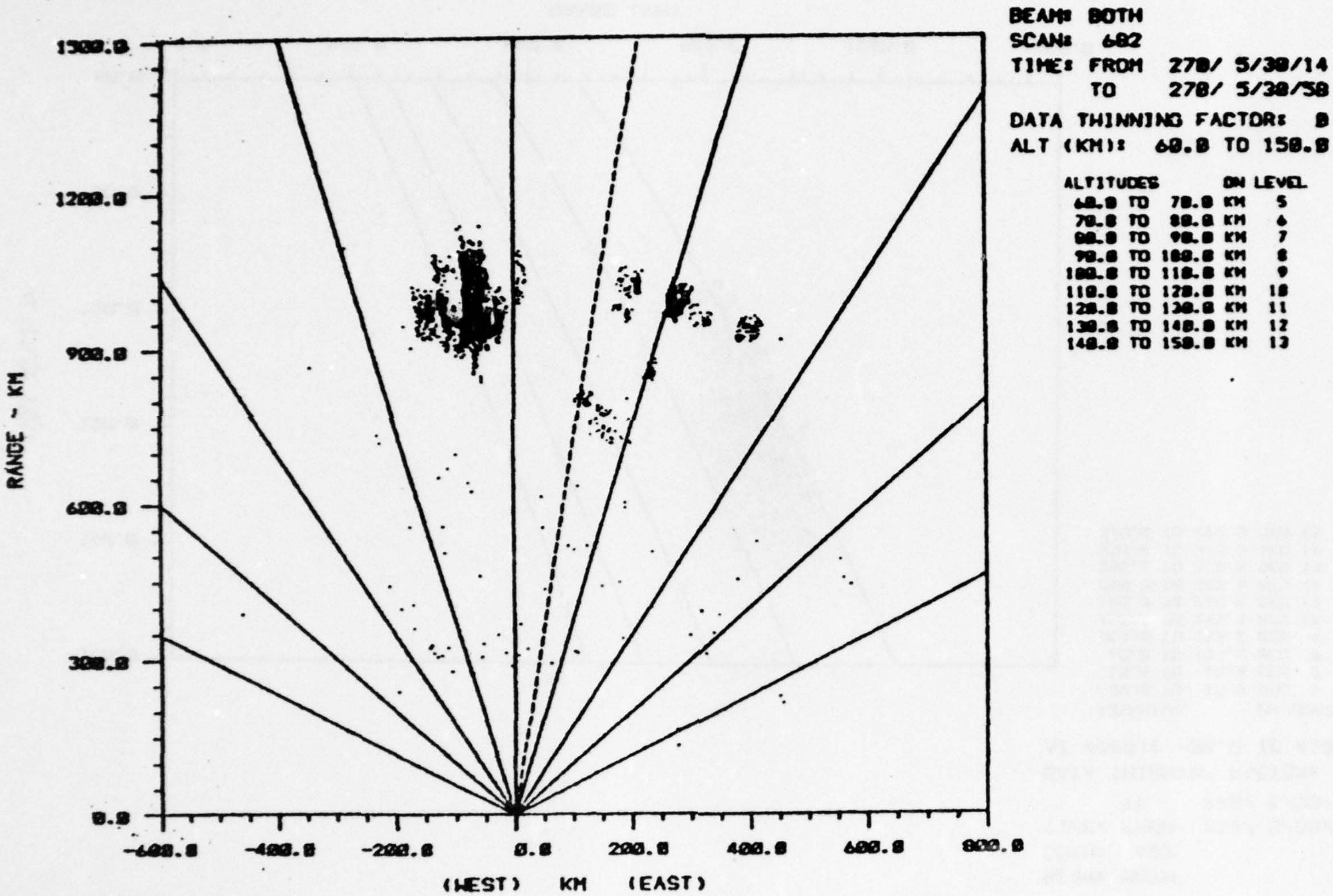
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 45.0

AZIMUTHS	ON LEVEL
-30.0 TO -22.5 DEG	6
-22.5 TO -15.0 DEG	7
-15.0 TO -7.5 DEG	8
-7.5 TO 0.0 DEG	9
0.0 TO 7.5 DEG	10
7.5 TO 15.0 DEG	11
15.0 TO 22.5 DEG	12
22.5 TO 30.0 DEG	13
30.0 TO 37.5 DEG	14
37.5 TO 45.0 DEG	15



M&S COMPUTING

Figure 5-136



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-137

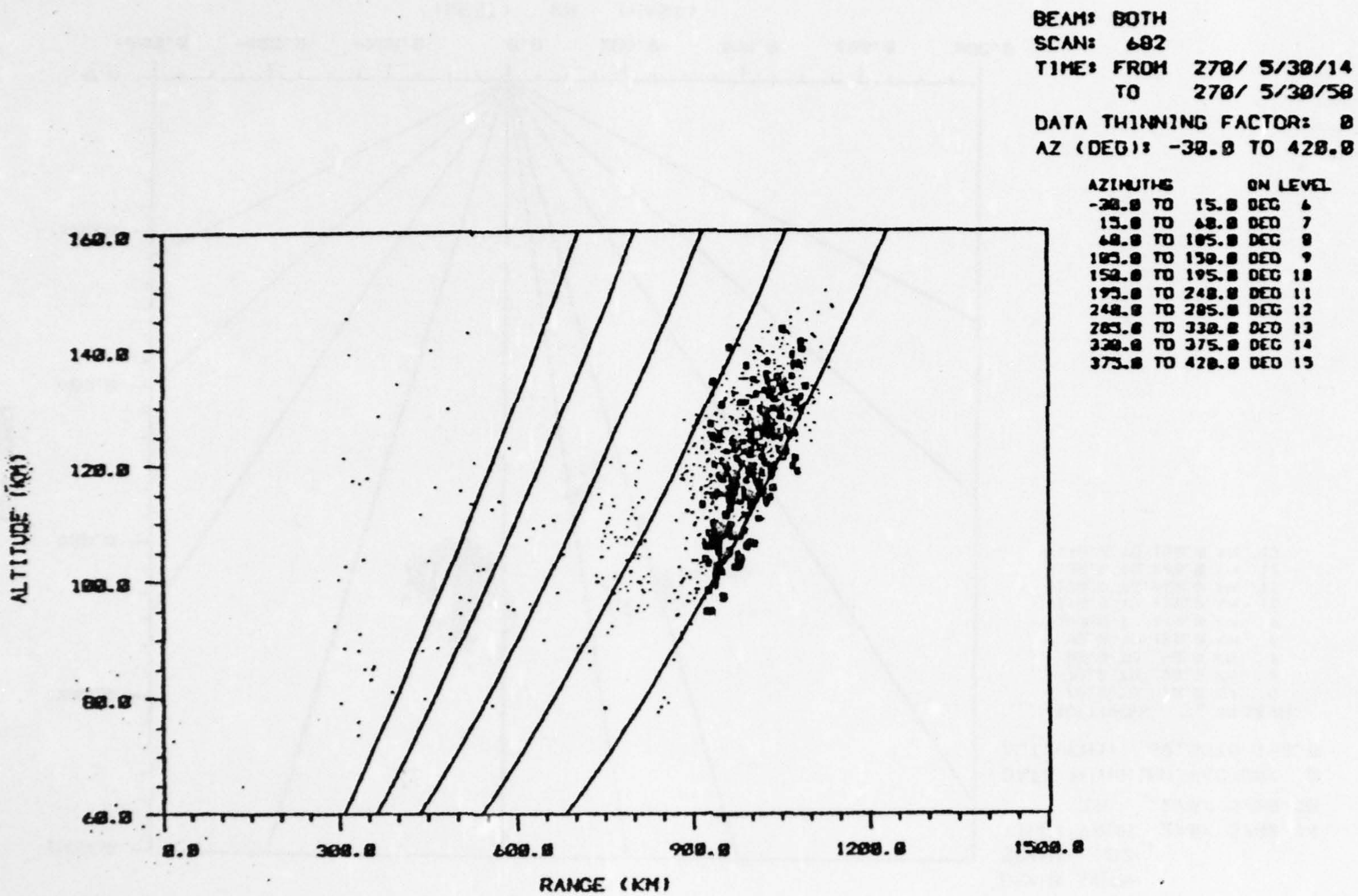

BEAM: BOTH
SCAN: 682
TIME: FROM 270/ 5/30/14
TO 270/ 5/30/58
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 420.0
AZIMUTHS ON LEVEL
-30.0 TO 15.0 DEG 6
15.0 TO 60.0 DEG 7
60.0 TO 105.0 DEG 8
105.0 TO 150.0 DEG 9
150.0 TO 195.0 DEG 10
195.0 TO 240.0 DEG 11
240.0 TO 285.0 DEG 12
285.0 TO 330.0 DEG 13
330.0 TO 375.0 DEG 14
375.0 TO 420.0 DEG 15
160.0
140.0
120.0
100.0
80.0
60.0
ALTITUDE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

Figure 5-138

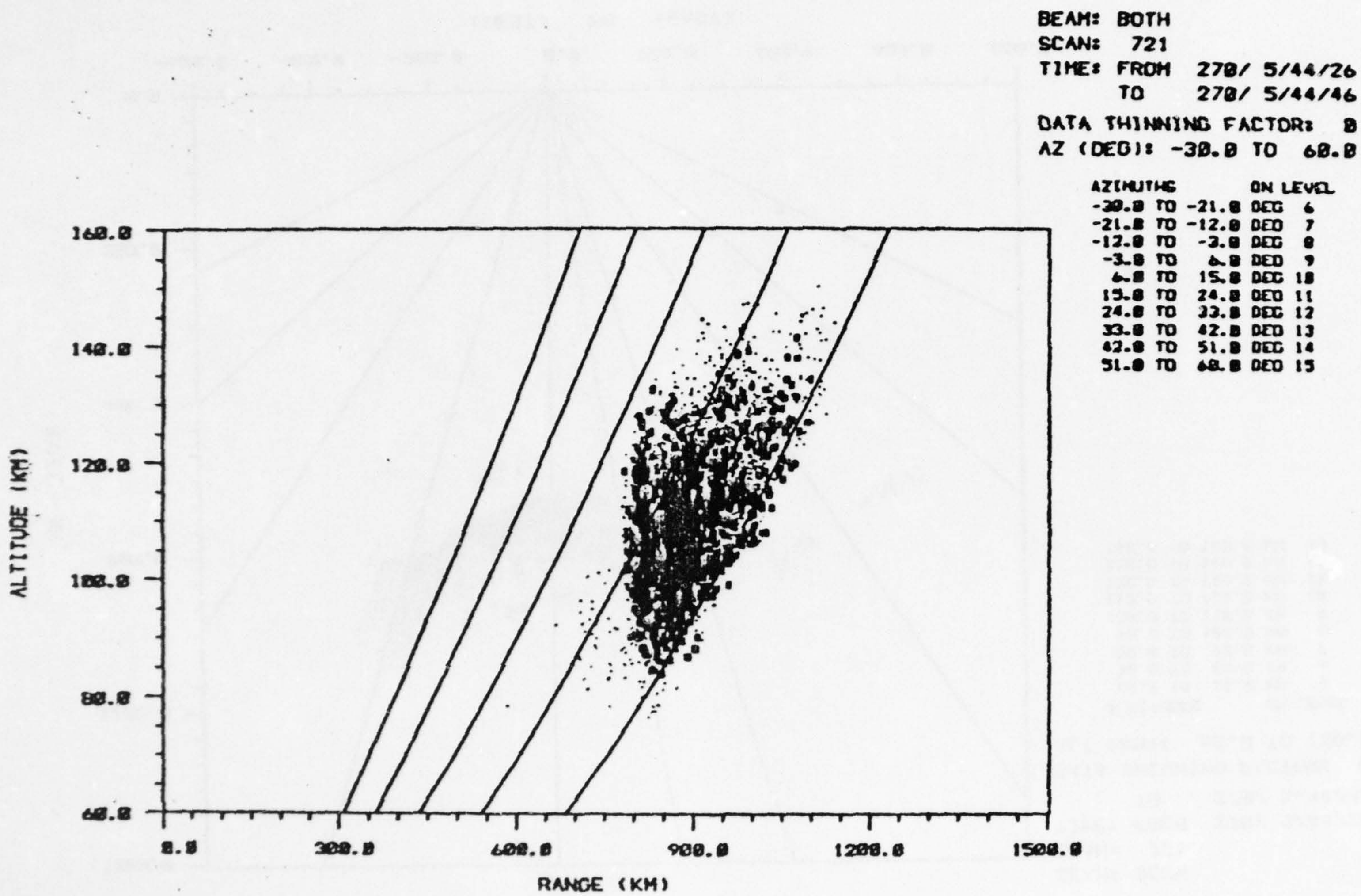
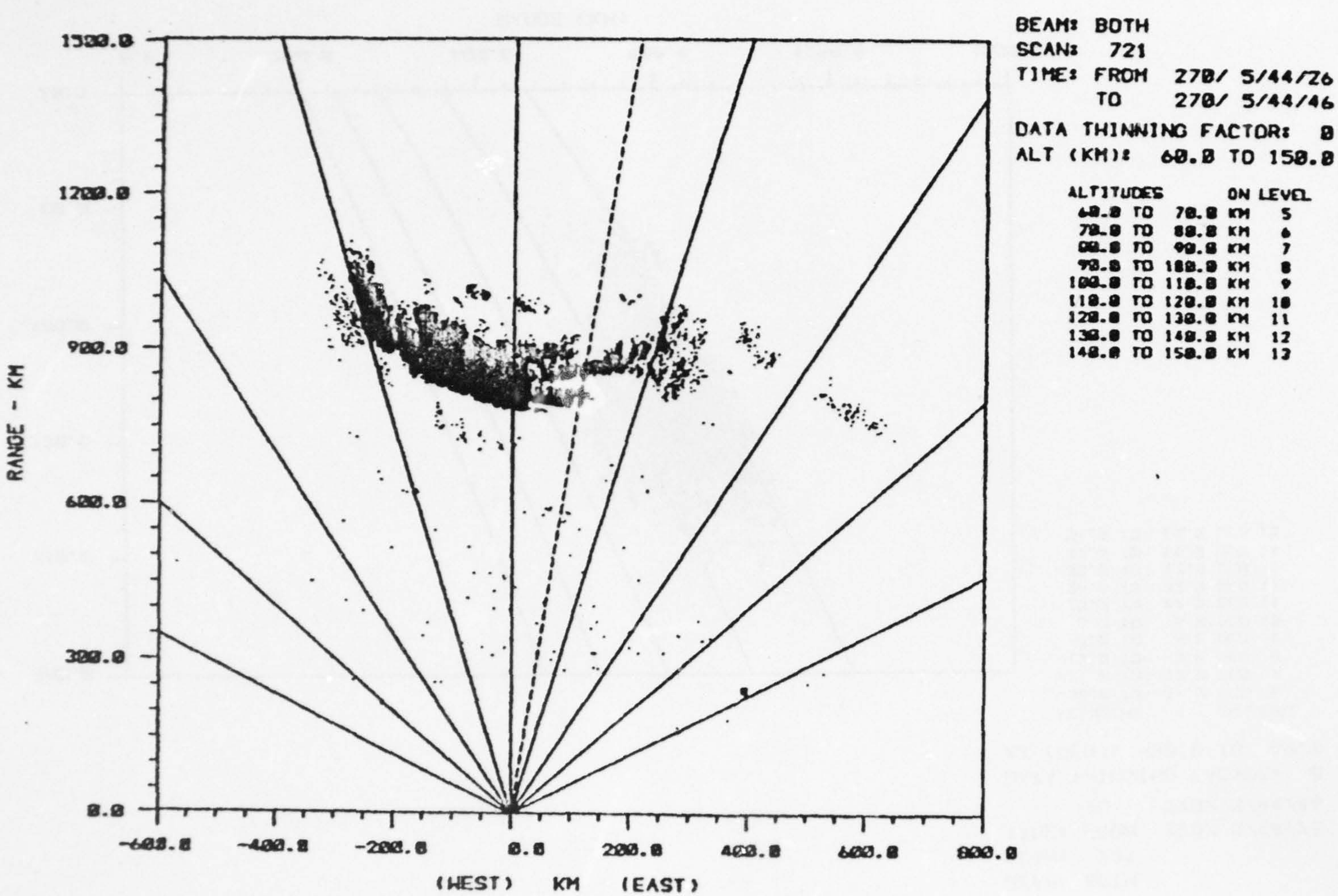

BEAM: BOTH
SCAN: 721
TIME: FROM 270/ 5/44/26
TO 270/ 5/44/46
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 60.0
AZIMUTHS ON LEVEL
-30.0 TO -21.0 DEG 6
-21.0 TO -12.0 DEG 7
-12.0 TO -3.0 DEG 8
-3.0 TO 6.0 DEG 9
6.0 TO 15.0 DEG 10
15.0 TO 24.0 DEG 11
24.0 TO 33.0 DEG 12
33.0 TO 42.0 DEG 13
42.0 TO 51.0 DEG 14
51.0 TO 60.0 DEG 15
160.0
140.0
120.0
100.0
80.0
60.0
ALTITUDE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

Figure 5-139



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-140

AD-A034 648 M AND S COMPUTING INC HUNTSVILLE ALA F/G 4/1
PAR AURORAL STUDY. VOLUME I.(U)
MAR 76 M J MITCHELL DASG60-74-C-0026
UNCLASSIFIED 76-0013 NL

3 OF 3
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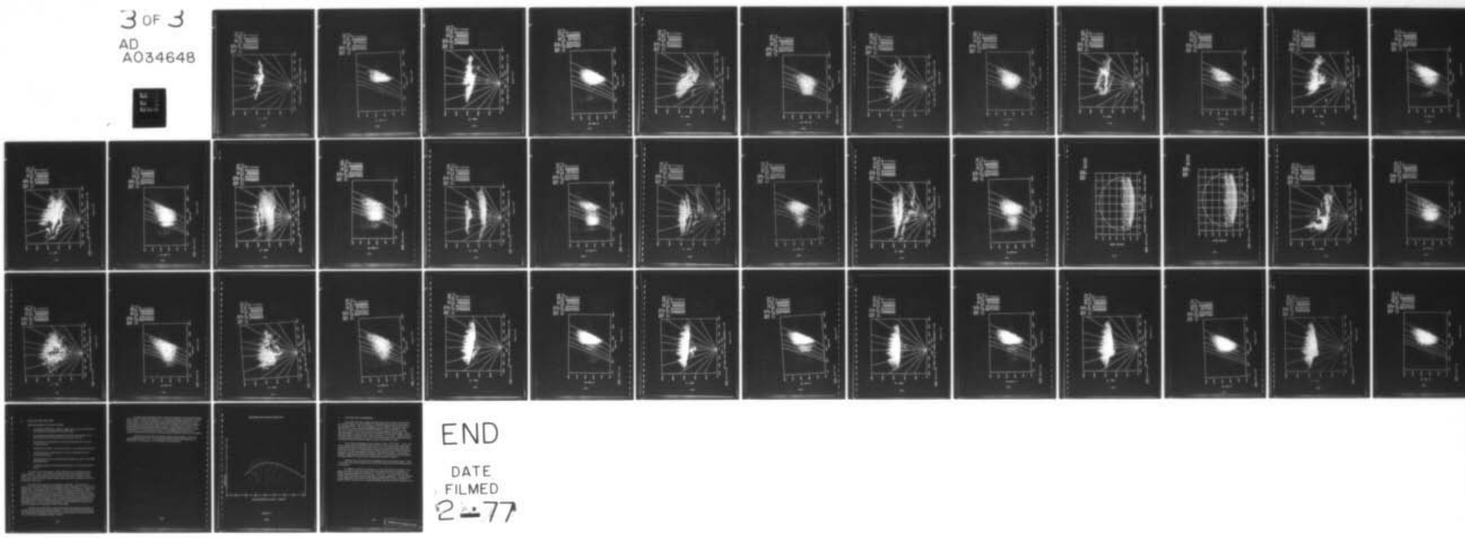
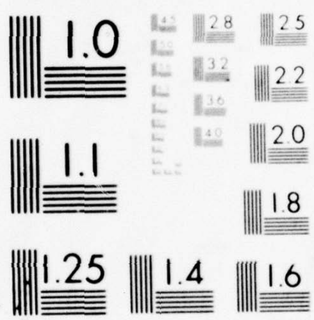
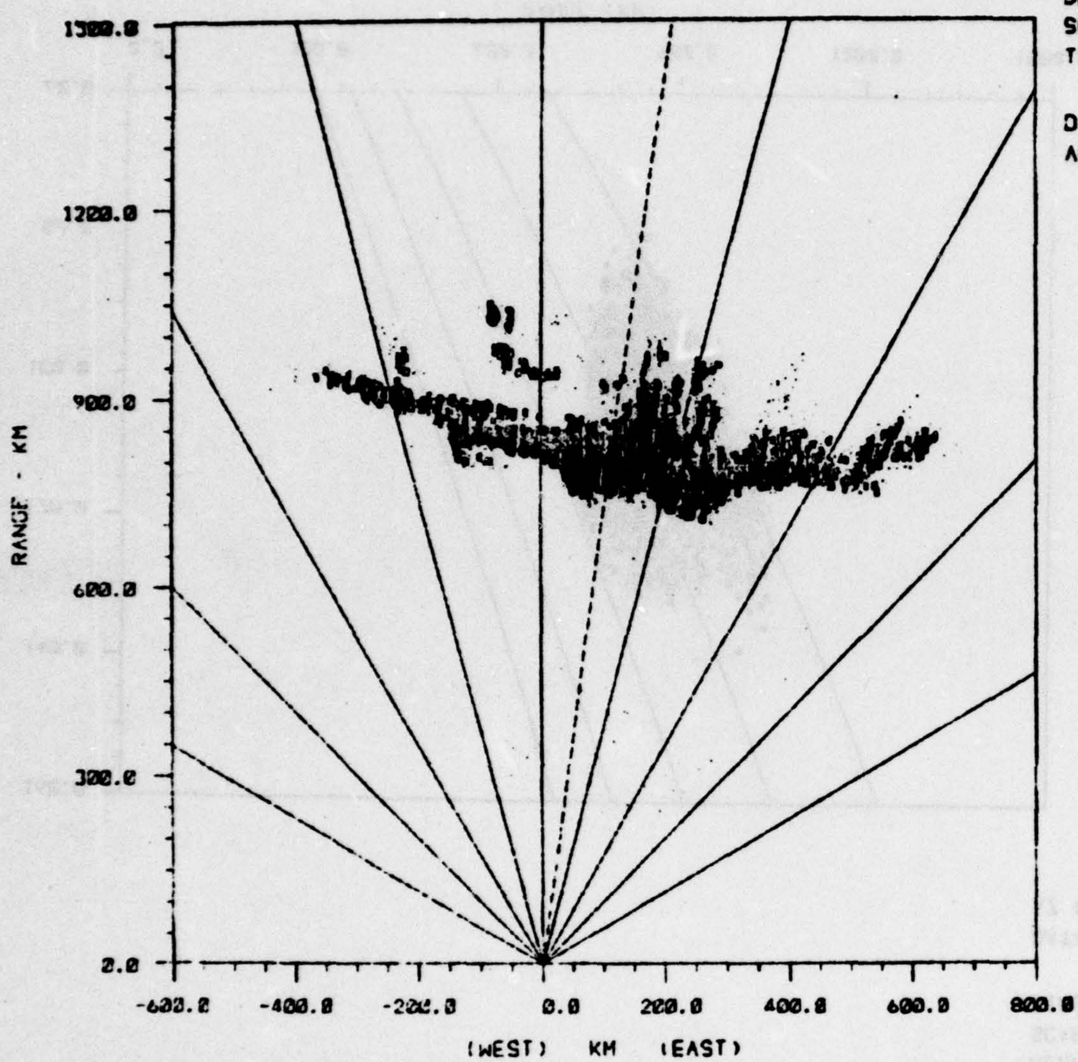
A034648



END
DATE
FILMED
2-77



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



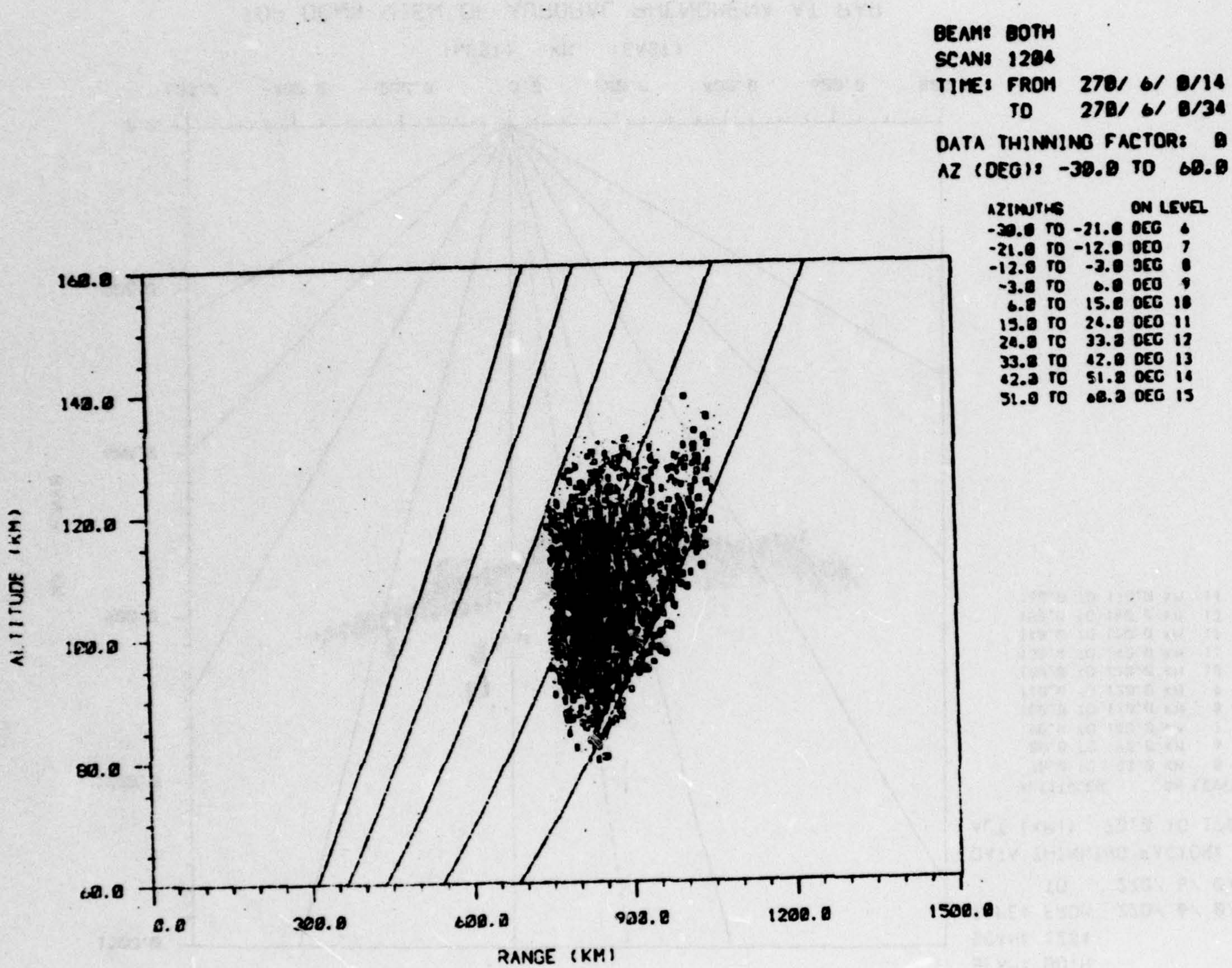
BEAM: BOTH
SCAN: 1204
TIME: FROM 270/ 6/ 0/14
TO 270/ 6/ 0/34

DATA THINNING FACTOR: 0
ALT (KM): 70.0 TO 170.0

ALTITUDES	ON LEVEL
70.0 TO 80.0 KM	5
80.0 TO 90.0 KM	6
90.0 TO 100.0 KM	7
100.0 TO 110.0 KM	8
110.0 TO 120.0 KM	9
120.0 TO 130.0 KM	10
130.0 TO 140.0 KM	11
140.0 TO 150.0 KM	12
150.0 TO 160.0 KM	13
160.0 TO 170.0 KM	14

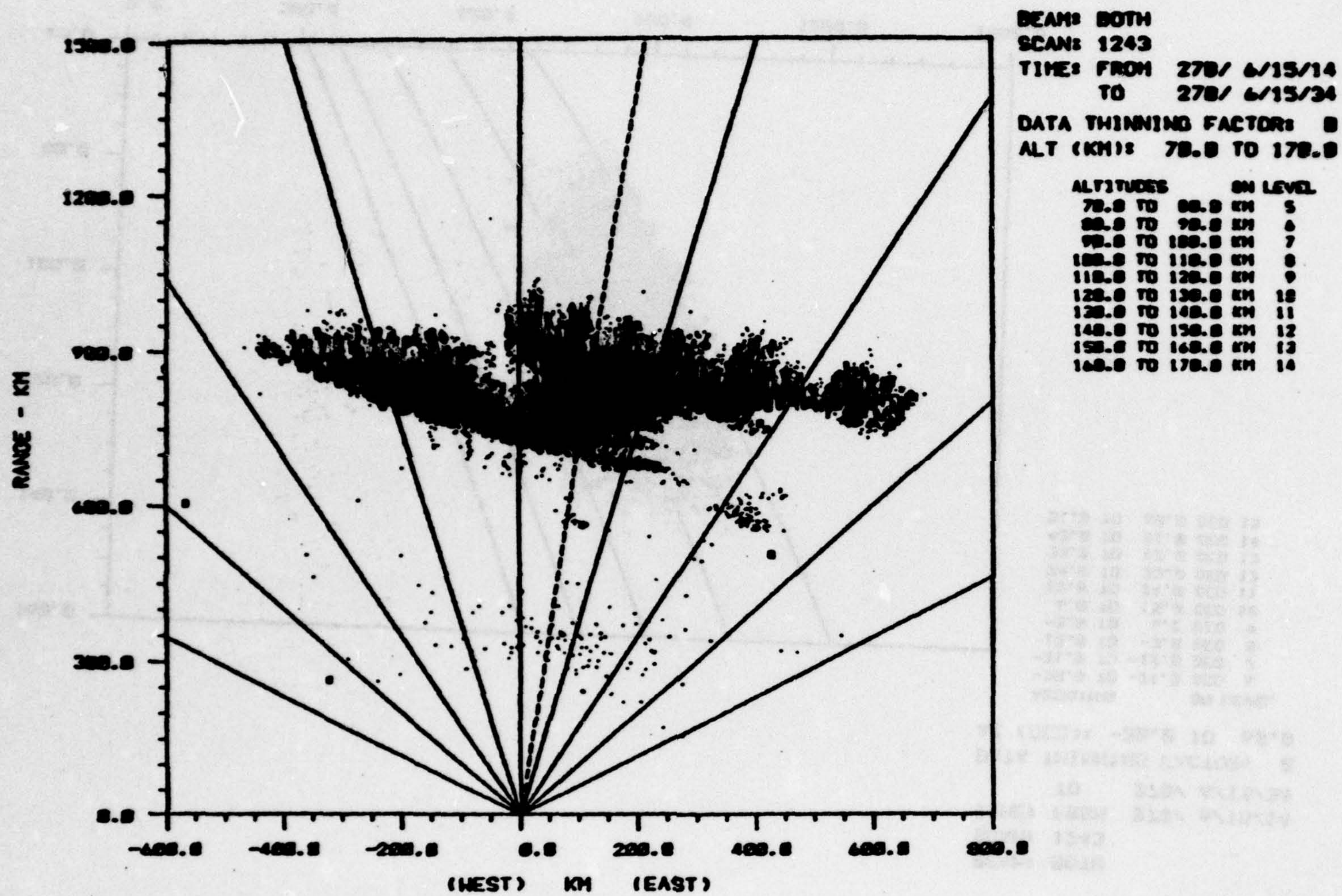
TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-141



BEAM: BOTH
SCAN: 1204
TIME: FROM 270/ 6/ 0/14
TO 270/ 6/ 0/34
DATA THINNING FACTOR: 0
AZ (DEG): -30.0 TO 60.0
AZIMUTHS ON LEVEL
-30.0 TO -21.0 DEG 6
-21.0 TO -12.0 DEG 7
-12.0 TO -3.0 DEG 8
-3.0 TO 6.0 DEG 9
6.0 TO 15.0 DEG 10
15.0 TO 24.0 DEG 11
24.0 TO 33.0 DEG 12
33.0 TO 42.0 DEG 13
42.0 TO 51.0 DEG 14
51.0 TO 60.0 DEG 15
ALTITUDE (KM)
160.0
140.0
120.0
100.0
80.0
60.0
RANGE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0

Figure 5-142



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-143

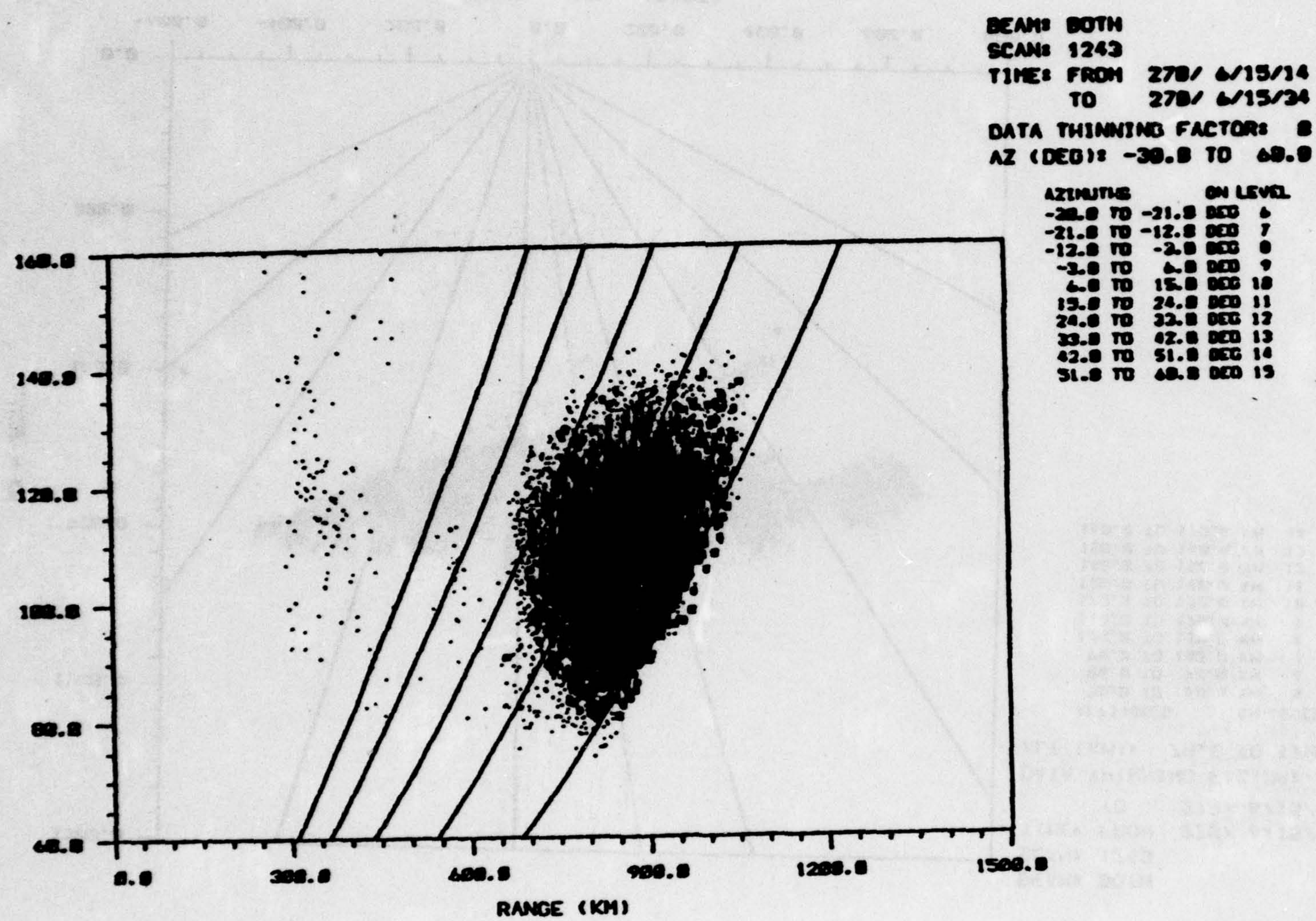
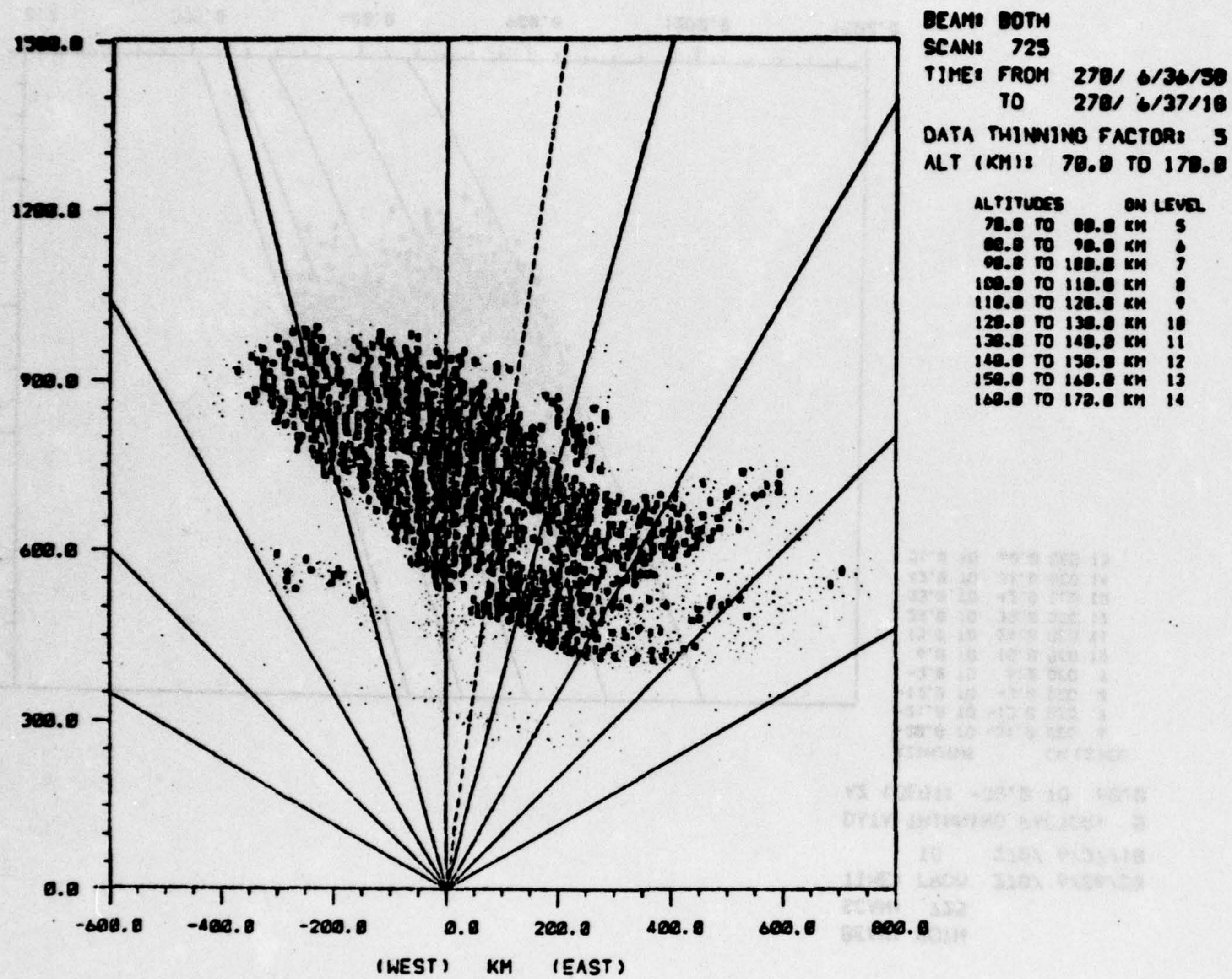

BEAM: BOTH
SCAN: 1243
TIME: FROM 278/ 6/15/14
TO 278/ 6/15/34
DATA THINNING FACTOR: 8
AZ (DEG): -30.0 TO 60.0
AZIMUTHS ON LEVEL
-30.0 TO -21.0 DEG 6
-21.0 TO -12.0 DEG 7
-12.0 TO -3.0 DEG 8
-3.0 TO 6.0 DEG 9
6.0 TO 15.0 DEG 10
15.0 TO 24.0 DEG 11
24.0 TO 33.0 DEG 12
33.0 TO 42.0 DEG 13
42.0 TO 51.0 DEG 14
51.0 TO 60.0 DEG 15
160.0
140.0
120.0
100.0
80.0
60.0
ALTITUDE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

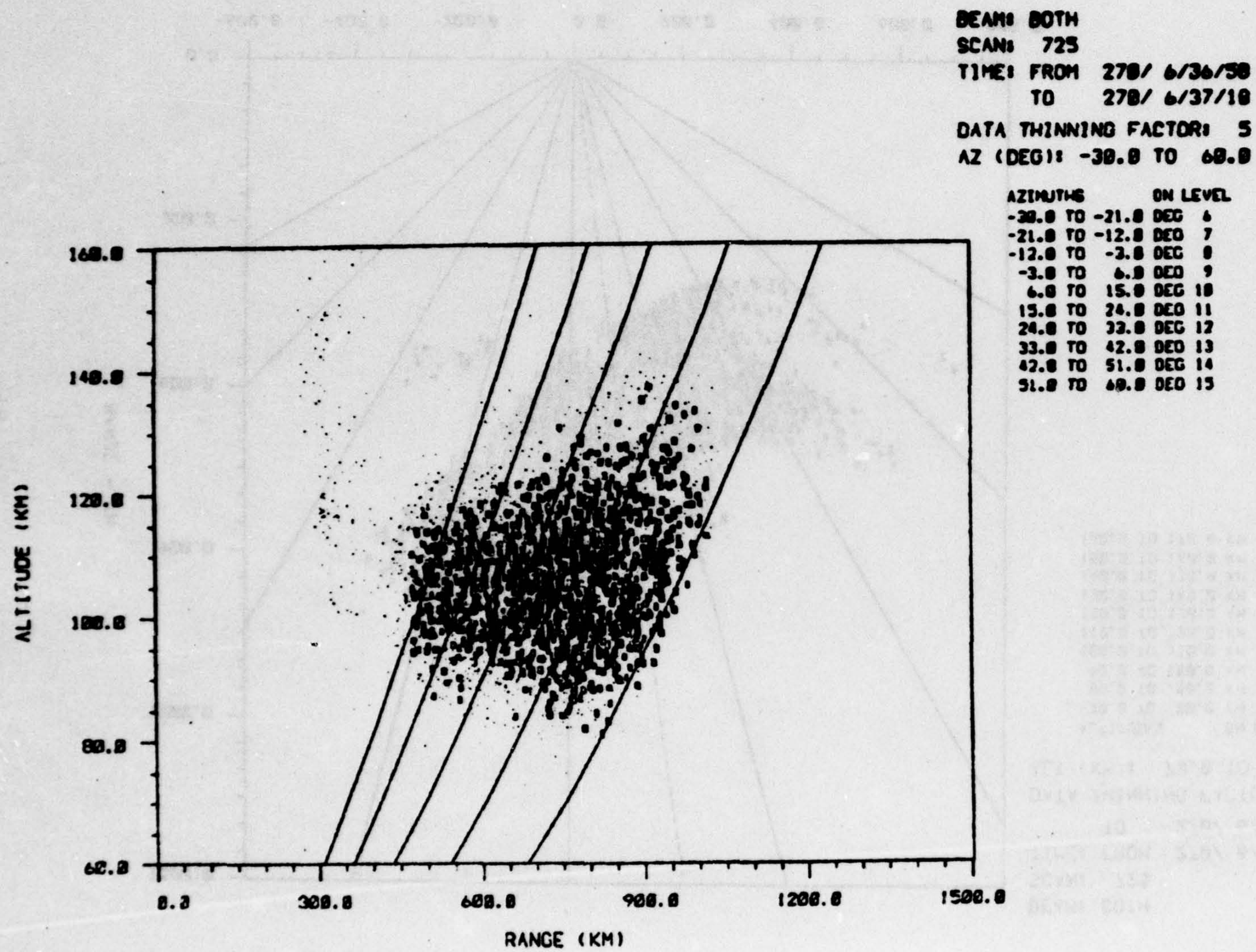
Figure 5-144



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

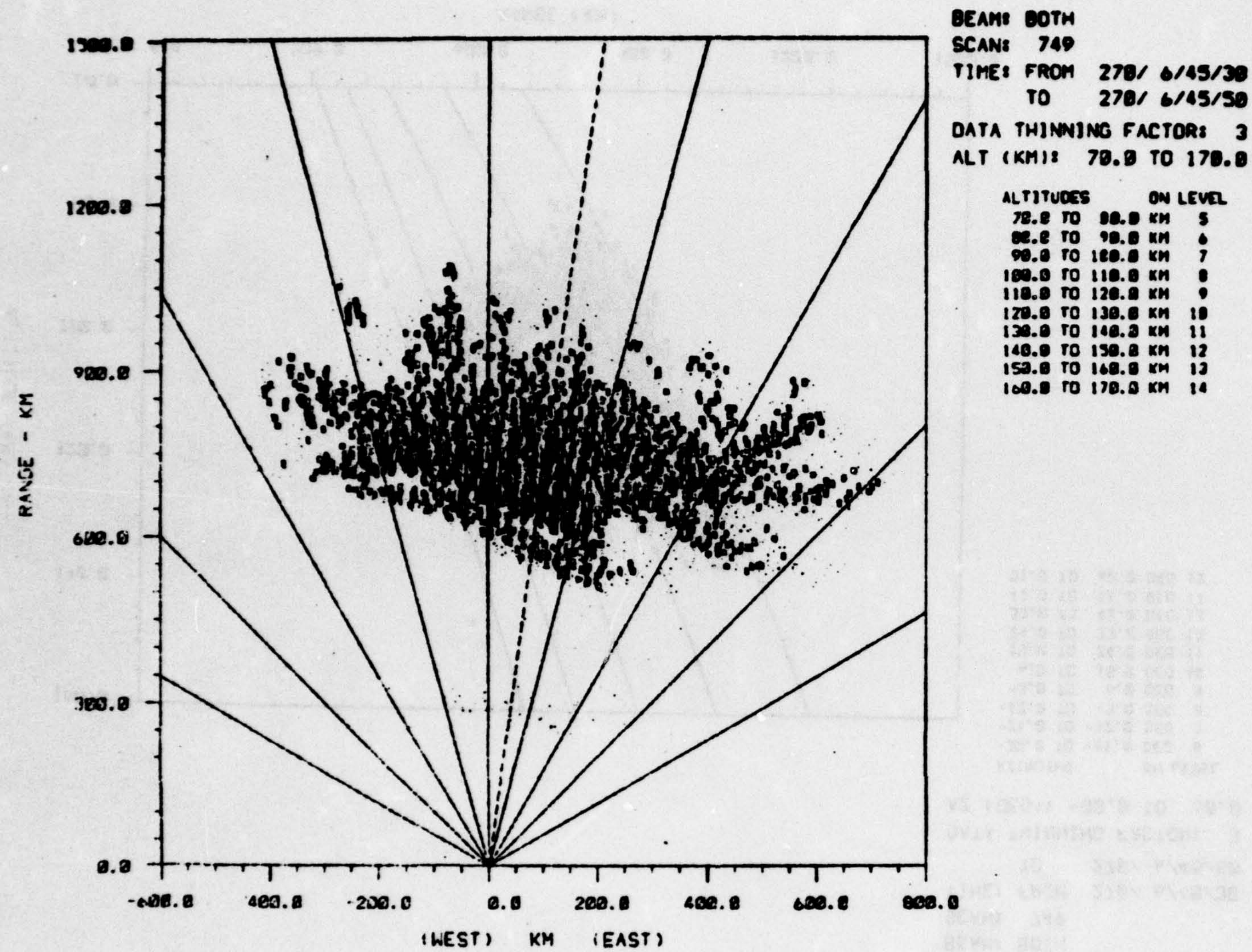
M&S OMPUTING

Figure 5-145



M&S COMPUTING

Figure 5-146



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-147

BEAM: BOTH
SCAN: 749
TIME: FROM 270/ 6/45/30
TO 270/ 6/45/50
DATA THINNING FACTOR: 3
AZ (DEG): -30.0 TO 60.0

AZIMUTHS	ON LEVEL
-30.0 TO -21.0 DEG	6
-21.0 TO -12.0 DEG	7
-12.0 TO -3.0 DEG	8
-3.0 TO 6.0 DEG	9
6.0 TO 15.0 DEG	10
15.0 TO 24.0 DEG	11
24.0 TO 33.0 DEG	12
33.0 TO 42.0 DEG	13
42.0 TO 51.0 DEG	14
51.0 TO 60.0 DEG	15

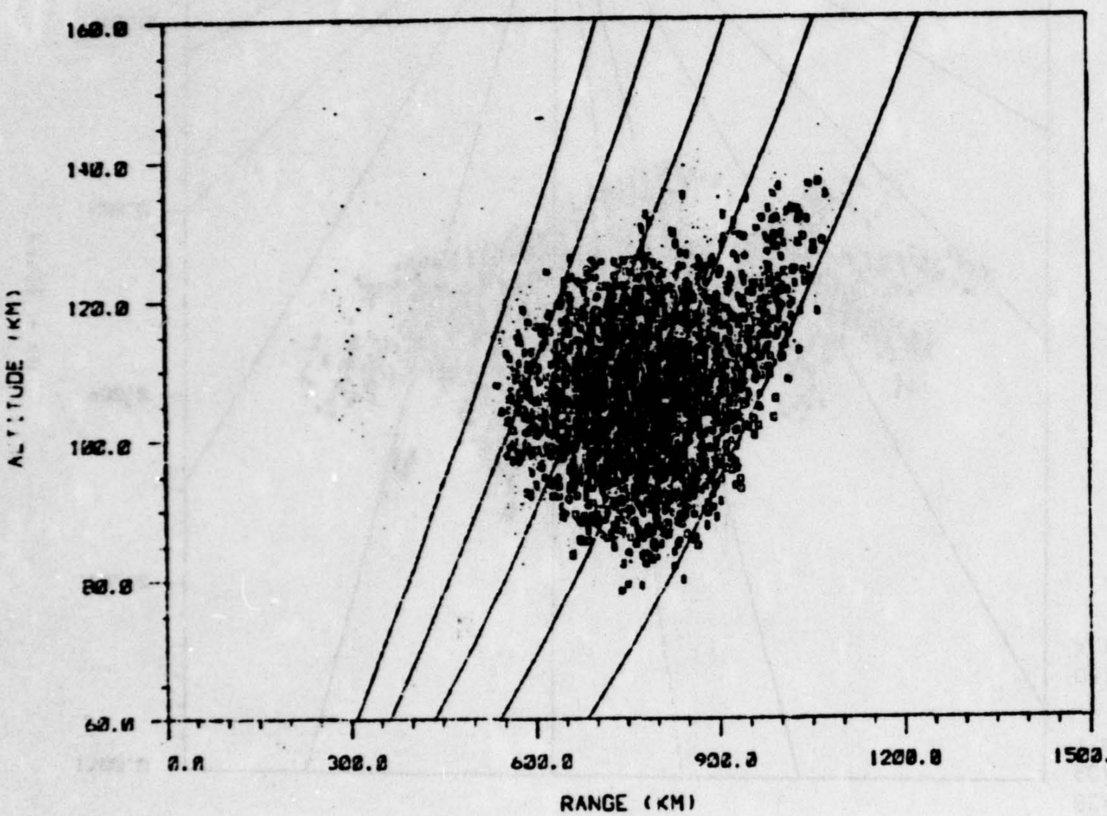
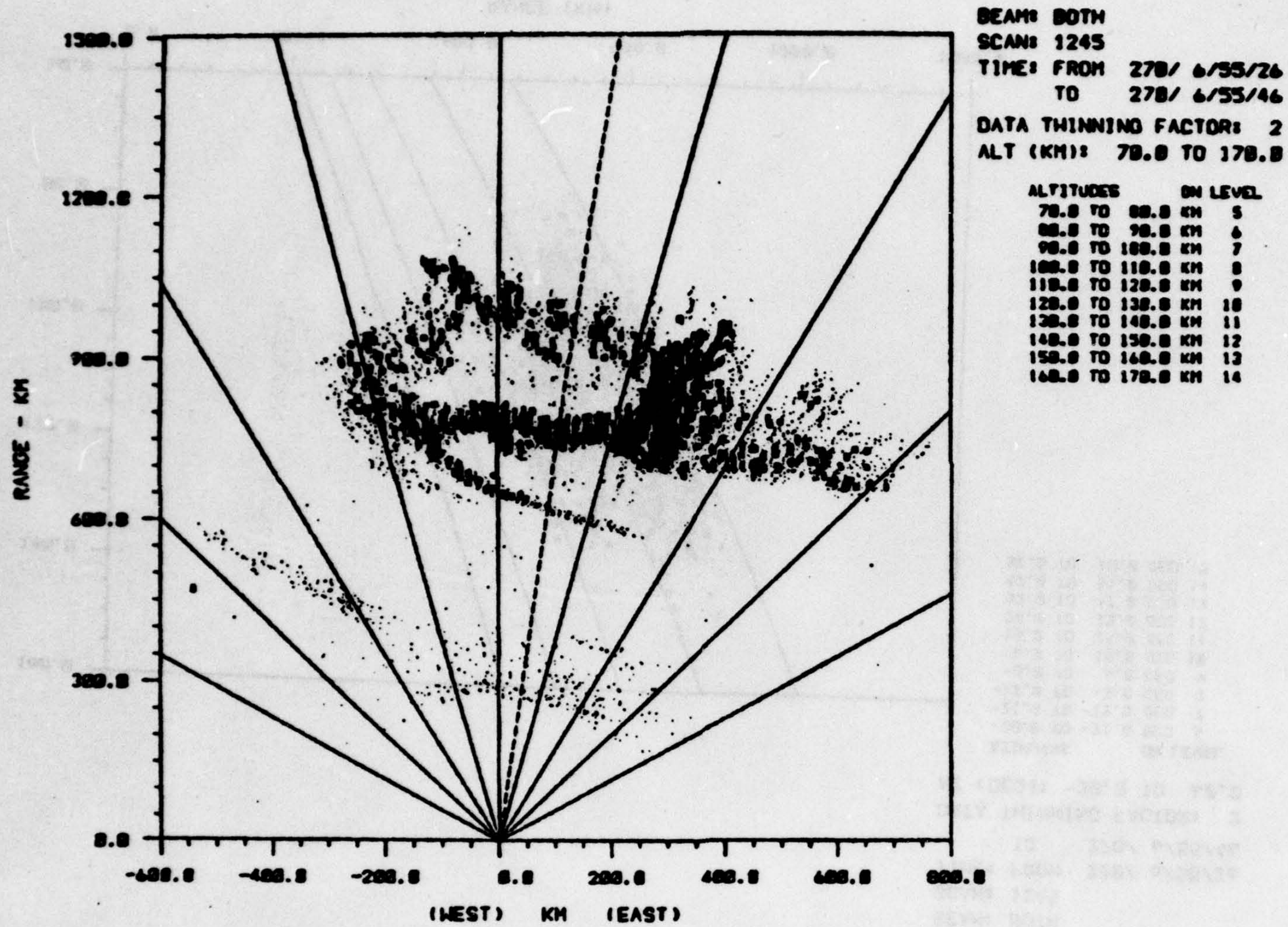


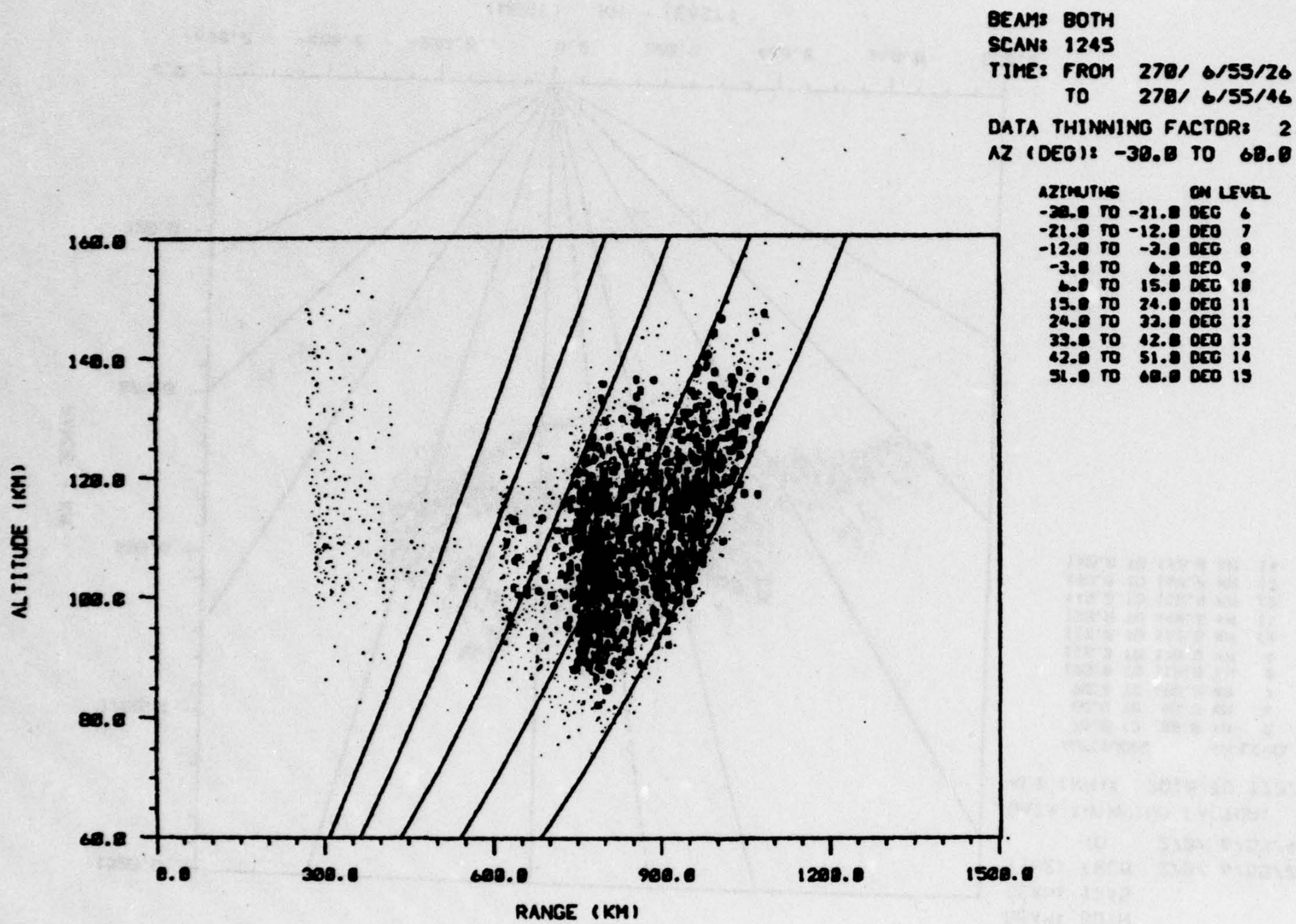
Figure 5-148



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

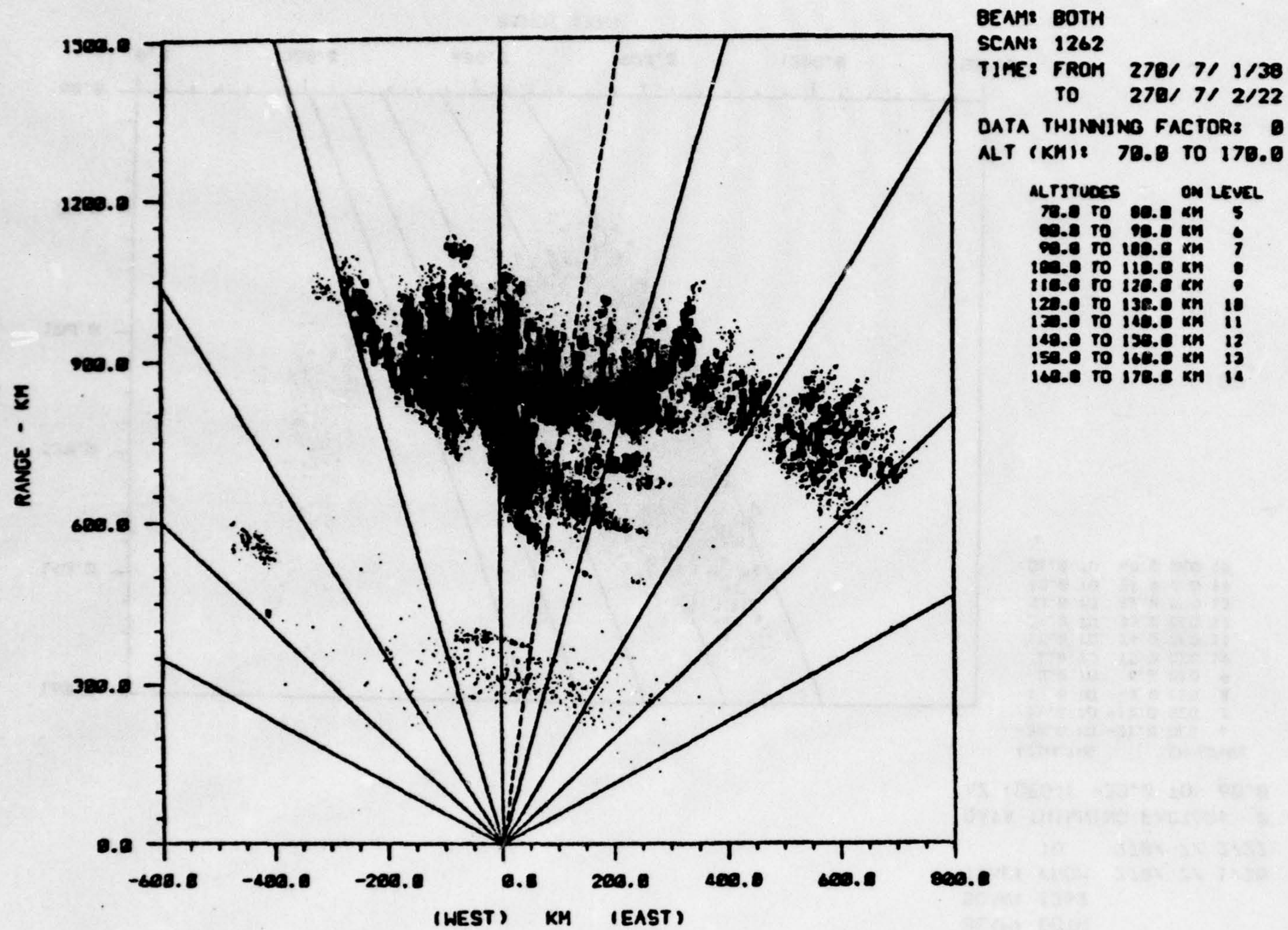
M&S OMPUTING

Figure 5-149



M&S OMPUTING

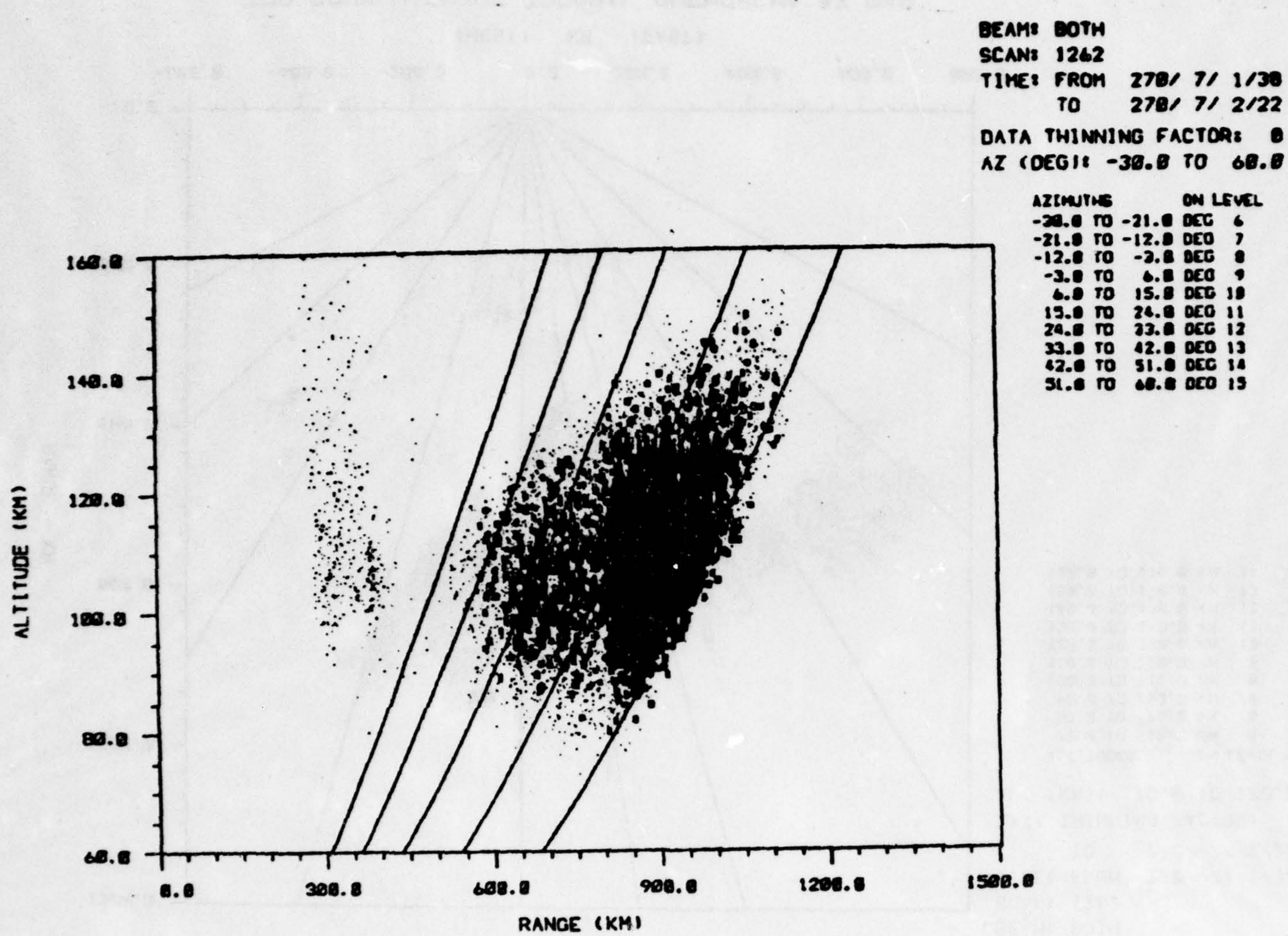
Figure 5-150



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

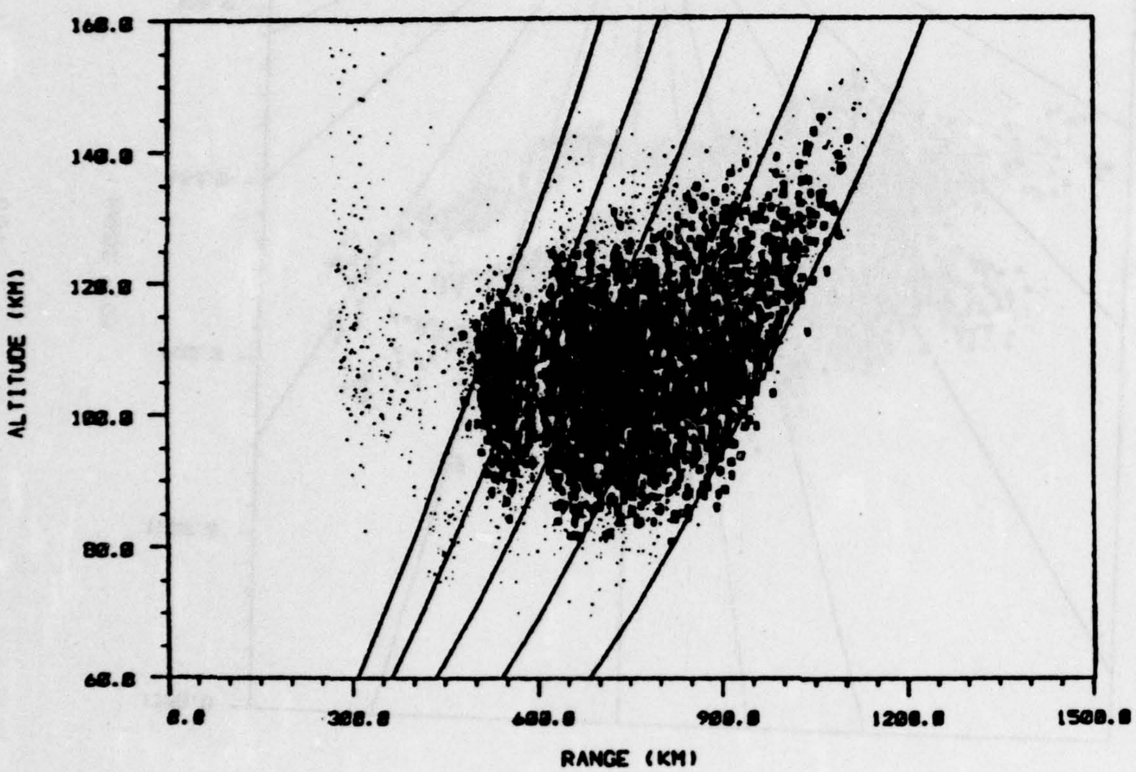
M&S OMPUTING

Figure 5-151



M&S OMPUTING

Figure 5-152



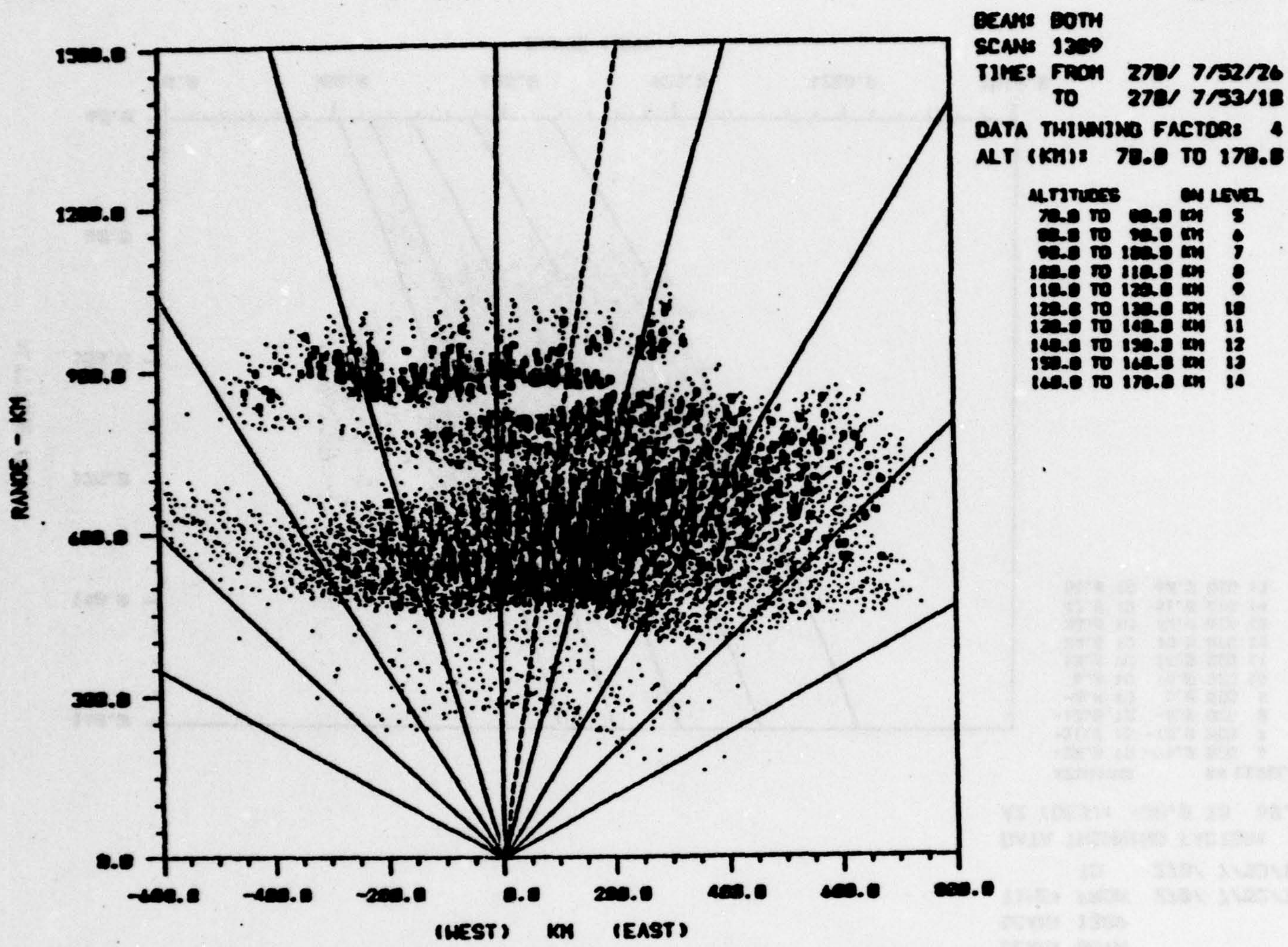
BEAM: BOTH
SCAN: 1280
TIME: FROM 278/ 7/13/16
TO 278/ 7/13/36

DATA THINNING FACTOR: 4
AZ (DEG): -30.0 TO 60.0

AZIMUTHS				ON LEVEL
-30.0	TO	-21.0	DEG	6
-21.0	TO	-12.0	DEG	7
-12.0	TO	-3.0	DEG	8
-3.0	TO	6.0	DEG	9
6.0	TO	15.0	DEG	10
15.0	TO	24.0	DEG	11
24.0	TO	33.0	DEG	12
33.0	TO	42.0	DEG	13
42.0	TO	51.0	DEG	14
51.0	TO	60.0	DEG	15

M&S OMPUTING

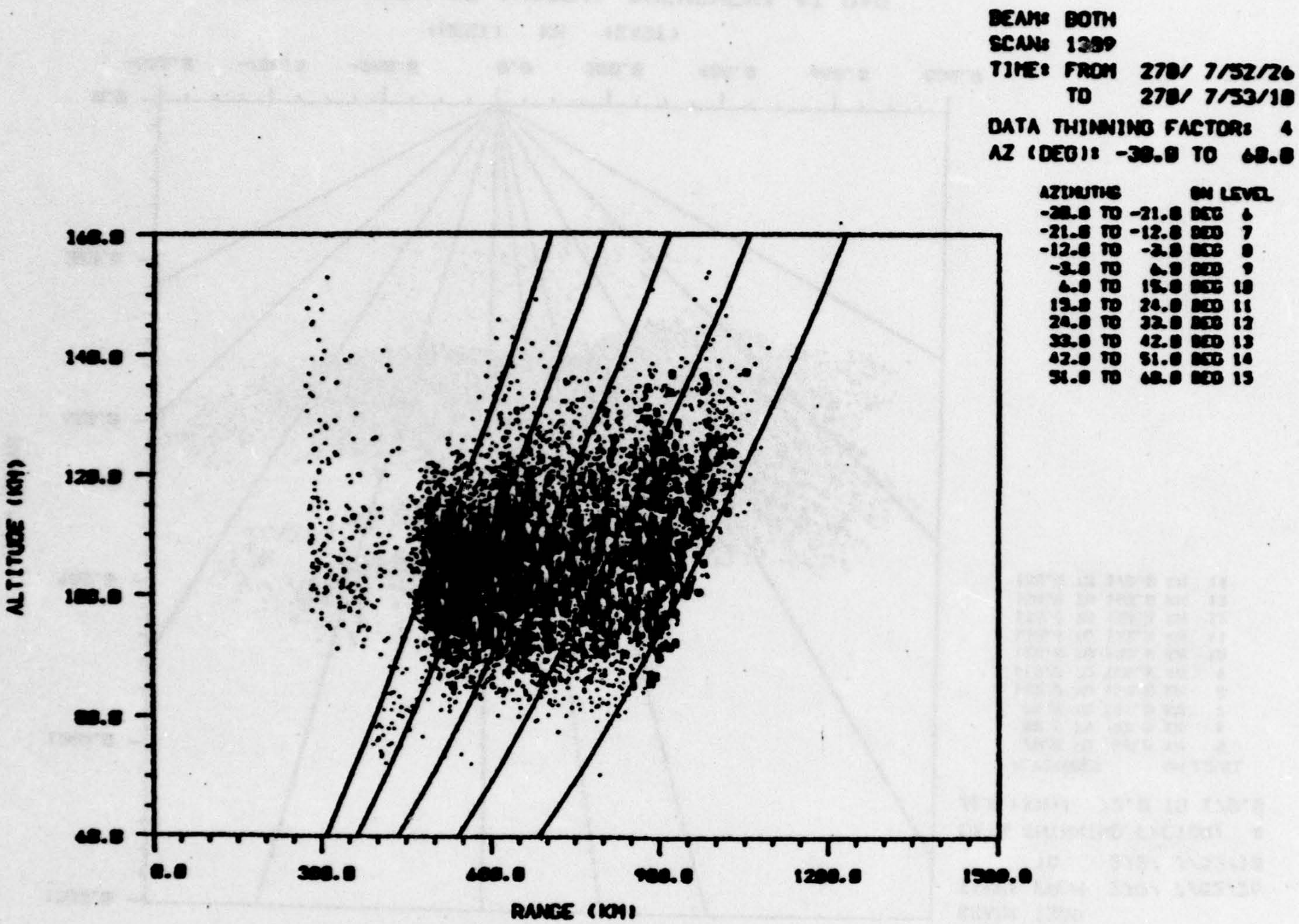
Figure 5-154



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

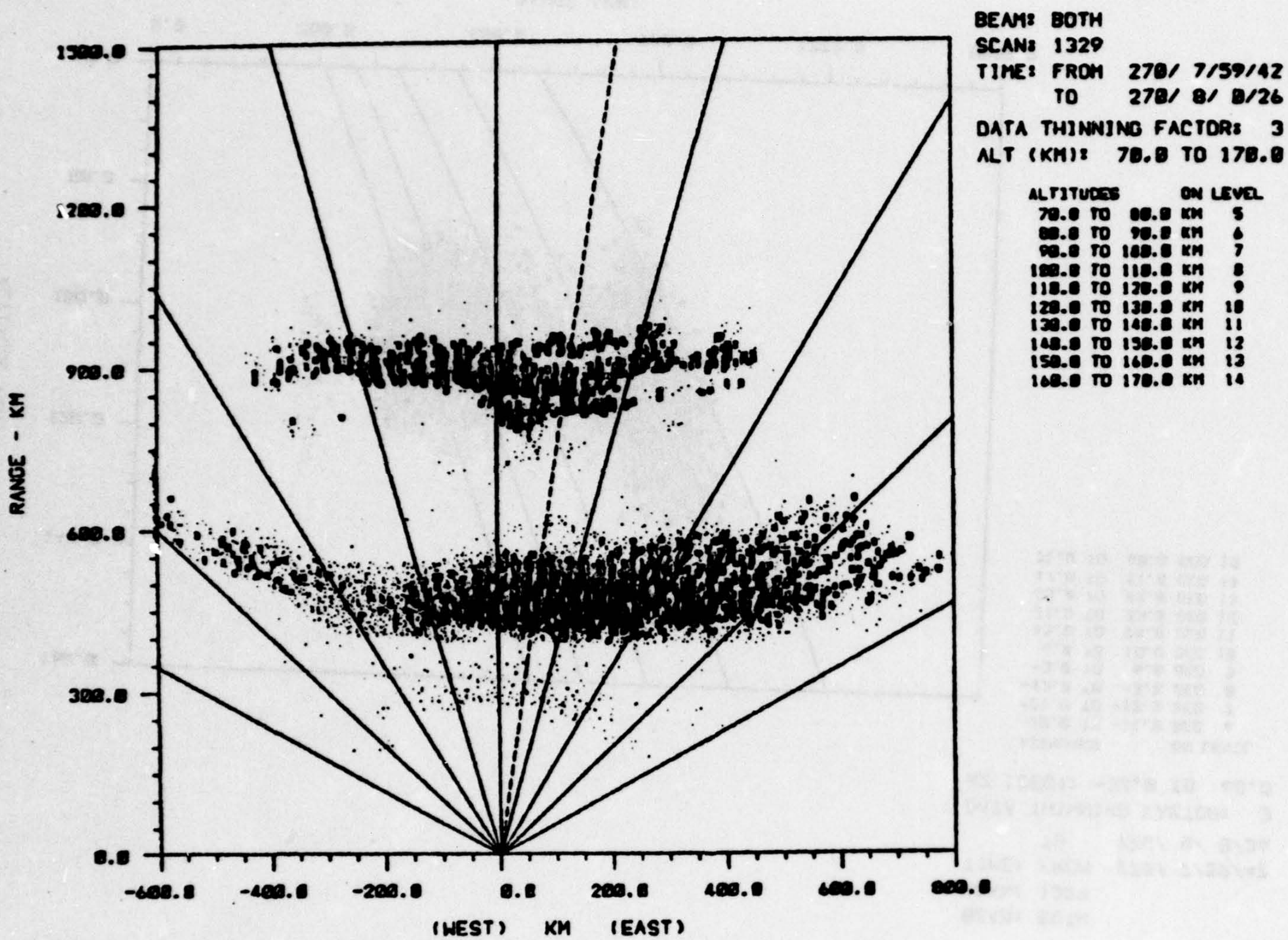
M&S OMPUTINO

Figure 5-155



M&S COMPUTING

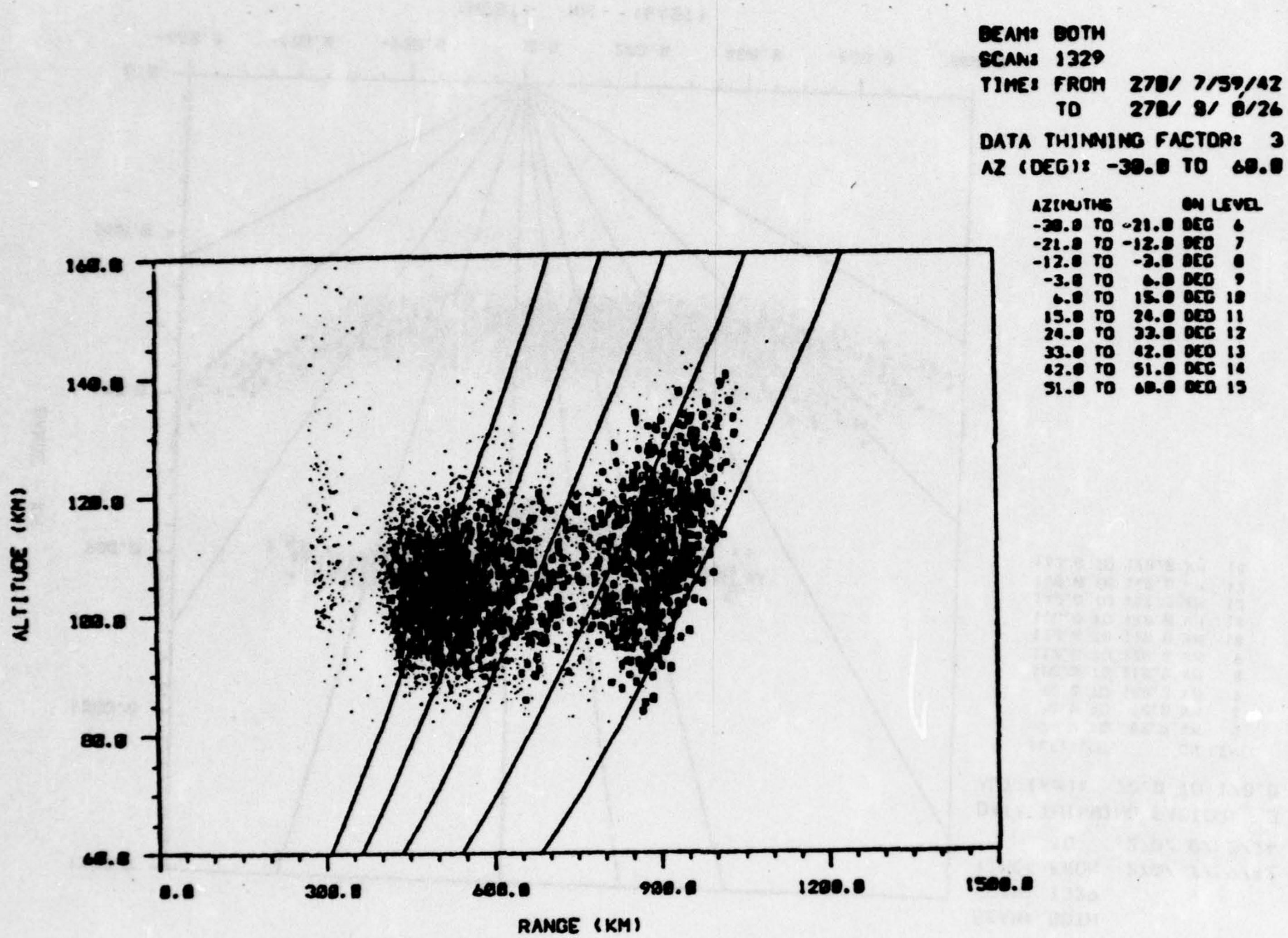
Figure 5-156



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

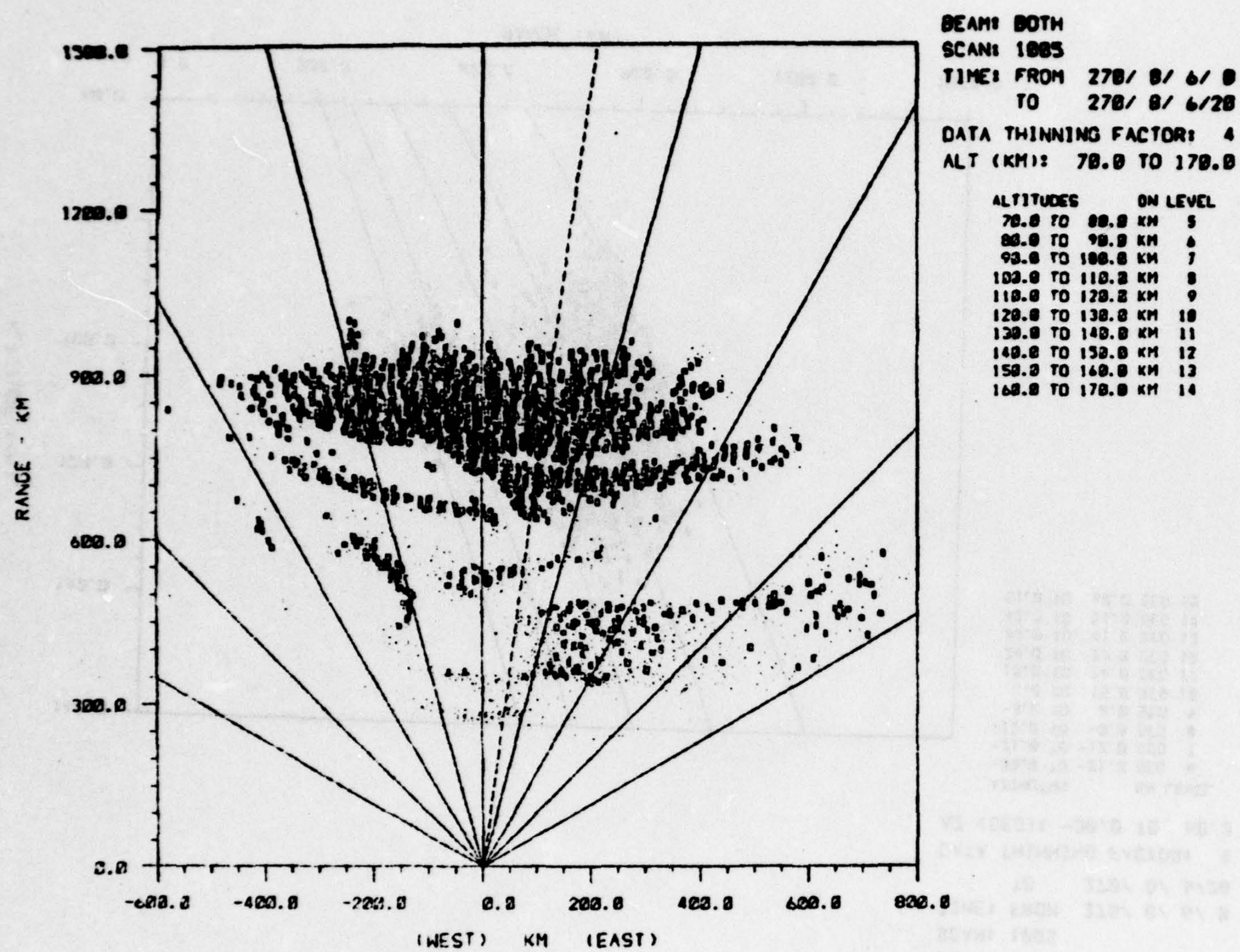
M&S OMPUTINO

Figure 5-157



M&S OMPUTINO

Figure 5-158



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-159

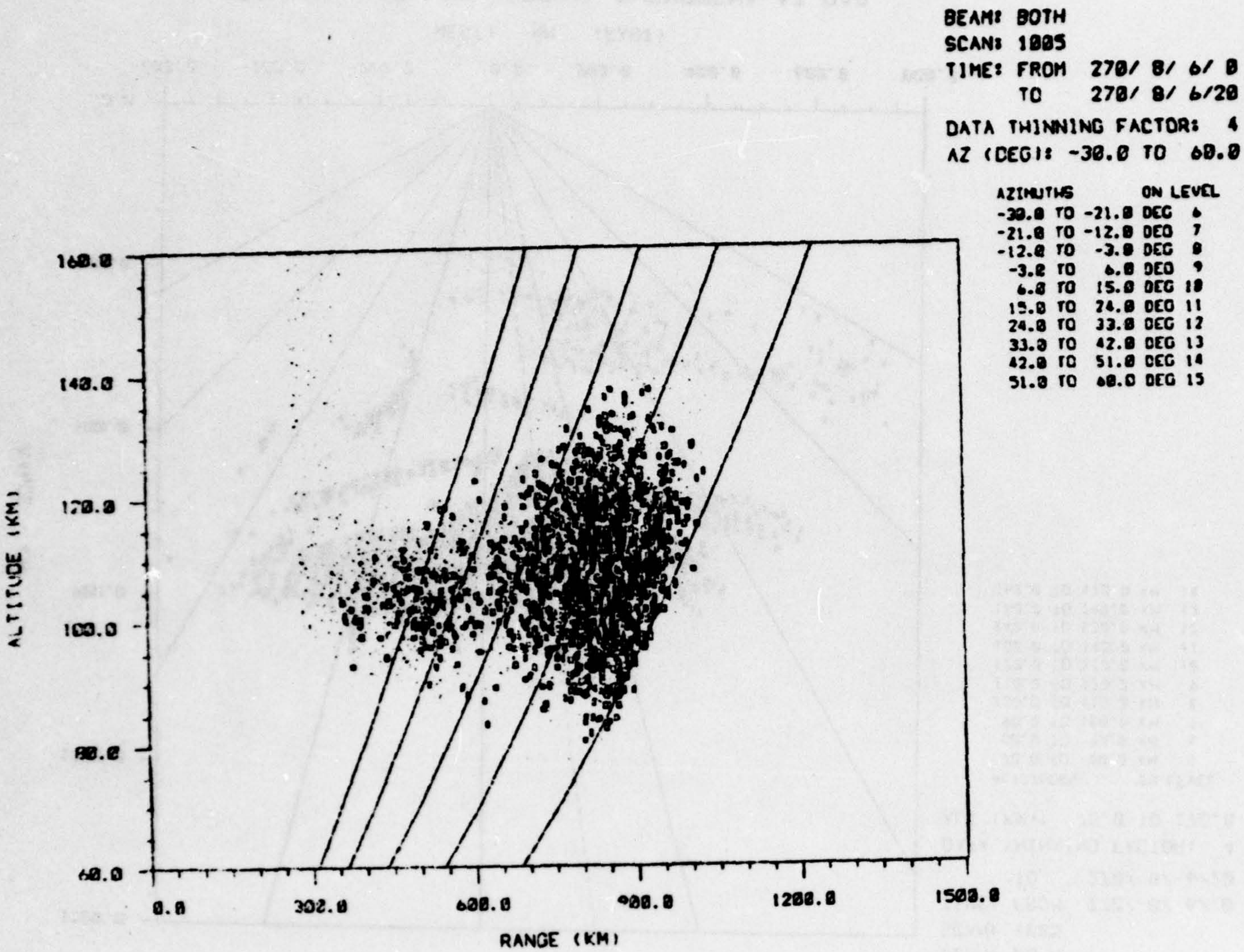

BEAM: BOTH
SCAN: 1005
TIME: FROM 270/ 8/ 6/ 0
TO 270/ 8/ 6/20
DATA THINNING FACTOR: 4
AZ (DEG): -30.0 TO 60.0
AZIMUTHS ON LEVEL
-30.0 TO -21.0 DEG 6
-21.0 TO -12.0 DEG 7
-12.0 TO -3.0 DEG 8
-3.0 TO 6.0 DEG 9
6.0 TO 15.0 DEG 10
15.0 TO 24.0 DEG 11
24.0 TO 33.0 DEG 12
33.0 TO 42.0 DEG 13
42.0 TO 51.0 DEG 14
51.0 TO 60.0 DEG 15
ALTITUDE (KM)
160.0
140.0
100.0
80.0
60.0
RANGE (KM)
0.0
300.0
600.0
900.0
1200.0
1500.0

Figure 5-160

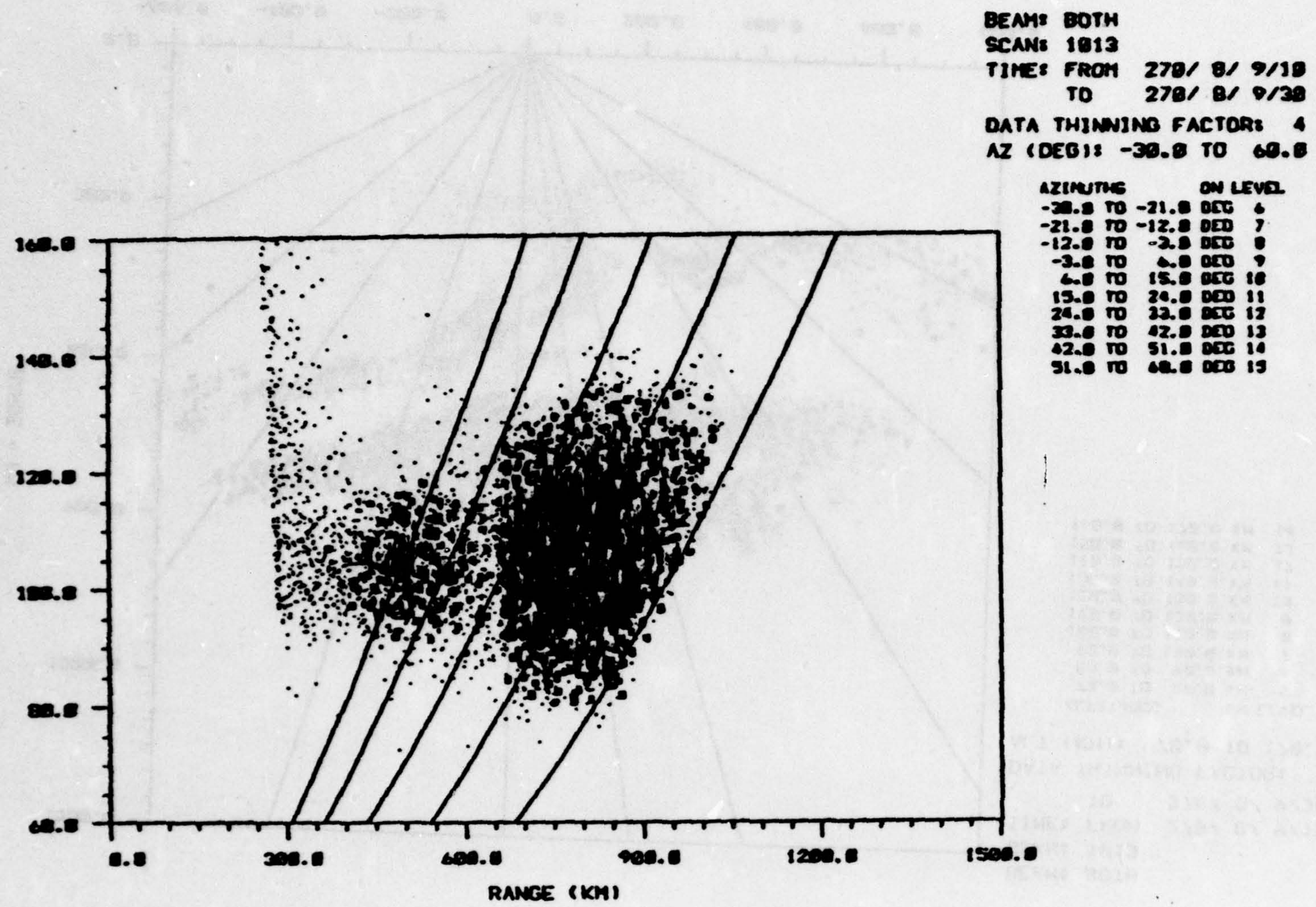
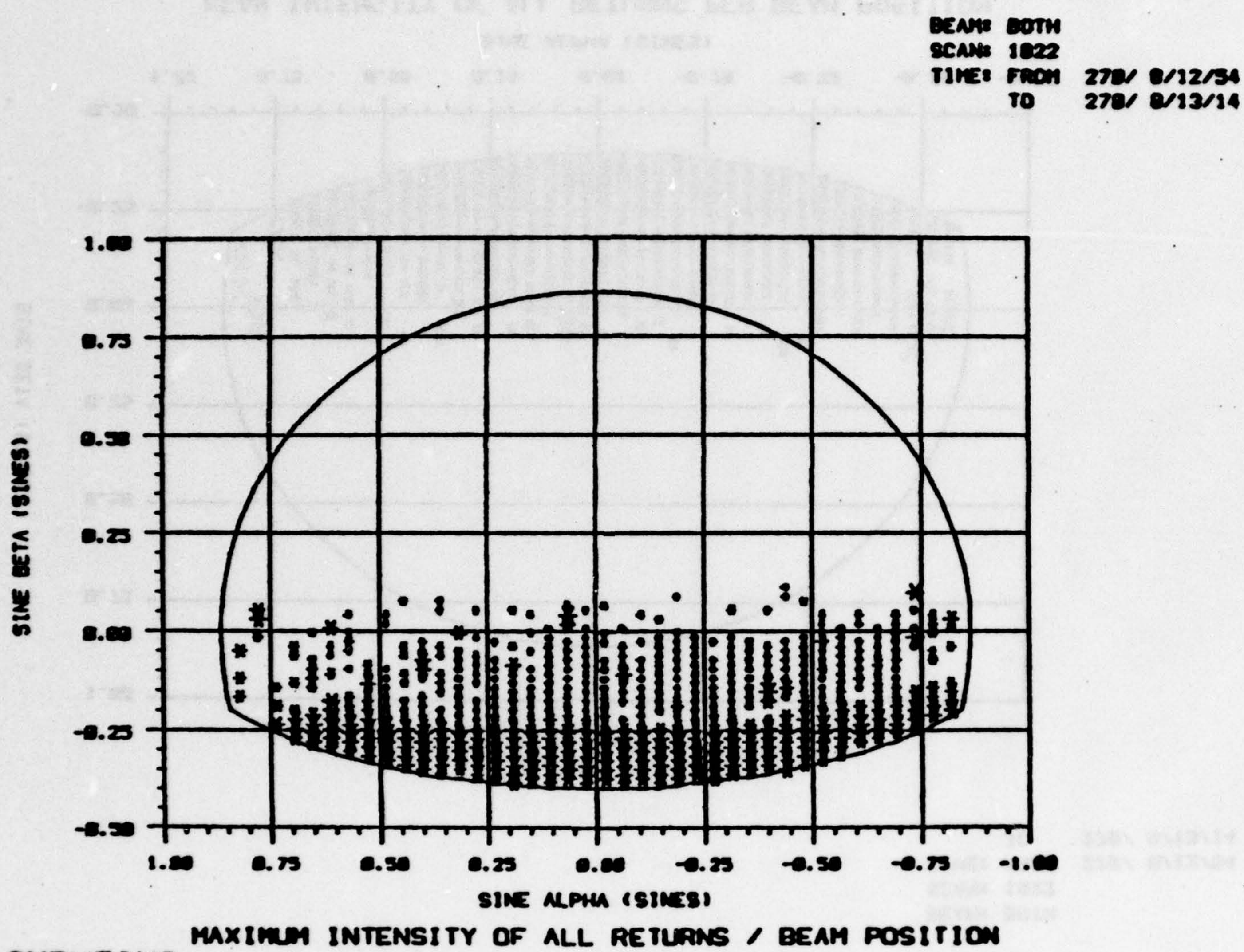
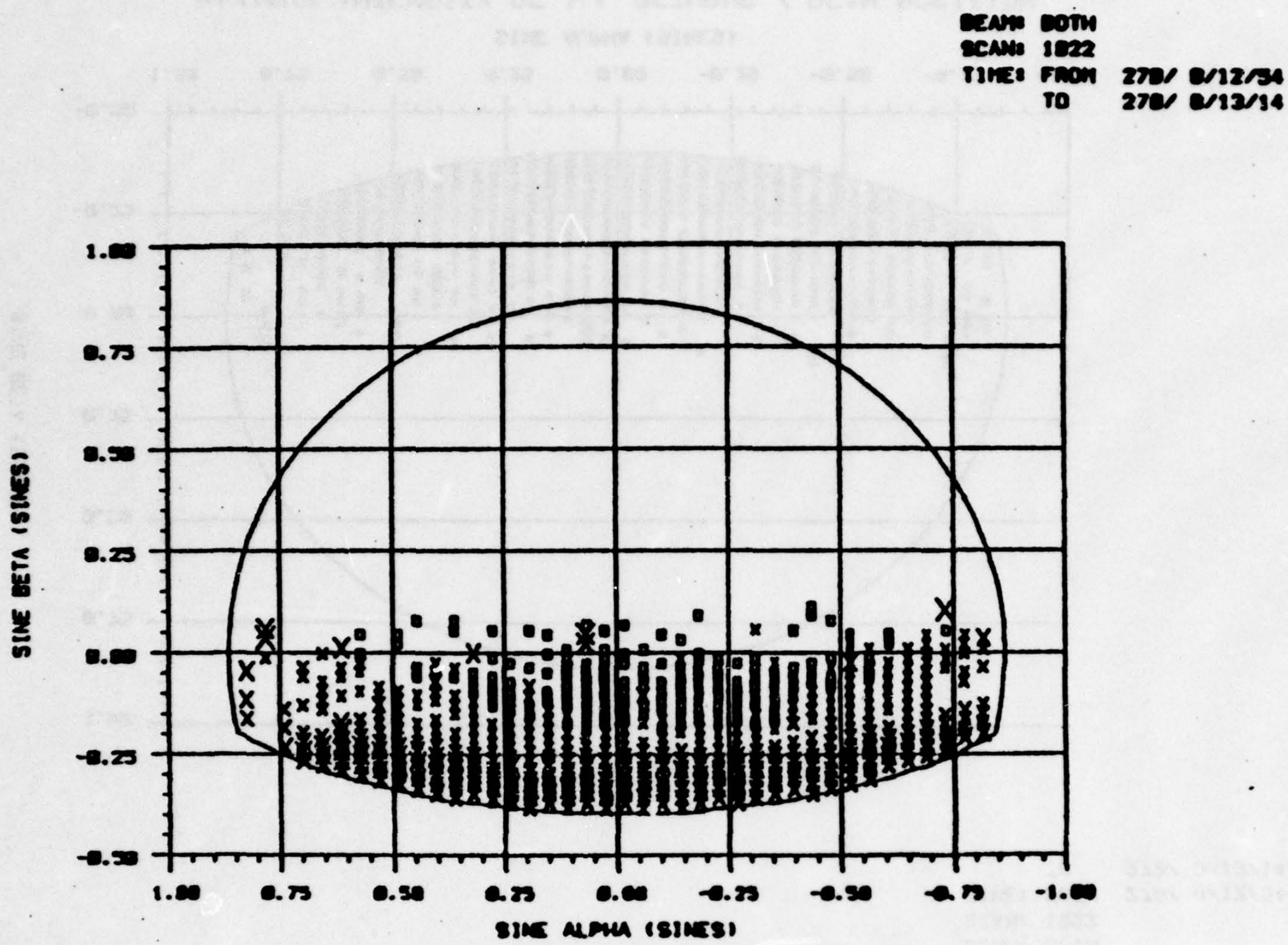

BEAM: BOTH
SCAN: 1013
TIME: FROM 270/ 8/ 9/10
TO 270/ 8/ 9/30
DATA THINNING FACTOR: 4
AZ (DEG): -30.0 TO 60.0
AZIMUTHS ON LEVEL
-30.0 TO -21.0 DEG 6
-21.0 TO -12.0 DEG 7
-12.0 TO -3.0 DEG 8
-3.0 TO 6.0 DEG 9
6.0 TO 15.0 DEG 10
15.0 TO 24.0 DEG 11
24.0 TO 33.0 DEG 12
33.0 TO 42.0 DEG 13
42.0 TO 51.0 DEG 14
51.0 TO 60.0 DEG 15
ALTITUDE (KM)
RANGE (KM)
160.0
140.0
120.0
100.0
80.0
60.0
0.0
300.0
600.0
900.0
1200.0
1500.0

Figure 5-162



MRS COMPUTING

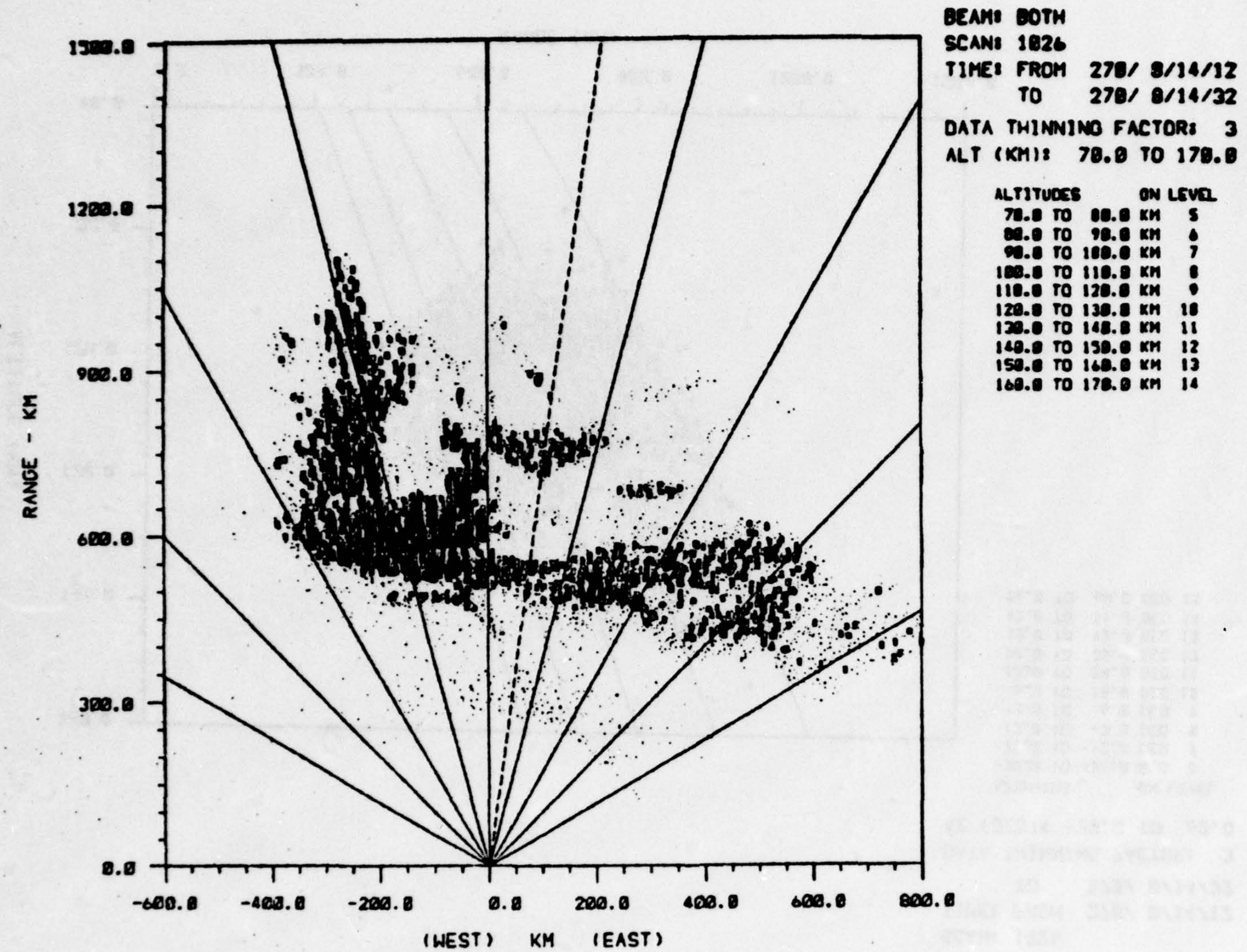
Figure 5-163



MEAN INTENSITY OF ALL RETURNS PER BEAM POSITION

M&S COMPUTING

Figure 5-164



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

Figure 5-165

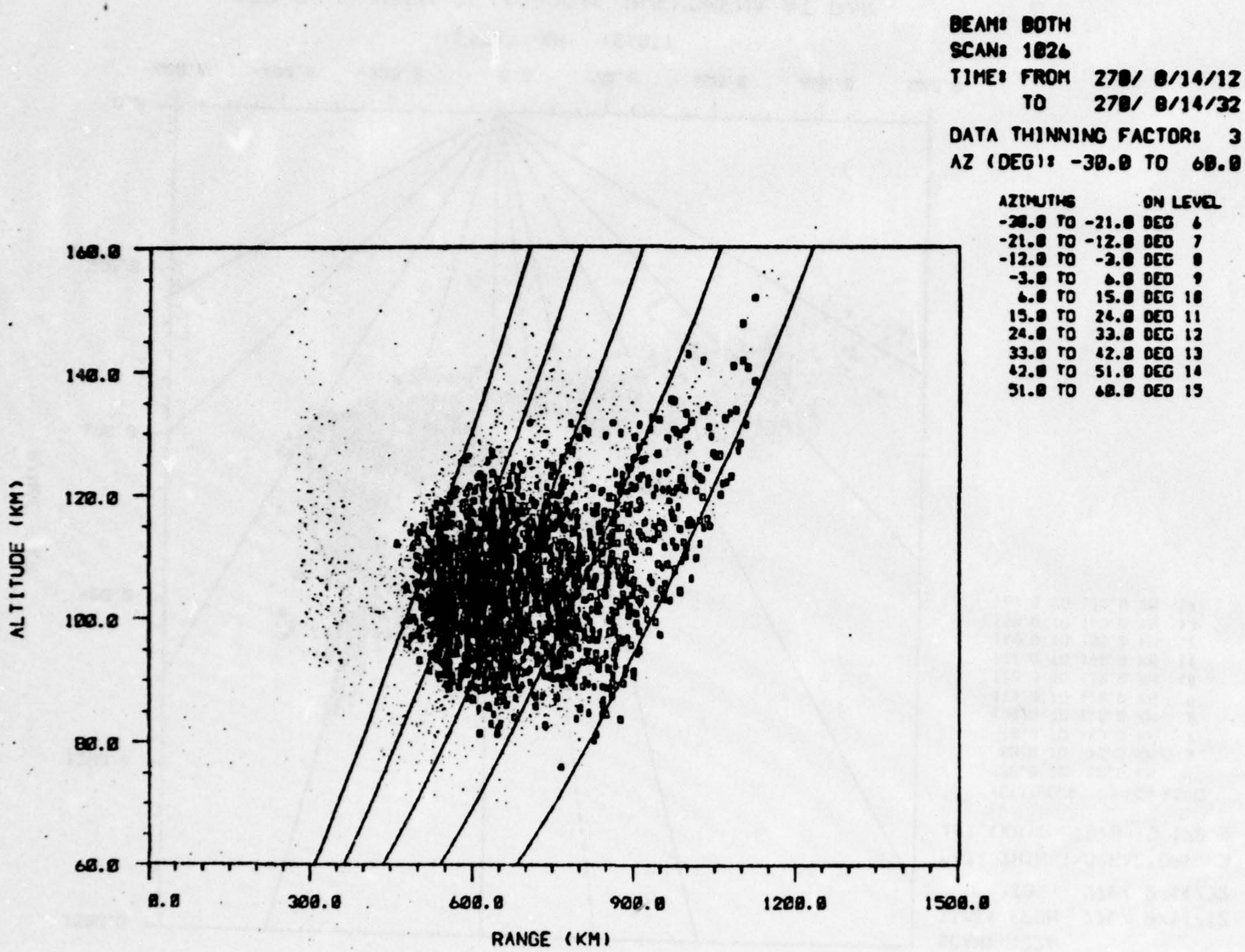
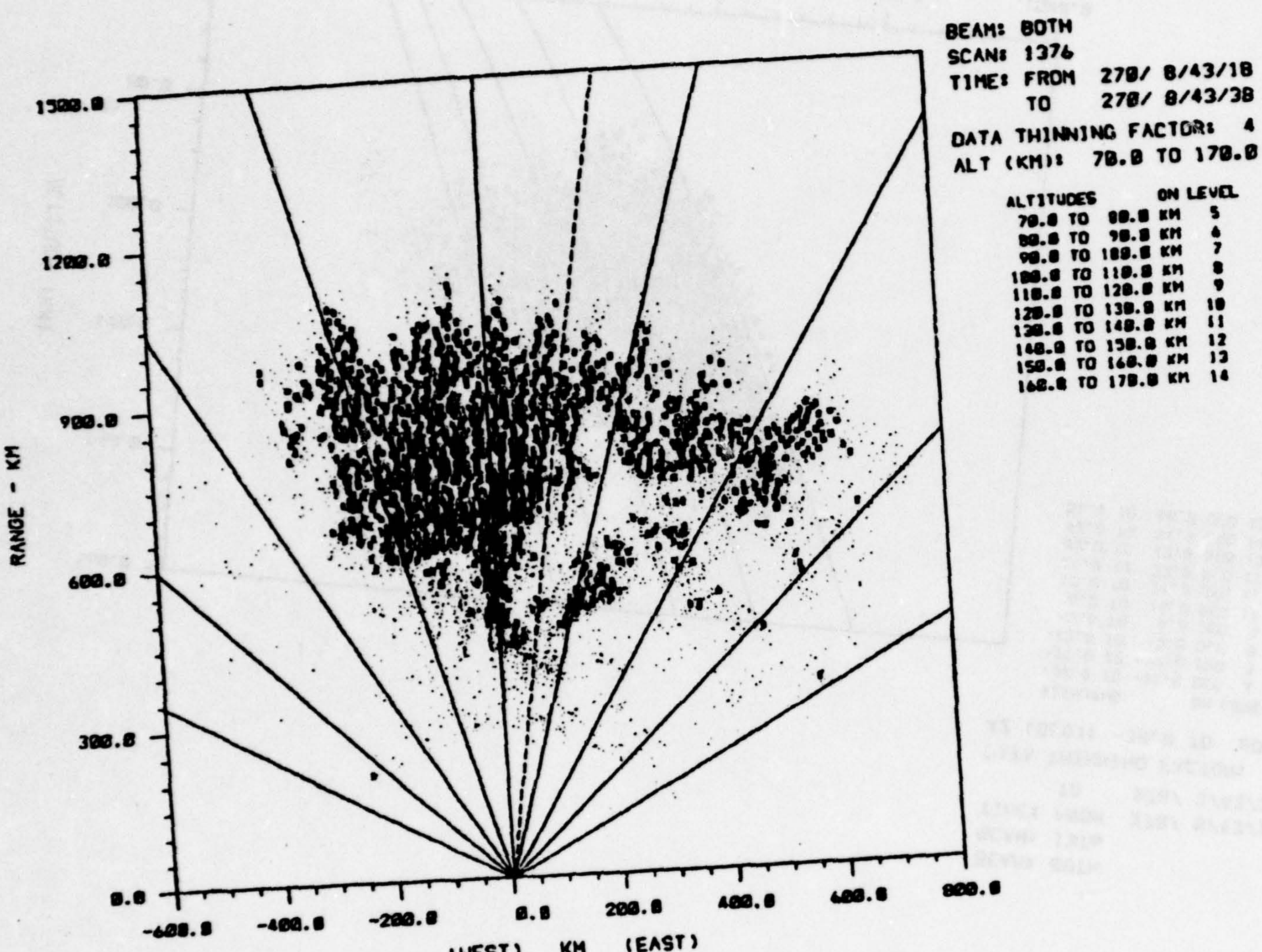

BEAM: BOTH
SCAN: 1026
TIME: FROM 270/ 0/14/12
TO 270/ 0/14/32
DATA THINNING FACTOR: 3
AZ (DEG): -30.0 TO 60.0
AZIMUTHS ON LEVEL
-30.0 TO -21.0 DEG 6
-21.0 TO -12.0 DEG 7
-12.0 TO -3.0 DEG 8
-3.0 TO 6.0 DEG 9
6.0 TO 15.0 DEG 10
15.0 TO 24.0 DEG 11
24.0 TO 33.0 DEG 12
33.0 TO 42.0 DEG 13
42.0 TO 51.0 DEG 14
51.0 TO 60.0 DEG 15
ALTITUDE (KM)
160.0
140.0
120.0
100.0
80.0
60.0
0.0
300.0
600.0
900.0
1200.0
1500.0
RANGE (KM)

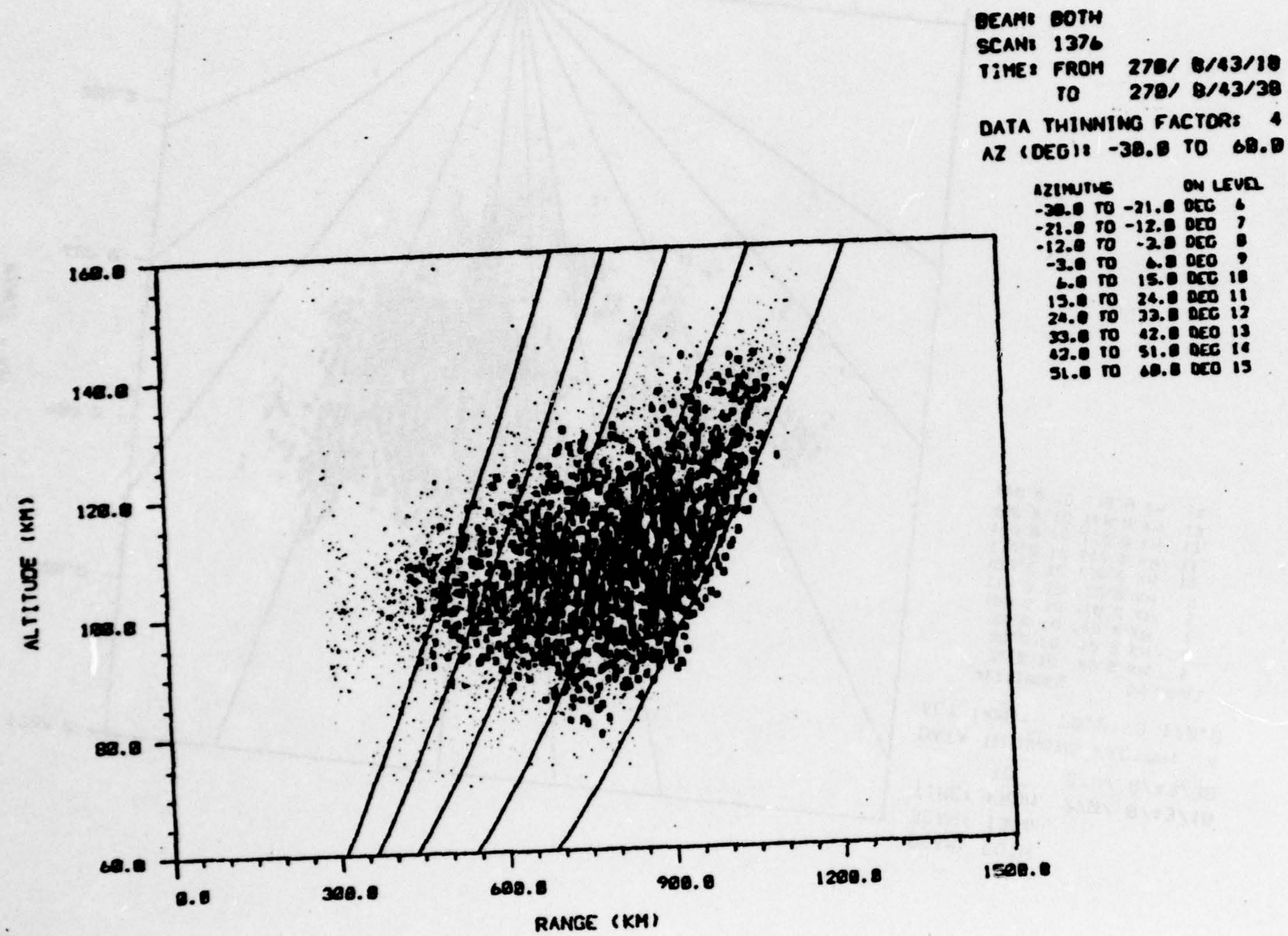
Figure 5-166



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

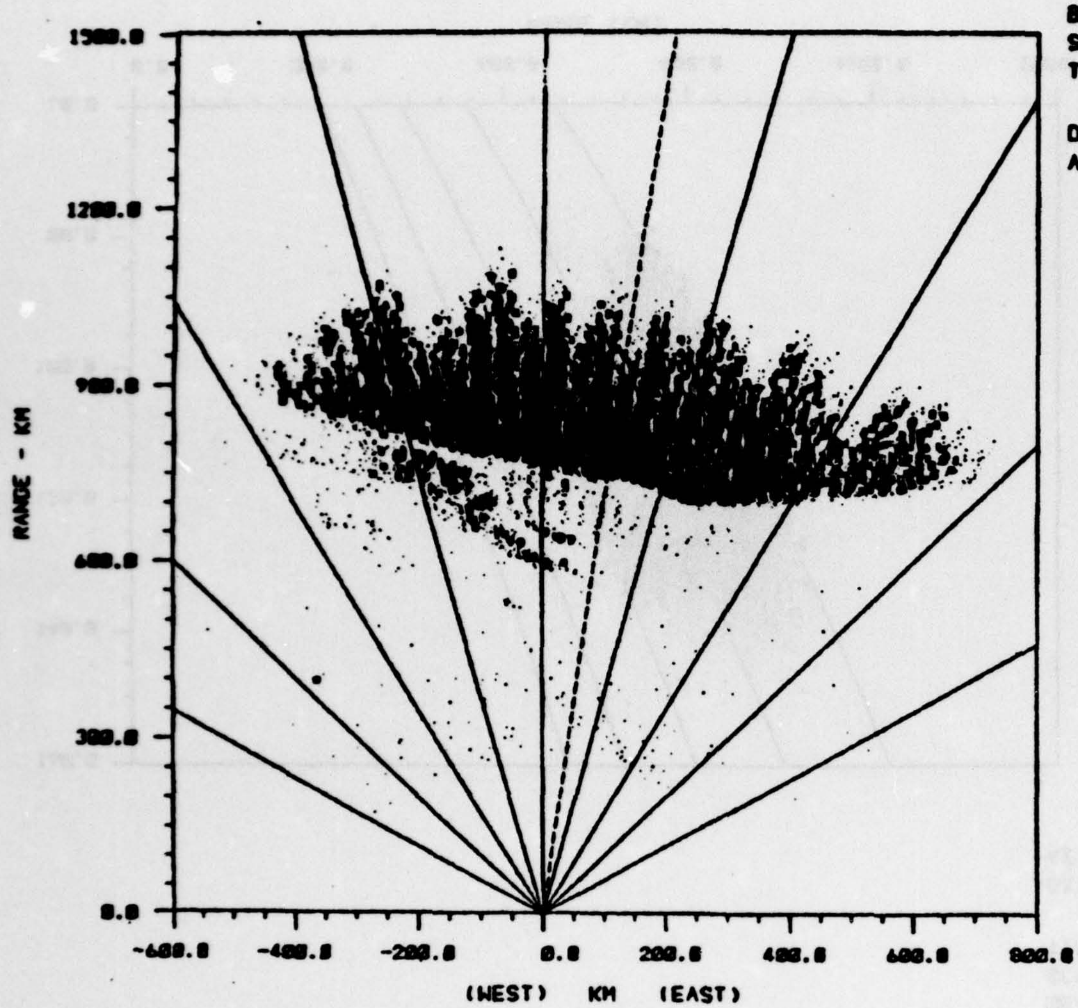
M&S OMPUTING

Figure 5-169



M&S COMPUTING

Figure 5-170



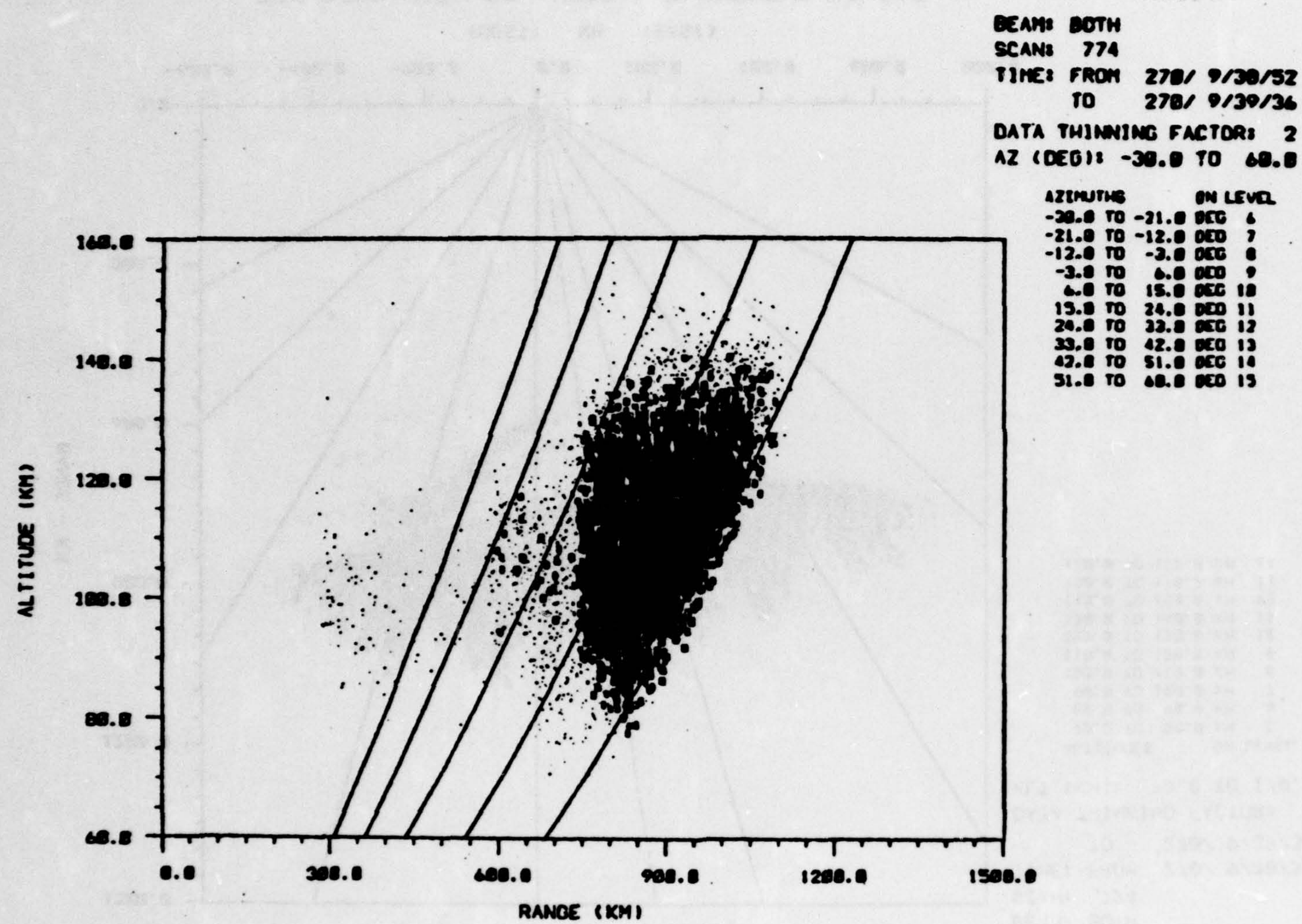
BEAM: BOTH
SCAN: 774
TIME: FROM 278/ 9/38/52
TO 278/ 9/39/36
DATA THINNING FACTOR: 2
ALT (KM): 78.0 TO 178.0

ALTITUDES	ON LEVEL
78.0 TO 88.0 KM	5
88.0 TO 98.0 KM	6
98.0 TO 108.0 KM	7
108.0 TO 118.0 KM	8
118.0 TO 128.0 KM	9
128.0 TO 138.0 KM	10
138.0 TO 148.0 KM	11
148.0 TO 158.0 KM	12
158.0 TO 168.0 KM	13
168.0 TO 178.0 KM	14

TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

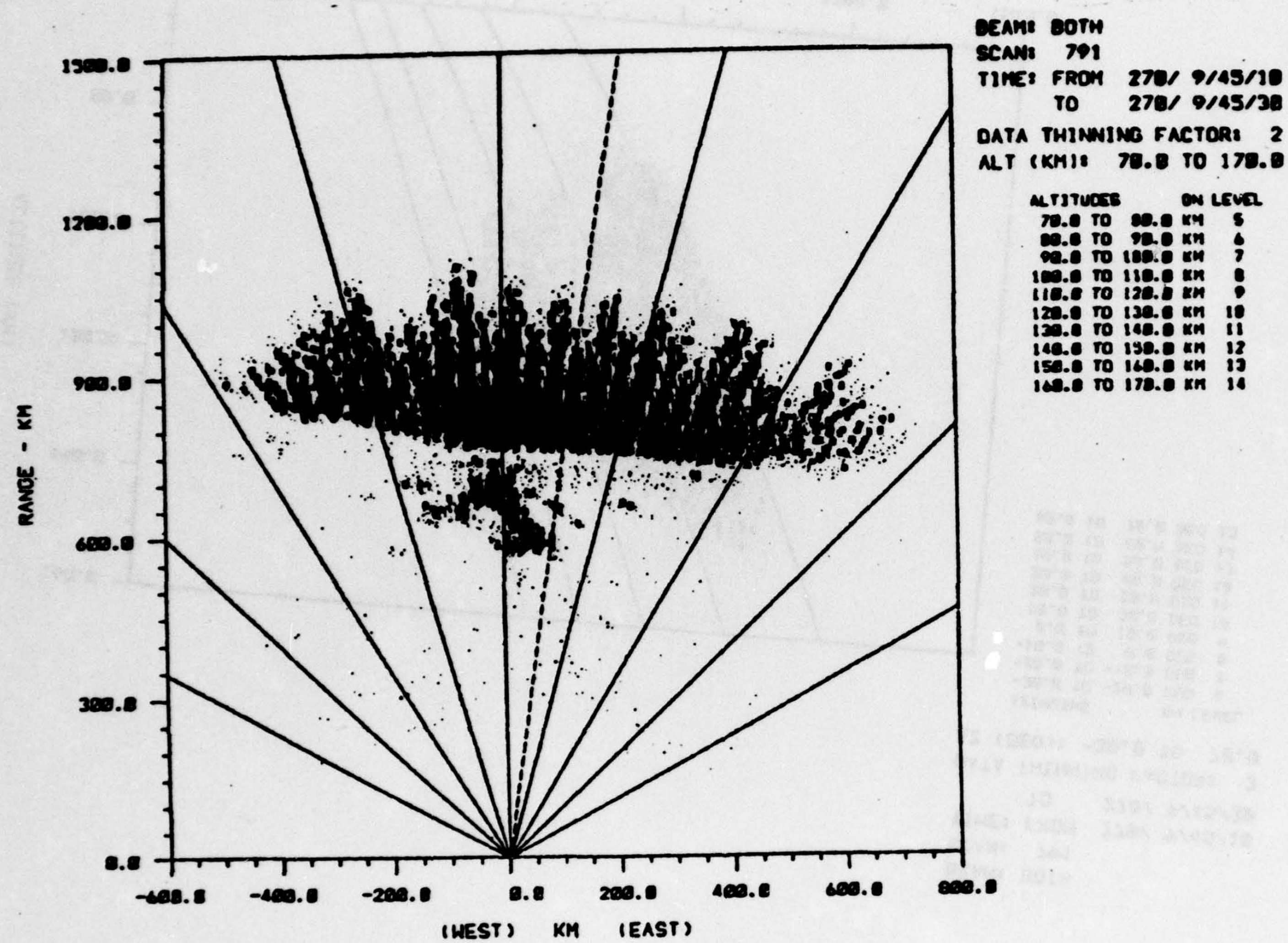
M&S OMPUTINO

Figure 5-171



M&S OMPUTING

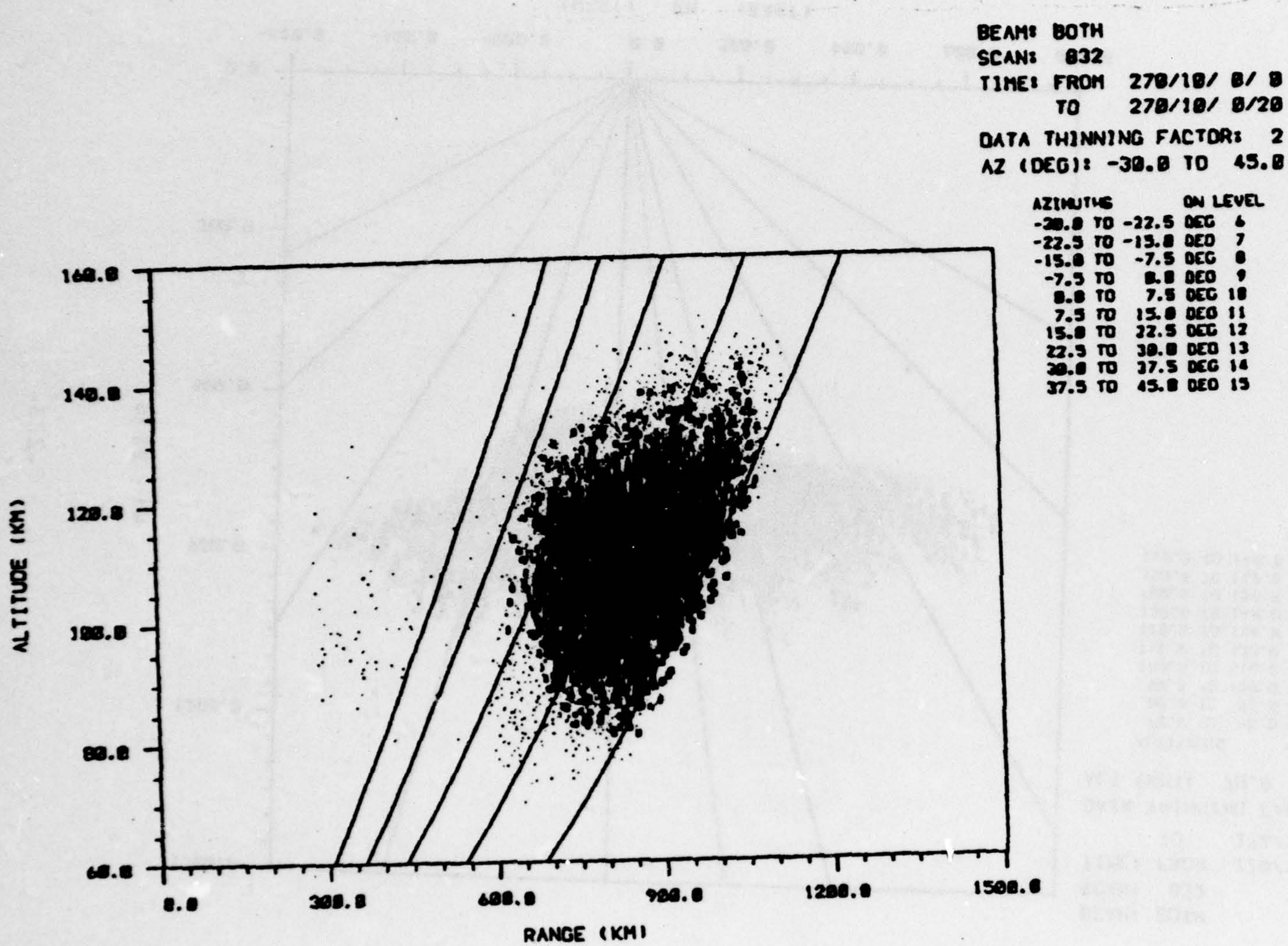
Figure 5-172



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

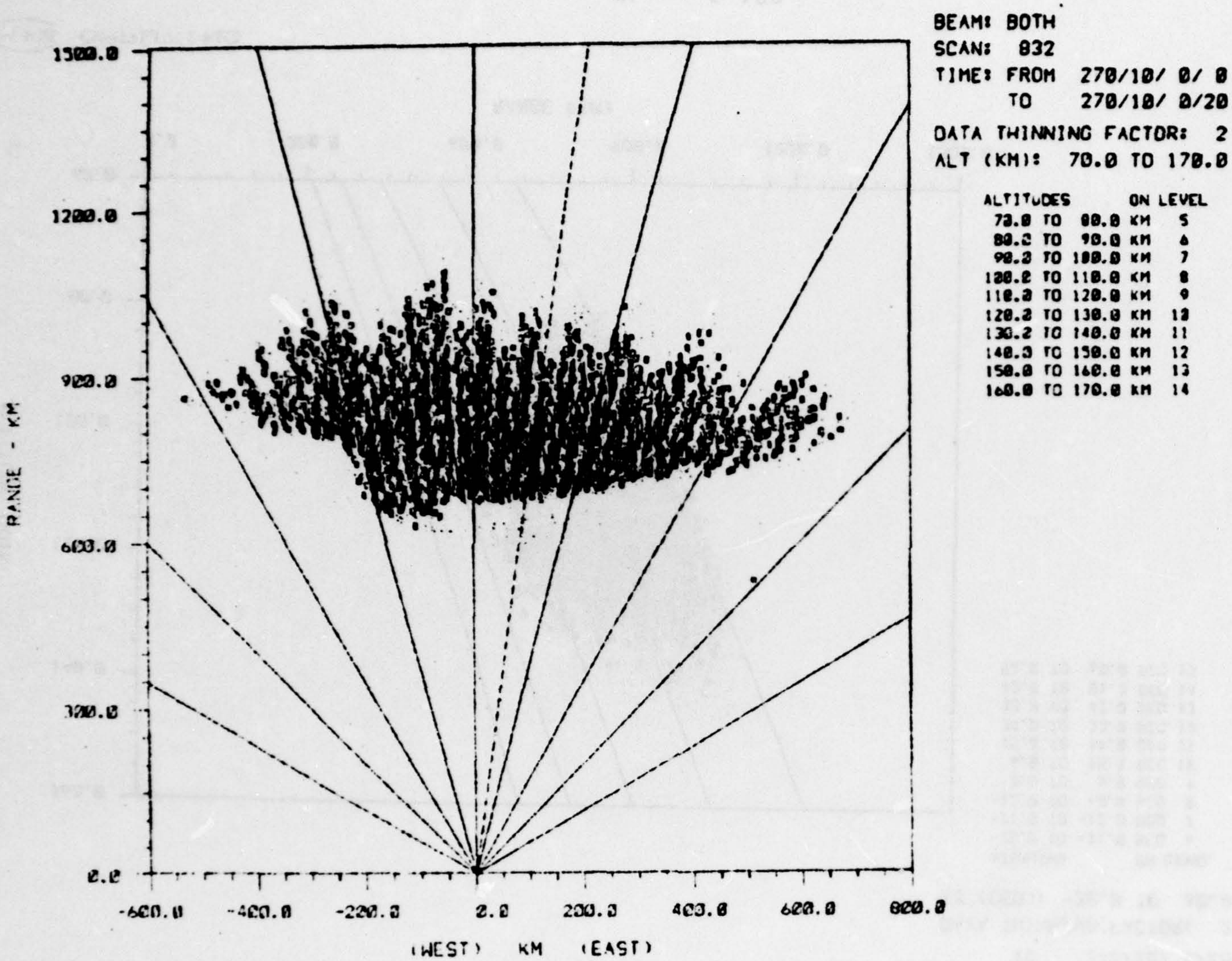
M&S OMPUTING

Figure 5-173



M&S COMPUTING

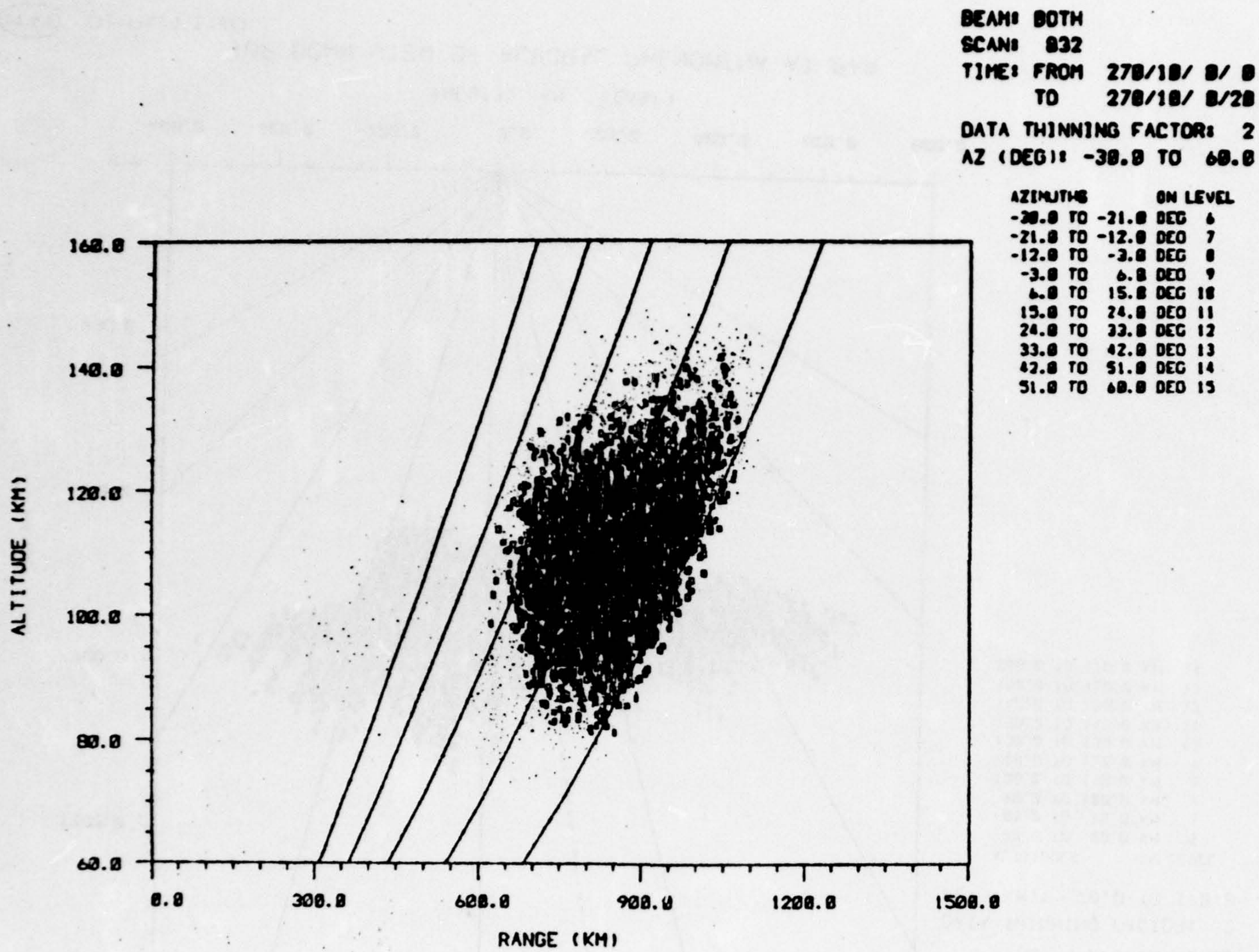
Figure 5-178



TOP DOWN VIEW OF AURORAL PHENOMENA AT PAR

M&S COMPUTING

Figure 5-179



M&S COMPUTING

Figure 5-180

6. GOALS OF THE ANALYSIS

The initial goals of the study included:

- o Accurately defining the region in space where auroral reflections could affect the operation of the PAR radar.
- o Determining the signal strength distribution and number of replies which could be expected from various regions.
- o Evaluating the reliability of auroral predictions from various outside sources.
- o Analyzing the effects of auroral activity on tracking performance.
- o Characterizing certain features of the morphology of entire auroral substorms.
- o Determining if the aurora generated significant noise in the PAR operating band.
- o Evaluating sidelobe blanking performance in an auroral environment.

As stated in the introduction, these analyses are incomplete at this time, however, some very interesting data has been presented here and a number of very useful analysis tools have been described. Within a short time, the results of some of these study areas should be available and will be published at that time.

The goals for analysis have expanded somewhat. One of the new efforts involves determining the geomagnetic aspect dependence of the auroral reflections. This task will be accomplished using the Geomagnetic Model and Spatial Filter described in Section 4. The basic analytical process will be similar to that used by previous researchers except that there will be a great deal more normalization of radar parameters to eliminate the effects of range, steering, and beam divergence. This normalization will be accomplished by representing the auroral intensity by its volume reflecting properties using a parameter which will be called Reflectivity. This technique is presently in the final stages of development at M&S Computing.

Another new study effort is directed toward determining the effect of altitude on the intensity of auroral echoes. This will be done by determining the distribution of auroral reflectivities from data points at various altitudes but on the same geomagnetic aspect contour.

SCATTER PLOT WITH CURVE FIT

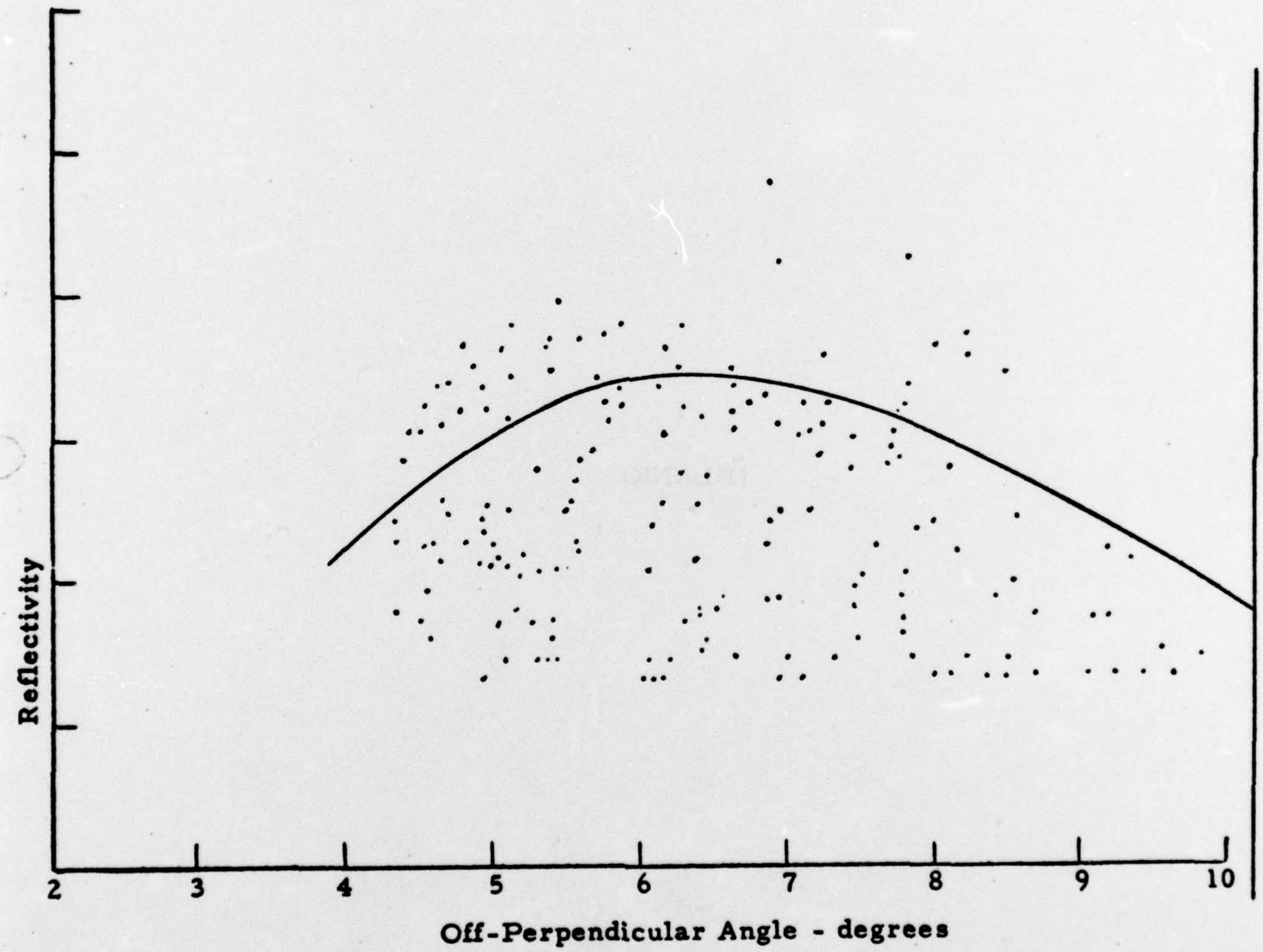


Figure 6-1