THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING

Department of Aerospace Engineering
High Altitude Engineering Laboratory

Quarterly Report

# HIGH ALTITUDE RADIATION MEASUREMENTS

1 October, 1967 - 31 December, 1967

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Table of Contents Page

List of Illustrations iii

Abstract iv

I. Introduction 1

II. Laboratory Testing and Development of the IRIS Interferometer 1

III. Preparations for the Next Balloon Flight 1

- A. The Texas Instruments IRIS Instrument 1
- B. The Filter-Wedge Spectrometer 2
- C. The MRIR Radiometer 2
- D. Other Balloon Gondola Installations 2
- E. Mobile Telemetry Ground Station Installations 4
- F. Gondola Testing 4
- G. Data Monitoring During the Balloon Flight (by P. A. Titus) 5

IV. Laboratory Measurements of $CO_2$ Transmission 6

V. Theoretical Study of Earth's Albedo 6

VI. Report Writing 9

VII. Future Work 9

# List of Illustrations

Page

1. Filter-wedge test configuration, auxiliary apparatus 10
2. Filter-wedge test configuration, instrument in test chamber. 11
3. MRIR 0.2-4.0μ channel calibration data 12
4. Coordinate systems used for albedo calculations 13
5. Coordinate systems, $\delta_s > 0$, $\delta_E > 0$, $\delta_s > \delta_E$ 14
6. Coordinate systems, $\delta_s > 0$, $\delta_E > 0$, $\delta_s < \delta_E$ 15
7. Coordinate systems, $\delta_s > 0$, $\delta_E < 0$ 16
8. Coordinate systems, $\delta_s < 0$, $\delta_E > 0$, 17
9. Coordinate systems, $\delta_s < 0$, $\delta_E < 0$, $\delta_s < \delta_E$ 18
10. Coordinate systems, $\delta_s < 0$, $\delta_E < 0$, $\delta_s > \delta_E$ 19

# Abstract

This report is a summary of project activities during the period 1 October to 31 December 1967. Progress in laboratory testing and development of the U.M. IRIS interferometer, preparations for the next balloon flight, laboratory measurements of $CO_2$ transmission, and the theoretical study of earth's albedo are described.

## I. Introduction

This is the 20th quarterly progress report on contract no. NASr-54(03) covering the period 1 October 1967 to 31 December, 1967. The project effort during this time was divided among the following tasks:

1. Laboratory testing and development of the U. M. IRIS interferometer.
2. Preparations for the next balloon flight.
3. Laboratory measurements of $CO_2$ transmission.
4. Theoretical Study of Earth's Albedo.
5. Report Writing.

## II. Laboratory Testing and Development of the IRIS Interferometer

The new mirror drive unit and the new mirror drive amplifier were installed in the interferometer.

The work on the Mylar beam splitter has been discontinued because of the combination of difficulties encountered:

a) The problem of obtaining Mylar of uniform thickness.

b) The problem of acoustical vibrations of the Mylar. The most serious result of these vibrations is the modulation of the reference interferogram used to control the sampling of the infrared interferogram

The Cooley-Tukey Fast Fourier Transform was modified for use on the 360 computer. This program will not be completely checked out until the 360 plotting routine is working properly.

Work has been started on the programming of the calculation for one sided interferograms.

## III. Preparations for the Next Balloon Flight

### A. The Texas Instruments IRIS Instrument

All of the plans and the design for the installation of the T. I. IRIS on the balloon gondola have been completed. In October, a visit was made to the Texas Instruments Co. to discuss the interface of U. of M. and T. I. equipment during the proposed acceptance tests which will take place at the T. I. Co. when the instrument is ready for delivery.

The T. I. IRIS enclosure has been mounted on the balloon gondola and the necessary access holes were cut in the gondola base plate.

A temperature control unit for the T. I. IRIS warm black body has been designed and constructed.

The drive mechanism for the T. I. IRIS blackbody was improved by the addition of a more powerful inverter.

### B. The Filter-Wedge Spectrometer

Two sets of calibrations of the filter wedge spectrometer were made, as a part of the procedure of becoming familiar with the instrument. The calibration was carried out with both the instrument and its electronics located in the environmental test chamber.

The test configuration is shown in figures 1 and 2. In figure 1 the environmental test chamber is shown in the right background. The blackbody temperature control unit is in the front center of the photograph. In figure 2, the Filter Wedge spectrometer and electronics package are shown in the test chamber. The gondola master programmer and telemetry chassis are shown on the right hand side of the photo.

A typical set of calibration data is shown in table 1. This data does not represent a final calibration for the instrument, since it has been returned to to Goddard for further calibrations and changes.

### C. The MRIR Radiometer

The calibration of the solar channel (0.2-4.0$\mu$) was checked. The results are shown in figure 3. The new data (Nov. 1967) show good agreement with data taken in January and June of 1965 and January 1966.

### D. Other Balloon Gondola Installations

The topic of complete dependence of all gondola timing on the crystal oscillator located in the IRIS control unit was reviewed. It was decided that a better approach might be to have a multivibrator in the master control unit which would normally be synchronized by pulses from the oscillator. In the event of a failure of the crystal oscillator in the IRIS control unit, the multivibrator would continue and the remainder of the gondola equipment would continue to operate, although with reduced timing accuracy.

### Table 1

### Filter Wedge Spectrometer Calibration Data

### $\lambda$ = 8.5 micrometers

| Reference Blackbody Temperature | Calibration Blackbody Temperature | Radiance Difference | Output Voltage |
|---|---|---|---|
| $T_R$ | $T$ | $N_\lambda - N_{\lambda R}$ | |
| °K | °K | $\mathrm{Watts \cdot cm^{-2} \cdot ster.^{-1} \cdot \mu^{-1}}$ | volts |
| 298.7 | 313.2 | 28.1 | -1.0 |
| 299.3 | 308.1 | 16.6 | -0.20 |
| 299.1 | 302.6 | 6.31 | 0.22 |
| 298.9 | 294.2 | -8.11 | 0.68 |
| 298.4 | 283.2 | -24.4 | 1.23 |
| 298.2 | 272.9 | -37.9 | 1.60 |
| 297.3 | 262.3 | -48.5 | 1.90 |
| 296.0 | 253.0 | -55.2 | 2.20 |
| 294.2 | 243.9 | -59.7 | 2.25 |
| 291.7 | 234.2 | -61.9 | 2.48 |

The multivibrator unit was constructed but has not yet been tested.

### E. Mobile Telemetry Ground Station Installations

The multiplexer position indicator was built. This device displays the step number of the gondola time division multiplexer on numerical indicators in the mobile telemetry station. The one second pulses sent from the gondola to operate the computer interrupt line are used to drive a counter utilizing Texas Instruments medium scale integrated circuit logic to drive the gas tubes. Reset facilities are provided to permit regaining sync should the telemetry signal be interrupted.

The bus time code distribution system was tested and installed in the bus. This system is a power amplifier which increases the voltage level of the pulses from the Astrodata time code generator to the level required to operate the marker pens on the Brush strip chart recorders. The input sensitivity can be adjusted for the lower signal level available when the time code is tape recorded and reproduced. A demodulator is included to demodulate carrier type time code outputs. AMR-B1 and IRIG-D codes are continuously recorded on the strip charts and are also placed on all magnetic tapes.

### F. Gondola Testing

The pressure gauges used for pressure altitude data on the balloon flight were calibrated against the MKS Baratron pressure gauge. Gauge GG11317 was accurate over its entire range to within ±0.1 mm Hg, gauge JJ 13552 had an offset of -1mm Hg over its entire range.

The IRIS control system was tested for compatibility with other gondola devices. Loss of synchronization occurred when some of the electromagnetic and electrically driven mechanical devices on the gondola functioned. The investigation of this failure was not completed at the end of this quarter, but it appears that proper suppression of the interference at the source is necessary. Additional shielding will also be installed. Filters on the logic lines entering and leaving the box are impractical as they could not discriminate between undersired transients and the .1ηsec rise time pulses required to operate the flip flop toggle inputs.

Much of the interference arises in the miscellaneous control chassis, which translates the circuit closures provided by the Master programmer into signals of the required power and duration to operate the nozzles, booms, and doors. This unit is going to be redesigned to remove the mirror circuit (which uses low level integrated circuit logic) from the proximity to the relay logic and power switching circuits and also to install separate control functions for the MRIR door, the IRIS door, and the filter wedge door, currently operated simultaneously. The redesign will include an upgrading of noise suppression devices. Almost none of the interference derives from signals that are needed in one part of the system, but are noise in another part. The noise is nearly all from switching transients that can be suppressed at the source without interfering with any proper function.

Erratic stepping of the MRIR solar calibration relay is expected to be corrected by relocation in a separate box and by better filtering. The worst offender in this case was the nozzle control, presently in the same shield box as the mirror logic. The TI logic switches on voltage level alone and not on rise time, permitting suppression of short transients on the input logic line without inhibiting the desired functions.

A full scale gondola check was tried. This test revealed several problems; incorrect wiring of one gondola thermister, absence of the MRIR door position indicator, no signal on IRIG channel 10, interchanged gondola thermister groups, failure of the MRIR door open switch, no interrupt pulses for the computer and double exposure of Maurer camera #1. The above malfunctions are being corrected.

### G. Data Monitoring During the Balloon Flight (by P. A. Titus)

The following subroutines were written for inflight processing of housekeeping data:

BLT, -T, +T, TMP

Process sampled thermistor data and print corresponding temperatures (±XX.XXX).

VTG

A program to handle the case in which the sampled thermistor voltage lies outside of the calibration range. In this case the voltage will be printed as (V±X.XXX).

GrTh

A program to process each event in both thermistor groups in proper manner and sequence

BAL

A single program to handle the processing of FAT (free air temperature thermistors) 2L and 2R, plus printout of all 15 monitors.

VOL

Whenever a voltage is sampled and interpolated and needs no further processing it is processed for printout.

VCF

If a voltage in VOL needs to be multiplied by a conversion factor, this is done, and it is processed for printout.

## IV Laboratory Measurements of $CO_2$ Transmission

During this period work has been directed toward the following:

a) Further definition of the degree of uncertainty in sample composition that will result from outgassing from the cell walls for cell walls of various materials.

b) calibration of the MKS Baratron pressure gage.

c) end to end system checkout.

It was found that for the worst of the cell wall materials investigated (anodized aluminum) the uncertainty in sample composition would be less than one percent if the $CO_2$ partial pressure is greater than ten torr. Ten torr is approximately equal to the minimum $CO_2$ partial pressure that will be run.

The MKS Baratron was calibrated over the range from 1 torr to 760 torr and was found to be highly accurate and repeatable.

End to end checkout of the measurement and recording system was begun. This is proceeding quite smoothly.

During the next period the system checkout and data reduction programs will be completed and data acquisition for $CO_2$-$N_2$ mixtures will begin.

## V Theoretical Study of Earth's Albedo

The second part of the theoretical study of earth's albedo was started during this work period (actually slightly before the end of the last work period). Suitable models of the earth, including detailed bi-directional reflectance functions will be specified for at least one day in each month of the year. The earth's albedo in several wavelength ranges will be calculated using the precise definition of albedo. These results will be compared with albedo values which would be obtained using a Danjon type of experiment with the Bond definition of albedo.

A geometrical problem was studied. This problem arises because the precise earth albedo calculations are carried out using one co-ordinate system, whereas Bond albedo calculations of necessity use another co-ordinate system. The two co-ordinate systems are shown in figure 4.

For the precise earth's albedo, the co-ordinates of a point Q on the earth sphere are given by ($\zeta', \eta'$), where $\zeta'$ is longitude (measured at the equator and $\eta'$ is colatitude, measured from the northpole N to the point Q. The position of the sun relative to Q is specified by its hour angle $h_s$ and its declination $\delta_s$.

The coordinate system used for the Bond Planetary Albedo has the equatorial circle defined by 0 (the center of the earth), S (the sub-solar point) and E (the sub-observer point). P is the pole of this co-ordinate system taken at the earth's surface on the normal 0P to the equatorial plane 0ES. The co-ordinates of the point Q are the longitude $\zeta$ and the co-latitude $\eta$. $\alpha$ is the phase angle.

The sub-observer point E is given by its hour angle $h_E$ and its declination $S_E$ with respect to the equator.

Equations relating the two sets of co-ordinates ($\zeta, \eta$) and ($\zeta', \eta'$) of a point Q in the sunlit portion of the earth are:

$$\cos\Theta = \sin\eta \cos(\zeta - \alpha) = \sin\delta_s \cos\eta' + \cos\delta_s \sin\eta' \cos h_s \qquad (1)$$

$$\cos\Theta = \sin\eta \cos\zeta = \sin\delta_E \cos\eta' + \cos\delta_E \sin\eta' \cos h_E \qquad (2)$$

$$h_s = \zeta'_s - \zeta' \qquad (3)$$

$$h_E = \zeta'_E - \zeta' \qquad (4)$$

$$\cos\alpha = \sin\delta_E \sin\delta_s + \cos\delta_E \cos\delta_s \cos(\zeta'_E - \zeta'_s) \qquad (5)$$

Transformation from a given set of co-ordinates ($\zeta', \eta'$) to the corresponding values ($\zeta, \eta$) is quite straightforward. Given the co-ordinates of E and of S, ($S_E, h_E$) and ($S_s, h_s$), respectively, we can calculate $\alpha$. Then, dividing the first two relations above, we find:

$$\frac{\cos\Theta o}{\cos\Theta} = \frac{\cos(\zeta-\alpha)}{\cos\zeta}$$

$$= \frac{\cos\zeta\cos\alpha + \sin\zeta\sin\alpha}{\cos\alpha}$$

$$= \cos\alpha + \tan\zeta\sin\alpha. \qquad (6)$$

thus $$\tan\zeta = \frac{-\cos\alpha + \dfrac{\cos\Theta o}{\cos\Theta}}{\sin} \qquad (7)$$

and $$\sin\eta = \frac{\cos\Theta}{\cos\zeta} \qquad (8)$$

The quantities $\cos\Theta_0$ and $\cos\Theta$ corresponding to each set of $(\zeta',\eta')$ are calculated. Then $(\zeta,\eta)$ are calculated as shown above.

The transformation in the reverse direction is not quite as straightforward; additional equations describing the position of P relative to N are needed in order to solve for the $(\zeta',\eta')$ corresponding to a given set of $(\zeta,\eta)$.

If the point Q lies in the northern hemisphere light slightly different geometrical configurations can occur:

| | |
|---|---|
| a) $\delta_s=0$, $\delta_E>0$ | (special case of e and g below) |
| b) $\delta_s=0$, $\delta_E<0$ | (special case of f and h below) |
| c) $\delta_s>0$, $\delta_E=0$ | (special case of e and f below |
| d) $\delta_s<0$, $\delta_E=0$ | (special case of g and h below) |
| e) $\delta_s>0$, $\delta_E>0$, $\delta_s>\delta_E$ | (see figure 5) |
| f) $\delta_s>0$, $\delta_E>0$, $\delta_s<\delta_E$ | (see figure 6) |
| g) $\delta_s>0$, $\delta_E<0$ | (see figure 7) |
| h) $\delta_s<0$, $\delta_E>0$ | (see figure 8) |
| i) $\delta_s<0$, $\delta_E<0$, $\delta_s<\delta_E$ | (see figure 9) |
| j) $\delta_s<0$, $\delta_E<0$, $\delta_s>\delta_E$ | (see figure 10) |

Different sets of equations have been derived for the $(\zeta,\eta)\rightarrow(\zeta',\eta')$ transformation for each of the cases. This large number of individual sets of equations is very cumbersome and seems to be more elaborate than needed to solve this problem. Computer implementation would be complicated indeed. The problem will be re-examined.

## VI Report Writing

The quarterly report 05863-19-P covering the period 1 July, 1967 - 30 September 1968 was written but not distributed.

L. W. Chaney presented a lecture on "Interferometric Spectroscopy" at the short course in Modern Optics for College Teachers, held in Detroit on 9, 10 October in conjunction with the meeting of the Optical Society of America. The course was sponsored by the Optical Society and the National Science Foundation.

S. R. Drayson presented a paper at the Specialist Conference on Molecular Radiation and its application to Diagnostic Techniques held at Marshall Space Flight Center on 5-6 October. His paper was entitled "Methods of Calculating Atmospheric Transmission Functions."

## VII Future Work

During the next quarter, work will continue on laboratory testing of the IRIS interferometer, preparations for the next balloon flight, laboratory measurements of $CO_2$ transmission and the theoretical study of earth's albedo.

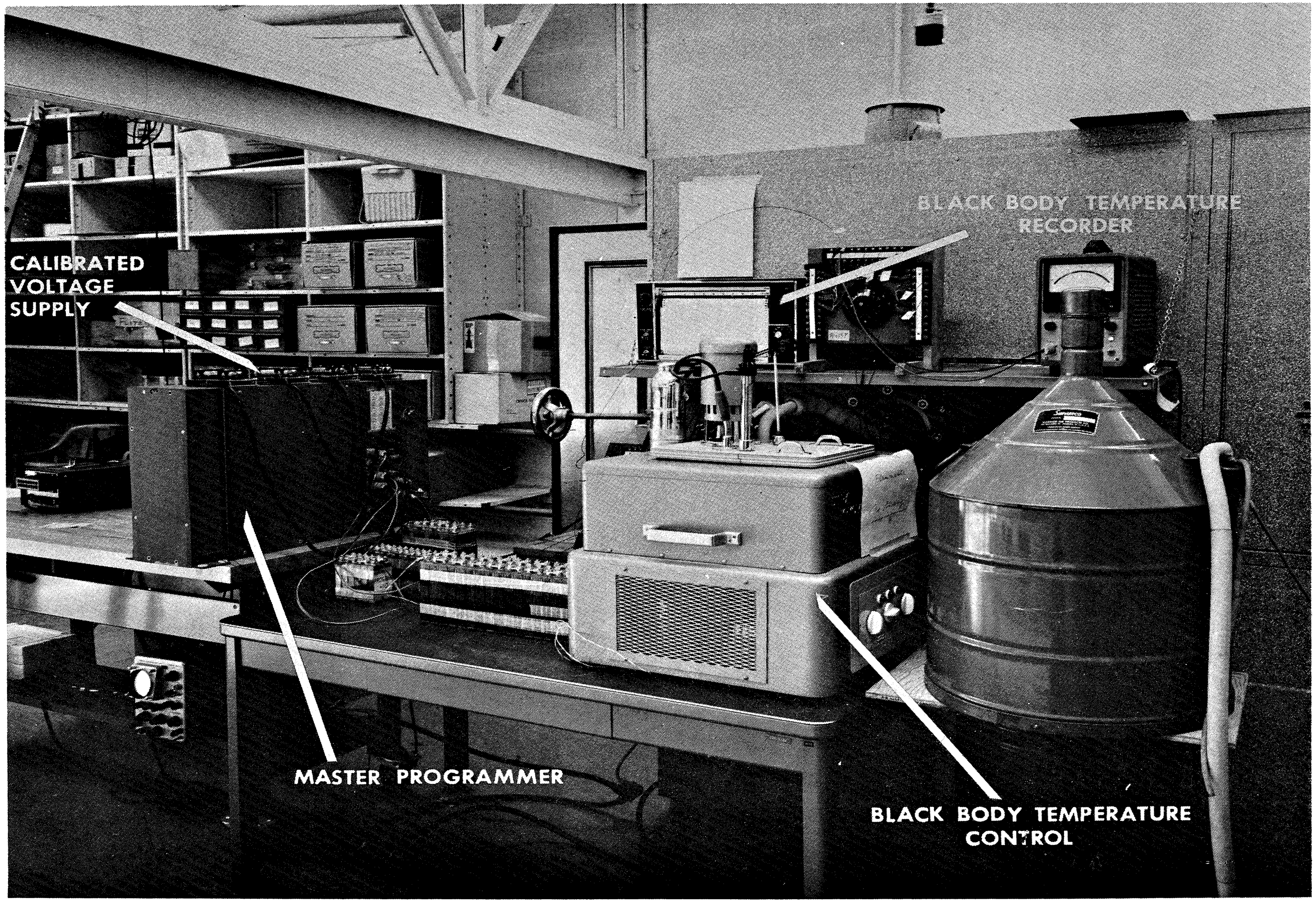

Fig. 1 Filter-Wedge test configuration, auxiliary apparatus

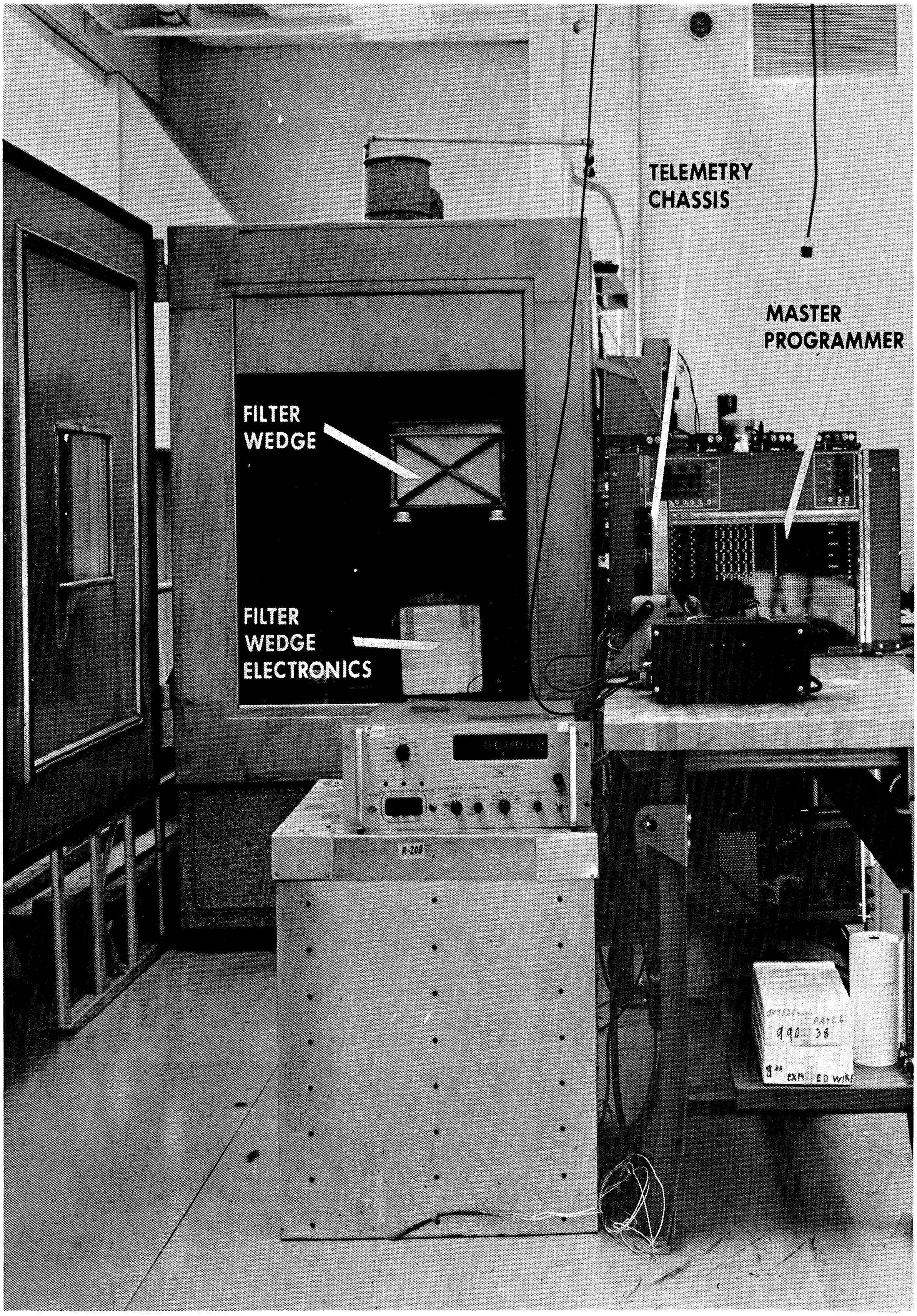

Fig. 2 Filter-Wedge test configuration, instrument in test chamber

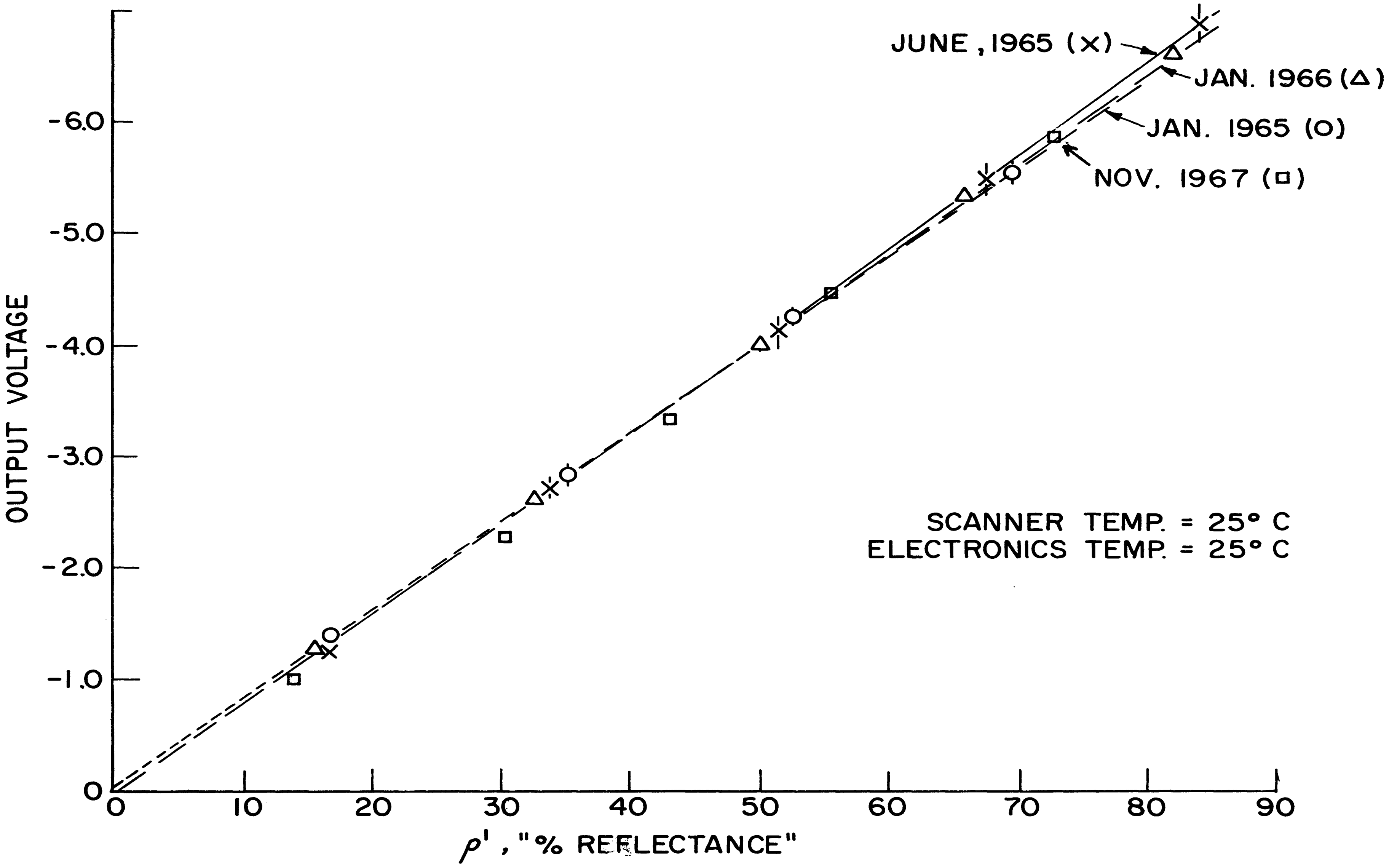

Fig. 3 MRIR 0.2-4.0$\mu$ channel calibration data

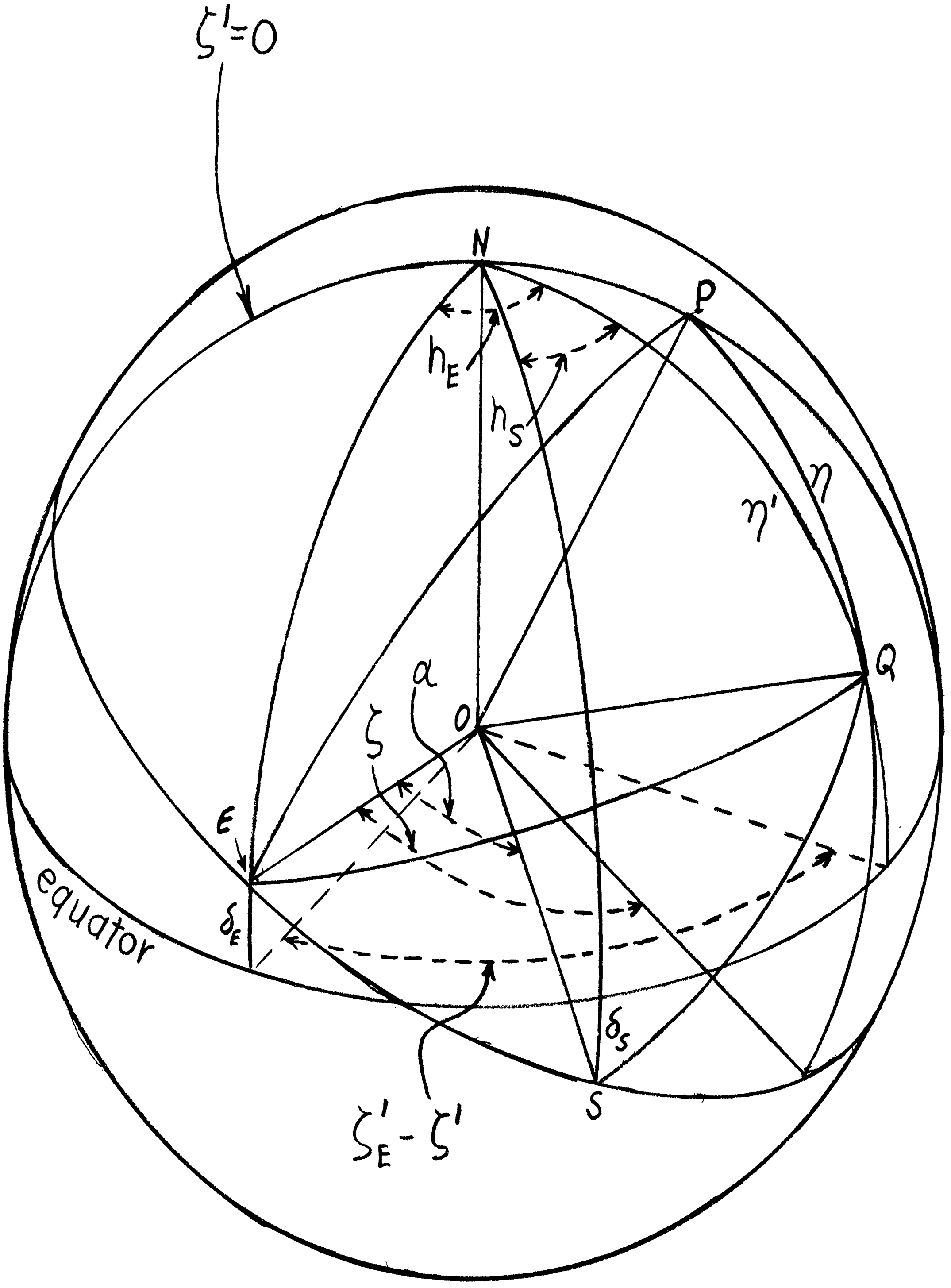

Fig. 4 Co-ordinate systems used for albedo calculations

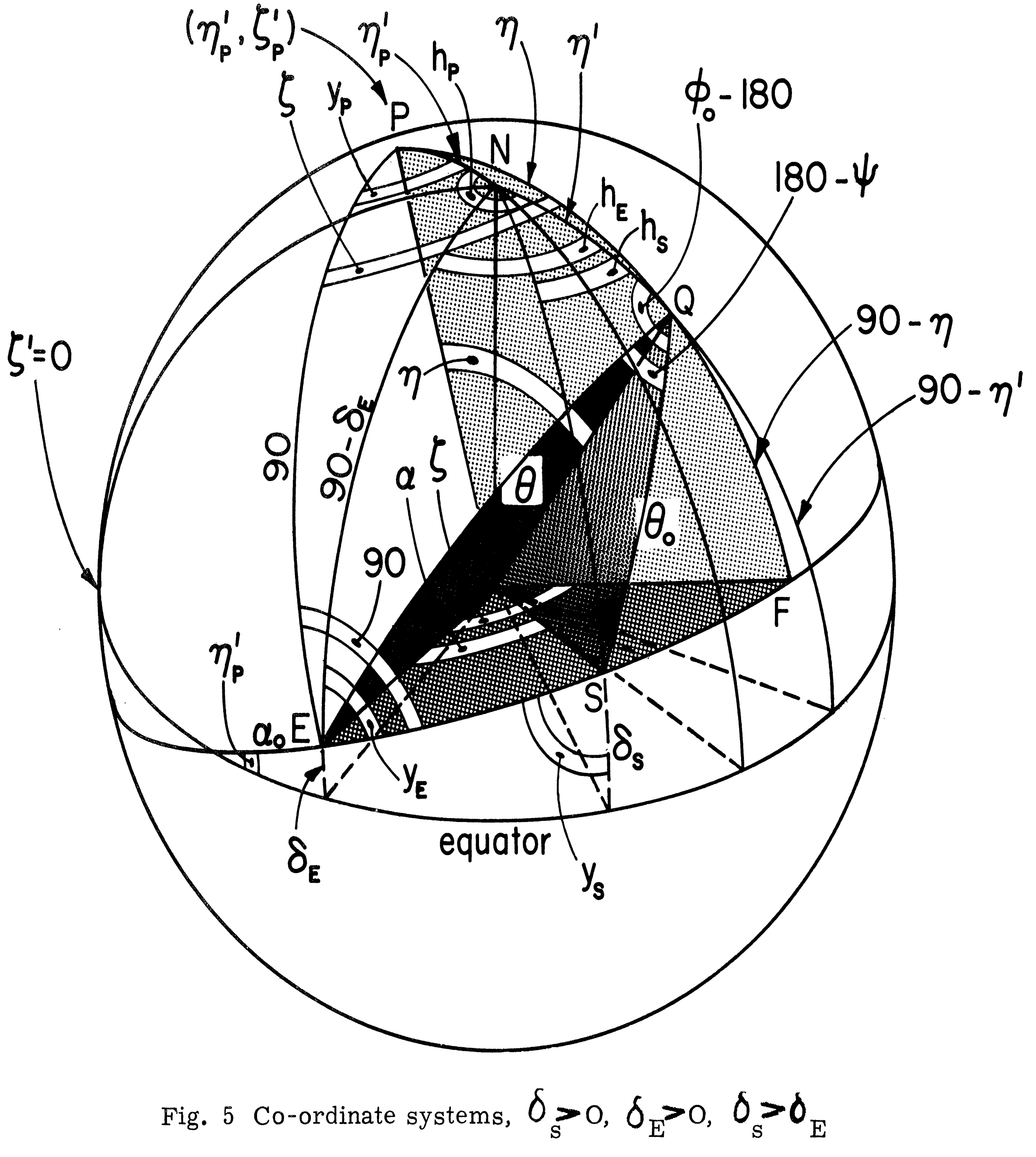

Fig. 5 Co-ordinate systems, $\delta_s > 0$, $\delta_E > 0$, $\delta_s > \delta_E$

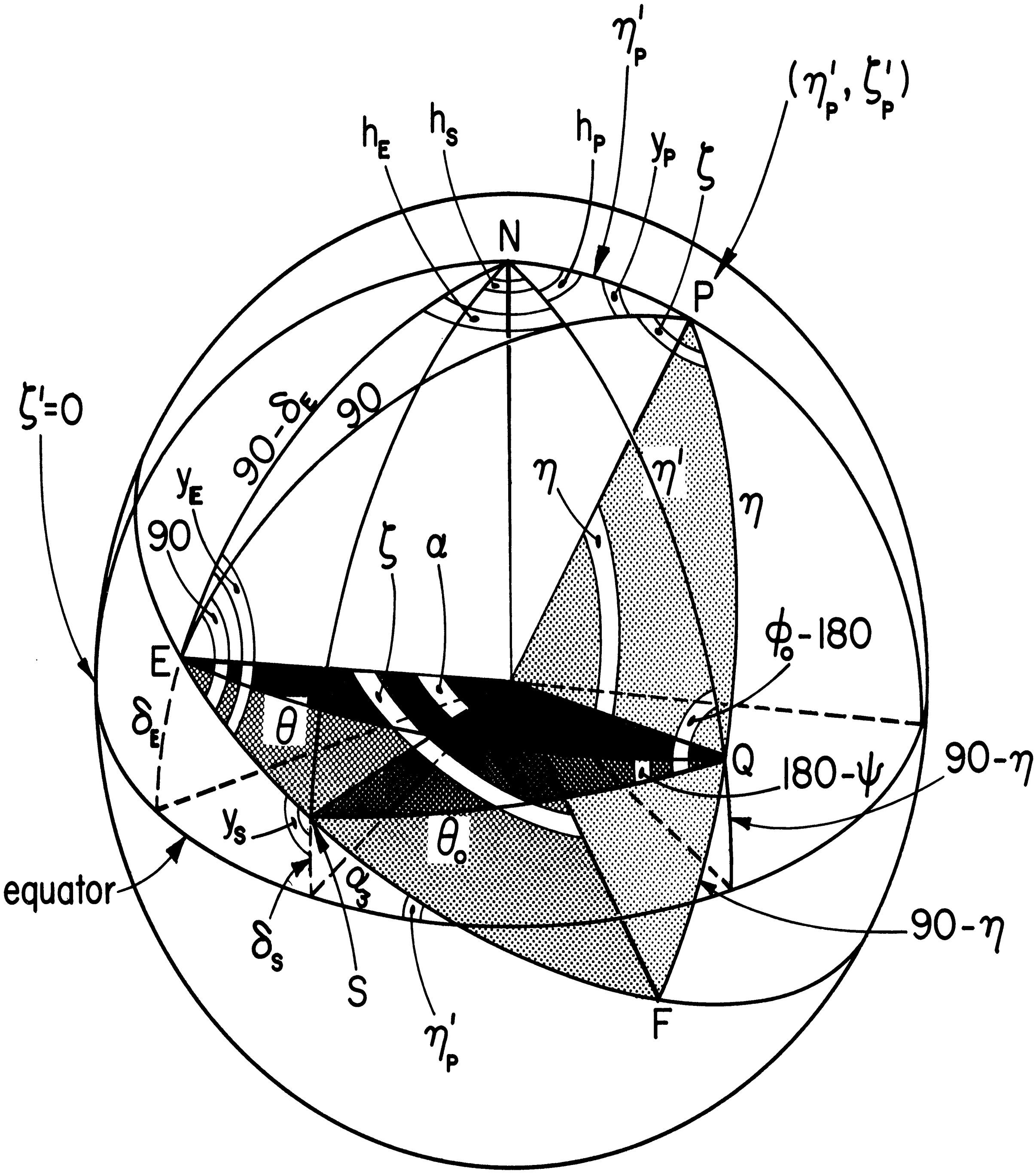

Fig. 6 Co-ordinate systems, $\delta_s > 0$, $\delta_E > 0$, $\delta_s < \delta_E$

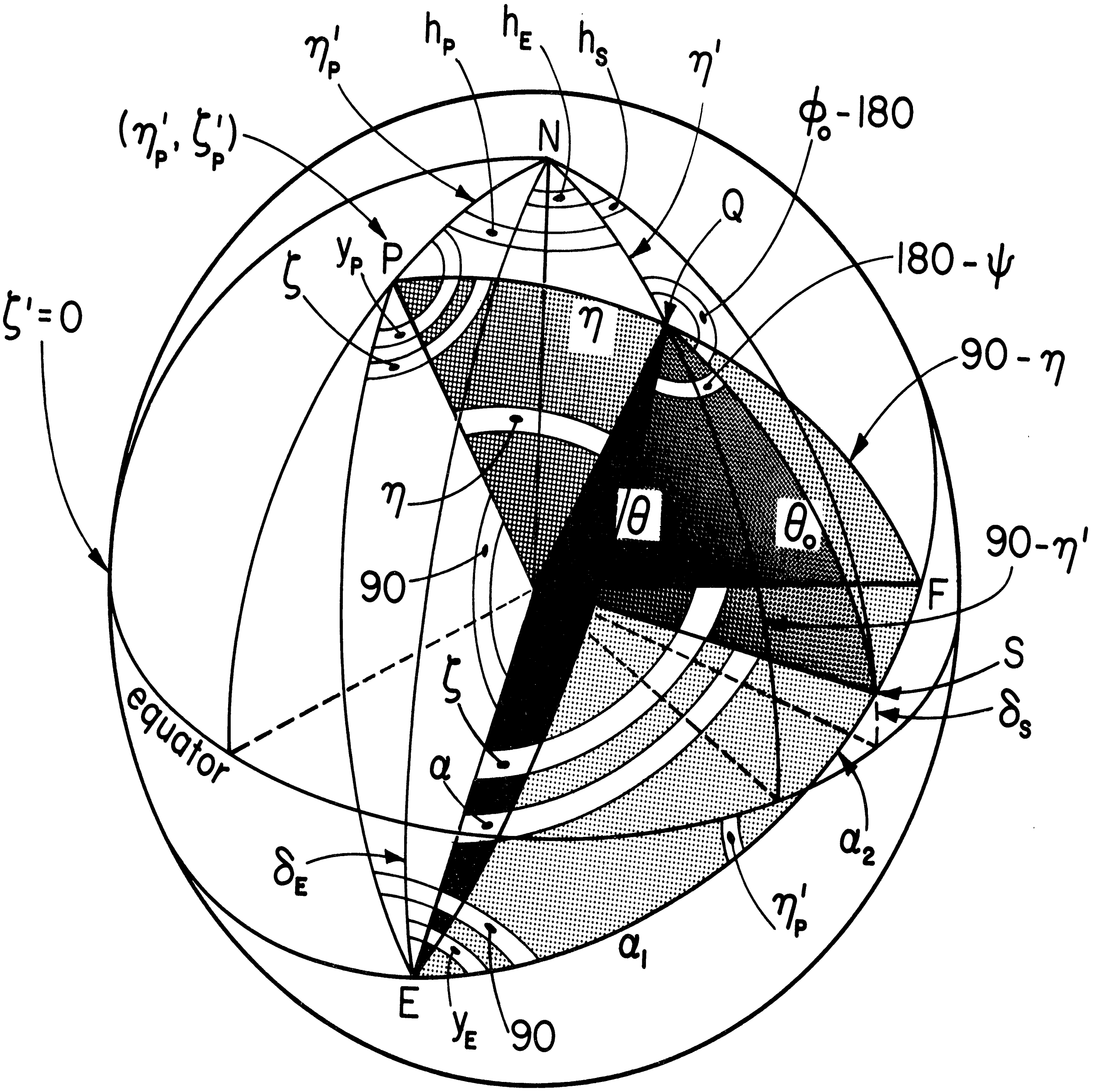

Fig. 7 Co-ordinate systems, $\delta_S > 0$, $\delta_E < 0$

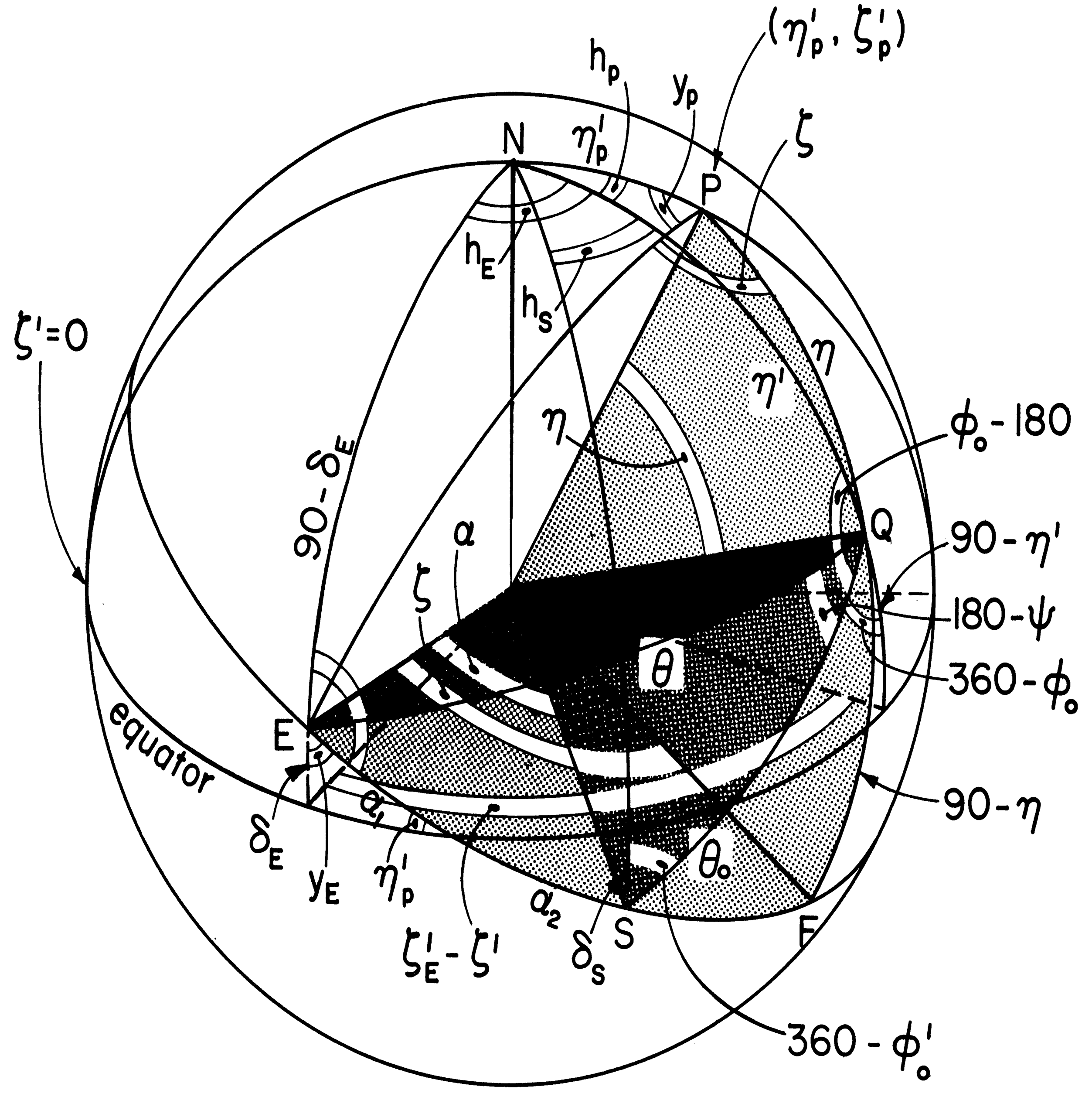

Fig. 8 Co-ordinate systems, $\delta_S < 0$, $\delta_E > 0$

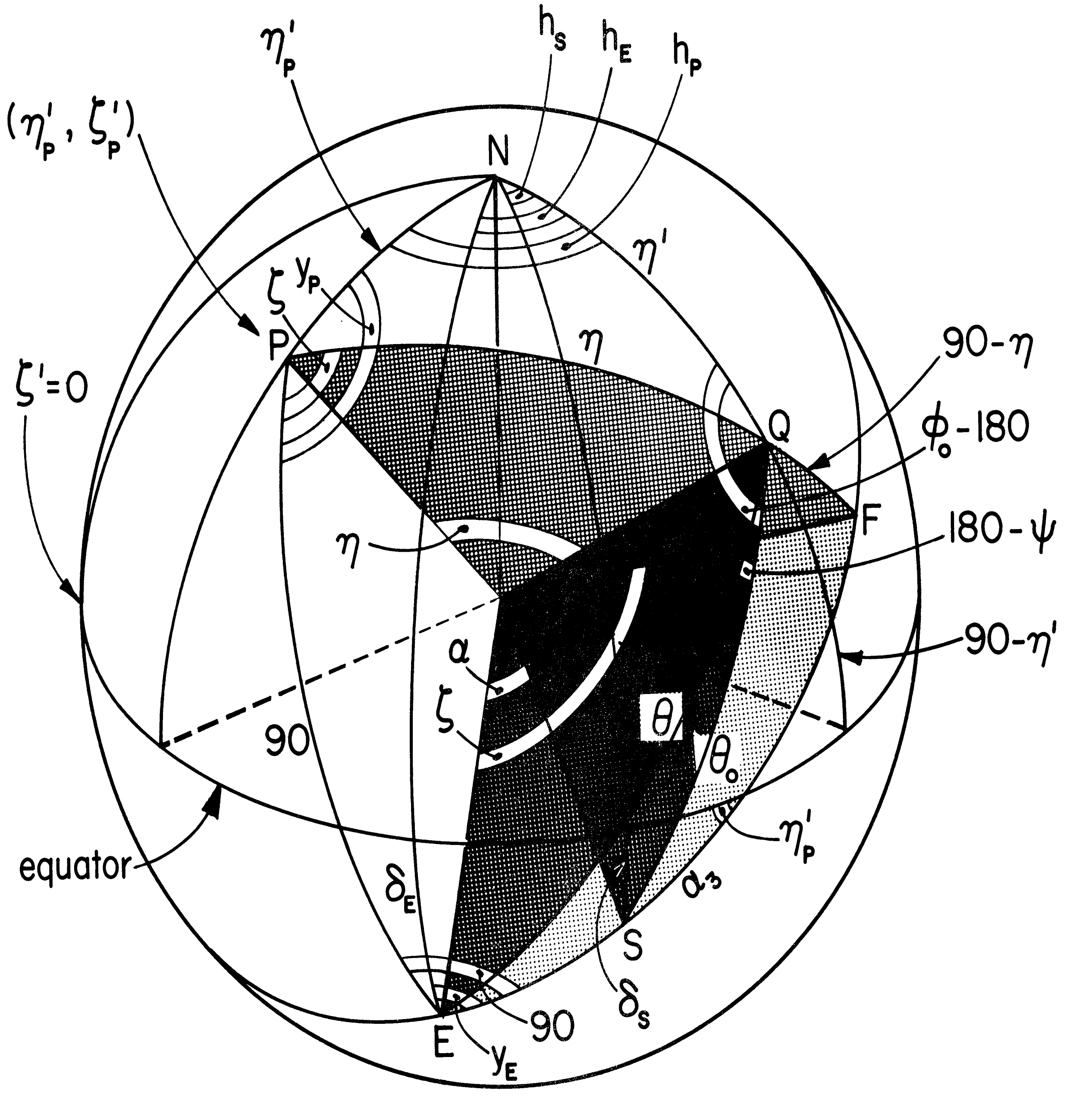

Fig. 9 Co-ordinate systems, $\delta_S < 0$, $\delta_E < 0$, $\delta_S < \delta_E$

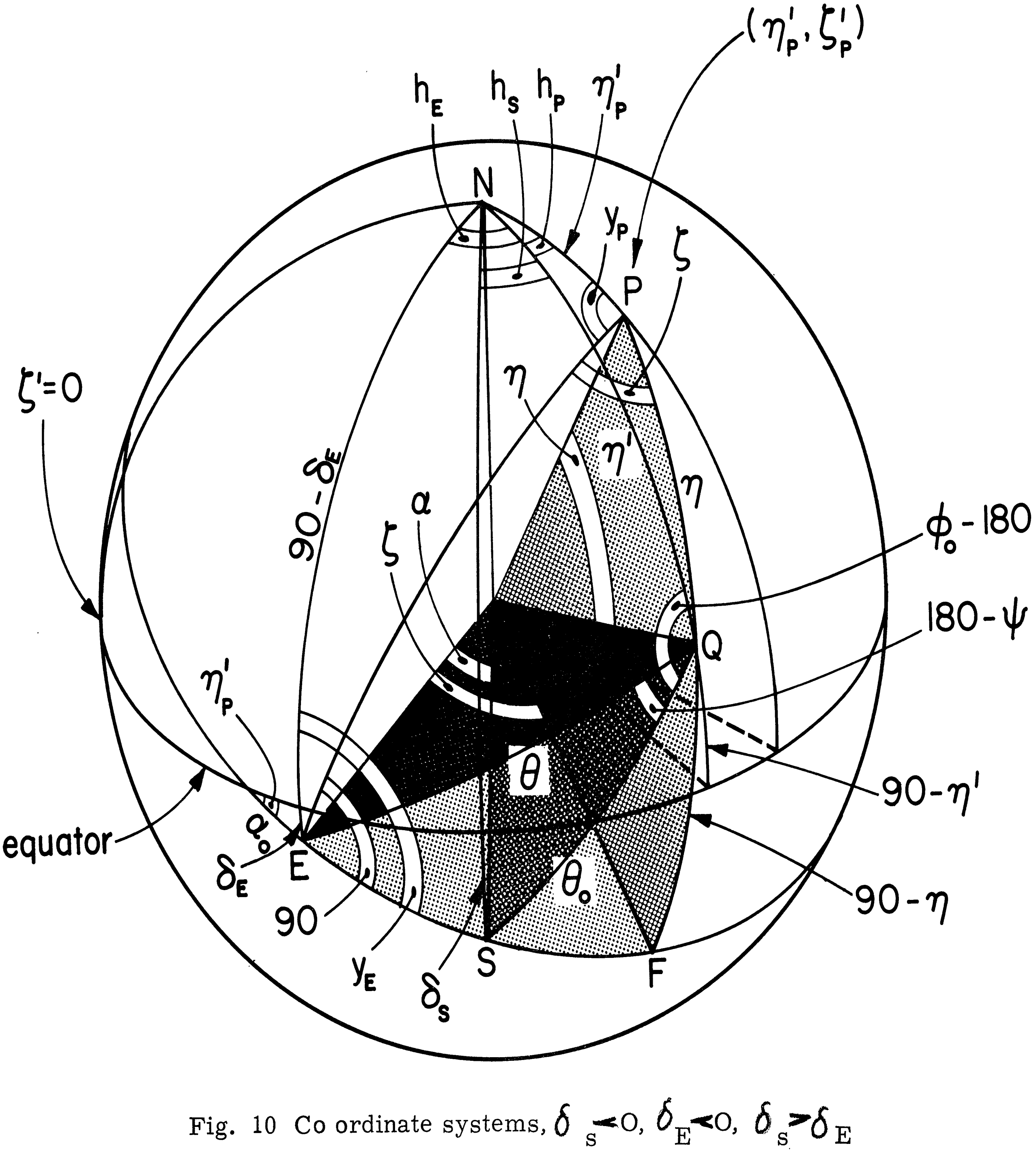

Fig. 10 Co ordinate systems, $\delta_s < 0$, $\delta_E < 0$, $\delta_s > \delta_E$