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A DATA BASE APPROACH TO ANALYSIS OF METEOR BURST DATA

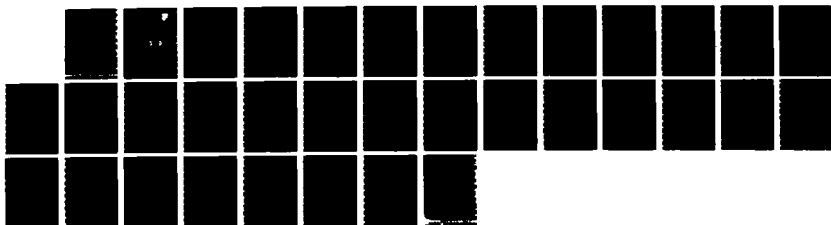
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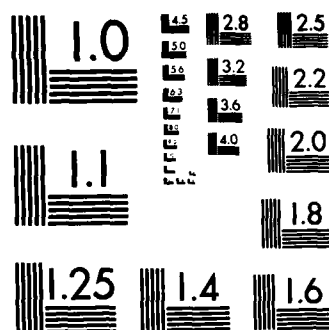
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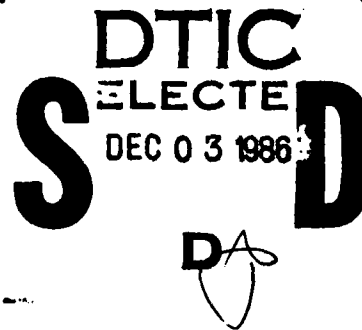
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Interim Report
October 1986

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A DATA BASE APPROACH TO ANALYSIS OF METEOR BURST DATA

Signatron, Inc.

Jay A. Weitzen



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19. ABSTRACT (Continue on reverse if necessary and identify by block number) This report describes an approach to the analysis of data from the USAF High Latitude Burst Test Bed in which a data base of key statistics is created from the raw data records. The data base approach reduces the storage, processing and analysis requirements while preserving the flexibility of analysis inherent in using raw data and can be used to analyze the propagation and communication properties of the high latitude meteor channel as a function of operating frequency, time of day, day, month, and propagation mechanism. Expert system techniques are integrated into the software to automate various elements of the analysis procedure allowing a massive amount of data to be processed in a time- and cost-efficient fashion. Examples of output from the data base are presented to show the power of the technique.				
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SECTION 1

INTRODUCTION

The U.S. Air Force has been conducting an extensive program in the Arctic to evaluate the effect of high latitude on meteor burst communication and has established a High Latitude Meteor Burst Test Bed with transmitter at Sondrestrom AB, Greenland and receiver at Thule AB, Greenland. The 1260 km research link operates continuously, cycling between four operating frequencies (45, 65, 104, and 147 MHz) every thirty minutes. Four second data records of the envelope of the received signal are collected whenever the received signal-to-noise ratio exceeds 4 dB. A 400 Hz FM signature is added to the probing signal to minimize false acquisitions. Data from a Data Precision D-6000 acquisition system is transferred to an HP-85 controller and from the controller to tape cartridge mass-storage. The transmitter cycles through four different frequencies every two hours with a five minute noise measurement at the beginning of each 30 minute interval. Depending on season, between 15 and 30 thousand four-second data records are acquired during a month of normal operation. The detail of the data from this link represents a wealth of information previously not available to researchers not only about the high latitude meteor channel but about the meteor channel in general. However, without an automated system for data processing, reduction and analysis, the volume of data from the experiment would be overwhelming.

This report describes an approach to the analysis and processing in which a data base of key statistics is created from the hundreds of thousands of data records. The data base can be accessed in a number of different ways to flexibly analyze both the propagation and communication properties of the channel. This approach exploits the large data sample to infer statistical

properties of the channel which are not available from previous studies which use small data samples, and at the same time it minimizes processing and storage requirements.

The data processing and analysis procedure consists of four steps as outlined in Figure 1-1. Raw voltage data from the tape cartridges is transferred to a mainframe computer and calibrated to received signal power. A 20-item header consisting of the date, time, noise level, frequency, transmitter power, and other pertinent information is attached to each 512-point data record.

In order to provide information on the frequency, received signal and diurnal properties of the various mechanisms (underdense trails, overdense trails, and ionospheric propagation) observed on the high latitude test bed, the next step in procedure identifies the dominant propagation mechanism of each data record as meteoric or non-meteoric. If the dominant mechanism in the data record is meteor propagation, the type of each trail (either underdense or overdense) within the data record is identified. Sporadic-E propagation and ionospheric scatter are the dominant non-meteoric propagation mechanisms observed on the test bed which is well above the auroral oval.

In preliminary efforts, classification of propagation mechanism and meteor type was performed manually requiring about two staff months (working 40 hours per week) to classify the data from just one month. A computer program incorporating artificial intelligence "expert system" techniques has been developed [Weitzen and Tolman, 1986] to emulate the operation of a human classifier to automate the classification procedure. The auto-classifier first identifies the dominant propagation mechanism as meteoric, non-meteoric, noise measurement, or false data, and if meteoric, it identifies the type (underdense or overdense) of up to four trails within the four-second data record. Using the auto-classifier, the time required to classify data from one

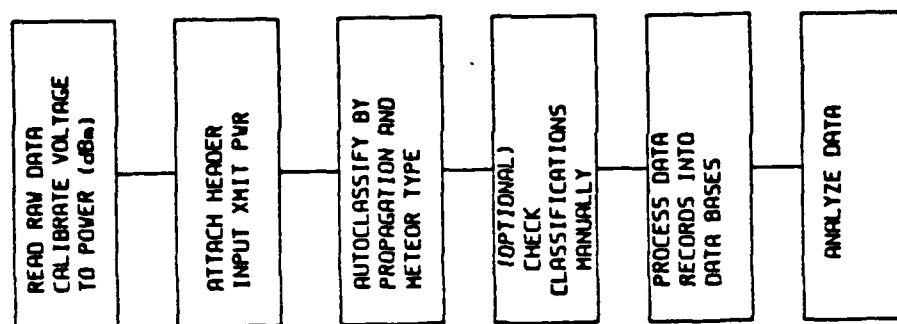


Figure 1-1 Flow chart for the data reduction analysis procedure

month operation was reduced from three staff months to 12 hours with an accuracy which was comparable to a human classifier.

After mechanism identification and classification, key information from the data records is entered into the data base. This procedure reduces the amount of data from 60-70 Mbytes per month to less than 10 Mbytes while preserving the key information that is in each data record. Information from the data base can be easily and efficiently queried using a series of software routines that have been developed. Raw data records are archived following data reduction.

SECTION 2

THE HIGH LATITUDE METEOR BURST DATA BASE

The driver program (see Figure 2-1) for the data reduction software operates on the header attached to each 512-point data record and identifies the data type associated with the record: meteor propagation, ionospheric propagation, noise measurement, or data to be discarded. Depending on the type of the record, a series of routines are called to enter data into the appropriate data bases. The processing routines operate on seven data bases which contain in an efficient and easily accessible format the information in the raw data which is required to determine the communication and propagation properties of the meteor channel. The seven data bases which will be described separately are:

1. link history
2. number of arrivals
3. trail inter-arrival times
4. signal durations
5. underdense decay time constants
6. duty cycle
7. fade bandwidth

2.1 LINK HISTORY DATA BASE

The link history data base archives miscellaneous information about the link from each 30 minute period during the day. This data base contains information on the received noise level measured during the five minute silent period at the beginning of each 30 minute acquisition interval. The noise information is combined with absolute signal level information in the other data bases to transform received signal level to signal-to-noise ratio (SNR) for communication analysis.

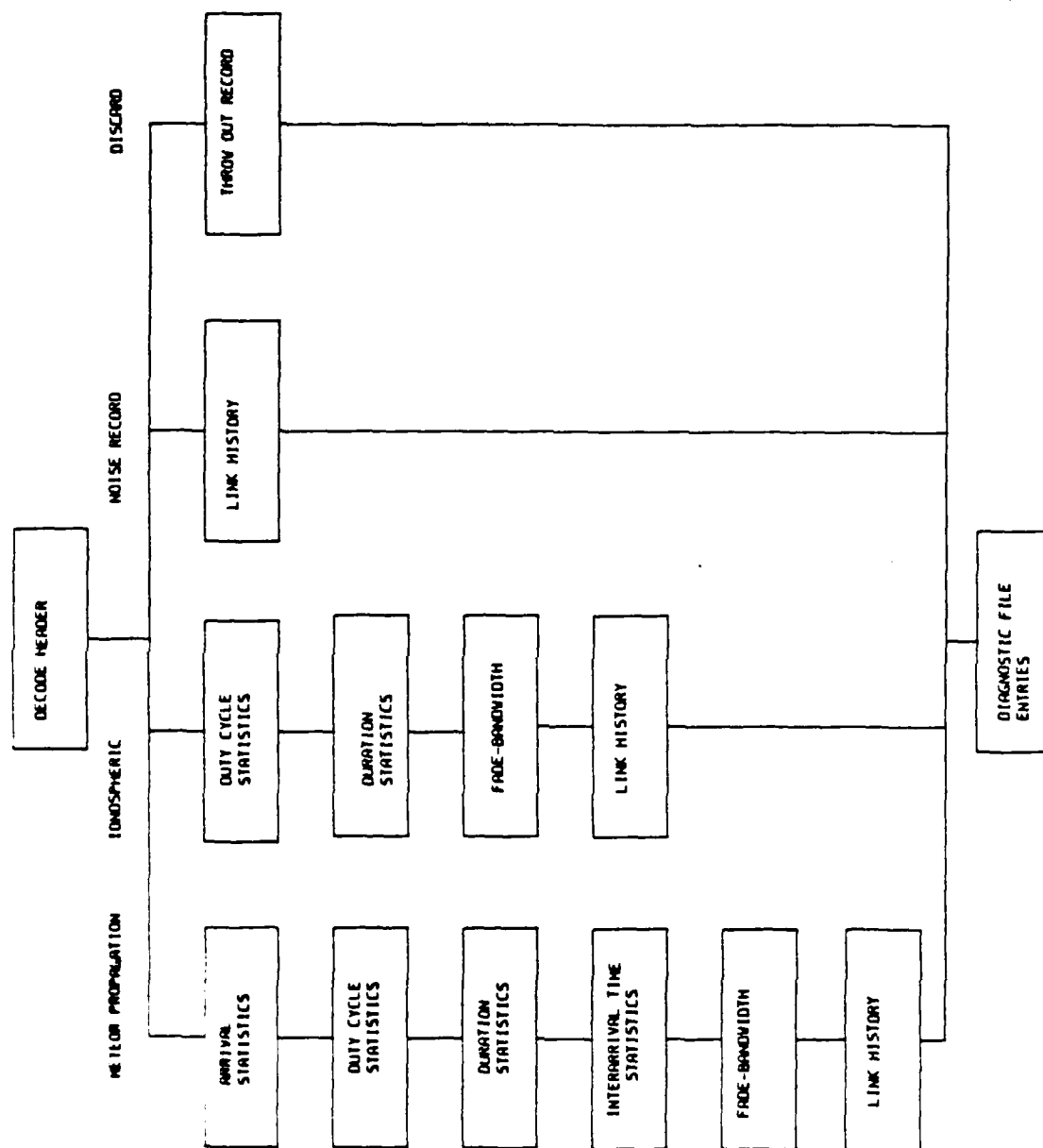


Figure 2-1 Flow chart for creation of data base entries.

In order to accurately determine meteor arrival rates, the amount of time during each 30 minute acquisition interval that the system was available to observe meteors must be determined and archived. Data transfer from the acquisition system to the controller requires about two seconds per data record during which the data acquisition system is disabled. If the 400 Hz FM signature which is part of the probing waveform is not detected at the beginning of a data record, a false trigger is declared and the data record is not transferred to the controller. The total time that the link was available is reduced by four seconds for each false trigger. During five minutes at the beginning of each 30 minute period, the transmitter is silent so that noise measurements can be performed. Finally, during times when sporadic-E is present, the arrival of meteors is obscured by the ionospheric propagation so this time is not counted in the meteor arrival rate statistics.

Other information in the link history data base is transmitter power and transmitter VSWR which is used to calculate effects of differences in effective radiated power at the various frequencies on the arrival rate of meteors.

2.2 METEOR ARRIVALS DATA BASE

The number of meteor arrivals exceeding a received signal threshold is an important statistic to researchers interested in predicting how physical, link and temporal factors effect the arrival rate of meteors. The number of meteors which exceed a signal threshold is determined for each 30 minute interval as a function of signal threshold, frequency, time of day, day and trail type. Information in this data base can be used to observe the fluctuation in arrival rate during a polar cap absorption (PCA) event, to determine the frequency dependence of the arrival rate as a function of time of day or season, to observe the relationship between received signal and number of trails or to

observe the ratio of underdense to overdense meteor trails. Arrival rates of meteors (meteors per minute) which satisfy the user specified signal requirements are computed by dividing the number of meteors which satisfy the signal criteria by the time that the link was available to observe meteors. This available time is computed, taking into account the five minute noise measurement interval, time that the link was not observing meteors due to data transfers and false triggers, and time that meteors were obscured by ionospheric propagation.

Data analysis routines can combine the received signal information in the arrival data base with noise level information in the link history data base to compute the arrival rate of meteors as a function of signal-to-noise ratio. This information can be used by communication engineers to predict the arrival rate of meteors which are useful for communication.

For each meteor trail in a four-second data record identified by the automatic trail classifier, the arrival processing routine computes the peak received signal (in dBm) and increments the appropriate day, time of day, frequency, trail type, and received signal data slots. Statistics are determined for each 30 minute data block, each of the four frequencies, and 40 different received signal thresholds for both underdense and overdense meteor trails.

2.3 INTERARRIVAL TIME DISTRIBUTION DATA BASE

The interarrival times data base provides information on the distribution of arrival times between meteors which exceed an RSL threshold for a specified duration. This data base can be used to verify that the arrival of meteors follows a Poisson distribution and to observe any non-Poisson properties which may be associated with meteor showers.

For each meteor trail (this data base does not consider whether trails are underdense or overdense) which satisfies the signal level and duration criteria, the time of arrival is noted in a table. The next time that a trail is detected which satisfies the same requirements, the interarrival time is computed, and the appropriate data slot in the data base is incremented. The arrival time is computed as a function of frequency, signal level and signal duration.

2.4 DISTRIBUTION OF SIGNAL DURATIONS DATA BASE

The signal durations data base contains information on the durations of meteor and ionospheric signals above various received signal thresholds. Duration statistics are required to determine the average throughput and message delivery time of the channel especially for realistic systems which transmit data in fixed-length packets. It is also useful for researchers interested in predicting the distribution of meteor trail durations as a function of physical and link parameters.

For each signal event within a four-second data record, the times relative to the start of the record that the signal exceeds and goes below the threshold are noted in a table. Since actual communication systems have some inherent capability to combat fades, the processing routines merge fades which are less than 40 ms in duration. The duration of each trail or ionospheric event above the threshold is determined after fade merging and the signal is attributed to one of the various event classes (underdense trails, overdense trails, and ionospheric propagation).

Duration statistics are computed for each 30-minute acquisition block as a function of time of day, frequency and received signal level for each of the propagation mechanisms (underdense trails, overdense trails, and ionospheric propagation).

Information which is stored in the data base as a function of received signal can be transformed by the analysis routines to become a function of signal-to-noise ratio by combining received signal information in this data base and noise information in the link history data base.

2.5 UNDERDENSE TIME CONSTANTS

Underdense meteor trails are observed to decay exponentially with a time constant which is a function of trail height, link distance, trail orientation, and frequency. In most work, the time constant of decay is assumed fixed for a given link but, in reality, it is a random variable. Statistics of the duration and time constants are required for the generation of accurate meteor burst simulations. For each trail identified by the trail-classifier as underdense, a minimum mean square error exponential fit to the trail is performed beginning at the maximum signal point. The statistics of the time constant are determined as a function of time of day, and frequency, averaged over each month.

2.6 DUTY CYCLE DATA BASE

The duty cycle data base determines statistics of the total time that the received signal exceeded a given threshold. The duty cycle is determined by dividing the time that the signal was above threshold by the total number of seconds that the link was active taking into account noise measurements and time that acquisition was disabled. This statistic is computed as a function of time of day, frequency, day, signal level and propagation mechanism (underdense, overdense or ionospheric propagation). The relative contribution to the total capacity of the channel due to the various mechanisms can be computed using this statistic. The communication routines combine the received signal measurements in the duty cycle data base with the noise information in the link history data base to determine the duty cycle as a function of signal-to-noise ratio.

For each meteor in the data record identified by the trail classifier, the number of seconds that the received signal level exceeds the threshold is computed and the appropriate duty cycle data slot based on time of day, frequency, day, received signal level and trail type is incremented. For records identified as ionospheric, the total duty cycle for the four second data record is computed and the appropriate data slot is incremented.

2.7 FADE BANDWIDTH DATA BASE

The final data base provides information about the fading of the envelope, primarily in overdense meteor trails and ionospheric events. This information is used to determine how fast the signals are fading. For each four-second data record which contains an overdense meteor trail or which is identified as ionospheric propagation, a 512-point FFT is performed on the data record and the bandwidth is computed. The statistic is computed as a function of time of day, frequency, fading bandwidth and propagation mechanism.

SECTION 3

ANALYZING THE DATA

Information in the monthly data bases can be retrieved and processed using a menu-driven front end program which calls a sub-set of 17 FORTRAN processing routines. The routines which allow the user to analyze the propagation and communication properties of the channel are described briefly. The routines can use information in several different data bases to compute the statistics and are grouped into two general headings: propagation routines and communication routines.

The first general grouping of routines allows the user to determine from the data bases important propagation parameters such as noise level, arrival rate of meteors, signal duty cycle, trail interarrival time, duration of trails and ionospheric events, information about the fade rate, and information about the time constants of exponentially decaying underdense trails. Statistics in this group are computed as a function of time of day, day of the month, frequency, and trail type and propagation mechanism. Statistics are computed for both received signal level (dBm) and signal-to-noise ratio (dB SNR) to allow both communication and propagation research. Statistics can be averaged over all or any combination of propagation mechanisms and for different time periods such as the same time period averaged over a whole month or year, daily averaged over all time periods, hourly for a month or day, or any combination or permutation. Normalized or unnormalized histograms and cumulative distributions can be computed. Output is presented in the form of files which can be accessed by plot routines or in table format.

The following figures are typical of output that can be obtained from the program. Figure 3-1 shows the diurnal

NOISE FEBRUARY 1985

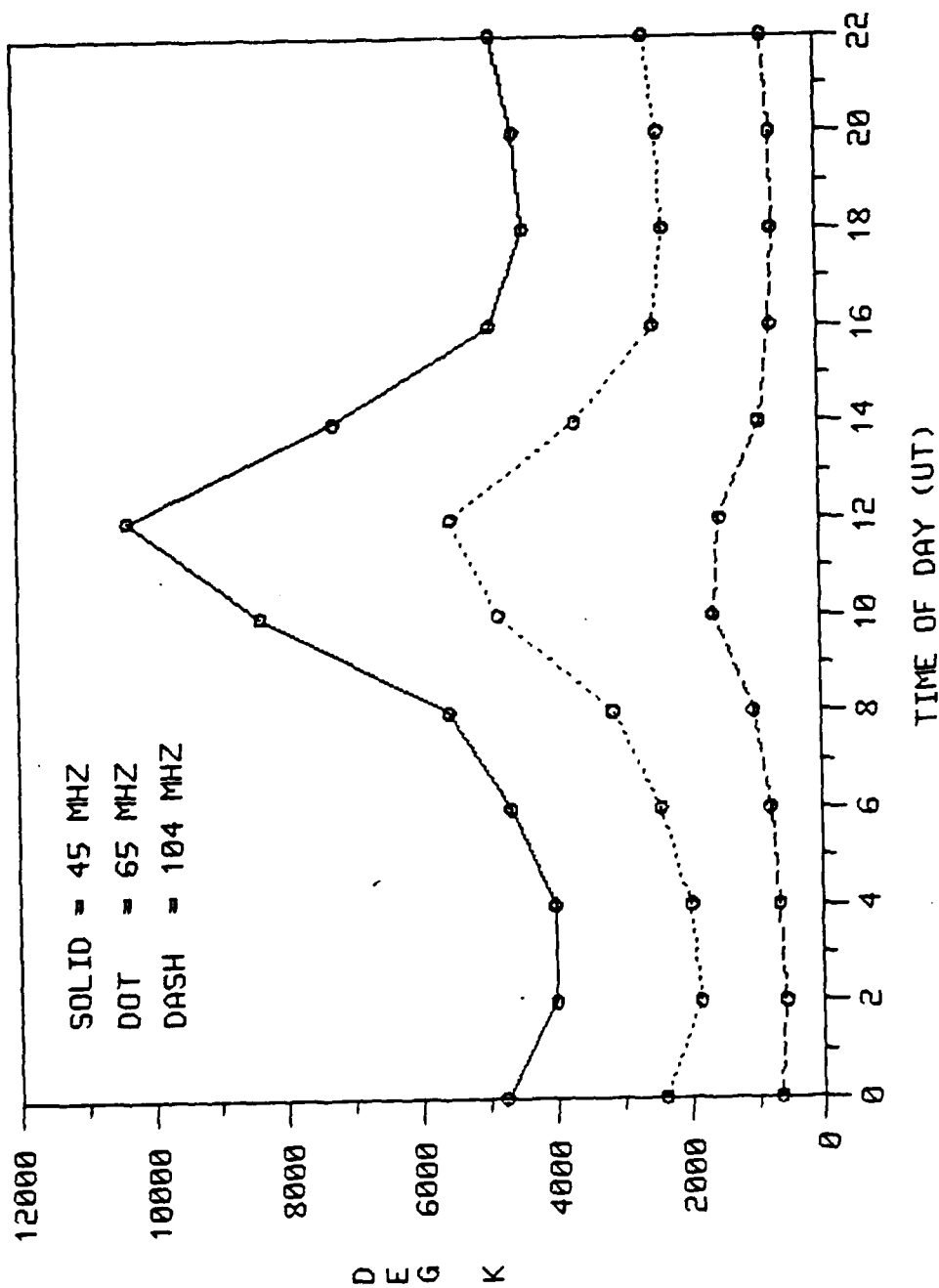
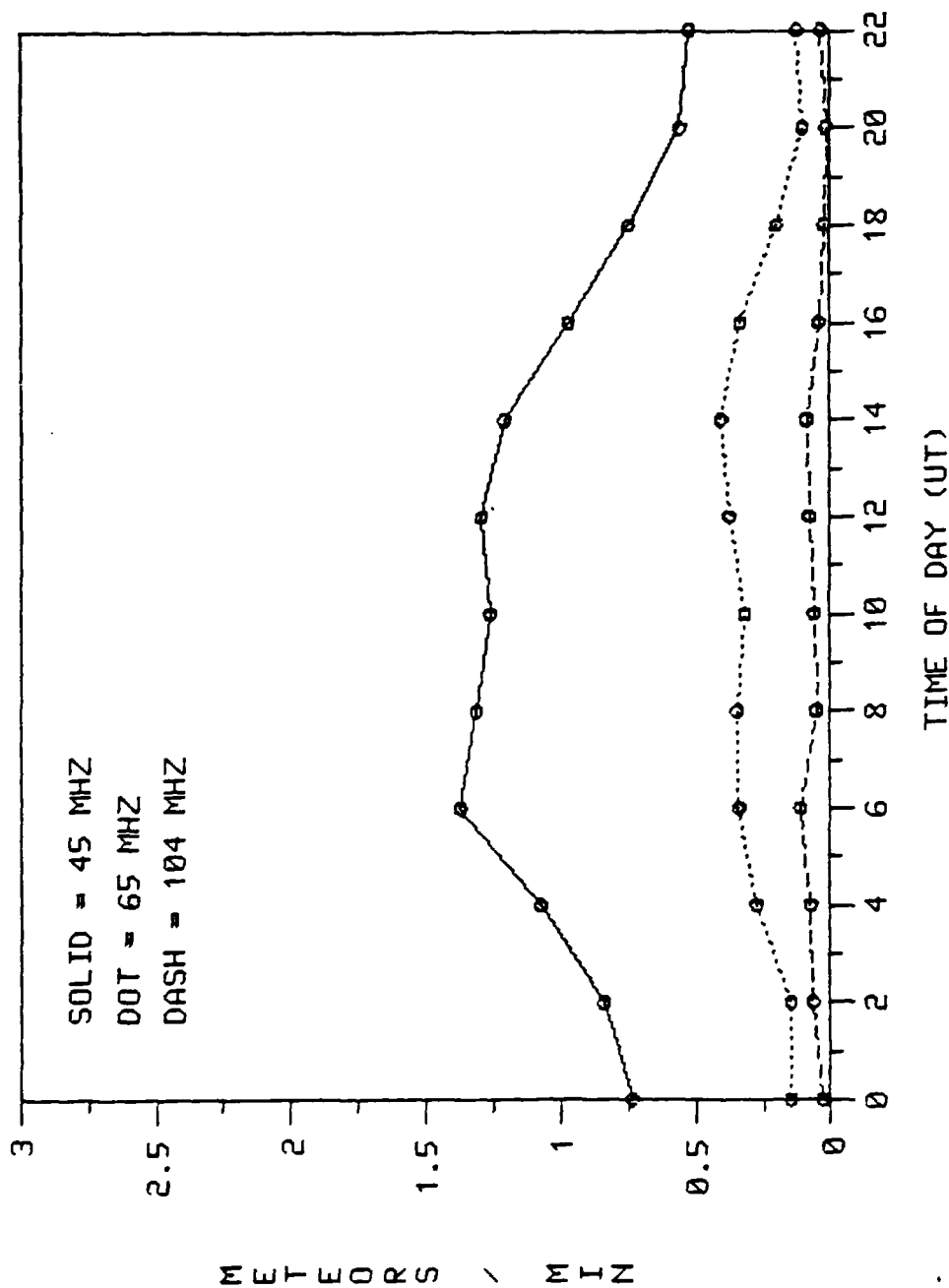


Figure 3-1 Hourly received noise temperature (deg K) for February 1985 at 45, 65, and 104 MHz.

variation is received noise temperature as a function of time of day for the month of February 1985, for 45, 65, and 104 MHz. Figure 3-2 shows the arrival rate of meteors which exceed 8 dB SNR in a 30 kHz bandwidth vs time of day averaged over the month of February 1985 at 45, 65, and 104 MHz. Figure 3-3 shows the relationship between arrival rate of meteors and received signal level (dBm) for underdense, overdense and all meteors at 45 MHz averaged over all the periods for February 1985. Figure 3-4 shows the relative contribution of the various propagation mechanisms (underdense trails, overdense trails, and ionospheric propagation) to the overall duty cycle of the channel vs received signal at 45 MHz for February 1985. Figure 3-5 shows an unnormalized histogram of underdense time constants averaged over all time periods for July 1985 at 45, 65, and 104 MHz. Figure 3-6 shows a normalized distribution of interarrival times for meteors which exceed 8 dB SNR for at least 100 ms for February 1985. The broken line represents an exponential (Poisson) fit to the data (solid line).

Communication routines allow a user to predict the performance of a user designed communication system for the propagation conditions observed. Users can select either a fixed rate communication system operating at a user selected rate or an advanced system which adapts its rate to the capacity of the channel. Communication parameters such as packet length, system overhead, packet overhead, acquisition time, modulation etc., are specified by the user to allow creation of an arbitrary communication system. Statistics can be averaged over time of day, propagation mechanism, etc. Some examples showing how the communication routines can be used are given. Figure 3-7 shows the average capacity of the meteor channel for a system which can adapt its data rate to the capacity of the channel up to a maximum rate of 256 kbps as a function of time of day averaged over

METEOR ARRIVAL RATE EXCEEDING -110.0 DBM RSL FEBRUARY 1985



OVERDENSE AND UNDERDENSE TRAILS

Figure 3-2 Arrival rate of meteors exceeding -110 dBm (RSL) versus time of day (UT) for February 1985 at 45, 65, and 104 MHz.

METEOR ARRIVAL RATE VS RSL FEBRUARY 1985

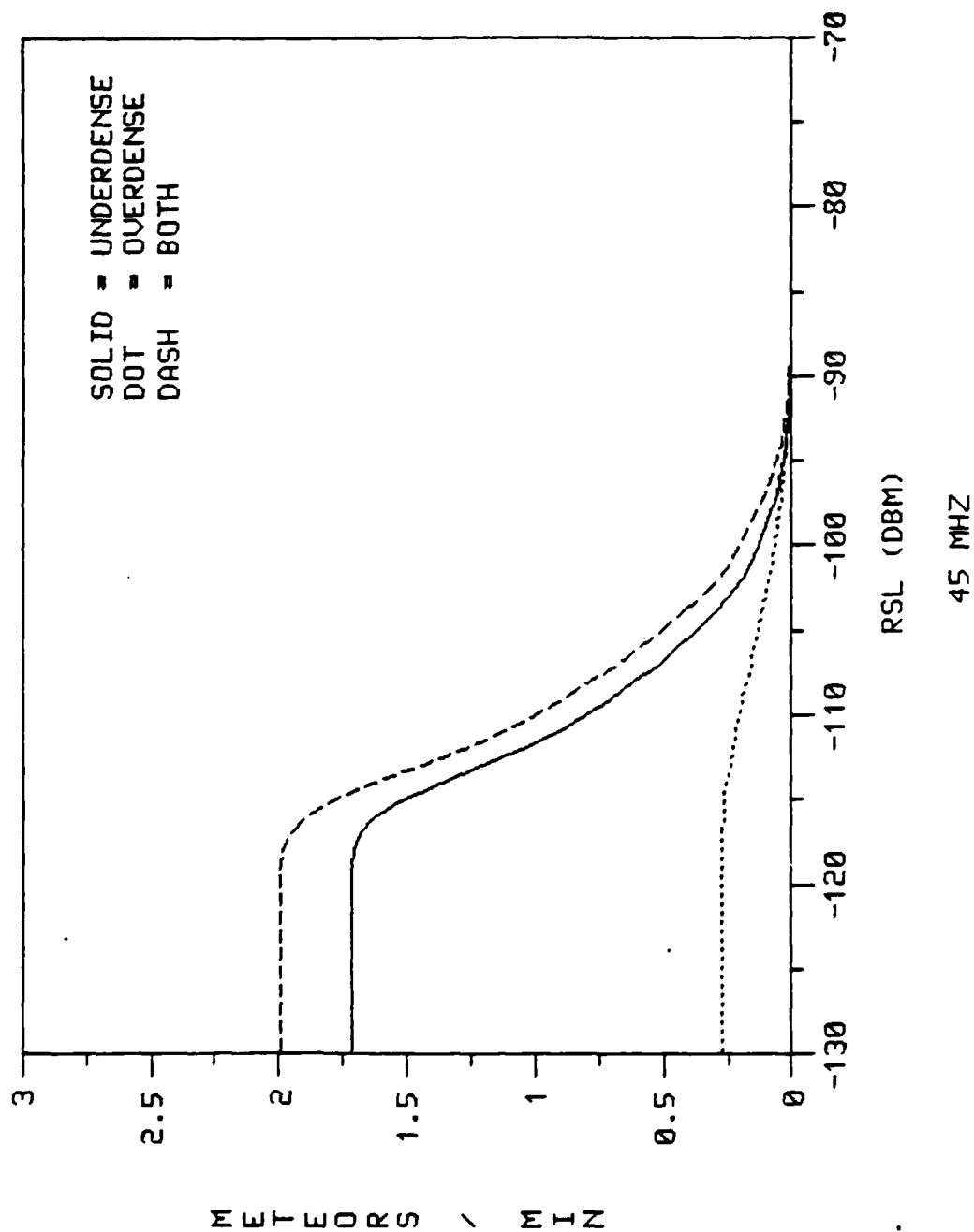


Figure 3-3 Arrival rate of meteors averaged over 24 hours versus received signal level for underdense, overdense, and all types of meteors at 45 MHz for February 1985.

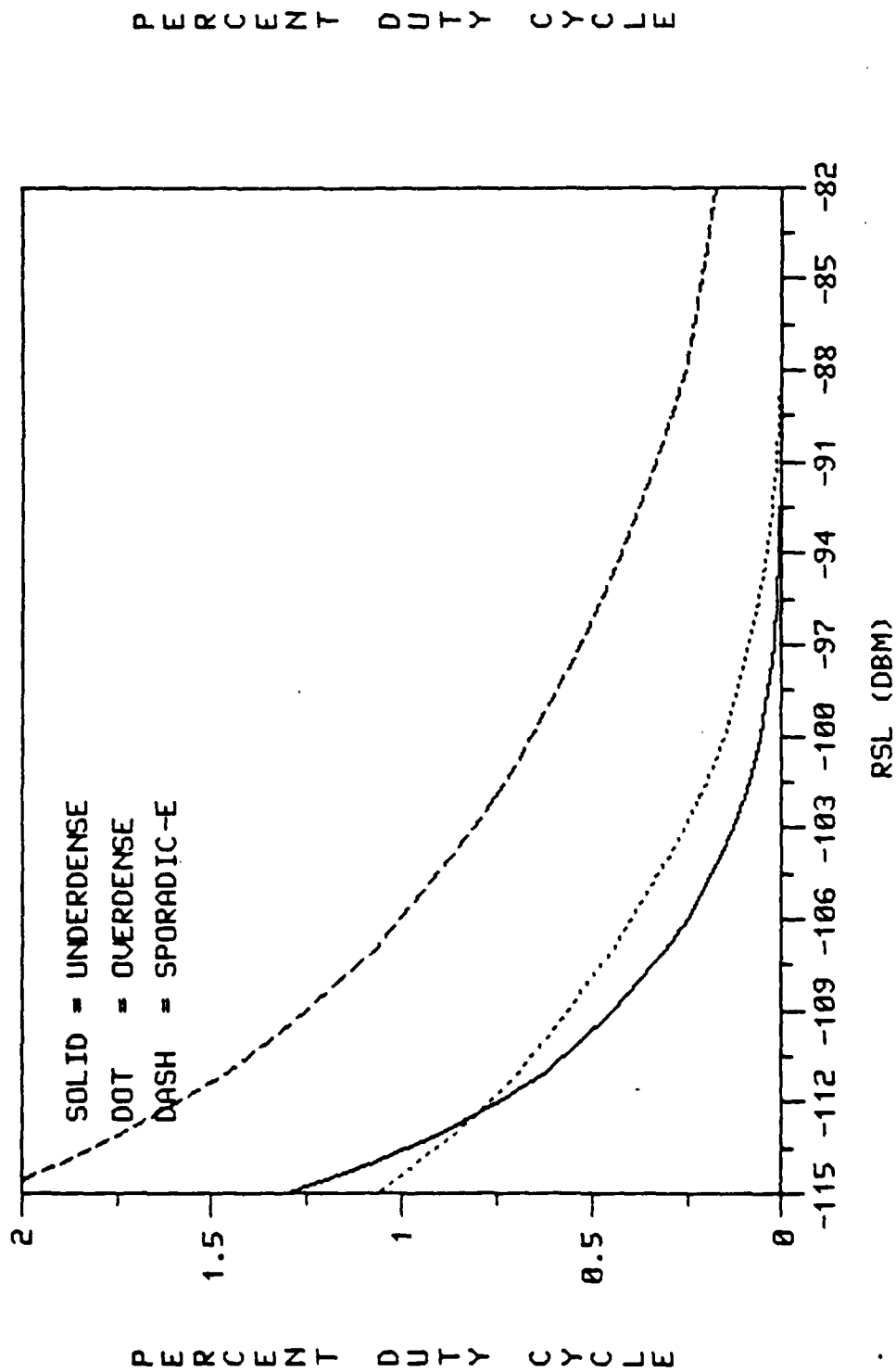


Figure 3-4 Duty cycle averaged over 24 hours versus received signal level for underdense meteors, overdense meteors, and ionospheric propagation for May 1985 at 45 MHz.

UNDERDENSE TIME CONSTANTS MAY 1985

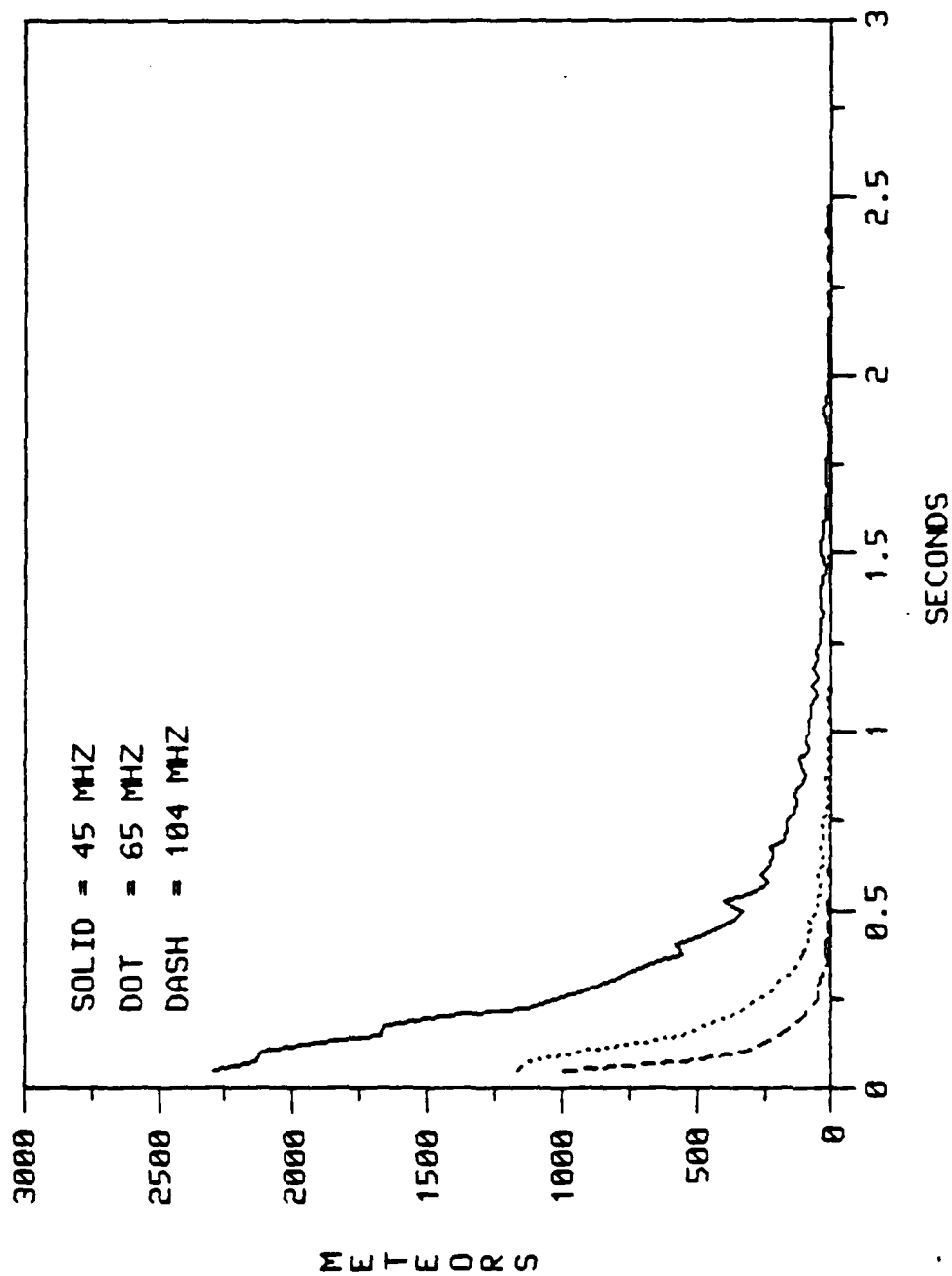
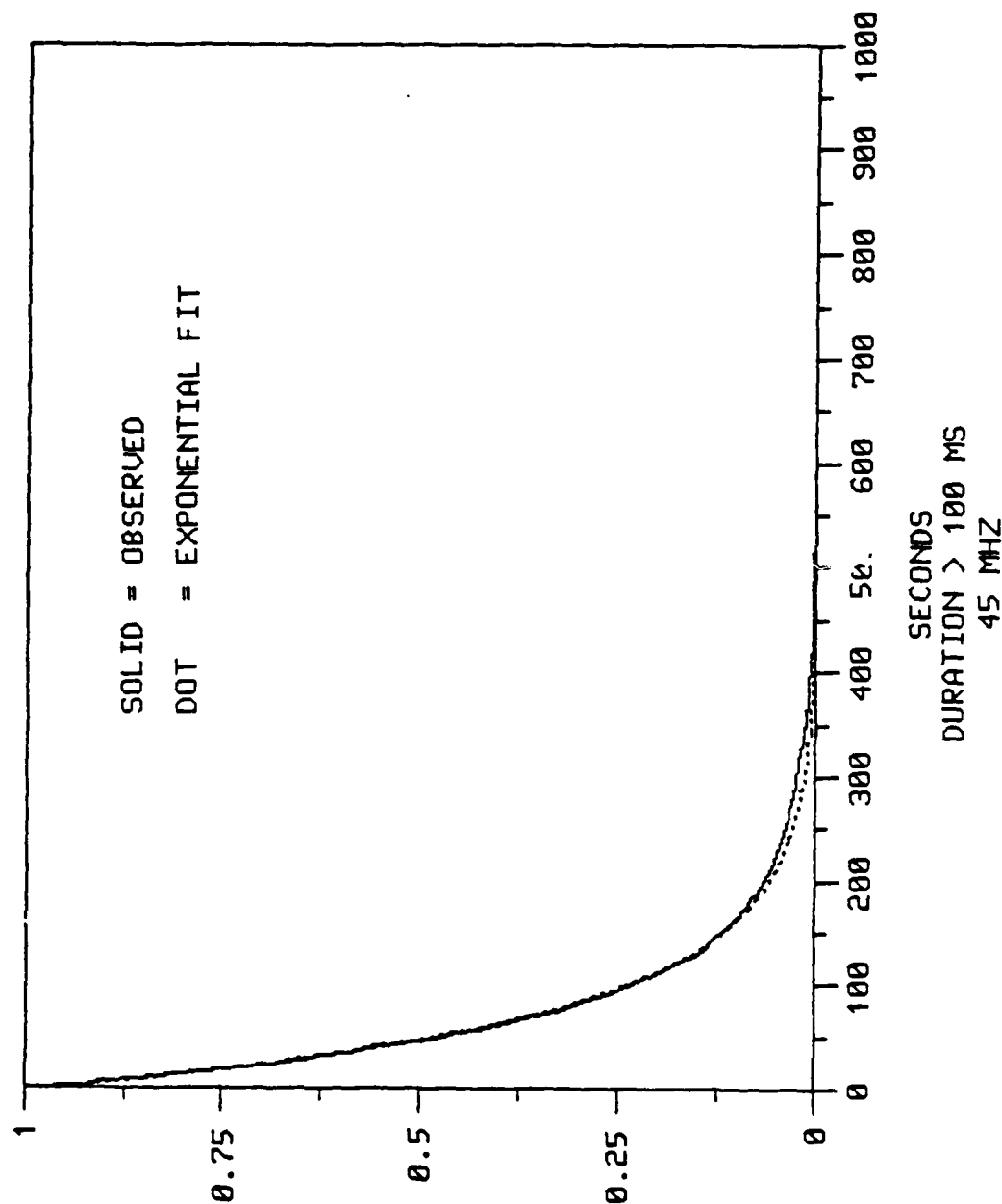


Figure 3-5 Histogram of underdense time constants for May 1985 at 45, 65, and 104 MHz.

PROBABILITY WAIT EXCEEDS X AXIS

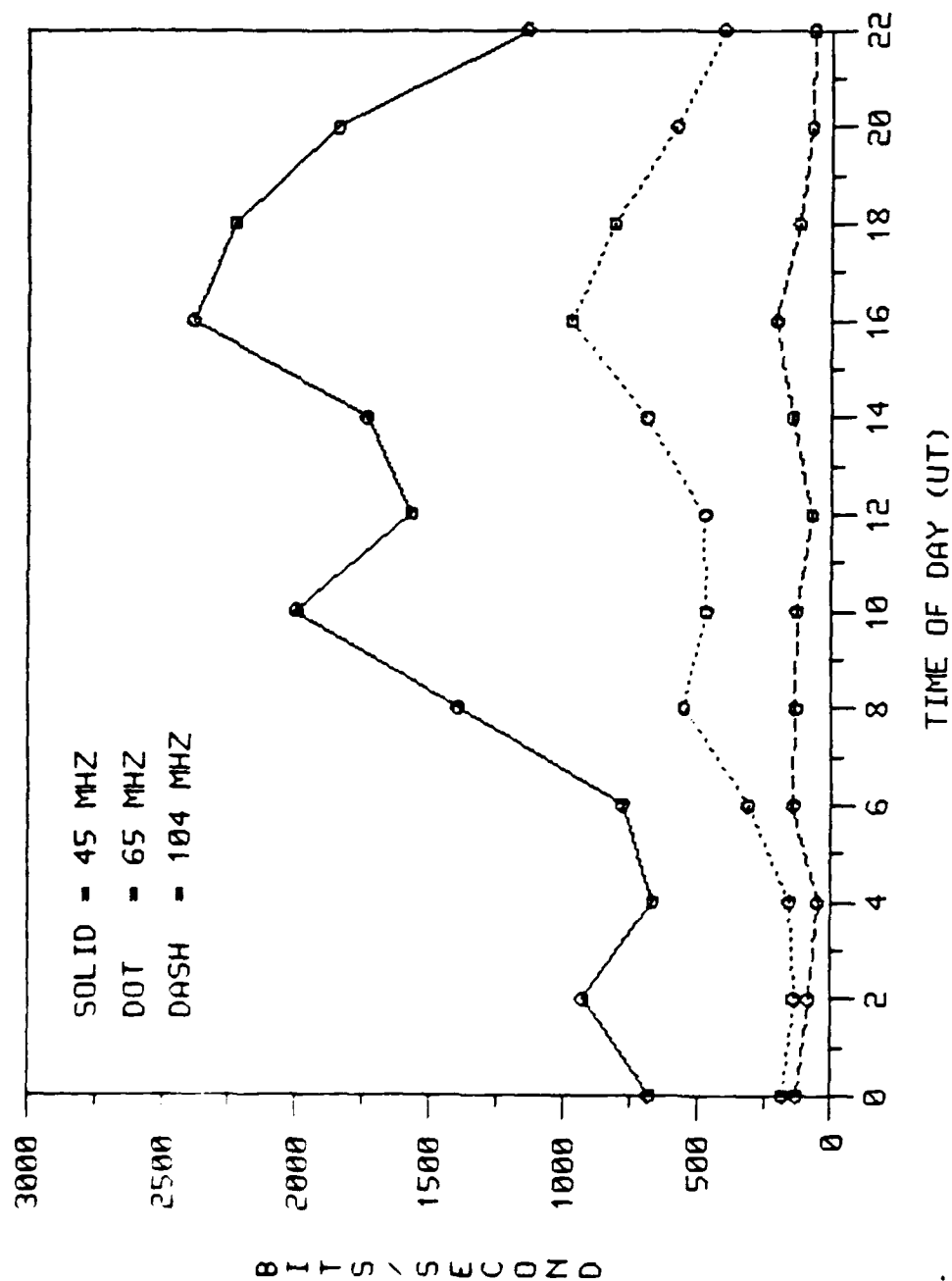
INTERARRIVAL TIME FEBRUARY, 1985



PROBABILITY WAIT EXCEEDS X AXIS.

Figure 3-6 Normalized distribution of interarrival time for meteors which exceed -110 dBm for 100 ms for February 1985 at 45 MHz. Broken line represents exponential fit to experimental data (solid line).

FULLY ADAPTIVE CAPACITY (BITS/SEC) FOR MAY 1985



OVERDENSE AND UNDERDENSE WITH 10^{-4} BIT ERROR RATE USING 2-PSK

Figure 3-7 Average throughput of meteor channel (underdense and overdense meteor trails) for fully adaptive system operating at rates up to 256 kbps at $BER = 10^{-4}$ using 2-PSK for May 1985 at 45, 65, and 104 MHz.

May 1985 assuming binary PSK modulation at $BER = 10^{-4}$ for 45, 65, and 104 MHz. Figure 3-8 shows the relative contribution to the total capacity from underdense, overdense, and ionospheric propagation averaged over the month of May 1985 for the same adaptive system at 45 MHz. The figure shows that the overdense trails which comprise about 25% of all the trails contribute about 50% of the total capacity in the channel. Figure 3-9 shows the average throughput of a fixed rate system operating at 10 kbps as a function of time of day for February 1985 at 45, 65, and 104 MHz. The system uses 2-PSK modulation with 1000 bit packets at 10^{-4} BER. Figure 3-10 shows the throughput of a fixed rate system using binary PSK at $BER = 10^{-4}$, 1000-bit packets with no overhead vs burst data rate averaged all February 1985 at 45, 65 and 104 MHz. Note that the capacity increases as the burst rate increases; however, because the system is using fewer meteors which are larger, the time to deliver messages also increases. Figure 3-11 shows how the time to deliver a fixed length message also increases as the burst data rate increases for the same system in February 1985. Note that the optimum burst rate in terms of message delivery time is different from the burst data rate which maximizes throughput for a fixed burst rate system.

FULLY ADAPTIVE CAPACITY (BITS/SEC) FOR MAY 1985

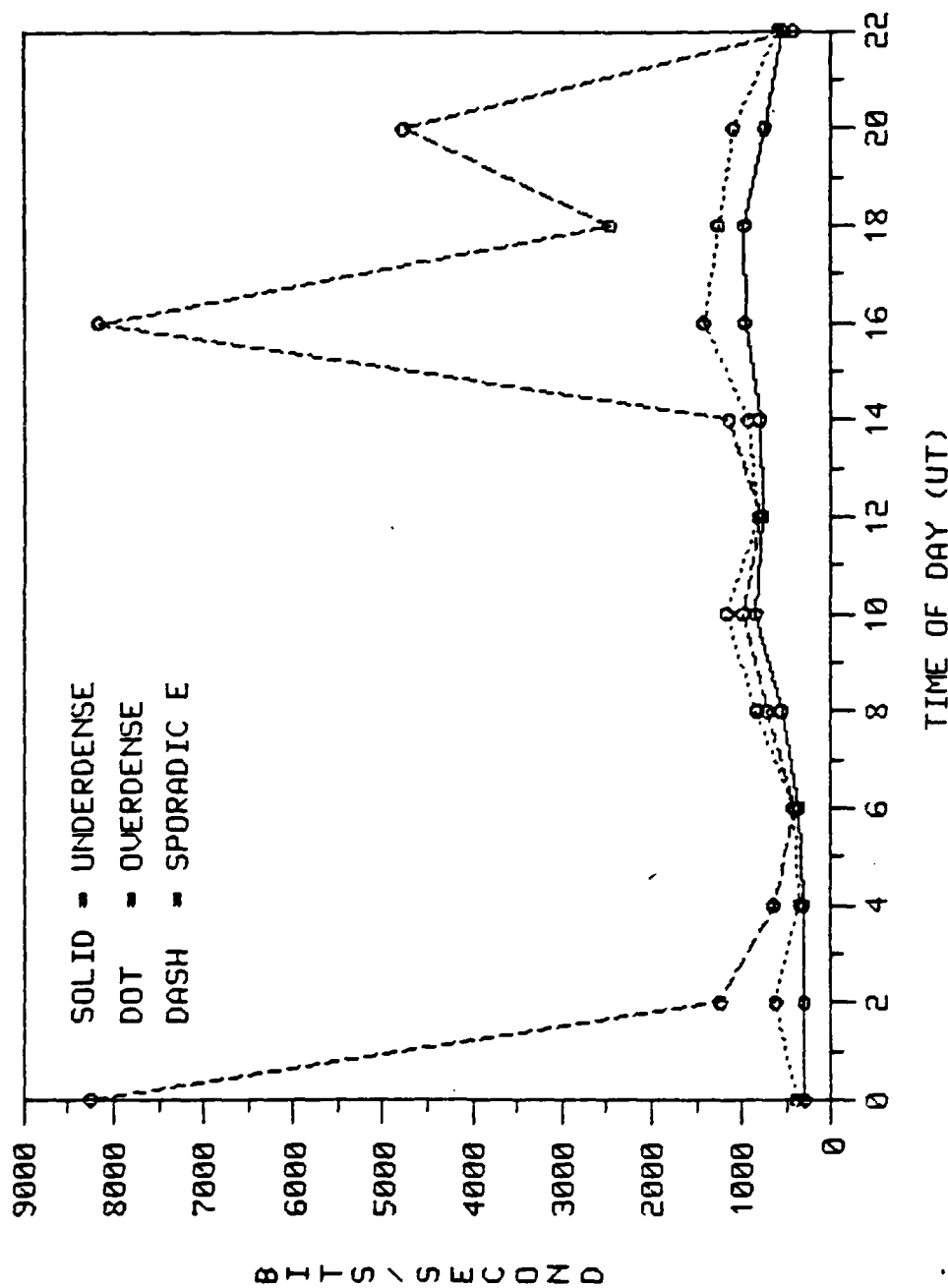


Figure 3-8 Average throughput of channel versus time of day for fully adaptive system operating at rates up to 256 kbps at BER = 10^{-4} using 2-PSK for underdense trails, overdense trails and ionospheric propagation for May 1985.

CAPACITY (BITS/SEC) FOR FIXED RATE SYSTEM, FEBRUARY 1985

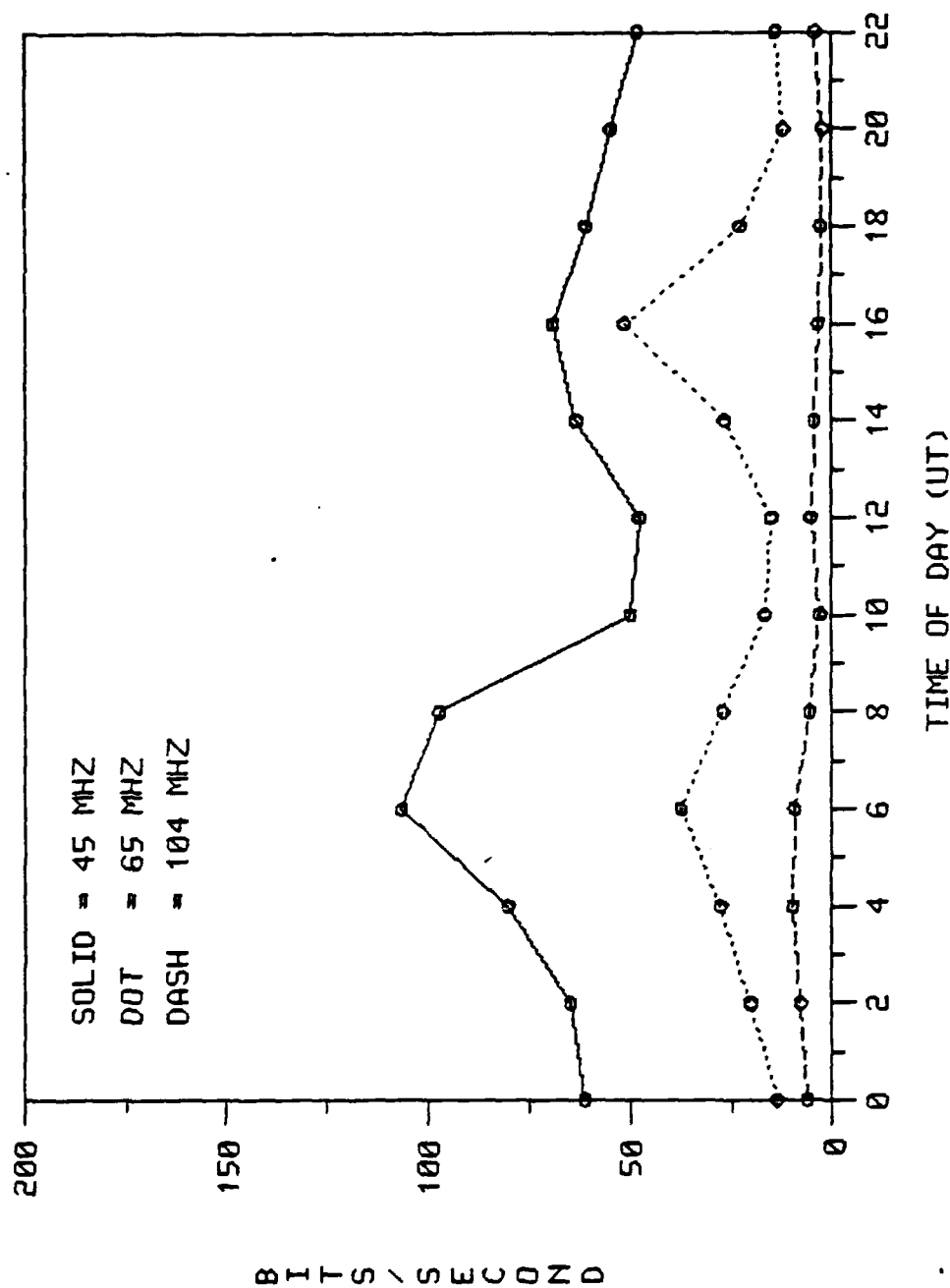


Figure 3-9 Average throughput of fixed rate communication system versus time of day at 45, 65, and 104 MHz for February 1985. The system uses 2-PSK modulation of 10 Kbps at 10^{-4} BER with 1000 bit message packets.

CAPACITY (BITS/SEC) FOR FIXED RATE SYSTEM, FEBRUARY 1985

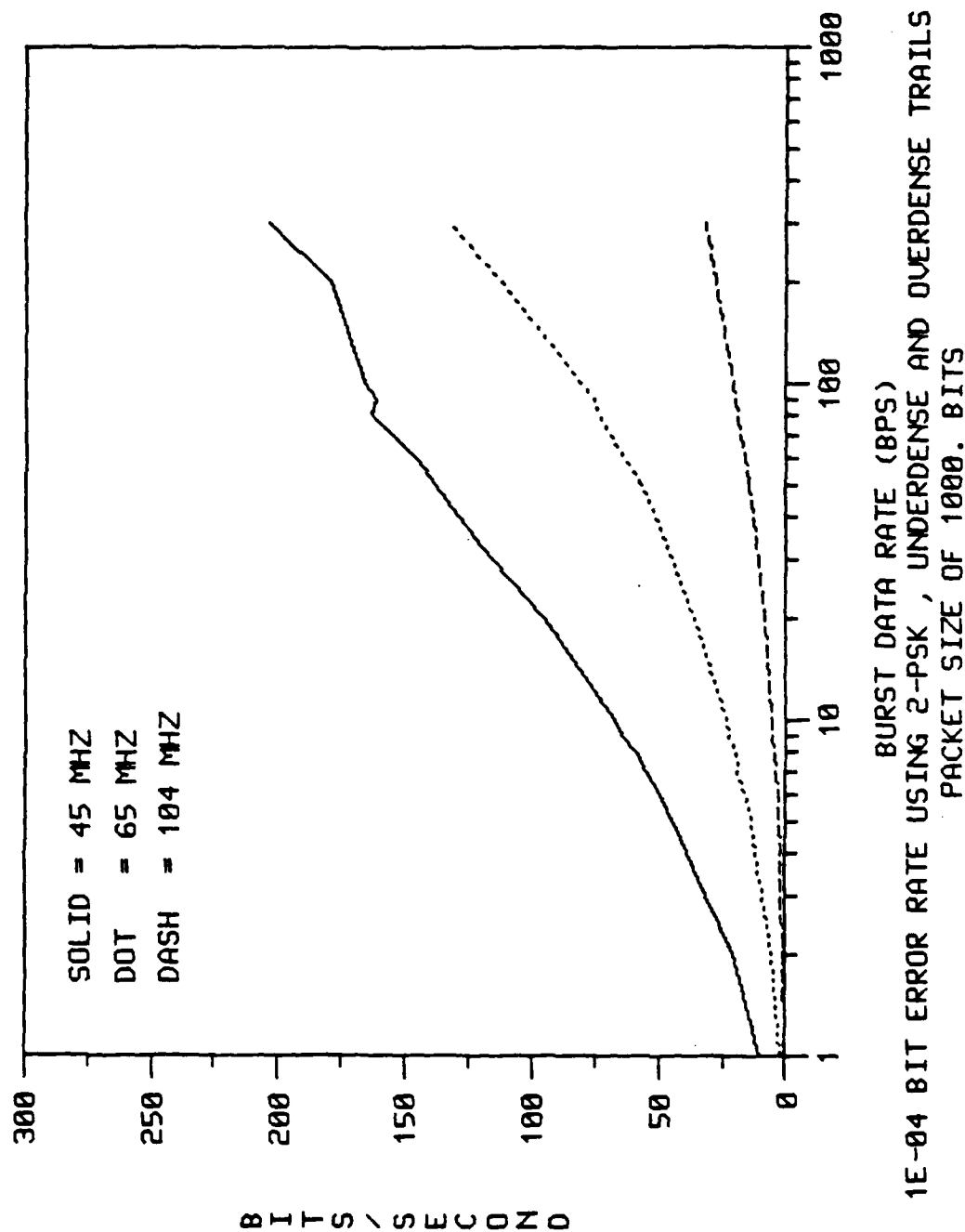
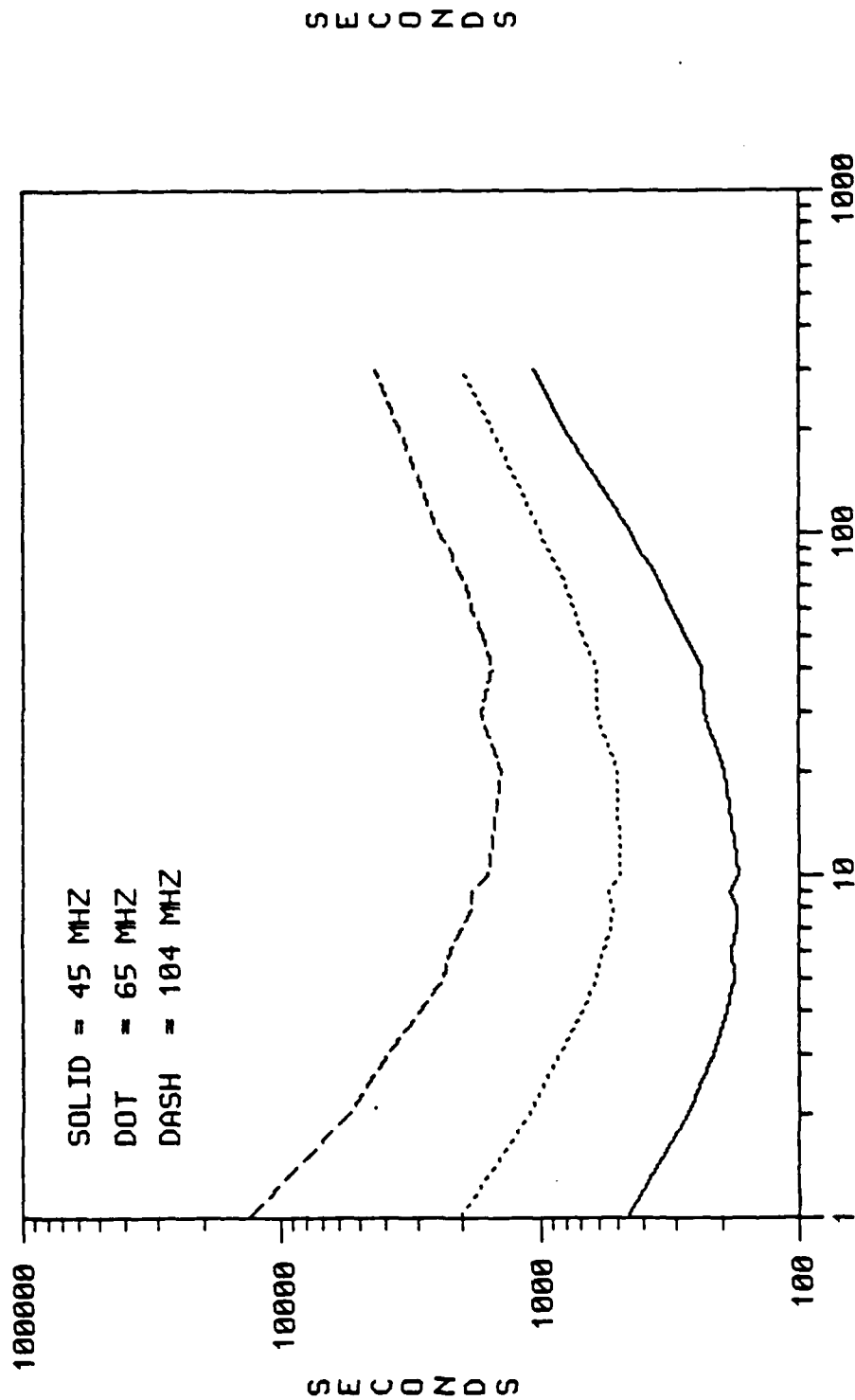


Figure 3-10 Average throughput for fixed rate communication system versus Burst Data Rate for 45, 65, and 104 MHz for February 1985. The modulation is 2-PSK at BER = 10^{-4} with 1000 fit message packets.

MESSAGE DELIVERY TIME FOR 1000 BIT MESSAGE FOR FEBRUARY 1985



DATA RATE IN KBPS
OVERDENSE AND UNDERDENSE WITH 1E-04 BIT ERROR RATE USING 2-PSK
PACKET SIZE = 1000 BITS CONFIDENCE = 90.0%

Figure 3-11 Time to deliver a 1000 bit message with 90 percent confidence versus burst data rate for system identical to system in Figure 3-10.

SECTION 4

CONCLUSIONS

The data base from the High Latitude Meteor Burst Test Bed program represents a powerful yet compact research resource for analyzing the communication and propagation properties of the high latitude meteor channel. The figures presented represent just a few of the many analyses that can be performed using the data base. In another report, the overall results from the high latitude program will be presented using the data base analysis procedure outlined in this report. The routines developed for the high latitude program can be applied to other meteor burst experiments to develop a more complete data base of meteor burst propagation information and could be applied to other propagation applications.

SECTION 5
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REFERENCE

Weitzen, J.A. and S. Tolman, A Technique for Automatic Classification of Meteor Trails and Other Propagation Mechanisms for the Air Force High Latitude Meteor Burst Test Bed, submitted to Radio Science.

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