CONTRACT NUMBER: NAS-9-13563

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

FINAL REPORT

APOLLO 12, 15 AND 16 LUNAR SURFACE MAGNETOMETER EXPERIMENT DATA ANALYSIS

FEBRUARY 1975

Prepared by

C. P. Sonett

Lunar and Planetary Laboratory

University of Arizona

Tucson, Arizona 85721

CONTRACT NUMBER: NAS-9-13563

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

FINAL REPORT

APOLLO 12, 15 AND 16 LUNAR SURFACE MAGNETOMETER EXPERIMENT DATA ANALYSIS

FEBRUARY 1975

Prepared by

C. P. Sonett

Lunar and Planetary Laboratory

University of Arizona

Tucson, Arizona 85721

TABLE OF CONTENTS

ABSTRACT

The polarization of magnetometer signals detected at the Apollo 15 Hadley site by the Lunar Surface Magnetometer (LSM) has been studied to determine the source of the signal anisotropy which is observed and is caused by the polarization. Instrument and data chain malfunction (cross-talk) seems ruled out. The source appears real and apparently connected with the Imbrium basin using reasonable inferences regarding the electromagnetic structure of the Moon. A theory is developed using Moons with "holes" and conducting caps where the Imbrium basin is; results of calculations are consistent, though not unique, in specifying an anomaly in the electrical conductivity underlying Mare Imbrium. Transfer functions are calculated from data taken while the Moon was in the lobes of the tail field of the Earth. Distinct differences are noted from plasma sheet and diamagnetic cavity transfer functions, but the lobes appear, as for all other data, not to be vacuum for study of the Moon. Lunar modelling using lobe data which fails to account for the presence of plasma is erroneous. A discussion is given of problems connected with transfer of data, software, and theoretical programs from NASA Ames Research Center to the University of Arizona, and a summary is given of the conversion from IBM to CDC formats.

SUMMARY

This report discusses problems associated with the transfer of Explorer 33, 35 and Lunar Surface Magnetometer data tapes from NASA Ames Research Center to the University of Arizona for continued use by the Principal Investigator at the latter location. Key issues under study include reformatting from an obsolescent IBM format to one compatible with the CDC 6400. At the close of this contract this problem had been solved for the Explorer tapes in a partially satisfactory way constrained by funds for computer operation in reformatting. The problem of reformatting LSM tapes continued under study after conclusion of the contract.

A large body of interpretive and theoretical computer programs were also copied at NASA Ames for shipment to the University of Arizona for incorporation into the research program there. Conversion of these programs from IBM to CDC format was proceeding at a satisfactory rate at contract termination (See Tables 1 and 2).

Continual difficulties with intermittant failures of Explorer 35 due to over-age became increasingly severe during this time period. Workaround programs had been initiated previously to attempt to enlarge the amount of data retrieved, but a large fraction of senior personnel time was required in addition. The status of Explorer 35 data cannot be said to be satisfactory at the time of the close of this contract, and very little data is available for comparison with Apollo 15 LSM, but continued effort should increase the data base.

Considerable effort was expended upon the signal anisotropy at the Apollo 15 site. This was determined, insofar as possible and with the cooperation of the JSC staff, to eliminate all possibility that

the effect was due to instrument or telemetry malfunction. An assignment to a regional effect on the Moon was made and model calculations carried out using a new theory for a spherical Moon with a conductivity anomaly of circular shape centered on Mare Imbrium. Reasonable fits between the data and the models were obtained, but the question of uniqueness still remained to be solved at the close of the contract.

We also investigated the response of the Moon in a region previously unexplored. The transfer functions for both radial and tangential fields were obtained in the lobes of the geomagnetic tail field where the plasma density is least of any space environment that the Moon passes through; also, the Magnetic field is most steady there. Nevertheless it was found that accurate transfer functions could be obtained and that the Moon behaves as a body immersed in a plasma. The idea that the Moon can be treated in the tail lobes as if in vacuum is erroneous at least for implications involving its response in the frequency range of 1-40 milliHz.

CONCLUSIONS

The transfer of computer software and data tapes is a large problem, incomplete at the time of this writing. Difficulties have been magnified by the obsolescent format represented by the IBM 704/7040 (DCS) system used at NASA Ames. A great deal of time and cost has been incurred because of this, though the problems do appear soluble. The largest effort remains keeping down the cost of transition from one computer system to the other.

It is becoming clear that the anomalous conductivity, apparently at the base of the polarization of signals at Apollo 15 Hadley site, is consistent with the hypothesis of a regional difference in the conductivity at great depth in the Moon in the region of Mare Imbrium, but is not necessarily restrictive to this model. The evolutionary implications are far from clear though simple models would suggest that the effect is a result of the impact which resulted in the formation of the basin.

The finding that the lunar response is not vacuum-like in the lobes of the geomagnetic tail field of the Earth has the consequence that analysis of data taken in this region will have to take into account the presence of plasma, but no theoretical work could be carried out on this problem in the six month interval of this contract.

INTRODUCTION

This report covers work done on analysis of Lunar Surface Magnetometer data during the period of July 1, 1973 - Dec. 31, 1973. During this time major changes were taking place in the analysis program, the most critical being the resignation of the Principal Investigator from NASA to accept the position of Professor, Head of the Planetary Science Department, and Director of the Lunar and Planetary Laboratory at the University of Arizona (Henceforth referred to as the U of A for brevity). In anticipation of this move, Johnson Spacecraft Center agreed to consider a contract proposal from the PI for continuation of the LSM analysis for the remaining six month period during which the PI role was defined, and that after this period any further funding would come under the jurisdiction of NASA Headquarters as part of the Lunar Synthesis Program.

The change of location of the PI was expected to cause major disruptions in the research program because of the need to transfer data, software, and documentation to the U of A in accordance with the Work Statement (Paragraph 2.3), which would place major responsibility there. Since the U of A had little previous computational facility experience in large scale spacecraft data analysis programs and no other personnel involved in the LSM program planned to transfer there, the likelihood of unanticipated requirements, was large. Therefore the PI planned early to maintain momentum in the ongoing research which had been under way jointly between NASA Ames and UCLA, while using the six month interval to also accomplish the transfer tasks.

These transfer tasks are not spelled out in the work statement of the contract, but represent serious and important efforts toward establishing a creditable analysis cabability at the U of A for continuing research. These statements are based upon the expectation, since realized, that continuation of funding via the Synthesis Program would take place; to foster this it was urgent that a capability at the U of A be rapidly established.

Key elements in establishing a research program at the U of A included transfer of both Explorer 33 and 35 data tapes from Ames, hard copy of these data, equivalent data from the Apollo LSM's and finally the transfer of appropriate computer programs which had been used regularly at Ames by the PI. These computer routines represented the accumulation of many years effort on both the Explorer 35 and LSM.
It became obvious early in the appraisal of the effort at the U of A, after arrival of the PI, that for the research functions specified by the work statement, a considerable body of research would have to functionally remain at Ames for the six month contract period but that the UCLA contributions could continue uninterrupted. In retaining the Ames research viability, it was recognized also that demands would be placed upon Ames for the transfer tasks and that a mix of tasks would result which could negatively impact the research efforts unless continually monitored.

Since at the start of this contract few Apollo 15 and no 16 tapes had been examined by the PI, it was clear from the onset that definition of all tasks, both research and transfer would require continual reappraisal during the six months contract cycle. A mediating influence on defining the transfer tasks was that the research work so closely used the data tapes that an automatic imput into the transfer requirements would result by "spin-off" from the research effort. This therefore was a key issue in retaining a viable research option at NASA Ames during this period, the other being the general need for continuing research at a fast pace.

Transfer problems originated from two sources. First, definition of possible tape problems was paced partially by the unavailability of most Apollo 15 and all Apollo 16 tapes prior to July 1, 1973. Secondly ,a basic incompatibility existed between the Ames (IBM) and U of A (CDC) computers. As a further complication all data (Explorer and LSM) had been processed on the obsolecent IBM 7090/7094 (DCS) system at Ames, a processing decision made years previously prior to availability of more modern computers, and later in order to reduce costs. Thus, a large scale data formatting problem for both Explorer and LSM existed, a fact known earlier and upon which work had begun prior to the resignation of the PI from NASA Ames. In addition to these problems, there was an urgent need to staff at the U of A for the program, a process started within days of the arrival of the PI there.

In these introductory remarks, it should also be borne in mind that although the existence of a signal anisotropy had been noted earlier in Apollo 15 data, this problem began to assume a principal research role just toward the beginning of this contract period when it was recognized that the effect was probably real and not instrumental. The resolution of the Apollo signal anisotropy was not only a problem of intrinsic scientific interest, but also a requirement to enable the carrying out of the major experimental studies regarding the lunar conductivity profile, especially if joint data from several LSM's were to be combined network fashion.

Though this is a final contract report, from both the programmatic and scientific standpoint, it should be recognized as a progress report on a continuing research effort. The close links with UCLA and especially NASA Ames remained uninterrupted during this period. Thus although ARC was funded separately, in accordance with Para. 2.0, the PI continued to carry out task monitoring both at UCLA and Ames, many of which technically closely linked with work at the U of A. These comments form the basis upon which the development of the research program at the U of A rested.

DATA ANALYSIS

During the period of this contract primary attention, aside from the problems of software and data transfer, were directed towards study of the anomalous signals received from the Apollo 15 LSM. It was early noted that the signals in the North-South and East-West directions were strongly coherent suggesting either an instrument malfunction involving sensor cross-talk or else a region with very anomalous electrical conductivity in the neighborood of Imbrium (Schubert, et al. 1974a). Discussions with Mr. Eichelman at JSC regarding this problem took place in the spring prior to transfer of the PI to the U of A. As a result the data train through the ALSEP central station and return to Earth was investigated by JSC personnel regarding the possibility of a cross talk effect associated with the TM transmission system. This study resulted in a negative finding. It was agreed that future attention would be directed towards the LSM itself. We obtained a record sample from Dr. Dyal from the initial period of LSM 15 when the calibration sequence on the instrument could be clearly studied. Although the one sample is imperfect from a statistical standpoint, no effects of cross talk could be found.

ANALYSIS OF THE ANOMALY

Based upon these null findings we proceeded with a full scale inquiry into the possible nature of the anomaly. Attention to this problem has been complicated by the intermittent failure modes of Explorer 35, the study of which sapped some effort from the LSM reduction. Since these data were vital for interpreting the LSM data, procedures for workaround of the failures of Explorer 35 had to be developed. Some experience in this from earlier work (prior to this contract period) aided. The bulk of the effort was directed at noise removal and correction of the field orientation which was done by determining field orientation while Explorer 35 was in the tail field of the Earth's magnetosphere. This work was carried out at Ames and immediately introduced into the LSM chain as available. Results of calculation of transfer functions for the first lunation of Apollo 15 showed that the induced magnetic field at the Hadley site was strongly polarized and the maximum signals were obtained from the Northwest direction (Smith, et al. 1974; Schubert, et al., 1974b). Such signals would normally be attributed to the presence of a bulk electrical conductivity at perhaps 200 km depth in a region near the magnetometer which was substantially different from the average conductivity of the Moon.

The procedure for analysis consisted of calculation of power spectra from the LSM and Explorer 35 data as a function of compass direction. It was shown that below about 5 milliHz there was no perceptible polarization. Irrespective of the direction of maximum forcing field signal from Explorer 35, the lunar return above about 5 milliHz tends to the Northwest direction. This additional frequency dependence is an important factor in the modelling and suggests a limit on the product of size and electrical conductivity.

Apollo 15 LSM polarization has been compared to that discovered on Apollo 12 (Sonett, et al. 1972). There the initial hypothesis was that the solar wind forced the remanent magnetic field, but it was shown that the anisotropy in signal persisted on the night side of the Moon, so that at least in part the source had to be elsewhere. The effect at Apollo 12 could still not be completely understood at the time of closing this contract. The Apollo 12 low frequency transfer function is also consistently larger than that from Apollo 15. Reports on both the data analysis and the theoretical modelling were prepared in abstract form for the Fifth Lunar Science Conference, with this contract period covering the initial phase of these reports (Sonett et al., 1974).

THEORETICAL TREATMENT OF THE ANOMALY

Experimentally it has been observed that the magnetic field, measured by the lunar surface magnetometer at the Apollo 15 site, shows a strong linearly polarized component at high frequencies ($\gtrsim$ 5 milliHz). The direction at the polarization is roughly oriented toward the center of the Mare Imbrium basin. The Apollo 15 site is on the edge of this basin or crater. Attempts to explain this polarization using either symmetric or asymmetric induction theory combined with a spherically symmetric electrical conductivity distribution have been unsuccessful. Because of the proximity of Imbrium and the coincidence of the geometry, it has been suggested that a local conductivity anomaly of the size of the Imbrium crater might be capable of producing the polarized response.

To model the conductivity anomaly we chose to examine the response of both a spherical current layer cap and a hole in an otherwise complete spherical current layer. [For a discussion of the use of complete spherical current layers in modeling lunar response see either or both Schubert and Colburn (1971) and Schubert and Schwartz (1972)]. Additional complete current layers or a conducting layered cone can be added easily to the model.

The solution of the electromagnetic induction problem, when the conductivity is an arbitrary function of both radius and angle, cannot be obtained using the normal spherical harmonic expansion. The utility of the thin current layer is based on the fact that a spherical harmonic expansion can be used for the fields, the complication arising in the satisfaction of the boundary conditions at the incomplete cap. The mixed boundary condition produces an infinite set of coupled linear equations in the infinite set of expansion coefficients. To obtain a numerical solution, the sets of equations and coefficients are truncated and the solution is obtained via a relaxation technique.

The geometry for the problem described above is shown in Figure 1. Fundamentally the electromagnetic problem can also be solved for the other orientation of the incident magnetic field and for vacuum as well as the plasma or confined boundary condition at the lunar surface. As an example of the effect of the conductivity anomaly see Figure 2 which shows H_θ for $\omega\mu\sigma(\sigma S)$=6.87, (a-b)=150km and $\theta_c=25^0$, 90^0 and 155^0, where ω is the angular frequency, μ the magnetic permeability and the other factors are as defined in Figure 1. Both vacuum (upper panel) and plasma conditions show a strong enhancement at the magnetic field near the edge of the cap. This enhancement does not appear for $H\phi$ or for the other orientation of the driving field. Thus at first sight either the hole or the cap could produce the observed polarization.

ARBITRARY K VECTOR

Recognizing the potential importance of the direction of arrival of the interplanetary wave field which excites the moon, we also continued work on the problem of the general induction with arbitrary k vector, but completion took place well after this contract period (Sonett and Colburn, 1974). The above work was reported at the Winter meeting of the American Geophysical Union and G. Schubert began work on an extended review of solar wind interaction with the Moon which was to be presented at the Asilomar Solar Wind Conference the following spring (Schubert and Lichtenstein, 1974).

LUNAR RESPONSE IN THE EARTH'S MAGNETIC TAIL

During the period of this grant the dependence of lunar electromagnetic induction on the plasma environment of the Moon was also investigated. Until this time there was no information on the nature of the lunar transfer function in either the lobes of the geomagnetic tail or the tail plasma sheet. Apollo 12 magnetometer data in these plasma environments were analyzed and the respective transfer functions were computed. Figure 3 shows the lunar electromagnetic transfer function in the plasma sheet (Schubert et al., 1974c). Figure 4 shows the comparative transfer function for the plasma sheet and in the tail lobes. Figures 5 and 6 show respectively a comparison of these transfer functions to quasi-vacuum theory. Quasi-vacuum theory is theory where the wave speed is changed from the speed of light (as would be the case in a vacuum) downward to masquerade as a wave travelling in plasma. It is only by this artifact that higher order modes can be introduced into the induction problem. The plasma sheet transfer functions were based on analyses of the power spectra of 27 one hour time swaths. The magnetotail lobe transfer functions were based on 37 one hour cases.

Study of these transfer functions showed that magnetic field changes in different plasma environments produced distinctive lunar inductive responses. In the plasma sheet, induced magnetic fields tangent to the lunar surface are amplified by confinement from the plasma. The degree of amplification is similar to that in the plasma void downstream of the Moon in the solar wind. However, the radial transfer function in the plasma sheet is quite different from this function on the night side of the Moon in the solar wind. The magneto-tail transfer functions are also distinct and interestingly different from what would be obtained by scattering of electromagnetic waves by a conducting sphere in vacuum. We are presently writing a paper summarizing the lunar inductive response characteristics in the lobes of the geomagnetic tail.

In an attempt to understand lunar induction in these different plasmas we computed theoretical lunar transfer functions using a quasi-vacuum theory. This theory is identical to ordinary vacuum scattering theory except for the use of an arbitrary velocity for scattered waves. Figures showing the comparison of quasi-vacuum transfer functions to plasma sheet and tail lobe measurements are included. As can be seen the theory fails to predict the extent of amplification of tangential magnetic fields in the plasma sheet. The theory is somewhat more successful in accounting for the observations in the lobes, but even here agreement of theory and data is not completely satisfactory, especially at frequencies above about 0.01 Hz.

DATA TRANSFER FROM AMES TO U OF A

A comparative analysis between existing theoretical models of lunar electromagnetic induction and magnetic field data requires a precise knowledge of both the lunar magnetic field and also the ambient interplanetary magnetic field. The ambient interplanetary magnetic field data, measured by Explorer 35 and at times by Explorer 33, defines the solar wind magnetic field forcing function which drives the lunar electromagnetic induction. It is by normalizing, component by component, the LSM's lunar electromagnetic response by the Explorer field, that the effective transfer function for the moon, independent of the magnitude and direction of the interplanetary field, is found. It should be noted that in a more refined analysis where higher order modes of the moon are sought or when local time is important, the direction of the interplanetary wave field is also required.

All Explorer 35 and 33 magnetometer data (individual vectors and sequence averages) useable for this have been processed and stored on magnetic tapes utilizing the now obsolete Ames IBM 7040/7094 DCS (Direct Coupled System) computer. Several unique characteristics of this computer system should be noted. First, the word length used is the standard IBM work of 32 bits. Also the IBM 7040/7094 DCS writes a blocked tape which does not translate characters from internal storage code to tape storage code. The Explorer tapes were written in odd parity (essentially BCD characters except for the DCS binary control words preceding each logical record) in which all logical records are stored in order. Groups of 2748 BCD characters are then separated, prefixed by a twelve character physical record control word and placed on tape followed by an inter-record gap. Each of the above tape characteristics of the 7040/7094 DCS creates problems when the tapes are being read on a CDC computer. A CDC computer requires a word length of 60 bits/word, even parity for a BCD format and tape storage code instead of DCS internal storage code. In addition, because of the continuous character stream format, a complicated search routine had to be developed to facilitate the retrieval of data intervals located within a tape. The complete set of conversion routines, especially written prior to the resignation of the PI from Ames, could be used to read a full data tape on a CDC 6400 or equivalent machine at an approximate cost of $130/reel. This was known to place an intolerable fiscal burden upon future research. On the other hand, conversion into a CDC format of all Explorer 35 data at Ames would also have been prohibitive. It was adjudged best to only transform the sequence average (SA) tapes, as these would later be used the most. Two trips were made to Ames during this period to coordinate the software transfer, and Ames personnel visited the U of A also for this purpose. Table 1 summarizes the development of computer programs to read data tapes at the U of A.

During the period of this contract all Explorer 35 and 33 individual vector (IV), sequence average (SA) and trajectory tapes were received as well as printouts and hard copy of the SA plots. Due to system modifications of the U of A CDC 6400 (from Scope 3.3 to Scope 3.4 operating system) all conversion routines for reading IV and SA data tapes had to be modified. At this time, input-output routines were developed to obtain disk storage and plotting capabilities. The IV tapes were received by common agreement in their original Ames DCS (IBM 7040/7094) configuration. As the running costs at the U of A are increased because of the reformatting required for these tapes and because of money restrictions, it was still deemed advisable to convert only the sequence average tapes at Ames. All these data have been cataloged and entered into a new filing system estabilshed in the Lunar and Planetary Laboratory.

The initial transfer of Apollo LSM tapes from Ames was reviewed and held up at Ames because of potential problems from noise. Initial inspection of some of these data for research purposes at Ames suggested that contamination by noise spikes would have a serious effect if power spectra were computed from them. It was agreed that the tapes would be temporarily held at Ames since the primary data reduction analysis still resided there, and a survey of the potential problems could best be made at Ames.

The PI was to receive 10 lunations of Apollo 15 and one of 16 on July 1, 1973. These tapes were delivered to the Ames Co-I's at this time when, upon mutual agreement they began processing for research use, i.e., the anisotropy problem on Apollo 15. This was a logical first step since procedures and programs had not yet been checked out at the U of A. It was found that excessive noise, detrimental to calculation of power spectra were present and that all tapes were suspect. Apparently these tapes had not been subject to the noise removal program, originally generated for Explorer 35 and transferred to P. Dyal for use in processing tapes from JSC; but irrespective of the noise source, a clean-up procedure was required. Since these tapes were also blocked for DCS, they required reformatting to read properly on the U of A 6400. Conversion of the format was deemed unadvisable until the noise removal procedure could be better understood. Meanwhile Ames continued to plan for formal conversion and to work on generation of a routine for conversion of LSM tapes using the University of California CDC 7600.

COMPUTER SOFTWARE TRANSFER

About 25 boxes of assorted programs for lunar data interpretation were transmitted from NASA Ames to the U of A. These programs were received in their original form for operation on the NASA Ames 360 computer. Conversion of computer routines for use on the U of A CDC 6400 included modification of program control cards, converting punched card decks from an 026 punch to an 029 punch, converting IBM in-line and library functions to their CDC equivalent, modifying core requirements to fit the CDC 6400 and changing all of the double precision IBM function calls to single precision CDC function calls (see Table 1).

The programs consisted of routines for calculation of lunar EM response using the various models developed at Ames, i.e. two layer, three layer, single and double current layer, and four layer Moons, continuously variable conductivity profile Moons, and the iteration program for converting the transfer function from LSM into a conductivity profile.

In addition to the model calculation routines, other analysis routines which include power spectral analysis, minimum variance k vector determinations, individual vector data corrections for spike and gap detection and their removal and the decimation procedures for LSM tapes were obtained and modified. Although most programs were only modified for IBM-CDC differences and output requirements (plots and disk storage), some fundamental program changes were investigated and initiated for

TABLE 1 TAPE CONVERSION AND READING ROUTINES IBM 7040/7094 DCS → CDC 6400

SATELLITE	DATA TYPE	ROUTINE DESCRIPTION	ROUTINE ORIGIN	MODIFICATIONS*	U OF A STATUS
Explorer 33 & 35	Individual Vector (I.V.) original	Reads DCS tape on CDC	Ames	A,B,C	Tested & working
Explorer 33 & 35	Sequence average	Converts DCS tape to CDC tape	Ames		Documented only
Explorer 33 & 35	Sequence average	Reads new CDC tape	Ames	A,B,C,	Tested & working
Apollo 12	I.V.	Converts DCS tape to CDC tape	Ames		Documented only
Apollo 15	I.V.	Converts DCS tape to CDC tape	Ames		Documented only
Apollo 12	I.V.	Reads new CDC tape	Ames	A	Ready
Apollo 15	I.V.	Reads new CDC tape	Ames	A	Ready

*Modifications

Type A - CDC Scope 3.4 control cards
B - Plotting capabilities
C - Disk Storage & Retrieval
D - Double to single precision conversions
E - 026 → 029 Punch conversion
F - Program Technique changes

the power spectral and the spike and gap removal routines. To efficiently obtain the maximum amount of information from a magnetic field time series, spectral analyses employing the Fast Fourier Transform (FFT) and the maximum entropy techniques were studied. The data gap routines were modified by using spline interpolation instead of linear interpolation to fill data gaps in the time series. Table 2 summarizes the computer analysis routines that are now functional at the U of A. Trial and modification of these routines began with the subject contract; work is still continuing on these as data arrives from Ames to be tested against the routine modification. The general rule for closing the modification and verifying programs begun under this contract includes concurrent tests at Ames and U of A of selected runs such as power spectra and forward calculations to ascertain that common results are yielded.

During the period of this contract Apollo LSM tapes were held at NASA Ames for both the noise survey problem which could be investigated as part of the regular reduction ongoing there. Most of the Apollo 15 tapes were not ready for transshippment during this time because of the computer hangups in reformatting the tapes at the University of California CDC 7600 facility. This problem was finally uncovered late this last year.

HIRING

Based upon the assumption that the analysis program would continue to be funded as part of the Lunar Synthesis Program from NASA Headquarters, an intensive effort was started to recruit senior personnel. Dr. Michael Wiskerchen , formerly of the U of Denver accepted an offer and came to the U of A on Sept. 1 at which time he began to work on

TABLE 2

MODELING & DATA ANALYSIS ROUTINES

ROUTINE NAME	DESCRIPTION	ROUTINE ORIGIN	MODIFICATIONS*	U OF A STATUS
2-layer-vacuum	2 layer moon model	Ames	A,D,E,	Tested & working
3 layer-vacuum	3 layer moon model	Ames	A,D,E,	Being tested
4 layer vacuum	4 layer moon model	Ames	A,D,E	Being tested
2 layer quasi vacuum	2 layer-confinement	Ames	A,D,E	Being tested
3 layer quasi vacuum	3 layer-confinement	Ames	A,D,E	Being tested
current layer	current layer model	Ames	A,D,E	Being tested
double current layer	double current layer model	Ames	A,D,E	Being tested
core + current layer	core + current layer model	Ames	A,D,E	Being tested
Inversion	best fit model to spectral data	Ames	A,D,E	Being tested
integrated profile	step wise integrated conductivity profile	Ames	A,D,E	Tested & working
spike detection	recognition of spikes on IV DATA	Ames	A,D,E	Being tested
GAP removal	lunar interpolation to fell gaps	Ames	A,D,E,F	Being tested
decimation routine	multi-weight decimation filter for Apollo	Ames	A,D,E	Being tested
spectral analysis	full spectral matrix for arbitrary coordinate	Ames	A,B,C,D,E,F	Tested & working
spectral rotation	rotation to ALSEP coordinates	Ames	A,D,E	Being tested
transfer function	matches Explorer & Apollo spectral estimates	Ames	A,D,E	Being tested
minimum variance	wave field disection from magnetic field time series	Ames	A,C,D,E	Being tested

*Modifications

Type A - CDC scope 3.4 control cards
B - Plotting capabilities
C - Disk storage & retrieval

Type D - Double to single precision conversions
E - 026 → 029 punch conversion
F - Program technique changes

the software and data transfer. Dr. J.K. Chao, formerly of NASA Goddard Space Flight Center, also joined the staff for part time association with the LSM work on Oct. 10 of 1973. Considerable time was spent by them in acquainting themselves with both the data formatting transition from IBM to CDC and the similar problems connected with the conversion of software programs.

EQUIPMENT

During the contract period we also ordered and received shelving and prepared a storage area for tapes and hard copy from NASA Ames. In conjunction with the research program we also investigated several desk top programmable calculators. A key function was to be the ability to carry out moderate sized calculations with a direct plotting capability to save expense in avoiding the need for CALCOMP or equivalent peripheral equipment at the U of A facility. Although the primary funding for the equipment was from other NASA grants some support was used from the subject contract, primarily for the plotting table. Investigation of several types of calculator showed the HP series to be superior for our needs when all factors such as maintainability and repair were included. We placed an order for an HP 9830 during this period.

PAPERS PREPARED FOR PUBLICATION DURING THIS TIME PERIOD

Papers written during this time:

Polarized magnetic field fluctuations at the site of Apollo 15: Possible regional influence of lunar induction, G. Schubert, B.F. Smith, C.P. Sonett, D.S. Colburn and K. Schwartz, Science, 183, 1194, 1974.

Regional electromagnetic induction at the Apollo 15 site, B.F. Smith, G. Schubert, C.P. Sonett, D.S Colburn and K. Schwartz, in Lunar Science V. Abstracts of papers submitted to the Fifth Lunar Science Conf., Houston, Part II, p. 715, 1974.

Mare imbrium: A regional site of anomalous electrical conductivity, G. Schubert, K. Schwartz, C.P. Sonett, B.F. Smith and D. S. Colburn, in Lunar Science V. Abstracts of papers submitted to the Fifth Lunar Science Conf., Houston, Part II, p. 678, 1974.

Papers worked on but published later:

Polarized electromagnetic response of the Moon, C.P. Sonett ,B.F.Smith, G. Schubert, D.S. Colburn and K. Schwartz, in Proc. Fifth Lunar Science Conf., in press, 1974.

Lunar dayside plasma sheet depletion: inference from magnetic observations, G. Schubert, B.R. Lichtenstein, C.T. Russell, P.J. Coleman , Jr., B.F. Smith, D.S. Colburn and C.P. Sonett, Geophys. Res. Lett. 1, 97, 1974.

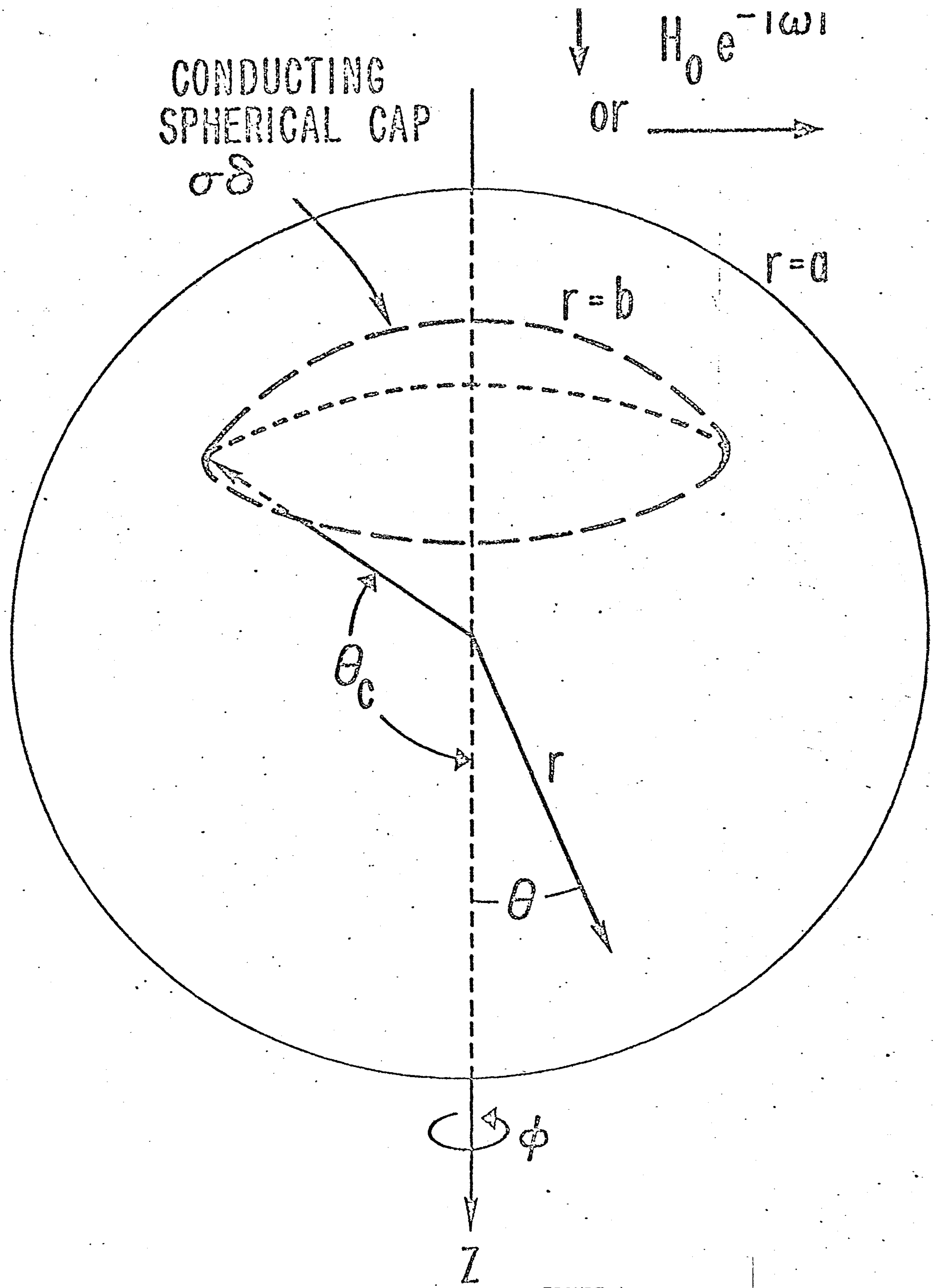
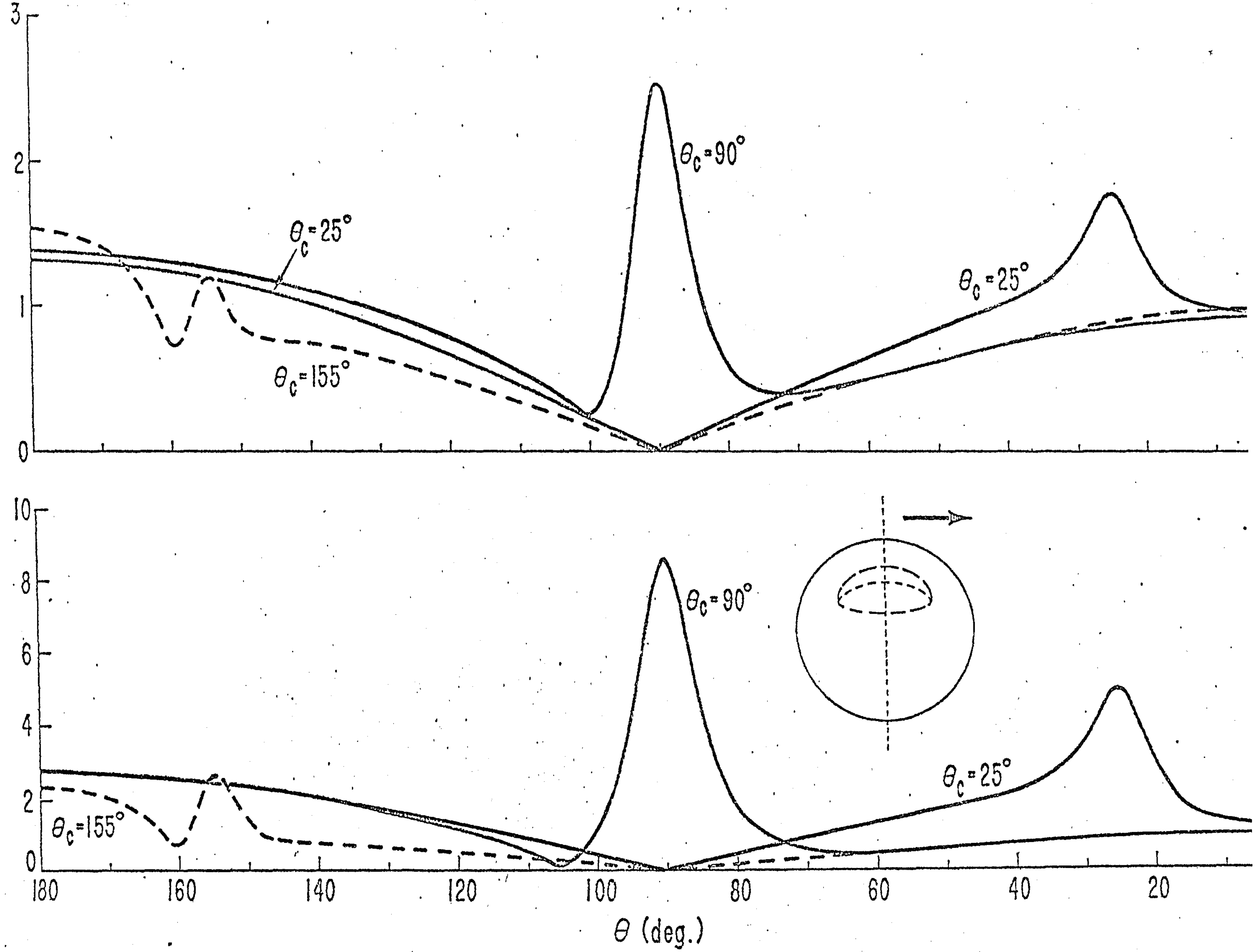

$H_0 e^{-i\omega t}$
or
CONDUCTING
SPHERICAL CAP
$\sigma\delta$
r=a
r=b
θ_c
r
θ
ϕ
Z

FIGURE 1



|H$_\theta$|
3
2
1
0
10
8
6
4
2
0
θ_c=25°
θ_c=155°
θ_c=90°
θ_c=25°
θ_c=90°
θ_c=25°
θ_c=155°
180
160
140
120
100
80
60
40
20
θ (deg.)

FIGURE 2

LUNAR ELECTROMAGNETIC TRANSFER FUNCTION IN PLASMA SHEET

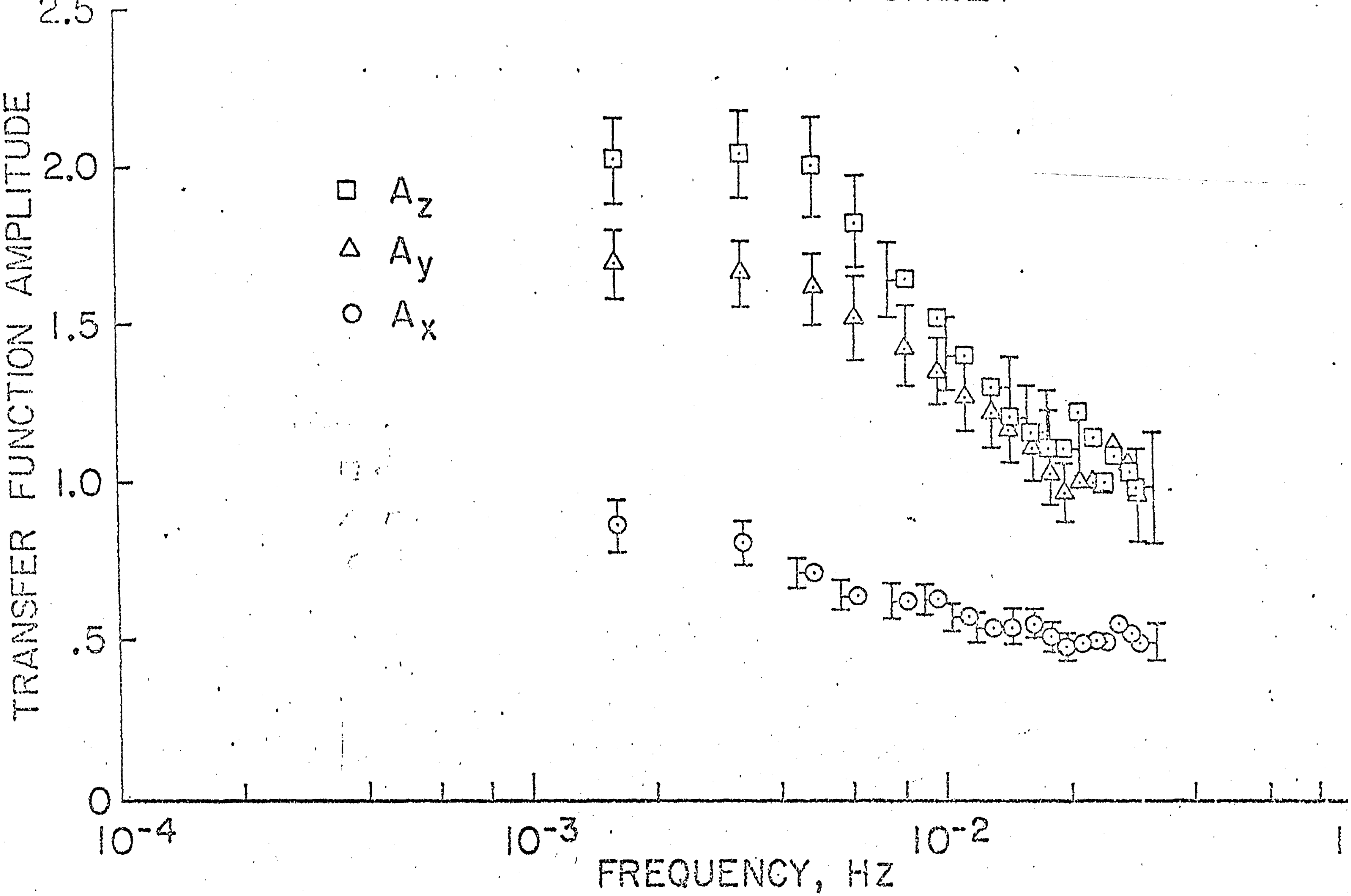


FIGURE 3

COMPARISON OF TRANSFER FUNCTIONS
IN LOBES AND PLASMA SHEET

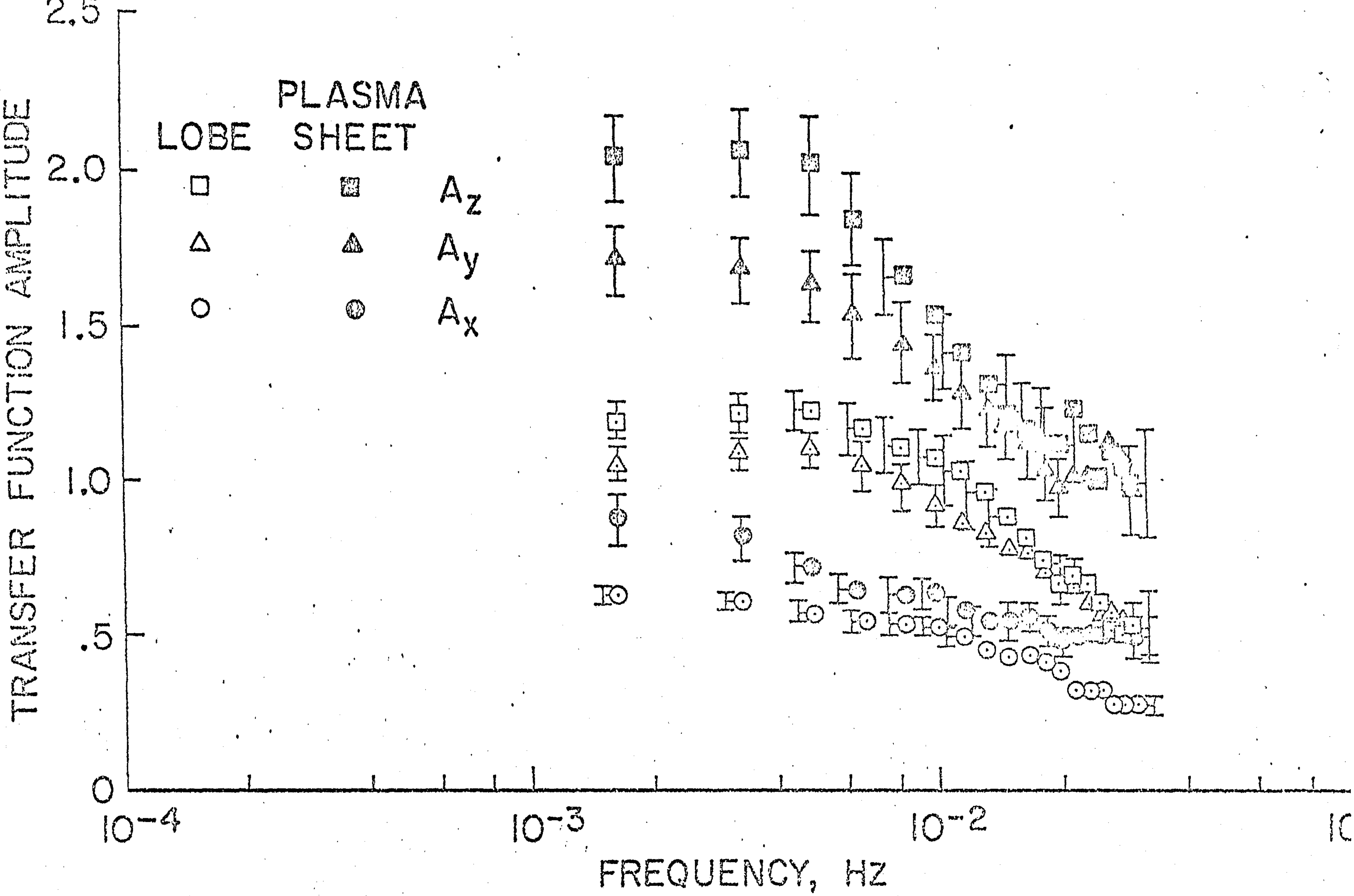


FIGURE 4

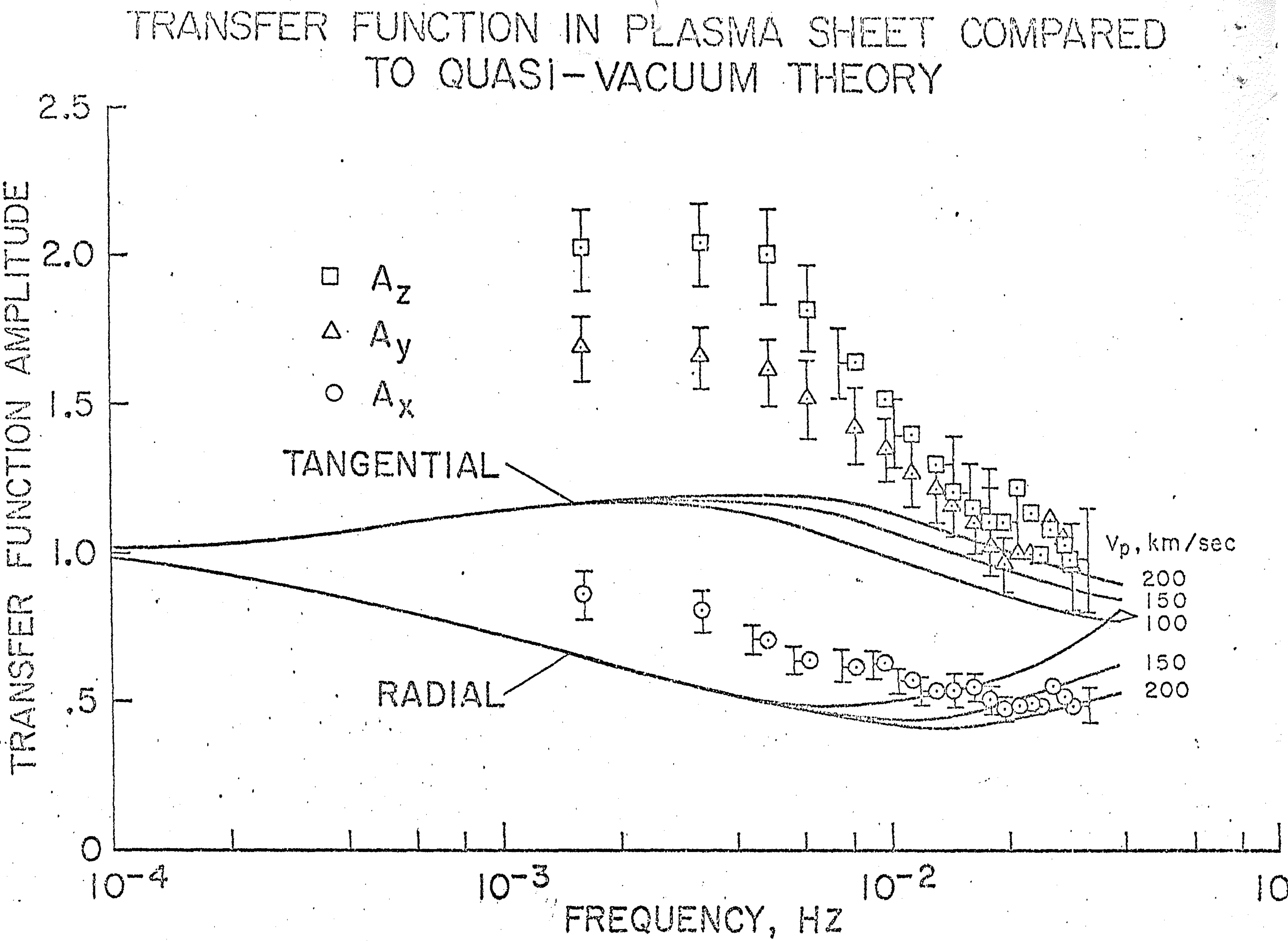

TRANSFER FUNCTION IN PLASMA SHEET COMPARED TO QUASI-VACUUM THEORY
2.5
2.0
1.5
1.0
.5
0
TRANSFER FUNCTION AMPLITUDE
□ A_z
△ A_y
○ A_x
TANGENTIAL
RADIAL
V_p, km/sec
200
150
100
150
200
10^{-4}
10^{-3}
10^{-2}
FREQUENCY, Hz

FIGURE 5

DISTRIBUTION LIST

NASA Johnson Space Center Experiments Procurement Section Attn: Brenda Traylor Mail Code BC241 Houston, Texas 77058	1 copy
NASA Johnson Space Center Technical Library Branch Attn: Retha Shirkey Mail Code JM6 Houston, Texas 77058	4 copies
NASA Johnson Space Center Management Services Division Attn: John T. Wheeler Mail Code JM7 Houston, Texas 77058	1 copy
NASA Johnson Space Center Space Requirements Branch Attn: W.F. Eichelman Mail Code TN3 Houston, Texas 77058	5 copies