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Error analysis of position fixing by satellite

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ERROR ANALYSIS OF POSITION FIXING BY SATELLITE

by

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The contents of this Paper reflect my own personnal views and are not necessarily endorsed by the UNIVERSITY.

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FOREWORD

Currently, Transit Satellite Navigation Receivers have outspoken advantages so that more and more satellite navigation receivers have been installed on board ships of maritime nations.

Because of the fact that Satellite Navigation is characterized by utility for all kinds of weather, worldwide coverage, easy operation, time-saving and demonstration of ships' longitudinal and latitudinal positions, it is widely welcomed by ships' masters and officers.

On top of these, it is considered to be one of the most reliable and accurate systems ever used, particularly in bad weather.

Satellite Navigation has ranked itself first among all current Navigation Aids including Loran, Decca and Omega systems as far as accuracy is concerned.

Therefore, captains and officers rely on this system to such an extent that they even take no notice of the discrepancies that might exist, satisfying themselves by merely operating it.

The reality is that some discrepancies do occur, sometimes serious ones under particular circumstances.

For example, the author once compared the accuracy of satellite-identified ship's position at sea near the coast of England with that of the ship's position actually observed from visual bearings, and found that the lalitudinal discrepancy was as much as 1.88 nautical miles. (n.m.)

Similar to the above-mentioned case, a maximum longtitudinal discrepancy found in the Japanese Sea was 2.33 n.m.

Another example demonstrates as well the maximum discrepancy of position was 1.529 n.m. east-west and 1.487 n.m. north-south, found from a stationary position in Malmö.

Interestingly enough, it has been observed that the accuracy of a ship's position varies with the direction in which the ship is sailing (position error in this case being perpendicular to the tracks followed by the ship), with the LMT time of observation (day and night) and with the receivers of various kinds (see annex A, table 1).

So it is quite necessary for the masters and officers to be aware of the variations in accuracy of Satellite Navigation and to guard against the practice of blind dependence in order to avoid accidents.

During a two-year period of study in the Maritime Education and Training Course at the World Maritime University, I have been engaged in a study of error analysis of observation by satellite in a stationary position. By using a computer to work out observations under different circumstances based on numerous results of observations gathered from six observation stations located in five countries and regions. Explanations with diagrams attached are given here for the purpose of analysing the causes of errors.

I would like to avail myself of this opportunity to express my sincere gratitude to course Prof. Zade and my supervisors Prof. Mulders and Prof. Jurdzinski for their kindness and the long time they spent directing work on this project.

I am also grateful to Captain Wagner for his great contribution to computer data processing, to Mr. J.E.Roeber and Mr.Thomas P.Nolan for their tremendous assistance in collecting observation information in New York and MITAGS, to Captain S.J.Singh for providing me with observation materials in Hong Kong, to Mr. G.L. Hasking at International Hydrographic Bureau for giving information regarding adjustment of the above-mentioned geographical positions,to my colleagues Prof. Yuan An Chun and Mr. Liang Li Gang for helping me collect information from Dalian Marine College, and to Prof. Chen Zhu Wei (President of Dalian Marine College) for his warm concerns and to all those concerned.

Malmö Nov. 1985

Chapter 1

Method of observation and collecting data in stationary position by the transit receiver

1.1. Malmö (Sweden)

1.1.1. Location of observation:
Electronic Laboratory of the World Maritime University

1.1.2. Type of receiver:
MAGNAVOX-1142 and RAYSAT-100

1.1.3. Height of antenna:
28 meters above mean sea level

1.1.4. Period of observation:
two receivers continually worked 27 days about 630 hours, from Oct.12,1984 to Nov. 7,1984

1.1.5. Number of observations
MAGNAVOX-1142:734, RAYSAT-100:735

1.1.6. Number of satellites:
30110,30130,30190,30200,30480

1.1.7. Original coordinate of input:
Latitude:55°36'.3 N. Longitude:12°58'.8E
(Local datum ED)

1.1.8. Connection between satellite receiver and computer
Because these two receivers have no printer, it is difficult to collect data. With Capt. Wagner's help, using a network (See Fig.1 and 2) to connect the receivers with a computer. Therefore, all data was written on a disk, by which it can easily be displayed on a screen. It's even more convenient for carrying, reading and storing than general print paper.

The greatest advantage is that the computer

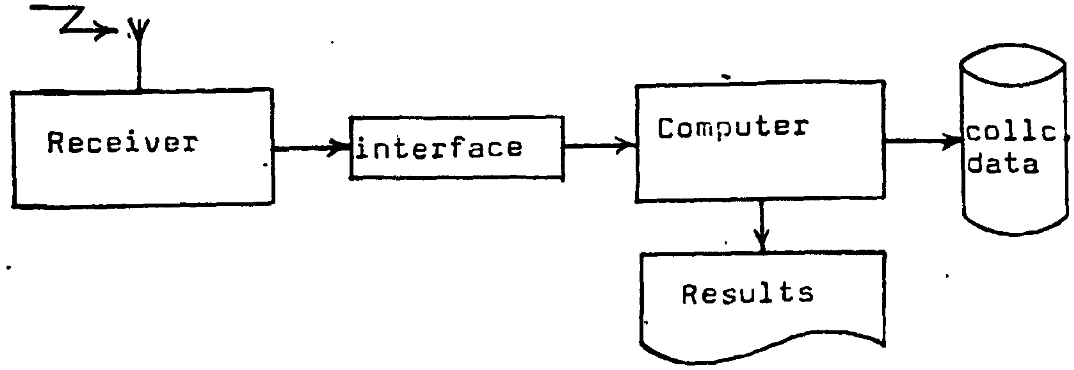


Fig. 1 Connection between Satellite Receiver and Computer

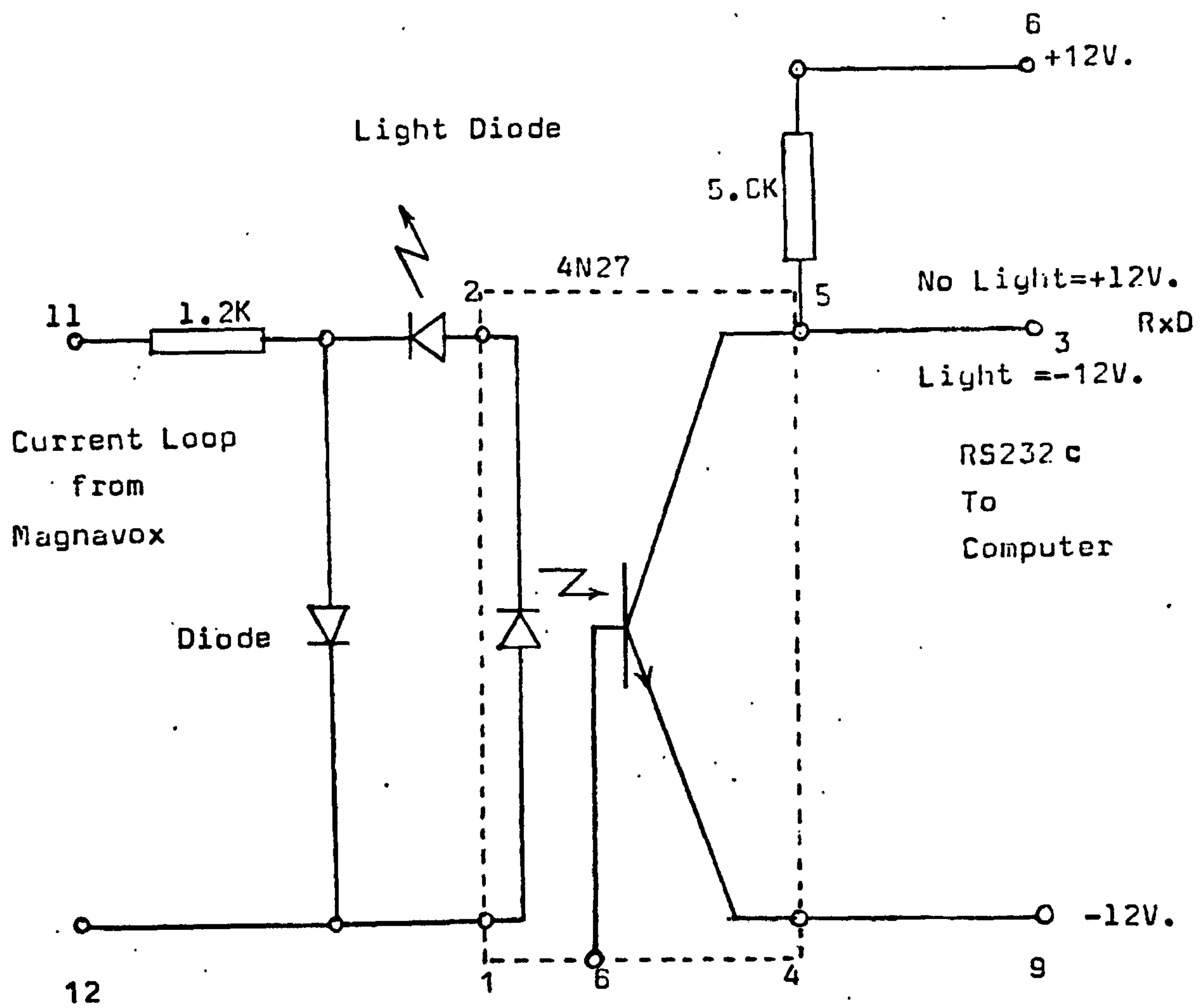


Fig.2 Interface Between Satellite Receiver and Computer

can quickly calculate results of errors of all observations (See table 1),using a special program (See annex B8 PR5A).

Furthermore, if needed, one can print out all data of observations and results of errors, etc, 95% confidence margin of latitude (M95-Lat.),95% confidence margin of longitude (M95-Long.),95% confidence radius of position (R95=accuracy) and mean position.

Moreover, according to the need, using program PR5A one can print out all data of observations and results of errors of different limits of elevations, different times of observations and different numbers of satellites respectively (See table 2,3,4,5 and 6).

1.2. Dalian (China)

1.2.1. Location of observation:
Electronic Laboratory of the Dalian Marine College

1.2.2. Type of receiver:
JLE-3400

1.2.3. Height of antenna:
47.5 meters above mean sea level

1.2.4. Period of observation:
July 4-July 7,1983

1.2.5. Number of observations:
98

1.2.6. Number of satellites:
30130,30140,30190,30200,30480

1.2.7. Position of antenna:
Lat.38°51'.98N,Long.121°31'.17E (WGS-72)

1.3. MITAGS (United States)

1.3.1. Location of observation:
Electroni Classroom of the Maritime Institute of Technology and Graduate Studies in Linthicum, Maryland

1.3.2. Type of receiver:
MAGNAVOX-1104

1.3.3. Height of antenna:
25 meters above mean sea level

1.3.4. Period of observation:
Jan.1- Jan.7,1985

1.3.5. Number of observations:
100

1.3.6. Number of satellites:
30110,30130,30200,30480,30500

1.3.7. Position of antenna:
Lat.39°12'.80N,Long.76°40'.20W (Local datum)

1.4. King's Point (United States)

1.4.1. Location of observation:
Electronic Laboratory of United States Merchant Marine Academy in New York

1.4.2. Type of receiver:
NAVIDYNE-4000

1.4.3. Height of antenna:
42 meters above mean sea level

1.4.4. Period of observation:
Oct.11-Oct.28,1984

1.4.5. Number of observations:
114

1.4.6. Position of antenna:
Bearing 000°, distance about 50 meters from following position:
Clarke 1866 spheroid, NAD 1927
Lat.40°48'43".42N, Long.73°45'47".85W (Local datum)

1.5. Hongkong

1.5.1. Location of observation:
Department of Nautical Studies, Hongkong Polytechnic

1.5.2. Type of receiver:
MAGNAVOX-1102

1.5.3. Height of antenna:
27.4 meters above mean sea level

1.5.4. Period of observation:
Arp.25-Apr.29,1985

1.5.5. Number of observations:
17

1.5.6. Number of satellites:
30110,30130,30200,30450,30480,30500

1.5.7. Position of antenna:
About 3120.2 meters north and 3632.6 meters east from following position:
Lat.22°16′38.″98N,Long.114°08′34.″59E (Local datum)

1.6. Amsterdam (The Netherlands)

1.6.1. Location of observation:
Stationary vessel in Amsterdam

1.6.2. Type of receiver:
NAVSTAR 601-S

1.6.3. Period of observation:
June 17-June 24,1985

1.6.4. Number of observation:
11

1.6.5. Number of satellites:
30110,30480,30500

1.6.6. True position of stationary vessel:
Lat.52°27.′56N,Long.5°02.′48E (Local datum)

1.7. Gdynia (Poland)

1.7.1. Location of observation:
Merchant Marine Academy of Gdynia

1.7.2. Type of receiver:
MAGNAVOX-1102

1.7.3. Period of observation:
Mar.3-June 1,1981

1.7.4. Number of observation:
1650

1.7.5. Position of antenna:
Lat. 54°31'.16 N,Long.18°33'.61E (Local datum)

Chapter 2

Results of the analysis of the observations

Concerning the several thousands of observed data gathered from six observation stations located in five countries and regions, in this paper my discussion will be primarily concerned with the 1,500 data using MAGNAVOX-1142 and RAYSAT-100 Satellite receivers gathered from Malmö (See annex A1,A2).

Because of the large number of data as compared with other places, the results calculated with Malmö data give a minute description of the distribution of position errors and of position fix accuracy under different conditions.

For other observation stations also analysis have been made however from a limited number of observations. (See annex A3,A4,A5,A6,A7.)

2.1. Program used in calculations (See annex B2-B8)

2.1.1. Statememt of computer program:

In order to calculate and analyze a large number of observed data, several computer programs were worked out using different observation stations.

2.1.1.1. Program-PRO:(See annex B2)

This program reads the data from:

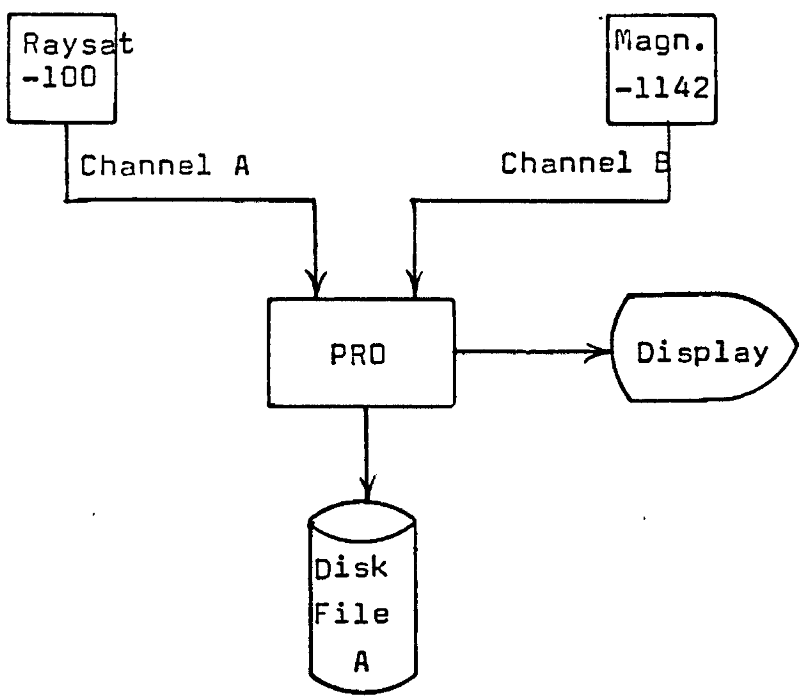
1) Satnav Raysat-100
2) Satnav Magnavox-1142

The program reads continuously from the two satnavs and checks the data of both receivers.

The program checks the length of the message and the condition that the messages are starting with correct characters. When the program finds correct data, then that line is stored in the memory until Raysat sends REC.(See program PRO)

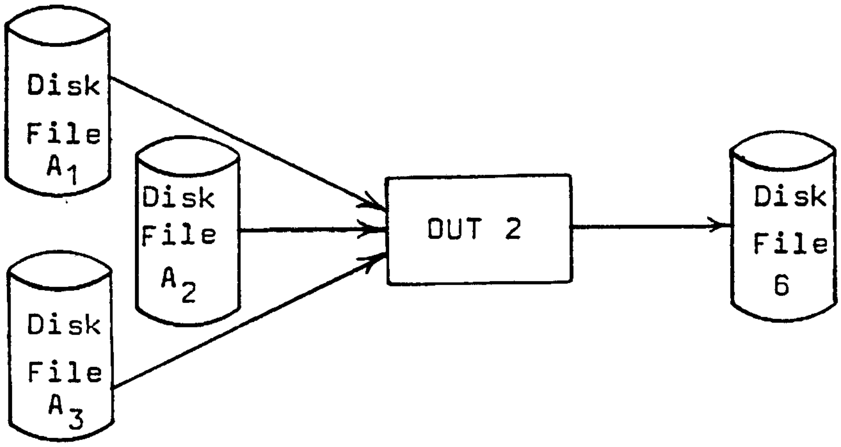
After we have saved the data from Raysat, the computer reads the data from Magnavox. First it checks the length of the data from Magnavox. Then all lines from Magnavox are stored.

When we get GMT, then check it if we had saved that GMT before. If it is the same GMT, then start from the begining again. If GMT is different from last time, then write on the disk and after that we start from begining again.



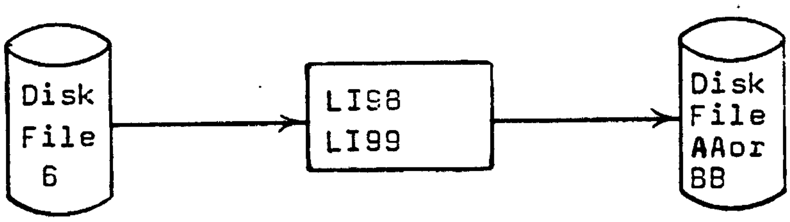
2.1.1.2. Program-OUT2: (See annex B3)

This program puts together Files A1,A2,A3 and so on to one file called File 6.



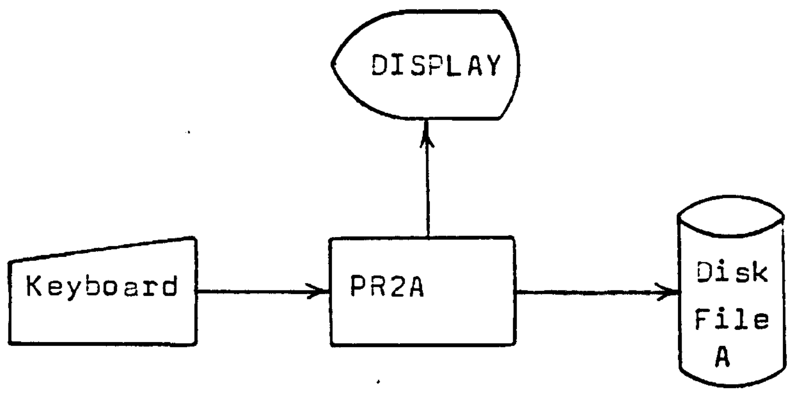
2.1.1.3. Program-LI98 and LI99 (See annex B4 and B5)

These programs translate File 6 to a new type of file with only data from Magnavox-1142 or Raysat-100, and also sorted out data which we dont need for the calculating program.One program (LI98) for Magnavox and one (LI99) for Raysat. Results are stored on disk file AA (Magnavox) and BB (Raysat).



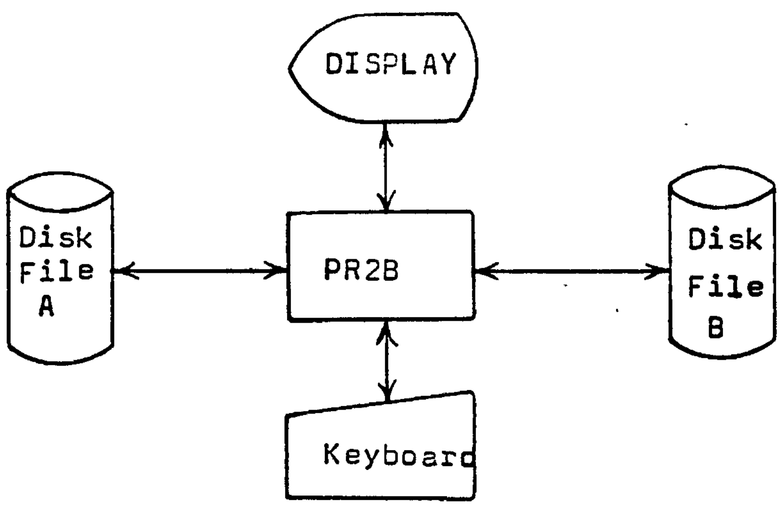
2.1.1.4. Program-PR2A: (See annex B6)

This program reads data from other places than Malmö from keyboard and saves it on a disk.



2.1.1.5. Program-PR2B: (See annex B7)

This program creates the data and it is also possible to change the data if some mistakes have been made. We read all data to File B and then we read it back to File A again. At the same time we check the data and add new data to the File A.



2.1.1.6. Program-PR5A (See annex B8)
(Flow Chart of PR5A See Fig.3)

This program was used to calculate and print out the following results:

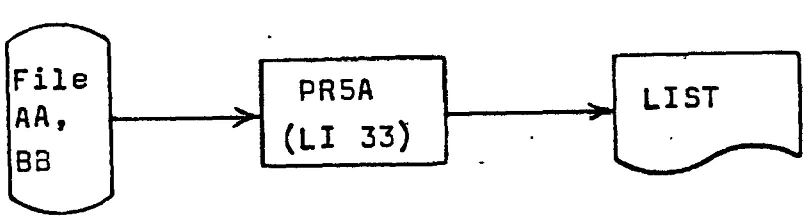
a) Mean position (Given in minutes of Latitude and Longitude only)

b) Latitude and Longitude difference between observed position and mean position, distance and direction of observed position from mean position

c) The radius of 95% probability area of position R95 (metres)

d) The 95% probability margin of Latitude and Longitude.
M95 Lat.(miles), M 95 Long.(miles).

In adition, using this program, one can calculate respectively the accuracy of different limits of satellite elevation (etc. every 5 or 10 degrees) and different times, (etc. every hour)(See table 2,3,4 and 5).



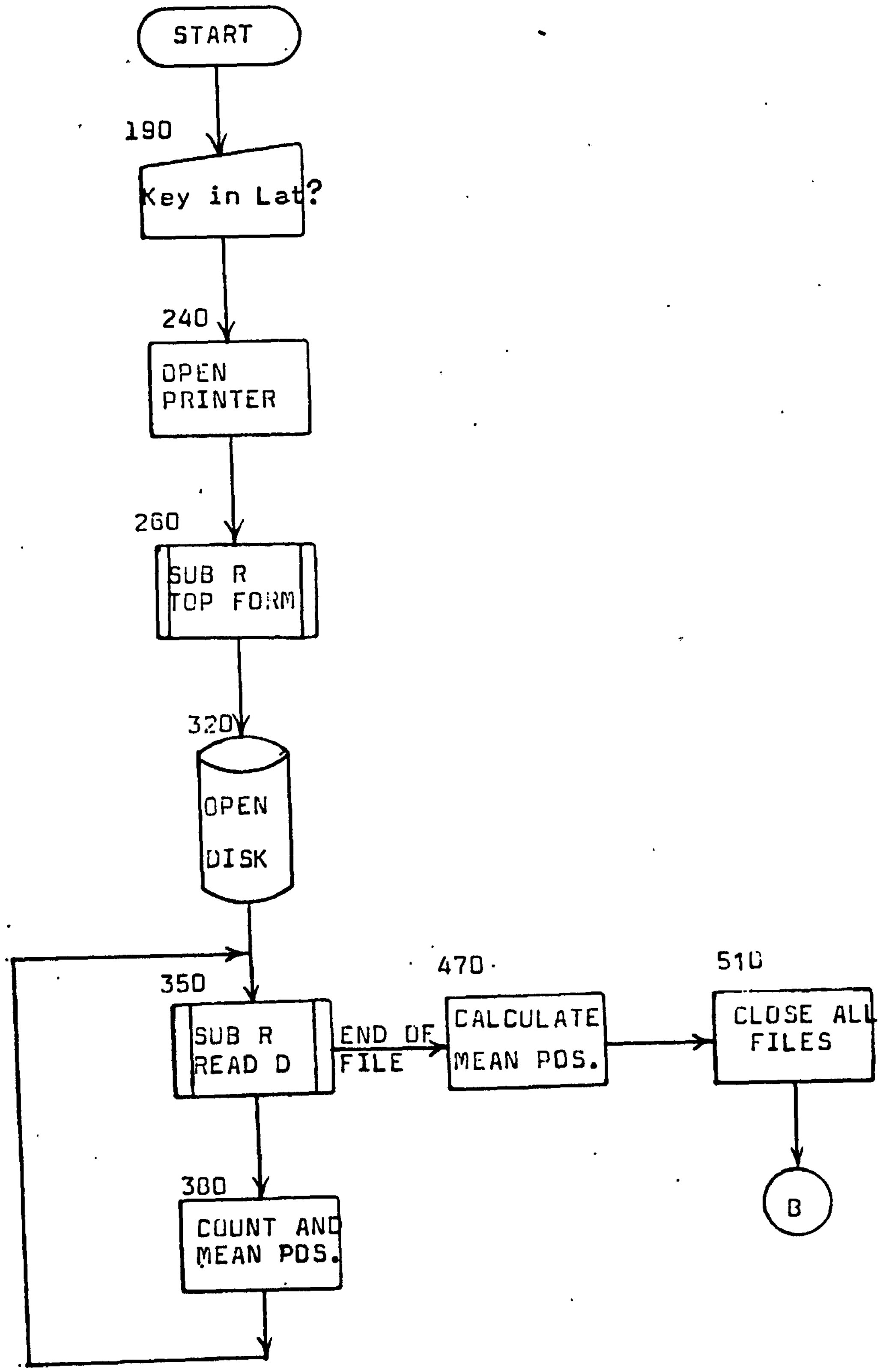


Fig. 3 Flow Chart of Program PR5A

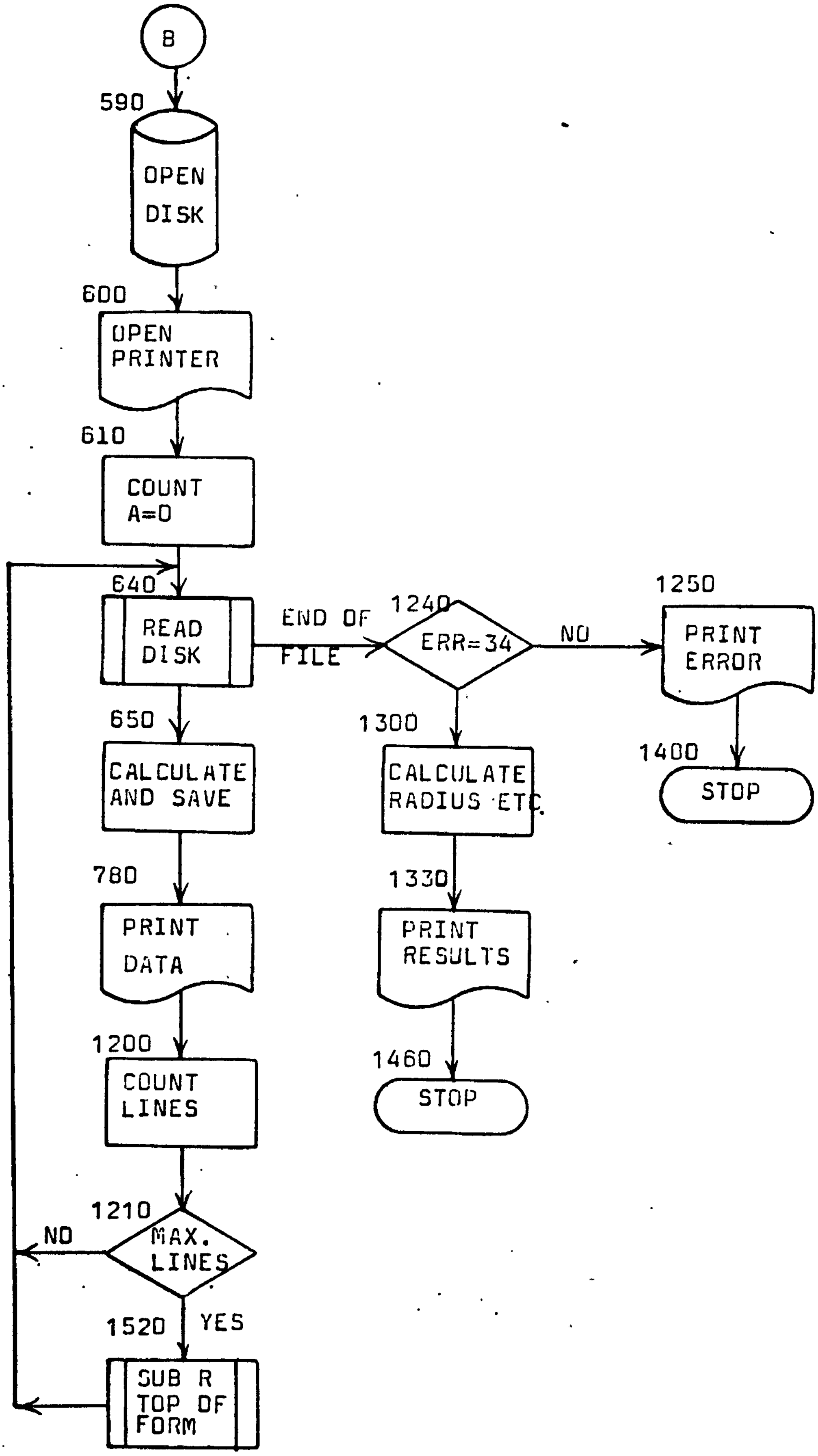
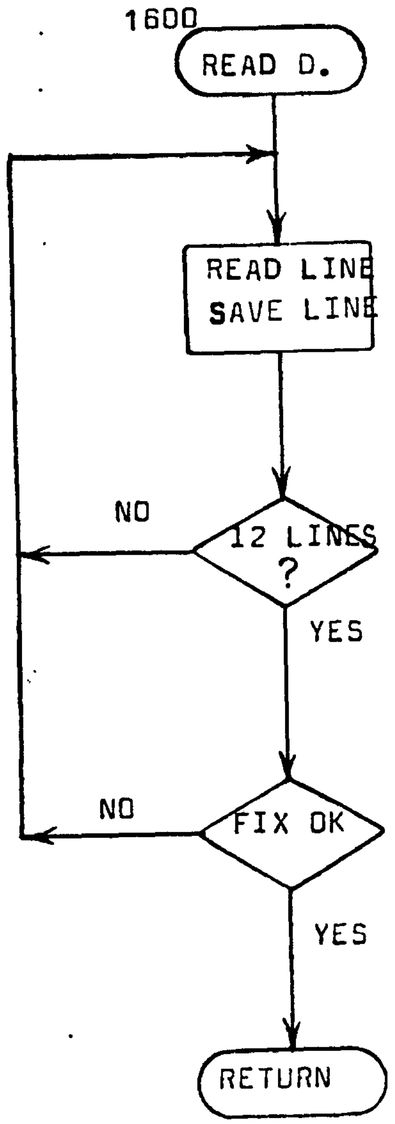


Fig.3 Flow Chart of Program PR5A
(Continued)

READ DISK :



PRINT TOP OF FORM :

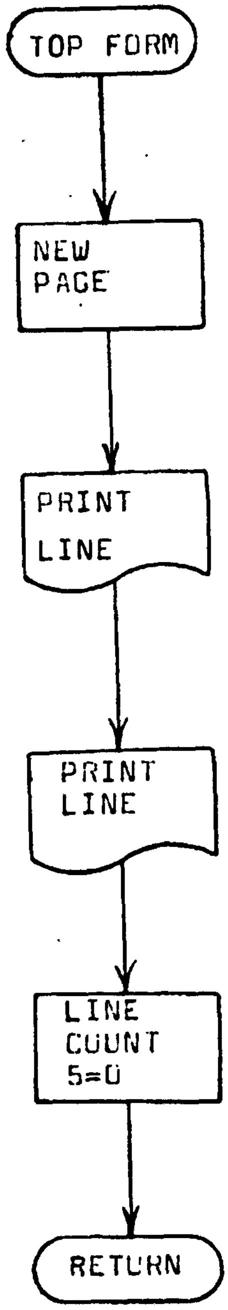


Fig.3 Flow Chart of Program PR5A

(Continued)

Abbreviation of PR5A

L1: Latitude of Observation Station

B2: Observational Latitude

L2: Observational Longitude

A: Numbers of Observations

R1: The Summation of Latitudes in Minutes

R2: The Summation of Longitude in Minutes

B3: Average of Latitude in Minutes

L3: Average of Longitude in Minutes

D2: The Latitude Difference between Observational Latitude and Average Latitude

D3: The Longitude Difference between Observational Longitude and Average Longitude

Q1: The Square of Latitude Difference between Observational Latitude and Average Latitude

Q2: The Square of Longitude Defference between Observational Longitude and Average Longitude

Q3: The Summation of Q 1

Q4: The Summation of Q 2

D1: The Distance from Average Position to Observational Position

T1: The Direction from Average Position to Observed Position

R: Radius of 95% Probability Area of Position

S1: Standard Deviation of Latitude

S2: Standard Deviation of Longitude

2.1.2. Formulas used in program PR5A

a) Mean position:

$$Lat.m = \frac{\sum Lat.}{A}, \qquad Long.m = \frac{\sum Long.}{A}$$

Where: A is the number of observations

b) Standard deviation:

$$\sigma\, Lat. = \sqrt{\frac{\sum (Lat.i - Lat.m)^2}{A-1}},$$

$$\sigma\, Long. = \sqrt{\frac{\sum (Long.i - Long.m)^2}{A-1}}$$

Where: Lat.i-Observation Latitude, i=1,2,3,·····A

Long.i-Observation Longitude, i=1,2,3·····A

c) Radius of 95% probability area of position:

$$R95 = 2\sqrt{\sigma^2 Lat. + \sigma^2 Long.\ \cos^2 Lat.m}$$

d) 95% confidence margin of latitude and longitude:

$$M95_{Lat.} = 2 \cdot \sigma_{Lat.},$$

$$M95_{Long.} = 2 \cdot \sigma_{Long.} \cos Lat.$$

2.2. Results of Observations
(See annex A1,A2,A3,A4,A5,A6,A7)

2.2.1. Summary of Stationary Observations.

No.	PLACE	TYPE of RECEIVER	TIMES of OBS.	MEAN POSITION		R 95		M 95 (N.M.)	
				Lat. (N)	Long. (E/W)	N.M.	METRES	Lat.	Long.
1	Malmö	RAYSAT 100	729	55°36.363'	12°58.909'	0.25	462.908	0.166	0.188
2	Malmö	MAGNAVOX 1142	728	55°36.323'	12°58.833'	0.111	205.637	0.058	0.095
3	Dalian	JLE 3400	98	38°52.029'	121°31.228'	0.313	580.084	0.203	0.229
4	King's Point	NAVIDYNE 4000	114	40°48.754'	73°45.667' W.	0.234	433.538	0.135	0.185
5	MITAGS	MAGNAVOX 1104	100	39°12.828'	76°40.271' W.	0.218	403.752	0.157	0.144
6	HongKong	MAGNAVOX 1102	17	22°18.256'	114°10.779'	0.206	381.577	0.079	0.185
7	Holland	NAVSTAR 601-S	11	52°27.579'	5°02.377'	0.338	720.975	0.338	0.164

Table 1 Summary of Stationary Observations

2.2.2. Statement about summary (2.2.1.)

a) No.1 shows the results after six observations which had very big errors (blunders) were removed.

b) No.2 shows the results of all observations using the MAGNAVOX-1142 receiver in Malmö. Similar to No.1, several very large errors, were eliminated from the data.

c) No.1 and No.2 have similar conditions of simultaneous observations, but the results are different. The reason is clear because different types of receivers were used. It is shown from the results at all observation stations that the MAGNAVOX Satellite Navigation Receiver has a stable performance and smaller errors. The discussion of the following paragraphs 2.3 and 2.4 is based upon the data gathered and analyzed from MAGNAVOX-1142 in Malmö and compared with the data gathered from RAYSAT in Malmö.

2.3. Influence of Elevation

The effects of various elevations of satellites will be considered below.

2.3.1. Observing results of various elevations of satellites (See table 2, 3 and Fig.4,5,6,7,8,9)

No.	Elevation From—To	No. of Fixes	Mean Position		R 95		M 95 (N.M.)	
			Lat. (N)	Long. (E)	N.M.	Metres	Lat.	Long.
1	3°—5°	20	55°36.'31	12°58.'776	0.276	510.897	0.156	0.23
2	5°—10°	125	36.32	58.82	0.151	278.811	0.1	0.112
3	10°—20°	193	36.319	58.837	0.098	180.714	0.049	0.085
4	20°—30°	134	36.324	58.839	0.079	146.539	0.029	0.074
5	30°—40°	82	36.322	58.833	0.069	127.853	0.037	0.058
6	40°—50°	71	36.326	58.833	0.058	107.469	0.02	0.055
7	50°—60°	51	36.329	58.838	0.052	95.411	0.031	0.041
8	60°—70°	45	36.33	58.837	0.086	158.942	0.026	0.083
9	70°—80°	40	36.328	58.851	0.127	235.023	0.036	0.124
10	80°—89°	24	36.327	58.864	0.201	372.97	0.039	0.20
11	85°—89°	11	36.334	58.831	0.23	425.512	0.023	0.234
12	10°—70°	564	36.323	58.836	0.084	151.582	0.042	0.13
13	30°—50°	147	36.324	58.834	0.064	119.147	0.03	0.102

Talbe .2 Results of Position Fix Accuracy with Various Elevations

(MAGNAVOX)

No.	Elevation From—To	No. of Fixes	Mean Position		R 95		M 95 (N.M.)	
			Lat.(N)	Long.(E)	N.M.	Metres	Lat.	Long.
1	2°—5°	26	55°36.353'	12°58.907'	0.308	571.124	0.169	0.25
2	5°—10°	90	36.373	58.921	0.155	287.126	0.089	0.122
3	10°—20°	194	36.36	58.904	0.219	406.435	0.129	0.171
4	20°—30°	134	36.359	58.895	0.213	395.027	0.124	0.167
5	30°—40°	81	36.356	58.91	0.32	592.51	0.172	0.261
6	40°—50°	61	36.369	58.914	0.207	382.658	0.12	0.162
7	50°—60°	62	36.366	58.898	0.22	406.825	0.108	0.185
8	60°—70°	59	36.353	58.909	0.258	478.29	0.099	0.232
9	70°—80°	54	36.364	58.926	0.117	216.266	0.076	0.085
10	80°—85°	30	36.385	58.921	0.248	459.336	0.199	0.138
11	85°—88°	19	36.302	58.886	0.769	1423.498	0.704	0.267

Table 3 Results of Position Fix Accuracy with Various Elevations

(RAYSAT)

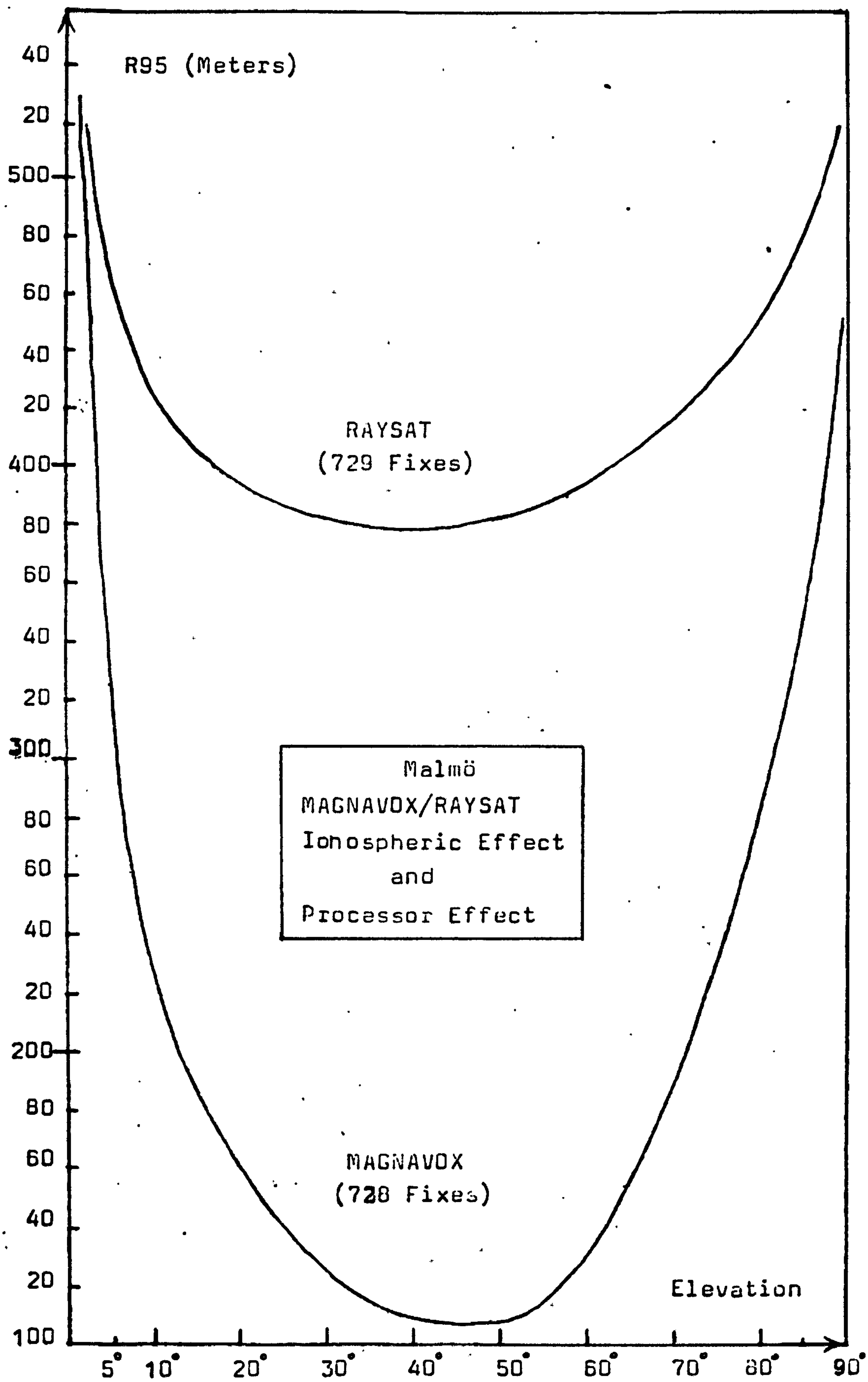


Fig.4 The Curves of Position Fix Accuracy With Various Elevations

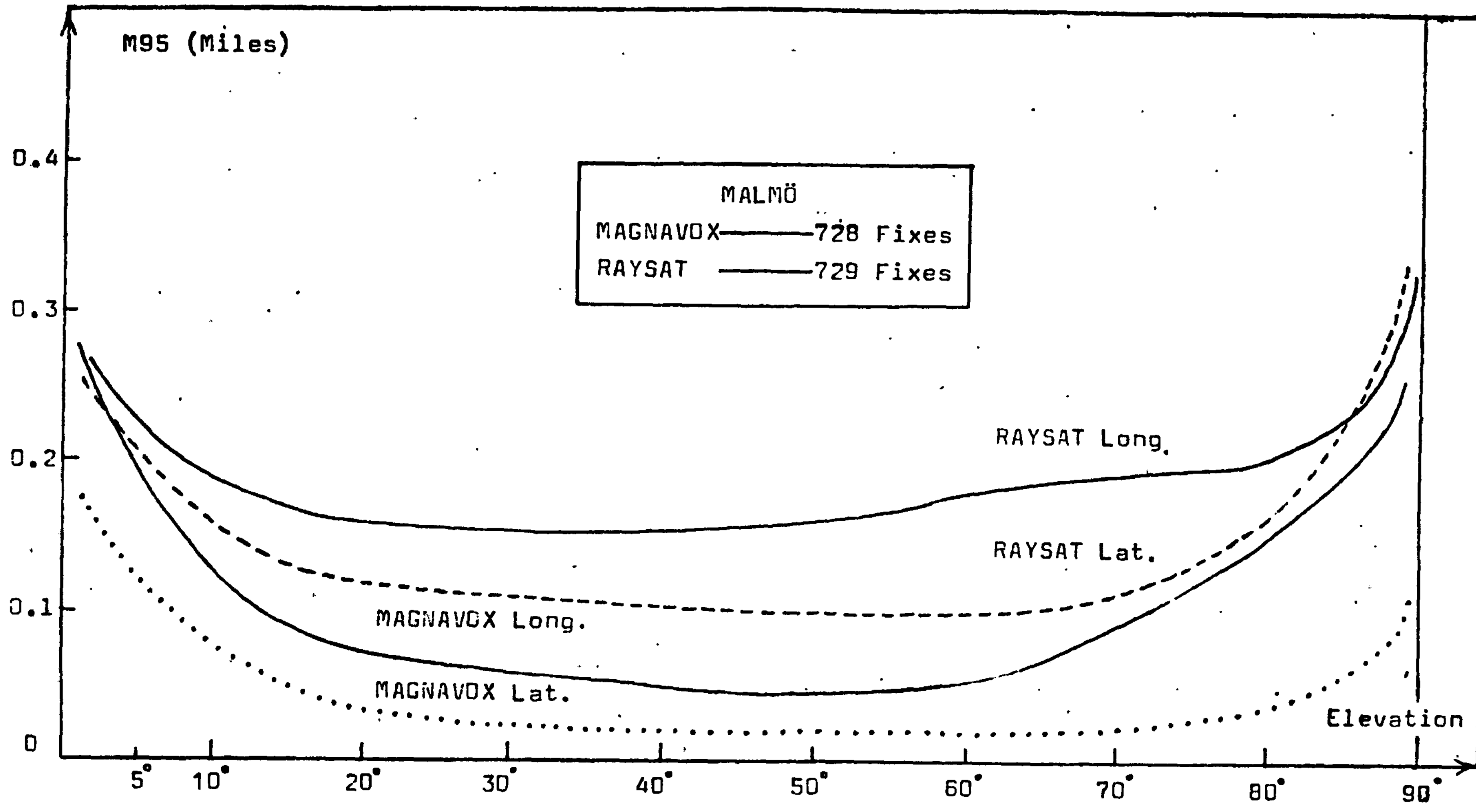


Fig.5 The Curves of Latitudinal and Longitudinal Accuracy With Varied Elevations

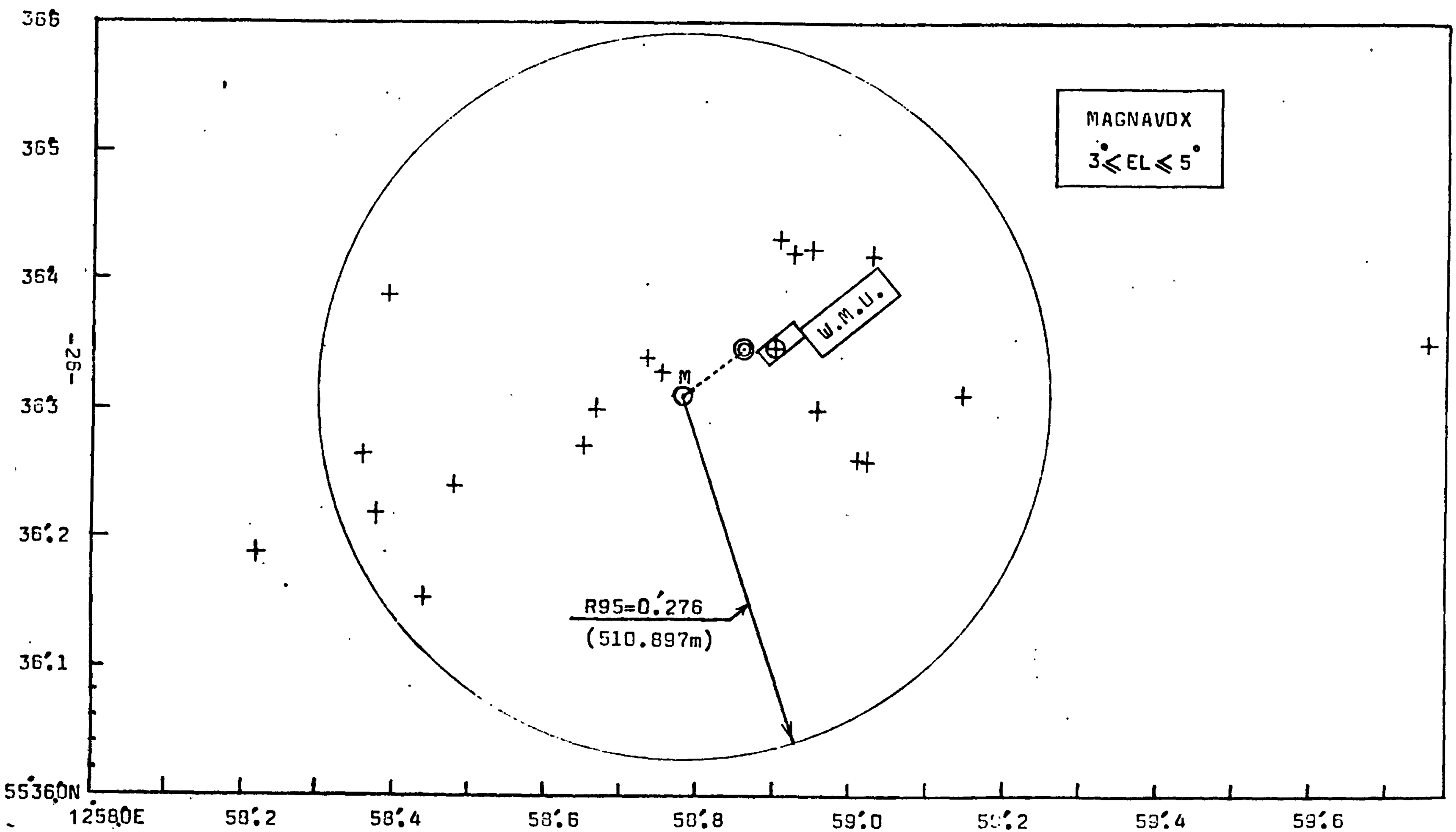


Fig.6 Distribution of 20 Points Recorded at W.M.U. in Malmö.

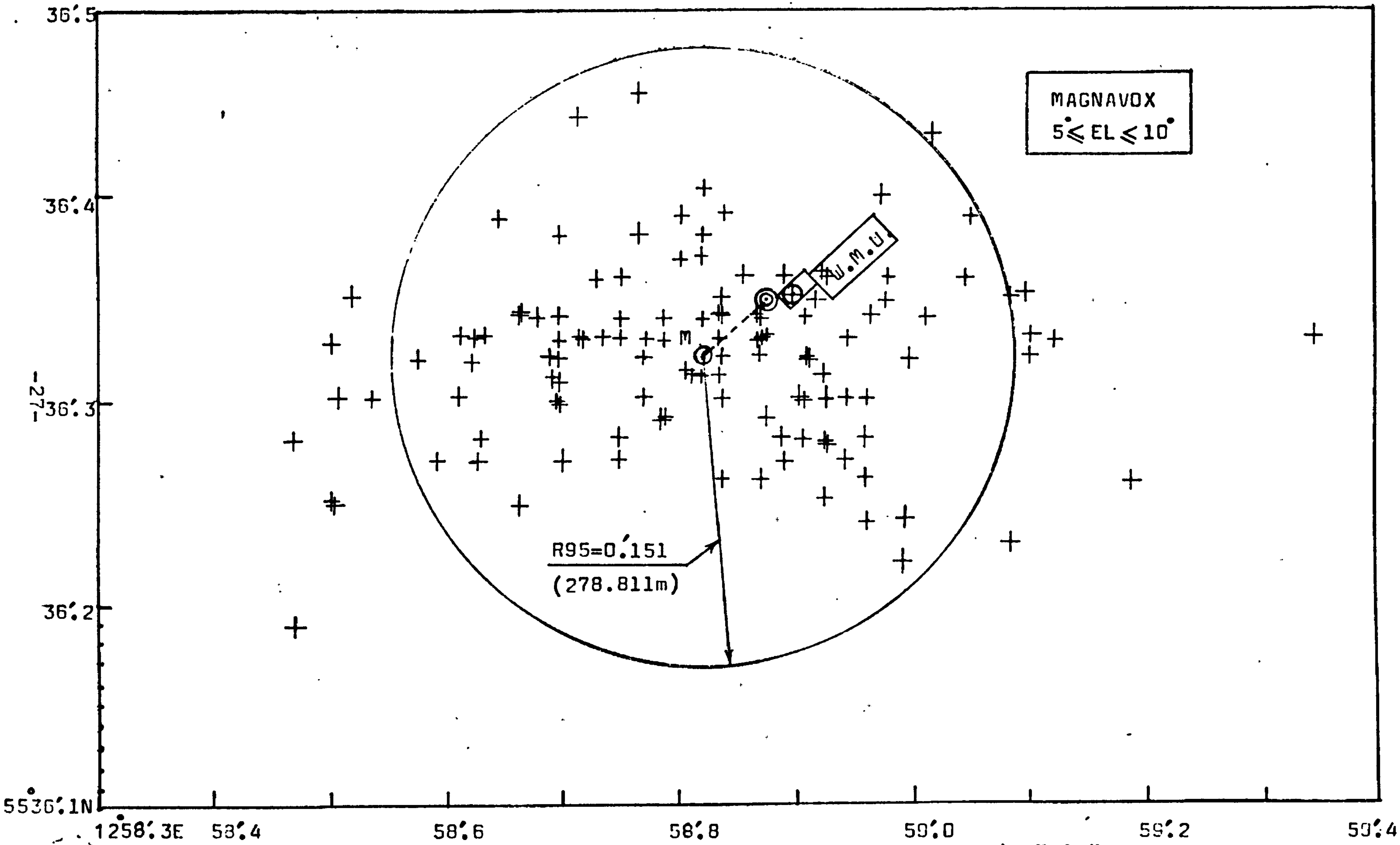


Fig.7 Distribution of 125 Points Recorded at W.M.U. in Malmö

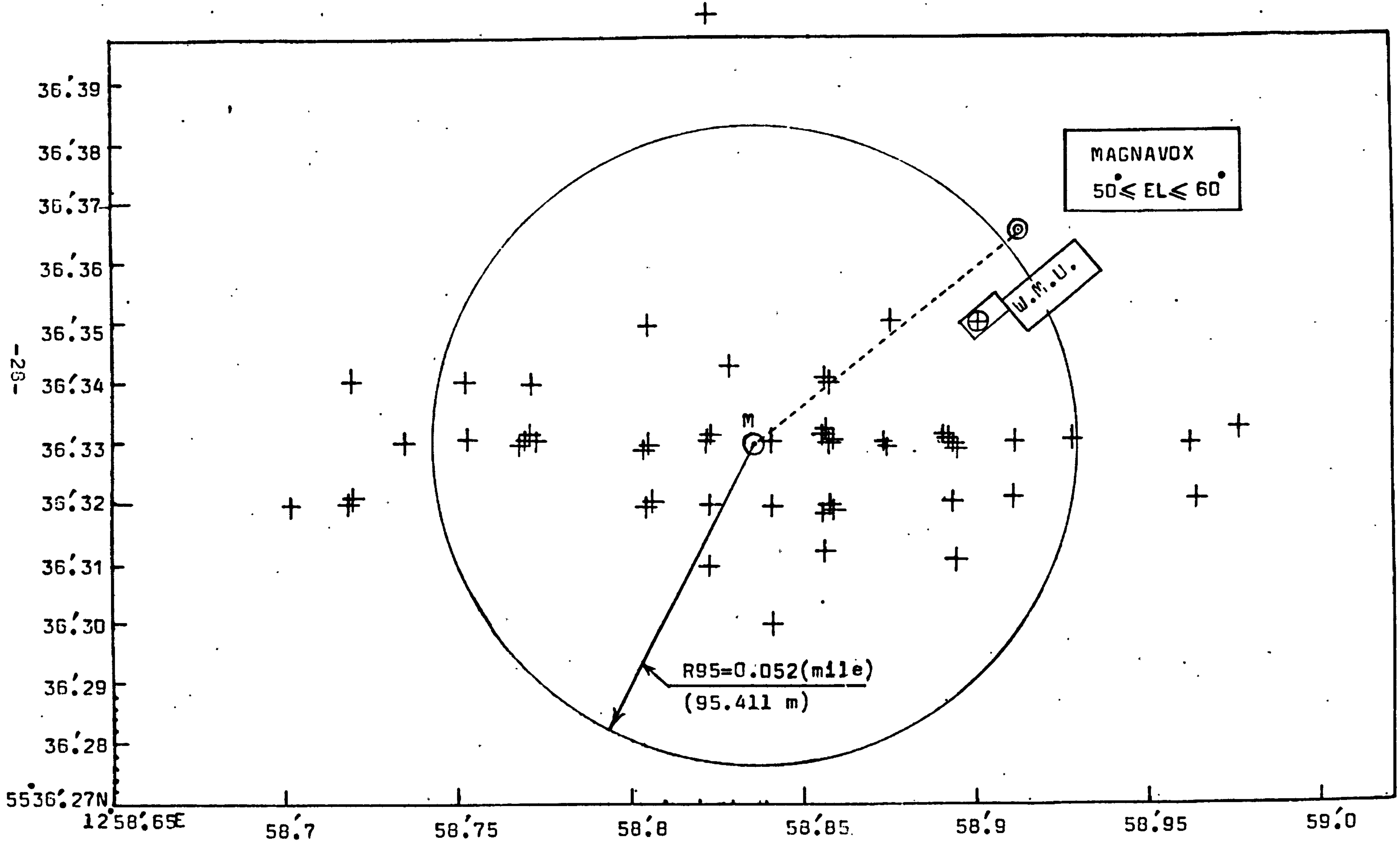


Fig 8 Distribution of 51 Points Recorded at W.M.U. in Malmö

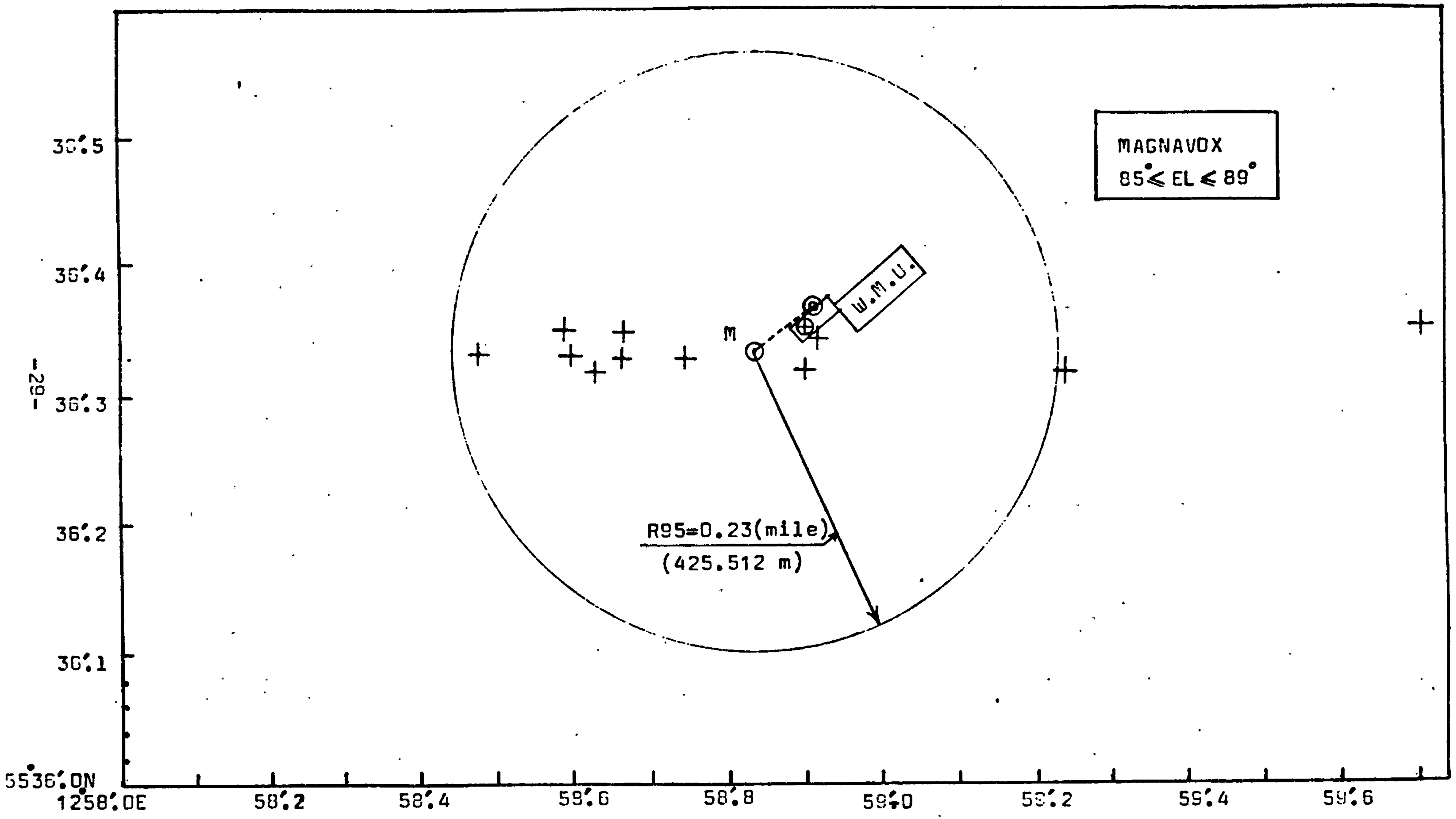


Fig 9 Distribution of 11 Points Recorded at W.M.U. in Malmö

2.3.2. Statement about (2.3.1.)

a) Table 2,3 and Fig.4 indicate that position fix accuracy is variant with elevations of satellites (ionospheric errors) and the type of receiver.

The highest position fix accuracy occurs at the limited elevation of satellites from 40°-60°. The R95 (MAGNAVOX) are close to 100 metres. Mean R95=101.44 metres ($40^\circ < EL < 60^\circ$, MAGNAVOX). While the R95 (RAYSAT) are close to 400 metres. Mean R95= 399.74 metres ($40^\circ < EL < 60^\circ$, RAYSAT)

b) The R95(MAGNAVOX) are all less than 150 metres, when the limit of satellite elevation is from 25°-65°.

While the R95(RAYSAT) are all greater than 400 metres, when the limit of satellite elevation is less than 25° and greater than 65°.

c) The R95(MAGNAVOX) are all less than 200 metres and mean R95=151.582 metres when the limit of satellite elevation is from 10°-70°.※

※ In general, the TRANSIT System is a very accurate navigation system. If elevation is between 10° and 70°, the error in the input ground-speed is small, the ionospheric conditions are not adverse and the receiver is of good quality, then the accuracy of a fix can be expressed by the statement that the 95% probability area has a radius R95=0.4 n.m. In conditions which are less favourable than those mentioned before R95 can increase to 2.0 n.m. or even surpass this value.(1).

d) The R95 (MAGNAVOX) are all greater than 250 metres, when the limit of satellite elevation is less than 10° and greater than 75°.

e) When the limit of satellite elevation is less than 5° and greater than 85°, very big position fix errors can be found. In this case, the R95(MAGNAVOX) are all greater than 400 metres. The R95 (RAYSAT) are even more.

f) Fig.5 with Table 2 and 3 shows that the longitudinal errors (M95 Long.) are greater than latitudinal errors (M95 Lat.). These results are the same as indicated in 2.2.1.

While the latitudinal errors of "RAYSAT" are three times of "MAGNAVOX", the longitudinal errors of "RAYSAT" are twice as large as "MAGNAVOX".

g) Fig.6,7,8,9 indicate the distribution of position fixes of limited satellite elevations. Symbol ⊙ is mean position of observations in WGS-72 coordinates.
Symbol ◎ is the mean position shifted from ⊙ (WGS) by calculated Lat. shift and Long.shift (See table 7)
Symbol ⊕ is the receiver's antenna position in local datum.

2.4. Influence of time (LMT)

2.4.1. Results of observation at different times.

(See table 4 and 5)

2.4.2. The curves of position fix accuracies

(See Fig.10-R95, Fig.11-M95 Lat. and M95 Long.

2.4.3. Results of observations of satellitic elevation from 30°-60° at different times.

(See table 6 and Fig.12.)

2.4.4. Statement about table 4,5 and Fig.10,Fig.11, table 6 and Fig.12:

a) The accuracy of position determined by satellite varies with LMT. Table 4 and 5 show the results of calculated observation data observed at one hour intervals,which were gathered by day and night continuously by MAGNAVOX-1142 and RAYSAT—100 in Malmö. The curve of M95 Lat.Fig.11 shows the latitude deviation which changes with time. The curve of M95 Long. (Fig.11) shows the longitude deviation which changes with time.

Generally speaking, the position fix accuracy is higher during night time than day-time. Specially it has lower accuracy around noon-time, that means that R95 appears biggest. Fig. 10 shows: R95 reaches a very high point, about 350 metres of "MAGNAVOX" and greater than 500 metres of "RAYSAT",at GMT 10.5h (Malmö Local time 11.5h). While R95 falls to the lowest point at GMT24h (Malmö LMT 01h). The figure indicates that the R95 appears somewhat greater before and after noon, while R95 appears smaller at night.

b) Fig.11 shows that the curves of M95 Long. and R95 (Fig.10) have a similar shape. These points tell us that the R95 of satellite fixes is mainly caused by longitude deviation, while latitude deviation has a smaller effect on R95. Fig.11 also shows that the M95 latitude and M95 Longitude of "RAY-SAT" greater than "MAGNAVOX".

c) Table 6 and Fig.12 show the results of calculated observation data observed with satellite elevation from 30°-60° at one hour intervals, which were gathered by day and night continuously by MAGNOVOX in Malmö.

d) Analysis of the reason for different position fix accuracy. The main reason is the disturbance by the ionosphere, which produces an error in the phase velocity . C phase varies with N-ions. The ionosphere is rather stable at night. The disturbance is then very small, so the position fix accuracy is higher. (R95 becomes smaller). Whereas after the sun rises, the ionosphere becomes very active. This causes a big disturbance which affects propagation velocity of the satellite's radio waves, so that position fix accuracy decreases.

2.4.5. Single and dual frequency receiver

If only a single frequency receiver is used, the effect of ionospheric refraction is to give the satellite an apparent orbit which has a greater curvature than the true orbit due to wavelength stretching. This will reduce the doppler frequency shift to some extent, pushing the apparent position of the fix obtained away from the satellite orbit. Since the satellites move in a north-south plane the effect is to produce errors which are mainly in the east-west plane. The magnitude of these errors depend on the sunspot activity, distance from the equator and the ionospheric density. It is almost zero at night but can reach up to 500 metres by day under the worst conditions (2).

If a dual frequency receiver is used, the ionosphoric effects will be different and a comparison of the two values will indicate the extent of the error. A correction can be made. For high accuracy the satellites therefore transmit their singnals at two frequencies, 400 MHz and 150 MHz. Dual frequency receivers will accept both frequencies and make the necessary correction for ionosheric refraction, but when a single frequency receiver is used, no correction is made. For example, fixes obtained with a typical shipborne dual frequency receiver are normally in the order of 100 metres though better accuracies than this can be and are obtained (3)

Table 4 Results of Observation at Different Times

(RAYSAT, MALMÖ)

No.	GMT From–To	No. of Fixes	Satellits Number	Mean Position Lat.(N)	Mean Position Long.(E)	R 95 N.M.	R 95 Metres	M 95 (±) Lat.(NM)	M 95 (±) Long.(NM)
1	0000–0100	14	130.	36.375	58.906	0.07	129.83	0.031	0.06
2	0100–0200	15	130,480,190.	36.396	58.957	0.13	240.322	0.079	0.099
3	0200–0300	18	110,130,190 200.	36.343	58.866	0.327	606.257	0.187	0.259
4	0300–0400	27	110,190,200.	36.35	58.872	0.346	641.46	0.226	0.252
5	0400–0500	36	110,190,200.	36.376	58.906	0.284	525.795	0.198	0.194
6	0500–0600	37	110,190,200.	36.33	58.947	0.53	981.631	0.498	0.145
7	0600–0700	40	110,130,190, 200,480.	36.373	58.915	0.141	260.461	0.03	0.134
8	0700–0800	48	110,130,190, 200,480.	36.36	58.912	0.163	301.302	0.098	0.124
9	0800–0900	46	110,130,190, 200,480.	36.358	58.909	0.159	294.839	0.101	0.118
10	0900–1000	40	110,130,200, 480.	36.348	58.887	0.204	377.36	0.113	0.163
11	1000–1100	31	110,130,200, 480.	36.382	58.89	0.355	656.65	0.105	0.33
12	1100–1200	27	130,200,480.	36.375	58.836	0.463	857.699	0.106	0.439
13	1200–1300	24	130,480.	36.376	58.979	0.115	212.841	0.036	0.106
14	1300–1400	28	130,190,480.	36.39	58.97	0.20	370.42	0.104	0.166
15	1400–1500	22	130,190,480.	36.37	58.921	0.267	494.488	0.151	0.212
16	1500–1600	21	110,130,190, 200,480.	36.325	58.953	0.29	537.986	0.228	0.168
17	1600–1700	28	110,190,200.	36.368	58.911	0.202	374.427	0.091	0.175
18	1700–1800	26	110,190,200.	36.37	58.908	0.106	197.189	0.04	0.096
19	1800–1900	36	110,130,190, 200.	36.356	58.92	0.271	501.703	0.192	0.182
20	1900–2000	35	110,130,190, 200,480.	36.366	58.909	0.202	373.683	0.078	0.181
21	2000–2100	41	110,130,190, 200,480.	36.377	58.893	0.135	249.231	0.042	0.124
22	2100–2200	42	110,130,190, 200,480.	36.369	58.916	0.108	200.491	0.077	0.072
23	2200–2300	29	110,130,200, 480.	36.351	58.886	0.197	364.909	0.145	0.127
24	2300–2400	19	130,200,480.	36.351	58.897	0.305	564.685	0.151	0.257
25	Total: 0000–2400	729	110,130,190, 200,480.	55° 36.363	12° 58.909	0.025	462.908	0.166	0.188

Table 5 Results of Observation at Different Times

(MAGNAVOX, MALMÖ)

No.	GMT From – To	No. of Fixes	Satellits' Number	Mean Position Lat. (N)	Mean Position Long. (E)	R_{95} N.M.	R_{95} Metres	M_{95} (N/M) Lat.	M_{95} (N/M) Long.
1	0000-0100	14	130,480.	36.325	58.85	0.055	102.025	0.036	0.041
2	0100-0200	15	130,480,190	36.325	58.81	0.137	252.289	0.097	0.097
3	0200-0300	18	130,480,190,110,200.	36.309	58.838	0.084	155.918	0.059	0.06
4	0300-0400	27	110,190,200.	36.305	58.859	0.064	118.234	0.054	0.032
5	0400-0500	36	110,190,200	36.313	58.869	0.078	145.195	0.036	0.07
6	0500-0600	37	110,190,200,130.	36.342	58.846	0.054	100.795	0.018	0.052
7	0600-0700	42	110,190,200,130,480.	36.329	58.82	0.058	107.277	0.028	0.05
8	0700-0800	47	110,190,200,130,480.	36.334	58.821	0.087	161.022	0.049	0.072
9	0800-0900	45	110,190,200,130,480.	36.318	58.801	0.113	210.111	0.054	0.101
10	0900-1000	39	110,130,200,480.	36.325	58.803	0.138	254.813	0.062	0.125
11	1000-1100	30	110,130,200,480.	36.341	58.832	0.19	352.506	0.062	0.184
12	1100-1200	27	130,480.	36.328	58.815	0.116	214.574	0.025	0.115
13	1200-1300	25	130,480.	36.338	58.77	0.074	137.873	0.028	0.07
14	1300-1400	28	130,480,190.	36.331	58.808	0.169	312.482	0.086	0.147
15	1400-1500	22	130,480,190,200.	36.325	58.853	0.165	305.172	0.064	0.155
16	1500-1600	21	110,190,200	36.33	58.912	0.073	135.538	0.043	0.059
17	1600-1700	27	110,190,200.	36.326	58.895	0.067	123.322	0.039	0.054
18	1700-1800	26	110,190,200,130.	36.324	58.865	0.086	159.503	0.024	0.084
19	1800-1900	36	110,190,200,130,480.	36.32	58.839	0.099	183.146	0.049	0.087
20	1900-2000	35	110,190,200,130,480.	36.308	58.817	0.153	283.233	0.104	0.112
21	2000-2100	39	110,130,200,480.	36.321	58.832	0.045	83.692	0.035	0.027
22	2100-2200	42	110,130,200,480.	36.323	58.834	0.092	171.228	0.069	0.06
23	2200-2300	30	110,130,200,480.	36.315	58.822	0.135	250.283	0.094	0.097
24	2300-2400	20	130,480	36.323	58.851	0.055	101.901	0.047	0.027
	Total:								
25	0000-2400	728	110,130,190,200,480.	36.323	58.833	0.111	205.637	0.058	0.095

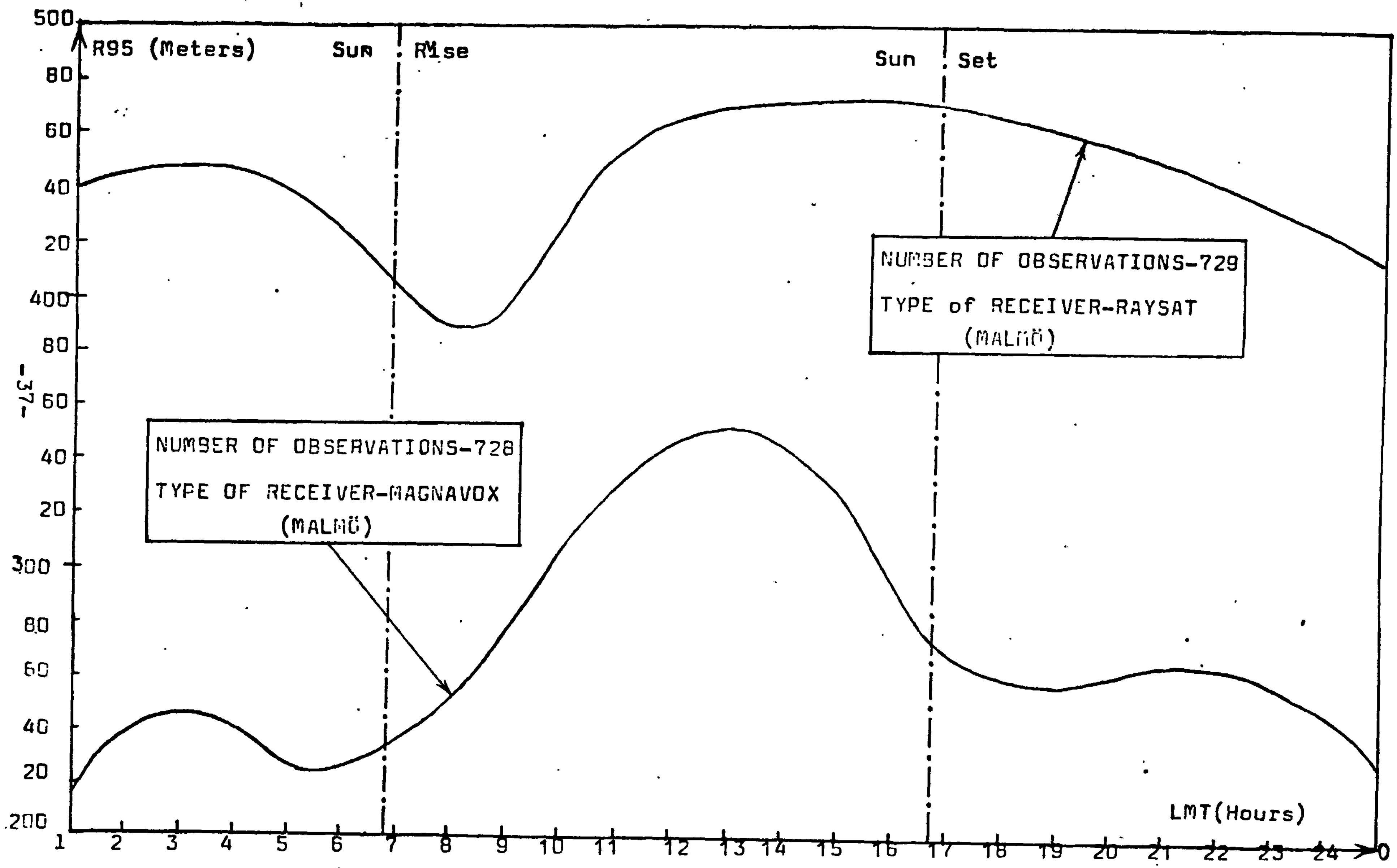


Fig.10 The Curves of Position Fix Accuracy at Different Times

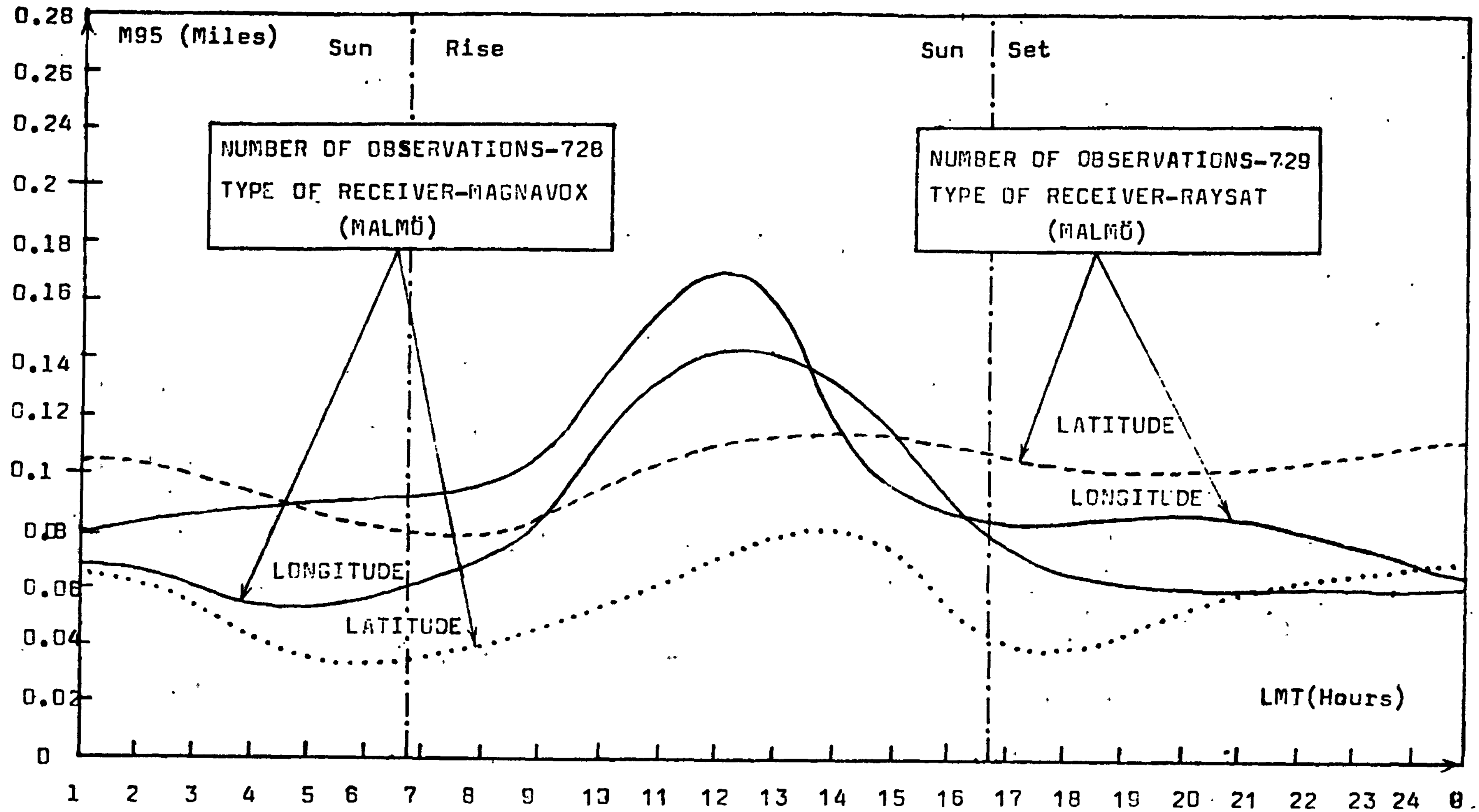


Fig.11 The Curves of Latitudinal and Longitudinal Accuracy at Different Times

Table 6 Position Fix Accuracy With Satellite Elevation From 30° to 60°

(MAGNAVOX, MALMÖ)

No.	G.M.T.	No. Of	Satellits'	Mean Position		R95		M95 (±)	
	From – To	Obs.	Number	Lat. (N)	Long. (E)	N.M.	Meters	Lat.	Long.
1	0000-0100	2	480,	36'.33	58'.84	0	0	0	0
2	0100-0200	NO	—	—	—	—	—	—	—
3	0200-0300	2	190,	36'.325	58'.845	0.027	49.883	0.013	0.041
4	0300-0400	4	190.	36'.323	58'.858	0.032	58.771	0.029	0.018
5	0400-0500	9	110, 190, 200,	36'.324	58'.863	0.043	80.461	0.017	0.072
6	0500-0600	19	110, 190, 200	36'.325	58'.838	0.054	100.398	0.017	0.092
7	0600-0700	10	110, 190, 200	36'.326	58'.813	0.046	85.657	0.018	0.076
8	0700-0800	11	110, 200,	36'.328	58'.789	0.044	80.741	0.021	0.068
9	0800-0900	14	130, 200, 480.	36'.326	58'.844	0.057	105.80	0.021	0.095
10	0900-1000	9	130, 480,	36'.33	58'.869	0.029	54.552	0.016	0.043
11	1000-1100	8	130, 480.	36'.339	58'.796	0.094	173.863	0.069	0.11
12	1100-1200	14	130, 480.	36'.326	58'.796	0.038	69.875	0.019	0.057
13	1200-1300	4	130, 480.	36'.333	58'.80	0.032	59.557	0.009	0.055
14	1300-1400	NO	—	—	—	—	—	—	—
15	1400-1500	1	190,	—	—	—	—	—	—
16	1500-1600	6	190.	36'.328	58'.912	0.037	68.626	0.031	0.033
17	1600-1700	9	110, 190, 200.	36'.327	58'.878	0.075	138.519	0.013	0.133
18	1700-1800	13	110, 190, 200.	36'.325	58'.844	0.058	108.143	0.02	0.098
19	1800-1900	11	110, 190, 200,	36'.322	58'.843	0.054	99.492	0.03	0.079
20	1900-2000	5	110, 200,	36'.326	58'.798	0.046	85.94	0.017	0.077
21	2000-2100	14	110, 130, 200, 480	36'.324	58'.834	0.038	69.586	0.028	0.043
22	2100-2200	12	130, 480.	36'.323	58'.84	0.037	68.942	0.019	0.057
23	2200-2300	9	130, 480.	36'.314	58'.817	0.125	230.669	0.091	0.149
24	2300-2400	8	130, 480,	36'.326	58'.846	0.04	74.653	0.027	0.052
	Total:								
25	0000-2400	194	110, 130, 190, 200, 480.	36'.326	58'.835	0.062	114.351	0.031	0.095

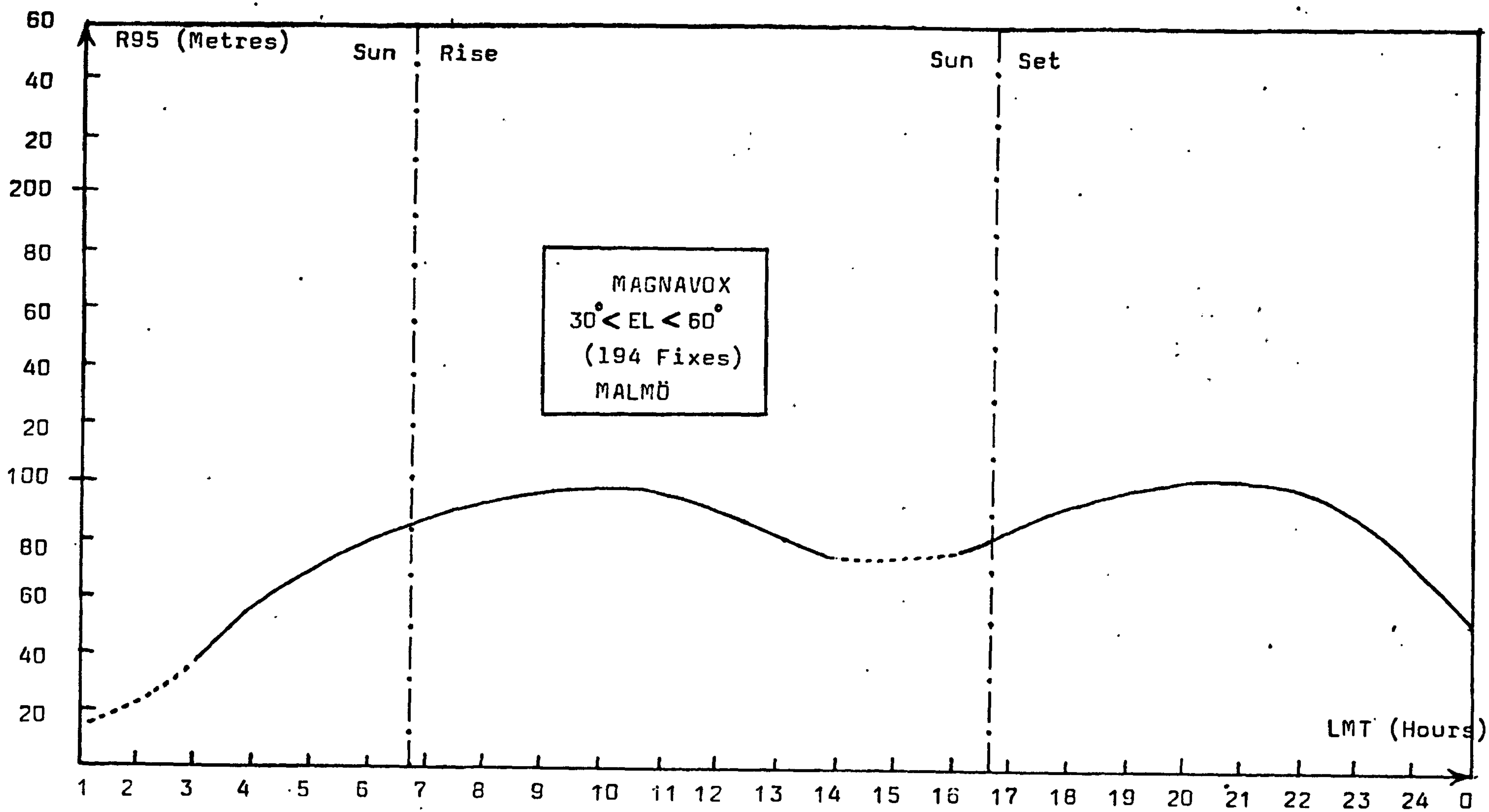


Fig (12) The Curves of Position Fix Accuracy at Different Times

Chapter 3

Reduction of Systematic Error Caused by Ellipsoid Datum References

3.1. The World Geodetic System of 1972 (WGS-72)

If a high accuracy of position fix is to be obtained, it is necessary to know precisely the systematic error caused by ellipsoid datum references. It is important to realize that charts are drawn and positions are defined with respect to a local reference datum. In the past each country has adopted its own charting datum based on a specific known location and a given ellipsoid. In China, we use the Chinese Datum, in Europe, the European Datum, in the United States, the North American Datum, etc. Different ellipsoids have been used by the countries so that positional errors have often been introduced when changing from one datum to another.

This difference can be of the order of several hundred metres, and can be analyzed when plotting a large number of position fixes obtained while a vessel is in port.(See Fig. 6,7,8 and 9)

The Transit System currently uses the World Geodetic System of 1972 (WGS-72). As a result, the same reference marker will have a different set of latitude and longitude coordinates in each reference datum. Apparent differences of 1/2 Kilomet r occur in some locations. (4)

A World Spheroid may not fit the earth very well at any one location, but WGS-72 Spheroid is the "best fit" to the WGS-72 geoid. But the WGS-84 geoid has been used, it has only a slight changed in data.

3.2. Datum Shift Constants

The coordinate differences between two datums can be resolved by knowledge of three offset parameters and the size and shape of each spheroid. First is the Δx, Δy, Δz offset between the center of the two shperoids. The size and shape of each spheroid are defined by the semi-major axis (a) and by the flattening coefficient (f). (See annex C.)

Annes C lists datum shift constants which can be used in converting from various datums to WGS-72 or inverse.

3.3. Coordinates Transformation Formulas

Annex D gives the formulas used to transform coodinates from WGS-72 position to chart datum position

3.4. The computer program used in calculating the shift from WGS-72 geoid to local gecid.

3.4.1. The program (PR1A)

See Fig.13. Flow chart of program PR1A, in detail see annex B1,PR1A.

3.4.2. The results of calculated shift of various observation positions. See table 7.

3.5. Reduction of Systematic Error.
(See Fig. 14,15,16,17,18,19)

These figures show the coordinate transformation from WGS-72 to charted position at several observational stations.

Where:

⊙ The mean position calculated by the computer program (PR5A-L133) (WGS-coordinates)

◎ The mean position shifted from ⊙ (WGS) by calculated Lat. shift and Long. shift (See table 5) to local datum.

⊕ The receiver's antenna position in local datum.

These figures indicate that the systematic errors caused by ellipsoid datum references of several observational stations have been reduced. The distance and direction between ◎ and ⊕ are caused by other systematic errors.

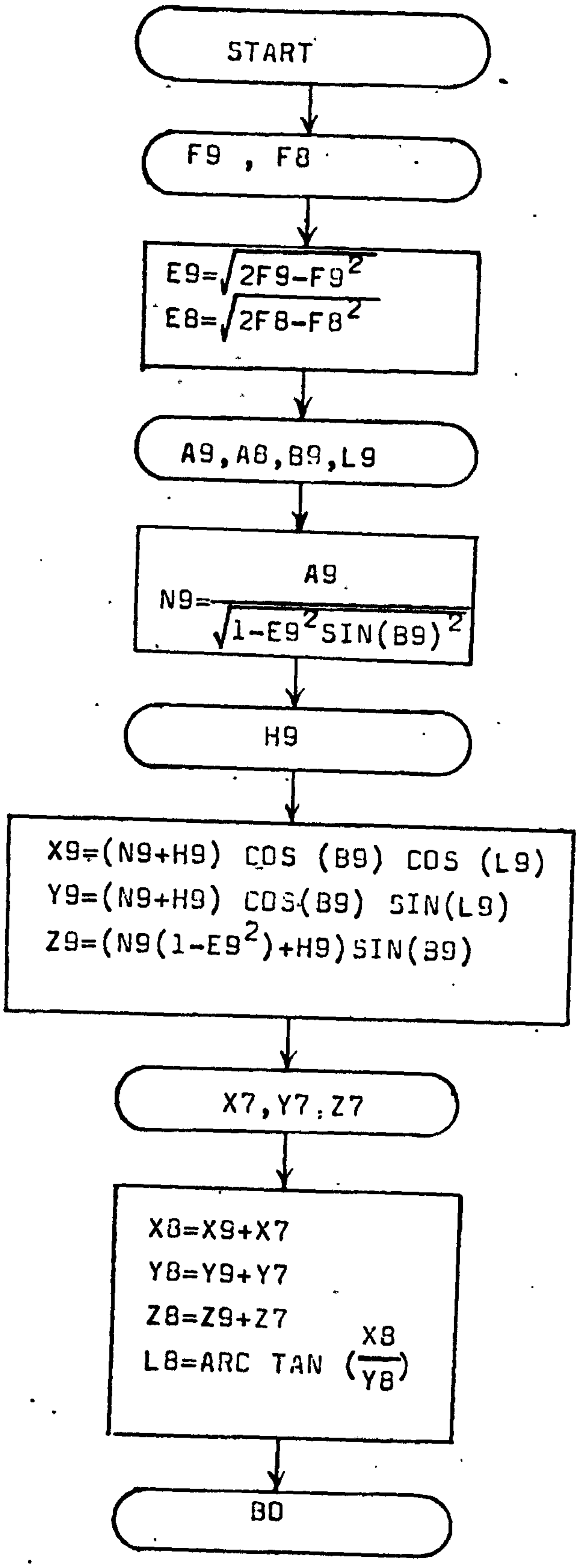


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Fig.13 Flow Chart of Program PR1A

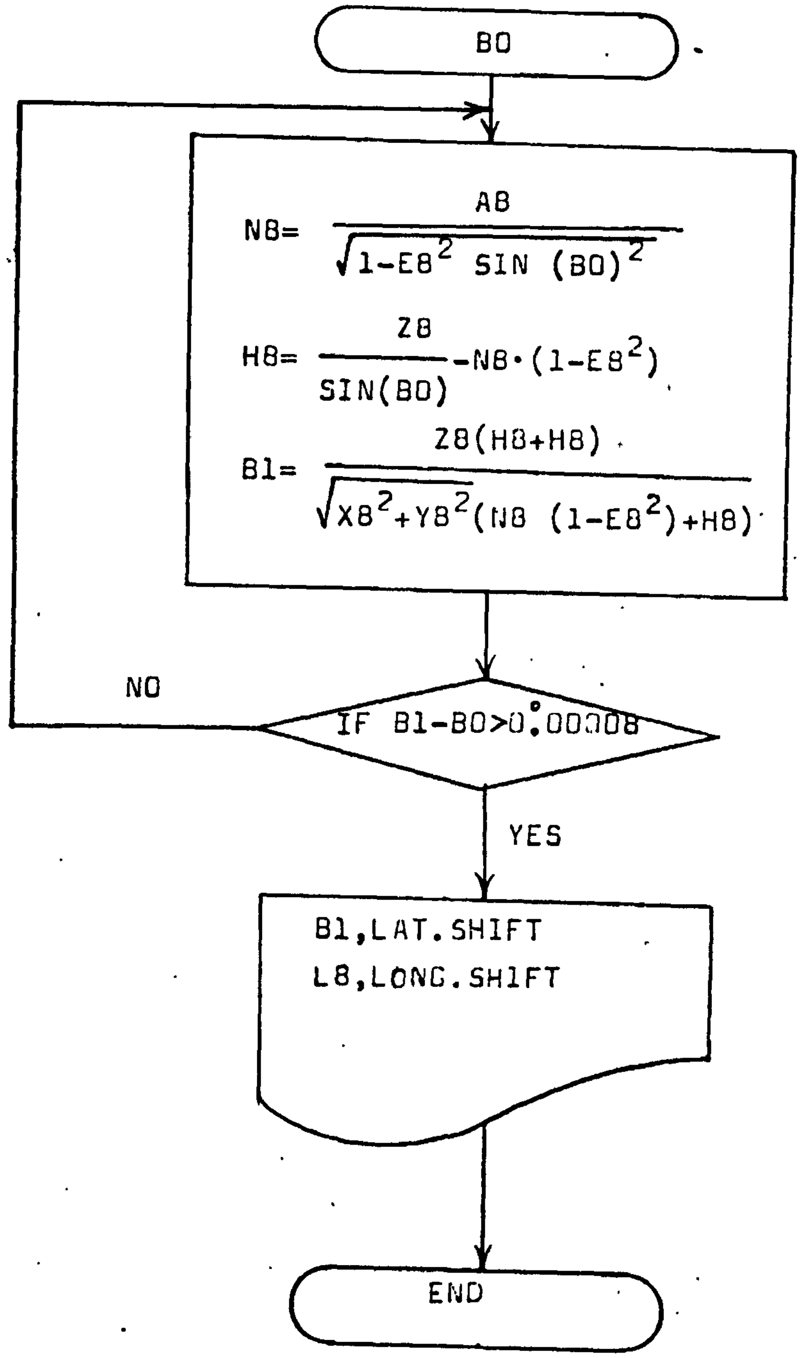


Fig.13. Flow Chart of Program PR1A
(Continued)

Abbreviation of PR1A

A9= a WGS (m)	A8= a Local (m)
E9= e WGS	E8= e Local
F9= f WGS	F8= f Local
B9= Lat. WGS	B8= Lat. Local
L9= Long.WGS	L8= Long.Local
N9= N WGS(m)	N8=N Local (m)
H9= h WGS (m)	H8=h Local (m)

X9=X WGS	X8=X Local
Y9=Y WGS	Y8=Y Local
Z9=Z WGS	Z8=Z Local

X7= Δ X, Y7= Δ Y, Z7= Δ Z

D=180/(4xATN (1))

Talbe 7 The Shifts of Observed Static Position

MALMÖ (WMU)

RECIPROCAL OF FLATTENING OF WGS 298.26
RECIPROCAL OF FLATTENING OF LOCAL 297
SEMIMAJOR AXIS OF WGS IN METERS 6378135
SEMIMAJOR AXIS OF LOCAL POSITION 6378388
LATITUDE OF WGS IN DEGR. AND MIN. 55 36.323
LONGITUDE OF WGS IN DEGR. AND MIN. 12 58.833
GEOID HEIGHT +HEIGHT OF ANTENNA IN METERS 53
ORIGIN OFFSET OF X AXIS 84
ORIGIN OFFSET OF Y AXIS 102
ORIGIN OFFSET OF Z AXIS 122

RESULTS
LATITUDE 55 36.35
LONGITUDE 12 58.9
LAT SHIFT 67.8 metres
LONG. SHIFT 80.19 metres

AMSTERDAM (THE NETHERLANDS)

RECIPROCAL OF FLATTENING OF WGS 298.26
RECIPROCAL OF FLATTENING OF LOCAL 297
SEMIMAJOR AXIS OF WGS IN METERS 6378135
SEMIMAJOR AXIS OF LOCAL POSITION 6378388
LATITUDE OF WGS IN DEGR. AND MIN. 52 27.585
LONGITUDE OF WGS IN DEGR. AND MIN. 5 2.456
GEOID HEIGHT +HEIGHT OF ANTENNA IN METERS 42
ORIGIN OFFSET OF X AXIS 83
ORIGIN OFFSET OF Y AXIS 109
ORIGIN OFFSET OF Z AXIS 122

RESULTS
LATITUDE 52 27.63
LONGITUDE 5 2.54
LAT SHIFT 89.61 metres
LONG. SHIFT 100.86 metres

DALIAN (CHINA)

RECIPROCAL OF FLATTENING OF WGS 298.26
RECIPROCAL OF FLATTENING OF LOCAL 297
SEMIMAJOR AXIS OF WGS IN METERS 6378135
SEMIMAJOR AXIS OF LOCAL POSITION 6378388
LATITUDE OF WGS IN DEGR. AND MIN. 38 52.031
LONGITUDE OF WGS IN DEGR. AND MIN. 121 31.21
GEOID HEIGHT +HEIGHT OF ANTENNA IN METERS 43
ORIGIN OFFSET OF X AXIS 131
ORIGIN OFFSET OF Y AXIS 347
ORIGIN OFFSET OF Z AXIS 0

RESULTS
LATITUDE 38 52
LONGITUDE 121 31
LAT SHIFT -53.28 metres
LONG. SHIFT -292.16 metres

KINGS POINT (U.S.A.)

RECIPROCAL OF FLATTENING OF WGS 298.26
RECIPROCAL OF FLATTENING OF LOCAL 294.996
SEMIMAJOR AXIS OF WGS IN METERS 6378135
SEMIMAJOR AXIS OF LOCAL POSITION 6378206.4
LATITUDE OF WGS IN DEGR. AND MIN. 40 48.75
LONGITUDE OF WGS IN DEGR. AND MIN. 73 45.64
GEOID HEIGHT +HEIGHT OF ANTENNA IN METERS -8
ORIGIN OFFSET OF X AXIS 22
ORIGIN OFFSET OF Y AXIS -157
ORIGIN OFFSET OF Z AXIS -176

RESULTS
LATITUDE 40 48.85
LONGITUDE 73 45.59
LAT SHIFT 195.63 metres
LONG. SHIFT -64.82 metres

GDYNIA (POLAND)

RECIPROCAL OF FLATTENING OF WGS 298.26
RECIPROCAL OF FLATTENING OF LOCAL 297
SEMIMAJOR AXIS OF WGS IN METERS 6378135
SEMIMAJOR AXIS OF LOCAL POSITION 6378388
LATITUDE OF WGS IN DEGR. AND MIN. 54 31
LONGITUDE OF WGS IN DEGR. AND MIN. 18 33
GEOID HEIGHT +HEIGHT OF ANTENNA IN METERS 45
ORIGIN OFFSET OF X AXIS 81
ORIGIN OFFSET OF Y AXIS 105
ORIGIN OFFSET OF Z AXIS 125

RESULTS
LATITUDE 54 31.03
LONGITUDE 18 33.06
LAT SHIFT 69.36 metres
LONG. SHIFT 73.47 metres

HONGKONG

RECIPROCAL OF FLATTENING OF WGS 298.26
RECIPROCAL OF FLATTENING OF LOCAL 297
SEMIMAJOR AXIS OF WGS IN METERS 6378135
SEMIMAJOR AXIS OF LOCAL POSITION 6378388
LATITUDE OF WGS IN DEGR. AND MIN. 22 18.256
LONGITUDE OF WGS IN DEGR. AND MIN. 114 10.779
GEOID HEIGHT +HEIGHT OF ANTENNA IN METERS 33.4
ORIGIN OFFSET OF X AXIS 84
ORIGIN OFFSET OF Y AXIS 103
ORIGIN OFFSET OF Z AXIS 127

RESULTS
LATITUDE 22 18.34
LONGITUDE 114 10.7
LAT SHIFT 159.59 metres
LONG. SHIFT -118.55 metres

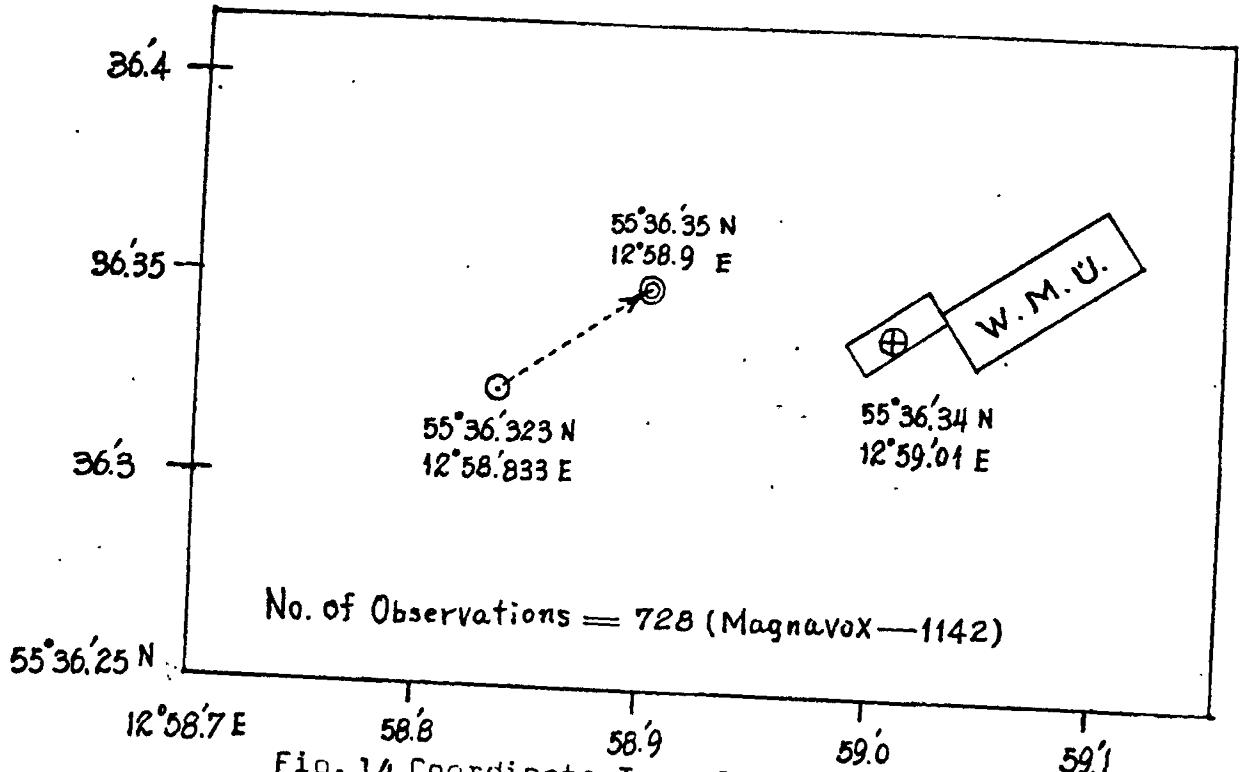


Fig. 14 Coordinate Transformation from WGS-72 to Charted Position in Malmö

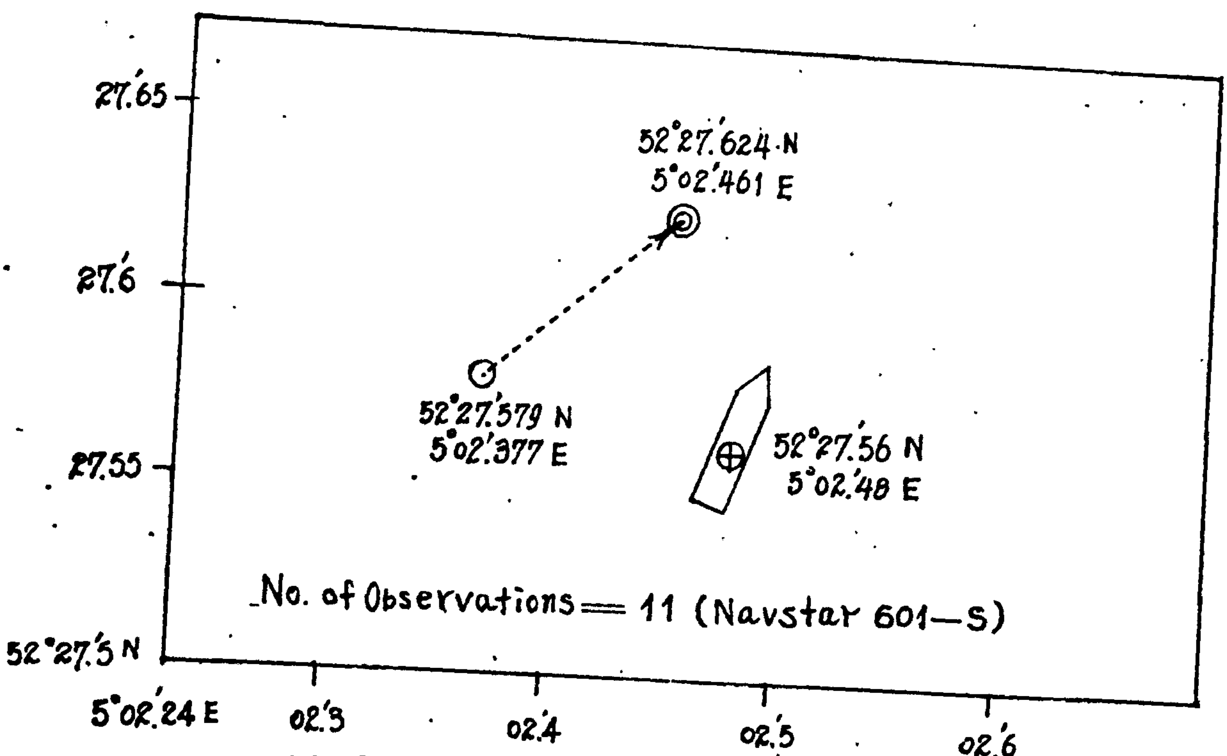


Fig. 15 Coordinate Transformation from WGS-72 to Charted Position in Amsterdam

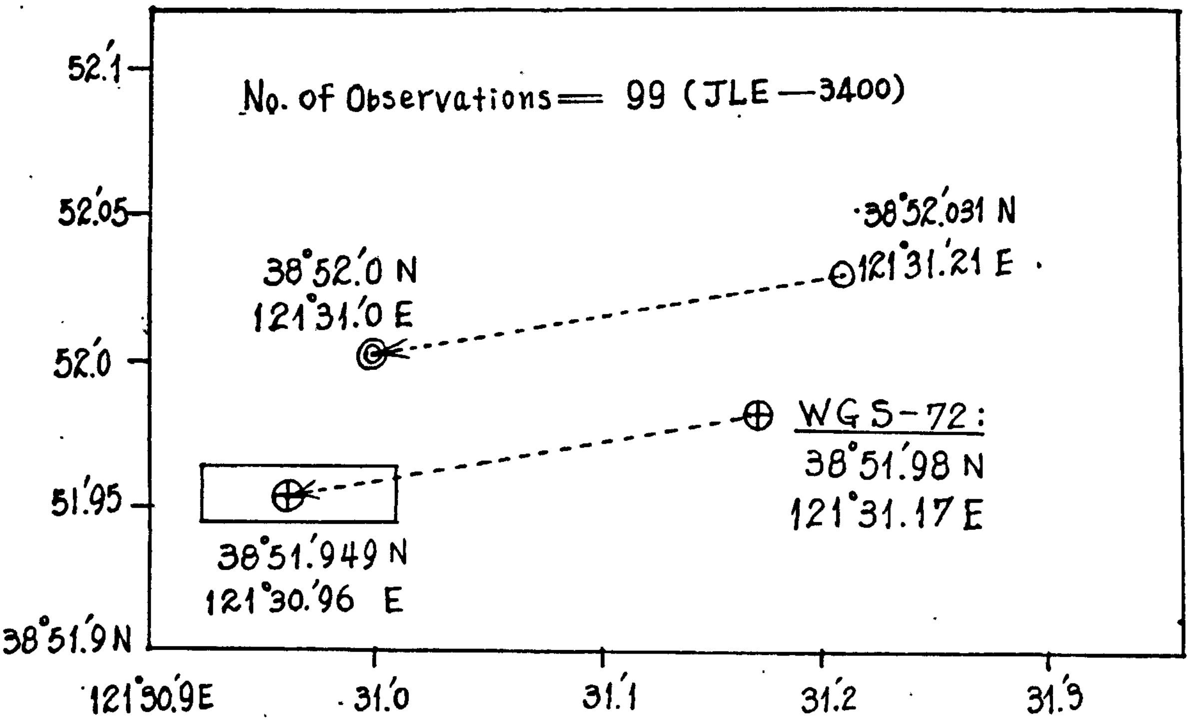


Fig. 16 Coordinate Transformation from WGS-72 to Charted Position in Dalian.

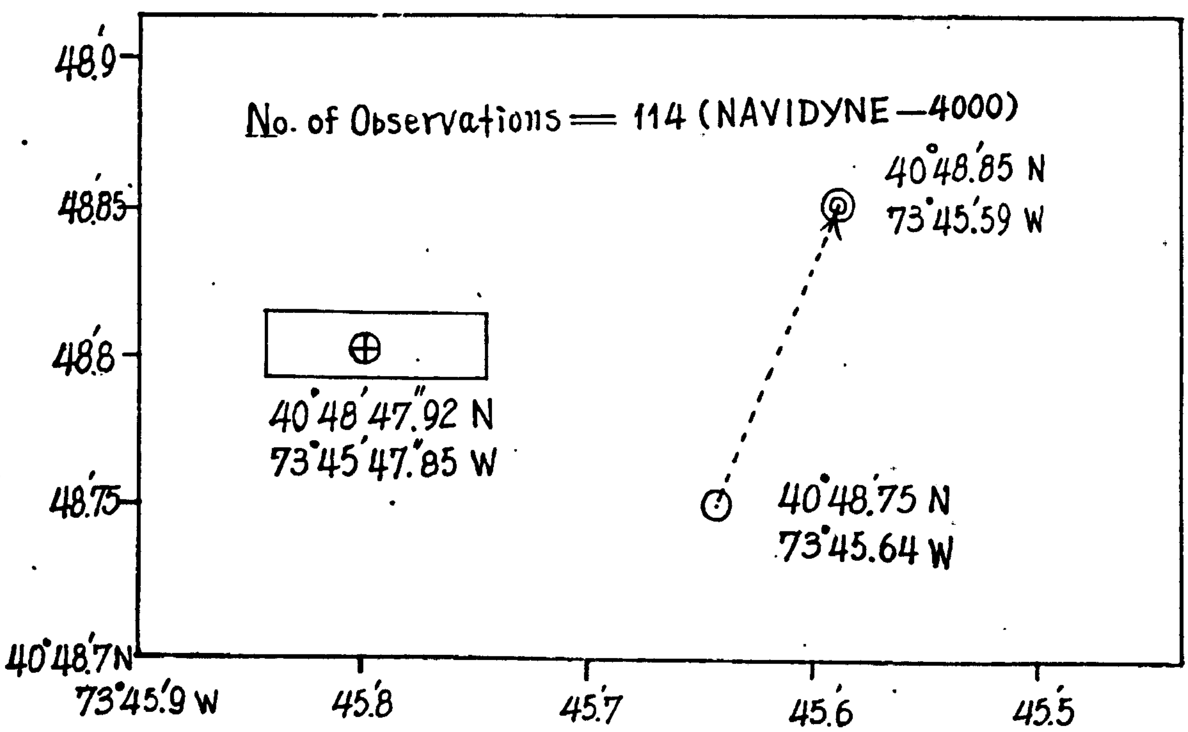


Fig.17 Coordinate Transformation from WGS-72 to Charted Position in Kings Point.

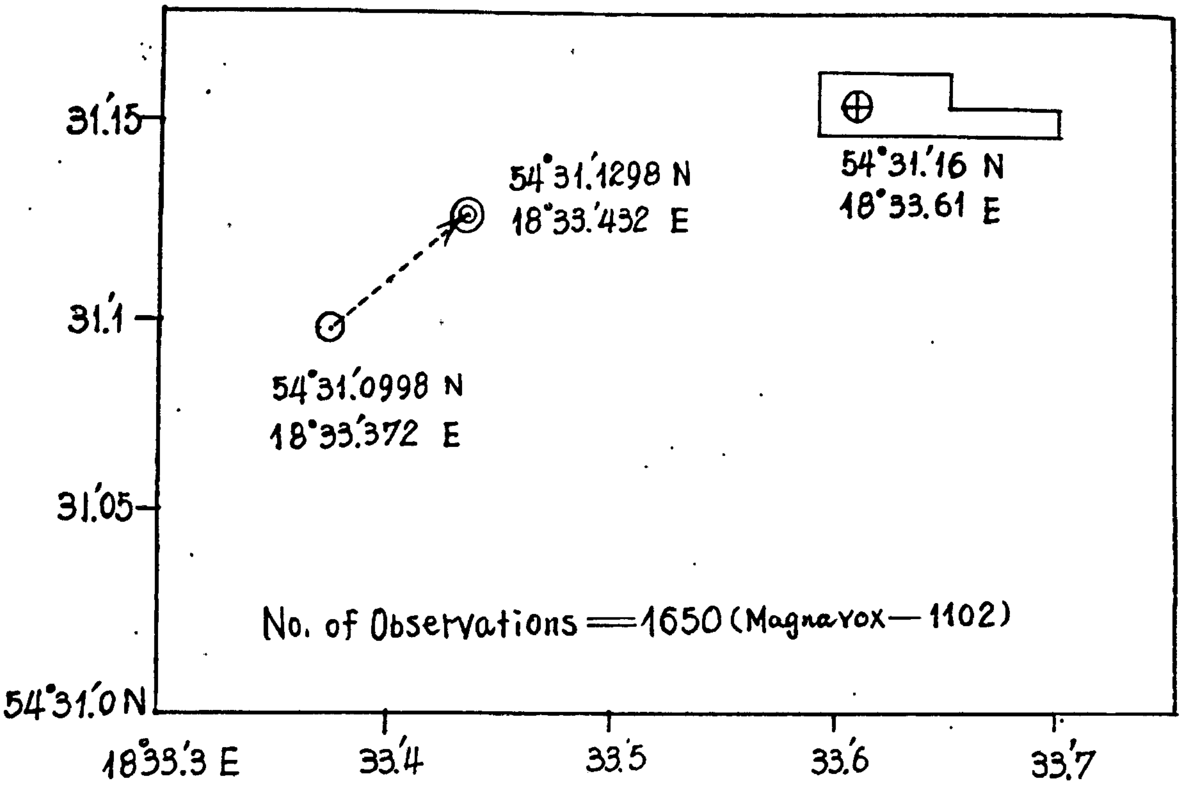


Fig.18 Coordinate Transformation from WGS-72 to Charted Position in Gdynia

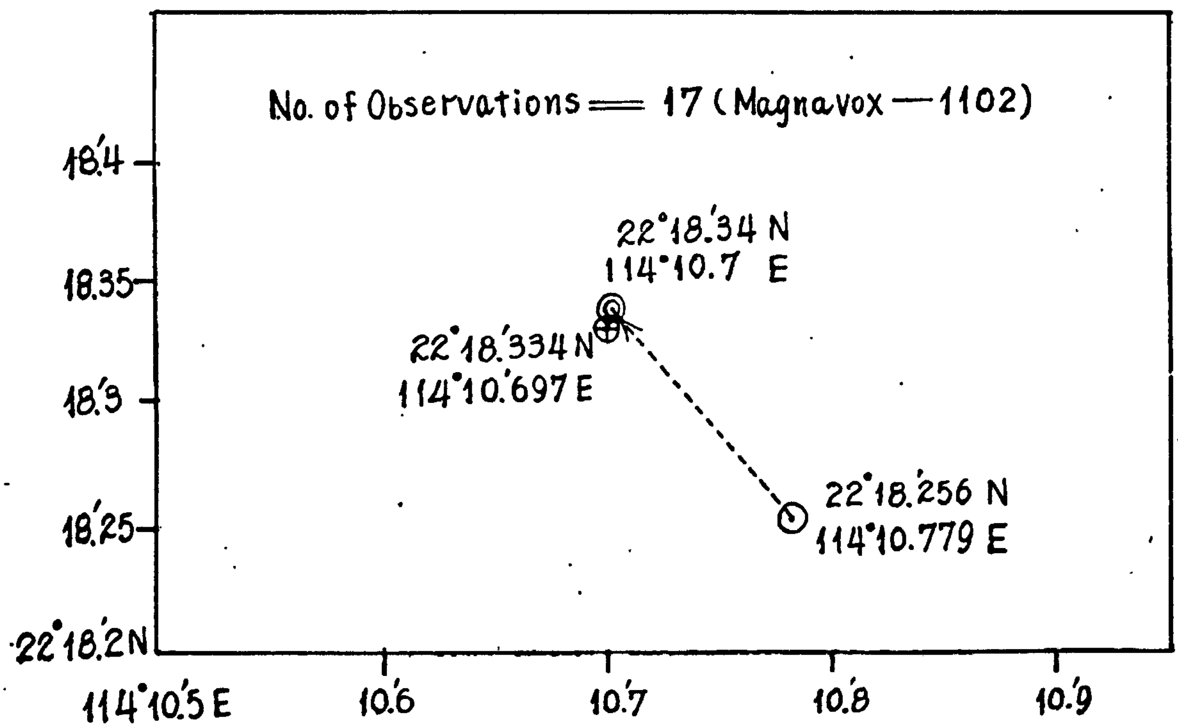


Fig.19 Coordinate Transformation from WGS-72 to Charted Position in Hongkong.

Conclusion

The data has been obtained by operation of TRANSIT Satellite Navigation Receivers of four different types in five countries and regions. The accuracy of such data has been analyzed through application of processing and calculation.

Generally speaking, analyses on the position fix accuracy revealed in other sources show that the accuracy (single frequency satellite navigation receiver) is about R95=0.2n.m. It's safe to say that the accuracy of position fix varies with different types of satellite navigation receivers being applied at different satellite elevations and observations at different times and sea areas.

From this analysis which was carried out with stationary receivers at known locations it follows:

a) Ionospheric disturbances produce large errors for either very low and very high elevations.

b) Ionospheric disturbances have largest influence during daytime.

c) The quality of the processor used in satellite navigation receivers differs with the price. High priced receivers perform better than the medium or low priced receivers.

d) The necessary coordinate shift from WGS-72 to local datum can amount to large values.

Therefore, the outcome of the above calculations serves as a reference only. A sea-going officer should be quite sure of the degree of accuracy under different circumstances, so that the captain can, to a great extent, make the right decisions according to the changing situation at sea, and as a result, effective measures can be taken for ensuring safe navigation.

It should be mentioned here again that where necessary one should correct geordetic coordinates when fixing position on a chart due to the fact that different geodetic systems are applied at different sea areas.

It is suggested, therefore, that in heavy trading areas, shift of geodetic system and WGS-72 used at the port of departure, at the port of destination and other important sea areas should be calculated well in advance. If correction is promptly made, better accuracy of ship position is maintained.

Because there is a limitation of range or accuracy in Omega System and other Navigation Aids, the TRANSIT Satellite Navigation System is the only effective one of the world-wide navigations systems. This case will extend the deadline until NAVSTAR, the new Global Position System (GPS) becomes operational end of 1988 or later.

But a ten-year overlap period from the time NAVSTAR becomes operational will allow users to operate TRANSIT equipment before having to purchase NAVSTAR equipment. The ten-year overlap also will give time for NAVSTAR manufacturers to develop, improve, and produce a sufficient range of equipment to serve the many expected applications. Thus, I feel certain that TRANSIT will continue to provide its most useful service until at least 1995 or later.

The position fix accuracy of GPS in present study:

a) The GPS fixes are free from the ship's velocity errors and the GPS-NAVSTAR receiver will provide twice the TRANSIT system accuracy.(5)

b) The resulting random range error is characterized by σ_r which is equal to the square root of the sum of all partial variances. σ_r is indicated by UERE (User Equivalent Range Error). UERE=15.3 metres.(6)

c) In the fully operational stage of the GPS (18 SV) it is expected that GDOP (Geometric Dilution of Precision) will be 6 in the worst case and so accuracy of GPS=R95 better than 180 metres.(7)

Notes

(1) "TRANSIT Satellite Position System" page 6-15
By Prof. J.H.Mulders

(2) Radio Aids, 1981 Chapter 8, page 19

(3) Supplyed by Container Ship VOYAGER of SEA-LAND U.S.A.

(4) The TRANSIT Navigation Satellite System (Magnavox)
by Thomas A. Stansell

(5) Handout of Satellite Navigation System. Page 5-29
by Prof. M.Jurdzinski

(6) TRANSIT Satellite Position System. Page 6-19
by Prof. J.H.Mulders

(7) TRANSIT Satellite Position System. Page 6-19
by Prof. J.H.Mulders.

Annex

A . Results Of Observations in Various Stations

A1 Results Of Observations (Raysat-100) in Malmö (729 Fixes)

A2 Results Of Observations (MAGNAVOX-1142) in Malmö (728 Fixes)

A3 Results Of Observations (JLE-3400) in Dalian (98 Fixes)

A4 Results Of Observations (Navidyne-4000) in King's Point (114 Fixes)

A5 Results Of Observations (Magnavox-1104) in MITAGS (100 Fixes)

A6 Results Of Observations (Magnavox-1102) in Hongkong (17 Fixes)

A7 Results Of Observations (Navstar 601-S) in The Netherlands (11 Fixes)

B Computer Programs

B1 PR1A (SHIFT)

B2 PRO (Satnav Input Program)

B3 OUT2

B4 L198 (Converting from Magnavox Data to Calculating File)

B5 L199 (Converting from Raysat Data to Calculating File)

B6 PR2A (Input Data)

B7 PR2B (Check and Correct Data)

BB PR5A (L133)

C <u>Transformation Parameters</u>

(Geodetic Datum to WGS 1972)

D <u>The Earth/The Geoid/Ellipsoids.</u>

A1 Results of Observations (Raysat-100) in Malmö (729 Fixes)

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO.	DATE Y.M.D.	TIME GMT	NUMBER
MO	RAYS	.026	-.089	.093	286.7	75	11	12 10 84	07 03 04	1
MO	RAYS	.016	.051	.054	72.1	72	20	12 10 84	07 15 25	2
MO	RAYS	-.014	.051	.053	104.7	17	19	12 10 84	07 47 39	3
MO	RAYS	.076	.161	.179	64.6	11	48	12 10 84	08 22 35	4
MO	RAYS	-.064	-.009	.064	187.8	17	13	12 10 84	08 43 04	5
MO	RAYS	-.024	-.049	.054	244.3	28	11	12 10 84	09 01 04	6
MO	RAYS	.016	-.369	.369	272.6	44	48	12 10 84	10 13 32	7
MO	RAYS	.026	-.069	.074	291.1	68	13	12 10 84	10 39 46	8
MO	RAYS	-.014	-.029	.032	244.9	54	48	12 10 84	12 02 28	9
MO	RAYS	.016	.071	.073	76.9	31	13	12 10 84	12 15 46	10
MO	RAYS	-.004	.051	.051	93.8	14	48	12 10 84	13 49 39	11
MO	RAYS	-.024	.001	.023	176.9	7	13	12 10 84	14 04 42	12
MO	RAYS	.116	.041	.124	19.5	10	19	12 10 84	14 39 11	13
MO	RAYS	-.004	.051	.051	93.8	37	19	12 10 84	16 16 07	14
MO	RAYS	.016	.041	.044	68.1	28	20	12 10 84	18 05 04	15
MO	RAYS	.026	-.009	.028	341.8	7	13	12 10 84	19 40 42	16
MO	RAYS	-.164	.051	.171	162.6	70	20	12 10 84	19 53 53	17
MO	RAYS	.036	-.059	.069	301.9	16	48	12 10 84	20 49 04	18
MO	RAYS	-.004	-.029	.029	263.2	31	13	12 10 84	21 30 00	19
MO	RAYS	.026	-.009	.028	341.8	61	48	12 10 84	22 36 28	20
MO	RAYS	.006	.031	.032	78.2	67	13	12 10 84	23 17 04	21
MO	RAYS	.026	-.029	.039	312.8	17	13	13 10 84	01 02 35	22
MO	RAYS	.016	.031	.035	62.1	18	19	13 10 84	03 24 07	23
MO	RAYS	-.004	-.009	.009	248.4	73	19	13 10 84	05 12 28	24
MO	RAYS	.026	.121	.124	77.6	29	20	13 10 84	06 07 04	25
MO	RAYS	.006	-.029	.029	282.9	29	19	13 10 84	06 58 35	26
MO	RAYS	.016	.031	.035	62.1	70	20	13 10 84	07 52 00	27
MO	RAYS	.006	.041	.042	81	7	19	13 10 84	08 42 42	28
MO	RAYS	-.174	-.209	.271	230.3	60	13	13 10 84	11 25 04	29
MO	RAYS	-.004	-.039	.039	264.9	67	48	13 10 84	11 39 46	30
MO	RAYS	.086	-.199	.217	293.5	14	13	13 10 84	13 13 39	31
MO	RAYS	.046	.051	.069	47.8	18	48	13 10 84	13 27 11	32
MO	RAYS	-.044	.081	.092	118.1	21	19	13 10 84	15 34 35	33
MO	RAYS	.036	.001	.037	2	12	20	13 10 84	16 58 07	34
MO	RAYS	.016	.041	.044	68.1	81	19	13 10 84	17 15 04	35
MO	RAYS	.016	.311	.312	87	52	20	13 10 84	18 45 04	36
MO	RAYS	.026	.031	.041	49.7	81	11	13 10 84	20 26 35	37
MO	RAYS	.066	.021	.07	17.7	13	48	13 10 84	20 49 04	38
MO	RAYS	.066	.021	.07	17.7	26	11	13 10 84	22 13 32	39
MO	RAYS	.016	.031	.035	62.1	48	48	13 10 84	22 27 18	40
MO	RAYS	.036	.141	.146	75.5	72	13	14 10 84	00 02 28	41
MO	RAYS	.036	.141	.146	75.5	39	19	14 10 84	03 41 18	42
MO	RAYS	.026	.011	.029	23	13	20	14 10 84	04 59 39	43
MO	RAYS	-.084	.021	.086	165.7	23	11	14 10 84	05 25 32	44
MO	RAYS	-.004	.001	.004	159.5	55	19	14 10 84	06 09 04	45
MO	RAYS	.026	.001	.027	2.8	52	20	14 10 84	06 43 32	46
MO	RAYS	.006	-.009	.011	307	88	11	14 10 84	07 35 39	47
MO	RAYS	-.014	.181	.182	94.2	14	19	14 10 84	07 54 07	48
MO	RAYS	.036	.081	.089	65.8	39	20	14 10 84	08 28 35	49
MO	RAYS	-.004	.041	.041	94.8	20	13	14 10 84	08 49 32	50
MO	RAYS	-.034	-.009	.035	194.6	27	48	14 10 84	09 27 32	51
MO	RAYS	.026	-.099	.102	285.1	9	20	14 10 84	10 16 14	52
MO	RAYS	.026	.131	.134	78.6	80	13	14 10 84	10 35 04	53
MO	RAYS	-.004	-.099	.099	268	4	11	14 10 84	10 48 49	54
MO	RAYS	.116	.291	.314	68.2	82	48	14 10 84	11 17 25	55
MO	RAYS	.006	.081	.082	85.4	26	13	14 10 84	12 22 35	56

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO.	DATE Y.M.D.	TIME GMT	NUMBER
MO	RAYS	.016	-.009	.019	332.3	42	19	28 10 84	17 18 00	449
MO	RAYS	.016	-.049	.051	288.8	52	19	28 10 84	18 48 07	450
MO	RAYS	-.054	-.479	.482	263.6	52	11	28 10 84	19 06 07	451
MO	RAYS	-.044	-.019	.047	203.3	9	13	28 10 84	20 10 28	452
MO	RAYS	.026	-.029	.039	312.8	57	20	28 10 84	20 37 04	453
MO	RAYS	.026	-.019	.032	324.8	37	13	28 10 84	20 58 07	454
MO	RAYS	-.014	.011	.018	140	14	20	28 10 84	21 58 00	455
MO	RAYS	.006	.121	.121	86.9	79	48	28 10 84	22 24 28	456
MO	RAYS	.016	-.009	.019	332.3	58	13	28 10 84	23 47 32	457
MO	RAYS	.016	-.009	.019	332.3	15	13	29 10 84	00 09 39	458
MO	RAYS	.096	.051	.109	28	20	19	29 10 84	02 31 39	459
MO	RAYS	.026	.001	.027	2.8	9	20	29 10 84	03 37 11	460
MO	RAYS	-.134	.001	.133	179.4	15	11	29 10 84	03 49 46	461
MO	RAYS	.516	.331	.614	32.7	81	19	29 10 84	04 19 32	462
MO	RAYS	.016	.111	.113	81.5	36	20	29 10 84	05 20 35	463
MO	RAYS	-.004	.011	.012	107	60	11	29 10 84	05 35 11	464
MO	RAYS	-.004	.151	.151	91.3	26	19	29 10 84	06 05 39	465
MO	RAYS	-.004	-.019	.019	259.6	11	13	29 10 84	07 00 42	466
MO	RAYS	-.064	-.019	.066	196.4	36	11	29 10 84	07 22 07	467
MO	RAYS	.016	-.059	.061	285.7	6	19	29 10 84	07 49 53	468
MO	RAYS	.016	-.179	.179	275.3	43	13	29 10 84	08 45 32	469
MO	RAYS	-.004	-.009	.009	248.4	48	48	29 10 84	09 12 57	470
MO	RAYS	.016	-.039	.042	293.2	51	13	29 10 84	10 32 35	471
MO	RAYS	-.014	.001	.014	174.5	50	48	29 10 84	11 01 32	472
MO	RAYS	.016	.091	.093	79.7	12	13	29 10 84	12 21 04	473
MO	RAYS	.066	.151	.165	66.3	13	48	29 10 84	12 48 35	474
MO	RAYS	-.024	.031	.039	126.8	23	19	29 10 84	14 41 39	475
MO	RAYS	.036	-.009	.038	346.6	15	20	29 10 84	16 12 35	476
MO	RAYS	.026	.021	.034	38.7	87	19	29 10 84	16 36 35	477
MO	RAYS	-.004	-.139	.139	268.6	65	20	29 10 84	17 59 04	478
MO	RAYS	.036	.031	.048	40.6	22	19	29 10 84	18 15 11	479
MO	RAYS	-.004	-.019	.019	259.6	76	11	29 10 84	19 44 00	480
MO	RAYS	.026	.071	.076	69.6	31	20	29 10 84	20 10 07	481
MO	RAYS	.026	.071	.076	69.6	8	20	29 10 84	21 27 11	482
MO	RAYS	-.054	.051	.074	136.2	25	13	29 10 84	23 20 07	483
MO	RAYS	.086	.001	.087	.9	6	13	30 10 84	01 15 39	484
MO	RAYS	.116	.121	.168	46.1	11	19	30 10 84	01 40 21	485
MO	RAYS	-.144	.121	.188	139.8	46	19	30 10 84	03 01 39	486
MO	RAYS	.016	.011	.02	34.3	16	20	30 10 84	04 13 11	487
MO	RAYS	-.054	.021	.058	158.3	32	11	30 10 84	04 46 28	488
MO	RAYS	-.004	.051	.051	93.8	49	19	30 10 84	05 16 07	489
MO	RAYS	.016	-.019	.025	311.5	65	20	30 10 84	05 57 04	490
MO	RAYS	-.004	.051	.051	93.8	68	11	30 10 84	06 32 35	491
MO	RAYS	-.004	-.049	.049	266	12	19	30 10 84	06 58 35	492
MO	RAYS	-.004	.021	.022	99.2	31	20	30 10 84	07 42 35	493
MO	RAYS	-.004	.001	.004	159.5	24	13	30 10 84	07 56 21	494
MO	RAYS	-.014	-.149	.149	264.8	16	11	30 10 84	08 20 35	495
MO	RAYS	-.014	.011	.018	140	36	48	30 10 84	08 50 00	496
MO	RAYS	.026	-.059	.064	294.3	7	20	30 10 84	09 30 14	497
MO	RAYS	.016	-.009	.019	332.3	88	13	30 10 84	09 42 14	498
MO	RAYS	-.054	-1.289	1.29	267.6	63	48	30 10 84	10 38 57	499
MO	RAYS	.026	.061	.067	66.6	22	13	30 10 84	11 30 07	500
MO	RAYS	-.004	.131	.131	91.5	16	48	30 10 84	12 26 07	501
MO	RAYS	.006	.071	.072	84.7	4	13	30 10 84	13 19 46	502
MO	RAYS	.246	.601	.65	67.7	13	19	30 10 84	13 52 35	503
MO	RAYS	.016	.011	.02	34.3	53	19	30 10 84	15 38 07	504

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO.	DATE Y.M.D.	TIME GMT	NUMBER
MO	RAYS	.016	.111	.113	81.5	10	13	07 11 84	11 58 07	729

MEAN POS. 36.363 58.909

R95 .25 nm IN METERS 462.908

M95 lat. +/- .166
M95 long. +/- .333

A2 Results of Observations (Magnavox-1142) in Malmö (728 Fixes)

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO.	DATE Y.M.D.	TIME GMT	NUMBER
MO	MAGN	.006	-.004	.008	333.2	63	19	12 10 84	06 02 28	1
MO	MAGN	.006	-.034	.034	281.4	74	11	12 10 84	07 03 04	2
MO	MAGN	-.004	.126	.127	91.5	69	20	12 10 84	07 15 25	3
MO	MAGN	.026	-.054	.06	296.6	16	19	12 10 84	07 47 39	4
MO	MAGN	.016	.056	.059	73.5	11	48	12 10 84	08 22 35	5
MO	MAGN	-.004	.026	.027	97	17	13	12 10 84	08 43 04	6
MO	MAGN	-.014	-.054	.055	256.1	28	20	12 10 84	09 01 04	7
MO	MAGN	.016	.046	.05	70.2	43	48	12 10 84	10 13 32	8
MO	MAGN	.046	-.014	.049	344	6	11	12 10 84	10 39 46	9
MO	MAGN	.006	-.014	.015	296.7	52	48	12 10 84	12 02 28	10
MO	MAGN	.006	-.014	.015	296.7	33	13	12 10 84	12 15 46	11
MO	MAGN	-.014	-.104	.104	262.7	14	48	12 10 84	13 49 39	12
MO	MAGN	-.004	-.154	.153	268.8	8	13	12 10 84	14 04 42	13
MO	MAGN	-.044	.176	.182	103.8	11	19	12 10 84	14 39 11	14
MO	MAGN	-.024	.046	.052	116.5	9	11	12 10 84	16 16 07	15
MO	MAGN	.006	.036	.037	79.5	38	11	12 10 84	18 05 04	16
MO	MAGN	.036	-.064	.073	300.1	8	13	12 10 84	19 40 42	17
MO	MAGN	.016	.016	.024	44.7	71	20	12 10 84	19 53 53	18
MO	MAGN	-.024	-.004	.023	188.4	16	48	12 10 84	20 49 04	19
MO	MAGN	.006	-.014	.015	296.7	34	13	12 10 84	21 30 00	20
MO	MAGN	.006	-.014	.015	296.7	59	48	12 10 84	22 36 28	21
MO	MAGN	.006	.036	.037	79.5	65	13	12 10 84	23 17 04	22
MO	MAGN	.016	.036	.04	65.4	17	13	13 10 84	01 02 35	23
MO	MAGN	.016	-.004	.017	348.5	17	19	13 10 84	03 24 07	24
MO	MAGN	.006	.046	.047	81.7	71	19	13 10 84	05 12 28	25
MO	MAGN	.006	.006	.009	44.2	29	20	13 10 84	06 07 04	26
MO	MAGN	.006	-.044	.044	278.8	29	19	13 10 84	06 58 35	27
MO	MAGN	.016	.006	.018	21.4	69	20	13 10 84	07 52 00	28
MO	MAGN	.016	-.094	.095	280.2	6	19	13 10 84	08 42 42	29
MO	MAGN	.026	.026	.038	44.8	59	13	13 10 84	11 25 04	30
MO	MAGN	.026	-.014	.03	333.4	65	48	13 10 84	11 39 46	31
MO	MAGN	.016	-.084	.085	281.4	15	13	13 10 84	13 13 39	32
MO	MAGN	.016	-.104	.105	279.2	18	48	13 10 84	13 27 11	33
MO	MAGN	.016	-.104	.105	279.2	23	19	13 10 84	15 34 35	34
MO	MAGN	.016	.086	.088	79	14	20	13 10 84	16 58 07	35
MO	MAGN	-.004	.076	.077	92.4	22	11	13 10 84	17 15 04	36
MO	MAGN	.006	.036	.037	79.5	53	20	13 10 84	18 45 04	37
MO	MAGN	-.014	.006	.015	153.6	13	48	13 10 84	20 26 35	38
MO	MAGN	.006	-.024	.024	286.1	27	11	13 10 84	20 49 04	39
MO	MAGN	.006	-.014	.015	296.7	47	48	13 10 84	22 13 32	40
MO	MAGN	.016	.056	.059	73.5	73	13	13 10 84	22 27 18	41
MO	MAGN	.006	.006	.009	44.2	49	48	14 10 84	00 02 28	42
MO	MAGN	-.004	.036	.037	95.1	5	11	14 10 84	03 41 18	43
MO	MAGN	-.004	.016	.017	101.1	13	20	14 10 84	04 59 39	44
MO	MAGN	-.004	.036	.037	95.1	24	11	14 10 84	05 25 32	45
MO	MAGN	.006	-.034	.034	281.4	52	19	14 10 84	06 09 04	46
MO	MAGN	-.004	.016	.017	101.1	50	20	14 10 84	06 43 32	47
MO	MAGN	.046	-.024	.052	333.4	6	48	14 10 84	07 35 39	48
MO	MAGN	.046	-.054	.071	311.2	13	19	14 10 84	07 54 07	49
MO	MAGN	-.004	-.054	.054	266.5	39	20	14 10 84	08 28 35	50
MO	MAGN	-.004	.046	.047	94	21	13	14 10 84	08 49 32	51
MO	MAGN	.006	.046	.047	81.7	28	48	14 10 84	09 27 32	52
MO	MAGN	.006	-.124	.124	273.1	9	20	14 10 84	10 16 14	53
MO	MAGN	-.004	-.164	.163	268.9	78	13	14 10 84	10 35 04	54
MO	MAGN	.066	-.024	.071	340.7	5	11	14 10 84	10 48 49	55
MO	MAGN	-.024	.346	.347	93.8	80	48	14 10 84	11 17 25	56

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO.	DATE Y.M.D.	TIME GMT	NUMBER
MO	MAGN	-.004	.056	.057	93.3	27	13	24 10 84	20 23 25	337
MO	MAGN	.016	-.004	.017	348.5	17	11	24 10 84	20 42 07	338
MO	MAGN	.006	.006	.009	44.2	53	48	24 10 84	21 40 28	339
MO	MAGN	-.074	-.104	.127	234.7	8	20	24 10 84	21 54 42	340
MO	MAGN	-.074	.056	.093	142.3	80	13	24 10 84	22 11 04	341
MO	MAGN	-.074	.056	.093	142.3	22	13	25 10 84	23 56 35	342
MO	MAGN	-.054	-.134	.144	248.2	4	13	25 10 84	01 40 49	343
MO	MAGN	.006	-.004	.008	333.2	12	19	25 10 84	02 17 39	344
MO	MAGN	.006	.036	.037	79.5	53	19	25 10 84	04 06 00	345
MO	MAGN	-.004	.016	.017	101.1	19	20	25 10 84	04 40 35	346
MO	MAGN	-.004	.036	.037	95.1	38	11	25 10 84	05 18 28	347
MO	MAGN	.016	-.054	.056	287.4	35	19	25 10 84	05 52 07	348
MO	MAGN	-.014	.006	.015	153.6	71	20	25 10 84	06 24 35	349
MO	MAGN	.016	-.044	.047	291.1	58	11	25 10 84	07 04 57	350
MO	MAGN	-.024	-.084	.087	254.4	8	19	25 10 84	07 37 11	351
MO	MAGN	-.004	-.034	.034	264.5	30	20	25 10 84	08 10 35	352
MO	MAGN	-.004	.056	.057	93.3	30	13	25 10 84	08 32 35	353
MO	MAGN	.006	-.084	.084	274.6	7	20	25 10 84	09 58 14	354
MO	MAGN	.016	.036	.04	65.4	74	13	25 10 84	10 18 35	355
MO	MAGN	.016	.106	.108	81.1	72	48	25 10 84	10 44 00	356
MO	MAGN	.016	.106	.108	81.1	20	13	25 10 84	12 06 35	357
MO	MAGN	.026	-.104	.107	284.5	20	48	25 10 84	12 31 32	358
MO	MAGN	.096	.026	.1	15.4	3	13	25 10 84	13 56 49	359
MO	MAGN	.016	.126	.128	82.5	17	19	25 10 84	14 28 35	360
MO	MAGN	.026	.136	.139	78.9	8	20	25 10 84	15 29 46	361
MO	MAGN	.016	.076	.078	77.7	65	19	25 10 84	16 14 28	362
MO	MAGN	.006	-.054	.054	277.2	33	19	25 10 84	18 01 32	363
MO	MAGN	.006	.036	.037	79.5	70	20	25 10 84	19 03 32	364
MO	MAGN	-.054	-.054	.075	225.1	7	19	25 10 84	19 50 14	365
MO	MAGN	-.004	-.004	.005	226.5	20	20	25 10 84	20 47 39	366
MO	MAGN	.006	.016	.018	67.8	42	48	25 10 84	21 18 00	367
MO	MAGN	.076	.076	.108	44.9	7	11	25 10 84	21 38 14	368
MO	MAGN	-.174	-.254	.307	235.6	4	20	25 10 84	22 29 46	369
MO	MAGN	-.004	.046	.047	94	54	48	25 10 84	23 06 28	370
MO	MAGN	-.054	-.084	.099	237.5	10	13	26 10 84	00 52 14	371
MO	MAGN	-.014	.156	.157	94.8	4	11	26 10 84	02 45 46	372
MO	MAGN	.006	-.004	.008	333.2	28	19	26 10 84	03 15 32	373
MO	MAGN	-.024	.026	.035	131.2	22	11	26 10 84	04 30 00	374
MO	MAGN	-.024	.026	.035	131.2	67	19	26 10 84	04 30 00	375
MO	MAGN	-.004	.076	.077	92.4	31	20	26 10 84	05 16 21	376
MO	MAGN	.006	-.054	.054	277.2	82	11	26 10 84	06 15 32	377
MO	MAGN	.006	-.054	.054	277.2	16	19	26 10 84	06 48 07	378
MO	MAGN	.016	-.034	.037	296.6	69	20	26 10 84	07 01 18	379
MO	MAGN	.006	.006	.009	44.2	17	13	26 10 84	07 43 11	380
MO	MAGN	-.014	-.054	.055	256.1	27	11	26 10 84	08 03 04	381
MO	MAGN	.016	.006	.018	21.4	25	48	26 10 84	08 31 32	382
MO	MAGN	.006	-.074	.074	275.3	18	20	26 10 84	08 47 39	383
MO	MAGN	.036	-.024	.044	327.5	63	13	26 10 84	09 28 57	384
MO	MAGN	.016	-.004	.017	348.5	5	11	26 10 84	09 52 42	385
MO	MAGN	-.004	-.064	.064	267.1	35	13	26 10 84	11 16 07	386
MO	MAGN	.016	-.034	.037	296.6	25	48	26 10 84	12 09 04	387
MO	MAGN	-.004	-.084	.083	267.8	8	13	26 10 84	13 05 11	388
MO	MAGN	-.004	.146	.147	91.3	9	19	26 10 84	13 39 46	389
MO	MAGN	.016	.096	.098	80.2	36	19	26 10 84	15 24 35	390
MO	MAGN	.006	.086	.087	85.5	15	20	26 10 84	16 07 39	391
MO	MAGN	.006	-.044	.044	278.8	59	19	26 10 84	17 11 04	392

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO	DATE Y.M.D.	TIME GMT	NUMBER
MO	MAGN	-.024	.046	.052	116.5	4	13	05 11 84	17 26 49	673
MO	MAGN	-.014	-.074	.075	259.8	22	19	05 11 84	17 45 32	674
MO	MAGN	.006	-.054	.054	277.2	70	11	05 11 84	18 00 42	675
MO	MAGN	.006	-.034	.034	281.4	52	20	05 11 84	18 44 57	676
MO	MAGN	-.024	.066	.071	109.2	13	48	05 11 84	18 57 46	677
MO	MAGN	-.014	.036	.039	109.9	22	13	05 11 84	19 16 35	678
MO	MAGN	.006	-.014	.015	296.7	19	11	05 11 84	19 46 07	679
MO	MAGN	-.044	-.034	.055	217.7	15	20	05 11 84	20 28 35	680
MO	MAGN	-.004	-.004	.005	226.5	47	48	05 11 84	20 44 57	681
MO	MAGN	.006	-.034	.034	281.4	82	13	05 11 84	21 04 28	682
MO	MAGN	.006	-.074	.074	275.3	3	11	05 11 84	21 29 53	683
MO	MAGN	.056	-.044	.071	322.6	8	19	06 11 84	01 10 49	684
MO	MAGN	-.034	-.034	.047	225.2	9	11	06 11 84	02 37 39	685
MO	MAGN	.006	.026	.027	75.7	40	19	06 11 84	02 59 04	686
MO	MAGN	-.004	.036	.037	95.1	35	11	06 11 84	04 22 28	687
MO	MAGN	.016	-.024	.029	305.6	47	19	06 11 84	04 46 07	688
MO	MAGN	-.004	.086	.087	92.1	44	20	06 11 84	04 57 25	689
MO	MAGN	-.004	.086	.087	92.1	5	13	06 11 84	05 42 14	690
MO	MAGN	-.004	-.084	.083	267.8	11	19	06 11 84	06 31 18	691
MO	MAGN	-.004	-.064	.064	267.1	52	20	06 11 84	06 42 49	692
MO	MAGN	-.014	.056	.058	103.2	24	13	06 11 84	07 26 35	693
MO	MAGN	-.014	-.124	.124	263.9	14	20	06 11 84	08 29 39	694
MO	MAGN	.006	.216	.217	88.2	80	48	06 11 84	09 48 28	695
MO	MAGN	.006	-.054	.054	277.2	24	13	06 11 84	11 00 07	696
MO	MAGN	.006	-.054	.054	277.2	22	48	06 11 84	11 36 00	697
MO	MAGN	.016	-.104	.105	279.2	5	13	06 11 84	12 49 46	698
MO	MAGN	.016	.086	.088	79	48	19	06 11 84	15 08 00	699
MO	MAGN	.006	.136	.137	87.2	17	11	06 11 84	15 23 11	700
MO	MAGN	-.004	.126	.127	91.5	20	20	06 11 84	15 49 32	701
MO	MAGN	.016	-.074	.075	282.9	40	19	06 11 84	16 55 04	702
MO	MAGN	.006	.056	.057	83.2	67	11	06 11 84	17 11 11	703
MO	MAGN	.016	.036	.04	65.4	72	20	06 11 84	17 36 28	704
MO	MAGN	-.004	.036	.037	95.1	12	13	06 11 84	18 25 39	705
MO	MAGN	-.004	.036	.037	95.1	9	19	06 11 84	18 43 39	706
MO	MAGN	.006	-.044	.044	278.8	32	11	06 11 84	18 57 39	707
MO	MAGN	.016	-.004	.017	348.5	32	20	06 11 84	19 21 04	708
MO	MAGN	.016	-.004	.017	348.5	46	13	06 11 84	20 14 28	709
MO	MAGN	.016	-.004	.017	348.5	8	11	06 11 84	20 42 14	710
MO	MAGN	.016	-.034	.037	296.6	8	20	06 11 84	21 04 14	711
MO	MAGN	.006	-.014	.015	296.7	47	13	06 11 84	22 01 04	712
MO	MAGN	.016	.016	.024	44.7	12	13	06 11 84	23 46 07	713
MO	MAGN	-.014	-.014	.019	225.4	16	48	07 11 84	00 01 04	714
MO	MAGN	-.004	.016	.017	101.1	21	19	07 11 84	02 08 35	715
MO	MAGN	-.014	.006	.015	153.6	20	11	07 11 84	03 34 07	716
MO	MAGN	-.004	.066	.067	92.8	20	20	07 11 84	03 49 39	717
MO	MAGN	.006	.036	.037	79.5	74	11	07 11 84	05 19 32	718
MO	MAGN	.006	-.054	.054	277.2	21	19	07 11 84	05 42 14	719
MO	MAGN	.006	.036	.037	79.5	13	13	07 11 84	06 37 11	720
MO	MAGN	.006	-.064	.064	276.1	29	11	07 11 84	07 07 04	721
MO	MAGN	.026	.036	.045	53.8	23	48	07 11 84	07 35 32	722
MO	MAGN	.006	.016	.018	67.8	50	13	07 11 84	08 22 28	723
MO	MAGN	-.024	-.194	.195	263.1	6	11	07 11 84	08 56 42	724
MO	MAGN	.016	-.104	.105	279.2	8	20	07 11 84	09 07 46	725
MO	MAGN	.016	-.104	.105	279.2	43	13	07 11 84	10 09 32	726
MO	MAGN	.026	-.054	.06	296.6	28	48	07 11 84	11 13 32	727
MO	MAGN	.006	-.074	.074	275.3	11	13	07 11 84	11 58 07	728

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO.	DATE Y.M.D.	TIME GMT	NUMBER

MEAN POS. 36.323 58.833

R95 .111 nm IN METERS 205.637

M95 lat. +/- .058
M95 long. +/- .169

A3 Results of Observations (JLE-3400) in Dalian (98 Fixes)

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO.	DATE Y.M.D.	TIME GMT	NUMBER
DL	MAGN	.02	.081	.085	75.8	24	140	830704	120000	1
DL	MAGN	-.06	.021	.063	159.7	56.2	200	830704	120000	2
DL	MAGN	-.09	-.049	.101	208.3	46.5	130	830704	120000	3
DL	MAGN	-.07	.291	.3	103.4	34.1	480	830704	120000	4
DL	MAGN	-.06	.031	.067	151.7	26.9	130	830704	120000	5
DL	MAGN	0	-.139	.138	270.3	9.3	190	830704	120000	6
DL	MAGN	-.13	-.289	.316	245.8	45.6	140	830704	120000	7
DL	MAGN	-.02	.151	.153	97.2	28	200	830704	120000	8
DL	MAGN	-.08	.001	.079	178.6	23.2	480	830704	120000	9
DL	MAGN	.04	-.009	.042	348.8	45.6	130	830704	120000	10
DL	MAGN	-.09	.171	.194	117.4	59.5	480	830704	120000	11
DL	MAGN	-.03	.101	.106	106	28.1	130	830704	120000	12
DL	MAGN	-.03	-.059	.065	243.2	20.4	140	830704	120000	13
DL	MAGN	-.08	.021	.082	164.5	10.5	200	830704	120000	14
DL	MAGN	.11	.201	.23	61.3	29.6	480	830704	120000	15
DL	MAGN	.01	-.139	.138	274.4	20.3	130	830704	120000	16
DL	MAGN	0	-.059	.058	270.7	46.9	480	830704	120000	17
DL	MAGN	-.02	.061	.065	107.3	60.5	130	830704	120000	18
DL	MAGN	.08	-.259	.27	287.4	32.7	190	830704	120000	19
DL	MAGN	.38	.121	.4	17.8	14.9	200	830704	120000	20
DL	MAGN	.22	.371	.432	59.3	12.9	200	830704	120000	21
DL	MAGN	.1	-.259	.277	291.3	16.4	480	830704	120000	22
DL	MAGN	-.25	-.339	.42	233.6	24.4	130	830704	120000	23
DL	MAGN	0	.111	.112	89.6	63.4	130	830705	120000	24
DL	MAGN	-.07	.131	.149	117.7	12.5	480	830705	120000	25
DL	MAGN	-.08	-.119	.142	236.1	31.4	190	830705	120000	26
DL	MAGN	.05	-.139	.147	290.2	59.8	140	830705	120000	27
DL	MAGN	-.06	.181	.191	108	33.3	190	830705	120000	28
DL	MAGN	-.03	.051	.06	119.4	35.3	200	830705	120000	29
DL	MAGN	.05	.001	.051	2.2	21.5	480	830705	120000	30
DL	MAGN	.12	-.029	.124	346.9	61.2	130	830705	120000	31
DL	MAGN	-.03	.011	.032	157.8	64.4	480	830705	120000	32
DL	MAGN	-.13	.111	.171	139.1	20.5	130	830705	120000	33
DL	MAGN	.16	-.039	.165	346.7	8.3	480	830705	120000	34
DL	MAGN	-.06	-.099	.115	238.8	13.6	190	830705	120000	35
DL	MAGN	0	.161	.162	89.7	54.4	140	830705	120000	36
DL	MAGN	.09	-.049	.103	332.1	43.1	200	830705	120000	37
DL	MAGN	-.07	-.069	.097	224.5	10.9	480	830705	120000	38
DL	MAGN	-.03	.071	.078	112.2	7.2	130	830705	120000	39
DL	MAGN	-.07	-.399	.404	260.1	59.1	130	830705	120000	40
DL	MAGN	-.12	.101	.157	139.5	18.1	480	830705	120000	41
DL	MAGN	.09	-.009	.091	354.9	24.1	130	830705	120000	42
DL	MAGN	.14	.071	.158	27.1	12.5	190	830705	120000	43
DL	MAGN	.05	-.259	.263	281.1	24.6	140	830705	120000	44
DL	MAGN	.01	.001	.011	10.3	10.1	200	830705	120000	45
DL	MAGN	-.1	.071	.123	144.1	48.4	140	830705	120000	46
DL	MAGN	-.04	-.009	.04	191.6	74.7	200	830705	120000	47
DL	MAGN	.02	.221	.223	84.7	86.1	480	830705	120000	48
DL	MAGN	.01	.041	.043	75.7	46.3	130	830706	120000	49
DL	MAGN	0	-.079	.078	270.5	13.2	480	830706	120000	50
DL	MAGN	.26	.391	.471	56.4	26.6	130	830706	120000	51
DL	MAGN	.01	.061	.063	80.2	48.5	130	830706	120000	52
DL	MAGN	0	.091	.092	89.6	25.1	480	830706	120000	53
DL	MAGN	-.12	-.059	.133	206	8.6	140	830706	120000	54
DL	MAGN	-.01	-.099	.098	264.6	41.4	190	830706	120000	55
DL	MAGN	-.05	-.139	.147	250.4	71.2	140	830706	120000	56

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO.	DATE Y.M.D.	TIME GMT	NUMBER
DL	MAGN	.11	-.149	.185	306.8	25.2190		830706	120000	57
DL	MAGN	.07	.191	.205	69.8	16.7140		830706	120000	58
DL	MAGN	.02	.041	.047	63.7	54.3200		830706	120000	59
DL	MAGN	.08	.101	.13	51.6	10.2480		830706	120000	60
DL	MAGN	-.06	.031	.067	151.7	10.5130		830706	120000	61
DL	MAGN	-.04	-.289	.291	262.2	70.2480		830706	120000	62
DL	MAGN	.02	-.229	.229	275.2	79.6130		830706	120000	63
DL	MAGN	.12	-.149	.191	309.2	19.2480		830706	120000	64
DL	MAGN	.32	-.079	.33	346.3	7.9 140		830706	120000	65
DL	MAGN	.13	-.039	.136	343.8	20.6200		830706	120000	66
DL	MAGN	-.03	.071	.078	112.2	18.8140		830706	120000	67
DL	MAGN	.03	-.419	.419	274.2	66.1200		830706	120000	68
DL	MAGN	.1	-.009	.101	355.4	10.8130		830706	120000	69
DL	MAGN	-.08	.061	.101	142	40.7480		830706	120000	70
DL	MAGN	.03	.151	.155	78.6	34.3480		830706	120000	71
DL	MAGN	.01	.021	.024	64	16.1130		830706	120000	72
DL	MAGN	-.03	-.029	.041	223.8	17.1190		830706	120000	73
DL	MAGN	-.03	-.089	.093	251.6	29.4140		830706	120000	74
DL	MAGN	-.05	-.199	.204	256	61.7190		830706	120000	75
DL	MAGN	-.11	-.009	.11	184.2	40.5140		830707	120000	76
DL	MAGN	-.01	-.069	.069	262.2	48.4200		830707	120000	77
DL	MAGN	.03	-.009	.032	345.3	26.3200		830707	120000	78
DL	MAGN	-.02	.061	.065	107.3	51.4480		830707	120000	79
DL	MAGN	-.04	-.089	.096	246	34.9130		830707	120000	80
DL	MAGN	-.13	.031	.133	166.1	26.8480		830707	120000	81
DL	MAGN	-.07	.111	.132	121.8	45.4140		830707	120000	82
DL	MAGN	-.11	-.179	.209	238.5	41.7200		830707	120000	83
DL	MAGN	-.07	.061	.093	138.2	32.4200		830707	120000	84
DL	MAGN	-.32	.201	.378	147.7	29.6480		830707	120000	85
DL	MAGN	-.06	-.079	.098	232.8	34.5130		830707	120000	86
DL	MAGN	-.04	-.079	.087	243.3	46.8480		830707	120000	87
DL	MAGN	-.03	.101	.106	106	37 130		830707	120000	88
DL	MAGN	-.06	-.049	.076	219	55.1190		830707	120000	89
DL	MAGN	-.1	-.039	.106	201	14.5200		830707	120000	90
DL	MAGN	.2	.301	.363	56.4	18.8190		830707	120000	91
DL	MAGN	.14	-.129	.19	317.7	12 200		830707	120000	92
DL	MAGN	-.01	-.069	.069	262.2	14.8130		830707	120000	93
DL	MAGN	-.04	.121	.128	107.9	11.1130		830707	120000	94
DL	MAGN	.08	.051	.096	32.8	10.2140		830707	120000	95
DL	MAGN	-.08	.091	.121	130.8	51.3190		830707	120000	96
DL	MAGN	-.02	.121	.123	99	15.4140		830707	120000	97
DL	MAGN	.14	.161	.215	49	15.4200		830707	120000	98

MEAN POS. 52.029 31.228

R95 .313 nm IN METERS 580.084

M95 lat. +/- .203
M95 long. +/- .295

A4 Results of Observations (Navidyne-4000) in King's Point
(114 Fixes)

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO.	DATE Y.M.D.	TIME GMT	NUMBER
KP	ND	-.005	.023	.023	101	33	0	841011	122400	1
KP	ND	-.065	-.177	.188	250	73	0	841011	134400	2
KP	ND	.075	.153	.171	63.7	9	0	841011	152800	3
KP	ND	-.105	.073	.127	145	33	0	841012	23200	4
KP	ND	.005	-.107	.107	273	36	0	841012	35400	5
KP	ND	.105	-.117	.158	312.1	47	0	841012	43000	6
KP	ND	-.015	-.027	.031	241.7	38	0	841012	54000	7
KP	ND	.005	.123	.123	87.4	30	0	841012	62000	8
KP	ND	-.015	.003	.015	168	14	0	841012	94600	9
KP	ND	-.175	.013	.175	175.7	42	0	841012	122800	10
KP	ND	-.055	-.057	.079	226.3	11	0	841012	131800	11
KP	ND	.015	.103	.104	81.4	32	0	841012	142000	12
KP	ND	-.045	.113	.122	111.5	26	0	841012	155400	13
KP	ND	-.025	-.027	.036	227.7	54	0	841012	174200	14
KP	ND	-.035	.043	.055	128.7	26	0	841015	23600	15
KP	ND	-.025	.013	.028	151.9	21	0	841015	31000	16
KP	ND	-.015	.053	.055	105.3	59	0	841015	45800	17
KP	ND	-.015	-.087	.088	260.5	9	0	841015	64000	18
KP	ND	.075	.263	.274	74	12	0	841015	65800	19
KP	ND	.015	.043	.046	70.2	57	0	841015	105200	20
KP	ND	.005	-.077	.077	274.1	26	0	841015	114600	21
KP	ND	-.015	.053	.055	105.3	20	0	841015	123200	22
KP	ND	-.005	.143	.143	91.8	53	0	841015	133400	23
KP	ND	.015	.203	.204	85.6	25	0	841015	142400	24
KP	ND	.035	-.037	.051	313.9	8	0	841015	144200	25
KP	ND	.035	-.157	.161	282.8	21	0	841015	151000	26
KP	ND	.035	.033	.049	42.9	62	0	841015	163400	27
KP	ND	-.035	-.117	.122	253.6	23	0	841015	182200	28
KP	ND	-.015	-.047	.049	252.9	77	0	841015	191600	29
KP	ND	-.025	.003	.025	172.8	26	0	851017	31600	30
KP	ND	.035	-.047	.059	307.1	57	0	851017	42600	31
KP	ND	-.005	-.007	.008	237.2	50	0	851017	50400	32
KP	ND	.065	.233	.242	74.3	24	0	851017	61400	33
KP	ND	-.065	.083	.105	127.8	9	0	851017	90800	34
KP	ND	-.005	-.127	.127	268	64	0	851017	105800	35
KP	ND	.025	-.087	.091	286.4	34	0	851017	115600	36
KP	ND	.125	-.487	.503	284.5	29	0	851017	120800	37
KP	ND	-.015	-.107	.108	262.3	15	0	851017	124200	38
KP	ND	-.035	.093	.099	110.3	40	0	851017	134200	39
KP	ND	.025	-.007	.026	344.8	26	0	851017	151600	40
KP	ND	.005	-.007	.009	308.6	34	0	851017	154800	41
KP	ND	.055	.073	.092	52.8	47	0	851017	170400	42
KP	ND	-.045	-.097	.107	245.4	41	0	851017	173800	43
KP	ND	.095	-.167	.192	299.8	43	0	851018	173800	44
KP	ND	-.025	.143	.145	99.7	33	0	841018	55200	45
KP	ND	-.025	-.047	.053	242.5	31	0	841018	100800	46
KP	ND	.075	-.157	.174	295.7	8	0	841018	105800	47
KP	ND	-.005	-.067	.067	266.2	35	0	841018	115400	48
KP	ND	-.005	.063	.063	94.1	60	0	841018	124400	49
KP	ND	.035	-.087	.094	292.2	11	0	841018	143000	50
KP	ND	-.035	.043	.055	128.7	24	0	841018	152600	51
KP	ND	.035	.123	.128	73.9	64	0	841018	161400	52
KP	ND	-.035	-.217	.22	261	58	0	841018	171400	53
KP	ND	-.075	.003	.075	177.6	8	0	841019	31200	54
KP	ND	.005	-.007	.009	308.6	31	0	841019	34000	55
KP	ND	-.005	-.067	.067	266.2	38	0	841019	51000	56

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO.	DATE Y.M.D.	TIME GMT	NUMBER
KP	ND	.045	.053	.07	49.4	45	0	841019	52800	57
KP	ND	-.015	.023	.027	122.1	13	0	841019	91600	58
KP	ND	.035	-.037	.051	313.9	19	0	841019	113600	59
KP	ND	-.015	-.077	.078	259.3	45	0	841019	130400	60
KP	ND	.005	-.067	.067	274.7	11	0	841019	134800	61
KP	ND	-.015	.123	.124	96.7	57	0	841019	142000	62
KP	ND	.025	.203	.205	82.8	29	0	841019	145000	63
KP	ND	-.055	.083	.099	123.3	18	0	841019	150200	64
KP	ND	.025	-.007	.026	344.8	34	0	841019	152400	65
KP	ND	.025	-.047	.053	298.5	20	0	841022	144000	66
KP	ND	-.015	.033	.036	113.6	41	0	841022	154400	67
KP	ND	.015	-.257	.257	273.5	65	0	841022	162600	68
KP	ND	-.015	-.167	.168	265	34	0	841022	173200	69
KP	ND	-.045	.273	.277	99.3	9	0	841022	181200	70
KP	ND	.125	-.227	.259	298.9	8	0	841022	203400	71
KP	ND	-.045	-.497	.499	264.9	56	0	841023	20400	72
KP	ND	.085	-.087	.122	314.5	53	0	841023	33800	73
KP	ND	.065	.003	.066	2.7	23	0	841023	52200	74
KP	ND	.015	.173	.174	84.9	26	0	841023	54600	75
KP	ND	-.025	.023	.034	136.7	22	0	841023	93000	76
KP	ND	.125	-.107	.165	319.6	6	0	841023	103000	77
KP	ND	-.165	.033	.168	168.6	26	0	841024	24600	78
KP	ND	-.015	-.037	.04	248.6	40	0	841024	33400	79
KP	ND	.015	.013	.02	40.1	51	0	841024	43400	80
KP	ND	-.005	.123	.123	92.1	35	0	841024	52400	81
KP	ND	-.115	.003	.115	178.5	8	0	841024	83800	82
KP	ND	.005	-.127	.127	272.5	60	0	841024	102800	83
KP	ND	-.195	-.037	.198	190.8	15	0	841024	121400	84
KP	ND	-.045	.023	.05	152.6	67	0	841024	125400	85
KP	ND	-.045	.063	.077	125.2	36	0	841024	131800	86
KP	ND	.145	.173	.226	49.9	10	0	841024	143800	87
KP	ND	-.005	.173	.173	91.5	22	0	841024	145600	88
KP	ND	.005	.093	.093	86.6	49	0	841024	162600	89
KP	ND	-.015	-.027	.031	241.7	61	0	841024	164800	90
KP	ND	-.255	-.067	.263	194.7	9	0	841024	193200	91
KP	ND	.235	-.047	.24	348.7	11	0	841024	204000	92
KP	ND	.005	.133	.133	87.6	70	0	841024	222800	93
KP	ND	-.215	.003	.214	179.2	12	0	841025	21400	94
KP	ND	.025	-.107	.11	283.4	30	0	841025	31200	95
KP	ND	.025	.143	.145	79.9	48	0	841025	50000	96
KP	ND	-.015	.053	.055	105.3	18	0	841025	52800	97
KP	ND	-.005	-.037	.037	263.1	28	0	841025	93800	98
KP	ND	.045	-.077	.089	300.6	17	0	841025	104200	99
KP	ND	.005	-.017	.018	288.1	37	0	841025	112400	100
KP	ND	-.015	.003	.015	168	34	0	841025	114400	101
KP	ND	.005	.143	.143	87.8	36	0	841025	133000	102
KP	ND	.155	-.047	.162	343.2	11	0	841025	135600	103
KP	ND	.165	.213	.27	52.2	12	0	841025	141600	104
KP	ND	-.045	.143	.15	107.3	16	0	841025	143400	105
KP	ND	.055	-.037	.067	326.4	33	0	841026	145400	106
KP	ND	-.005	-.007	.008	237.2	66	0	841026	160200	107
KP	ND	-.025	.043	.05	119.6	40	0	841026	164000	108
KP	ND	-.035	-.057	.067	238.8	11	0	841026	174800	109
KP	ND	.035	.193	.196	79.6	20	0	841028	54000	110
KP	ND	-.065	.023	.068	160.3	16	0	841028	85400	111
KP	ND	.015	-.067	.069	283.1	9	0	841028	100000	112

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO.	DATE Y.M.D.	TIME GMT	NUMBER
KP	ND	-.005	.063	.063	94.1	66	0	841028	104200	113
KP	ND	.015	.033	.037	64.9	8	0	841028	122400	114

MEAN POS. 48.754 45.667

R95 .234 nm IN METERS 433.538

M95 lat. +/- .135
M95 long. +/- .244

A5 Results of Observations (Magnavox-1104) in MITAGS (100 Fixes)

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO.	DATE Y.M.D.	TIME GMT	NUMBER
MI	MAGN	-.008	-.021	.022	248.9	15	13	850101	214600	1
MI	MAGN	.022	-.131	.133	279.6	26	48	850101	224400	2
MI	MAGN	.012	.219	.22	86.9	78	13	850101	233600	3
MI	MAGN	.022	-.051	.055	293.5	11	13	850102	11600	4
MI	MAGN	.012	-.021	.024	300.1	55	50	850102	50800	5
MI	MAGN	.032	-.121	.125	284.8	10	20	850102	62400	6
MI	MAGN	.062	.189	.199	71.9	24	50	850102	65600	7
MI	MAGN	-.018	.079	.081	102.8	61	11	850102	73400	8
MI	MAGN	-.038	-.081	.089	244.8	78	20	850102	81200	9
MI	MAGN	.012	.129	.13	84.7	20	11	850102	92000	10
MI	MAGN	.022	-.091	.093	283.6	15	13	850102	94600	11
MI	MAGN	-.048	-.061	.077	231.7	14	48	850102	100800	12
MI	MAGN	.162	.029	.165	10.3	11	13	850102	132000	13
MI	MAGN	-.028	.009	.03	161.6	15	48	850102	134400	14
MI	MAGN	-.008	-.131	.131	266.5	31	50	850102	163200	15
MI	MAGN	-.028	-.121	.124	256.9	43	50	850102	182000	16
MI	MAGN	.002	-.051	.051	272.3	28	11	850102	184600	17
MI	MAGN	-.008	.019	.021	112.5	26	20	850102	191200	18
MI	MAGN	.002	-.051	.051	272.3	45	11	850102	203200	19
MI	MAGN	-.018	-.021	.027	229	38	20	850102	205800	20
MI	MAGN	.142	.059	.154	22.7	19	48	850102	222200	21
MI	MAGN	.032	-.021	.038	327.1	47	13	850102	224600	22
MI	MAGN	.002	.089	.089	88.7	73	48	850103	1000	23
MI	MAGN	-.048	-.041	.063	220.3	27	13	850103	3200	24
MI	MAGN	.142	.039	.147	15.5	11	48	850103	15800	25
MI	MAGN	.012	-.081	.082	278.5	41	50	850103	44400	26
MI	MAGN	.002	.139	.139	89.2	33	50	850103	63200	27
MI	MAGN	.012	.029	.032	67.7	27	11	850103	64400	28
MI	MAGN	.022	-.051	.055	293.5	23	20	850103	70200	29
MI	MAGN	-.018	.109	.111	99.4	46	11	850103	83000	30
MI	MAGN	.072	.039	.082	28.6	47	20	850103	84800	31
MI	MAGN	-.028	-.021	.035	216.5	9	48	850103	94200	32
MI	MAGN	.002	-.031	.031	273.7	45	13	850103	104400	33
MI	MAGN	-.058	-.111	.125	242.3	63	48	850103	113400	34
MI	MAGN	-.108	-.031	.112	195.9	21	48	850103	132200	35
MI	MAGN	.002	-.041	.041	272.8	23	50	850103	160800	36
MI	MAGN	-.168	-.171	.24	225.5	54	50	850103	175800	37
MI	MAGN	.002	-.141	.141	270.8	80	11	850103	193800	38
MI	MAGN	-.028	.029	.041	133.7	59	20	850103	195000	39
MI	MAGN	.022	.049	.054	66	20	13	850103	215200	40
MI	MAGN	-.058	-.021	.062	199.6	8	13	850104	12400	41
MI	MAGN	.062	-.111	.127	299.3	29	50	850104	42200	42
MI	MAGN	.022	.119	.121	79.6	46	50	850104	61000	43
MI	MAGN	-.018	.029	.034	121.6	49	20	850104	74200	44
MI	MAGN	.052	.159	.168	71.9	21	20	850104	92400	45
MI	MAGN	.062	-.071	.094	311.2	20	13	850104	95400	46
MI	MAGN	-.028	-.091	.095	252.8	48	48	850104	111400	47
MI	MAGN	.002	.119	.119	89	58	13	850104	114000	48
MI	MAGN	-.038	-.011	.039	195.7	28	48	850104	130000	49
MI	MAGN	-.008	-.001	.008	185	16	50	850104	154400	50
MI	MAGN	.002	.109	.109	89	79	50	850104	173400	51
MI	MAGN	-.008	-.031	.032	255.4	16	20	850104	184000	52
MI	MAGN	.022	-.051	.055	293.5	37	11	850104	185400	53
MI	MAGN	.022	-.071	.074	287.3	12	50	850104	192000	54
MI	MAGN	-.008	-.051	.051	261	59	20	850104	202600	55
MI	MAGN	.012	.009	.015	37.8	33	11	850104	204000	56

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO.	DATE Y.M.D.	TIME GMT	NUMBER
MI	MAGN	.012	-.021	.024	300.1	60	13	850104	225200	57
MI	MAGN	.002	.009	.01	77.9	59	48	850104	232600	58
MI	MAGN	.052	-.111	.122	295.2	21	13	850105	3800	59
MI	MAGN	.102	.199	.224	62.9	22	48	850105	11400	60
MI	MAGN	.082	-.111	.138	306.5	22	50	850105	35800	61
MI	MAGN	-.008	.149	.15	93.1	60	50	850105	54800	62
MI	MAGN	.132	.059	.145	24.2	14	20	850105	63000	63
MI	MAGN	.032	-.081	.087	291.6	36	11	850105	65400	64
MI	MAGN	-.028	.149	.152	100.6	76	20	850105	81600	65
MI	MAGN	.012	.149	.15	85.4	34	11	850105	84000	66
MI	MAGN	-.058	.009	.059	170.9	11	50	850105	152000	67
MI	MAGN	-.008	-.061	.061	262.5	73	50	850105	171200	68
MI	MAGN	.012	-.041	.042	286.4	16	11	850105	180400	69
MI	MAGN	.002	-.081	.081	271.4	18	50	850105	185800	70
MI	MAGN	.012	-.031	.033	291.3	36	20	850105	191600	71
MI	MAGN	-.008	.009	.012	130.7	76	11	850105	195200	72
MI	MAGN	-.028	-.031	.042	227.6	27	20	850105	210200	73
MI	MAGN	.062	-.071	.094	311.2	27	13	850105	220200	74
MI	MAGN	.022	-.011	.024	334.1	45	48	850105	230200	75
MI	MAGN	-.008	-.011	.013	233.2	44	13	850105	234800	76
MI	MAGN	.022	.209	.21	84	30	48	850106	5200	77
MI	MAGN	-.018	-.031	.036	239.6	31	20	850106	71000	78
MI	MAGN	-.018	.179	.18	95.7	65	11	850106	75200	79
MI	MAGN	-.008	.179	.179	92.6	33	20	850106	85200	80
MI	MAGN	.012	-.101	.101	276.8	26	13	850106	100000	81
MI	MAGN	-.038	.079	.088	115.6	26	48	850106	102600	82
MI	MAGN	-.648	.129	.661	168.7	47	13	850106	114800	83
MI	MAGN	-.018	-.011	.021	210.7	76	48	850106	121600	84
MI	MAGN	-.018	-.031	.036	239.6	54	50	850106	165000	85
MI	MAGN	-.018	-.081	.083	257.4	24	50	850106	183600	86
MI	MAGN	-.008	-.081	.081	264.3	46	11	850106	190400	87
MI	MAGN	.002	-.131	.131	270.9	73	20	850106	195400	88
MI	MAGN	-.048	-.071	.085	235.8	26	11	850106	204800	89
MI	MAGN	.012	-.041	.042	286.4	11	13	850106	210800	90
MI	MAGN	.002	-.071	.071	271.6	12	20	850106	213600	91
MI	MAGN	.022	-.081	.084	285.2	33	48	850106	224000	92
MI	MAGN	-.008	-.151	.151	267	70	13	850106	224000	93
MI	MAGN	.012	.189	.19	86.4	42	48	850107	2800	94
MI	MAGN	.032	-.001	.032	358.7	15	13	850107	4200	95
MI	MAGN	-.008	-.081	.081	264.3	65	50	850107	50200	96
MI	MAGN	.022	.159	.161	82.1	25	11	850107	84800	97
MI	MAGN	-.018	.069	.072	104.6	65	48	850107	115400	98
MI	MAGN	.092	.129	.159	54.6	15	13	850107	124400	99
MI	MAGN	-.008	-.051	.051	261	11	48	850107	133800	100

MEAN POS. 12.828 40.271

R95 .218 nm IN METERS 403.752

M95 lat. +/- .157
M95 long. +/- .186

A6 Results Observations (Magnavox-1102) in Hongkong (17 Fixes)

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO.	DATE Y.M.D.	TIME GMT	NUMBER
HK	MAGN	.004	.031	.031	82.5	17	110	850425	5111	1
HK	MAGN	.024	.091	.094	75.2	12	130	850425	12518	2
HK	MAGN	-.016	.131	.132	96.9	66	130	850425	31207	3
HK	MAGN	-.026	-.059	.064	246.3	32	450	850425	43532	4
HK	MAGN	-.006	.051	.052	96.6	24	200	850426	5311	5
HK	MAGN	-.026	.001	.026	177.4	48	130	850426	22207	6
HK	MAGN	-.076	-.059	.096	217.8	18	130	850426	40814	7
HK	MAGN	-.076	-.059	.096	217.8	18	130	850426	40814	8
HK	MAGN	.084	-.179	.198	295.2	22	500	850426	103014	9
HK	MAGN	.004	-.029	.029	278.1	11	110	850426	5911	10
HK	MAGN	.014	.061	.063	77	18	130	850426	13207	11
HK	MAGN	.024	.061	.066	68.5	13	480	850426	20207	12
HK	MAGN	-.006	.141	.141	92.4	69	450	850426	35000	13
HK	MAGN	.054	.071	.089	52.8	17	200	850429	5746	14
HK	MAGN	.034	.021	.04	31.8	25	130	850429	13842	15
HK	MAGN	.004	-.029	.029	278.1	59	480	850429	30428	16
HK	MAGN	-.016	-.249	.249	266.3	16	480	850429	45311	17

MEAN POS. 18.256 10.779

R95 .206 nm IN METERS 381.577

M95 lat. +/- .079
M95 long. +/- .2

A7 Results of Observations (NAVSTAR 601-S) in The Netherlands (11 Fixes)

PLACE	REC. TYPE	LAT DIF.	LON DIF.	POS. DIS	POS. DIR.	EL	SAT. NO.	DATE Y.M.D.	TIME GMT	NUMBER
HL	MAGN	0	-.298	.297	270.2	58	480	850617	100000	1
HL	MAGN	0	.052	.053	89	14	500	850617	124200	2
HL	MAGN	.02	.082	.085	75.8	29	110	850617	155000	3
HL	MAGN	.02	.132	.134	81	28	480	850618	75000	4
HL	MAGN	-.49	.052	.492	173.8	17	480	850618	112000	5
HL	MAGN	.19	-.108	.219	330.7	11	500	850618	122200	6
HL	MAGN	.02	.062	.066	71.6	47	500	850618	140600	7
HL	MAGN	.12	.052	.132	23.6	16	110	850618	150000	8
HL	MAGN	.07	-.228	.238	287.3	36	480	850621	102000	9
HL	MAGN	.02	.022	.031	47.4	18	480	850624	110000	10
HL	MAGN	.02	.172	.174	83.1	43	500	850624	133600	11

MEAN POS. 27.579 2.377

R95 .389 nm IN METERS 720.975

M95 lat. +/- .338
M95 long. +/- .289

Annex B Computer Program

B1 PR1A

```
10 REM * * *  PR1A(SHIFT) * * *
20 REM MED(N) OF W.M.U.  LI LIANTING
30 REM VER 85-04-09
40 REM 16.45
50 DOUBLE
60 ; "HAVE YOU A PRINTER ? (Y/N)  ";
70 GET A$
80 ; A$
90 IF A$="y" OR A$="Y" THEN A$="Y" : GOTO 130
100 IF A$="n" OR A$="N" THEN A$="N" : GOTO 130
110 ;
120 GOTO 60
130 IF A$="N" THEN 150
140 OPEN "PR:" AS FILE 1
150 REM SHIFT FROM WGS-72 TO LOCAL CHART DATUM
160 INPUT "RECIPROCAL OF FLATTENING OF WGS";F9
170 IF A$="N" THEN 190
180 PRINT #1 "RECIPROCAL OF FLATTENING OF WGS";F9
190 F9=1/F9
200 INPUT "RECIPROCAL OF FLATTENING OF LOCAL ELLIPSOID ";F8
210 IF A$="N" THEN 230
220 PRINT #1 "RECIPROCAL OF FLATTENING OF LOCAL ELLIPSOID ";F8
230 F8=1/F8
240 INPUT "SEMIMAJOR AXIS OF WGS IN METERS";A9
250 INPUT "SEMIMAJOR AXIS OF LOCAL ELLIPSOID";A8
260 IF A$="N" THEN 290
270 PRINT #1 "SEMIMAJOR AXIS OF WGS IN METERS ";A9
280 PRINT #1 "SEMIMAJOR AXIS OF LOCAL ELLIPSOID";A8
290 E9=SQR(2*F9-F9*F9)
300 E8=SQR(2*F8-F8*F8)
310 D=180/(4*ATN(1))
320 INPUT "LATITUDE OF WGS IN DEGR. AND MIN. "W1,W2
330 B9=W1+W2/60
340 INPUT "LONGITUDE OF WGS IN DEGR. AND MIN. ";W3,W4
350 L9=W3+W4/60
360 IF A$="N" THEN 390
370 PRINT #1 "LATITUDE OF WGS IN DEGR. AND MIN. " W1;W2
380 PRINT #1 "LONGITUDE OF WGS IN DEGR. AND MIN. ";W3;W4
390 L9=L9/D
400 B9=B9/D
410 INPUT "GEOID HEIGHT ";H9
420 INPUT "ORIGIN OFFSET OF X AXIS";X7
430 INPUT "ORIGIN OFFSET OF Y AXIS";Y7
440 INPUT "ORIGIN OFFSET OF Z AXIS";Z7
450 IF A$="N" THEN 500
460 PRINT #1 "GEOID HEIGHT";H9
470 PRINT #1 "ORIGIN OFFSET OF X AXIS ";X7
480 PRINT #1 "ORIGIN OFFSET OF Y AXIS ";Y7
490 PRINT #1 "ORIGIN OFFSET OF Z AXIS ";Z7
500 N9=A9/SQR(1-(E9*E9*SIN(B9)*SIN(B9)))
510 X9=(N9+H9)*COS(B9)*COS(L9)
520 Y9=(N9+H9)*COS(B9)*SIN(L9)
530 Z9=(N9*(1-E9Ü2)+H9)*SIN(B9)
540 X8=X9+X7
550 Y8=Y9+Y7
560 Z8=Z9+Z7
570 L8=ATN(Y8/X8)*D
580 IF Y8>0 AND X8>0 GOTO 620
590 IF Y8>0 AND X8<0 GOTO 640
600 IF Y8<0 AND X8<0 GOTO 640
610 IF Y8<0 AND X8>0 GOTO 660
620 L8=L8
630 GOTO 680
640 L8=180+L8
650 GOTO 680
```

```
670 GOTO 680
680 PRINT
690 PRINT "RESULTS "
700 W3=FIX(L8)
710 W2=L8-W3
720 W1=60*W2
730 B0=B9
740 N8=A8/SQR(1-(E8*E8*SIN(B0)*SIN(B0)))
750 H8=Z8/SIN(B0)-N8*(1-E8Ü2)
760 B1=Z8*(N8+H8)/SQR(X8Ü2+Y8Ü2)/(N8*(1-E8Ü2)+H8)
770 B1=ATN(B1)*D
780 B2=ABS(B1-B0*D)
790 IF B2<.00008 THEN 850
800 B0=B1/D
810 W4=FIX(B1)
820 W5=B1-W4
830 W6=60*W5
840 GOTO 740
850 PRINT "LATITUDE ";W4;INT(W6*100)/100
860 PRINT "LONGTUDE ";W3;INT(W1*100)/100
870 W8=INT(((B1-B9*D)*60*1852)*100)/100
880 W9=INT(((L8-L9*D)*60*1852*COS(B1/D))*100)/100
890 PRINT "LAT SHIFT ";W8
900 PRINT "LONG. SHIFT ";W9
910 IF A$="N" THEN 980
920 PRINT #1
930 PRINT #1 "RESULTS "
940 PRINT #1 "LATITUDE ";W4;INT(W6*100)/100
950 PRINT #1 "LONGITUDE";W3;INT(W1*100)/100
960 PRINT #1 "LAT SHIFT ";W8;"METERS"
970 PRINT #1 "LONG. SHIFT ";W9;"METERS"
980 END
```

B2 PRO

```
10 REM PRO
20 REM SATNAV INPUT PROGRAM
30 ; CHR$(12)
40 OPEN "PR:VSA36B72.11" AS FILE 1
50 OPEN "V24:VSA36B72.77" AS FILE 4
60 PREPARE "SAT6.DAT" AS FILE 3
70 INPUT LINE #4,A$
80 B$=MID$(A$,1,3)
90 IF LEN(A$)<17 THEN 110
100 Q$=MID$(A$,1,17)
110 IF B$="LAT" THEN 180
120 IF B$="LON" THEN 200
130 IF B$="LFX" THEN 220
140 IF B$="REC" THEN 270
150 GOTO 70
160 ! ; A$
170 GOTO 70
180 X$=MID$(A$,1,16)
190 GOTO 70
200 Y$=MID$(A$,1,16)
210 GOTO 70
220 IF MID$(A$,5,5)=T$ THEN 70
230 T$=MID$(A$,5,5)
240 ; #3 "RAY " Q$+X$+Y$+C$
250 ; "RAY ";T$;B$;A$;X$;Y$;C$
260 GOTO 300
270 C$=MID$(A$,11,5)
280 ; C$
290 GOTO 70
300 ! MAGNA
310 INPUT LINE #1,A$
320 IF LEN(A$)<10 THEN 310
330 B$=MID$(A$,1,2)
340 C$=MID$(A$,5,3) : REM error
350 D$=MID$(A$,6,4)
360 IF S1=1 THEN 470
370 IF C$="LON" THEN 520
380 IF C$="LAT" THEN 560
390 IF B$="EL" THEN 440
400 IF D$=" GMT" THEN 600
410 IF D$="DATE" THEN 640
420 ; A$;B$
430 GOTO 310
440 S1=1
450 GOTO 310
460 ! SAT DATA
470 S1=0
480 ; CUR(12,40);A$
490 D1$=A$
500 GOTO 670
510 ! LON
520 ; CUR(13,40);A$
530 D2$=A$
540 GOTO 310
550 ! LAT
560 ; CUR(14,40);A$
570 D3$=A$
580 GOTO 310
590 ! GMT
600 ; CUR(15,40);A$
610 D4$=A$
620 GOTO 310
630 ! DATE
640 ; CUR(16,40);A$
650 D5$=A$
660 GOTO 310
```

```
670 IF D4$=F4$ THEN 310
680 ; " WRITE ON DISK ";Y
690 Y=Y+1
700 F4$=D4$
710 ; #3;"MAGN "+D1$+D2$+D3$+D4$+D5$
720 GOTO 70
```

```
10 REM OUT2
20 T$="0"
30 ON ERROR GOTO 270
40 OPEN "SAT.DAT" AS FILE 1
50 ON ERROR GOTO 270
60 GOTO 90
70 OPEN S$ AS FILE 1
80 ON ERROR GOTO 270
90 INPUT LINE #1,W$
100 W=LEN(W$)
110 W$=MID$(W$,1,W-2)
120 IF W<17 THEN 90
130 A$=MID$(W$,1,3)
140 IF A$="RAY" THEN ; W$
150 IF A$="MAG" THEN ; W$
160 ; W$
170 GOTO 90
180 IF B$="O" THEN 250
190 IF B$="A" THEN 210
200 GOTO 90
210 C$=MID$(A$,12,8)
220 PRINT "MAG " TAB(10);C$;TAB(20);D$
230 L=L+1
240 GOTO 90
250 D$=MID$(A$,12,8)
260 GOTO 90
270 T$=ADD$(T$,"1",0%)
280 S$="SAT"+T$+".DAT"
290 ; S$
300 CLOSE
310 GOTO 70
```

```
10 REM LI98
20 REM CONVERTING FROM MAGNAVOX TO DATA  FOR CALCULATION
30 ; CHR$(12)
40 OPEN "DR0:SAT6.DAT" AS FILE 1
50 PREPARE "DR1:FILEB.DDD" AS FILE 2
60 ! ON ERROR GOTO 480
70 FOR N=0 TO 5
80   INPUT #1,A$
90   PRINT A$
100 NEXT N
110 INPUT #1,A$
120 IF ""=A$ THEN 110
130 IF "RAY"=LEFT$(A$,3) THEN 110
140 IF "GMT"=LEFT$(A$,3) THEN 530
150 IF "DAT"=LEFT$(A$,3) THEN 550
160 IF "MAG"=LEFT$(A$,3) THEN 200
170 IF "LON"=LEFT$(A$,3) THEN 280
180 IF "LAT"=LEFT$(A$,3) THEN 200
190 GOTO 110
200 D1$="MO"
210 D2$="MAGN"
220 W$=MID$(A$,6,2)
230 D9=VAL(W$)
240 W$=MID$(A$,25,2)
250 E1=VAL(W$)
260 ; D9,E1
270 GOTO 110
280 W$=MID$(A$,6,2)
290 D6$=MID$(A$,5,1)
300 W$=MID$(A$,8,2)
310 D7=VAL(W$)
320 W$=MID$(A$,10,5)
330 W$=MID$(A$,11,5)
340 D7=VAL(W$)
350 GOTO 110
360 ; #2;D1$
370 ; #2;D2$
380 ; #2;D3$
390 ; #2;D4
400 ; #2;D5
410 ; #2;D6$
420 ; #2;D7
430 ; #2;D8
440 ; #2;D9
450 ; #2;E1
460 ; #2;E2$
470 ; #2;E3$
480 GOTO 110
490 PRINT ERRCODE
500 CLOSE 2
510 ; "END OF PROGRAM "
520 END
530 E3$=MID$(A$,5,LEN(A$)-4)
540 GOTO 110
550 E2$=MID$(A$,6,LEN(A$)-5)
560 GOTO 360
```

B5 LI99

```
10 REM LI99
20 REM CONVERTING FROM RAYSAT DATA TO CALCULATING FILE FOR PROGR. LI
30 ; CHR$(12)
40 OPEN "DR0:SAT6.DAT" AS FILE 1
50 PREPARE "DR1:FILEA.DDD" AS FILE 2
60 ON ERROR GOTO 530
70 FOR N=0 TO 5
80   INPUT #1,A$
90 NEXT N
100 INPUT #1,A$
110 IF ""=A$ THEN 100
120 IF "RAY"=LEFT$(A$,3) THEN 160
130 IF "GMT"=LEFT$(A$,3) THEN 570
140 IF "DAT"=LEFT$(A$,3) THEN 590
150 GOTO 100
160 IF 27>LEN(A$) THEN 100
170 D1$="MO"
180 D2$="RAYS"
190 D3$=MID$(A$,27,1)
200 W$=MID$(A$,30,2)
210 D4=VAL(W$)
220 W$=MID$(A$,33,5)
230 D5=VAL(W$)
240 IF D5>38 THEN 610
250 IF D5<34 THEN 610
260 D6$=MID$(A$,43,1)
270 W$=MID$(A$,46,2)
280 D7=VAL(W$)
290 W$=MID$(A$,49,5)
300 D8=VAL(W$)
310 IF D8>60 THEN 610
320 IF D8<56 THEN 610
330 W$=MID$(A$,19,2)
340 D9=VAL(W$)
350 W$=MID$(A$,16,2)
360 E1=VAL(W$)
370 GOTO 100
380 REM
390 IF Z9=1 THEN Z9=0 : GOTO 100
400 ; #2;D1$
410 ; #2;D2$
420 ; #2;D3$
430 ; #2;D4
440 ; #2;D5
450 ; #2;D6$
460 ; #2;D7
470 ; #2;D8
480 ; #2;D9
490 ; #2;E1
500 ; #2;E2$
510 ; #2;E3$
520 GOTO 100
530 CLOSE 2
540 ; "END OF PROGRAM "
550 CHAIN "LI3"
560 END
570 E3$=MID$(A$,5,LEN(A$)-4)
580 GOTO 100
590 E2$=MID$(A$,6,LEN(A$)-5)
600 GOTO 380
610 Z9=1
620 GOTO 100
```

```
10 REM * * * PR2A * * *
20 REM MED(N) OF W.M.U.  LI LIANTING
30 REM VER 85-05-01
40 ; CHR$(12)
50 OPEN "FILE1.DAT" AS FILE 1
60 D1$="HK"
70 D2$="MAGN"
80 D3$="N"
90 D4=22
100 D5=18
110 D6$="E"
120 D7=114
130 D8=10
140 D9=0
150 E1=0
160 E2=851230
170 E3=120000
180 ; CHR$(12)
190 ; "PLACE (";D1$;")"; : INPUT W$
200 IF W$="" THEN 240
210 IF "S"=LEFT$(W$,1%) THEN 610
220 IF "s"=LEFT$(W$,1%) THEN 610
230 IF W$<>"" THEN D1$=W$
240 ; "RECEIVER TYPE (";D2$;")"; : INPUT W$
250 IF W$<>"" THEN D2$=W$
260 ; "LAT (";D3$;")"; : INPUT W$
270 IF W$<>"" THEN D3$=W$
280 ; "LAT DEGR.  (";D4;")"; : INPUT W$
290 IF W$<>"" THEN D4=VAL(W$)
300 ; "LAT MIN.  (";D5;")"; : INPUT W$
310 IF W$<>"" THEN D5=VAL(W$)
320 ; "LONG (";D6$;")"; : INPUT W$
330 IF W$<>"" THEN D6$=W$
340 ; "LONG DEGR.  (";D7;")"; : INPUT W$
350 IF W$<>"" THEN D7=VAL(W$)
360 ; "LONG MIN.  (";D8;")"; : INPUT W$
370 IF W$<>"" THEN D8=VAL(W$)
380 ; "ELEVATION (";D9;")"; : INPUT W$
390 IF W$<>"" THEN D9=VAL(W$)
400 ; "SAT. NO. (";E1;")"; : INPUT W$
410 IF W$<>"" THEN E1=VAL(W$)
420 ; "DATE (";E2;")"; : INPUT W$
430 IF W$<>"" THEN E2=VAL(W$)
440 ; "GMT (";E3;")"; : INPUT W$
450 IF W$<>"" THEN E3=VAL(W$)
460 ; "OK ? "; : GET A$
470 IF A$="N" OR A$="n" THEN ; "NOT SAVED " : FOR N=0 TO 1000 : NEXT N : GOTO 180
480 ; #2;D1$
490 ; #2;D2$
500 ; #2;D3$
510 ; #2;D4
520 ; #2;D5
530 ; #2;D6$
540 ; #2;D7
550 ; #2;D8
560 ; #2;D9
570 ; #2;E1
580 ; #2;E2
590 ; #2;E3
600 GOTO 180
610 CLOSE 2
620 ; "END OF PROGRAM "
630 END
```

```
10 REM * * * PR2B * * *
20 REM MED(N) OF W.M.U.  LI LIANTING
30 REM VER 85-05-01
40 DIM Z$(12)
50 ; CHR$(12)
60 OPEN "FILE1.DAT" AS FILE 1
61 PREPARE "DR1:FILE2.DAT" AS FILE 2
70 FOR N=1 TO 12
80   INPUT LINE #1 Z$(N)
90 NEXT N
100 D1$=LEFT$(Z$(1),LEN(Z$(1))-2)
110 D2$=LEFT$(Z$(2),LEN(Z$(2))-2)
120 D3$=LEFT$(Z$(3),LEN(Z$(3))-2)
130 D4=VAL(LEFT$(Z$(4),LEN(Z$(4))-2))
140 D5=VAL(LEFT$(Z$(5),LEN(Z$(5))-2))
150 D6$=LEFT$(Z$(6),LEN(Z$(6))-2)
160 D7=VAL(LEFT$(Z$(7),LEN(Z$(7))-2))
170 D8=VAL(LEFT$(Z$(8),LEN(Z$(8))-2))
180 D9=VAL(LEFT$(Z$(9),LEN(Z$(9))-2))
190 E1=VAL(LEFT$(Z$(10),LEN(Z$(10))-2))
200 E2=VAL(LEFT$(Z$(11),LEN(Z$(11))-2))
210 E3=VAL(LEFT$(Z$(12),LEN(Z$(12))-2))
220 ; CHR$(12)
230 ; "PLACE (";D1$;")"; : INPUT W$
240 IF W$="" THEN 280
250 IF "S"=LEFT$(W$,1%) THEN 650
260 IF "s"=LEFT$(W$,1%) THEN 650
270 IF W$<>"" THEN D1$=W$
280 ; "RECEIVER TYPE (";D2$;")"; : INPUT W$
290 IF W$<>"" THEN D2$=W$
300 ; "LAT (";D3$;")"; : INPUT W$
310 IF W$<>"" THEN D3$=W$
320 ; "LAT DEGR.  (";D4;")"; : INPUT W$
330 IF W$<>"" THEN D4=VAL(W$)
340 ; "LAT MIN.  (";D5;")"; : INPUT W$
350 IF W$<>"" THEN D5=VAL(W$)
360 ; "LONG (";D6$;")"; : INPUT W$
370 IF W$<>"" THEN D6$=W$
380 ; "LONG DEGR.  (";D7;")"; : INPUT W$
390 IF W$<>"" THEN D7=VAL(W$)
400 ; "LONG MIN.  (";D8;")"; : INPUT W$
410 IF W$<>"" THEN D8=VAL(W$)
420 ; "ELEVATION (";D9;")"; : INPUT W$
430 IF W$<>"" THEN D9=VAL(W$)
440 ; "SAT. NO. (";E1;")"; : INPUT W$
450 IF W$<>"" THEN E1=VAL(W$)
460 ; "DATE (";E2;")"; : INPUT W$
470 IF W$<>"" THEN E2=VAL(W$)
480 ; "GMT (";E3;")"; : INPUT W$
490 IF W$<>"" THEN E3=VAL(W$)
500 ; "OK ? "; : GET A$
510 IF A$="N" OR A$="n" THEN ; "NOT SAVED " : FOR N=0 TO 1000 : NEXT N : GOTO 220
520 ; #2;D1$
530 ; #2;D2$
540 ; #2;D3$
550 ; #2;D4
560 ; #2;D5
570 ; #2;D6$
580 ; #2;D7
590 ; #2;D8
600 ; #2;D9
610 ; #2;E1
620 ; #2;E2
630 ; #2;E3
640 GOTO 70
650 CLOSE 2
660 ; "END OF PROGRAM "
```

B8 PR5A(LI33)

```
10 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
20 REM * * * * * * * * PR5A (LI33) * * * * * * * * * * * * * *
30 REM * LI LIANTING                                          *
40 REM * MED(N) OF W.M.U.                                     *
50 REM * VER 85-05-20                                         *
60 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
70 DOUBLE
80 DIM A$(15)
90 REM A$(1)=PLACE                  A$(2)=REC.TYPE
100 REM A$(3)=LAT N/S               A$(4)=LAT DEG.
110 REM A$(5)=LAT MIN.              A$(6)=LON. W/O
120 REM A$(7)=LON DEG.              A$(8)=LON MIN.
130 REM A$(9)=EL.                   A$(10)=SAT. NO.
140 REM A$(11)=DATE                 A$(12)=HOURS
150 REM
160 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
170 REM START PROGRAM
180 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
190 INPUT "LAT ? "L9
200 L9=L9*PI/180
210 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
220 REM OPEN PRINTER
230 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
240 OPEN "PR:VSA50B72.55" AS FILE 2
250 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
260 GOSUB 1520 : REM PRINT TOP OF FORM
270 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
280 REM * * * * * * R E A D   I N   D A T A * * * * * * * * * * *
290 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
300 REM OPEN DISK FILE
310 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
320 OPEN "FILEA.DDD" AS FILE 1
330 ON ERROR GOTO 470 : REM END OF FILE
340 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
350 GOSUB 1600 : REM READ DISK
360 B2=VAL(A$(5))
370 L2=VAL(A$(8))
380 A=A+1 : REM COUNT FIXES
390 R1=R1+B2
400 R2=R2+L2
410 GOTO 350
420 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
430 REM
440 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
450 REM CALCULATE THE MEAN POSITION
460 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
470 B3=R1/A
480 L3=R2/A
490 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
500 REM CLOSE PRINTER AND DISKFILE
510 CLOSE
520 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
530 REM
540 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
550 REM * * * * * * R E A D   I N   D A T A  AGAIN * * * * *
560 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
570 REM OPEN DISKFILE AND PRINTER
580 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
590 OPEN "FILEA.DDD" AS FILE 1
600 OPEN "PR:" AS FILE 2
610 A=0 : REM COUNTER A=0
620 ON ERROR GOTO 1240 : REM END OF FILE
630 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
640 GOSUB 1600 : REM READ DISK
650 B2=VAL(A$(5))
660 L2=VAL(A$(8))
```

```
670 A=A+1 : REM COUNT FIXES
680 Q1=(B2-B3)^2
690 Q2=(L2-L3)^2
700 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
710 REM SAVE MEAN POSITION
720 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
730 Q3=Q3+Q1
740 Q4=Q4+Q2
750 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
760 REM PRINT FIXT DATA AND POS. DIF. AND POS.DIR.
770 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
780 ; #2;TAB(3);A$(1);TAB(8);A$(2),TAB(16);INT((B2-B3)*1000)/1000;
790 ; #2;TAB(24);INT((L2-L3)*1000)/1000;
800 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
810 REM CALCULATE  POSITION DISTANCE IN NM
820 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
830 D2=B2-B3
840 D3=L2-L3
850 D1=SQR(D2*D2+D3*D3)
860 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
870 REM PRINT POSITION DISTANCE IN NM
880 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
890 ; #2;TAB(30);INT(D1*1000+.5)/1000;
900 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
910 REM CALCULATE POSITION DIRECTION IN DEGREEDS
920 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
930 IF D2>0 AND D3>0 THEN T1=ABS(180/PI*ATN(D3/D2))
940 IF D2<0 AND D3>0 THEN T1=180-ABS(180/PI*ATN(D3/D2))
950 IF D2<0 AND D3<0 THEN T1=180+ABS(180/PI*ATN(D3/D2))
960 IF D2>0 AND D3<0 THEN T1=360-ABS(180/PI*ATN(D3/D2))
970 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
980 REM PRINT POSITION DIRECTION IN DEGREEDS
990 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1000 REM
1010 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1020 ; #2;TAB(37);INT(T1*10+.5)/10;
1030 REM PRINT OUT THE TIME
1040 E1=LEN(A$(12))
1050 E1$=RIGHT$(A$(12),E1-1)
1060 E2$=MID$(A$(12),E1-3,2)
1070 E3$="00"
1080 T9=63
1090 IF E1=4 THEN 1120
1100 IF E1=5 THEN E3$=MID$(A$(12),E1-4,1) : T9=64
1110 IF E1=6 THEN E3$=MID$(A$(12),E1-5,2)
1120 A8=A8+1 : REM COUNTER FOR TOTAL FIXES
1130 ; #2;TAB(45);A$(9);TAB(49);A$(10);TAB(55);A$(11);
1140 ; #2;TAB(65);A$(12);
1150 REM PRINT FIX NUMBER
1160 PRINT #2 USING "####";TAB(75);A8
1170 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1180 REM COUNT LINES IN BOX "S" IF 55 NEW PAGE
1190 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1200 S=S+1
1210 IF S>55 THEN GOSUB 1480 : REM PRINT TOP OF FORM
1220 GOTO 640
1230 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1240 IF ERRCODE=34 THEN 1300 ! REM IF CODE 34 THEN END OF FILE
1250 ; "ERR ";ERRCODE
1260 GOTO 1460
1270 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1280 REM
1290 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1300 S1=Q3/(A-1)
1310 S2=Q4/(A-1)
1320 R=2*SQR((S1+S2*COS(L9)*COS(L9)))
```

```
1330 ; #2
1340 ; #2;"MEAN POS.";
1350 ; #2;TAB(15);INT((B3*1000)+.5)/1000;TAB(23);INT((L3*1000)+.5)/1000
1360 ; #2
1370 ; #2;"R95 ";INT(R*1000+.5)/1000 "NM IN METERS ";INT(R*1852*1000+.5)/1000
1380 ; #2
1390 ; #2
1400 S1=SQR(Q3/(A-1))
1410 S2=SQR(Q4/(A-1))
1420 REM 99%=2.58, 95%=1.96, 90%=1.65
1430 ; #2;TAB(1);"M95 lat.  +/- ";INT(S1*1.96*1000)/1000
1440 ; #2;TAB(1);"M95 long. +/- ";INT(S2*1.96*1000)/1000
1450 ; #2;CHR$(12)
1460 CLOSE
1470 END
1480 ; #2;CHR$(12) : REM NEXT PAGE
1490 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1500 REM PRINT SUB-ROUTINE TOP OF FORM
1510 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1520 ; #2 "PLACE  REC.      LAT     LON   POS.    POS.      SAT.  DATE       TIME        NUMBER"
1530 ; #2 "       TYPE      DIF.    DIF.  DIS     DIR.  EL  NO    Y.M.D.     GMT"
1540 ; #2
1550 S=0
1560 RETURN
1570 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1580 REM READ DISK SUB ROUTINE
1590 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1600 FOR N=1 TO 12
1610   INPUT #1A$(N)
1620   PRINT A$(N)
1630 NEXT N
1640 GET Q$
1650 REM TEST FOR  DIFFERENT GROOPS
1660 IF A$(9)="2" THEN 1600
1670 IF A$(9)="3" THEN 1600
1680 IF A$(9)="4" THEN 1600
1690 IF A$(9)="5" THEN 1760
1700 IF A$(9)="6" THEN 1760
1710 IF A$(9)="7" THEN 1760
1720 IF A$(9)="8" THEN 1760
1730 IF A$(9)="9" THEN 1760
1740 IF A$(9)="10" THEN 1760
1750 IF A$(9)>"10" THEN 1600
1760 RETURN
1770 REM * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

WARNING: FOR TRANSFORMING FROM WGS TO CHART DATUM, THE SIGNS FOR ΔX, ΔY, ΔZ, Δa and Δf, AS GIVEN IN THE TABLE, MUST BE REVERSED FOR USE IN THE ABRIDGED MOLODENSKY FORMULAS

TRANSFORMATION PARAMETERS
GEODETIC DATUM TO WGS 1972*
(WGS 72 MINUS DATUM)

15 SEPTEMBER 1983

GEODETIC DATUM	REFERENCE ELLIPSOID			TRANSFORMATION PARAMETERS			DOPPLER** STATIONS USED	SOURCE***
	NAME	Δa (m)	$\Delta f \times 10^4$	ΔX (m)	ΔY (m)	ΔZ (m)		
EUROPEAN 1950	International	-253.000	-0.14223913					
Mean value				-84	-103	-127		1
Denmark, Finland, Norway, Sweden				-84±1	-102±1	-122±1	17	2
Belgium, Federal Republic of Germany (West Germany), France, Luxembourg, Switzerland, The Netherlands				-83±1	-109±1	-122±1	54	2
Albania, Austria, Bulgaria, Czechoslovakia, Estonia, German Democratic Republic (East Germany), Hungary, Latvia, Lithuania, Poland, Romania, USSR, Yugoslavia				-81±1	-105±2	-125±3	8	2
Iraq, Israel, Jordan, Lebanon, Saudi Arabia, Syria, Turkey				-81±2	-106±1	-137±2	34	2

DATUM, THE SIGNS FOR ΔX, ΔY, ΔZ, Δa AND Δf, AS GIVEN IN THE TABLE, MUST BE REVERSED FOR USE IN THE ABRIDGED MOLODENSKY FORMULAS

GEODETIC DATUM TO WGS 1972*
(WGS 72 MINUS DATUM)

15 SEPTEMBER 1983

GEODETIC DATUM	REFERENCE ELLIPSOID			TRANSFORMATION PARAMETERS			DOPPLER** STATIONS USED	SOURCE***
	NAME	Δa (m)	$\Delta f \times 10^4$	ΔX (m)	ΔY (m)	ΔZ (m)		
<u>G. SEGARA</u>	Bessel	737.845	0.10006272					
Borneo				-386	688	35	3	2
<u>GUAM 1963</u>	Clarke 1866	-71.400	-0.37295850					
Mean value				-89	-235	254		1
<u>GUX 1 ASTRO</u> (See 1968 DOS)	International	-253.000	-0.14223913					
Guadalcanal				260±1	-194±1	-756±1	2	2
<u>HJORSEY 1955</u>	International	-253.000	-0.14223913					
Iceland				-76±1	39±1	-90±3	6	2
<u>HONG KONG 1963</u>	International	-253.000	-0.14223913					
Mean value				-140	-264	-194	1	2
<u>IAGS ASTRO</u>	Clarke 1866	-71.4	-0.37295850					
Grand Cayman Island				49	119	128	1	2

DATUM, THE SIGNS FOR ΔX, ΔY, ΔZ, Δa AND Δf, AS GIVEN IN THE TABLE, MUST BE REVERSED FOR USE IN THE ABRIDGED MOLODENSKY FORMULAS

GEODETIC DATUM TO WGS 1972*
(WGS 72 MINUS DATUM)

15 SEPTEMBER 1983

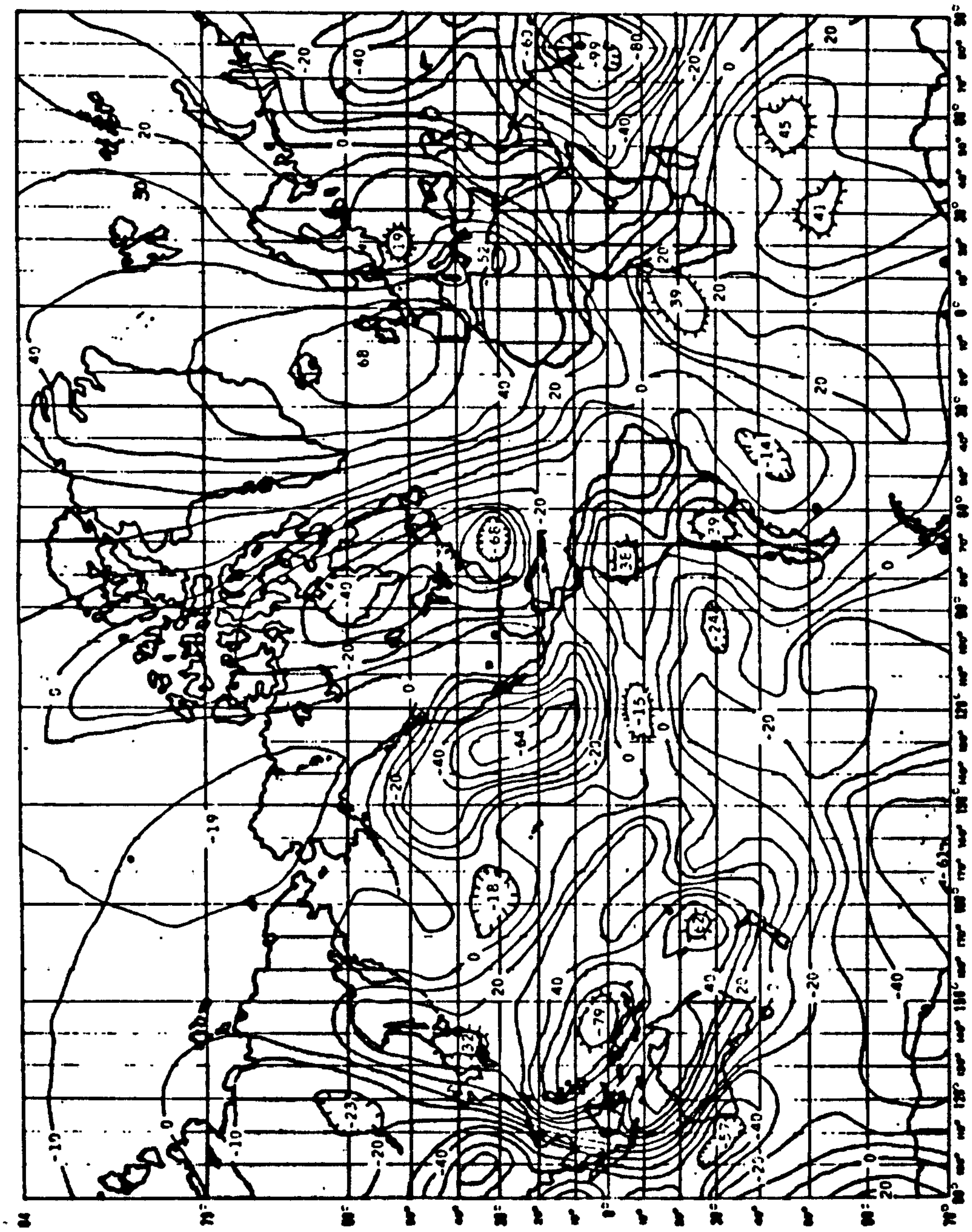
GEODETIC DATUM	REFERENCE ELLIPSOID			TRANSFORMATION PARAMETERS			DOPPLER** STATIONS USED	SOURCE***
	NAME	Δa (m)	$\Delta f \times 10^4$	ΔX (m)	ΔY (m)	ΔZ (m)		
MARCUS ISLAND ASTRO 1952	International	-253.000	-0.14223913					
Mean value				134	-222	-31	1	2
MERCHICH	Clarke 1880	-114.145	-0.54781925					
Morocco				--	--	--	--	--
MERCURY 1960	Fischer 1960	-31.000	0.00449585					
NAD 27 Area				-25	46	-49		1
ED 50 Area				-13	-88	-5		1
TD Area (Tokyo Datum)				18	-132	60		1
MIDWAY ASTRO 1961	International	-253.000	-0.14223913					
Mean value				917	-43	1219	1	2
MODIFIED MERCURY 1968	Fischer 1968	-15.000	0.00449585					
NAD 27 Area				-4	12	-7		1
ED 50 Area				-3	1	-6		1
TD Area (Tokyo Datum)				22	34	2		1
NANKING 1960	International	-253.000	-0.14223913					
China				-131	-347	0		1

DATUM, THE SIGNS FOR ΔX, ΔY, ΔZ, Δa, Δf,
AS GIVEN IN THE TABLE, MUST BE REVERSED
FOR USE IN THE ABRIDGED MOLODENSKY FORMULAS

GEODETIC DATUM TO WGS 1972*
(WGS 72 MINUS DATUM)

15 SEPTEMBER 1983

GEODETIC DATUM	REFERENCE ELLIPSOID			TRANSFORMATION PARAMETERS			DOPPLER** STATIONS USED	SOURCE***
	NAME	Δa (m)	$\Delta f \times 10^4$	ΔX (m)	ΔY (m)	ΔZ (m)		
NAHRWAN	Clarke 1880	-114.145	-0.54781925					
Masirah Island				-233±1	-156±1	365±1	2	2
NAPARIMA	International	-253.000	-0.14223913					
Trinidad and Tobago				-16	365	167	1	2
NORTH AMERICAN 1927	Clarke 1866	-71.400	-0.37295850					
Mean value				-22	157	176		1
Alaska and Canada				-9	139	173		1
Alaska				-13±1	142±1	174±1	39	2
Bahamas				-21±2	156±2	170±3	7	2
Canada				-21±2	163±1	179±1	91	2
Central America				-19±2	159±1	182±2	19	2
Cuba				-26	155	170	1	2
Dominican Republic, Haiti				-27±3	168±3	166±3	3	2
Jamaica				-28±1	165±2	168±1	2	2
Mexico				-22±1	156±1	175±1	24	2
United States (Contiguous)				-22±1	157±1	177±1	305	2
OLD EGYPTIAN 1930	Helmert 1906	-65.000	0.00449585					
Mean value				-120±2	98±2	-16±3	13	2

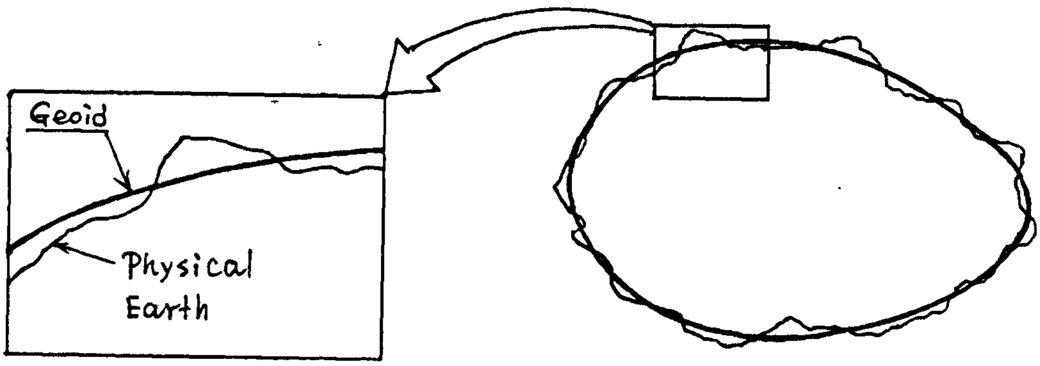


—Contour map of geoidal height (meters).

Annex D The Earth/The Geoid/Ellipsoids

1. The Earth

The earth is a "very irregular" shaped body which also is not homogenous. This physical earth is approximated by a somoth body which is called Geoid.



2. The Geoid.

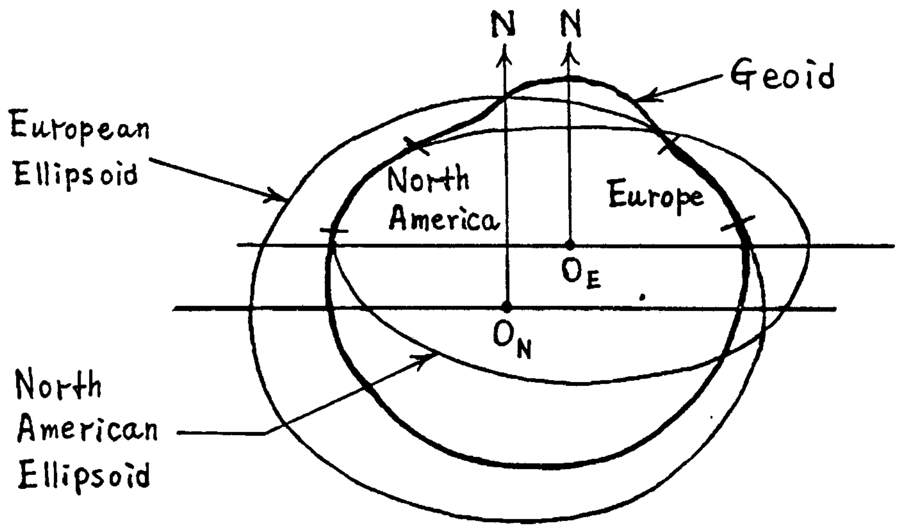
The Geoid is a hypothetical shape of the earth if it was completely covered with water.

The Geoid therefore is a smooth body but mathematically still very complex. Its surface is at least a 10th order-body.

3. Ellipsoids

In order to be able to calculate with a mathematically managable body of the second order, the geoid is approximated by a certain ellipsoid.

For a certain part of the earth there is an ellipsoid which approximates the geoid the best.



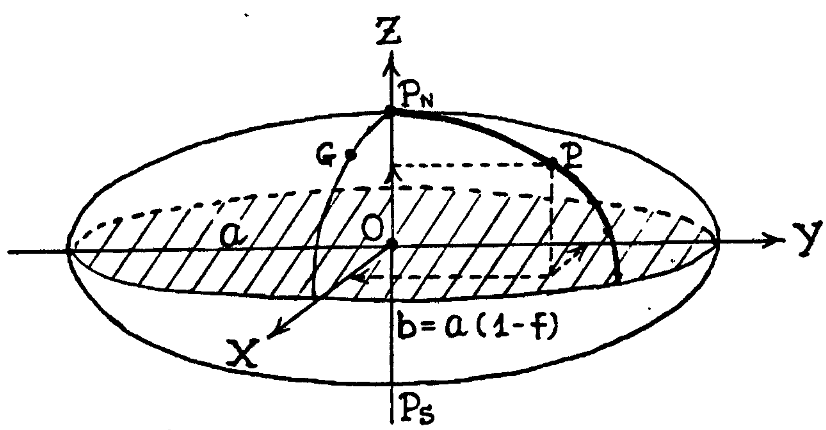
3.1. Spheroid

All these ellipsoids (also denoted by spheroid) differ in:

1) Position of their centres(O)
   Which are also the origins of a three dimensional coordinate (X,Y,Z) system
2) Shape, which is defined by:
   a=semi-major axis
   f= flattening

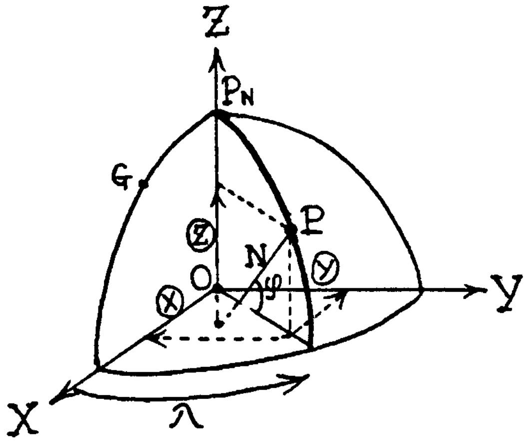
3.2. Mathematical Coordinates on an Ellipsoid

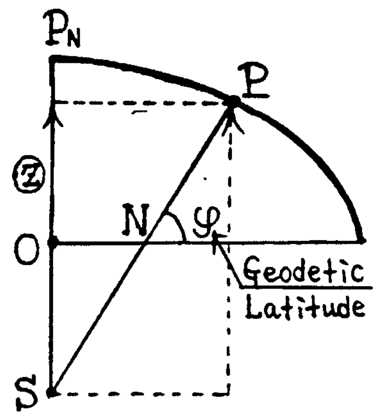
Earth-bound ellipsoids are generated by rotating a meridianal ellips round the Z-axis.



Where: a=Semimajor axis
b=a(1-f)=semiminor axis
$e^2=2f-f^2$

The Z-axis is the polar axis and the X-axis is in the equatorial plane and in the meridian of Greenwich.





Now point P with X,Y,Z coordinates has:

1) Distance N=PS (radius of curvature of the meridian) being equal to:

$$N=\frac{a}{\sqrt{1-e^2\sin^2\varphi}}$$

2) Geodetic latitude (φ)
3) Geodetic (east) longitude (λ)

Point P which is h metres above the ellipsoid.
The coordinates X,Y,Z obey:

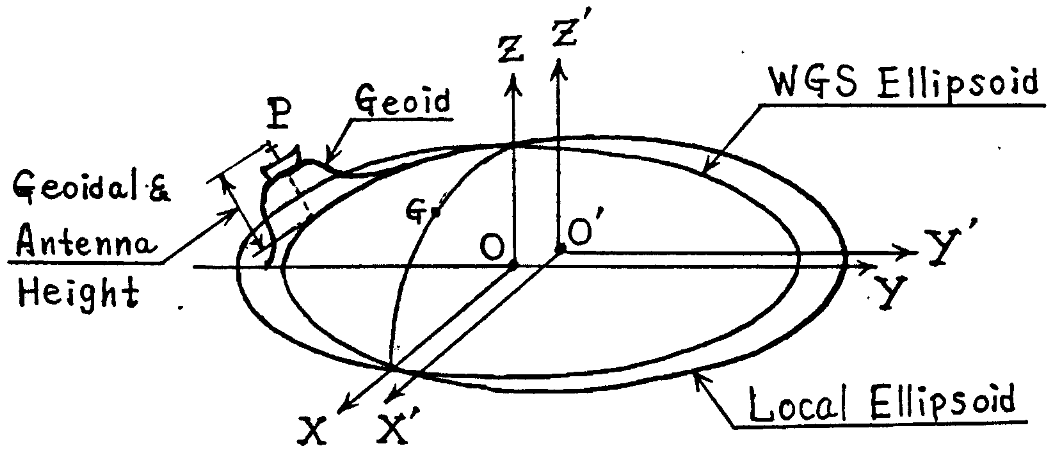
$X=(N+h)\cos\varphi\cos\lambda$

$Y=(N+h)\cos\varphi\sin\lambda$

$Z=[N(1-e^2)+h]\sin\varphi$

3.3. WGS-72

This ellipsoid is a worldwide-best-fit for the geoid and is chosen in satellite navigation as uniform ellipsoid. The latitude and longitude which are represented by the Sat-Navigator are the geodetic latitude and longitude on the WGS-Ellipsoid provided the antenna-height and geoidal-height are correctly inserted in the receiver.



So with Lat.(φWGS) and Long.(λWGS) from receiver and

aWGS=6378.135 KM
fWGS=$(298.26)^{-1}$
h=geoidal height relative to WGS-72

One can calculate of the position: φWGS, λ WGS

$$X_{WGS}=(N_{WGS}+h)\cos\varphi_{WGS}\cos\lambda_{WGS}$$
$$Y_{WGS}=(N_{WGS}+h)\cos\varphi_{WGS}\sin\lambda_{WGS}$$
$$Z_{WGS}=(N_{WGS}(1-e^2_{WGS})+h)\sin\varphi_{WGS}$$

With: $$N_{WGS}=\frac{a_{WGS}}{\sqrt{1-e^2\sin^2\varphi_{WGS}}},\quad (e^2=2f-f^2)$$

The Cartesian Coordinates(X_{WGS}, Y_{WGS}, Z_{WGS}) of the position are known.

3.4 The Local Ellipsoid and the Chart in Use

The point P (Position) of which the coordinates in WGS are known of course has other coordinates in the local ellipsoid and thus in the local chart which chart is derived from the local ellipsoid.

With the shift in the origin of the local X Y Z-axis relative to the origin of WGS-72 the Cartesian Coordinates in the local system can be calculated. (See annex C)

$$X_{local\ ellips} = X_{WGS} + \Delta X$$
$$Y_{local\ ellips} = Y_{WGS} + \Delta Y$$
$$Z_{local\ ellips} = Z_{WGS} + \Delta Z$$

Now with:

$$X_{local} = (N_{local} + h_{local}) \cos \varphi_{local} \cos \lambda_{local} \quad (A)$$

$$Y_{local} = (N_{local} + h_{local}) \cos \varphi_{local} \sin \lambda_{local} \quad (B)$$

$$Z_{local} = (N_{local}(1 - e^2_{local}) + h_{local}) \sin \varphi_{local} \quad (C)$$

φ_{local} and λ_{local} can be calculated.

3.5. Solution for φ_{local} and λ_{local}

1) From $\frac{Y_{local}}{X_{local}} = \tan \lambda_{local}$,

the local East long. can be calculated:

$$\lambda_{local} = \text{Arc} \tan \left(\frac{Y_{local}}{X_{local}}\right)$$

2) Because φ_{local} and h_{local} are not known an iterative solution is followed:

Begining with $\varphi_1 = \varphi_{WGS}$ as starting value $\varphi_0 \rightarrow \varphi_1 = \varphi_0$

From (C) follows:

$$h_1 = \frac{Z_{local}}{\sin \varphi_0} - N_1 \left(1 - e^2_{local}\right)$$

With: $N_1 = \frac{a}{\sqrt{1 - e^2_{local} \sin^2 \varphi_0}}$, $e^2 = 2f_{local} - f^2_{local}$

From (B) and (A) follow:

$$\cos^2\varphi_1 = \frac{X^2_{local} + Y^2_{local}}{(N_1+h_1)^2}$$

$$\cos\varphi_1 = \frac{\sqrt{X^2_{local} + Y^2_{local}}}{(N_1+h_1)}$$

and this dividing with (C)

$$\tan\varphi_1 = \frac{Z_{local}(N_1+h_1)}{\sqrt{X^2_{local}+Y^2_{local}} \cdot (N_1(1-e^2_{loc})+h_1)}$$

If $|\varphi_1 - \varphi_0| > 0''.005$ $(0^\circ.000008)$

Goto $\varphi_1 = \varphi_0$

Print φ_1 local, λ local

The Systematic Coordinates Shift Due to Local Datum.

Obtaining the local coordinates φ local, λlocal, gives us :

The latitude shift to be applied to the readings= $\varphi_{loc.} - \varphi$ WGS.

The longitude shift to be aplied to the readings= $\lambda_{loc.} - \lambda$ WGS.

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