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USAF/GL Meteor Scatter Data Analysis Program. A User's Guide

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This document describes the use and theory of the Geophysics Laboratory meteor scatter data analysis package. Each of the 16 primary data analysis statistics is discussed along with options for each statistic and data output formats. Examples of analysis using each statistic are provided. Theory behind each statistic is described.

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1.0 INTRODUCTION

Equipment on the USAF high latitude meteor scatter test bed operating from Sondrestrom AB, Greenland to Thule AB, Greenland has been upgraded to improve the data gathering capability. New receivers with a bandwidth of 100 Hz have replaced the older systems with 3 KHz and 30 KHz [Ostergaard et al, 1985] bandwidths. The reduced bandwidth allows observation and study of trails 15 dB weaker than on the previous systems. In addition the number of frequencies has been increased from four (45, 65, 104, and 147 MHz) to six with the addition of 35 and 85 MHz filling the gaps between 65 and 104 MHz.

A new microprocessor data acquisition system provides continuous logging of data replacing the older system which had 1.5 second gaps between every 4 second record. Data is collected on both vertical and horizontal channels allowing study of the Faraday polarization rotation phenomena. Increased data from the system requires a new approach to data analysis.

Data from the acquisition system consists of 5 second records of 500 received signal power measurements from the horizontally polarized channel, 500 received signal power measurements from the vertically polarized channel and 500 measurements of the phase of the vertical channel relative to the horizontal channel. The presence of the 400 Hz FM modulated signature, used to differentiate signal from noise bursts, is indicated by the sign of the phase channel (negative indicates presence of the 400 Hz tone). Data is logged continuously in 5 second records with no gaps between successive records. Only records in which the 400 Hz tone is detected are transferred to the mass storage tape unit.

This document describes the AFGL/ULCAR (Air Force Geophysics Laboratory/University of Lowell Center for Atmospheric

Research) meteor burst data analysis package. Software is written in VAX FORTRAN and consists of about 30,000 lines of code. The software is divided into four operating levels based on their input and output access:

Level 0: Transfer Level (Converts and transfers raw data tapes to VAX)

Level 1: Classification Level (operates on trail files)

Level 2: Analysis Level (reads trail files, operates on data bases)

Level 3: Presentation Level (reads data bases)

Level zero software formats and transfers raw data from tape cartridges to the AFGL VAX computer. A 20 item header consisting of the date, time, noise level, frequency, and other information is attached to each 1500 point data record.

The next step in the analysis procedure, comprising level 1 software, is classification in which the dominant propagation mechanism in each data record or sequence of records is identified and if the dominant mechanism is meteor propagation, the type of each meteor trail in the record or sequence of records (underdense or overdense) is identified and entered into the header along with the time of the beginning of the trail.

Classification is an important element of the analysis procedure because several different propagation mechanisms are observed on the high latitude test bed: underdense meteor trails, overdense meteor trails, sporadic-E propagation and weak ionospheric scatter. The test bed is well above the auroral zone so that auroral scatter is not generally observed. Identification and separation of the mechanisms is required for detailed scientific and engineering analysis, an objective of the high latitude program.

The purpose of the classification level is to identify the dominant propagation mechanism in each record as meteor propagation or sporadic-E/ionospheric propagation. The classifications are entered into the data header attached to each record.

Level two analysis software reads classified meteor trail data files and computes a number of key statistics from the data, entering the results into the various data bases. Level two consists of several routines, one which creates blank data bases for each month and a routine which analyzes data. In addition there are several utilities which allow access to the data bases to change entries. The utilities are described in Appendix B. Seven data bases are created:

Number of Arrivals Exceeding a Threshold
Time Above a Threshold
Distribution of Trail Durations
Fading Statistics
Noise and Link History Statistics
Underdense Time Constants

The presentation software (level three) allows users to query the data bases in a number of different ways. Use and assumptions in the presentation level are the subject of this document.

The hierarchal software structure controls and limits access to data bases and raw data. For example, once a data base has been created by level two analysis software, data can only be examined and read, not changed by the presentation software.

2.0 USING METEOR BURST STATISTICS PACKAGE

The Meteor-Burst Statistics Generating Program is a menu-driven FORTRAN program supporting 16 individual statistical subroutines which are used to analyze the meteor scatter data bases.

This manual walks a user through processing an individual *statistic and provide insight into how each statistic is* processed. All the menus available to the user are presented for quick reference. More comprehensive descriptions of each option accompany each menu.

The user is advised to scan through this manual before using the program to become acquainted with the various options that are available and the user specified parameters for each option. The user should also understand the assumptions which are inherent in each of the analysis options.

2.1 Data Bases, Naming Conventions, and Glossary of Terms

2.1.1 Data Bases and Naming Conventions

The Meteor-Burst Statistic Generating Program accesses the monthly data bases created by the level 2 analysis software. The naming convention for the data bases is given below.

ARRIVALS data base	ARIVmonthyear.DAT
SNR data base	SNRmonthyear.DAT
DURATION data base	DURmonthyear.DAT
POWER AND NOISE LEVEL data base	HISmonthyear.DAT
FADING data base	FADmonthyear.DAT
TIME CONSTANT data base	TCONSmonthyear.DAT
FARADAY ROTATION data base	FARmonthyear.DAT

2.1.2 Glossary of Terms

On-line help is available from the statistics program, however the user must be able to interpret the sometimes cryptic notation. A partial Glossary of terms is presented.

BW (bandwidth): Effective noise bandwidth in Hz. Default is 100 Hz.

BIT ERROR RATE (BER): Communication statistics are computed based on average bit error rate BER assuming additive white Gaussian noise channel. The signal to noise threshold required to support transmission at the specified rate is determined from the modulation type, and the bandwidth.

Index	Bit Error Rate
2	10^{-2}
3	10^{-3}
4	10^{-4}
5	10^{-5}
6	10^{-6}

BIT RATE (DATA RATE): Used in the communication statistics is the data rate on the channel

CONFIDENCE: In communication applications, confidence is the probability that a message can be delivered in a given period of time. Assuming all arrivals are independent Poisson events,

$$\text{Confidence} = 1 - e^{-\left(\frac{\text{time}}{\lambda}\right)}$$

where λ is the average arrival rate of events.

DAY•TOD: Results for each 2 hour period for each day of the month are presented. Day.tod = day + (hour_index-1)/12. This is designed to facilitate plotting of the data.

DOWN TIME: At the lower frequencies, significant portions of each time period may be dominated by sporadic-E propagation. During this time, meteors are obscured. So as not to skew the statistics, time during which sporadic-E is dominant is removed from the time available for measurement. If there is too much sporadic-E during a time period, then that period can be removed from averaging since the time available to observe meteors is too short. The default is 240 seconds (4 minutes). The user has the option to increase or decrease this quantity. Increasing it allows periods during which there was significant sporadic-E activity to be included in the data set while reducing the quantity reduces the allowed sporadic-E contamination.

EVENT TYPE: Depending on the statistic, several different event types or combinations are allowed. For statistics in which sporadic-E is included the following event options are available:

Index	Event type
1	Underdense meteor trails
2	Overdense meteor Trails
3	Sporadic-E
4	not used
5	Underdense and Overdense Trails
6	Sporadic-E and Meteor Trails

For statistics computed only for meteor trails, the following event options are available:

Index	Event type
1	Underdense meteor trails
2	Overdense meteor Trails
3	Underdense and Overdense Trails

FREQ: Frequencies on which the link operates

Index	frequency	num min/2 hour block
35	35 Mhz	10
45	45 Mhz	13
65	65 Mhz	15
85	85 Mhz	15
104	104 Mhz	20
147	147 Mhz	20

MODULATION: The software allows communication performance of a user specified link to be inferred from the raw propagation data. Communication performance is based on additive Gaussian White Noise (AWGN) channels with infinite transmission bandwidth and 1 bit/Hz receive bandwidth. The following modulations are considered:

1: 2-FSK (coherent)
2: 2-PSK (BPSK)
3: 4-PSK (QPSK)
4: MSK (OQPSK)
5: DPSK (differentially coherent)
6: 2-FSK (non-coherent)
7: 8-PSK

NOISE TYPE: Three different noise measures can be selected in the analysis. Before each transmission period, five second noise measurements (500 sample points) are performed with the transmitter off using data from the vertical channel. This is referred to as the measured vertical noise. During the automatic classification procedure, average noise levels with the transmitter on are computed on both the vertical and horizontal channel. This measurement includes all points in which the signal flag is off except 5 points preceding the beginning of the flag. If there are not more than 5000 points in the data set, then the measured vertical noise is used. These measures constitute the derived horizontal and derived vertical noise levels. The derived noise measurements include the effect of ionospheric scatter propagation which is considered as a multiplicative noise source. The default is the measured vertical.

Index	Noise Type
0	Measured vertical
1	Derived Horizontal
2	Derived Vertical

PACKET: The basic unit of message protocol. Used in communication statistics, the user specifies the length of the packet in bits and the number of bits in each packet which are not information (OVERHEAD).

POWER FACTOR REDUCTION: In communication statistics allows user to reduce the effective transmitter power by the PFR. For example, +10 dB PFR changes the effective transmitter power from 1000 W to 100 W. -10 dB changes the power from 1000 W to 10,000 W.

RSL: Received signal level in dBm. For the analysis package levels from -150 dBm to -70 dBm in 2 dB increments are considered.

Index	RSL(dBm)	Index	RSL(dBm)
1	-150	21	-110
2	-148	22	-108
3	-146	23	-106
4	-144	24	-104
5	-142	25	-102
6	-140	26	-100

7	-138	27	- 98
8	-136	28	- 96
9	-134	29	- 94
10	-132	30	- 92
11	-130	31	- 90 Limit of Receiver
12	-128	32	- 88
13	-126	33	- 86
14	-124	34	- 84
15	-122	35	- 82
16	-120	36	- 80
17	-118	37	- 78
18	-116	38	- 76
19	-114	39	- 74
20	-112	40	- 72

SNR: SIGNAL TO NOISE RATIO in dB relative to the specified bandwidth. If no bandwidth is specified the 100 Hz effective system bandwidth is assumed. A user specified bandwidth must be greater than the 100 Hz effective system bandwidth.

THROUGHPUT: Computed by the communication statistics, this is the average data rate supported by the channel assuming full use of all available channel time (i.e. message input queues are full). Throughput is sometimes interchanged with Capacity.

TOD: Time of day. The day is divided into twelve two hour periods during which a complete measurement cycle of 6 frequencies occurs. When TOD is requested by the program, the user enters the time period number. For example 0 to 2 hours UT constitutes time period 1, 22 to 24 hours UT constitutes time period 12. Entering 13 causes averaging to occur over all 12 hour periods during a day. All time is referenced to Universal Time (UT) which is 4 hours ahead of local time at Thule AB, Greenland.

Universal Time (UT)	Index
0 - 2	1
2 - 4	2

4 - 6	3
6 - 8	4
8 - 10	5
10 - 12	6
12 - 14	7
14 - 16	8
16 - 18	9
18 - 20	10
20 - 22	11
22 - 24	12
Entire Day (0 - 24)	13

24 HOUR STATISTICS: These statistics compute the daily average. For this statistic to be computed, there must be data from all 12 periods during a calender day. If there is down time in excess of the specified limit during a given period, that period will not be considered in the analysis and no 24 hour average will be computed for that day. This can be remedied by increasing the maximum down time.

Waiting Time: Average time required to send a message over the channel.

2.2 Description of Statistical Analysis Options

The following is a list of statistical analysis options available in the package.

Stat	Analysis performed
101	Number of arrivals exceeding a RSL threshold
102	Number of arrivals exceeding a SNR threshold
103	Distribution of time above a RSL threshold
104	Distribution of time above a SNR threshold
105	Noise level and link-up time history
106	Distribution of durations above RSL threshold

107 Distribution of durations above SNR threshold
108 Time constants
109 Fading Statistics
201 Throughput for idealized adaptive system (for all events)
202 Throughput for idealized adaptive system (for all frequencies)
203 Throughput for realistic adaptive rate system (for all events)
204 Throughput for realistic adaptive rate system (for all frequencies)
205 Throughput for realistic fixed rate system (for all frequencies)
206 Throughput for realistic fixed rate system (for all events)
207 Time required to transmit a message (for fixed rate system)

The following pages describe each of the 16 main statistical analysis routines. See each individual menu for information on which options are available and the user specified parameters for each option.

2.3 Propagation Statistics

2.3.1 Trail Arrival Rate Statistics

Statistics of the number of meteor trails as a function of peak received signal level (RSL) and signal to noise ratio (SNR) are important in modeling applications and to determine the depth of absorption events. For each meteor trail identified by the trail classifier, the peak signal level is determined and recorded in the data base. The average noise level (derived horizontal and vertical) are removed from the peak horizontal and vertical channel data respectively. The search window begins 7 points (70 ms) before the acquisition flag begins and continues over the entire trail. The precursor has been included because it has been observed that the phase locked loop requires approximately 50 ms to acquire lock during which fast rise underdense trails may reach their peak. Three point moving averaging is used in this statistic.

The arrival rate of meteor trails is determined by dividing the number of trails exceeding the required threshold by the time that the system was available to observe meteor trails. Periods during which sporadic-E was the dominant propagation mechanism are excluded from the total time. This is called "down time". The user has the option to specify the maximum amount of down time that may be present in a given time period before the data is ignored in the calculation. The default is 240 sec (4 minutes) which corresponds to approximately 1/2 of the observation time at the lower frequencies (35 and 45 MHz) where sporadic-E is prevalent.

Arrival statistics are computed for both horizontal and vertical polarizations. The user can specify output in either the normalized arrival rate (meteors/min) or unnormalized where both the number of meteors and the total observation time is presented. This allows access to the raw arrival numbers and observation time. Plots are available only in the meteors/min format.

2.3.1.1 Menu 101: Number of Arrivals vs. RSL

Statistic 1 computes statistics of the arrival of meteor trails as a function of peak receive signal level. Analysis options are shown in the menu below:

Op	x-Axis	y-Axis	User Specified Parameters
1	tod	total or #/min	RSL, trail type, max down time, polarization

2	RSL	"	tod, trail type, max down time, polarization
3	day.tod	"	RSL, trail type, max down time, polarization
4	NOT IMPLEMENTED		
5	tod	"	RSL, freq, max down time, polarization
6	RSL	"	tod, frequency, max down time, polarization
7	day.tod	"	RSL, frequency, max down time, polarization
8	NOT IMPLEMENTED		
9	tod	"	day, RSL, trail type, max down time, polarization
10	RSL	"	day, tod, trail type max down time, polarization
11	day	"	RSL, trail type, max down time, polarization

Option 101-1: This option calculates for all frequencies the arrival rate of meteor trails exceeding a specified received signal level as a function of time of day averaged over the entire month. Two output formats are available: 1) the total number of meteor arrivals/total number of minutes or 2) the number of meteor arrivals per minute. Figure 1 plots the arrival rate (meteors/min) as a function of time of day for March 1989.

Option 101-2: This option produces for all frequencies a distribution function of the number of meteor trails as a function of received signal threshold. Two output formats are available: 1) the

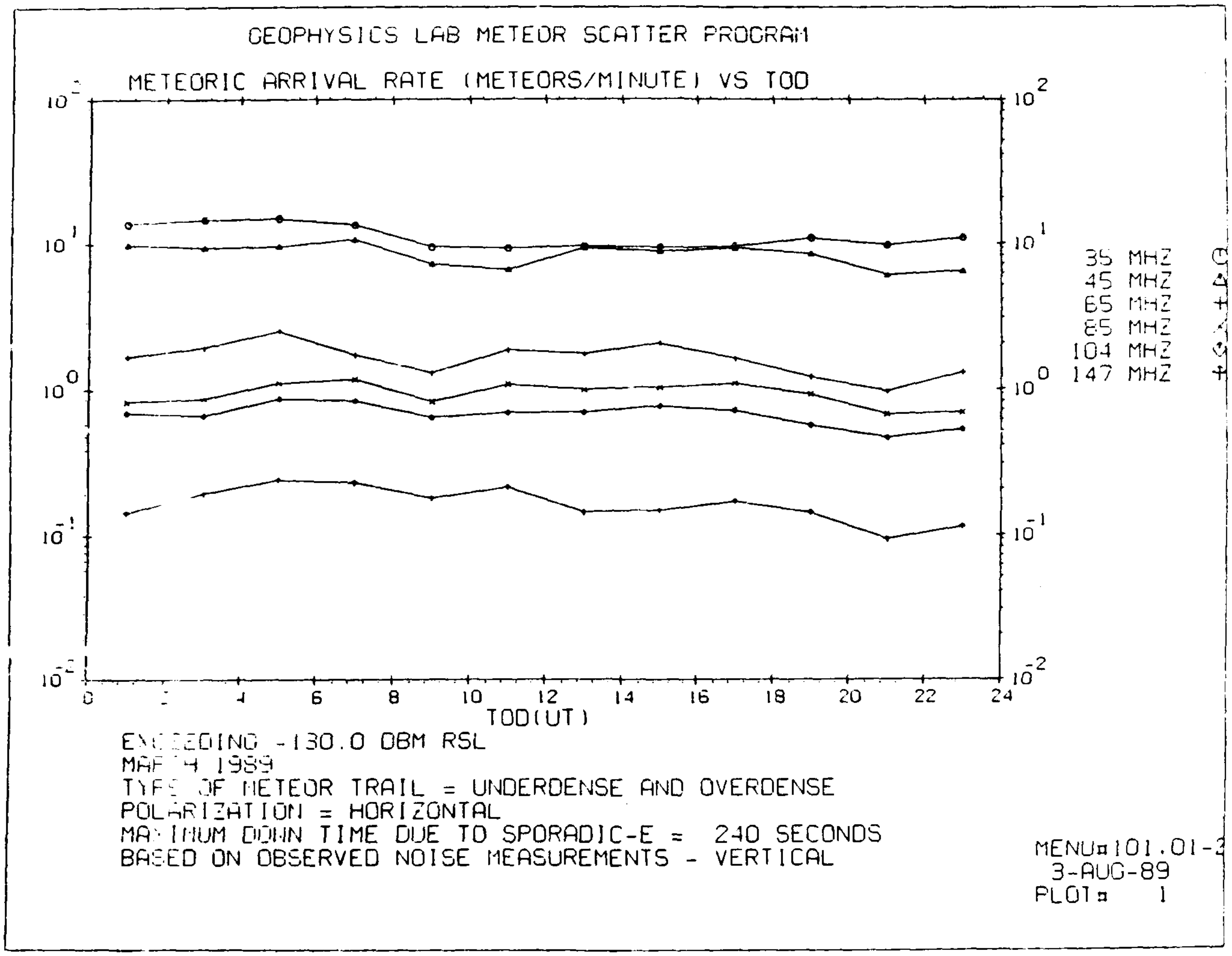

Figure 1. Statistic 101-1 Output Format 2

total number of meteor arrivals/total number of minutes or 2) the number of meteor arrivals per minute. The range of received signal levels is -150 dBm to -72 dBm in increments of 2 dBm (note that the current limit of the receiver equipment is -90 dBm). Arrivals can be averaged over one 2 hour period or over 24 hours. Averages based on 1 month of data.

Option 101-3: This option calculates for all frequencies the arrival rate of meteor trails exceeding a specified received signal level for each time period for the complete month. Two output formats are available: 1) the total number of meteor arrivals/total number of minutes or 2) the number of meteor arrivals per minute.

Option 101-4: NOT IMPLEMENTED AT THIS TIME.

Option 101-5: This option is essentially the same as 101-1 with the exception that data is displayed at one frequency for the different trail types.

Option 101-6: This option is essentially the same as 101-2 with the exception that data is displayed at one frequency for the different trail types. Figure 2 plots the arrival rate of meteors (meteors/min) as a function of received signal level using this statistic.

Option 101-7: This option is essentially the same as 101-3 with the exception that data is displayed at one frequency for the different trail types.

Option 101-8: NOT IMPLEMENTED AT THIS TIME.

Option 101-9: This option is identical to option 101-1 with the exception that data is averaged over only one day. User specifies the day.

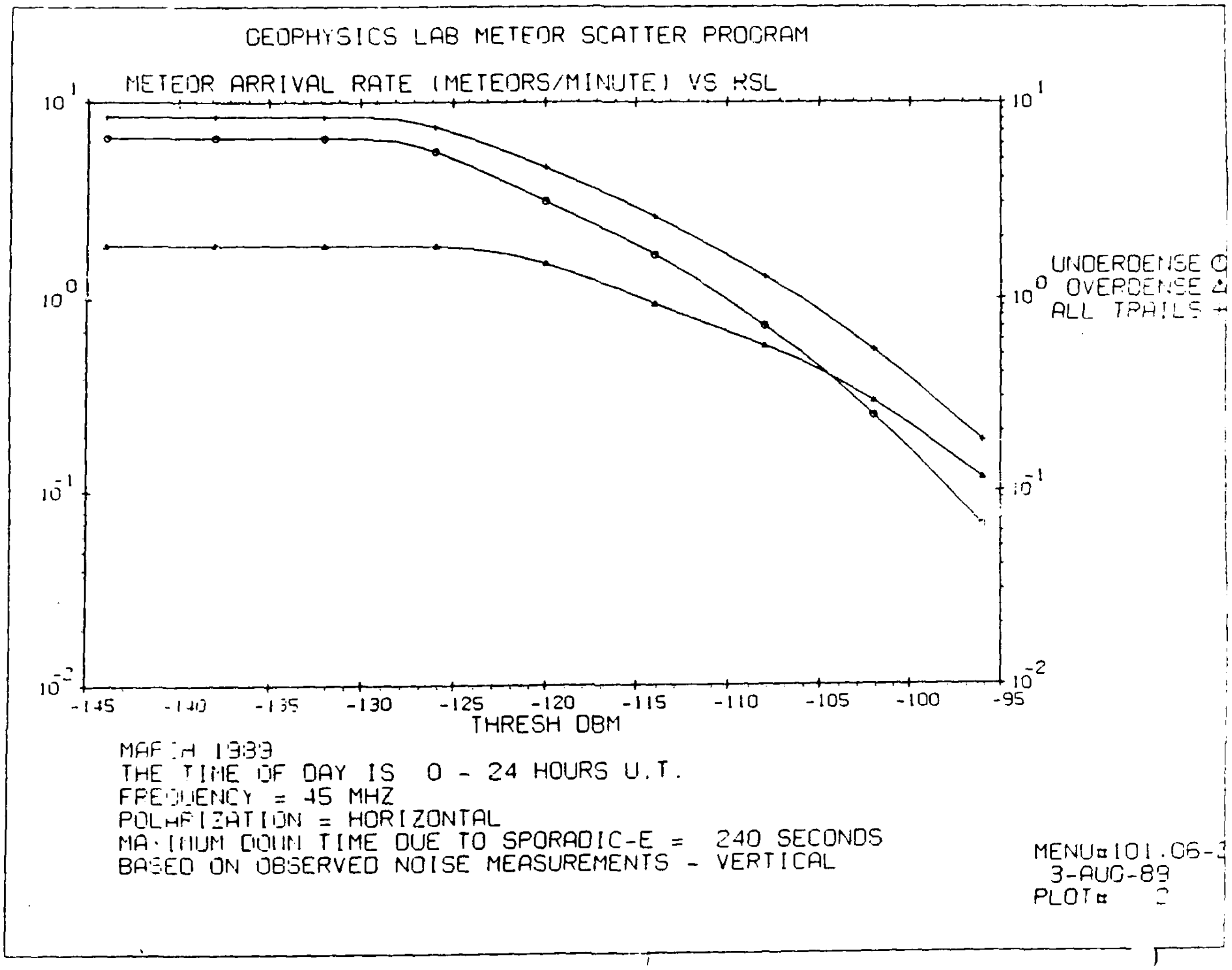

Figure 2. Statistic 101-6 Output Format 2

Option 101-10: This option is identical to option 101-2 with the exception that data is averaged over only one day. User specifies the day.

Option 101-11: This option is used to determine 24 hour PCA effects. It computes the 24 hour average arrival rate of meteor trails (meteors/min) exceeding a specified threshold for each day of the month. For a number to be calculated there must be data for each of the 12 periods during a day. Note: if the level of sporadic-E is greater than the maximum specified level, data for a given period will be ignored and the 24 hour average cannot be calculated. To remedy this problem, increase the maximum sporadic-E time (max down time).

2.3.1.2 Menu 102: Number of Arrivals vs. SNR

Statistic 102 computes statistics of the arrival of meteor trails as a function of peak signal to noise ratio (SNR). This statistic is a dual of statistic 101. Analysis options are shown in the menu below:

Op	x-Axis	y-Axis	User Specified Parameters
1	tod	totals or #/min	SNR, trail type, BW, max down time, polarization
2	SNR	"	tod, trail type, BW, max down time, polarization
3	day.tod	"	SNR, trail type, BW, max down time, polarization
4	NOT IMPLEMENTED		
5	tod	"	SNR, frequency, BW, max down time, polarization

6	SNR	"	tod, frequency, BW, max down time, polarization
7	day.tod	"	SNR, frequency, BW, max down time, polarization
8	NOT IMPLEMENTED		

Option 102-1: This option calculates for all frequencies the arrival rate of meteor trails exceeding a specified SNR as a function of time of day averaged over the entire month. Two output formats are available: 1) the total number of meteor arrivals/total number of minutes or 2) the number of meteor arrivals per minute.

Option 102-2: This option produces for all frequencies a distribution function of the number of meteor trails as a function of SNR. Two output formats are available: 1) the total number of meteor arrivals/total number of minutes or 2) the number of meteor arrivals per minute. The range of signal to noise ratios is 0 - 59 dB in increments of 1 dB. Arrivals can be averaged over one 2 hour period or over 24 hours. Averages based on 1 month of data. Figure 3 plots the arrival rate of trails (meteors/min) as a function of SNR relative to 100 Hz.

Option 102-3: This option calculates for all frequencies the arrival rate of meteor trails for each time period for the complete month. Two output formats are available: 1) the total number of meteor arrivals/total number of minutes or 2) the number of meteor arrivals per minute.

Option 102-4: NOT IMPLEMENTED AT THIS TIME.

Option 102-5: This option is essentially the same as 102-1 with the exception that data is displayed at one frequency for the different trail types.

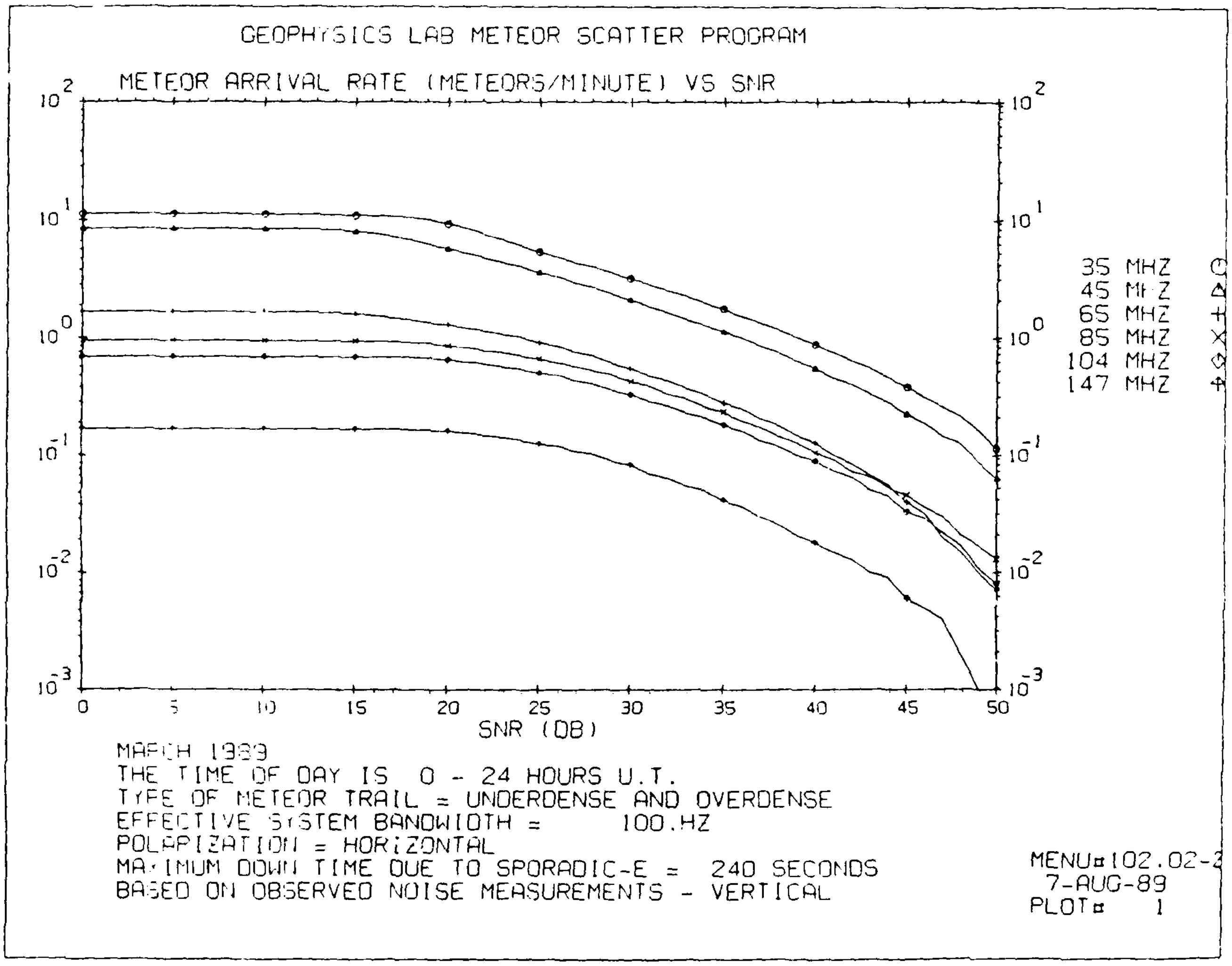

Figure 3. Statistic 102 2 Output Format 2

Option 102-6: This option is essentially the same as 102-2 with the exception that data is displayed at one frequency for the different trail types.

Option 102-7: This option is essentially the same as 102-3 with the exception that data is displayed at one frequency for the different trail types.

Option 102-8: NOT IMPLEMENTED AT THIS TIME.

2.3.2 Time Above Signal Threshold (Duty-Cycle Statistics)

This statistic computes the duty-cycle above various signal and signal to noise thresholds. For each received signal threshold, the number of points (10 ms/point) for which the signal is above the threshold is computed. This statistic is computed for both the horizontal and vertical channels. Horizontal and vertical derived noise measures are used when removing the noise level from the signals. To minimize storage requirements (data for each frequency is stored as a 16 bit integer), the time above is quantized into 50 ms units using the nearest integer function. For example anything between 1 and 1.5 is approximated as 1 anything between 1.5 and 2.5 is approximated as 2, etc. The time above the threshold is divided by the total time to compute duty - cycle measures. For meteor trails, the time during which sporadic-E was present is removed from the total time (see down time in glossary). For sporadic-E, the duty cycle is based on the total time in the period. Duty cycle is presented as a percent or in time above/total time format. Only the duty cycle in percent is available in plot format. SNR duty-cycle measures are derived from the basic measure and can be specified relative to the system bandwidth of 100 Hz or relative to a user specified bandwidth greater than 100 Hz. The user can specify output in a normalized duty cycle form (% time above threshold) or in an unnormalized form in which the number of seconds above threshold and the total observation time are presented.

2.3.2.1 Menu 103: Distribution of Time Above RSL

This routine computes statistics of the duty cycle as a function of peak receive signal level (RSL). Analysis options are shown in the menu below:

Op	x-Axis	y-Axis	User Specified Parameters
1	RSL	%time above RSL or #sec above RSL/total time	day, tod, event type, polarization
2	RSL	"	tod, event type, polarization
3	tod	"	month, RSL, event type, polarization
4	tod	"	month, day, RSL, event type, polarization
5	RSL	"	day, tod, frequency, polarization
6	RSL	"	tod, frequency, polarization
7	tod	"	RSL, frequency, polarization
8	tod	"	day, RSL, frequency, polarization
9	day.tod	"	RSL, event type, polarization
10	day.tod	"	RSL,frequency, polarization

Option 103-1: This option calculates for all frequencies the distribution of duty cycle above a signal threshold as a function of RSL threshold. Two output formats are available: 1) number of seconds above threshold/total time or 2) duty cycle (% of time above threshold). Duty cycle can be averaged over one 2 hour period or over 24 hours. Averages based on 1 day of data.

Option 103-2: This option is essentially the same as 103-1 with the exception that the averaging period is 1 month instead of one day. Figure 4 presents sample output using this statistic.

Option 103-3: This option calculates for all frequencies the duty cycle exceeding a RSL threshold as a function of time of day. Two output formats are available: 1) number of seconds above threshold/total time or 2) duty cycle (% of time above threshold). Averages based on one month of data.

Option 103-4: This option is essentially the same as 103-3 with the exception that the averaging period is 1 day instead of 1 month.

Option 103-5: This option is essentially the same as 103-1 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

Option 103-6: This option is essentially the same as 103-2 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

Option 103-7: This option is essentially the same as 103-3 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

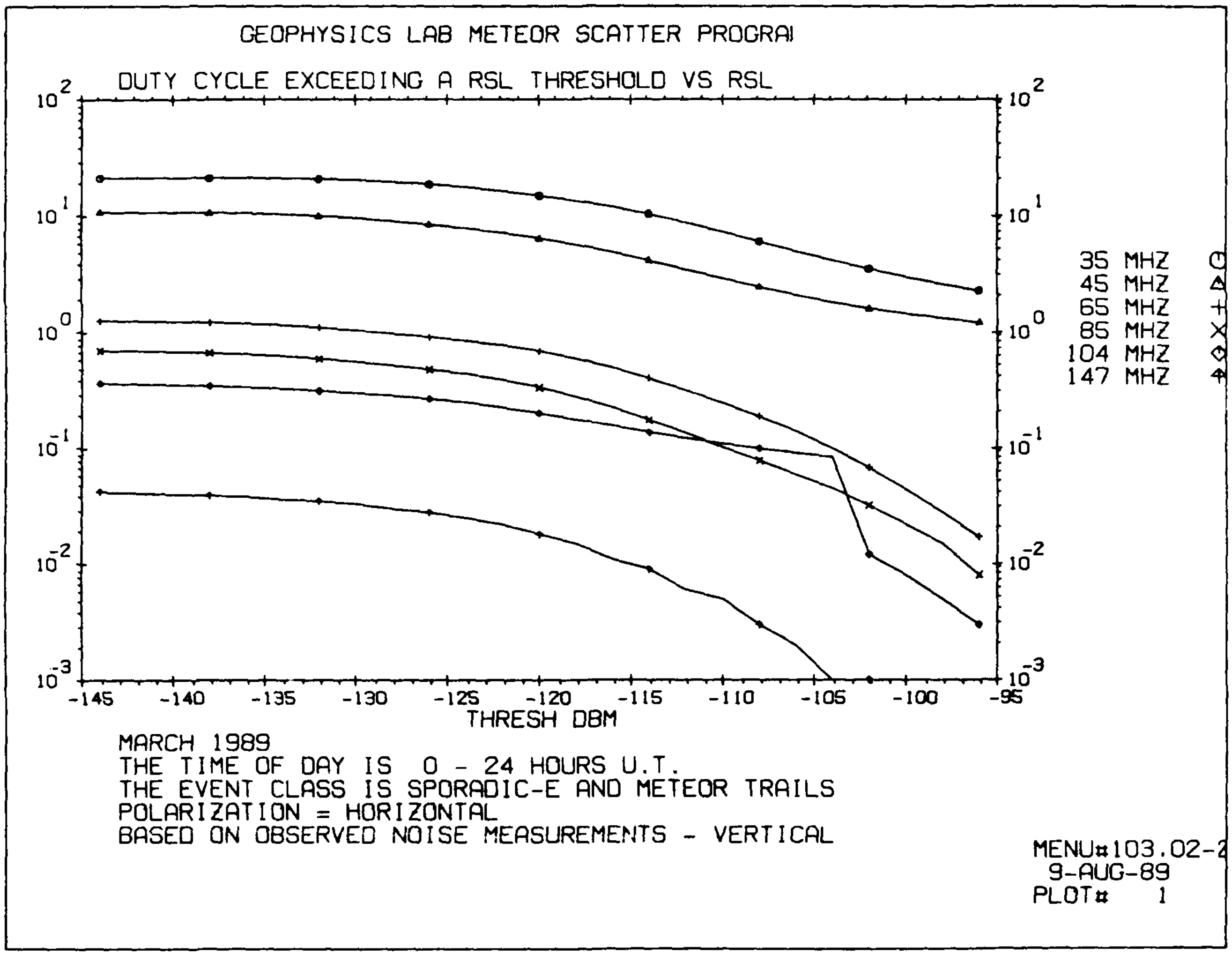

Figure 4. Statistic 103-2 Output Format 2

Option 103-8: This option is essentially the same as 103-4 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

Option 103-9: This option calculates for all frequencies the duty cycle for each time period for the complete month. Two output formats are available: 1) number of seconds above threshold/total time or 2) duty cycle (% of time above threshold).

Option 103-10: This option is essentially the same as 3.9 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

2.3.2.2 Menu 104: Distribution of Time Above SNR

Statistic 104 computes statistics of the duty cycle as a function of signal to noise ratio relative to the 100 Hz or user specified. Analysis options are shown in the menu below: This statistic is a dual of statistic 103.

Op	x-Axis	y-Axis	User Specified Parameters
1	SNR	% time above SNR or #sec above SNR/total time	day, tod, event type, polarization, BW
2	SNR	"	tod, event type, polarization,BW
3	tod	"	SNR, event type, polarization,BW
4	tod	"	day, SNR, event type, polarization, BW

5	SNR	"	day, tod, frequency, polarization, BW
6	SNR	"	tod, frequency, polarization,BW
7	tod	"	SNR, frequency, polarization,BW
8	tod	"	day, SNR, frequency, polarization, BW
9	day.tod	"	SNR, event type, polarization, BW
10	day.tod	"	SNR, frequency, polarization, BW

Option 104-1: This option calculates for all frequencies the distribution of duty cycle above a signal to noise ratio. Two output formats are available: 1) number of seconds above SNR/total time or 2) duty cycle (% of time above SNR). The range of signal to noise ratios is 0 - 59 dB in increments of 1 dB. Duty cycle can be averaged over one 2 hour period or over 24 hours. Averages based on 1 day of data.

Option 104-2: This option is essentially the same as 104-1 with the exception that the averaging period is 1 month instead of one day. Figure 5 plots duty cycle as a function of signal to noise ratio for March 1989.

Option 104-3: This option calculates for all frequencies the duty cycle exceeding a SNR as a function of time of day. Two output formats are available: 1) number of seconds above SNR/total time or 2) duty cycle (% of time above SNR). The averaging period for this statistic is 1 month.

Option 104-4: This option is essentially the same as 104-3 with the exception that the averaging period is 1 day instead of 1 month.

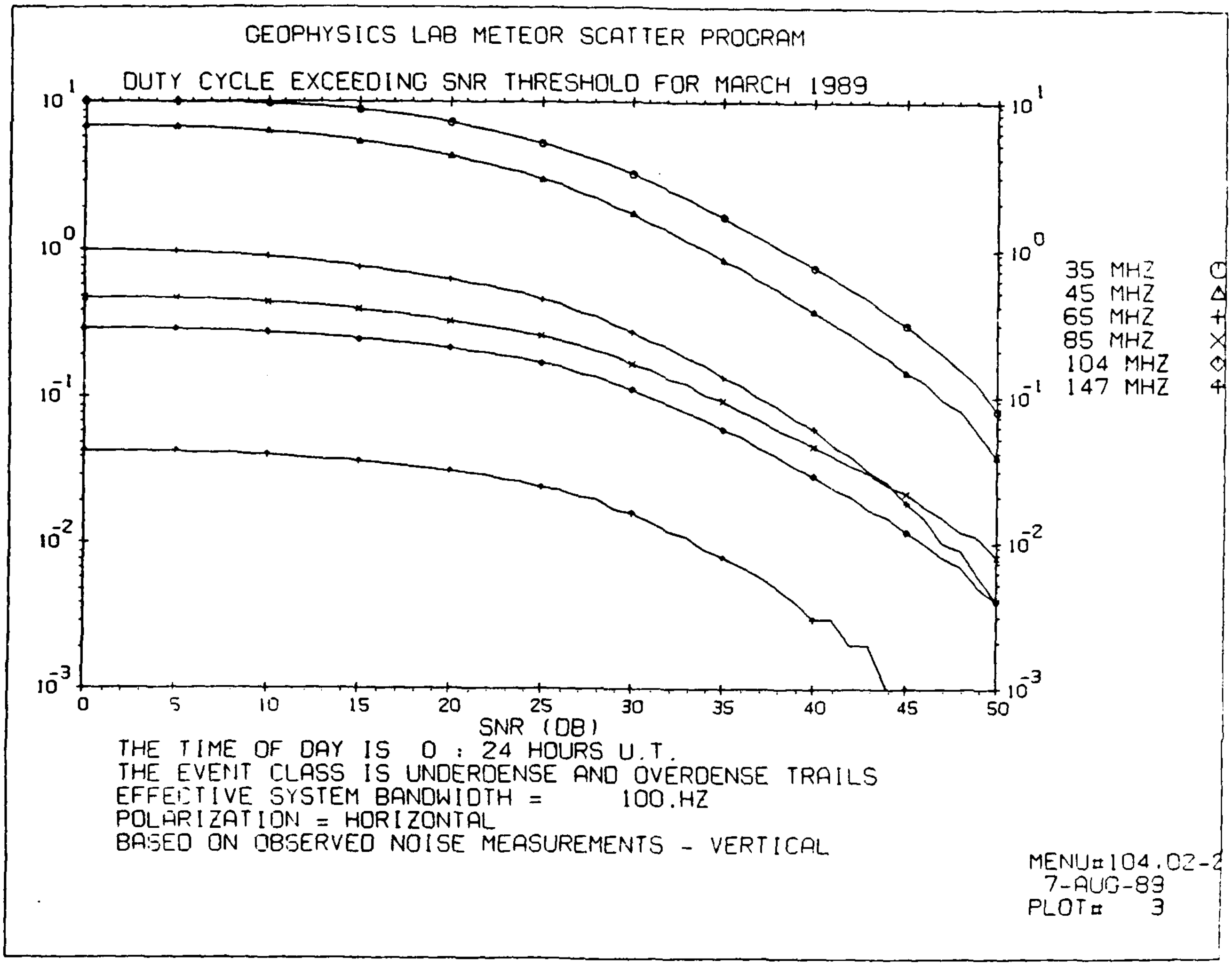

Figure 5. Statistic 104-2 Output Format 2

Option 104-5: This option is essentially the same as 104-1 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

Option 104-6: This option is essentially the same as 104-2 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

Option 104-7: This option is essentially the same as 104-3 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

Option 104-8: This option is essentially the same as 104-4 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

Option 104-9: This option calculates for all frequencies the duty cycle for each time period for the complete month. Two output formats are available: 1) number of seconds above SNR/total time or 2) duty cycle (% of time above SNR).

Option 104-10: This option is essentially the same as 4.9 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

2.3.3 Noise and Link Statistics

The link history data base provides information on the down time, measured vertical noise level, derived horizontal noise, derived vertical noise level, transmitter power and link availability.

2.3.3.1 Menu 105: Link Noise and Transmitter Statistic

Options available from the link history and noise data base are:

Op	x-Axis	y-Axis	User Specified Parameters
1	day	% time link up	
2	tod	noise temp	noise type
3	tod	noise temp.	day,,noise type
4	tod	noise figure	noise type
5	tod	noise figure	day,noise type
6	day.tod	noise temp.	noise type
7	day.tod	noise level	noise type
8	day.tod	noise figure	noise type
9	day	24 hr noise level	noisc type
10	day.tod	transmitter level	

User must specify the noise type (see Glossary). Note that noise figure is in dB relative to 290 K and absolute noise level are in the 100 Hz noise bandwidth.

Option 105-1: This option calculates for all frequencies the percentage of time the link was up for all days in the month.

Option 105-2: This option calculates for all frequencies the hourly noise temperature as a function of time of day. Averages based on 1 month of data.

Option 105-3: This option is essentially the same as 105-2 with the exception that the averaging period is 1 day instead of 1 month.

Option 105-4: This option calculates for all frequencies the hourly noise figure (dB) above 290 K as a function of time of day. Averages based on 1 month of data.

Option 105-5: This option is essentially the same as 105-4 with the exception that the averaging period is 1 day instead of 1 month.

Option 105-6: This option calculates for all frequencies the noise temperature for each time period for the complete month.

Option 105-7: This option calculates for all frequencies the noise level (dBm) for each time period for the complete month. Figure 6 plots the noise level (dBm) for each time period. Note that -200 dBm denotes that there is no noise measurement for the given period.

Option 105-8: This option calculates for all frequencies the noise figure (dB) above 290 K for each time period for the complete month.

Option 105-9: This option calculates for all frequencies the 24 hour noise level (dBm) as a function of day for the complete month.

Option 105-10: This option calculates for all frequencies the transmitter power level in watts for each time period for the complete month.

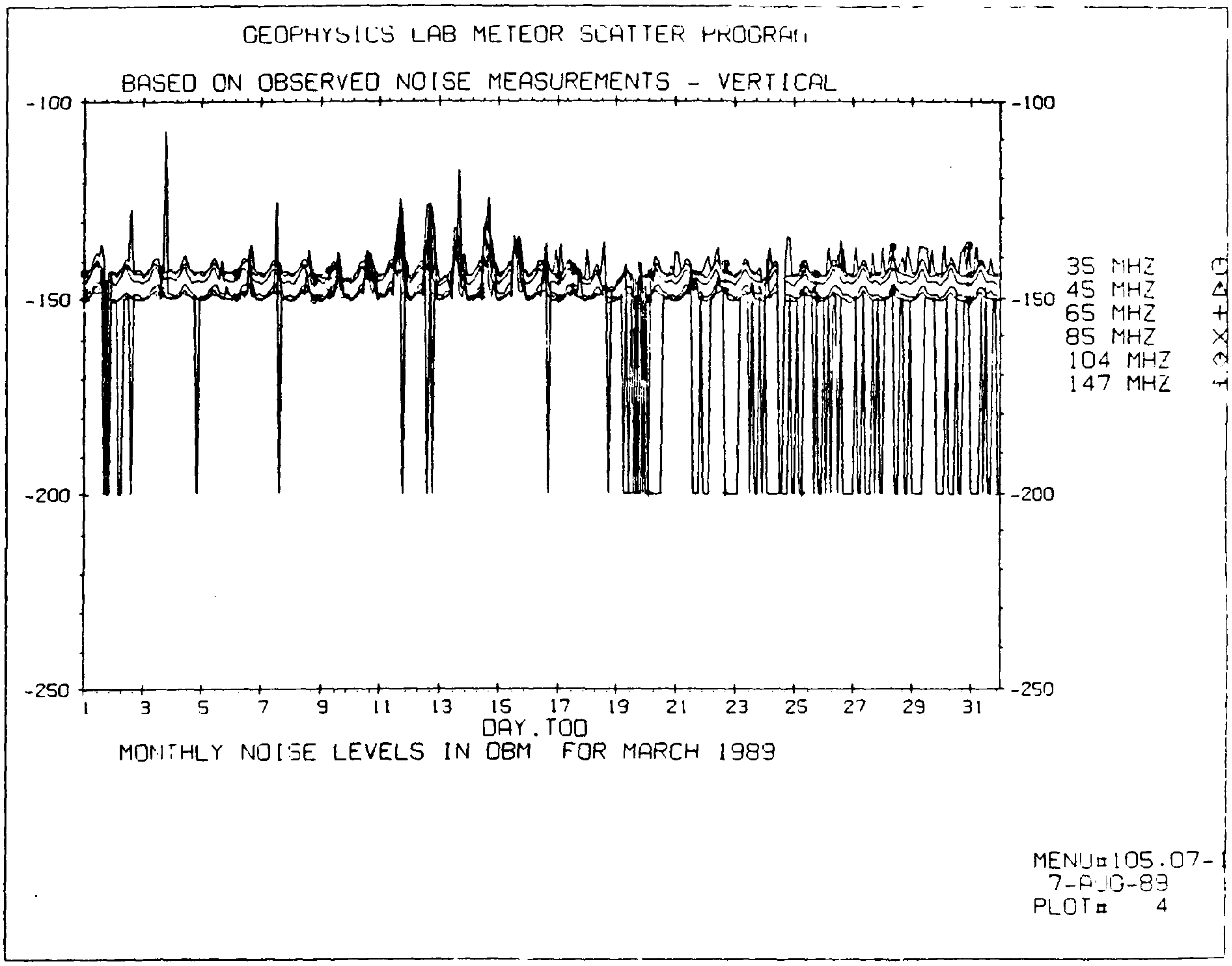

Figure 6. Statistic 105-7 Output Format 1

2.3.4 Event Duration Statistics

Duration statistics are used in both communication and propagation analysis. Duration is computed by the following method. For each meteor trail or sporadic-E event, the time at which a given signal threshold is exceeded is computed. The time at which the signal goes below the threshold or the lock flag is lost is computed. The duration above the threshold is computed. If the beginning of the next event is less than 40 ms from the end of the previous excursion, the two events are merged into one event. If the duration exceeds 4 seconds, the duration is stored as 4 seconds. This statistics is computed only for the horizontal data channel and the horizontal derived noise level is used as the base for removing noise from the signal. Three point moving averaging is used on the data. The delta t for storing durations is nonlinear. For durations between 0 and 1 second, delta-t = 25 ms. for durations greater than 1 second, delta-t = 100 ms. This minimizes storage requirements and provides increased resolution over the range for which most meteor trails occur. The nonlinear delta-t is taken into consideration in the computation of histograms. A number of different output formats are available. The user can request histograms and distribution functions in either normalized or unnormalized format.

2.3.4.1 Menu 106: Duration vs. RSL

This option computes statistics of the duration of meteor trails and Sporadic-E as a function of peak receive signal level. Analysis options are shown in the menu below:

Op	x-Axis	y-Axis	User Specified Parameters
1	duration	*histogram or distribution of durations above RSL*	*tod, RSL, event type*
2	duration	histogram or distribution of durations above RSL	tod, RSL, frequency
3	tod	average duration above RSL	RSL, event type
4	tod	average duration above RSL	RSL, frequency
5	RSL	average duration above RSL	event type, tod
6	RSL	average duration above RSL	frequency, tod
7	DIAGNOSTIC: NOT AVAILABLE TO USER		
8	Day.Tod	Average duration above RSL	RSL, event type
9	Day.Tod	Average duration above RSL	RSL, frequency

Option 106-1: This option calculates for all frequencies event durations exceeding a specified threshold. Four output formats are available: 1) unnormalized histogram, 2) unnormalized distribution, 3) normalized histogram corresponding to f(t)*delta-t, 4) normalized distribution. Note that 3) has limited meaning because the time scale is not uniform. The range of durations is 0 to 1.0 sec in increments of 0.025 sec and 1.0 to 4.0 sec in increments of 0.1 sec.

Durations can be averaged over one 2 hour period or over 24 hours. Durations based on 1 month of data. Figure 7 plots the unnormalized distribution of underdense and overdense trail durations for March 1989.

Option 106-2: This option is essentially the same as 106.1 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

Option 106-3: This option calculates for all frequencies the average duration of events exceeding a specified threshold as a function of time of day. Averages based on 1 month of data.

Option 106-4: This option is essentially the same as 106.3 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

Option 106-5: This option calculates for all frequencies the average duration of events exceeding a specified threshold as a function of RSL. The range of received signal levels is -150 dBm to -72 dBm in increments of 2 dBm. Note that the current maximum of the receiver equipment is -90 dBm. Averages based on 1 month of data.

Option 106-6: This option is essentially the same as 106-5 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

Option 106-8: This option calculates for all frequencies the average duration of events exceeding a specified threshold as a function of time of day. Averages based on each time period

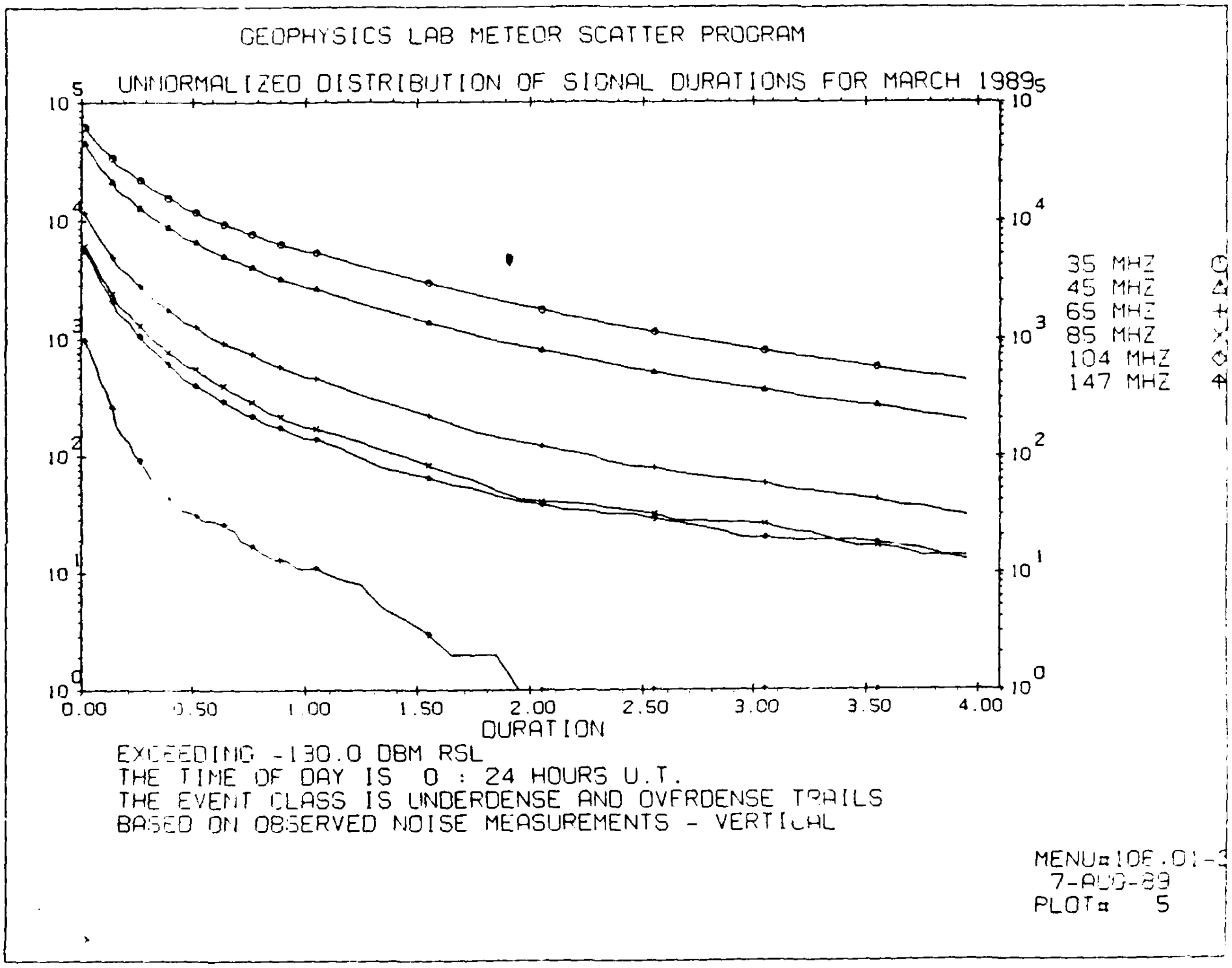

Figure 7. *Statistic 106-1 Output Format 3*

Option 106-9: This option is essentially the same as 106-3 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.). Data is presented for each time period.

2.3.4.2 Menu 107: Duration vs. SNR

This option computes statistics of the duration of meteor trails and Sporadic-E as a function of peak receive signal level. Routines in this option are equivalent to the duration vs RSL statistics with the exception that statistics are computed as a function of signal to noise ratio relative to the 100 Hz bandwidth. Analysis options are shown in the menu below:

Op	x-Axis	y-Axis	User Specified Parameters
1	duration	histogram or distribution of durations above SNR	tod, SNR, event type, BW
2	duration	histogram or distribution of durations above SNR	tod, SNR, frequency, BW
3	tod	average duration above SNR	SNR, event type, BW
4	tod	average duration above SNR	SNR, frequency, BW
5	SNR	average duration above SNR	event type, tod, BW
6	SNR	average duration above SNR	frequency, tod, BW

7	NOT IMPLEMENTED		
8	Day.Tod	Average duration above SNR	SNR, event type
9	Day.Tod	Average duration above SNR	SNR, frequency

Option 107-1: This option calculates for all frequencies event durations exceeding a specified SNR. Four output formats are available: 1) unnormalized histogram, 2) unnormalized distribution, 3) normalized histogram corresponding to f(t)*delta-t, 4) normalized distribution. Note that 3) has limited meaning because the time scale is not uniform. The range of durations is 0 to 1.0 sec in increments of 0.025 sec and 1.0 to 4.0 sec in increments of 0.1 sec. Durations can be averaged over one 2 hour period or over 24 hours. Durations based on 1 month of data.

Option 107-2: This option is essentially the same as 107-1 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

Option 107-3: This option calculates for all frequencies the average duration of events exceeding a specified SNR as a function of time of day. Averages based on 1 month of data. Figure 8 plots average trail duration exceeding 10 dB as a function of time of day for March 1989.

Option 107-4: This option is essentially the same as 107-3 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

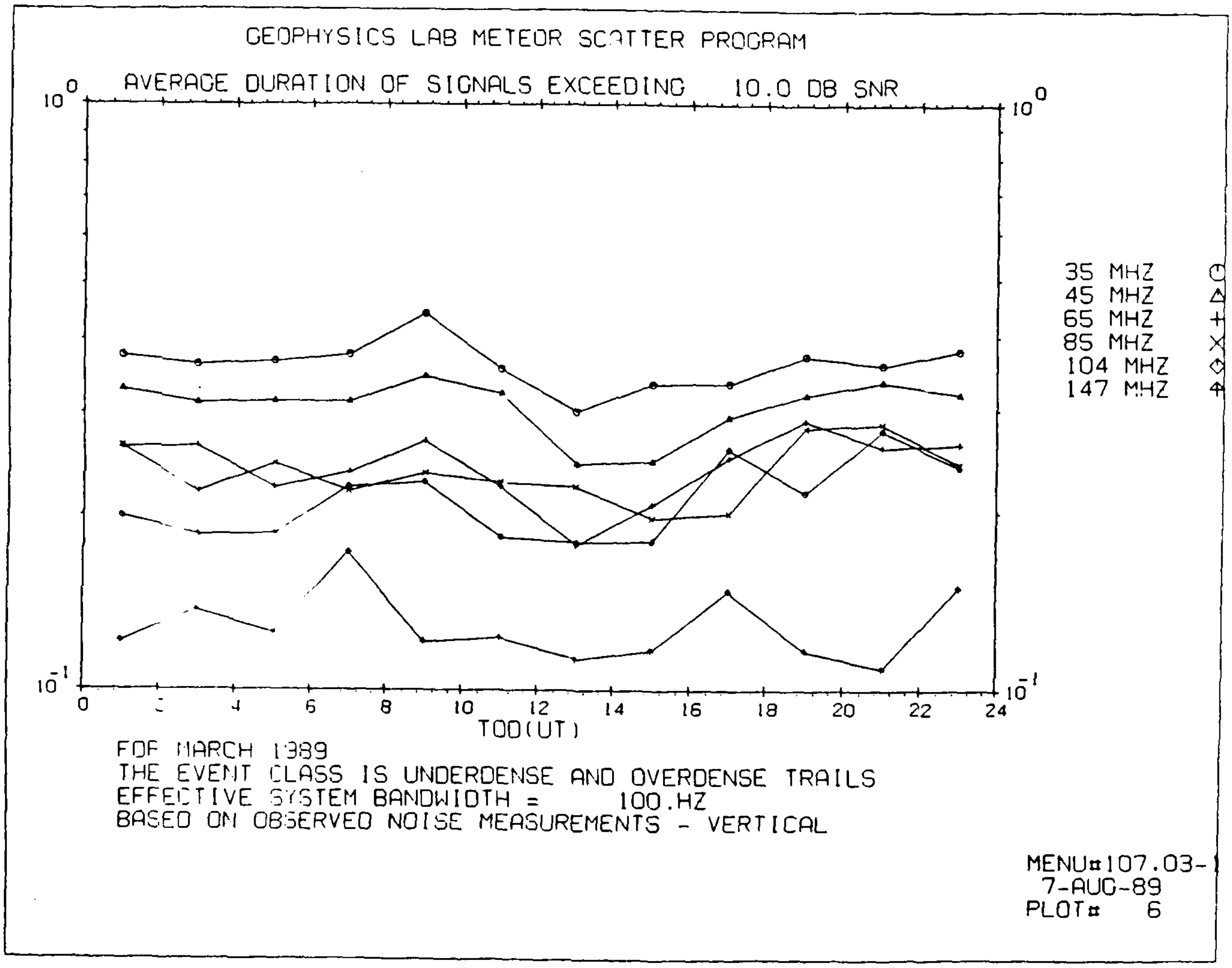

Figure 8. Statistic 107-3 Output Format 1

Option 107-5: This option calculates for all frequencies the average duration of events exceeding a specified SNR as a function of SNR. The range of signal to noise ratios is 0 dB to 59 dB in increments of 1 dB.

Option 107-6: This option is essentially the same as 107-5 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events.)

Option 107-7: This option calculates for all frequencies the average duration of events exceeding a specified SNR as a function of time of day. Averages are based on each time period.

Option 107-8: This option is essentially the same as 107-3 with the exception that statistics are calculated at one frequency for each of the event types (underdense, overdense, sporadic-E, all trails, and all events). Data is averaged over each time period.

2.3.5 Fading and Decay Statistics

Statistics of meteor trail and sporadic-E fading are of interest to both communication engineers and propagation researchers.

2.3.5.1 Menu 108: Underdense Trail Decay Statistics

Statistics of the decay of underdense meteor trails are useful for determining height distributions. During classification, the time constant for each underdense meteor trail is computed from the Minimum Mean Square Error (MMSE) fit to an exponential. Statistics are computed as a function of time of day for each day. Analysis options available are listed in the menu below.

Op	x-Axis	y-Axis	User Specified Parameters
1	time	histogram or distribution of underdense decay constants	tod
2	tod	average underdense time constants	
3	day	average underdense time constants	
4	day.tod	average underdense time constants	

Option 108-1: This option calculates for all frequencies the total number of underdense meteor trails as a function of decay time constants. Four output formats are available: 1) unnormalized histogram, 2) unnormalized distribution, 3) normalized histogram corresponding to f(t)*delta-t, and 4) normalized distribution. The range of time constants is 0.025 to 2.475 sec. in increments of 0.025 sec. Totals can be calculated over one 2 hour period or over 24 hours. Averages based on 1 month of data. Figure 9 plots an unnormalized histogram of underdense time constants for March 1989.

Option 108-2: This option calculates for all frequencies the average underdense decay time constants as a function of time of day. 24 hour average time constants are also calculated. Averages based on 1 month of data.

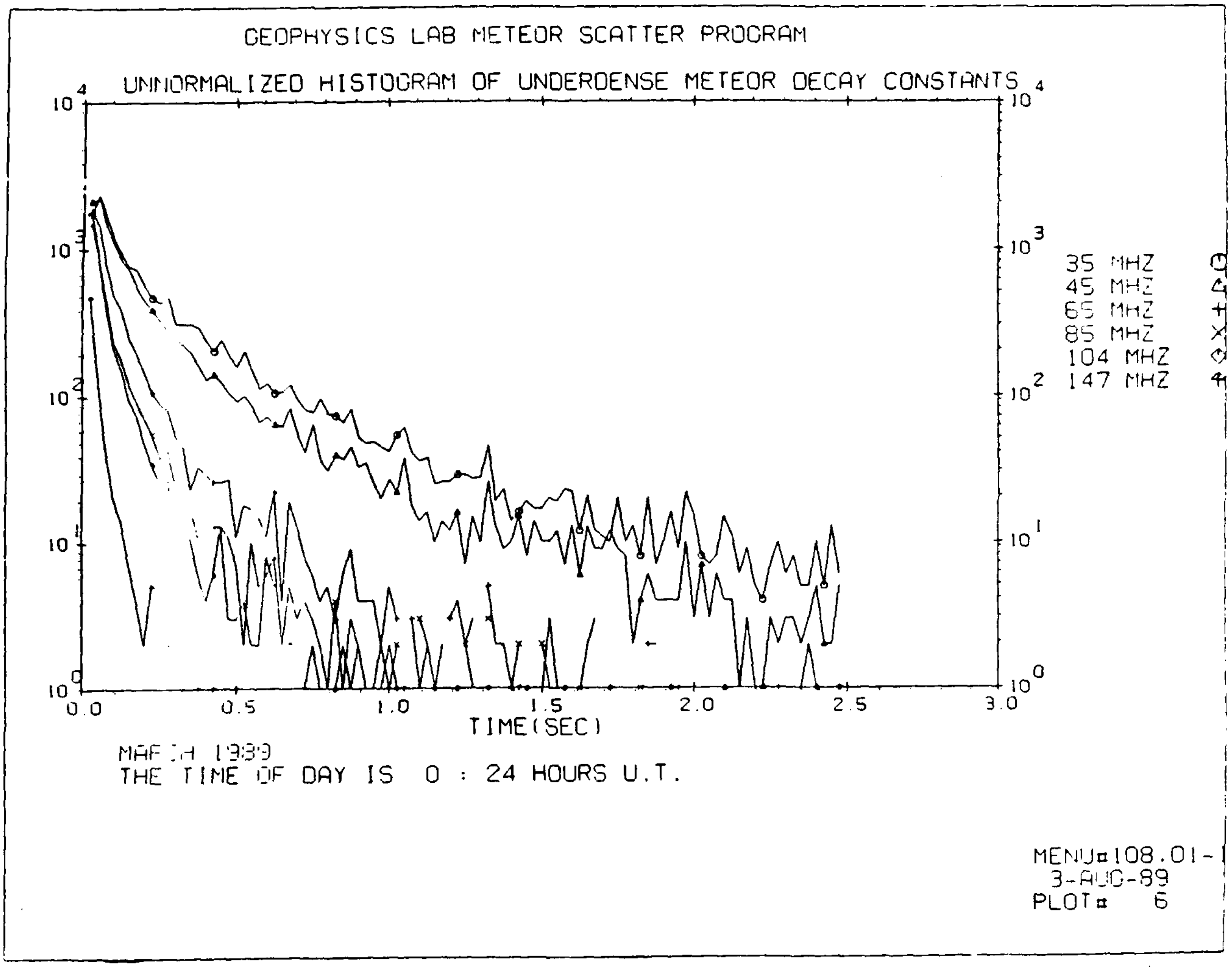

Figure 9. Statistic 108-1 Output Format 1

Option 108-3: This option calculates for all frequencies the 24 hour average underdense decay time constants as a function of day.

Option 108-4: This option calculates for all frequencies the average underdense decay time constants for each time period for the complete month.

2.3.5.2 Menu 109: Fading Statistics

A fade is said to occur when the signal to noise ratio drops in excess of 3 dB below 10 dB SNR relative to the specified bandwidth and then goes back above the threshold during the life of a trail. The thresholds considered are 10 dB (SNR) relative to 100, 300, 600, 1200, 1600, 2400, 4800, 8000, 9600, 19200, 32000, 64000, and 128,000 Hz.

Threshold above noise (dB) = $10\log(10^{((10+10\log(Bw/100))/10)}+1)$.

The 1 in the equation takes into consideration the (S+N)/N

If the duration of the fade is greater than 1 second, then we say that the event has ended and a new even begins. Fades per second are computed as the number of fades per event divided by the duration of an event.

For meteor trails three statistics are computed. 1) fades per trail, 2) fades per second of event duration, and 3) distribution of fade durations. For Sporadic-E, only the latter two statistics are available and meaningful.

Option	x-Axis	y-Axis	Other Parameters
1	Fades/sec	Histogram of Distribution of Fades/second	tod, event type, BW
2	Fades/sec	Histogram or Distribution of Fades/second	tod, frequency, BW
3	Fades	Histogram or Distribution of Fades/trail	tod, event type, BW
4	Fades	Histogram or Distribution of Fades/trail	tod, frequency, BW
5	Duration	Histogram or Distribution of Fade Duration	tod, event type, BW
6	Duration	Histogram or Distribution of Fade Duration	tod, frequency, BW
7	tod	Average Fades/sec	event type, BW
8	tod	Average Fades/sec	frequency, BW
9	tod	Average Fades/trail	event type, BW
10	tod	Average Fades/trail	month, frequency, BW
11	tod	Average Fade Duration	month, event type, BW

12	tod	Average Fade Duration	month, frequency, BW

Option 109-1: This option produces histograms or distributions of fades/second for each of the six frequencies. User specifies the output format and the event type.

Option 109-2: This option produces histograms or distributions of fades/second for each of the event types. User specifies the output format and the frequency.

Option 109-3: This option produces histograms or distributions of fades/trail for each of the six frequencies. User specifies the output format and the event type. Figure 10 plots a histogram of fades per trail.

Option 109-4: This option produces histograms or distributions of fades/trail for each of the event types. User specifies the output format and the frequency.

Option 109-5: This option produces histograms or distributions of fade durations for each of the six frequencies. User specifies the output format and the event type.

Option 109-6: This option produces histograms or distributions of fade durations for each of the event types. User specifies the output format and the frequency. Figure 11 plots histogram of fade durations using this statistic.

Option 109-7: Computes average fades per second for each of the six frequencies. The user specifies the event type and the bandwidth.

Option 109-8: Computes average fades per second for each of the six frequencies. The user specifies the event type and the bandwidth.

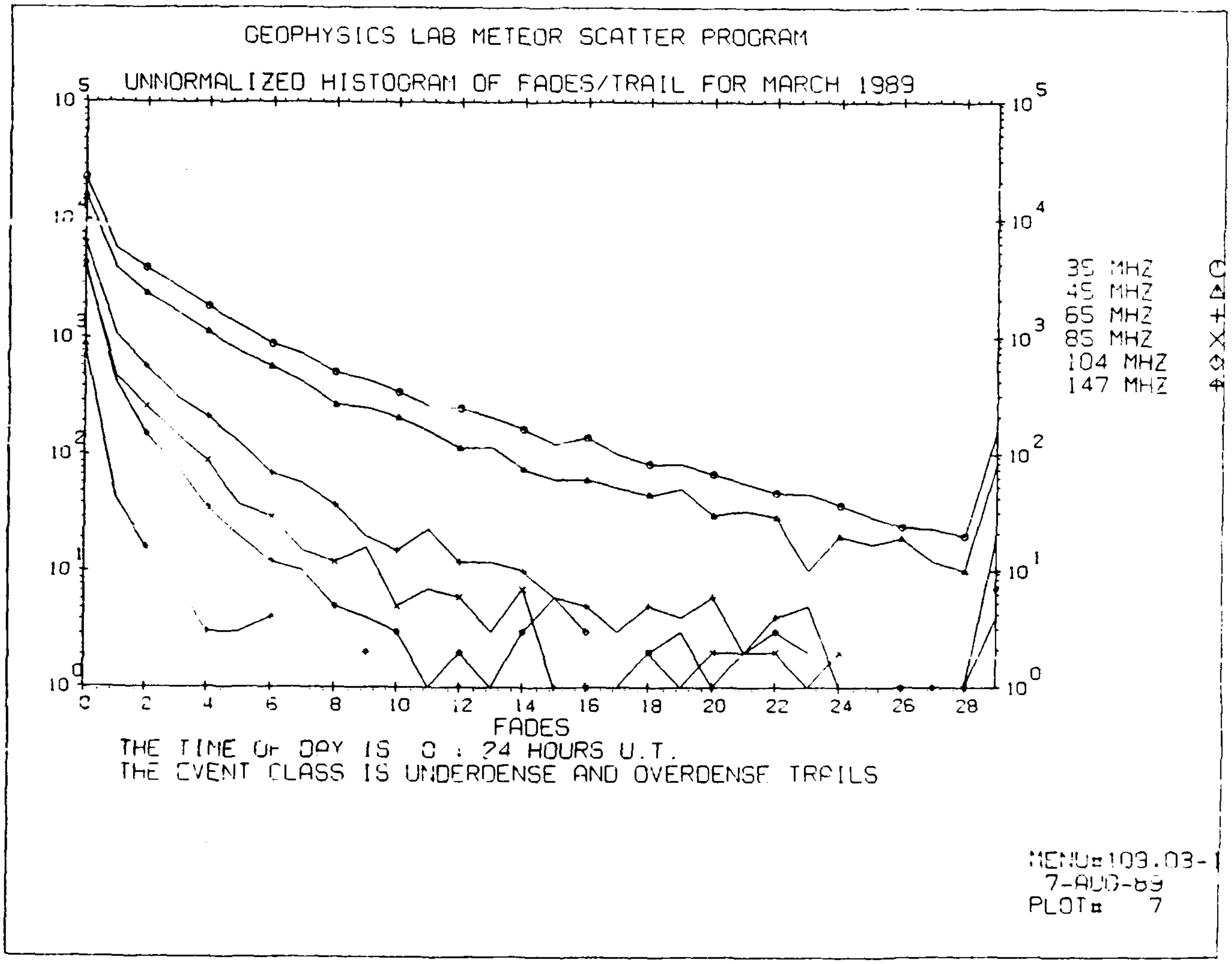

Figure 10. Statistic 109-3 Output Format 1

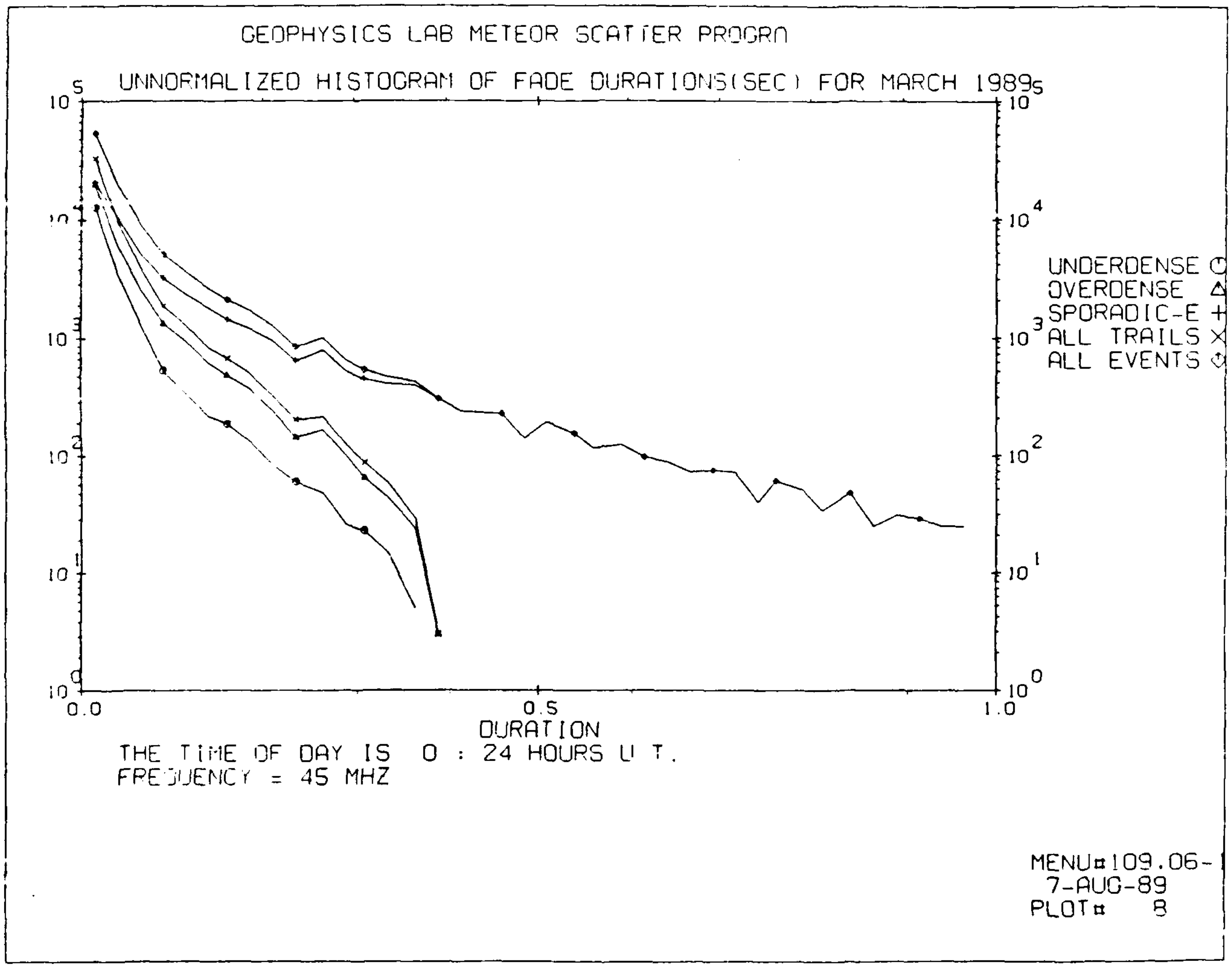

Figure 11. Statistic 109-6 Output Format 1

Option 109-9: Computes the average number of fades per meteor trail as a function of the frequency and the bandwidth. output is presented for each type of trail

Option 109-10: Computes the average number of fades per meteor trail as a function of the event type and the bandwidth. output is presented for each six frequencies.

Option 109-11: Computes the average fade duration as a function of time of day. Output is presented for each type of event. The user specifies the bandwidth and frequency.

Option 109-12: Computes the average fade duration as a function of time of day. Output is presented for each type of event. The user specifies the bandwidth and frequency.

2.4 Communication Statistics

In order to predict the performance of a communication system given the detailed propagation statistics collected on the link, a series of routines have been developed. There are a number of assumptions built into the calculations which must be explained.

It is assumed that the noise is additive white Gaussian. Thresholds for communication are based on descriptions of Oetting [1980] and Proakis [1988]. No multipath is assumed in the channel. Infinite transmission bandwidth is assumed and the effective receive bandwidth is 1 symbol/Hz. The following table lists the required SNR normalized to a symbol rate of 1 symbol /sec as a function of bit error rate for the various modulations. Recall that for 2-PSK, 2-DPSK (differentially coherent), 2-FSK(non-coherent) and 2-FSK (coherent) there is 1 bit/symbol. For QPSK,MSK there are two bits/symbol and for 8-PSK there are 3 bits/symbol. E_b/N_o can be inferred from the SNR/Symbol by subtracting the 10log(bits/symbol). In each of these statistics, the user has the option to specify which noise measurement they wish to use. Data rate is computed in bits/ second and the symbol rate is computed from data rate/bits/symbol. SNR/Symbol used in calculations.

BER	2PSK	4-PSK	MSK	8-PSK	2FSK(nc)	2FSK(c)	2DPSK
10^{-2}	4.3	7.3	7.3	12.64	8.9	7.3	5.9
10^{-3}	6.73	9.73	9.73	15.07	10.93	9.73	7.93
10^{-4}	8.4	11.4	11.4	16.57	12.13	11.4	9.3
10^{-5}	9.6	12.6	12.6	17.87	13.34	12.61	10.34
10^{-6}	10.56	13.56	13.56	18.4	14.85	13.56	11.18

In some routines the user is required to specify the message structure. Initialization time is the time required to establish the protocol handshake and acquire carrier in coherent systems. One initialization time is required per transmission. Packet length is the total packet length in bits, including message and overhead. Overhead is defined as anything in a packet which is not message. Fixed packet lengths (in bits) are assumed.

Communication statistics are computed as a function of time of day, data rate, packet structure, etc. At high data rates, performance as a function of packet length (bits) is of limited value since the difference in trail duration is very small, often less than the resolution of the data bases.

The first set of routines (menu 201, 202) compute the average throughput assuming a variable data rate adaptive system which adapts on a packet by packet basis modeling a more realistic system. User specifies an initialization time, packet size (bits), number of overhead bits, bit error rate, data rate and modulation type. This statistic is computed based on the duration data base. Since the duration data base is used, 40 ms fade merging is assumed. Throughput is computed as follows. For each 2 dB signal increment, the data rate supported given the modulation, noise level and bit error rate is computed. For each duration above the SNR, the number of packets which could be sent is multiplied by the number of events observed. Throughput is defined as the number of message packets which could be sent over the channel summed over all event durations and all data rates (signal thresholds) divided by the total time. For meteor trails, the down time (see Glossary) has been removed. Because the integration is over signal levels and durations, these statistics are computationally and disk access intensive.

The second set of routines (menu 203, 204) compute the capacity in the channel assuming an infinitely adaptive system which can adapt on a bit by bit basis to the dynamic channel conditions. This statistic represents an upper bound on the throughput performance. Statistics are inferred from the duty cycle data base. The user may specify the maximum data rate to consider. If the data rate that the channel will support exceeds the maximum data rate, the maximum is assumed. This statistic can be computed for either vertical or horizontal channels. Throughput is computed as follows. For each 2 dB signal increment, the data rate supported given the modulation, noise level and bit error rate is computed. Throughput is defined as the duty cycle above signal threshold between levels N and N+1 multiplied by the average data rate supported by levels N and N+1. Levels are integrated to compute the total throughput. For meteor trails, the down time (see Glossary) has been removed from the duty cycle calculations.

NOTE: The conditions for menu 201 and 202 are essentially the same as for statistics 203 and 204 with no overhead and small packet duration. There may be some difference in the output due to different data bases used to compute the statistics. Recall that the duration data base used for the latter routines has inherent 40 ms fade merging. This effectively increases the duty cycle above a given threshold. For this reason, the output of statistics 201 and 202 may be somewhat pessimistic relative to 203 and 204. The only reason to even use the former set of routines is that they can access both vertical and horizontal data and are useful in Cross polarization calculations. Otherwise use 203 and 204 with 0 initialization time, 1 bit packet length and no overhead.

The third set of routines (205, 206) compute the throughput assuming a fixed data rate system with a data packet format. User specifies an initialization time, packet size (bits), number of overhead bits, bit error rate, data rate and modulation type. This statistic is based on the duration data base. Since the duration data base is used, 40 ms fade merging is assumed. Throughput is computed as follows: The minimum signal level required to support the data rate at the specified BER is computed given the noise level for each hour. For each duration above the threshold, the number of packets which could be sent is computed. Throughput is the sum over all durations of the number of message packets multiplied by the number of message bits per packet divided by the total time available. For meteor trail statistics down time (see Glossary) has been removed from the total time.

The fourth routine type (207) computes the waiting time to deliver a message for a fixed rate system with a given confidence. Two options are considered; message piecing and single trail transmission. Single trail transmission requires that the entire message be sent over one trail while message piecing allows a message to be broken up into packets which can be sent over more than one trail. The statistics uses the duration data base and includes automatic 40 ms fade merging.

Single trail transmission: The first step is to compute the arrival rate of trails which are long enough to support transmission of the message at the specified bit error rate. Given the data rate, bit error rate, the modulation type and the noise, the minimum signal threshold is computed. The number of trails exceeding the threshold with duration longer than the minimum required to send one message is computed. The number of trails is divided by the total time to compute the arrival rate. Down time is removed from the total time (see glossary). Assuming trails arrive according to Poisson Statistics, the delivery time can be computed from

$$\text{Delivery time} = -\lambda \ln(1 - \text{Confidence})$$

where λ is the average arrival rate of trails capable of supporting message transmission.

<u>Message piecing</u>: For this case an exact closed form solution is not possible and a number of assumptions are required. The first step is to compute the average arrival rate of trails which can support an minimum of 1 packet plus the initialization time given the data rate, noise, and specified bit error rate. Let this arrival rate be x_0. We also compute the average duration of trails which exceed the minimum threshold. Let the average duration of meteor trails be t_0. In addition we compute the number of packets required to send the messages n. Let the duration of a packet including overhead be t_p. The maximum number of trails required to send the message is n and the minimum number of trails required is 1.Let $t_m = nt_p$. The probability that a message can be delivered in a time t_d is given by

$$P(\text{Delivery in } t_d) = \sum_{\text{ntrails}=1}^{n} P(\text{ntrails in } t_d)P(\text{ntrails sum to } (t_m - \text{ntrails } t_p)$$

$$+ \sum_{\text{ntrails}=n+1}^{\infty} P(\text{ntrails in})$$

The total excess duration required in the n trails is (t_m-ntrails t_p) since by definition, each trail considered can support at least 1 data packet. In the second summation, 0 excess time is required since there are at least n usable trails. The probability that there are exactly j in a time t_d is given from Poisson statistics as

$$P(\text{ntrails } t_d) = \frac{e^{-x_0 t_d}}{j!}\left(x_0 t_d\right)^j$$

In order to calculate the probability that the total duration of the n trails sums to (t_m-ntrails t_p), we need to make an assumption without which there is no hope of obtaining a solution. Assume that trail duration is exponentially distributed with average t_0. Making this assumption the probability that n trails will have total duration in excess of t_m is given by Erlang's formula as

$$P(\text{ntrails sum to } (t_m\text{-ntrails } t_p)\text{sec}) = \Gamma(\text{ntrails}, t_m\text{-ntrails})$$

where $\Gamma(n,x)$ is the incomplete Gamma function with appropriate scale factors and average duration t_0. To solve for t_d given the specified confidence we use an iterative method which homes in on the minimum t_d such that the confidence is satisfied.

NOTE: This method becomes more accurate as the number of packets in the message increases. For small numbers of packets, the results are not as accurate. This is an approximation and should be considered as such. Because the computation requires an iterative homing solution method, this calculation is computationally intensive.

2.4.1 Menu 201: Data Rate with Infinitely Adaptive System (All Events)

This statistic computes the capacity in the channel assuming an infinitely adaptive system which can adapt on a bit by bit basis to the dynamic channel conditions. This statistic represents an upper bound on the throughput performance. Statistics are inferred from the duty cycle data base. The user may specify the maximum data rate to consider. If the data rate that the channel will support exceeds the maximum data rate, the maximum is assumed. Output from this statistics is presented for each type of event and the user specifies the frequency. Analysis options are listed below:

Op	x-Axis	y-Axis	User Specified Parameters
1	tod	throughput	BER, modulation, max data rate, month, frequency, polarization
2	tod	throughput	BER, modulation, max data rate, month, day, frequency, polarization
3	NOT IMPLEMENTED		
4	day.tod	throughput	BER, modulation, max data rate, month, frequency, polarization
5	day	throughput	BER, modulation, max data rate, tod, frequency, polarization
6	day	throughput	BER, modulation, max data rate, frequency, polarization
7	NOT IMPLEMENTED		
8	d-rate	throughput	BER, modulation, max data rate, frequency, polarization

Option 201-1: This option calculates for all event types the average capacity (bits/sec) as a function of time of day. Averages based on 1 month of data. Figure 12 shows output using this statistic. Link conditions for the calculation are indicated on the plot.

Option 201-2: This option is essentially the same as 201-1 with the exception that data is averaged over 1 day instead of 1 month.

Option 201-3: NOT IMPLEMENTED AT THIS TIME

Option 201-4: This option calculates for all event types the average capacity (bits/sec) for each time period for the complete month.

Option 201-5: This option calculates for all event types the average capacity (bits/sec) as a function of day. Capacity can be averaged over one 2 hour period or over 24 hours.

Option 201-6: This option calculates for all event types the average capacity (bits/sec) as a function of day. Capacity averaged over all 12 daily time periods.

Option 201-7: NOT IMPLEMENTED AT THIS TIME.

Option 201-8: This option calculates for all event types the average capacity (bits/sec) as a function of data rate. The range of data rates is 0 - 2000 Kbps in increments of 5 Kbps. Averages based on 1 month of data.

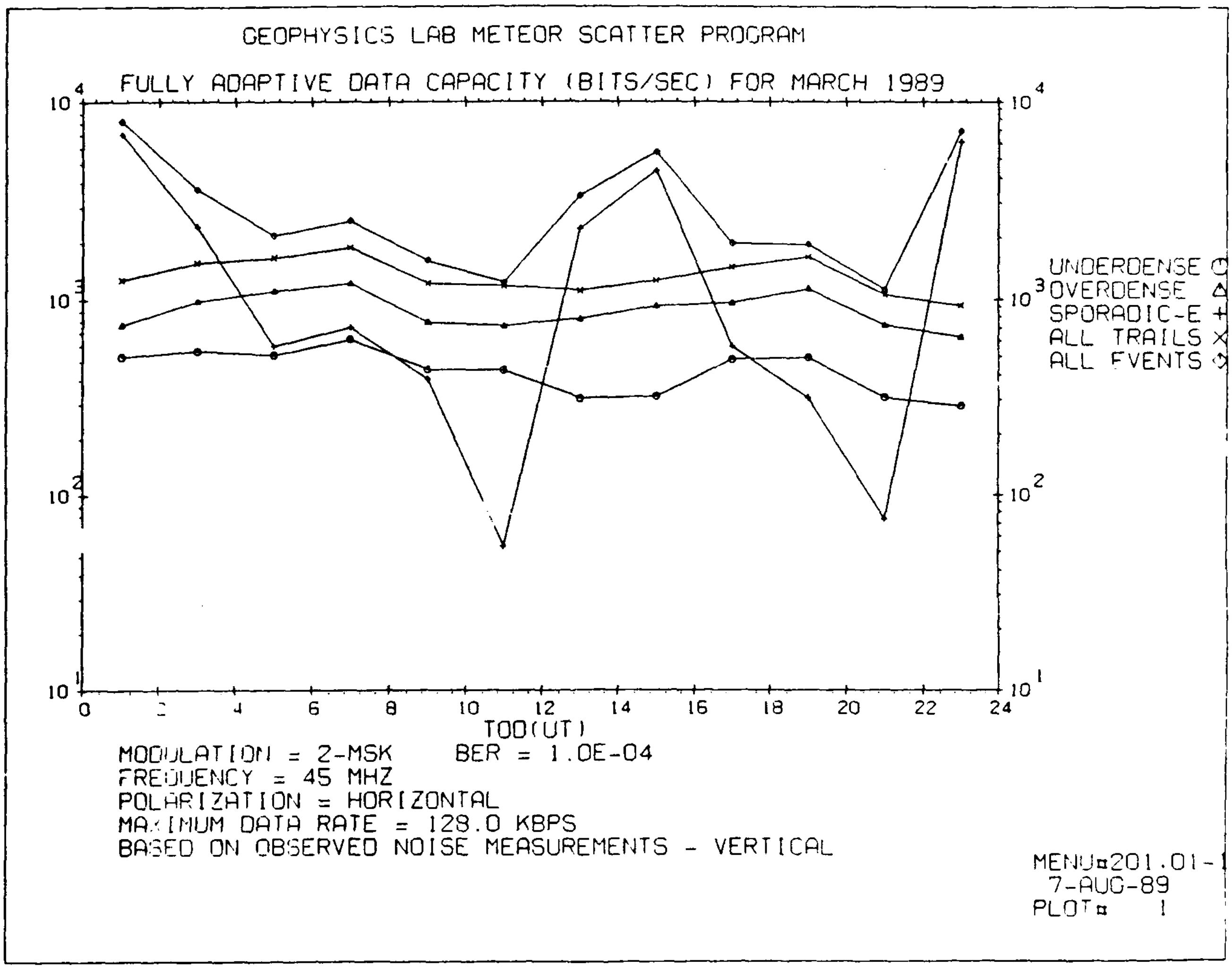

Figure 12. Statistic 201-1 Output Format 1

2.4.2 Menu 202: Data Rate with Infinitely Adaptive System (All Frequencies)

These statistics are equivalent to the previous statistics with the exception that statistics are computed for all frequencies for the specified event type (underdense, overdense, sporadic-E, all trails, and all events). Analysis options are listed below:

Op	x-Axis	y-Axis	User Specified Parameters
1	tod	throughput	BER, modulation, max data rate, event type, polarization
2	tod	throughput	BER, modulation, max data rate, day, event type, polarization
3	NOT IMPLEMENTED		
4	day.tod	throughput	BER, modulation, max data rate, event type, polarization
5	day	throughput	BER, modulation, max data rate, tod, event type, polarization
6	day	throughput	BER, modulation, max data rate, event type, polarization
7	NOT IMPLEMENTED		
8	d-rate	throughput	BER, modulation, max data rate, event type, polarization

Option 202-1: This option calculates for all frequencies the average capacity (bits/sec) as a function of time of day. Averages based on 1 month of data.

Option 202-2: This option is essentially the same as 202-1 with the exception that data is averaged over 1 day instead of 1 month.

Option 202-3: NOT IMPLEMENTED AT THIS TIME

Option 202-4: This option calculates for all frequencies the average capacity (bits/sec) for each time period for the complete month.

Option 202-5: This option calculates for all frequencies the average capacity (bits/sec) as a function of day. Capacity can be averaged over one 2 hour period or over 24 hours.

Option 202-6: This option calculates for all frequencies the average capacity (bits/sec) as a function of day. Capacity averaged over all 12 daily time periods.

Option 202-7: NOT IMPLEMENTED AT THIS TIME.

Option 202-8: This option calculates for all frequencies the average capacity (bits/sec) as a function of data rate. The range of data rates is 0 - 2000 Kbps in increments of 5 Kbps. Averages based on 1 month of data. Figure 13 an unnormalized histogram of data rates supported by the link for march 1989.

2.4.3 Menu 203: Data Rate with Infinitely Adaptive System. Includes Effects of Overhead and Initialization Time (For All Events)

These statistics are equivalent to the previously described statistics with the exception that statistics are computed for all event types (underdense, overdense, sporadic-E, all trails, and all events). Analysis options are listed below:

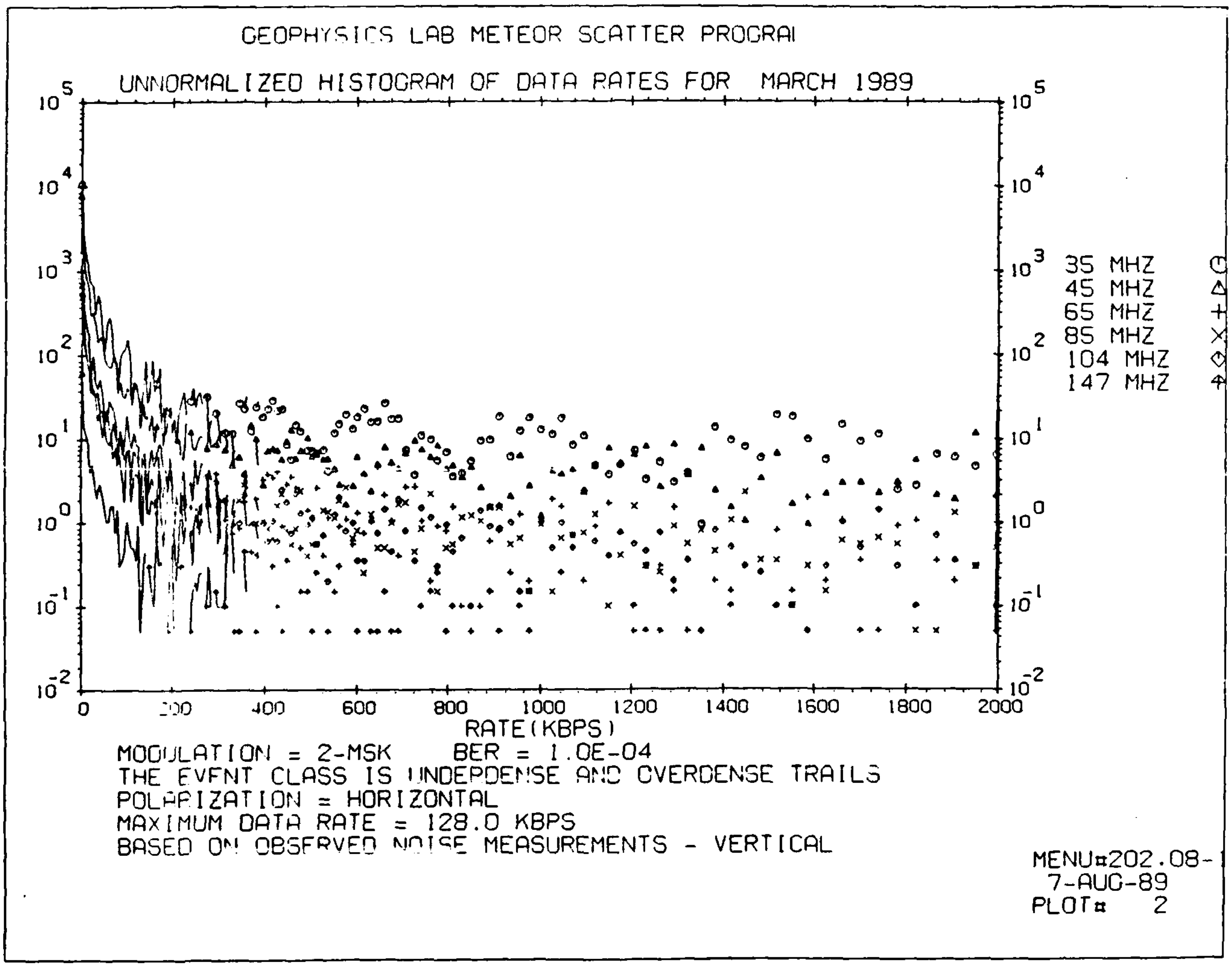

Figure 13. Statistic 202-8 Output Format 1

Op	x-Axis	y-Axis	User Specified Parameters
1	tod	throughput	BER, modulation, max data rate, packet size, initialization time, frequency, overhead bits
2	tod	throughput	BER, modulation, max data rate, packet size, initialization time, day, frequency, overhead bits
3	NOT IMPLEMENTED		
4	day.tod	throughput	BER, modulation, max data rate, packet size, initialization time, frequency, overhead bits
5	day.tod	throughput	BER, modulation, max data rate, packet size, initialization time, tod, frequency, overhead bits
6	day	throughput	BER, modulation, max data rate, packet size, initialization time, frequency, overhead bits

Option 203-1: This option calculates for all event types the average capacity (bits/second) as a function of time of day. Averages based on 1 month of data.

Option 203-1: This option is essentially the same as 203-1 with the exception that the data is averaged over 1 day instead of 1 month. Figure 14 shows output using this statistic

Option 203-3: NOT IMPLEMENTED AT THIS TIME.

Option 203-4: This option calculates for all event types the capacity (bps) for all days of the month.

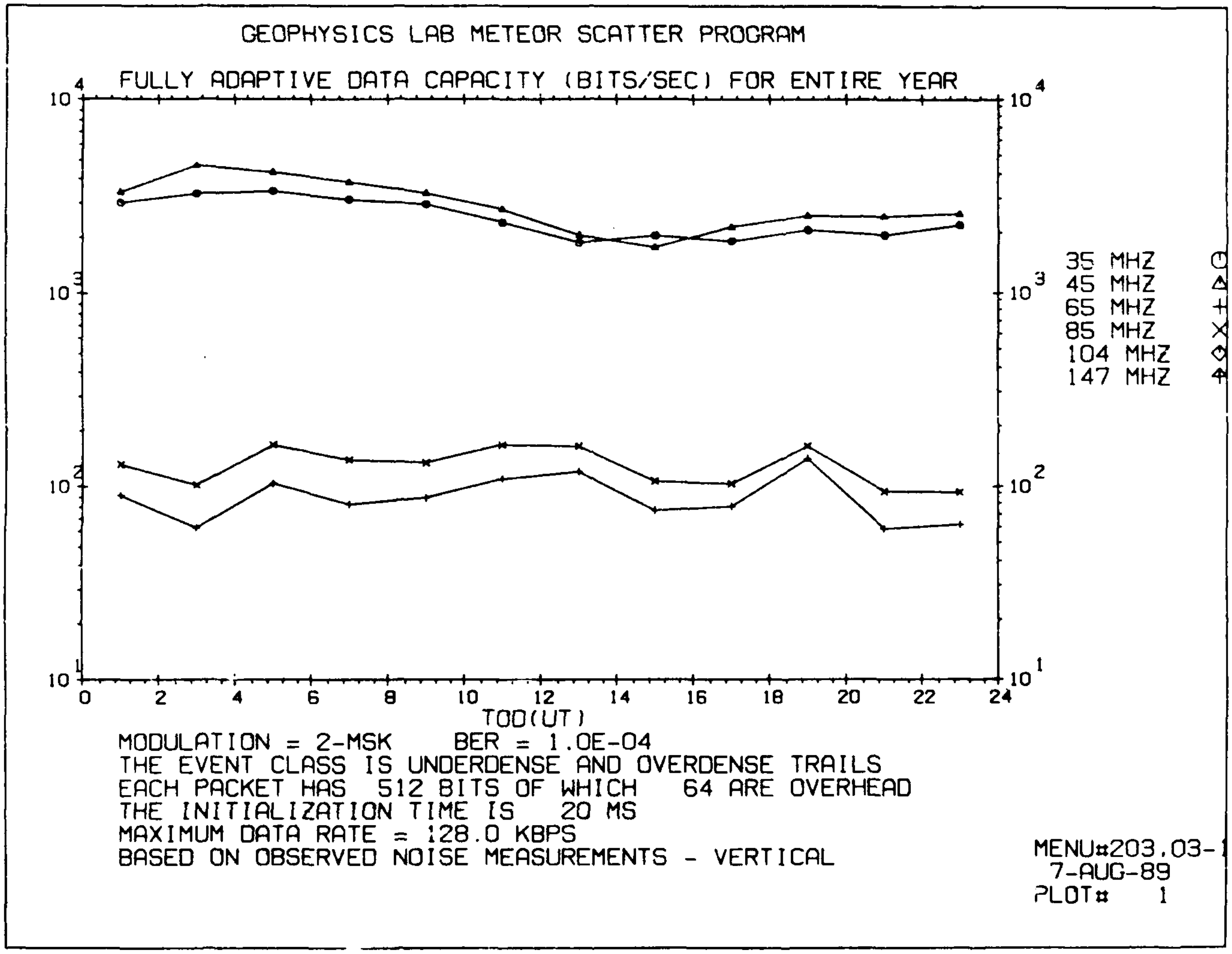

Figure 14. Statistic 203-3 Output Format 1

Option 203-55: This option calculates for all event types the average capacity (bits/second) for all days of the month. Capacity can be averaged over one 2 hour period or over 24 hours.

Option 203-6: This option calculates for all event types the 24 hour average capacity (bits/second) for all days of the month.

2.4.4 Menu 204: Data Rate with Infinitely Adaptive System. Includes Effects of Overhead and Initialization Time (For All Frequencies)

This set of routines compute the throughput assuming an infinitely adaptive system which adapts on a packet by packet basis. This user specifies bit-error-rate, modulation type, packet size, overhead and initialization time. This statistic accesses the duration and noise history data bases. Analysis options are listed below:

Op	x-Axis	y-Axis	User Specified Parameters
1	tod	throughput	BER, modulation, max data rate, packet size, initialization time, event type, overhead bits
2	tod	throughput	BER, modulation, max data rate, packet size, initialization time, day, event type, overhead bits
3	NOT IMPLEMENTED		
4	day.tod	throughput	BER, modulation, max data rate, packet size, initialization time, event type, overhead bits
5	day.tod	throughput	BER, modulation, max data rate, packet size, initialization time, tod, event type, overhead bits

6	day	throughput	BER, modulation, max data rate, packet size, initialization time, event type, overhead bits

Option 204-1: This option calculates for all frequencies the average capacity (bits/second) as a function of time of day. Averages based on 1 month of data. Figure 15 plots capacity as a function of time of day for March 1989 using this statistic option.

Option 204-2: This option is essentially the same as 204-1 with the exception that the data is averaged over 1 day instead of 1 month.

Option 204-3: NOT IMPLEMENTED AT THIS TIME.

Option 204-4: This option calculates for all frequencies the average capacity (bits/second) for all days of the month.

Option 204-5: This option calculates for all frequencies the average capacity (bits/second) for all days of the month. Capacity can be averaged over one 2 hour period or over 24 hours.

Option 204-6: This option calculates for all frequencies the 24 hour average capacity (bits/second) for all days of the month.

2.4.5 Menu 205: Data Rate with Fixed Rate System (All Frequencies)

This routine routine computes the throughput assuming a fixed data rate system with a data packet format. This statistic is based on the duration data base. Routines include effects due to: bit-error-rate, modulation type, packet size, overhead, data rate, and initialization time. Analysis options are listed below:

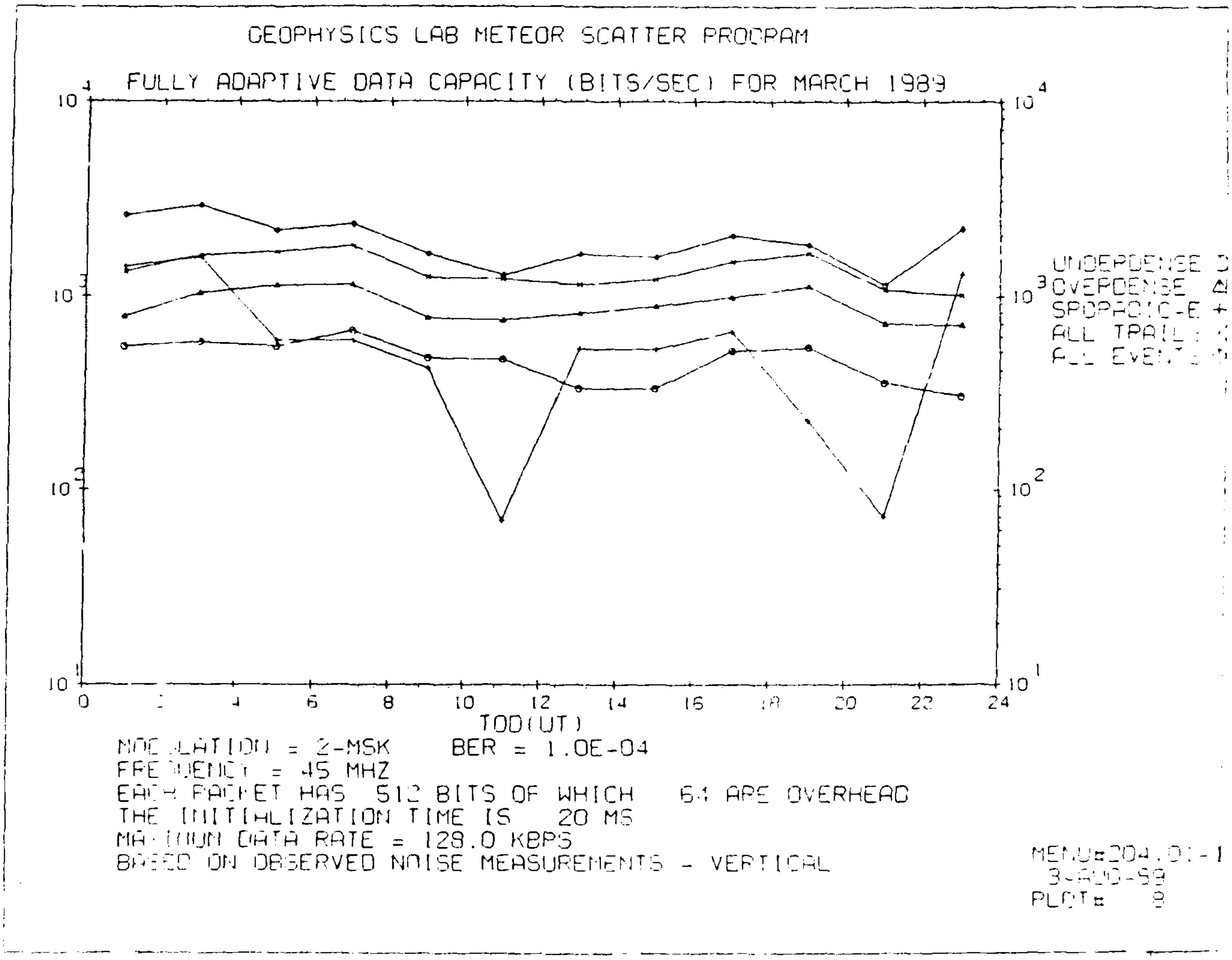

Figure 15. Statistic 204-1 Output Format 1

Op	x-Axis	y-Axis	User Specified Parameters
1	tod	throughput	BER, modulation, overhead bits, packet size, initialization time, rate, event type
2	packet size	throughput	BER, modulation, overhead bits, initialization time, rate, tod, event type
3	data rate	throughput	BER, modulation, overhead bits, packet size, initialization time, tod, event type
4	day.tod	throughput	BER, modulation, overhead bits, packet size, initialization time, rate, event type
5	day	throughput	BER, modulation, overhead bits, packet size, initialization time, rate, tod, event type

Option 205.1: This option calculates for all frequencies the average capacity (bits/second) as a function of time of day. Averages based on 1 month of data.

Option 205.2: This option calculates for all frequencies the average capacity (bits/second) as a function of packet size. The range of packet sizes is 100 to 4000 bits in increments of 100 bits. Capacity can be averaged over one 2 hour period or over 24 hours. Averages based on 1 month of data.

Option 205-3: This option calculates for all frequencies the average capacity (bits/second) as a function of data rate. The range of data rates is 1 - 10, 10 -100, and 100 - 900 KBPS. Capacity can be averaged over one 2 hour period or over 24 hours. Averages based on 1 month of data. Figure 16 shows sample output using this statistic.

Option 205-4: This option calculates for all frequencies the average capacity (bits/second) for each time period for the complete month.

Option 205-5: This option calculates for all frequencies the average capacity (bits/second) for each day of the month. Capacity can be averaged over one 2 hour period or over 24 hours.

2.4.6 Menu 206: Data Rate with Fixed Rate System (All Events)

These statistics are equivalent to the previously described statistics with the exception that statistics are computed for all event types (underdense, overdense, sporadic-E, all trails, and all events). Analysis options are listed below:

Op	x-Axis	y-Axis	User Specified Parameters
1	tod	throughput	BER, modulation, overhead bits, packet size, initialization time, rate, frequency
2	packet size	throughput	BER, modulation, overhead bits, initialization time, rate, tod, frequency
3	data rate	throughput	BER, modulation, overhead bits, packet size, initialization time, tod, frequency
4	day.tod	throughput	BER, modulation, overhead bits, packet size, initialization time, rate, frequency

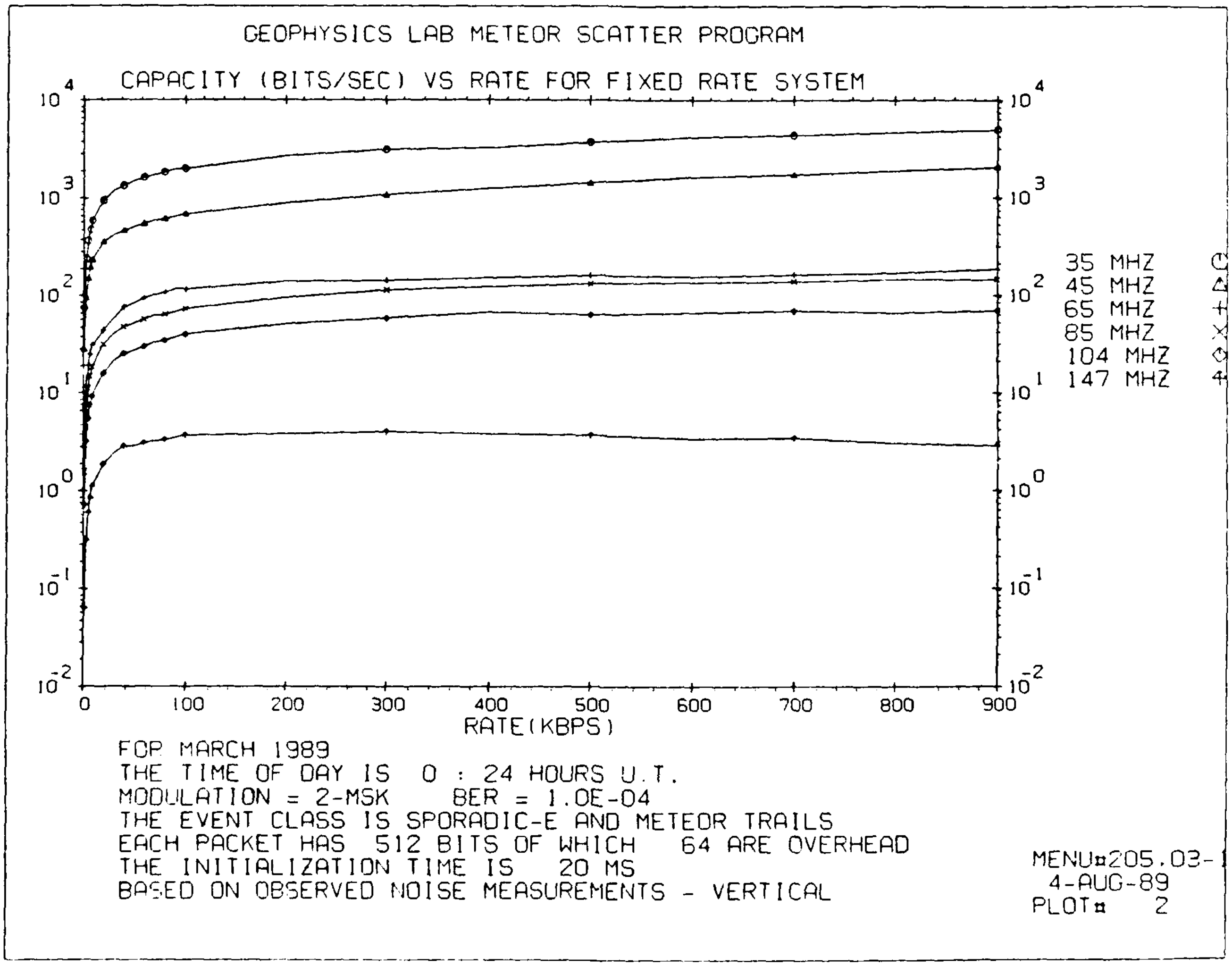

Figure 16. Statistic 205-3 Output Format 1

5	day	throughput	BER, modulation, overhead bits, packet size, initialization time, rate, tod, frequency

Option 206-1: This option calculates for all event types the average capacity (bits/second) as a function of time of day. Averages based on 1 month of data

Option 206-2: This option calculates for all event types the average capacity (bits/second) as a function of packet size. The range of packet sizes is 100 to 4000 bits in increments of 100 bits. Capacity can be averaged over one 2 hour period or over 24 hours. Averages based on 1 month of data.

Option 206-3: This option calculates for all event types the average capacity (bits/second) as a function of data rate. The range of data rates is 1 - 10, 10 -100, and 100 - 900 KBPS. Capacity can be averaged over one 2 hour period or over 24 hours. Averages based on 1 month of data.

Option 206-4: This option calculates for all event types the average capacity (bits/second) for each time period for the complete month.

Option 206-5: This option calculates for all event types the average capacity (bits/second) for each day of the month. Capacity can be averaged over one 2 hour period or over 24 hours. Figure 17 shows sample output using this statistic.

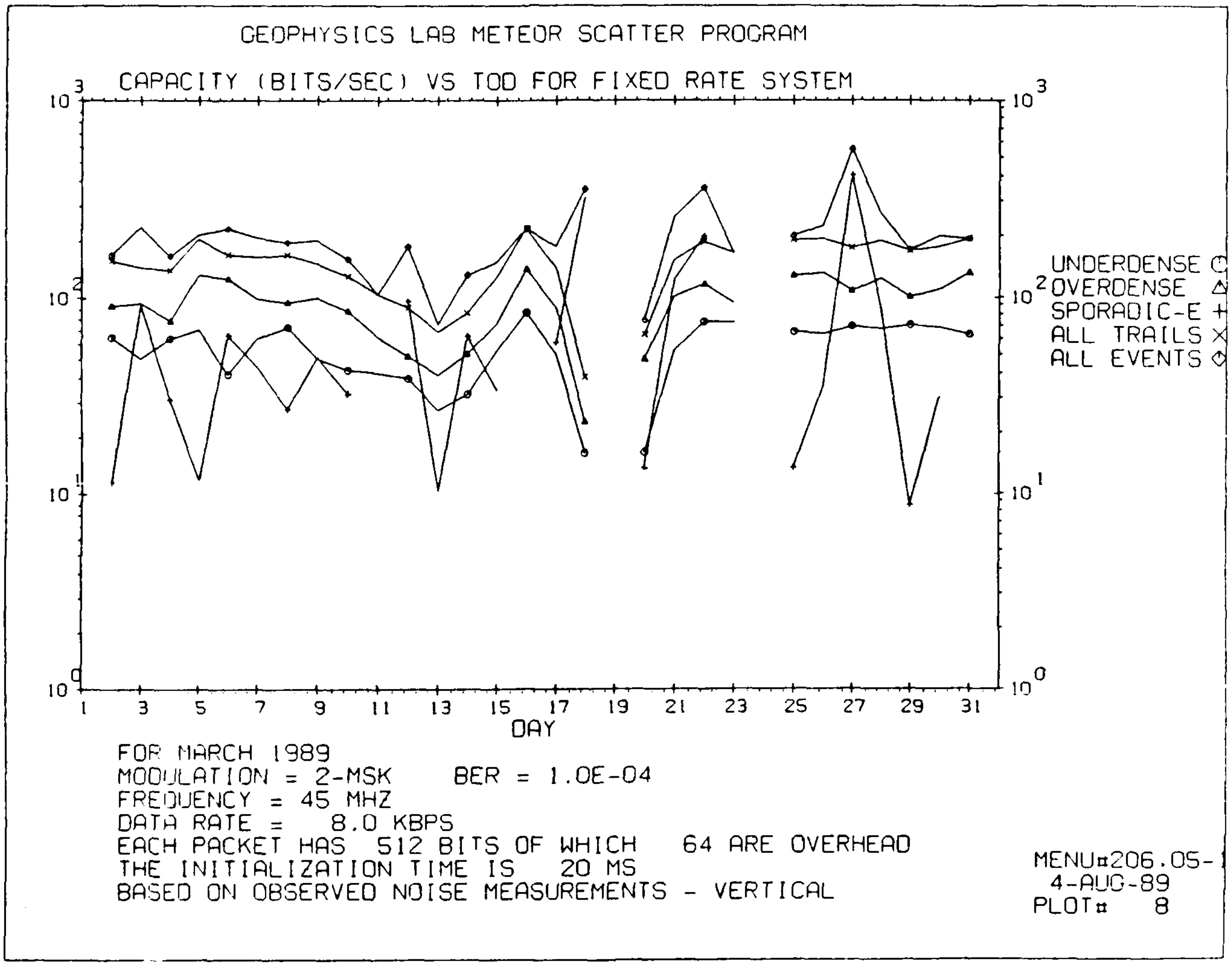

Figure 17. Statistic 206-5 Output Format 1

2.4.7 Menu 207: Message Waiting Time

Message waiting time statistics compute the waiting time to deliver a message for a fixed rate system with a specified confidence. Confidence is the probability that the message can be delivered in the specified time. Two options are considered; message piecing and single trail transmission. Message piecing allows a message to be broken up into packets which can be sent over more than one trail. Single trail transfer requires a trail long enough to send the entire message. This statistic includes effects due to: bit-error-rate, modulation type, packet size, overhead, data rate, initialization time, confidence level, and message length. Analysis options are listed below:

Op	x-Axis	y-Axis	User Specified Parameters
1	tod	deliv time	BER, modulation, power factor overhead bits, packet size, rate, initialization time, conf., mess. length
2	message length	deliv time	BER, modulation, power factor overhead bits, tod, packet size, rate, initialization time, conf.
3	data rate	deliv time	BER, modulation,power factor overhead bits, tod, packet size, initialization time, conf., mess. length
4	conf	deliv time	BER, modulation, power factor overhead bits, tod, packet size, rate, initialization time, mess. length
5	day.tod	deliv time	BER, modulation, power factor overhead, packet size, rate initialization time, mess length

Option 207-1: This option calculates for all frequencies the average delivery time as a function of time of day. Averages based on 1 month of data. Figure 18 shows sample output using this statistic.

Option 207-2: This option calculates for all frequencies the average delivery time as a function of the message length. The range of message lengths is 200 to 10,000 bits in increments of 200 bits. Delivery time can be averaged over one 2 hour period or over 24 hours. Averages based on 1 month of data.

Option 207-3: This option calculates for all frequencies the average delivery time as a function of the system data rate. The range of data rates is 1-10, 10-100, and 100-900 kbps. Delivery time can be averaged over one 2 hour period or over 24 hours. Averages based on 1 month of data.

Option 207-4: This option calculates for all frequencies the average delivery time as a function of the delivery confidence level. The range of confidence levels is 0.5 to 1.0 (representing 50 to 100%) in increments of 0.01. Delivery time can be averaged over one 2 hour period or over 24 hours. Averages based on 1 month of data.

Option 207-5: This option calculates for all frequencies the average delivery time as a function of time of day. Averages based on each hour of data.

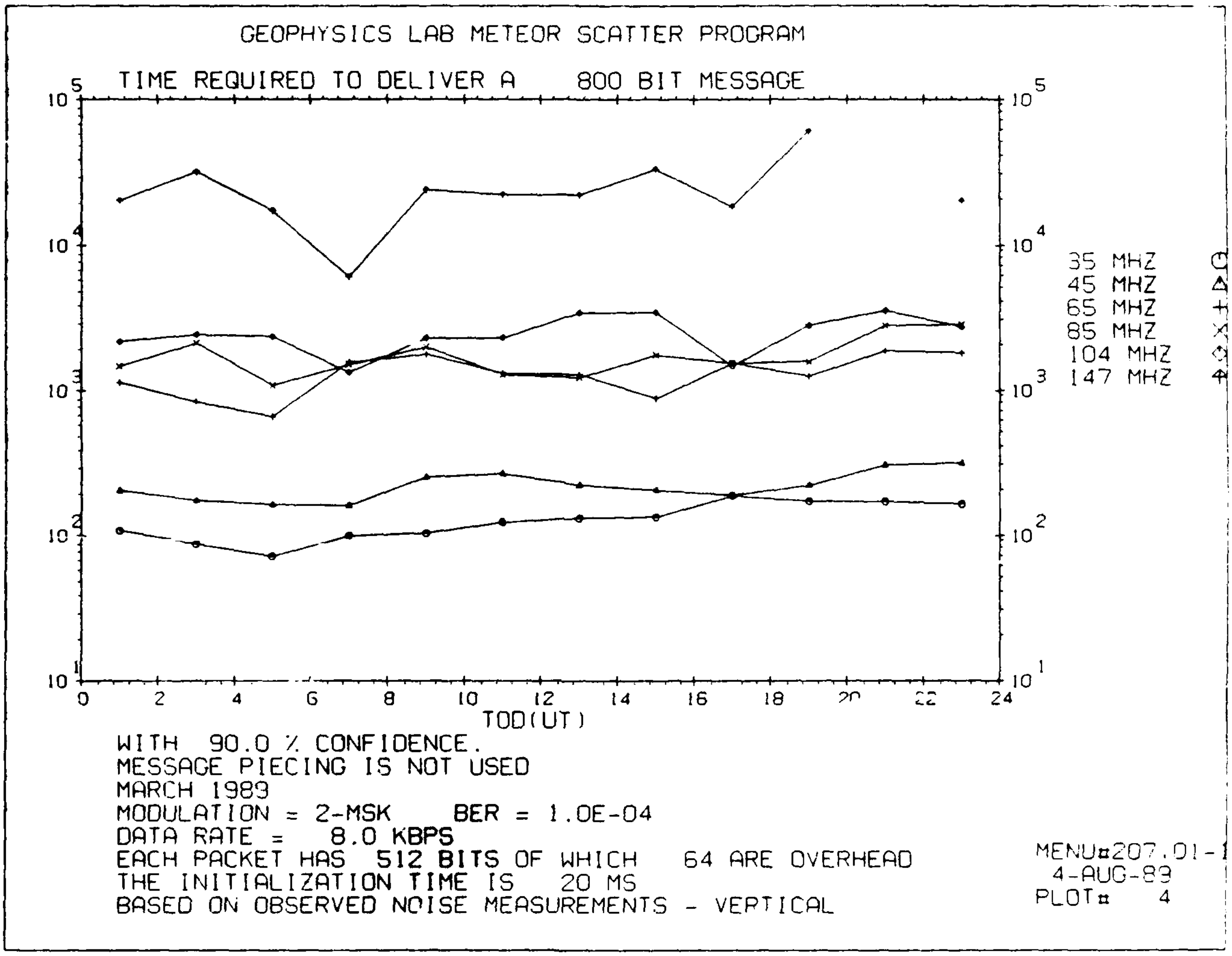

Figure 18. Statistic 207-1

3.0 REFERENCES

Oetting, J. D., "An analysis of meteor burst communications for military applications," IEEE Trans. on Comm., Vol. COM-28, No. 9, September, pp. 1591-1601, 1980.

Ostergaard, J. C., J. E. Rasmussen, M. J. Sowa, J. M. Quinn and P. A. Kossey, "Characteristics of high latitude meteor scatter propagation parameters over the 45-104 MHz band," Proceedings AGARD Conf. Proc. CP-382, 1985.

Proakis, J. G., "Digital Communications," McGraw-Hill Book Company, New York, 1983.

APPENDIX A

Running the Statistics Package

Running the Statistics Package

To run the Meteor-Burst Statistic Generating Program the user should enter the following command:

PLOTMET2

Upon entry into the meteor burst statistics program the user is prompted by the following inputs:

<u>NORMAL - MODE ? (Y/N)</u>

Answering y at this point will

<u>USE JENS - NORD - DATA Y/N ?</u>

Answering "Y" will access the NORD data that is available on the system.

<u>USE DEFAULT - DIR & FILE NAMES ? (Y/N)</u>

Answer "Y" causes the default data base directories to be used. The only condition for which N should be entered is if the user has created custom data bases.

<u>WOULD YOU LIKE TO DECLARE THE MONTH AND YEAR AT THIS TIME (Y/N)</u>

Answering "y" at this point will allow the user to input the month and year. If "y" is chosen the month and year can not be changed during this execution. If the user answers "n" the month and year will be prompted for during the execution of each and every individual statistic.

APPENDIX B

Utilities

Utilities

The basic hierarchy of the package does not allow write access to the data bases once created. It is occasionally necessary to change a value, especially of the transmitter power or the noise level. Two off line utilities SET_POWER and SET_NOISE have been created to accomplish these tasks. The programs prompt the user for each required entry. Before changing values, a confirmation is required before values in the data base will be changed. Once changed there is no record of the previous value so extreme caution is required when using these routines.

One special use of the SET_POWER utility is to eliminate questionable data from analysis. By setting the transmitter power to 0, data from that period is not considered in the analysis. A positive value greater than 0 indicates that the transmitter was operating and that data should be considered in the analysis.