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Sincerely,

for Donald Nicholson
Paul J. Jacobsmeyer
Chief

Enclosures:
As stated

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NATIONAL BUREAU OF STANDARDS REPORT

9839

Final Report

ELECTROMAGNETIC PULSE SIGNAL CLASSIFICATION AND IDENTIFICATION OF NEARBY SFERICS IN THE HIGH ALTITUDE NUCLEAR DETECTION STUDIES (HANDS) PROGRAM

VOLUME II

Sponsored by
Advanced Research Projects Agency
Nuclear Test Detection Office
ARPA Order No. 183

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NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
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ELECTROMAGNETIC PULSE SIGNAL CLASSIFICATION AND IDENTIFICATION OF NEARBY SFERICS IN THE HIGH ALTITUDE NUCLEAR DETECTION STUDIES (HANDS) PROGRAM

VOLUME II

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Sponsored by
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PREFACE

This work is reported in two volumes. Volume I contains the description of the experimental plan which includes the rationale for the signal selection and classification criteria which were employed. Volume II contains the description of the experimental equipment and system configuration, the calibration procedures employed, the experimental results and conclusions.

We acknowledge the contributions of the many individuals which have made this project possible. The collaboration of A. Glenn Jean, and the entire HANDS staff of the ESSA Research Laboratories is especially appreciated. Don R. Boyle, E.F. Ainsworth, W.B. Truitt, P.G. Stein, T.B. Hall and J.H. McGrath all contributed to the design, development, installation or operation of the experimental equipment. C.L. Albright and D.S. Grubb provided assistance in data reduction and J.R. Pino furnished essential administrative and secretarial support.

ABSTRACT

Electromagnetic pulse signals from certain classes of nuclear events, in terms of height of burst and distance, have features which afford a means of recognition. Similar features are also observed in atmospherics, but these have a smaller normalized source function amplitude. An experiment was conducted to investigate the feasibility of measuring the distance to nearby sferics using azimuth and amplitude data observed at two sites separated by a few kilometers. Knowledge of the distance to the source and the observed amplitude would permit calculation of the normalized source function amplitude which might be used as a discriminant. Data were also collected on the frequency of simultaneous (within equipment and propagation delay) observation at both sites, of signals exceeding 10 V/m amplitude and 10 V/m/µs rate of rise which persisted for one microsecond or less. Transients from lightning would not be expected to meet these criteria over propagation distances of more than a few kilometers.

The distance ranging experiment did not yield results which were within acceptable limits in accuracy based on the locations and dispersion of fixes plotted during a period of activity from a presumably isolated thunderstorm region whose position was established by weather radar. Results from the spaced transient detectors were favorable and this technique appears sufficiently promising to warrant further investigation under the HANDS program.

ELECTROMAGNETIC PULSE SIGNAL CLASSIFICATION AND IDENTIFICATION OF NEARBY SFERICS IN THE HIGH ALTITUDE NUCLEAR DETECTION STUDIES (HANDS) PROGRAM

VOLUME II

BY

R.T. MOORE
K.M. GRAY

I. INTRODUCTION

The rationale for the design of the experimental plan to collect data for the classification and identification of nearby sferics has been described in Volume I, NBS Report 13A-101 (SRD), of this report.

This plan required the measurement of amplitude and azimuth data on individual signals at two sites with a baseline separation of 20 to 30 kilometers. Data from the remote station were relayed by a high-speed digital microwave link to the base station at Table Mountain where they were recorded, together with locally obtained measurements on the same sferic signal.

Additionally, signals meeting certain preset waveform criteria were independently recorded at Table Mountain.

A brief outline of the equipment configuration which was employed at Campion and at Table Mountain is contained in Sections II and III. System Calibration is described in Section IV. Section V describes the experimental results, and Section VI the conclusions.

A sample of the data collected is reproduced in the Appendix.

II. REMOTE STATION EQUIPMENT CONFIGURATION

Siting

In the selection of a site for the remote station, primary consideration was given to locations which were within line of sight of the Table Mountain Facility and at a distance of about 30 km. Secondary considerations included accessibility to power and telephone lines and terrain which was geographically similar to that at Table Mountain.

Several areas to the north of Table Mountain were surveyed, and from these a site one mile west of Campion, Colorado appeared most suitable. It was 27.5 km on a true bearing of 26 degrees from Table Mountain and located just to the west of the brow of a slight elevation that provided a line-of-sight microwave path to the base station.

A small area approximately 100 feet north of the road was leased and enclosed by a rope fence to keep cattle out. A van housing the remote station equipment was positioned within the enclosure, together with a trailer mounted motor generator and a small metal utility shack. Two meter whip antennas for the AWRE transient detector and the Digital dB meter were mounted on small ground planes within the enclosure while the crossed loops and sense antenna for the azimuth digitizer equipments were mounted on a 15-foot high wooden platform located about 100 feet northwest of the enclosed area. Buried plastic conduit was employed to bring the cables from the platform to the van within the enclosed area.

The antenna for the microwave data link equipment was mounted on a six-foot tripod fastened to the roof of the equipment van and aligned with Table Mountain. The north-south loops of the azimuth digitizer equipment was also aligned in the same direction, thus all bearing data was relative to the base line between the two stations.

Power for operation of the remote station was obtained from the REA serving the area. Two power distribution systems were employed within the van, a utility system and an instrument power system. The utility system served lights, air conditioning and heating equipments and the convenience outlets on the maintenance bench. The instrument power was obtained from a 1.5 KVA electric motor generator mounted on a small trailer. The motor generator was equipped with a large flywheel and its inertia would maintain the output voltage to at least 105 volts for interruptions of motor power having a duration of up to three seconds. The instrumentation equipment was isolated from voltage transients and momentary outages which are frequent during thunderstorms by this arrangement. Under-voltage protection was provided by automatically disconnecting the instrumentation from the generator when its output was less than 105 volts.

A leased land-line between Campion and Table Mountain was employed for communications and remote monitor and control functions. Unauthorized entry, excess temperature and power status at Campion were continuously displayed on a monitor panel at Table Mountain. Primary power at Campion could be turned on and off from Table Mountain and a limited equipment calibration could also be remotely initiated. Telephone signalling could be accomplished from either station, but monitor and control functions were disabled when the line was employed for voice communications. This capability for voice communications between the two stations was indispensable in establishing and checking out the operation of the Campion equipment.

Equipment Description

The general configuration of the instrumentation at the Campion station is shown in Figure II-1. With the exception of the antennas and their cable drivers, the equipment was mounted in two standard 19-inch racks in the instrument van.

Incoming signals exceeding a nominal threshold of 0.5 V/m caused a master trigger to be generated by the AWRE Signal Normalizer. This trigger initiated the timing sequence employed by the system. The Digital dB Meter and Azimuth Digitizer operations were started and the control system was reset. The Digital dB Meter was gated on for a period of 60 μs and the peak signal amplitude (either polarity) observed within this period was stored. At the end of 60 μs the stored value was digitized. Digitization required an additional 60 μs and the data was then transferred to the buffer and modem interface where bits were added identifying it as an amplitude measurement and indicating whether or not a transient detector output had also occurred. The data word was then output serially to the microwave equipment for transmission at a rate of one bit each four microseconds. The azimuth data from the azimuth digitizer is available no sooner than 200 μs after the master trigger. It, in turn, is transferred to the buffer for assembly with additional bits providing identity and validation information and it is then transmitted at a time ranging from 20 to 200 μs after the amplitude data.

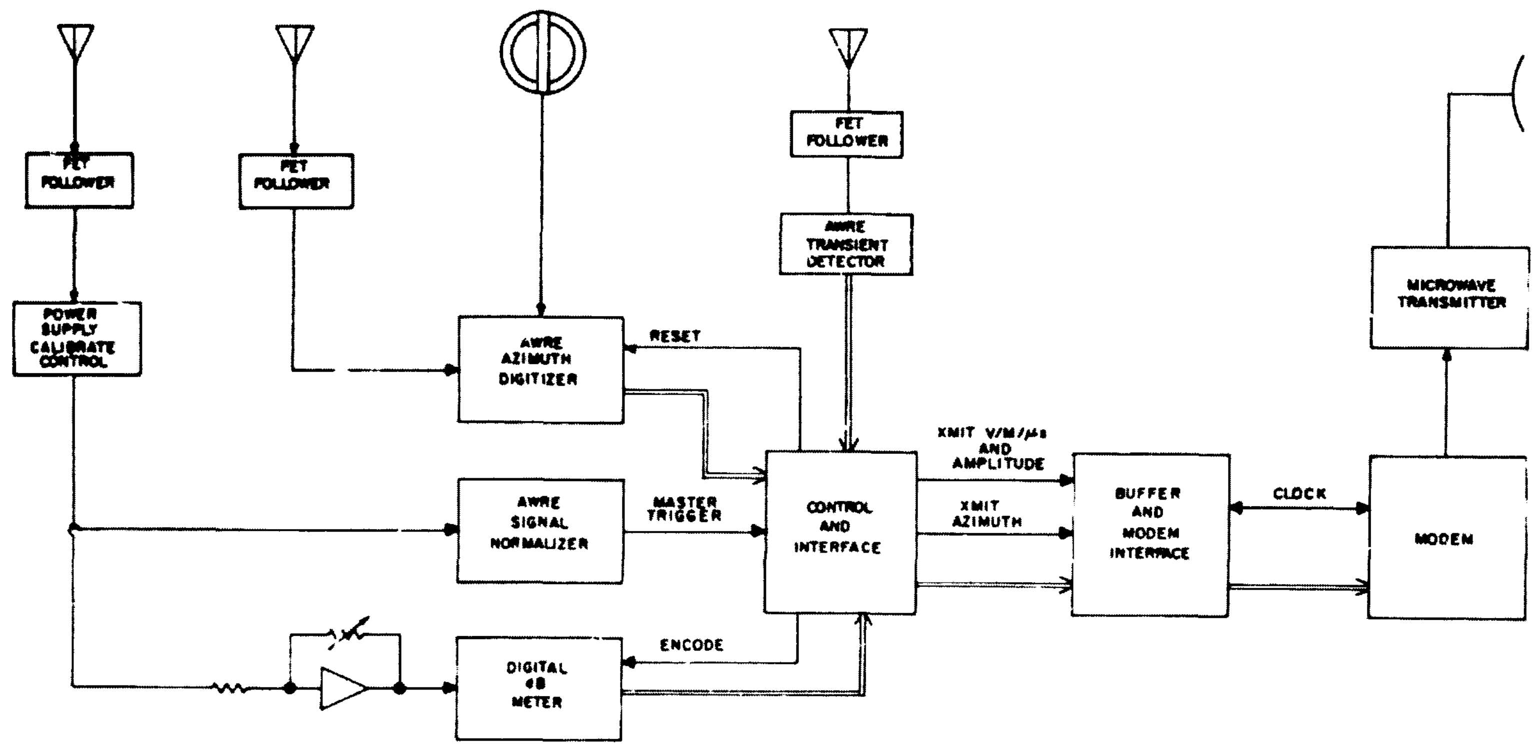


FIGURE II-1. CAMPION EQUIPMENT CONFIGURATION

A brief functional description of the major instrumentation components shown in Figure II-1 follows:

AWRE Azimuth Digitizer and Azimuth Display

The Azimuth Digitizer and Display, supplied through the courtesy of AWRE, was used for receiving the sferic signals and digitizing their angle of arrival. Two crossed-loop antennas and an omnidirectional vertical antenna are used for signal pickup. The vertical antenna and its associated cable driver have a bandwidth from 1000 Hz to 150 kHz, while the crossed loops form part of a narrow-band tuned circuit centered at 11.1 kHz. The vertical antenna is used to resolve the 180-degree ambiguity associated with crossed-loop direction finding. The digitized azimuth, in the form of a serial pulse train, is counted and displayed on the Azimuth Display unit at the same time it is transferred to the buffer. The equipment was set up to accept and process sferic signals separated in time by four or more milliseconds.

Calibration signals could be applied locally or remotely to the equipment. In the local calibration mode, any of the eight quadrature azimuth directions may be simulated by a selector switch. In the remote mode, only that azimuth direction corresponding to a single position of the selector switch may be simulated.

AWRE Signal Normalizer

The signal normalizer, also supplied through the courtesy of AWRE, is designed to generate a master trigger when signals exceeding a preset amplitude threshold are observed and to normalize the amplitude of these signals to provide a peak output that is constant within 10 dB from input signals having up to 50 dB variation in peak amplitude. In the equipment configuration employed at Campion, only the amplitude discrimination and master trigger functions were utilized.

Digital dB Meter and Display

This unit is used to measure the peak amplitude of the received signal. It operates directly from a wide-band antenna driver and produces a binary coded 9-bit number plus sign which represents the peak amplitude, in dB, of the received electromagnetic signal. The 0.1 dB frequency response is 1 kHz to 150 kHz and response is down 3.0 dB at 250 kHz. Resolution is 0.1 dB over a 51.1 dB dynamic range and accuracy is ±0.2 dB over that range within the 1 kHz to 150 kHz frequency band. The unit is initiated by the "Master Trigger" pulse and digitizes the peak amplitude occurring within a 60 μs time bracket referenced to that trigger. The digitized amplitude and sign are displayed on the display unit and at the same time a level change is produced indicating the end of conversion and causing the data to be transferred to the buffer for transmission.

AWRE Transient Detector

The AWRE transient detector provides an output pulse upon receipt of a signal having a peak amplitude greater than 10 V/m. A second output is provided by signals having a rate-of-rise ≥10 V/m/μs which persists for one microsecond or less. A third output is provided when both of the foregoing criteria are met. Each of these outputs is employed to actuate one of three electromechanical counters incorporated in the equipment but only the output resulting from signals meeting both amplitude and rate-of-rise criteria was relayed to Table Mountain.

Control

The control unit is activated by the Master Trigger and produces a sequence of timing signals employed by other portions of the system. These include commands to transmit amplitude data and transmit azimuth data. In addition, the control unit performs certain validity tests on the amplitude and azimuth data and incorporates the results of these tests in the transmitted messages.

Buffer

The buffer gates the digital information, representing amplitude and azimuth, into temporary storage, and then, under the command of the Control Unit, sequentially scans the digital data, presenting it in serial form to the Microwave Transmitter. The sequential scan rate is controlled by a clock operating at 250 kHz. Two frames of data are sequenced, one representing peak amplitude and the other representing azimuth. Each frame of data is 14 bits in length, starting out with a double zero as the block or frame identifier, then followed by a flag bit which is used to indicate the type of frame, i.e., amplitude or azimuth. The remaining bits are used for data. The logical ones and zeros of the data word are as follows: two transitions per bit time equal a logical one, and one transition per bit time equals a logical zero.

Microwave Transmitter

The microwave transmitter provides one watt output on a carrier frequency of 1755 mHz. It is frequently modulated and provides a base-band response from 300 Hz to approximately 750 kHz. The antenna is equipped with a four-foot diameter parabolic reflector providing 25 dB gain. This reflector is attached to a six-foot tripod and mounted on the roof of the van.

III. TABLE MOUNTAIN EQUIPMENT CONFIGURATION

The general configuration of the base station equipment employed at Table Mountain is shown in Figure III-1. The installation was made in the ARPA building and the equipment (excluding computer) occupied approximately five and one-half standard 19-inch racks.

Facilities for measuring the azimuth and amplitude of sferics and the detection of transients were identical to the equipments used at Campion. These data were digitally recorded using the HANDS SDS-930 computer. It had been the intention to process these data in real time to identify nearby sferics, but it was necessary to modify this plan to accommodate only on-line data recording with the computer.

The basic facilities for measuring and recording azimuth and amplitude are supplemented by special equipments for detecting signals meeting preset combinations of waveform feature criteria, classifying these signals in accordance with the selected combinations of features and recording the results on a high-speed transient recorder independent of the HANDS computer.

A brief functional description of each of the major equipment components which have not already been described follows:

Microwave Receiver

The microwave receiver is the companion component of the transmitter used at Campion and has compatible performance characteristics. The incoming signals are picked up with an antenna equipped with a four-foot parabolic reflector mounted on the roof of the ARPA building and in "line of sight" of the Campion antenna. The incoming signal is demodulated to obtain the 250 kHz data bit stream. This signal is then input to the Computer Interface and Control logic.

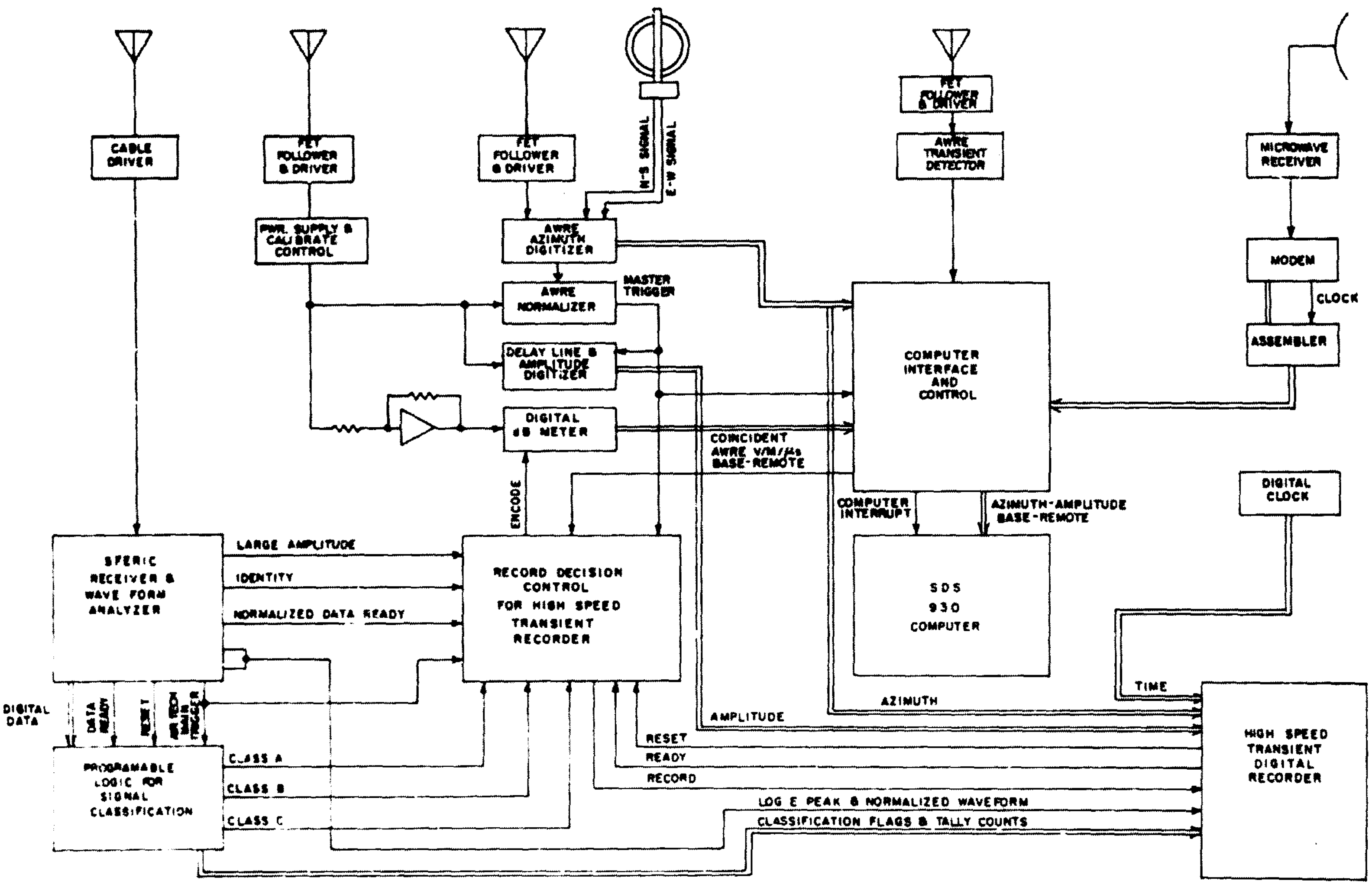


FIGURE III-1. TABLE MOUNTAIN EQUIPMENT CONFIGURATION

Computer Interface and Control

The Computer Interface and Control accepts the output of the microwave receiver, recovers the clock, decodes the bit stream into ones and zeros and strobes the data bits into the appropriate register for subsequent processing and recording. The logic is arranged to detect a double zero in the bit stream, indicating the start of the data frame. The detection of the double zero opens a gate which accepts the next 12 bits, under clock control, to the buffer register. There the data are assembled with a corresponding amplitude (or azimuth) measurement observed by the Table Mountain equipment. A computer priority interrupt is then generated and the data is input to the SDS-930 computer and tagged with the time, resolved to the nearest centisecond.

AWRE Normalizer

This equipment is used somewhat differently than the normalizer at Campion inasmuch as, in addition to producing a master trigger or initiation pulse for the whole system, it also performs a scaling operation on the analog waveform. The analog waveform is simultaneously applied to the normalizer and a delay line. While in the delay line, the signal peak amplitude is measured. Based upon this measurement, a series of "gated" 10 dB amplifiers are set up. One millisecond later the analog signal from the delay line is input to the "gated" amplifiers. The resulting output signals are thus "coarse" normalized to within 10 dB.

After the coarse (10 dB) normalization of the signal, the normalized signal is again scaled, or measured, to the nearest unit of dB. The amplitude of the signal is then displayed in decimal form to the nearest unit of dB. A further scaling of the analog waveform is performed with an additional delay line being used for storage of the waveform while the gain of an amplifier is adjusted digitally in one dB steps. This operation yields an analog waveform, delayed in time by 2 ms from the master trigger, and normalized to the nearest unit of dB. This waveform is available for recording by the high-speed transient recorder if desired.

Record Decision Control

The Record Decision Control is used to control the peripheral high-speed transient recorder. The control is operated from one or more sense lines from the various equipments. When signals or events meeting preset criteria occur, a record decision results and the high-speed transient recorder is enabled. The criteria employed to initiate recording are described in Section V.

High-speed Transient Recorder

The high-speed transient recorder equipment is intended to digitize normalized analog waveforms and record these with appropriate header information on magnetic tape. It contains a six-bit analog-to-digital converter operating at a one mHz sample rate, a 1024 word core memory, control logic and a magnetic tape transport. Digitized analog waveform samples are loaded into the core memory at the sample rate. Header information consisting of a date time group, identity and flag characters and other data is then input to the memory from buffer registers. The memory contents may then be recirculated and output through a digital-to-analog converter to display the stored waveform on an oscilloscope or alternatively recorded on digital magnetic tape. Normally this latter mode of operation was employed. Maximum recording rate is approximately 30 signals per second each having a maximum duration of one millisecond.

The tape unit is a standard 7-track tape recorder. Bit densities of 556 BPI and 800 BPI can be manually selected.

Sferic Receiver and Waveform Analyzer

This equipment was built to NBS specifications and performs the following functions:

A) Receives atmospheric signals in the frequency range of 1.0 kHz to 5.0 mHz, over a dynamic range of from 0.1 V/m to 2500 V/m.

B) Examines the signal for certain presettable waveform features including amplitude and half-cycle duration and determines if a processing sequence is to be initiated.

C) Measures the peak amplitude of the incoming signal and normalizes same to ± 1 dB over the full dynamic range specified. One millisecond later the signal is available in analog form with a constant peak amplitude of 5 volts ± 1 dB.

D) Determines if the signal peak amplitude exceeds 10 V/m. Signals having peak amplitude greater than 10 V/m are specially classified.

In addition, twenty-eight discrete values associated with seven parameters of waveform features can be set up by front panel controls. A digital output is produced for each parameter value met or exceeded by the analog waveform (all measurements are performed on either the first or second half-cycle of the waveform).

The following parameters may be set up and subdivided into signal ranges: waveform polarity; rate of rise; time to peak; peak amplitude; multiple peak; early peak and half-cycle duration.

Certain other control signals are produced, such as "data ready", "signal equality", and "waveform ready to record".

All of these signals and controls are available on separate lines and can logically be combined in other equipments as desired.

Signal Classification Logic

The signal classification logic is arranged to accept up to six digital inputs from the sferic receiver and waveform analyzer in three separate groups. Each group is logically combined to produce inputs to the Record Decision Control. The groups are identified by characters located within the format of the record to facilitate analysis of the data. In addition, the receipt of signals having peak amplitude greater than 10 V/m by the sferic receiver and waveform analyzer or a signal meeting both criteria of the AWRE Transient Detector would also produce a record command.

The equipment is also used to count the number of signals not meeting criteria required for recording by the transient recorder. The overflow of the event counter then causes a record command to be produced.

Antenna Calibration Facilities

Facilities were incorporated at both Campion and Table Mountain to calibrate the antenna cable drivers of the AWRE normalizer equipment and the Digital dB meter. Signals with known characteristics could be injected into the system and the response measured, to assure proper operation.

System Timing

The basic timing diagram of the overall system is shown in Figure III-2. The entire timing cycle is referenced to the "Master Triggers" produced at Table Mountain. Figure III-3 illustrates the time frame diagram and shows the tolerances or time spreads between the two stations. The time correlated, two-station data, is always available within one millisecond of the Base Station Master Trigger. This would permit direct correlation of signals with the

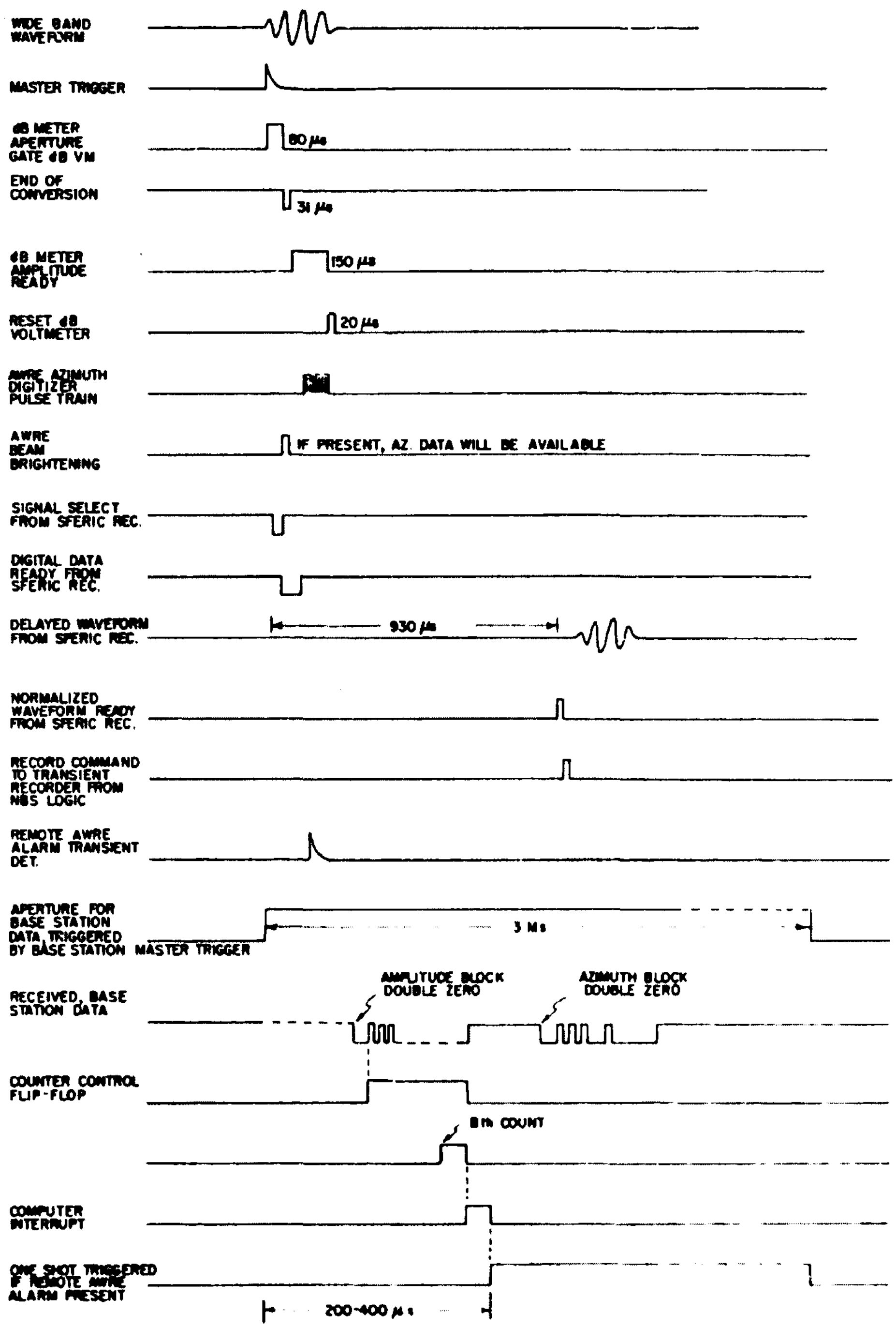


FIGURE III-2. SYSTEM TIMING DIAGRAM

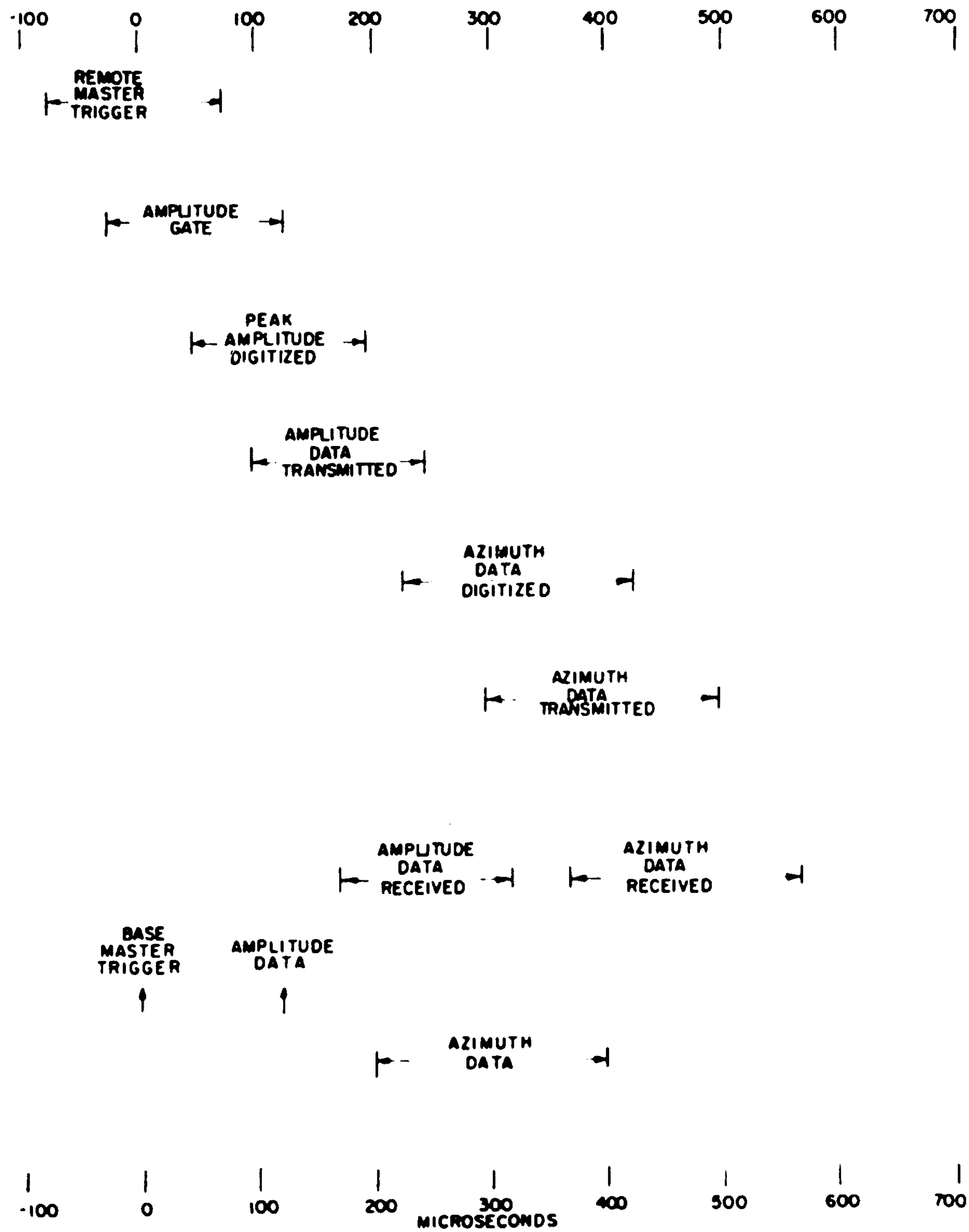


FIGURE III-3. TIME FRAME DIAGRAM

sferic receiver and waveform analyzer equipment in real time, and would allow all of the signal classifications to be performed within this time period. The basic system resolution was limited to four milliseconds minimum between signals by the Azimuth Digitizer. The transient recorder was limited to a recycle time of about 34 milliseconds, however, by the digital magnetic tape transport.

IV. SYSTEM CALIBRATION

The effects of local environmental factors can normally be expected to influence the apparent value of azimuth and to a lesser extent, the amplitude of a signal as observed at a given location. The unavoidable presence of conductors, such as power lines, antennas, fences, etc., in the vicinity of direction finding loops causes distortions in an incoming wave front which vary as a function of azimuth. For accurate position fixing, it is necessary to determine these siting effects and to apply appropriate corrections to the observed data. In this case, since range information was desired rather than position information, the calibration procedures employed were somewhat different than those which might be used in a position fixing network.

Amplitude Calibration

As an initial step in the amplitude calibration process, a field survey was conducted.

Two Type NM-10A Field Strength Meters were calibrated by the NBS Radio Standards Laboratory. These were then set up at the Campion and Table Mountain sites and on June 8 and 9, 1967, a series of simultaneous measurements were taken of the field strength of VLF transmissions from Annapolis, Panama, Hawaii and Seattle. Following the observations, the field strength meters were again recalibrated and the data was reduced.

Seventeen time coincidental observations were made at each site. The average field strength of a given VLF signal as observed at Table Mountain was 1.63 dB greater than that observed at Campion. The mean was 1.70 dB and the standard deviation of the data was 2.00 dB.

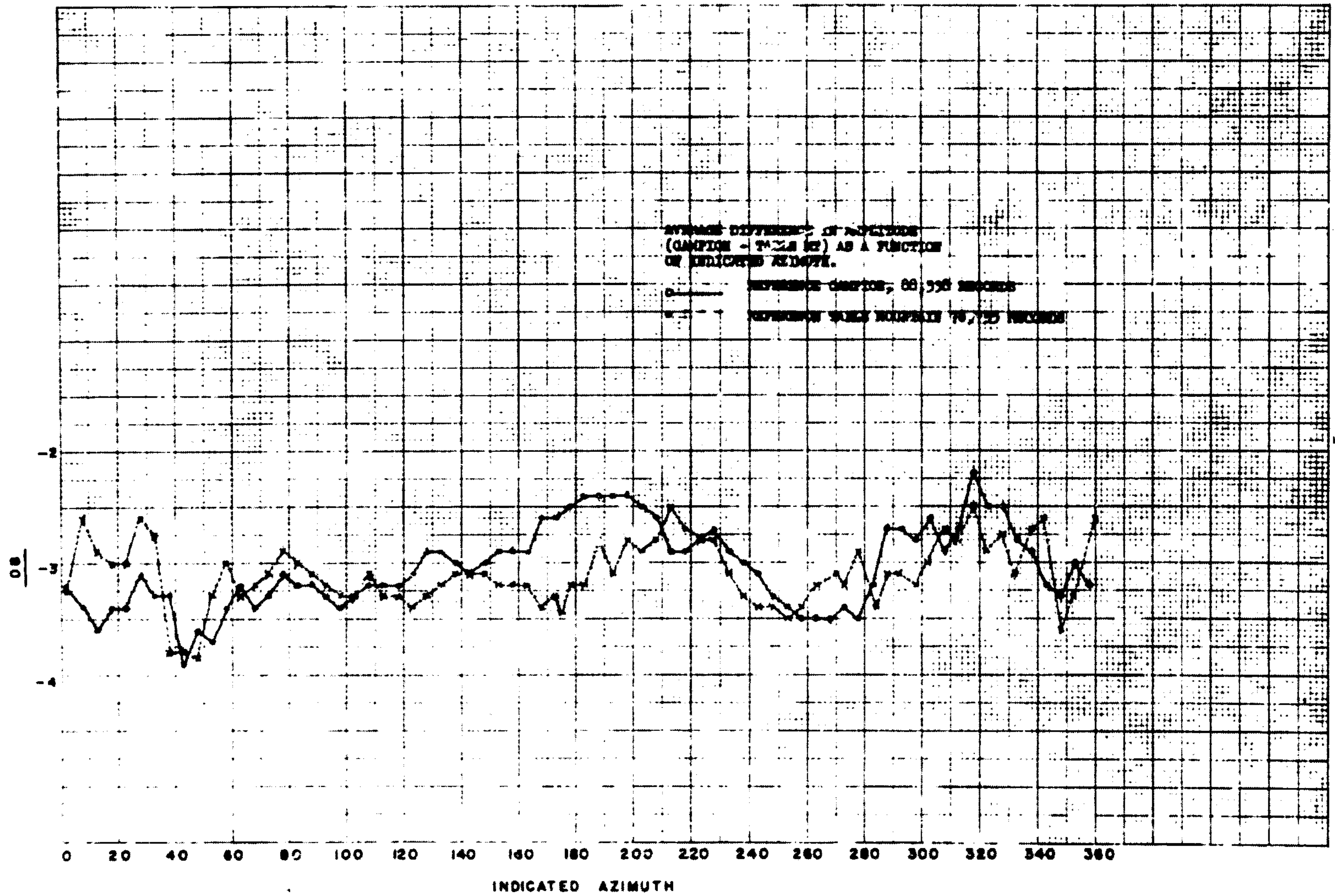
Using the NM-10A as a two-terminal tuned voltmeter, the transfer function of the whip antenna and receiver used to excite the digital dB meter was measured as -20.96 dB, with a standard deviation 1.78 dB, in terms of V/m field strength versus output voltage. Replacing the antenna with its calculated equivalent capacitance of 22 pf, and exciting this with a signal generator, a value of -21.76 dB was observed at 20 kHz. The latter value was adopted as reference and the operational amplifier gain at Table Mountain was set to provide an indicated output of 15.9 dB on the digital dB meter from a 20 kHz signal having a calculated amplitude equal to that resulting from a 1.0 V/m field strength. The gain at Campion was set 1.6 dB higher to offset the observed average difference in field intensity of distant VLF stations at that site.

To test the validity of these settings, a statistical evaluation of the observed amplitude of sferic signals was undertaken. Signals from relatively distant sferics arriving from directions normal to the base line would be expected to have the same average amplitude as observed at each station, while the amplitude of signals arriving from directions along the base line would be expected to be slightly greater at the station nearest the source.

Figure IV-1 shows the average difference in amplitude of 88,338 sferics plotted as a function of indicated azimuth at Campion and 79,735 sferics plotted as a function of indicated azimuth at Table Mountain. These data were selected from signals having indicated amplitude at both stations of $0.28 \text{ V/m} \lesssim A \lesssim 0.5 \text{ V/m}$. If a median source function amplitude of 360 V/m at 1 km and random geographic distribution is assumed, an average range of approximately 900 km may be calculated. This would result in a displacement of the theoretical equi-amplitude curve by about 0.25dB along the base-line (N-S) direction as compared to its values in directions normal to the base line (E-W).

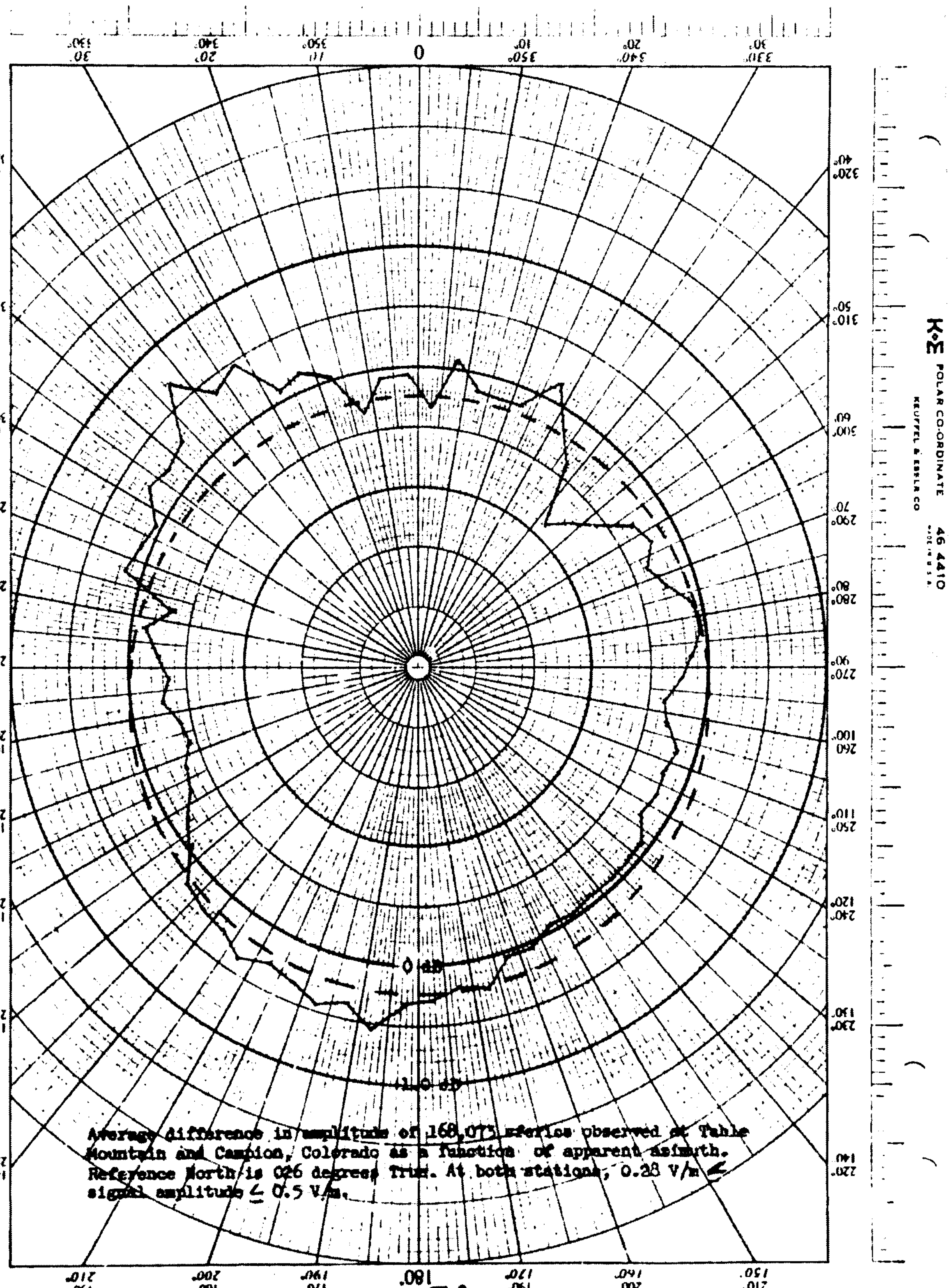
The curves in Figure IV-1 show an interesting correlation in form but have an average displacement of 3.04 dB from zero. The average value of both curves is shown in Figure IV-2 in polar coordinate form after subtracting 3.0 dB displacement, the median difference in amplitude. The standard deviation of the curve from the median value is 0.30 dB.

The 3 dB displacement of the value of the curve from zero was a source of immediate concern. It was discovered upon reduction of the first data tapes at NBS, Gaithersburg, Md. in late October, 1967. Data collection was terminated on November 3, 1967 and the terminal calibration check disclosed that the response of the Campion amplitude measuring equipment was 3.0 dB less than that observed at the time of the last calibration which was made on August 12, 1967 prior to the collection of presumably valid data. It was caused by a malfunction in the cable driver.



-2
-3
-4
δB
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
INDICATED AZIMUTH

Figure IV-1



Average difference in amplitude of 168,073 sferics observed at Table Mountain and Campion, Colorado as a function of apparent azimuth. Reference North is 026 degrees True. At both stations, 0.28 V/m ≤ signal amplitude ≤ 0.5 V/m.

Figure IV-2

This also affected the frequency response as shown in Figure IV-3.

As an aid in evaluating these effects and their influence on the experiment, the data base was subjected to further processing. The average difference in amplitude was computed as a function of amplitude as observed at Table Mountain for those signals arriving from azimuths within ±5° of East and West. The results are shown in Table IV-1 and Figure IV-4.

Table IV-1

Field Strength	No. of Signals	Δ Amp. dB CAM - TM
0.5 - 1.0 V/m	5105	-3.21
1.0 - 2.0 V/m	750	-3.71
2.0 - 4.0 V/m	151	-3.83
4.0 - 8.0 V/m	16	-3.87
8.0 -16.0 V/m	1	-5.4

There appears to be a tendency for the difference in observed amplitude to increase with increasing signal amplitude. This is consistant with the observed impairment to the high frequency response at Campion.

Azimuth Calibration

During the 1966 thunderstorm season, efforts were made to obtain azimuth calibration data to compensate for siting errors at Table Mountain by correlating optically obtained azimuth data with data from the AWRE azimuth digitizer. Although some potentially useful data was obtained, the process was not efficient. Other means were employed after invalidation of this data base occurred when the crossed-loop antenna at Table Mountain was destroyed by high winds.

The process was based on evaluating the average difference in indicated azimuth, as a function of azimuth for a large number of moderately distant sferics. The signals selected were a subset of those employed in calculating amplitude differences, i.e., indicated amplitudes between 0.28 V/m and 0.5 V/m, but excluded certain time intervals when the station log records indicated that azimuth data might be invalid. 73,961 pairs of azimuth observations were then processed by computing the average difference in azimuth for the pairs associated with

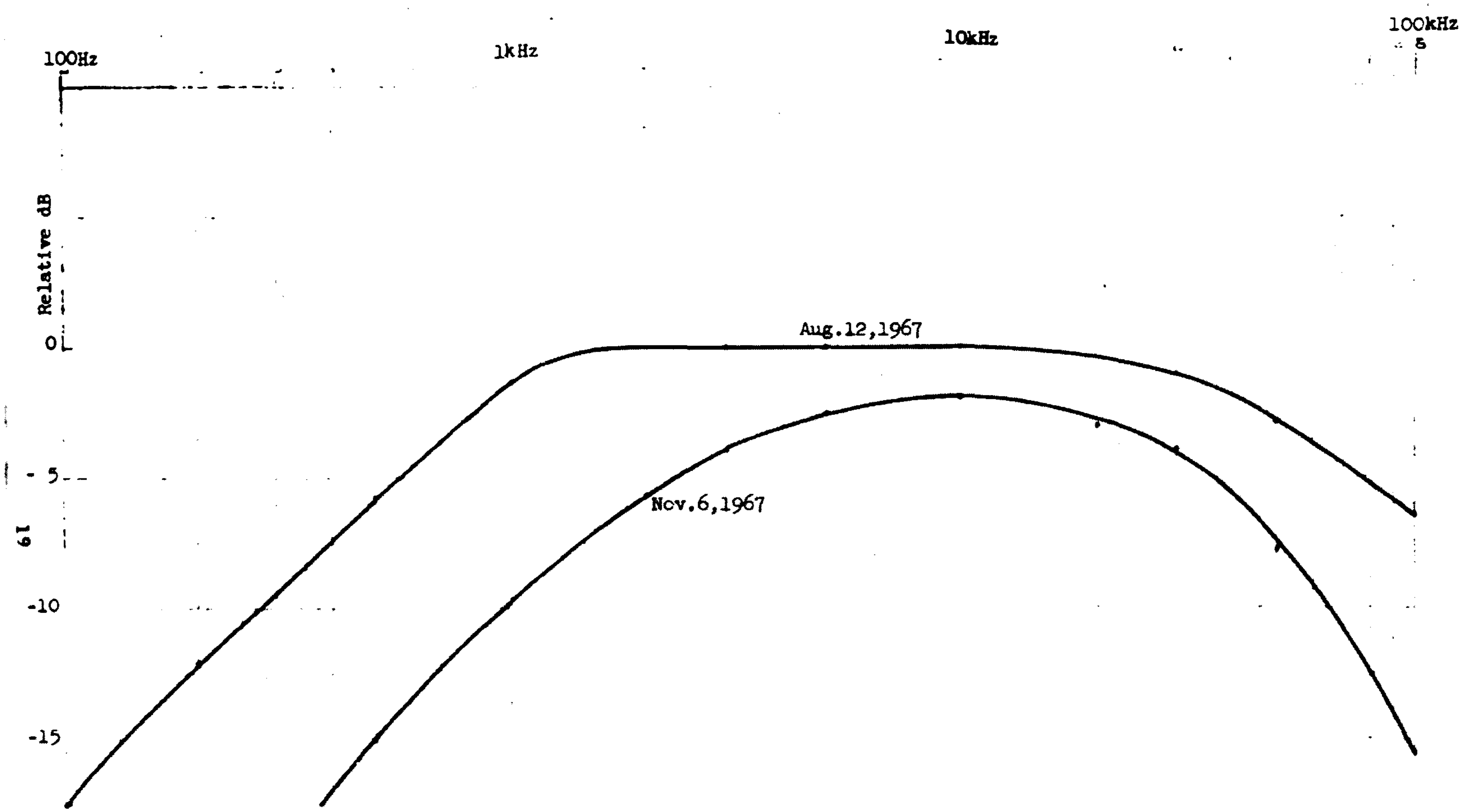


Figure number IV-3 Frequency Response of Input Circuitry to Digital dB meter at Campion

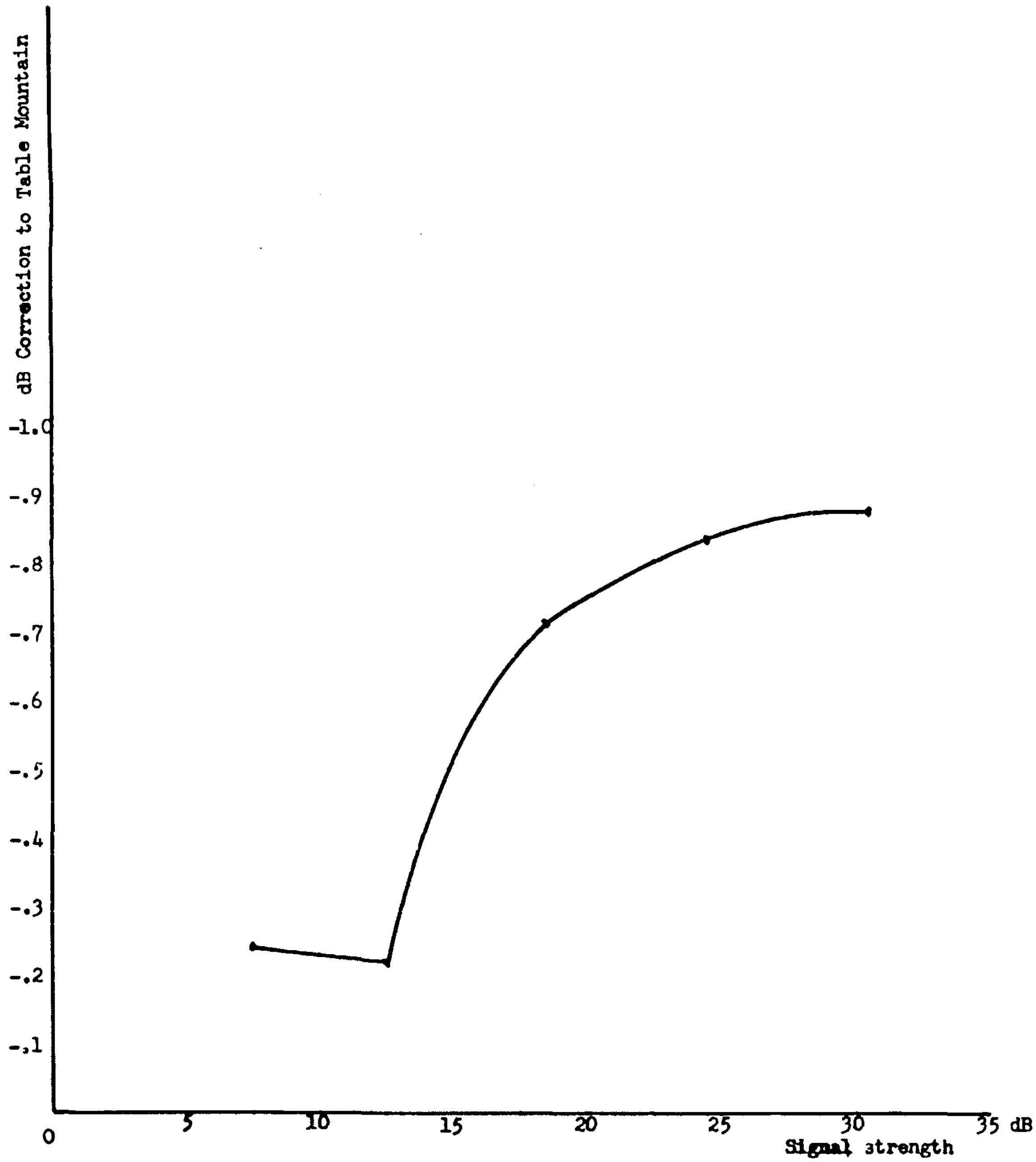


Figure number IV-4 Correction to Table Mountain each 5-degree segment of azimuth as observed at Table Mountain. In computing these averages, any individual pair having a difference in excess of 45 degrees was disregarded. 4,998 such instances occurred. The data were then reprocessed in a similar manner except excluding any individual pair having a difference of more than ±15 degrees from the average difference as previously calculated for that 5-degree sector. 10,727 pairs of signals were excluded on this basis. The remaining 63,234 pairs did not, of course, have uniform distribution as a function of azimuth. The average population is 878 pairs per 5-degree cell, the mean population is 421 pairs and the minimum is 14 pairs.

The average difference in azimuth as computed above represents the magnitude of the combined effects of siting errors at both stations for infinitely distant signal sources. Since the actual signals employed have an estimated average range of approximately 900 km, a convergence of approximately 1.7 degrees is indicated at an azimuth of 90 degrees. The convergence would decrease sinusoidally to zero at zero degree azimuth. The correction for convergence has been applied to the average difference in azimuth and the results are shown in Figure IV-5.

In order to evaluate the relative contribution of each station to the total siting errors shown in Figure IV-5, it is necessary to compare observed azimuth data with centers of atmospherics activity in known locations. The U.S. Weather Bureau disseminates radar summaries of cloud cover over the major portion of the continental United States at two hour nominal intervals. These charts were reviewed for the months of September and October 1967 to determine time intervals when suitably isolated areas of activity were reported. Three such instances were noted and samples of the Campion and Table Mountain data collected during these times was printed out and analyzed. In the one case in which siting errors were large, it was found that the Campion contribution was at least twice the Table Mountain contribution to the total siting error. The instances where weather activity could be correlated with azimuth data as described above occurred within relatively restricted regions of azimuth 123° - 127°, 212° - 228° and 40° - 42°. Of these, only the first is in a region where total azimuthal siting errors were large.

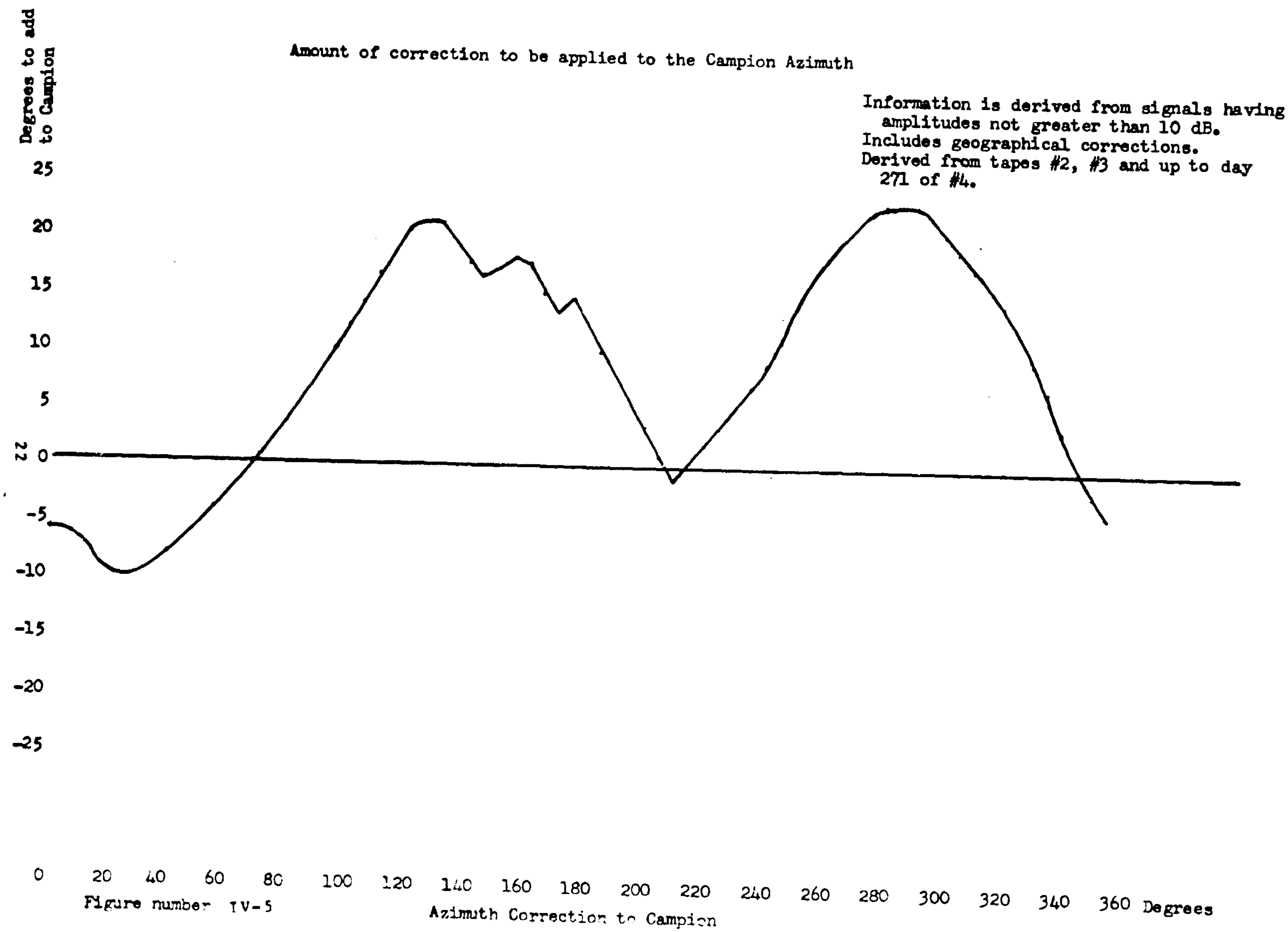


Figure number IV-5

As an aid in evaluating the effect of applying the total azimuth correction to either station, Figure IV-6 was constructed. This figure shows the apparent distance as a function of Table Mountain azimuth to fix positions resulting from a 12-degree convergence in azimuth. One set of curves shows the total correction applied to the Table Mountain indicated azimuth. A second set of curves represents application of the total correction to the Campion indicated azimuth. The difference in distance is indicated by a third set of curves.

The greatest percentage error occurs in directions where amplitude differences would be expected to be useful in establishing range. An arbitrary decision was therefore made to apply the total correction to the Campion azimuth data.

V. EXPERIMENTAL RESULTS

The installation of the equipment described in Section III was made by a team of engineers and technicians from NBS, Washington, D.C. in June and July 1967, acting in collaboration with the regular HANDS staff.

During this period, it was ascertained that the original plan involving real-time processing of the two-station azimuth and amplitude data on the SDS 930 computer at Table Mountain could not be implemented due to unavailability of the necessary computer programs and the unavailability of personnel to generate them and integrate them in the existing 930 operating system within the time constraints established by the summer thunderstorm season.

There was no reasonable alternative but to modify the experimental plan to provide for digital acquisition only of the two-station data with the 930 computer and to process these data at NBS, Washington, where they would be correlated with independently recorded data obtained from the sferic receiver and waveform analyzer.

Under this arrangement, the two-station data could be recorded along with data from the other HANDS sensors with an acceptable amount of programming effort and minimum modification to the 930 operating system.

The output or "N" tapes from the 930 each contain several days of multisensor data. They are processed using the central computer facilities at Boulder Laboratories. As one of the processing steps, arrangements were made to strip

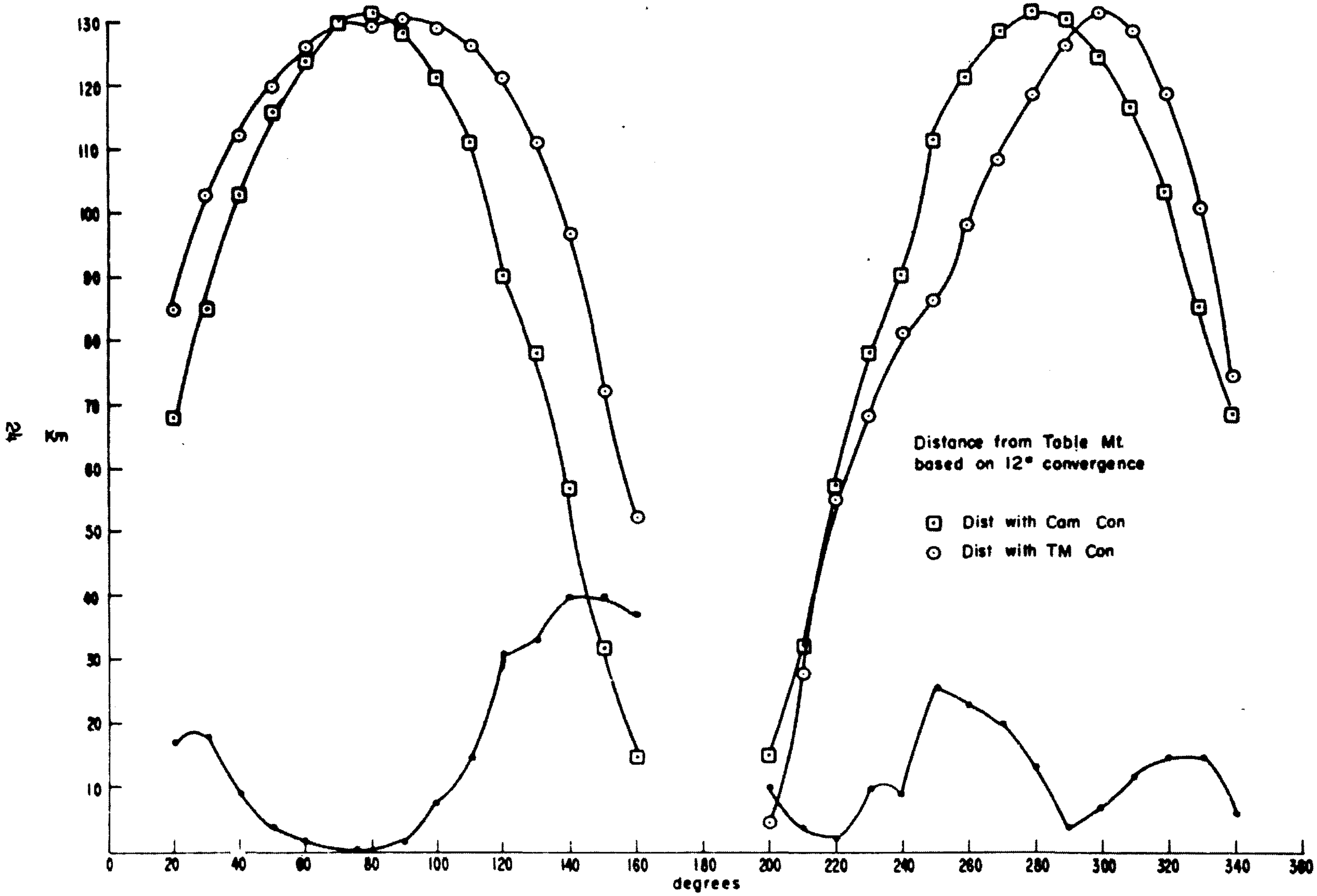


FIGURE IV-6 TABLE Mt. AZIMUTH

off the two-station data and rerecord this on separate digital magnetic tapes which were then shipped to Washington.

Data from the sferic receiver and waveform analyzer was recorded on the high-speed digital transient recorder and these tapes were then shipped directly to Washington without prior processing at Boulder.

The first two-station data tape was received in Washington late in July and preliminary examination of printouts of the raw data indicated the probability that equipment malfunction had occurred. This probability was confirmed and several equipment failures were located and corrected by August 19, 1967. Data collection was again initiated but almost immediately interrupted by a series of computer outages and another failure of the AWRE azimuth digitizer at Table Mountain. Following the correction of these faults, two-station data collection was again resumed on September 6, 1967 (day 249) and maintained for continuous periods ranging from a few hours to a few days duration until November 3 (day 307). The times at which data was collected which was presumed (at the time) to be valid are shown in bar graph form in Figure V-1 for the period from day 249 to day 268. The operation from day 269 to day 307 was more nearly continuous but little or no local thunderstorm activity occurred during this time.

The second and third tapes of two-station data were received in late September and early October. They were accompanied by sample print-outs of the raw data as shown in Figure V-2. The format is described as follows:

HEADING Record No., Day of Year, Hour of Day, etc.

TIME CAMPION AMP TABLE MT AMP TIME

CAMPION AZIMUTH TABLE MT AZIMUTH, etc.

TIME: The time word consists of 6 digits: minutes, seconds and centiseconds.

AMPLITUDE: The amplitude word consists of 24 bits (8 octal digits) encoded as follows:

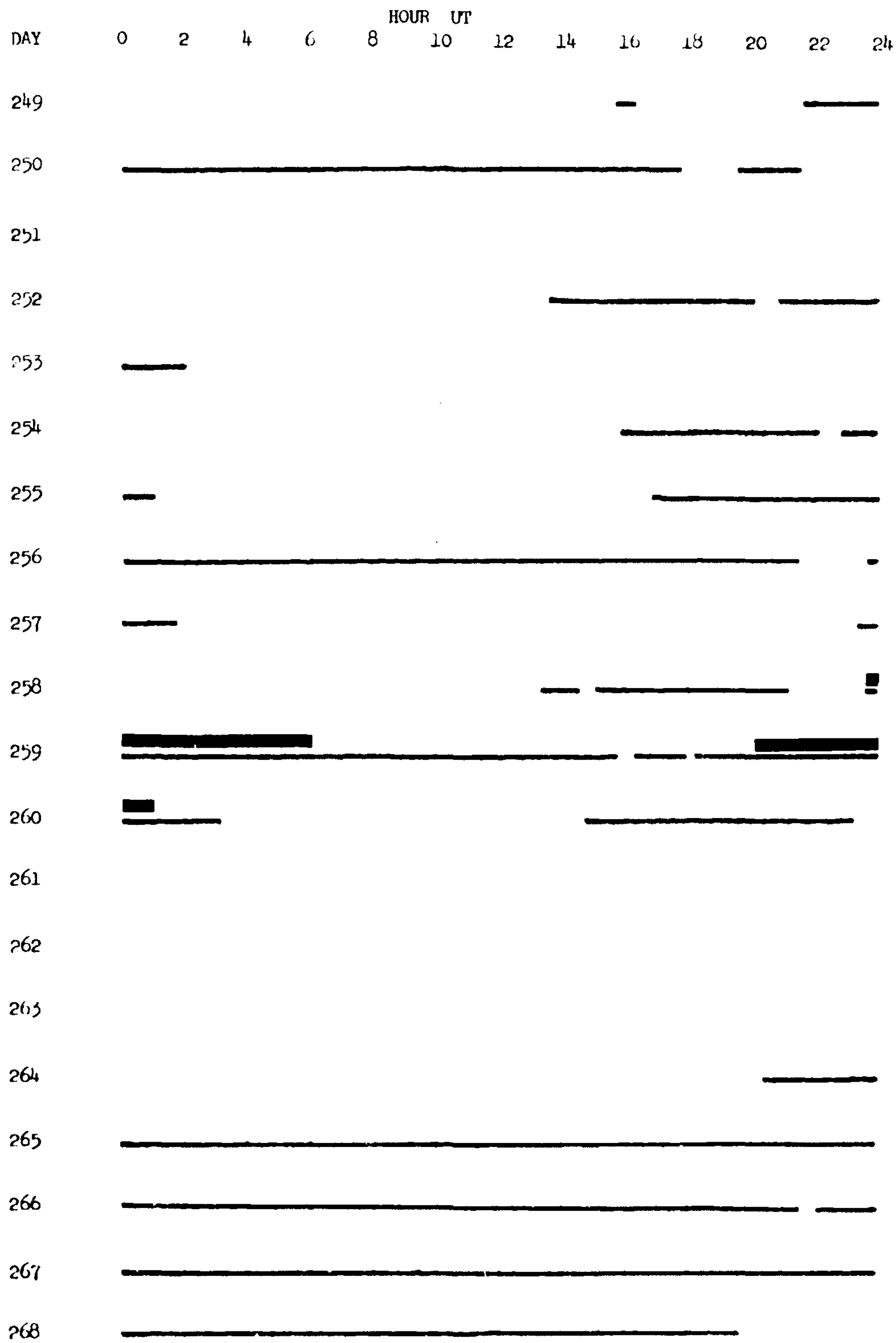

HOUR UT
DAY
0 2 4 6 8 10 12 14 16 18 20 22 24
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268

Figure V-1

REC 932, DAY 260 HOUR 21 (6261) 1CMM 59 CS 23462.86 MS 6692.639

21	327.92	327.-2 1 00 3024	327.92 6000 6000	327.92 6000 6000	327.94 1000 3026	327.95 6000 6000
		327.-6 1.00 3004	327.96 6000 6000	328.52 1000 3000	328.52 6000 6000	328.53 1000 3000
		328.54 6 00 5900	328.60 1000 3045	328.60 6000 6000	329.26 1065 3130	329.26 5122 4472
21	329.3	329.30 1 27 3106	329.30 6000 4000	329.33 1053 3066	329.33 5067 4462	329.36 1004 3011
		329.36 5167 4463	329.42 6000 6900	329.46 1056 3065	329.46 5106 4445	329.52 1044 3071
		329.52 6 00 4524	329.59 1031 3024	329.59 6000 6000	329.99 1177 3232	329.99 4224 5165
21	1239.54	1239.54 4150 5602	1239.58 1154 3215	1239.58 4147 6000	1239.58 4147 6000	1239.60 3127 3127
		1239.60 5170 4201	1239.61 4204 6000	1239.71 6000 6000	1239.82 1000 3117	1239.83 6000 6000
		1239.84 1.00 3000	1239.85 6000 6000	1239.87 1131 3165	1239.87 5140 4441	1239.92 6000 6000
21	1240.14	124 .14 1113 3143	1240.14 5207 4200	1240.17 1027 3130	1240.17 6000 6000	1240.22 5211 4201
		124 .25 1134 3203	1240.25 5125 4441	1240.28 1021 3054	1240.28 6000 6000	1240.65 1115 3161
		124 .65 5140 4442	1241.02 4625 4540	1241.04 1000 3000	1241.04 6000 4000	1241.05 1021 3124
21	2023.83	2023.83 1 24 3050	2023.83 6000 6000	2023.83 6000 6000	2023.85 1000 3000	2023.86 6000 6000
		2023.87 1 19 3000	2023.87 6000 6000	2023.90 1001 3041	2023.90 6000 6000	2024.08 1000 3015
		2024.09 6 00 4000	2024.09 1212 3227	2024.10 4565 4566	2024.10 1000 3123	2024.10 6000 6000
21	2024.14	2024.13 1153 3161	2024.13 5025 4542	2024.14 1000 3020	2024.14 6000 4206	2024.14 6000 4206
		2024.35 1 00 3161	2024.35 4563 4601	2024.40 1043 3132	2024.40 5657 4565	2024.74 1000 3004
		2024.75 6 00 4000	2024.78 1000 3000	2024.78 6000 6000	2024.93 1111 3157	2024.94 6000 6000
21	2649.02	2649. 2 1 05 3031	2649.02 6000 4457	2649.04 1032 3165	2649.04 6000 6000	2649.12 6000 6000
		2649.12 1 34 3126	2649.13 6000 6000	2649.17 1001 3203	2649.17 5062 4462	2649.19 6000 6000
		2649.19 6 00 6000	2649.21 6000 6000	2649.53 1073 3104	2649.54 5040 4544	2650.58 1174 3255
21	2650.58	2650.58 5121 4461	2650.58 1000 3145	2650.58 6000 6000	2650.60 1000 3044	2650.60 6000 6000
		2650.60 6.00 6000	2650.61 6000 6000	2650.61 6000 6000	2650.65 1000 3032	2650.65 6401 6000
		2650.65 1172 3227	2650.66 5141 4441	2650.68 1000 3000	2650.69 6000 6000	2650.72 5131 4444
21	3258.49	3258.49 6 00 6000	3258.49 6000 6000	3258.50 1126 3243	3258.50 5101 4425	3258.51 6000 6000
		3258.53 1.27 3150	3258.53 6000 6000	3258.54 6000 6000	3258.56 1076 3150	3258.56 5066 4420
		3258.59 1.00 3031	3258.59 6000 6000	3258.59 6000 6000	3258.63 6000 6000	3258.64 6000 6000
21	3258.69	3258.59 1169 3231	3258.69 4967 5522	3258.90 1274 3350	3258.91 5504 4021	3258.92 1136 3140
		3258.93 5507 4020	3258.94 1024 3077	3258.94 6000 4025	3259.27 1067 3156	3259.27 5347 5405
		3259.76 1 44 3362	3259.76 5210 4166	3300.45 1226 3301	3300.46 5040 4527	3300.64 1146 3242
21	3913.80	3913.80 6 00 6000	3913.80 1026 2000	3913.84 1000 3000	3913.84 6000 6000	3913.86 1000 3000
		3913.87 6.00 6000	3913.87 6000 6000	3913.97 1103 3111	3913.97 5020 4546	3913.98 1040 3006
		3913.98 6.00 6000	3913.98 6000 6000	3913.99 1103 3140	3913.99 6000 6000	3914.00 5103 4464
21	3914.03	3914. 3 1.07 3114	3914.03 4631 4544	3914.03 4631 4544	3914.07 1000 3000	3914.07 6000 6000
		3914. 7 6.00 6000	3914.08 1023 3071	3914.08 6000 6000	3914.08 6000 6000	3914.12 1074 3042
		3914.12 6 00 6000	3914.12 6000 6000	3914.46 1064 3075	3914.46 5120 4450	3914.58 1104 3115
21	4545.82	4545.82 6.00 6000	4545.84 1000 3000	4545.84 6000 6000	4545.84 6000 6000	4545.87 1000 3000
		4545.87 6.00 6000	4545.87 6000 6000	4545.88 1153 3250	4545.88 1000 2000	4545.97 1064 3065
		4545.98 6 00 6000	4545.98 6000 6000	4546.04 1042 3072	4546.04 5420 4066	4546.05 1073 3142
21	4546.05	4546. 5 5440 4050	4546.06 3005 3005	4546.07 6000 6000	4546.08 1000 3033	4546.08 6000 6000
		4546. 8 6.00 6000	4546.10 1133 3200	4546.10 5451 4041	4546.12 1000 2000	4546.13 1000 3000
		4546.13 6 00 6000	4546.13 6000 6000	4546.14 1000 3000	4546.14 6000 6000	4546.14 6000 6000
21	5254.72	5254.72 4503 6000	5254.80 3001 3056	5254.81 5041 6000	5254.84 1000 3023	5254.84 6000 6000
		5254.84 6.00 6000	5254.85 1000 3032	5254.85 6000 6000	5254.85 6000 6000	5254.86 1000 3000
		5254.86 6.07 6000	5254.86 6007 6000	5254.88 1001 3030	5254.88 4445 6000	5254.88 4445 6000
21	5254.92	5254.92 4470 6000	5254.92 4470 6000	5254.94 1000 3266	5254.94 4510 4402	5254.96 6000 4502
		5254.96 6.00 4502	5255.03 5231 4430	5255.04 6104 6000	5255.04 6104 6000	5255.05 3033 3066
		5255. 5 6.00 6000	5255.05 6000 6000	5255.21 4421 6000	5255.53 1000 3000	5255.53 6000 6000

FIGURE V-2. SAMPLE PRINT-OUT OF RAW DATA

```
-- Flag - must be zero to indicate amplitude word
|  -- V/m/µs bit - used only in summary statistics
|  |  -- Overload bit - must be a 1 for valid data
|  |  |  -- 9-bit binary amplitude data - LSB
|  |  |  |  equal to 0.1 dB, MSB = 25.6 dB
|  |  |  |__________________
0  X  1  X X X X X X X X X 0 X 1 X X X X X X X X X
                           |<------------------------->
                           |     Same meanings
                           |  as first half of word
CAMPION AMPLITUDE <--      |->TABLE MT AMPLITUDE
```

<u>AZIMUTH</u>: The azimuth word consists of 24 bits (8 octal digits) encoded as follows:

```
-- Flag - must be 1 to indicate azimuth word
|  -- Validity - must be 0 to indicate valid data
|  |  -- Binary hundreds of degrees
|  |  |  -- BCD tens degrees
|  |  |  |  -- BCD units degrees
|  |  |  |  |
1  0  X X X X X X X X X X 1 0 X X X X X X X X X X
                          |<------------------------->
                          |     Same meanings
                          |  as first half of word
CAMPION AZIMUTH    <--    |->TABLE MT AZIMUTH
```

The first step in processing was the preparation of a "Valid Data" tape by screening the raw two-station data against the following series of tests:

A valid amplitude word must:

1) be associated with a valid azimuth word having the same time to $\pm.01$ second, and,

2) the octal representation of each half word must begin with 1 or 3, i.e., both flag bits must be 0 and both overload bits must be 1, and,

3) have a non-zero value for the binary representation of amplitude.

Any word not meeting these three criteria should be rejected. A valid azimuth word must:

1) have 4 or 5 as the octal representation of the start of each half word, i.e., the flag bit must be 1 and the validity bit must be 0, and,

2) contain no illegal BCD characters in the tens or units positions.

Any invalid azimuth word should be rejected from further processing.

This screening was intended to eliminate signals which had been observed only at Table Mountain or only at Campion rather than at both sites, and to further eliminate time correlated pairs of signals when the validity of the data was questionable because of overload, zero amplitude indication, etc.

A program was then prepared to convert the information to engineering units, compute the difference in observed amplitude and azimuth for each signal pair and print out the first twenty records after the start of each hour for manual inspection. A sample of this output is shown in Figure V-3. The time span covered by the first twenty records of each hour is a useful indicator of the relative level of sferic activity. It ranges from a few seconds during active periods to a few hundred seconds during times of low activity.

The "Valid Data" tapes were then processed to develop the average difference in amplitude and average difference in azimuth curves plotted as a function of azimuth for calibration purposes as described in Section IV of this report. The 3 dB offset in difference in amplitude was observed at this time and identification of its cause a few days later raised grave doubts as to whether or not any valid conclusions could be drawn from these data.

As a test, however, two sample time intervals were selected when there was moderate activity as indicated by the data recording rates. These were periods of a few hours duration beginning on days 258 and 259. They are designated by wide bars in Figure V-1. An "Edited Valid Data" tape was prepared which encompassed these time periods and in which 3.0 dB was added to each Campion amplitude measurement. This tape was processed with the R-45 tape from the sferic receiver and waveform analyzer to extract information to

PAGE: 180

2-STATION DATA

DAY NO. 260 HOUR 2

TIME(SEC)	AMPLITUDE(DB) CAMP.	TM	DIFF.	AZIMUTH(DEGREES) CAMP.	TM	DIFF.
.52	5.0	5.6	-.6	146	161	-15
1.83	.7	6.9	-6.2	140	193	-53
4.11	7.8	8.0	-.2	156	173	-17
4.66	5.4	9.1	-3.7	132	132	0
4.73	3.1	11.0	-7.9	358	347	11
6.89	6.8	11.9	-5.1	118	154	-36
10.53	8.2	12.1	-3.9	90	103	-13
12.50	10.1	10.7	-.6	160	167	-7
19.31	9.7	12.1	-2.4	158	173	-15
19.99	12.8	17.7	-4.9	97	125	-28
28.70	5.0	13.4	-8.4	125	145	-20
30.87	9.1	10.3	-1.2	168	186	-18
32.86	9.1	9.8	-.7	148	173	-25
34.16	.7	18.2	-17.5	90	104	-14
34.20	9.1	9.3	-.2	67	104	-37
36.05	10.2	14.6	-4.4	145	171	-26
43.60	4.6	8.7	-4.1	101	130	-29
45.55	13.6	17.4	-3.8	103	122	-19
45.57	3.5	10.2	-6.7	101	115	-14
45.57	3.1	5.9	-2.8	99	115	-16

FIGURE V-3. SAMPLE OUTPUT OF FIRST 20 RECORDS OF AN HOUR prepare a "Coincidence" tape. The "Coincidence" tape contained measurement data made from signals which were positively correlated. Both time and Table Mountain Azimuth were required to be in agreement from both source tapes for the signal to be accepted for entry on the "Coincidence" tape. A flow diagram of the selection process is shown in Figure V-4.

The "Coincidence" tape was then processed to extract only those signals which were indicated as being within the potential ranging distance of the system. That is, signals which showed $\geq$ 12° convergence in corrected azimuth or $\geq$ 2 dB difference in amplitude. Signals which did not meet these criteria were considered unresolved as their normalized source function amplitude could not be determined with "acceptable" accuracy from the available data. The flow diagram for this selection process is shown in Figure V-5.

The sferic receiver and waveform analyzer equipment was arranged to initiate a record on the high-speed transient recorder (R-45 tape) under any of several conditions which might occur individually or collectively. The circumstances contributing to record initiation are indicated by the contents of two six-bit "Identity" characters contained in each record.

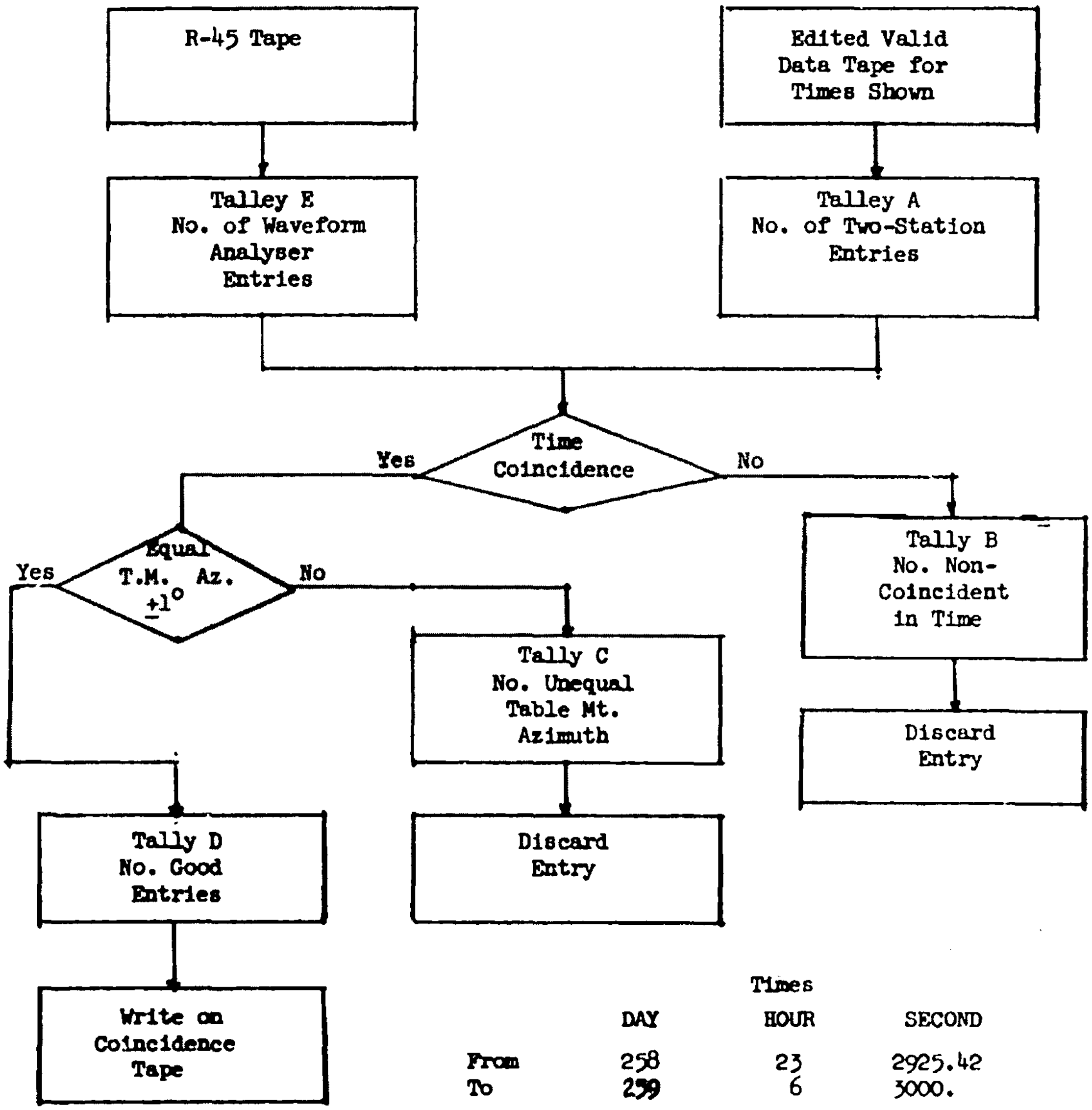
Recording was initiated under any of the following circumstances:

a. Receipt of a signal having waveform features as described in Table V-1 but provided also that the peak amplitude of the first half-cycle was $\geq$ 0.5 V/m and its duration (or the duration of the immediately following half-cycle was $\geq$ 10μs.

b. Receipt of any signal having a peak amplitude $\geq$ 10 V/m.

c. Simultaneous (within propagation delay time) triggers from the AWRE transient detectors at Campion and Table Mountain.

d. The overflow of a 9-bit counter that is advanced by one count for each signal accepted for processing by the waveform analyzer, i.e., amp $\geq$ 0.5 V/m, duration $\geq$ 10 μs. Each overflow indicates that 512 signals have been accepted for processing.



Times

	DAY	HOUR	SECOND
From	258	23	2925.42
To	259	6	3000.
From	259	20	5.32
To	260	02	3180.

FIGURE V-4 - Flow diagram for the preparation of "COINCIDENCE" tape from two-station data and sferic receiver and waveform analyser data.

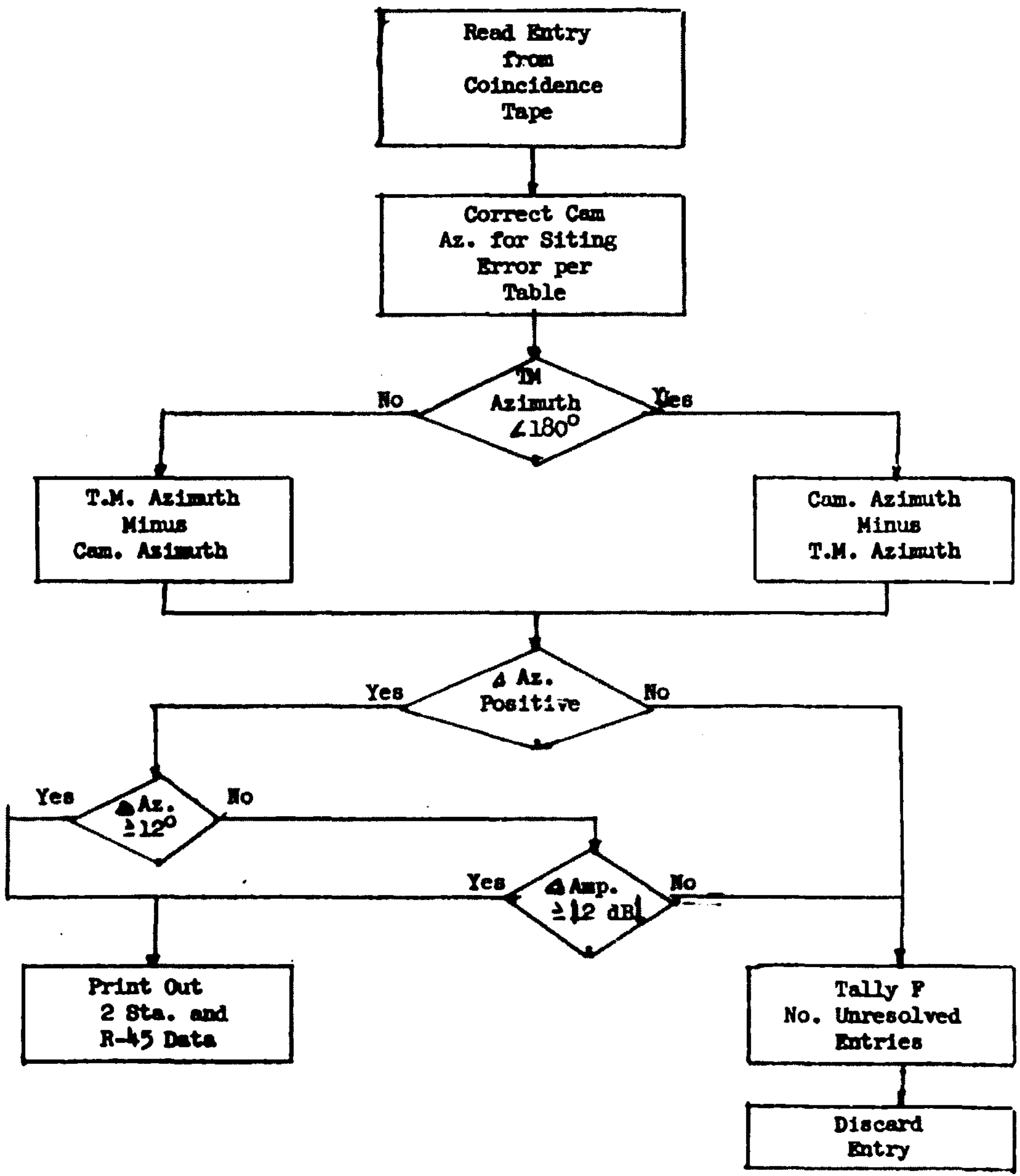


Figure V-5 - Flow diagram for preparation of useful entries.

e. The overflow of a 7-bit counter that is advanced by one count each time the quantization of the waveform features of an accepted low level signal (0.5 V/m $\leq$ amplitude $\leq$ 10 V/m) matches the features of the immediately preceding signal and provided less than 200 ms has elapsed since the receipt of that signal.

Table V-1

Class	First half-cycle features Rate of Rise	Duration	Peak Amp.	Polarity
A	$\geq$ 1.0 V/m/μs	$\leq$ 30 μs	$\geq$ 1.0 V/m	Neg.
B	$\geq$20.0 V/m/μs	$\leq$ 20 μs	$\geq$ 1.0 V/m	
C	$\geq$10.0 V/m/μs	$\leq$ 30 μs	$\geq$ 1.0 V/m	

The settings shown in Table V-1 above may be associated with the classes of interesting events described in Volume I of this report.

During the time interval from day 258, hour 23, second 2925.42 until day 259, hour 6, second 3000.00, there were 18,439 sets of two-station amplitude and azimuth entries on the "Edited Valid Data Tape". During the same time interval, there were 4,567 entries on the waveform analyzer (R-45) tape. Of these, 444 were coincident in both time and Table Mountain azimuth on both records and these were transferred to the "Coincidence Tape".

Analysis of the "Identity" characters associated with the 4,567 waveform analyzer records reveals the following:

a. 15,360 $\pm$511 signals were accepted for processing by the waveform analyzer.

b. 3,371 signals had peak amplitude $\geq$ 10 V/m and the remainder, 11,989 $\pm$511 had peak amplitude $\geq$ 0.5 V/m.

c. 768 $\pm$127 signals had waveform features matching those of a signal processed 200 ms or less earlier and were discarded as multiple stroke sferics.

d. 1162 signals fell in one or more of the classification levels shown in Table V-1.

e. 849 signals fell in Class A.

f. 3 signals fell in Class B.

g. 266 signals fell in Class C.

h. 4 signals fell in Classes A and B.

i. 40 signals fell in Classes A and C.

j. No entries resulted from coincident triggers from the AWRE transient detectors at Campion and Table Mountain.

The 444 entries which were coincident with the two-station data were reduced to 290 "useful data" entries by the processing shown in Figure V-5. These 290 entries had the following classifications:

a. 39 signals had peak amplitude $\geq$ 10 V/m.

b. 159 signals fell in Class A.

c. 78 signals fell in Class C.

d. 10 signals fell in Classes A and C.

e. 4 entries resulted from overflow of the signal accept counter.

These 290 entries were printed out and are reproduced in Appendix I.

The second time period, beginning on day 259, hour 20, second 5.32 and extending to day 260, hour 1, second 41.00 contained 15,580 sets of two-station data and 3318 entries of waveform analyzer data. Of these, only one was coincident in time and in Table Mountain azimuth and was transferred to the "Coincidence Tape".

Analysis of the "Identity" characters associated with the 3,318 waveform analysis entries resulted in the following summaries:

a. 15,360 $\pm$511 signals were accepted for processing by the waveform analyzer.

b. 422 signals had peak amplitudes $\geq$ 10 V/m.

c. 1024 $\pm$127 signals had waveform features matching those of a signal processed 200 ms or less earlier and were discarded as multiple stroke sferics.

d. 2,868 signals fell in one or more of the classification levels shown in Table V-1.

e. 2,213 signals fell in Class A.

f. 48 signals fell in Class B.

g. 503 signals fell in Class C.

h. 7 signals fell in Classes A and B.

i. 97 signals fell in Classes A and C.

j. One entry resulted from coincident triggers from the AWRE transient detectors at Campion and Table Mountain. This was also coincident with one of the 7 signals falling in Classes A and C.

The 290 "useful data" records from time period one were transcribed from computer tapes to a printed output for manual examination and evaluation. This was accomplished using a plotting table at a scale of 5 km = 1 inch. Fixed azimuth circles with pull strings were centered over the scaled positions of Table Mountain and Campion and curves representing selected equal differences in amplitude were laid out around each station. The distance from Table Mountain to a sferic source was determined by measuring from the intersection of the azimuths and by measuring from the intersection of the Table Mountain azimuth with the curves of equal difference in amplitude.

The radar summary report for day No. 258 hour 23:45 shows only one area of cloud cover within 900 km of Table Mountain. This is a small, well defined region of thunderstorm and light shower activity extending from about 50 km north of Pueblo, Colorado to about 150 km north northeast of Pueblo as reported by the Pueblo weather radar. There is no complete assurance that there were not other regions of activity outside of coverage of the weather radar network; however, the records at Stapleton Field, Denver, Colorado report light thunderstorm activity to the southwest to southeast at that time.

The radar summary report two hours later shows the area of activity to have spread considerably to the south and east. Stapleton Field records do not indicate thunderstorm activity for this later time.

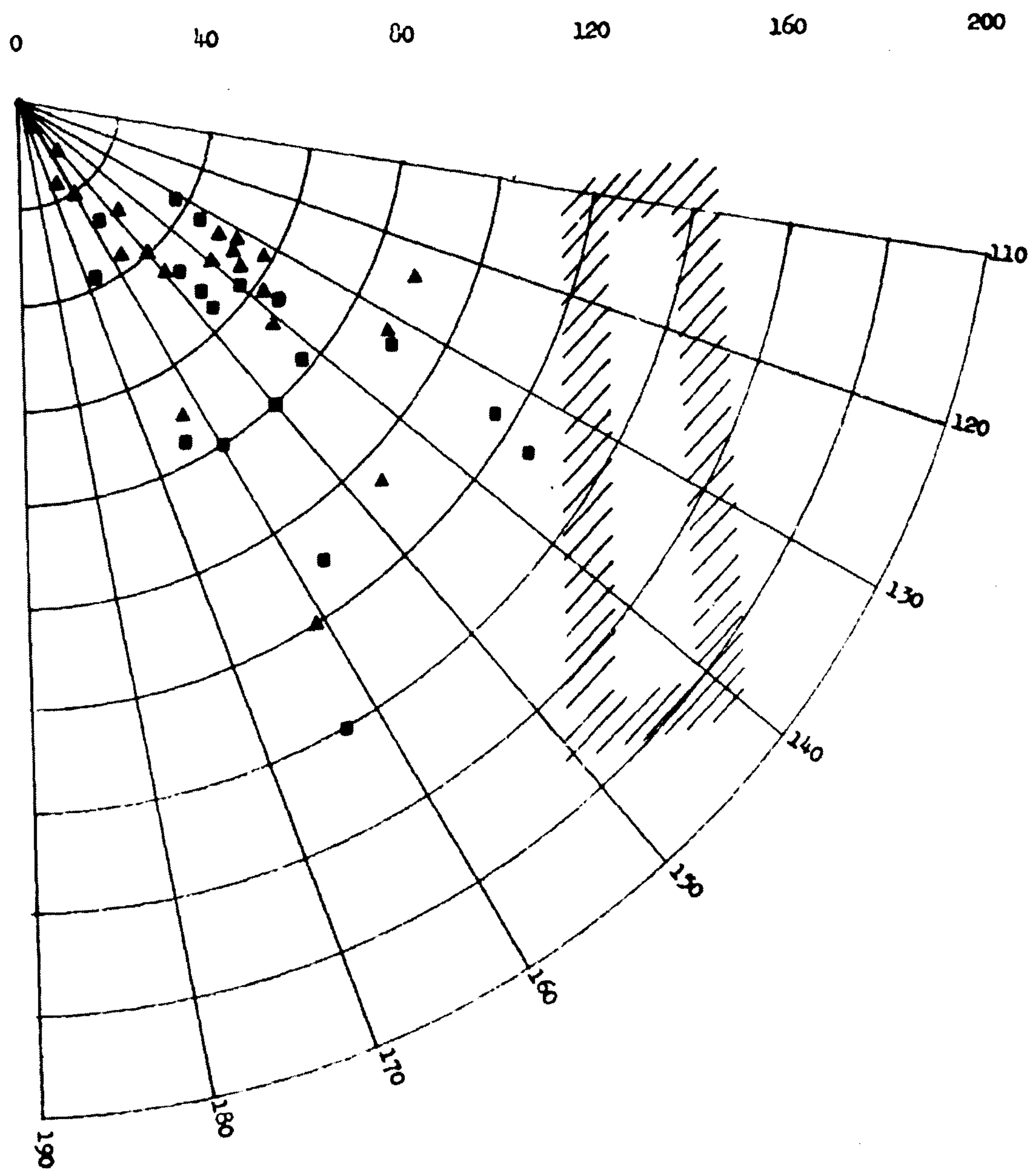
The 23:45 position of the active area as reported by radar was centered at the approximate position represented by an azimuth of 130° and range of 155 km to Table Mountain as shown by the hatched outline in Figures V-6 through V-11. These figures also show the plotted position of the "useful data" fixes for six successive 10-minute intervals beginning at about 23:50.

The plotted fixes show an average range from Table Mountain that is considerably less than the range to the active area. In fact, many of the fixes are at a range that is less than the 50 km distance from Table Mountain to Stapleton Field. Since Stapleton reported no thunderstorm activity to the north, it seems unlikely that these fixes could be valid.

In Figure V-6 the average range of the fixes shown is about 60 km. The average amplitude is approximately 1.2 V/m indicating an average normalized source function amplitude on the order of 72 V/m at 1.0 km. Such a low value further supports the conviction that the fixes are invalid and that the sferic activity took place in the region reported by the radar summary.

The results from plotting these data from the selected time periods are interpreted as confirming the invalidity of the Campion amplitude data. In addition, they show evidence of considerably greater variations in azimuth data than had been anticipated. Because of these gross inconsistencies, no attempt was made to plot the remaining data from time period one, and further processing of two-station data from other time periods was terminated.

Data from two of the tapes from the high-speed transient recorder were processed independently to determine the number of entries which were initiated as a result of time coincidental (within equipment and propagation delay limits) triggers from the AWRE Transient Detectors at Campion and Table Mountain. These triggers were generated by signals exceeding 10 V/m in amplitude and having a rate of rise of at least 10 V/m/μs which did not persist for more than one microsecond. One tape covered the period from day 235 through day 238 and contained three entries; one each on day 235, 237 and 238. The second tape covered the period from day 255 through day 269. Sixteen entries occurred on day 255 and one each on days 259, 260, 261 and 269. The 16 entries on day 255 were not considered valid as they were not supported by daily counts accumulated on electromechanical counters activated by the Table Mountain Transient Detector. They are believed to have been caused by system tests.



▲ FIX BASED ON INTERSECTION OF TWO AZIMUTHS.

■ FIX BASED ON INTERSECTION OF AN AZIMUTH WITH EQUAL AMPLITUDE DIFFERENCE CURVE.

Figure V-6

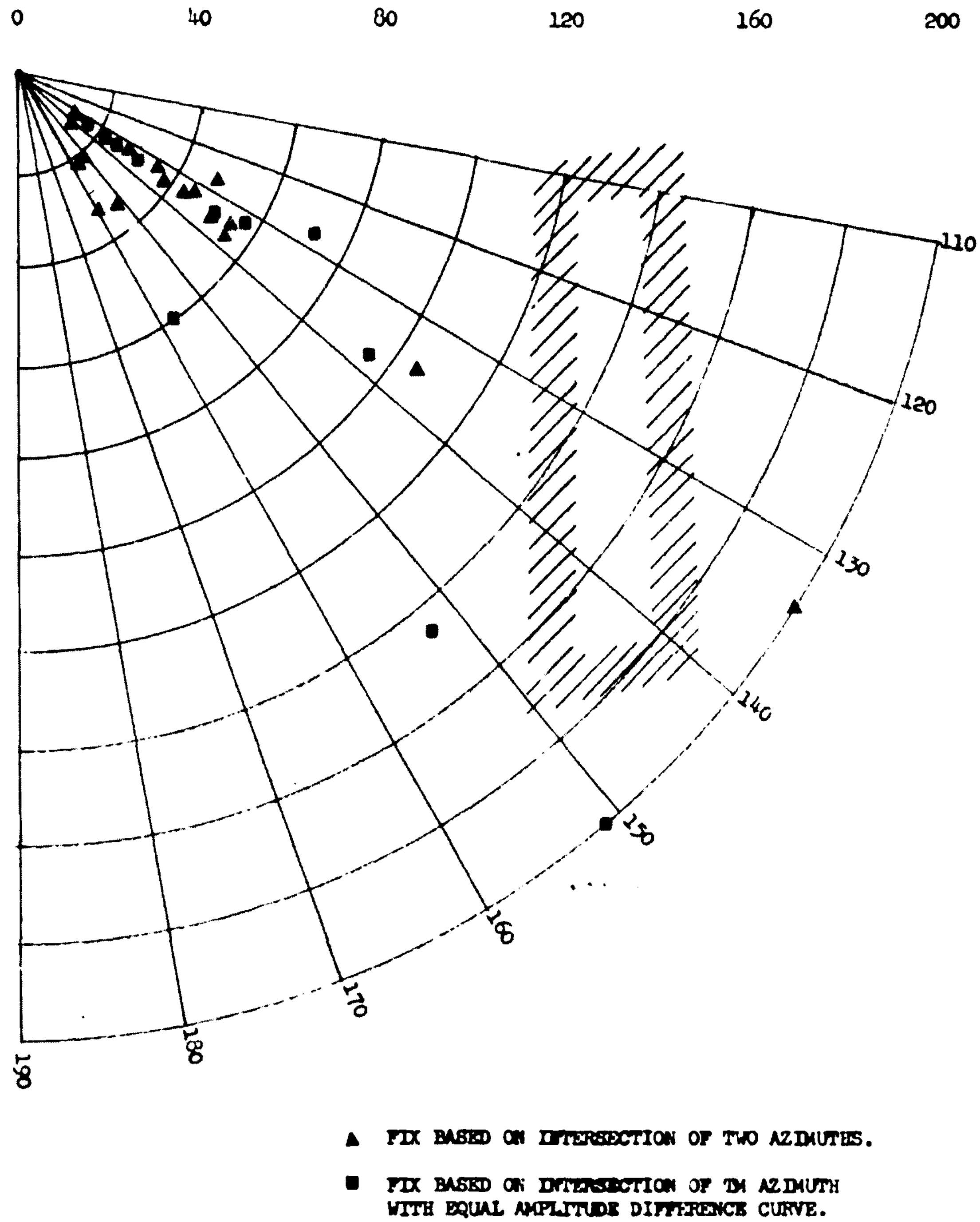
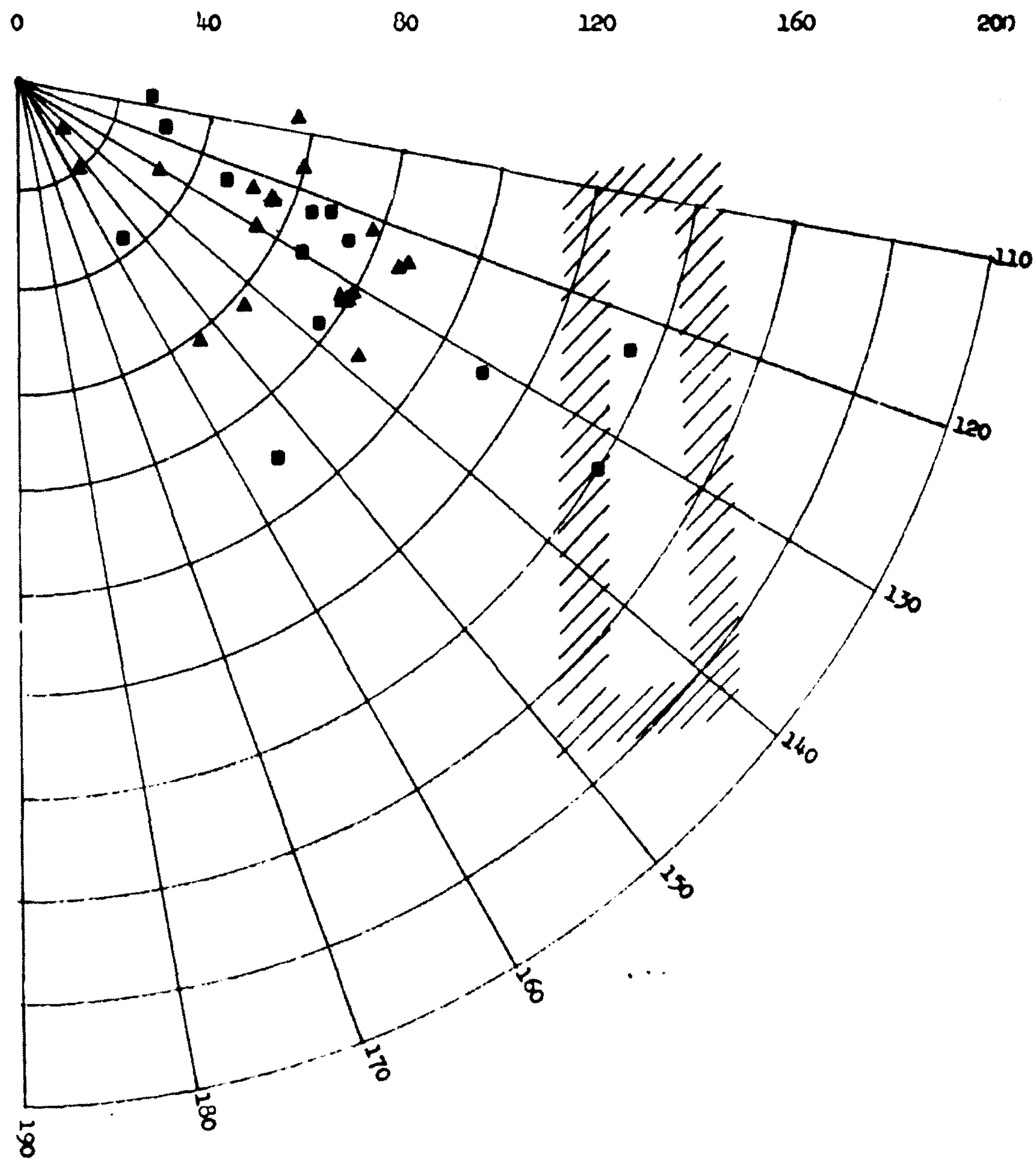

0
40
80
120
160
200
110
120
130
140
150
160
170
180
190
▲ FIX BASED ON INTERSECTION OF TWO AZIMUTHS.
■ FIX BASED ON INTERSECTION OF TM AZIMUTH WITH EQUAL AMPLITUDE DIFFERENCE CURVE.

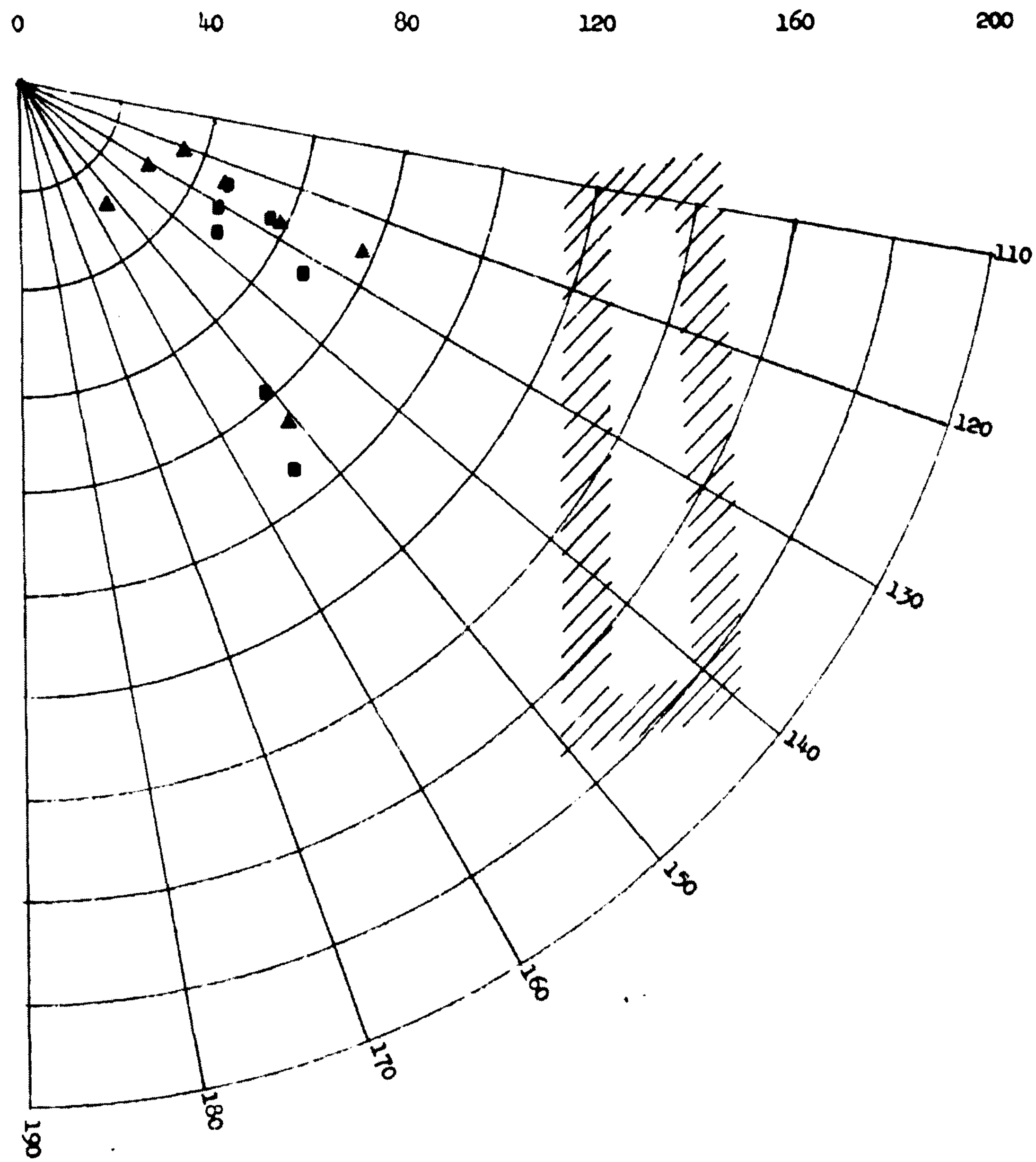
Figure V-7



▲ FIX BASED ON INTERSECTION OF TWO AZIMUTHS.

■ FIX BASED ON INTERSECTION OF TM AZIMUTH WITH EQUAL AMPLITUDE DIFFERENCE CURVE.

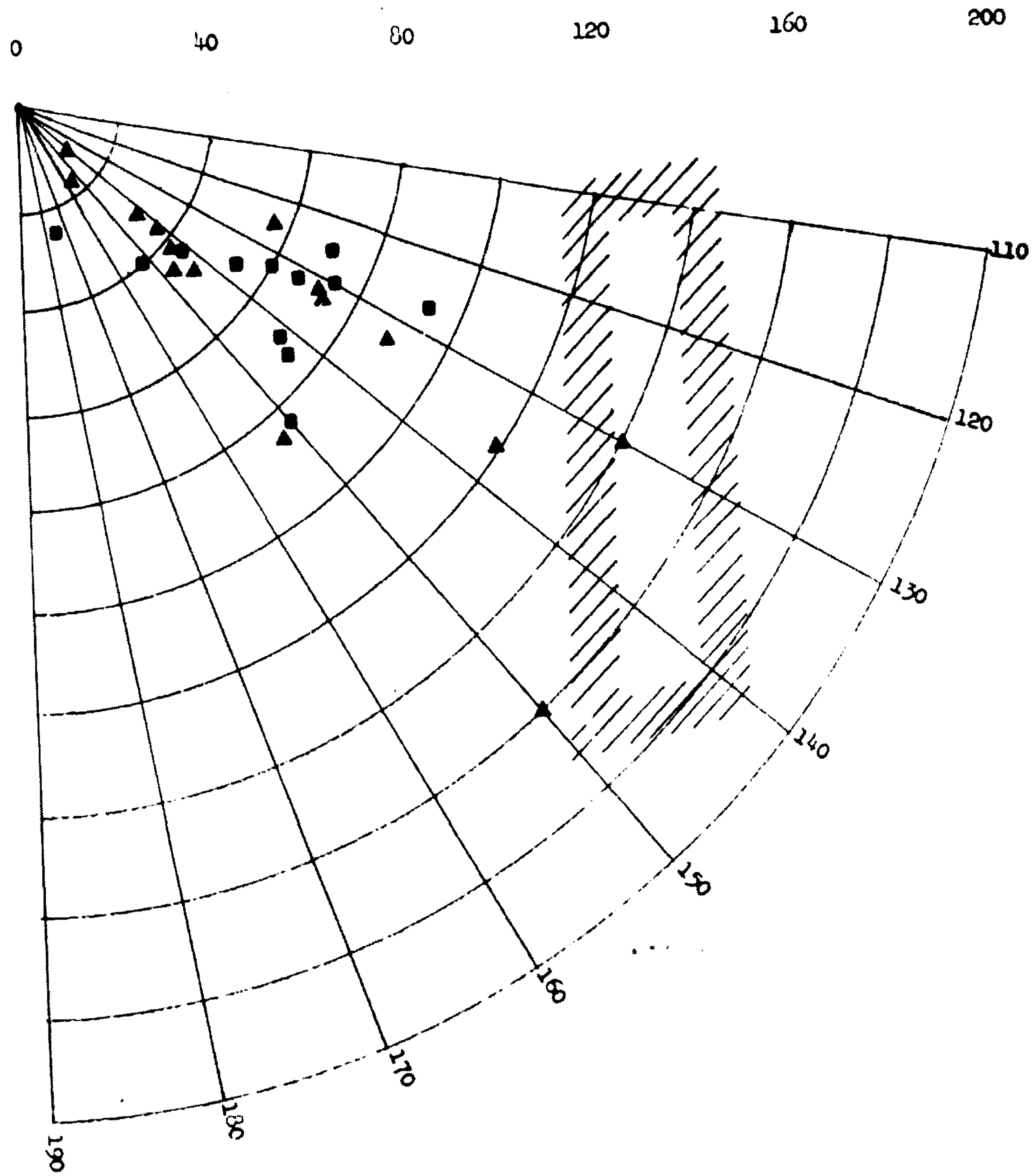
Figure V-8



▲ FIX BASED ON INTERSECTION OF TWO AZIMUTHS.

■ FIX BASED ON INTERSECTION OF TM AZIMUTH WITH EQUAL AMPLITUDE DIFFERENCE CURVE.

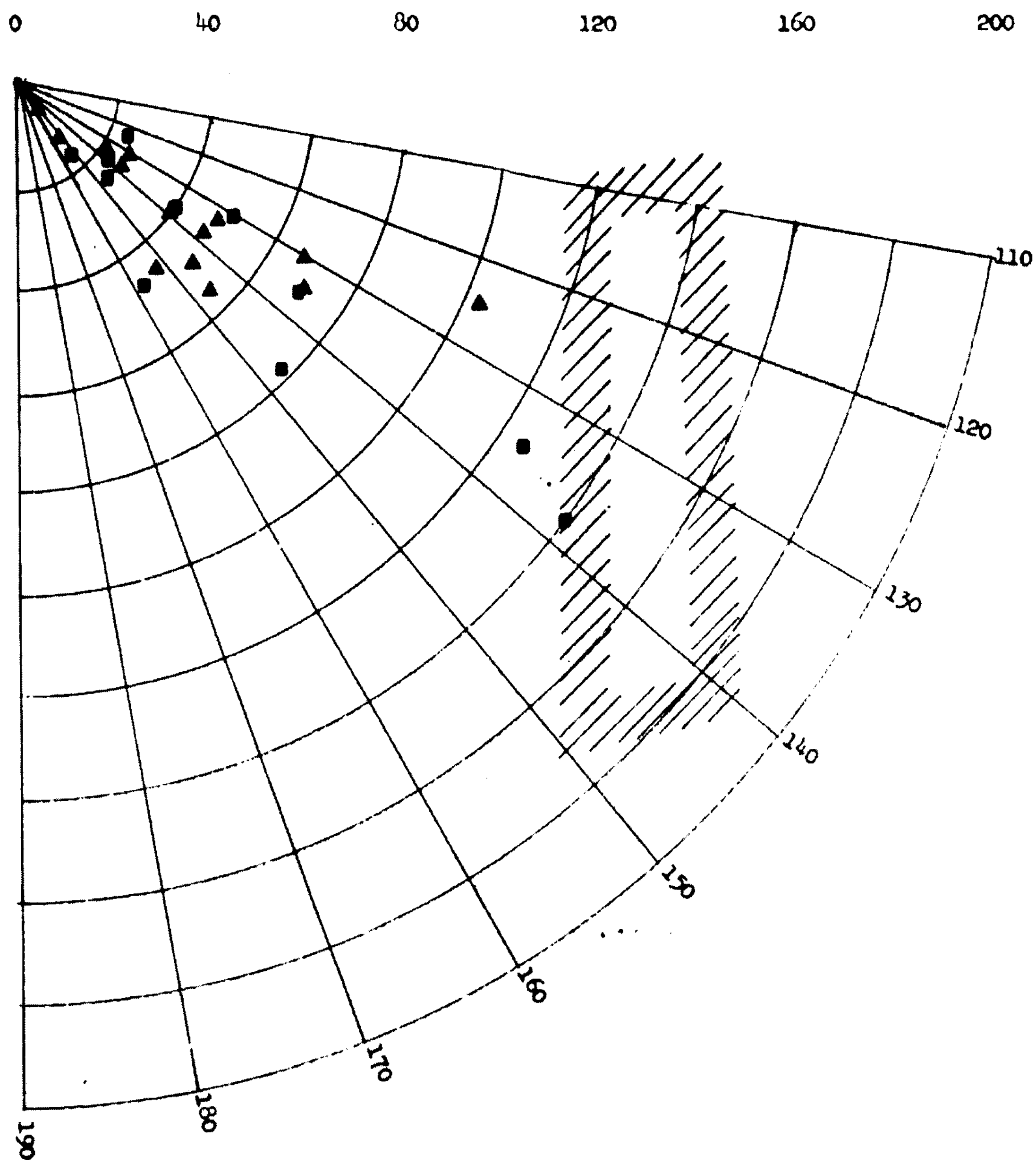
Figure V-9



▲ FIX BASED ON INTERSECTION OF TWO AZIMUTHS.

■ FIX BASED ON INTERSECTION OF TM AZIMUTH WITH EQUAL AMPLITUDE DIFFERENCE CURVE.

Figure V-10



▲ FIX BASED ON INTERSECTION OF TWO AZIMUTHS.

■ FIX BASED ON INTERSECTION OF TM AZIMUTH WITH EQUAL AMPLITUDE DIFFERENCE CURVE.

Figure V-11

Discussion of Results

The fixes of sferic activity shown in Figures V-6 through V-11 result from what is believed to be a single area of thunderstorm activity located in the approximate position of the hatch-bounded rectangle. The storm is centered at an azimuth nearly midway between that at which bearing information only could be used for establishing fixes and one on which only azimuth-amplitude difference fixing could be employed. In fact, its azimuth would have been almost ideal for a comparative evaluation of these two methods of obtaining range if the Campion amplitude data had been reliable. It is, however, slightly beyond the nominal ranging capability of the system based on the design assumptions of ±1.0 dB amplitude measurement capability and ±2° azimuth measuring capability and the "useful signal" processing shown in Figure V-5. Had these original measurement accuracy assumptions been realized, most of the "coincident" records from the time period should not have appeared in the "useful data" output but rather have been reported as unresolved. Only 154 of the 444 coincident data points were so classified. 290 records, nearly two-thirds of the total, showed azimuth convergence ≥ 12° or amplitude difference ≥ 12° dB. Of the 104 records plotted in Figures V-6 through V-11, 80 were based on an azimuth difference ≥ 12°, 68 were represented by an amplitude difference ≥ 2 dB and 44 met both criteria.

Because of the malfunction in the Campion equipment for measuring amplitude, no conclusions can be drawn from the fixes which are based on difference in amplitude intersections with a single azimuth.

The fixes based on the intersection of two azimuths, however, were obtained from equipment which was believed to be functioning normally. These show a considerable variation in range for events occurring on the same azimuth as observed at Table Mountain. If the thunderstorm activity is accepted as being in the area shown by the radar summary, the dispersion in fix positions strongly suggests that the uncertainty in azimuth determination is somewhat greater than was anticipated. For example, the azimuth fixes in Figures V-6 through V-11 on an azimuth of from 130° to 140° at Table Mountain were plotted from azimuths having an average convergence of 15° but the range of convergence was from 4° to 32°. Of the 42 sets of data in this group, 22 sets show azimuth convergence that is more than ±2° different from the average convergence, 15 sets show azimuth convergence more than ±4° different from the average convergence, and 10 sets of data are more than ±6° from the average value of convergence. The rather broad skirts of this distribution curve may have additional significance in that these data were centered in a narrow segment of azimuth and since the presumed region of origin was moderately distant compared to the inter-station separation, large differences in the effects of polarization induced errors would hardly be expected.

The data shown in Appendix I lists signal amplitude as observed by the AWRE signal normalizer at Table Mountain. These values correlate very poorly with the values obtained from the Digital dB Meter at Table Mountain. Some differences would be expected as a result of the differences in bandwidth and sample time aperture in the two equipments, but the variations appear to be greater than anticipated from those factors.

Another anomaly in the data results from the low number of data entries which were coincidental in both time and azimuth. During the first time period there were approximately 18 thousand two-station data entries and about 15 thousand signals were processed by the waveform analyzer, yet only 444 of these were coincident in both time and Table Mountain azimuth. Considerable difficulty was experienced in reading the magnetic tape from the waveform analyzer and it was necessary to ignore the parity check in the tape reading process. The reading problems may account for the small number of coincident records and probably are the reason for the occasional instance where the Table Mountain azimuth as derived from two record sources operating from the same instrument differs by one degree.

VI. CONCLUSIONS AND RECOMMENDATIONS

The results of processing the data base sample as described in Section V lead to only a few conclusions which may be approached with confidence.

There appears to be no doubt that the malfunction of the amplitude measuring equipment at Campion has resulted in apparent differences in amplitude which may be as much a function of sferic waveform as they are of sferic location. Thus, it is not possible to evaluate the effectiveness of obtaining fixes from the amplitude difference technique using the available data base.

There is clear evidence from the data that variations in the amplitude of signals received over propagation paths a few hundred kilometers long were dependent on the direction of arrival. The average combined magnitude of these variations was on the order of one dB for the two sites employed in the experiment. These variations appear to be reasonably consistent and reproducible and could presumably be at least partly corrected by a suitable fixed compensation curve.

The observed dispersion in indicated azimuth does not permit establishing range from the intersection of two azimuths to the desired accuracy in even the most favorable quadrants. Thus, even if the experimental design objectives ragarding amplitude measurements had been obtained, the results might have been satisfactory in quadrants centered along the baseline direction but would have still been inadequate in the quadrants centered on 90° and 270°. From examination of the data observed during time period one, it appears that the waveform characteristics shown in Table V-1 may be useful as discriminants against more than 90 percent of sferics which have propagated over distances of about 150 km. It is significant that this discrimination ratio could not have been materially improved by the two-station system under any circumstances as the activity occurred at a distance beyond the design ranging limits of the system. From this, it may be concluded that if all sferics within a 100 km radius were correctly ranged and identified, there would still be a false alarm rate of about 10 percent due to signals which met the waveform acceptance criteria employed but were outside the ranging distance of this type of two-station system.

It is interesting to note the ratios of signals which were observed in each of the three classes shown in Table V-1. A high rate of rise appears to be a very powerful discriminant even at amplitude thresholds as low as 1.0 V/m. At 20 V/m/μs rate of rise, a rejection ratio of over 2000:1 occurred. This is over 40 times greater than the rejection ratio observed at 10 V/m/μs rate of rise.

The use of the spaced pair of AWRE Transient Detector Systems is reported by Grubb* to provide a discrimination

* Grubb, R.N., Lightning Background Discrimination Experiments Using a Spaced Pair of AWRE Transient Detector Systems, Hands Group Note, 26 October 1967.

ratio of about 100:1 against lightning signals exceeding 10 V/m. During the two periods selected for data reduction, only a single coincident trigger was recorded from these transient detectors. Based on the somewhat limited experimental evidence, they appear to offer considerable promise as a discriminator against high amplitude atmospherics. Used in conjunction with other sensors responsive to a high altitude nuclear burst within the field of view, they should contribute to a significant reduction in false alarm rates and to enhanced detection capability for this class of event.

If the rate-of-rise criteria of the spaced transient detectors were increased from 10 μV/m/μs to 20 μV/m/μs, it is believed that the false alarm rate should be reduced to a value very close to zero. An experiment to verify this conviction has been proposed to the HANDS group with the recommendation that it be conducted during the summer of 1968.

It is also recommended that additional experiments be conducted using the waveform analyzer equipment. This equipment includes several parameter quantizers in addition to those listed in Table V-1, and their potential as discriminants has not been fully investigated.

USCOMM-DC-NBS

APPENDIX I

Single and 2-station Coincident Data Points

The listing of single and 2-station data points from time period one follows the format described below:

Each page of the listing is headed with the day of the year (1967) and hour of the day and the remaining data is listed in 13 columns.

Column 1 lists the time in seconds and centiseconds past the hour shown in the heading.

Columns 2, 3 and 4 show the indicated amplitude in dB (1.0 V/m = 15.9 dB) at Campion and Table Mountain and their difference, respectively. The Campion values have been adjusted by +3.0 dB based on the calibration procedures described in the report.

Columns 5, 6 and 7 show the azimuth observed at Campion and Table Mountain and their difference, respectively. Azimuth data are referenced to the baseline between the two sites and Campion values have been adjusted in accordance with the correction curve shown in Figure IV-5.

Columns 8 and 9 show the amplitude and azimuth data recorded from the AWRE Signal Normalizer and Azimuth Digitizer at Table Mountain. Amplitude is indicated in dB but is inverted in sense from data shown in columns 2 and 3, i.e., decreasing values indicate increasing signal amplitude and a value of zero indicates overload.

Columns 10 and 11 are flag characters. Flag 1 (column 10) was not used. Flag 2 shows a value of 15 during periods of normal data recording.

Column 12 shows a coarsely quantized value of peak amplitude as obtained from the Sferic Receiver and Waveform Analyser. A value of 32 represents a peak amplitude of approximately 0.5 V/m. Decreasing values indicate increasing signal strength in steps of approximately 3 dB, e.g., 30 indicates approximately 1.0 V/m peak amplitude.

Column 13 shows a four digit value used for identification of signal classification:

If digit one = 4	Signal is Class A*
If digit one = 2	Signal is Class B*
If digit one = 1	Signal is Class C*
If digit two = 4	Signal amplitude $\geq$ 10 V/m
If digit two = 2	Transient detector coincidence occurred
If digit two = 1	Not used
If digit three = 4	512 events have been accepted for processing
If digit three = 2	128 signals have had matching waveforms
If digit three = 1	Not used
Digit four	Not used

Summation is allowed, i.e., a value of 5 in digit one indicates a signal meeting both Class A and Class C criteria.

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* See Table V-1.

NET: 5

SINGLE AND 2-STATION COINCIDENT DATA POINTS

DAY NO. 256 HOUR 23

TIME(SEC)	AMPLITUDE(DB) CAMP.	TM	DIFF.	AZIMUTH(DEGREES) CAMP.	TM	DIFF.	SINGLE STATION DATA AMPL.	AZ.	F1	F2	PEAK	IDENT
3049.15	8.0	12.1	-4.1	143	133	10	0	133	0	15	31	4000
3066.65	5.3	8.0	-2.7	177	160	17	43	159	0	15	27	4000
3113.85	25.1	28.1	-3.0	154	140	14	0	140	0	15	22	0400
3113.97	3.1	1.1	2.0	151	138	13	29	138	0	15	30	1000
3116.58	22.0	23.4	-1.4	150	135	15	25	136	0	15	28	4000
3122.15	32.7	18.8	13.9	165	161	4	0	162	0	15	28	4000
3163.89	3.1	4.6	-1.5	152	134	18	19	134	0	15	23	0400
3229.97	15.4	16.7	-1.3	175	163	12	33	163	0	15	30	4000
3237.76	3.6	7.4	-3.8	147	147	0	0	147	0	15	28	5000
3237.76	16.0	19.3	-3.3	154	147	7	0	147	0	0	28	5000
3237.85	38.1	22.5	15.6	162	150	12	0	150	0	15	26	1000
3247.30	11.6	16.4	-4.8	187	167	20	0	167	0	15	27	4000
3281.90	6.2	8.6	-2.4	153	142	11	19	141	0	15	22	0400
3281.97	15.3	18.0	-2.7	150	137	13	29	137	0	15	30	1000
3295.66	16.0	13.7	2.3	175	166	9	0	165	0	15	30	4000
3300.95	5.1	11.0	-5.9	167	157	10	18	157	0	15	22	0400
3320.29	14.9	16.8	-1.9	149	133	16	69	133	0	15	30	4000
3341.25	17.4	19.3	-1.9	173	156	17	0	155	0	15	28	1000
3403.04	3.7	.5	3.2	165	180	-15	26	180	0	15	26	1000
3403.19	28.7	18.7	10.0	164	147	17	28	147	0	15	30	1000
3407.93	19.3	22.9	-3.6	147	146	1	26	145	0	15	27	4000
3443.28	6.0	4.5	1.5	138	125	13	19	126	0	15	22	0400
3460.82	15.0	18.7	-3.7	148	133	15	0	133	0	15	30	1000
3537.14	23.6	26.0	-2.4	162	150	12	0	150	0	15	27	4000
3578.48	3.1	15.3	-12.2	168	163	5	17	163	0	15	26	4000
3578.57	13.8	16.3	-2.5	165	164	1	0	164	0	15	30	4000
3586.98	10.6	8.0	2.6	161	160	1	36	160	0	15	31	4000

SINGLE AND 2-STATION COINCIDENT DATA POINTS

DAY NO. 259 HOUR 0

TIME(SEC)	AMPLITUDE(Db) CAMP.	TM	DIFF.	AZIMUTH(DEGREES) CAMP.	TM	DIFF.	SINGLE STATION DATA AMPL.	AZ.	F1	F2	PEAK	IDENT
13.19	6.2	13.9	-7.7	156	136	20	0	135	0	15	30	4000
74.22	19.4	20.5	-1.1	192	155	37	28	156	0	15	29	1000
75.27	29.5	19.3	10.2	169	160	9	39	160	0	15	30	1000
106.28	26.3	14.2	12.1	168	142	26	0	141	0	15	30	4000
112.89	6.0	5.1	.9	150	135	15	18	136	0	15	22	0400
121.87	3.9	4.3	-.4	153	133	20	0	133	0	15	22	0400
126.96	17.6	23.6	-5.8	165	137	28	0	137	0	15	28	4000
149.99	18.4	21.6	-3.2	152	135	17	27	136	0	15	30	1000
182.44	9.4	15.8	-6.4	153	136	17	0	135	0	0	28	4000
227.69	25.9	27.7	-1.8	151	138	13	19	138	0	15	22	0400
227.77	22.6	24.8	-2.2	147	128	19	0	128	0	15	26	1000
243.98	11.2	16.3	-5.1	145	136	9	28	135	0	15	30	5000
385.25	14.0	16.3	-2.3	168	167	1	0	167	0	15	30	1000
399.43	17.9	19.0	-1.1	167	151	16	28	152	0	15	30	4000
441.58	12.7	12.4	.3	183	171	12	0	172	0	15	30	4000
444.48	18.2	21.0	-2.8	151	133	18	0	133	0	15	28	4000
485.73	14.9	13.2	1.7	153	134	19	0	134	0	15	30	4000
487.97	6.6	3.7	3.1	138	134	4	26	134	0	15	28	1000
493.38	10.1	13.4	-3.3	170	157	13	37	157	0	15	30	1000
556.29	21.6	15.3	6.3	182	182	0	27	181	0	15	26	4000
574.51	21.4	22.9	-1.5	165	153	12	26	153	0	15	28	4000
633.82	23.6	25.8	-2.2	147	138	9	19	138	0	15	26	1000
685.52	6.6	11.3	-4.7	130	108	22	19	108	0	15	22	0400
690.25	28.3	16.1	12.2	143	131	12	0	132	0	15	30	1000
741.70	5.6	7.9	-2.1	137	122	15	38	121	0	15	26	4000
752.30	20.7	23.1	-2.4	146	130	16	0	130	0	15	30	4000
766.62	12.2	13.5	-1.3	145	133	12	36	133	0	15	30	4000
796.98	16.5	17.5	-1.0	195	123	72	0	123	0	15	30	4000
911.40	14.4	14.5	-.1	144	132	12	19	131	0	15	22	0400
911.40	7.5	21.1	-13.6	145	132	13	9	131	0	0	22	0400
916.05	16.6	17.0	-.4	141	124	17	28	124	0	15	31	1000
916.21	16.4	16.9	-.5	142	125	17	0	126	0	15	31	1000
916.26	7.4	11.7	-4.3	136	117	19	0	117	0	15	27	4000
986.36	24.2	25.9	-1.7	154	131	23	0	132	0	15	26	4000
990.64	24.7	27.8	-3.1	137	124	13	0	124	0	15	22	0400
990.68	19.5	21.5	-2.0	137	125	12	0	126	0	15	0	1000
1003.32	4.1	8.9	-4.8	162	154	8	26	154	0	15	25	4000
1059.71	4.6	25.2	-20.6	154	143	11	24	143	0	15	27	1000
1089.68	15.8	18.2	-2.4	127	123	4	0	123	0	15	26	4000
1103.69	3.6	13.4	-9.8	142	123	19	19	123	0	15	22	0400
1128.71	8.9	8.7	.2	170	145	25	29	146	0	15	26	5000
1154.91	16.3	18.6	-2.3	169	154	15	29	154	0	15	27	1000
1296.46	4.3	26.9	-22.6	147	121	26	19	122	0	15	22	0400
1406.74	11.3	14.8	-3.5	142	137	5	0	137	0	15	30	1000
1407.16	17.2	19.7	-2.5	137	133	4	0	133	0	15	30	1000
1449.53	21.2	23.4	-2.2	167	154	13	0	154	0	15	30	4000
1515.82	15.7	18.3	-2.6	159	151	8	0	152	0	15	28	4000
1540.15	14.4	17.2	-2.8	144	128	16	29	128	0	15	27	1000
1614.89	18.8	22.0	-3.2	142	126	16	28	125	0	15	30	4000
1723.90	7.[illegible]	10.7	-3.6	155	132	23	18	131	0	15	26	1000
1750.12	4.4	5.0	-.6	146	126	20	0	125	0	15	27	4000

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SINGLE AND 2-STATION COINCIDENT DATA POINTS

DAY NO. 259 HOUR 0

	AMPLITUDE(DB)			AZIMUTH(DEGREES)			SINGLE STATION DATA					
TIME(SEC)	CAMP.	TM	DIFF.	CAMP.	TM	DIFF.	AMPL.	AZ.	F1	F2	PEAK	IDENT
1822.50	25.0	27.3	-2.3	144	126	18	0	125	0	15	26	4000
1844.51	21.8	24.5	-2.7	146	133	13	0	133	0	15	28	1000
1854.28	4.4	4.1	.3	159	143	16	24	143	0	15	26	1000
1904.98	19.6	22.1	-2.5	145	132	13	0	131	0	15	30	4000
1912.76	25.2	27.6	-2.4	150	134	16	18	134	0	15	22	0400
1973.48	15.0	15.6	-.6	145	133	12	34	133	0	15	28	4000
2000.05	15.3	18.3	-3.0	144	136	8	29	135	0	15	32	1000
2053.55	15.4	17.1	-1.7	157	143	14	0	143	0	15	30	4000
2095.58	15.0	17.2	-2.2	137	130	7	28	130	0	15	31	4000
2106.71	12.1	14.5	-2.4	154	150	4	0	150	0	15	29	4000
2112.61	13.0	12.6	.4	171	156	15	37	155	0	15	30	4000
2126.59	11.1	13.7	-2.6	161	142	19	0	141	0	15	31	4000
2238.50	18.8	19.2	-.4	160	147	13	29	147	0	15	30	1000
2254.44	8.2	14.6	-6.4	190	174	16	33	174	0	15	28	4000
2264.84	10.7	14.6	-3.9	159	142	17	29	141	0	15	28	4000
2267.95	15.2	17.7	-2.5	157	143	14	32	143	0	15	28	4000
2299.82	3.3	4.4	-1.1	174	282	-108	38	281	0	15	28	4000
2363.76	24.3	26.3	-2.0	146	127	19	18	127	0	15	26	4000
2367.71	10.7	15.3	-4.6	159	152	7	29	151	0	15	26	4000
2544.17	8.6	28.5	-19.9	156	131	25	19	132	0	15	22	0400
2554.04	19.4	20.9	-1.5	148	135	13	0	136	0	15	26	4000
2588.34	10.6	13.1	-2.5	161	136	25	0	135	0	15	28	4000
2680.03	3.9	9.9	-6.0	158	145	13	28	146	0	15	26	4000
2682.38	14.7	17.9	-3.2	145	131	14	29	132	0	15	29	4000
2690.37	3.6	25.6	-22.0	161	152	9	0	151	0	15	26	1000
2723.05	5.2	9.2	-4.0	169	137	32	36	137	1	15	30	4000
2723.12	4.6	11.2	-6.6	156	140	16	0	140	0	15	28	5000
2801.69	14.3	20.7	-6.4	135	125	10	0	126	0	15	26	4000
2812.28	20.1	22.6	-2.5	158	147	11	0	147	0	15	28	4000
2837.90	14.7	22.6	-7.9	171	151	20	26	152	0	15	28	1000
2843.27	5.2	3.8	1.4	193	346	-153	38	345	0	15	28	4000
2854.78	5.0	23.4	-18.4	150	134	16	25	134	0	15	28	5000
2854.88	17.5	18.8	-1.3	153	138	15	28	138	0	15	30	1000
2958.81	16.2	20.1	-3.9	176	157	19	28	157	0	15	28	4000
3126.02	11.8	15.1	-3.3	155	137	18	29	137	0	15	31	4000
3152.55	14.8	15.9	-1.1	150	137	13	34	137	0	15	28	4000
3163.11	18.5	20.7	-2.2	150	133	17	28	133	0	15	27	1000
3166.73	13.9	17.3	-3.4	164	150	14	0	150	0	15	30	1000
3189.42	11.4	13.9	-2.5	155	143	12	0	143	0	15	31	4000
3262.70	16.5	17.8	-1.3	168	154	14	29	154	0	15	30	4000
3372.57	13.6	18.2	-4.6	162	142	20	28	141	0	15	30	4000
3427.42	13.0	14.9	-1.9	149	135	14	35	136	0	15	30	4000
3439.97	10.5	14.6	-4.1	151	145	6	32	146	0	15	28	4000
3449.57	13.3	14.9	-1.6	158	130	28	28	130	0	15	28	4000
3479.85	16.6	17.3	-.7	158	141	17	0	142	0	15	30	4000
3563.97	12.3	16.4	-4.1	156	143	13	29	143	0	15	30	4000
3587.47	9.5	10.9	-1.4	143	131	12	37	132	0	15	30	4000

SINGLE AND 2-STATION COINCIDENT DATA POINTS

DAY NO. 259 HOUR 1

	AMPLITUDE(DB)			AZIMUTH(DEGREES)			SINGLE STATION DATA					
TIME(SEC)	CAMP.	TM	DIFF.	CAMP.	TM	DIFF.	AMPL.	AZ.	F1	F2	PEAK	IDENT
52.97	12.5	20.6	-8.1	154	143	11	27	143	0	15	27	1000
59.56	28.8	30.9	-2.1	136	112	24	0	111	0	15	22	4000
94.90	9.9	5.1	4.8	173	156	17	38	155	0	15	30	4000
113.32	14.8	17.2	-2.4	147	133	14	29	133	0	15	30	1000
136.32	4.3	5.3	-1.0	158	138	20	19	138	0	15	22	0400
199.45	4.9	7.7	-2.8	173	156	17	38	155	1	15	26	4000
249.91	17.7	21.0	-3.3	154	140	14	0	140	0	15	27	4000
290.39	17.6	20.4	-2.8	138	131	7	0	132	0	15	30	1000
317.79	8.9	12.4	-3.5	167	158	9	38	158	0	15	30	4000
324.12	18.9	22.2	-3.3	157	143	14	27	143	0	15	28	4000
372.12	15.7	18.3	-2.6	158	147	11	29	147	0	15	28	4000
388.92	10.2	12.9	-2.7	147	145	2	0	146	0	15	28	4000
467.36	26.4	28.6	-2.2	134	118	16	19	118	0	15	22	4000
487.34	4.3	.8	3.5	171	313	-142	38	313	0	15	28	4002
502.94	8.4	7.1	1.3	183	315	-132	40	316	0	15	28	4000
527.30	4.1	7.9	-3.8	149	130	19	19	130	0	15	22	0400
530.65	3.3	9.2	-5.9	162	148	14	0	148	0	15	26	4000
565.58	19.3	22.4	-3.1	154	142	12	0	141	0	15	27	4000
570.96	8.3	12.1	-3.8	142	120	22	19	120	0	15	22	0400
581.20	20.3	20.1	.2	176	158	18	28	158	0	15	28	4000
583.31	15.9	16.6	-.7	161	148	13	0	148	0	15	30	4000
671.81	14.0	15.8	-1.8	164	146	18	35	145	0	15	38	4000
675.91	11.5	9.4	2.1	100	91	9	23	92	0	15	26	5000
763.09	26.9	28.6	-1.7	157	135	22	0	136	1	15	24	4000
763.49	14.9	17.3	-2.4	151	142	9	0	141	0	15	27	4000
772.61	7.0	7.3	-.3	152	135	17	0	136	0	15	26	1000
808.30	21.7	23.8	-2.1	160	256	-96	26	255	0	15	27	4000
856.15	26.7	16.9	9.8	178	190	-12	85	190	0	15	28	4000
914.73	16.4	19.4	-3.0	151	141	10	28	142	0	15	38	1000
1070.23	3.1	8.8	-5.7	191	95	96	38	96	0	15	34	4000
1081.43	20.6	29.7	-9.1	175	163	12	0	163	0	15	22	4000
1101.82	24.2	26.9	-2.7	149	134	15	18	134	0	15	28	5000
1157.97	7.1	20.1	-13.0	129	120	9	29	120	0	15	28	1000
1210.83	15.5	18.2	-2.7	129	116	13	0	115	0	15	30	4000
1215.04	11.3	16.6	-5.3	154	142	12	28	141	0	15	30	4000
1226.29	3.6	10.4	-6.8	138	113	25	0	113	0	15	30	4000
1260.22	5.7	24.3	-18.6	155	145	10	25	146	0	15	26	1000
1302.86	8.1	12.3	-4.2	138	128	10	0	128	0	15	26	1000
1302.97	11.3	15.3	-4.0	154	140	14	29	140	0	15	26	1000
1485.91	8.6	9.1	-.5	155	112	43	0	111	0	15	28	4000
1527.43	24.2	26.3	-2.1	138	125	13	18	126	0	15	26	1000
1527.52	10.1	23.8	-13.7	134	117	17	0	117	0	15	28	1000
1532.65	10.6	11.8	-1.2	157	138	19	0	138	0	15	32	4000
1573.82	8.0	16.7	-8.7	144	141	3	0	142	0	15	27	4630
1595.14	5.3	27.6	-22.3	154	138	16	0	138	0	15	27	1000
1601.52	6.3	9.3	-3.0	142	134	8	26	134	0	15	30	1000
1601.66	5.5	3.2	2.3	150	140	10	28	140	0	15	30	1000
1640.05	30.1	32.3	-2.2	131	117	14	0	117	0	15	22	4000
1653.32	4.3	9.0	-4.7	145	116	29	19	115	0	15	22	0400
1701.75	3.3	14.6	-11.3	143	132	11	35	131	0	15	28	4000
1728.48	4.9	10.6	-5.7	154	147	7	39	147	0	15	31	4000

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SINGLE AND 2-STATION COINCIDENT DATA POINTS

DAY NO. 259 HOUR 1

TIME(SEC)	AMPLITUDE(DB) CAMP.	TM	DIFF.	AZIMUTH(DEGREES) CAMP.	TM	DIFF.	SINGLE STATION DATA AMPL.	AZ.	F_1	F2	PEAK	IDENT
1747.59	7.8	10.9	-3.1	150	136	14	27	135	0	15	30	1000
1856.13	13.1	18.8	-5.7	163	143	20	28	143	0	15	26	4000
1885.40	5.8	6.9	-1.1	154	142	12	39	141	3	15	26	4000
1897.52	7.0	10.3	-3.3	170	280	-110	39	280	0	15	22	0400
1971.38	4.9	.4	4.5	159	141	18	25	142	0	15	28	1000
1971.42	13.9	14.2	-.3	162	136	26	36	135	0	15	31	1000
1981.77	14.8	15.2	-.4	138	94	44	34	94	0	15	31	4000
2036.40	9.8	11.6	-1.8	145	128	17	18	128	0	15	22	0400
2041.54	4.7	23.7	-19.0	161	141	20	0	142	0	15	28	1000
2103.33	21.1	22.5	-1.4	153	135	18	28	136	0	15	28	4000
2186.27	11.8	23.1	-11.3	155	141	14	26	142	0	15	30	1000
2188.70	5.0	5.1	-.1	156	138	18	29	138	1	15	27	5000
2210.15	7.6	5.2	2.4	170	163	7	27	163	0	15	27	1000
2223.29	3.6	5.6	-2.0	138	122	16	0	121	0	15	22	0400
2320.01	25.3	29.0	-3.7	143	132	11	0	131	0	15	22	0400
2389.41	7.5	6.6	1.0	174	158	16	25	158	0	15	27	1000
2389.53	5.5	29.2	-23.7	164	151	13	19	152	0	15	22	0400
2431.41	19.3	21.9	-2.6	138	130	8	0	130	0	15	26	1000
2444.73	14.9	15.0	-.1	148	133	15	34	133	0	15	30	4000
2605.34	3.5	4.8	-1.3	152	134	18	39	134	1	15	31	4000
2677.29	5.2	7.7	-2.5	127	114	13	0	114	0	15	28	1000
2677.39	25.3	27.8	-2.5	144	126	18	0	125	0	15	22	0400
2733.[illegible]4	16.0	19.0	-3.0	144	128	16	29	128	0	15	30	1000
2860.78	10.8	12.9	-2.1	164	162	2	0	161	3	15	34	4000
2899.44	26.2	27.5	-1.3	141	128	13	0	128	0	15	26	1000
2906.04	5.9	5.8	.1	163	146	17	24	145	0	15	26	1000
2913.78	6.2	11.4	-5.2	143	124	19	18	124	0	15	22	0400
2943.54	3.1	21.9	-18.8	136	127	9	0	127	0	15	28	1000
2960.14	15.1	17.0	-1.9	154	134	20	29	134	0	15	26	4000
3010.15	8.5	9.4	-.9	168	82	86	19	81	0	15	22	0400
3057.44	5.4	2.2	3.2	136	120	16	19	120	0	15	22	0400
3067.49	14.7	17.7	-3.0	146	130	16	0	130	0	15	31	4600
3264.99	9.2	24.4	-15.2	163	151	12	0	152	0	15	27	1000
3345.76	7.1	3.7	3.4	153	150	3	0	150	0	15	28	1000
3345.80	14.0	17.2	-3.2	178	163	15	0	163	0	15	30	1000
3360.46	24.5	14.5	10.0	144	132	12	0	131	0	15	30	4000
3535.07	6.7	10.0	-3.3	158	154	4	24	154	0	15	26	4000
3560.03	19.2	22.4	-3.2	195	152	43	27	151	0	15	29	1000

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SINGLE AND 2-STATION COINCIDENT DATA POINTS

DAY NO. 259 HOUR 2

TIME(SEC)	AMPLITUDE(DB) CAMP.	TM	DIFF.	AZIMUTH(DEGREES) CAMP.	TM	DIFF.	SINGLE STATION DATA AMPL.	AZ.	F1	F2	PEAK	IDENT
20.75	17.0	20.0	-3.0	122	118	4	28	118	0	15	30	4000
96.92	11.2	14.4	-3.2	148	133	15	0	133	0	15	27	4000
128.91	9.3	14.3	-5.0	143	113	30	0	113	1	15	31	4000
207.29	13.6	14.8	-1.2	158	130	28	0	130	0	15	27	4000
209.45	5.7	6.8	-1.1	157	133	24	0	133	0	15	22	0400
287.77	16.6	19.4	-2.8	161	146	15	29	145	0	15	27	4000
455.15	9.9	13.2	-3.3	169	150	19	36	150	0	15	31	4000
525.79	12.2	13.7	-1.5	145	128	17	36	128	0	15	32	4000
727.57	26.5	28.7	-2.2	155	143	12	19	143	0	15	22	0400
751.82	5.9	21.4	-15.5	149	138	11	0	138	0	15	28	1000
792.90	19.5	22.3	-2.8	157	135	22	27	136	1	15	27	1000
[illegible]	18.3	20.1	-1.8	154	130	24	28	130	0	15	30	1000
953.25	5.5	2.4	3.1	110	86	24	0	85	0	15	28	1000
954.92	15.6	16.8	-1.2	161	147	14	33	147	0	15	28	4000
981.46	20.9	22.6	-1.7	153	136	17	26	135	0	15	28	1000
1024.73	18.4	17.3	.7	168	180	-12	0	180	0	15	30	4000
1058.37	15.3	15.7	-.4	151	131	20	34	132	0	15	26	4000
1090.67	19.4	21.9	-2.5	152	140	12	0	140	0	15	26	0040
1160.35	17.6	16.0	1.6	149	130	19	0	130	0	15	30	4000
1410.31	3.4	8.2	-4.8	176	152	24	28	151	1	15	28	4000
1418.54	17.9	20.1	-2.2	158	128	30	0	128	0	15	27	4000
1524.50	8.5	8.1	.4	152	127	25	19	127	0	15	22	0400
1542.69	16.2	16.1	.1	170	200	-30	29	200	0	15	30	4000
1659.37	13.3	17.0	-3.7	173	153	20	28	153	0	15	30	4000
1847.61	20.3	23.0	-2.7	173	146	27	0	145	0	15	30	1000
1930.38	11.9	15.2	-3.3	160	138	22	29	138	0	15	31	4000
1940.79	5.5	10.7	-5.2	189	140	49	28	140	0	15	27	0040
1974.44	11.0	15.3	-4.3	161	136	25	0	135	1	15	26	4000
2130.14	12.8	12.9	-.1	162	300	-138	37	300	0	15	31	4000
2229.36	3.1	.6	2.5	137	135	2	39	136	3	15	30	4000
2244.39	17.1	22.1	-5.0	137	0	137	28	0	0	15	30	4000
2248.38	11.0	11.4	-.4	165	153	12	39	153	0	15	30	4000
2272.88	19.1	19.5	-.4	174	161	13	0	162	0	15	28	4000
2298.97	9.5	13.9	-4.4	161	150	11	0	150	0	15	30	4000
2347.32	4.7	4.6	.1	151	134	17	19	134	0	15	26	1000
2391.45	3.7	6.4	-2.7	138	131	7	39	132	0	15	30	4000
2398.31	3.4	7.2	-3.8	161	130	31	29	130	0	15	31	1000
2738.47	23.2	24.8	-1.6	177	324	-147	24	324	0	15	31	4000
2774.40	10.6	15.1	-4.5	161	144	17	0	144	0	15	30	4000
2883.37	5.6	6.5	-.9	168	141	27	19	142	0	15	27	5000
2908.32	14.0	17.2	-3.2	161	140	21	0	140	0	15	28	0030
2988.33	5.2	9.1	-3.9	130	242	-112	28	241	0	15	24	4000
3026.39	12.9	16.4	-3.5	116	107	9	29	107	0	15	28	4000
3026.50	12.3	10.9	1.4	124	204	-80	78	204	0	15	31	4000
3137.38	5.2	1.7	3.5	159	141	18	38	142	0	15	31	4000
3235.64	9.4	7.8	1.6	151	127	24	18	127	0	15	22	0400
3278.94	7.8	11.2	-3.4	156	288	-132	38	288	0	15	23	4000
3361.31	18.4	20.3	-1.9	142	116	26	0	115	0	15	26	0040
3491.03	11.8	28.3	-16.5	141	128	13	19	128	0	15	26	4000
3560.33	17.7	25.2	-7.5	250	274	-24	9	274	0	15	18	0400

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SINGLE AND 2-STATION COINCIDENT DATA POINTS

DAY NO. 259 HOUR 3

TIME(SEC)	AMPLITUDE(DG) CAMP.	TM	DIFF.	AZIMUTH(DEGREES) CAMP.	TM	DIFF.	SINGLE STATIoN DATA AMPL.	AZ.	F_1	F_2	PEAK	IDENT
98.37	11.2	14.6	-3.4	160	131	29	0	132	0	15	22	0400
98.39	3.5	22.8	-19.3	197	130	67	27	130	0	15	28	1000
98.48	10.0	31.2	-21.2	167	124	43	0	124	0	15	22	0400
105.32	4.7	16.5	-11.8	226	126	100	35	125	0	15	30	4000
213.20	13.1	13.6	-.5	216	121	95	29	122	0	15	24	4000
366.01	14.3	15.2	-.9	258	141	117	0	142	0	15	31	4000
603.20	13.1	17.9	-4.8	121	196	-75	31	195	0	15	28	4000
615.16	18.7	18.8	-.1	232	153	79	0	153	0	15	28	4000
743.56	15.2	17.9	-2.7	187	173	14	0	173	0	15	31	4000
752.64	5.0	4.0	1.0	169	131	38	19	132	0	15	22	4000
1135.78	28.1	15.1	13.0	131	118	13	35	118	0	15	31	1000
1717.43	8.7	6.7	2.0	108	92	16	23	91	0	15	29	1000
2004.03	3.9	1.8	2.1	124	91	33	29	92	0	15	30	5000
2020.37	20.8	22.7	-1.9	141	114	27	0	114	0	15	28	1000
2020.40	3.4	27.7	-24.3	149	120	29	0	120	0	15	26	4000
2682.29	6.0	3.6	2.4	145	138	7	29	138	0	15	26	1000
2796.58	3.3	5.6	-2.3	160	304	-144	38	304	1	15	22	0400
2845.39	3.8	28.0	-24.2	135	131	4	0	132	0	15	23	0400

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SINGLE AND 2-STATION COINCIDENT DATA POINTS

DAY NO. 259 HOUR 4

TIME(SEC)	AMPLITUDE(Db) CAMP.	TM	DIFF.	AZIMUTH(DEGREES) CAMP.	TM	DIFF.	SINGLE STATION DATA AMPL.	AZ.	F1	F2	PEAK	IDENT
363.39	7.3	16.5	-9.2	161	147	14	0	147	0	15	22	4000
804.98	21.4	22.0	-.6	177	160	17	26	160	0	15	26	4000
1282.40	8.2	11.5	-3.3	129	127	2	38	127	0	15	30	4000
3326.96	11.1	15.5	-4.4	81	77	4	0	77	0	15	30	4000
3490.21	15.9	7.3	8.6	150	117	33	27	117	0	15	26	4000

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SINGLE AND 2-STATION COINCIDENT DATA POINTS

DAY NO. 259 HOUR 5

	AMPLITUDE(DB)			AZIMUTH(DEGREES)			SINGLE STATION DATA					
TIME(SEC)	CAMP.	TM	DIFF.	CAMP.	TM	DIFF.	AMPL.	AZ.	F_1	F2	PEAK	IDENT
111.31	12.5	13.9	-1.4	175	161	14	32	162	0	15	30	4000
1284.13	4.4	9.8	-5.4	113	223	-110	29	223	0	15	26	4000