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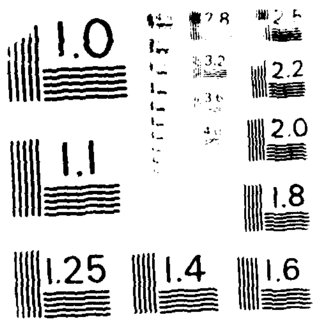
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TECHNICAL MEMORANDUM

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ASSESSMEMT OF THE DIFFERENTIAL TECHNIQUE FOR LAND NAVIGATION WITHIN 1000 km OF OMEGA AUSTRALIA

J.H. Silby

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TECHNICAL MEMORANDUM

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ASSESSMENT OF THE DIFFERENTIAL TECHNIQUE FOR LAND NAVIGATION WITHIN 1000 km OF OMEGA AUSTRALIA

J.H. Silby

SUMMARY

Navigation section of Radio Group, Electronics Research Laboratory was required to investigate the behaviour of the Australian Omega transmissions within Australia. This paper reports the approach used to undertake this investigation at points within the area of modal interference and the results obtained. Conclusions are drawn on the efficacy of using the Omega Australia transmissions in the differential mode in the areas investigated and comment is made on the use of differential Omega for land navigation in Australia drawing also on the results of trials reported previously.

DSTO ERL SALISBURY

POSTAL ADDRESS: Director, Electronics Research Laboratory,
Box 2151, GPO, Adelaide, South Australia, 5001.

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1. INTRODUCTION

Navigation section of Radio Group, Electronics Research Laboratory was required to investigate the behaviour of the Australian Omega transmissions within Australia. Data were to be collected in order to provide a basis for assessment of the achievable accuracy when employing these transmissions in a differential Omega navigation system as discussed in reference 1. This method requires the establishment of a base station at a known location and the measurement of displacement from that position using differential phase information.

In order to investigate the behaviour of the Australian Omega transmissions within the expected area of modal interference, measurements were taken at a number of positions within South Australia and in the eastern states.

With a base station located at Salisbury, checks were made on the absolute navigational accuracy for movements to Port Lincoln and Mount Gambier. Data were collected at Morgan and Port Vincent in order to obtain some appreciation of the scatter before the navigation trials. These sites are shown in figure 1.

The base station was then moved to Wagga in New South Wales where the behaviour of Omega Australia could be investigated at positions close to the transmitting aerial. Data were collected at Hay, Narrandera, Mangalore, Bathurst, Moruya, and Mallacoota. These positions were chosen because of their distance from Omega Australia and the availability of permanent survey markers. The positions of the sites occupied and the position of the Australian Omega transmitter are shown in figure 2.

For translocation measurements within South Australia, the base equipment was housed in Bld 57 TSAN at the Defence Research Centre Salisbury (DRCS) and the mobile equipment mounted in a Toyota Land Cruiser (figure 3). When the base station was transferred to Wagga, it was mounted in a Ford D700 truck which was parked alongside a permanent survey marker at Wagga airport. The truck is shown in figure 4. Note that the aerials shown on the roof of the truck are not part of the Omega system. The Omega aerial was situated over a permanent survey marker.

Communication between mobile and base stations was restricted to a High Frequency (HF) radio link.

2. METHOD OF MEASUREMENT

The equipment used for these experiments has been described in reference 1.

Signal phase increment between a reference point and the mobile station was recorded.

Data were collected by two methods, manually and on a floppy disc. As the disc was of limited capacity, measurements recorded on it are relative to the mobile position. Thus the data recorded on floppy disc shows, in the main, the scatter of the received phase angle of the mobile position.

3. EXPERIMENTAL PROCEDURE

3.1 Data collection within South Australia

For all movements within South Australia the base equipment was housed in Bld 57 TSAN at DRCS. The mobile equipment was mounted in a Toyota Land

Cruiser. Data were collected at Morgan, Port Vincent and Port Lincoln. These sites are shown on the map (figure 1).

(a) Scatter in distance

For these measurements, the Land Cruiser was driven to Morgan and Port Vincent. It was left at a convenient location (grid references 54HUH774220 and 53HOB617475 respectively) with power supplied by a 2.2 kV A Honda generator.

The variation of phase angle of the signal emanating from Omega Australia was measured and recorded on a floppy disc. The data collected at these points represents the apparent movement of the position of the mobile aerial. Data were recorded at all points visited.

(b) Scatter in relative distance

The vehicle was driven to a permanent survey marker at Port Lincoln and at Mount Gambier. Before travelling to each of these sites, the phase angle of the signal was measured at a survey marker at DRCS. This phase angle was used as a reference angle for all subsequent measurements taken during that sortie.

On arrival at each site, the phase angle of the received signal was measured every half hour of the working day for a period of one week. The measured phase angle was compared with the computed phase angle for the change in distance between the base station and that site.

These data were collected during normal working hours. Scatter data were recorded on the floppy disc to supplement those recorded manually. In this way, the short term scatter about the mean could be easily computed.

Whilst at Port Lincoln, detailed measurements were taken for the 13.6 kHz signal only. Later viewing of the recorded data showed that measurements needed to be made on all three frequencies. This was done on subsequent sorties.

3.2 Collection of data with base at Wagga

Whilst at Wagga, the base equipment was located in the Ford D700 truck and the mobile equipment in the Toyota Land Cruiser. Data were collected at the base station and sequentially at each of Bathurst, Hay, Narrandera, Mangalore, Mallacoota and Moruya.

The mobile equipment was driven from Wagga to each of the aforementioned sites. Before driving to a site, the phase angle of the signal was measured at Wagga and this phase angle was then used as a reference angle for measurements at that site. The sites visited are shown on the map of figure 2. Signal phase angle was measured every half hour for two days during working hours at each site simultaneously and compared with the computed phase change for that separation. Each site was visited twice, with an interval of two weeks between each visit. Scatter data were collected on floppy disc to supplement those manually recorded.

4. RESULTS

4.1 Scatter measurements

(1) Morgan

Data were gathered at Morgan over a period of three days. The scatter of the error in measured distance obtained from the 13.6 kHz signal of Omega Australia is illustrated in figure 5. This figure shows that the spread of data is of the order of 200 m during daylight hours with a marked increase in scatter at night.

Figure 6 is a plot of the spread of the error in distance obtained from Omega Japan on 13.6 kHz. The plot shows a spread of approximately 200 m during daylight hours with a decrease in accuracy during the night. This decrease in accuracy is not as marked as those taken using the transmission from the Australian station. It was postulated that this decrease in accuracy was a result of modal interference during the night on the transmissions emanating from Omega Australia. The lesser scatter on the Australian transmissions during daylight is explained by the greater signal to noise ratio of the signal received from Omega Australia compared to that from Omega Japan.

(2) Port Vincent

Figure 7 is a plot of scatter for Omega Australia on 13.6 kHz taken at Port Vincent over a three day period. It was noted that, while these results are similar to those obtained at Morgan, the period of increased scatter is longer.

Figure 8 is a plot of scatter obtained from the 10.2 kHz Australian transmission. This plot shows trends similar to those obtained at 13.6 kHz.

The results of the scatter measurements indicated that Omega Australia could be used for differential navigation during daylight hours in South Australia at the locations studied but that the night time variability in the value of incremental phase with distance, due probably to the effects of multi mode transmission, would preclude its use at night.

4.2 Port Lincoln

The indicated distance between base and mobile equipments, as read from difference in phase, was set to zero before moving the mobile equipment to a survey point at Port Lincoln airfield. In this way, the difference in electromagnetic radial distance from the transmitter to Salisbury and Port Lincoln was measured directly and compared to the actual value. Differential measurements were taken every half hour of the working day at the Port Lincoln survey point and plotted against time. The error in electromagnetic radial distance between Salisbury and Port Lincoln using the 13.6 kHz transmissions from Japan, La Reunion and Australia are shown in figure 9. Errors are plotted against Centre Standard Time (CST).

Figure 9 shows the scatter of the measurements for each station, the error in distance and the effects of the clock drift. Removal of the component due to the drift in clock frequency gives an average error of -259 m for the transmission from Japan, -180 m for the transmission from La Reunion, and -1300 m for that of Australia. The error of -1300 m for the measurements taken on the Australian transmissions indicate that signals are present from more than one stable mode of transmission.

A regression analysis of the errors depicted in figure 9 produces a straight line equation which passes through zero at very nearly the time that the equipments were adjusted to give identical phase readings at Salisbury.

Measurements utilising the transmissions from Japan and La Reunion display an average error of the same sign suggesting that an adjustment should be made to the value used for the velocity of propagation which was the velocity of light (c).

The scatter of error in radial distance for measurements utilising Omega Australia and Omega Japan is shown in figures 10 and 11. The signal from Omega Australia is correlated over a smaller time period than at Morgan and Port Vincent and the decorrelation at night has, on average, a greater magnitude.

4.3 Mount Gambier

Due to a malfunction in the equipment, no differential radial distance data for the base and mobile stations was obtained.

The diurnals taken show that modal interference is evident. Figures 12 to 16 show typical diurnal trends and all except that of figure 14 behave in a similar and expected manner. However, the diurnal shift at Mount Gambier for the 13.6 kHz transmissions is opposite in sign to that obtained at Salisbury and is of lesser magnitude. One would expect that, at some point between Salisbury and Mount Gambier, there would not be any observed diurnal phase shift.

The anomalous behaviour of this diurnal would give rise to a large average error during the day and random variations at night, similar to that obtained at Port Lincoln but opposite in sign.

Although no absolute measurement of error was possible, the error relative to that observed for Omega Japan was recorded. These errors are shown in figures 17 to 19. The straight lines are drawn to show the average error and the effective clock drift of data recorded by hand over a three day period. The effects of multiple stable modes can be observed on the 13.6 kHz and 11.3 kHz transmissions but it is not evident on the 10.2 kHz transmissions. The recorded data was repeated from day to day and it was thought then that the adoption of calibration procedures might allow the use of Omega Australia in the eastern half of Australia.

It should be pointed out that the absolute values of phase angle shown in figures 12 to 16 have no significance as the plotter was programmed to auto scale the results and equate the most negative value to zero.

4.4 Wagga

The objective of the Wagga trial was to investigate the anomalous propagation of the Omega Australia transmissions and to determine whether or not it was feasible to reduce the observed errors by calibration. That is, if the observed errors were consistent, would it be possible to produce error contours which could be used to correct observations based upon differential operation from some particular base station site. Figures 20 to 25 depict results obtained during the day between Wagga and various sites. These figures show separately the apparent variation of radial distance from Omega Australia of both the base station and the mobile station based on individual phase measurements during the course of a day for each of the Omega frequencies.

It is immediately clear that the correlation between base and mobile is poor and that the differential approach would yield variations in position of several kilometres during the day. As expected in these areas, the average error in radial range was large and site dependent.

Figure 26 shows diurnal trends at the Wagga base station over several days. Clearly, the diurnal variations at the base station itself are not repeated from day to day.

Figure 27 shows a recorded diurnal cycle of phase shift at the Wagga base station for Omega Australia on 13.6 kHz and figure 28 shows one for 11.3 kHz. The 13.6 kHz diurnal has the day/night transition phase shift in the expected direction but undergoes large variations during the day as well as those normally obtained at night, whereas the 11.3 kHz diurnal exhibits a phase shift in the opposite direction.

5. CONCLUSIONS

5.1 The results of the South Australian section of the experiment suggest that, at least during the day, the phase anomalies on transmissions from Omega Australia could be modelled and, therefore, corrected. If the results from Port Lincoln and Mount Gambier as well as from a few measurements taken whilst travelling to Mount Gambier are combined and referenced to Port Lincoln, they can be represented as in figure 29. Taking Port Lincoln as the datum point and moving towards Mount Gambier (and as a consequence towards Omega Australia) we see a monotonic increase of error on 13.6 kHz. The other two frequencies exhibit turnover points between Salisbury and Tintinara (see figure 3).

It is concluded that Omega Australia could be used for navigation in the differential mode within South Australia during daylight if calibration in the form of error contours is employed.

5.2 The objective of the measurements in New South Wales and Victoria was to investigate phase anomalies in the transmission from Omega Australia and to determine whether it was possible to model them or to produce error contours. On the evidence obtained it appears that this is not possible. Figures 20 to 25 show separately the apparent variation of radial distance from Omega Australia of the base station and the mobile. Clearly the correlation is very poor and, as a consequence, the differential approach is not satisfactory. It could still be possible to produce error contours as a function of both time and distance if the results were repeatable from day to day. However, it can be seen from figure 26 that the diurnal variations at the Wagga base station do not repeat from day to day. It must be concluded that any precision navigation utilising transmissions from Omega Australia is not feasible in the region examined.

6. COMMENTS ON THE OMEGA SYSTEM

6.1 Omega was designed to serve as a world wide maritime navigation system. However, the combination of modal interference, long path reception and polar ice cap absorption severely limits the number of stations which can be used on the Australian continent. This problem is compounded by the need for each transmitter to be turned off for one month of each year for maintenance. As a result, Omega does not provide a 24 hour year round coverage over the Australian continent. Details of usable stations are given in reference 2. Previous measurements taken by Radio Group confirm this.

6.2 The equipment used in these trials indicated a marked decrease in correlation between the variation in signal phase measured at the base station and that measured at the mobile within the geographic bounds of this investigation. This decorrelation occurs on all stations to varying degrees and has also been reported in references 3 to 5. The author has not been able to fault the equipment in laboratory testing indicating that this decorrelation must be real. The overall effect is to severely limit the time during which accurate (100 m) land navigation can be achieved using the Omega system in differential mode. Other sources of error when using Omega on land are listed in reference 1 (trees, power lines etc) and these error sources may severely limit the area in which the differential technique would be useful in military applications.

6.3 Radio Group measurements show that the Omega system is useful in the differential mode during daylight hours in selected terrain. Omega Australia can be used only in the western and northern regions of the continent where the more rapidly attenuating higher order modes are not present. Over much of the continent there are only three stations which can be used (Japan, Reunion, and Australia, the transmission from Argentina being in the polar shadow) and each station is turned off for one month of each year. As three stations are required for hyperbolic navigation, 24 hours all year differential navigation is not feasible over the whole of the continent.

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No.	Author	Title
1	Edgar, R.S.	"The Application of Differential Omega to Land Navigation Within Australia". ERL-0129-TM, March 1980
2	Lynn, K.J.W. and Zahorujko, I.	"The Effect of Omega Australia's Completion on the Performance of the AN/APN-99 Omega Navigation Set". ERL-0349-TR, December 1985
3	Edgar, R.S.	"Land Navigation in North West Australia Utilising Differential Omega". ERL-0218-TR, October 1981
4	Silby, J.H.	"A Seaborne Navigation Trial Utilising Differential Omega". ERL-0295-TM, December 1983
5	Edgar, R.S. and Silby, J.H.	"Land Navigation in the Kimberleys Utilising Differential Omega". ERL-0358-TM, February 1986

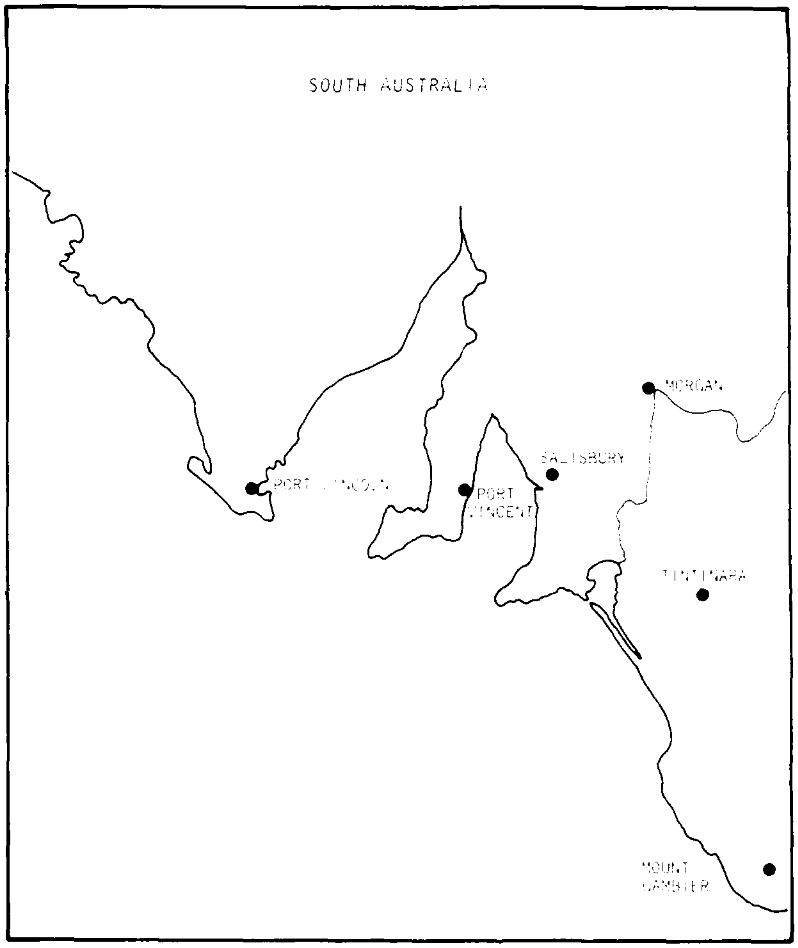


Figure 1. Map showing Morgan, Port Vincent, Port Lincoln and Mount Gambier

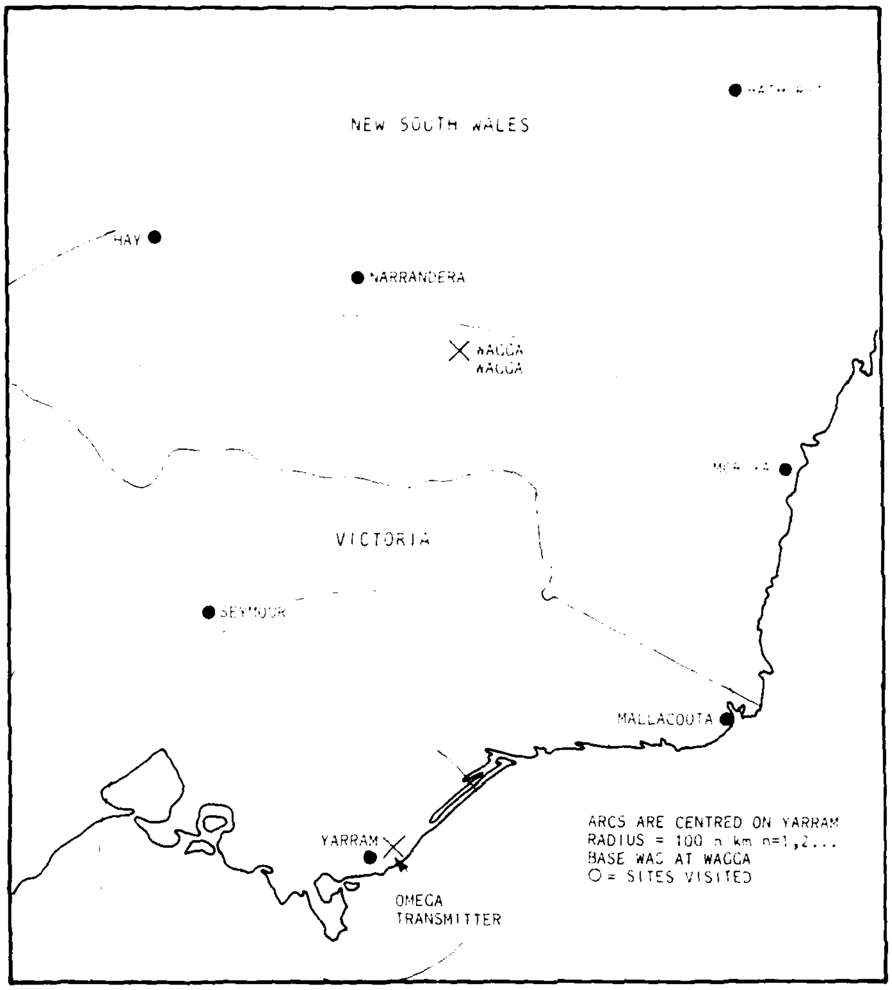


Figure 2. Map of New South Wales and Victoria showing field sites

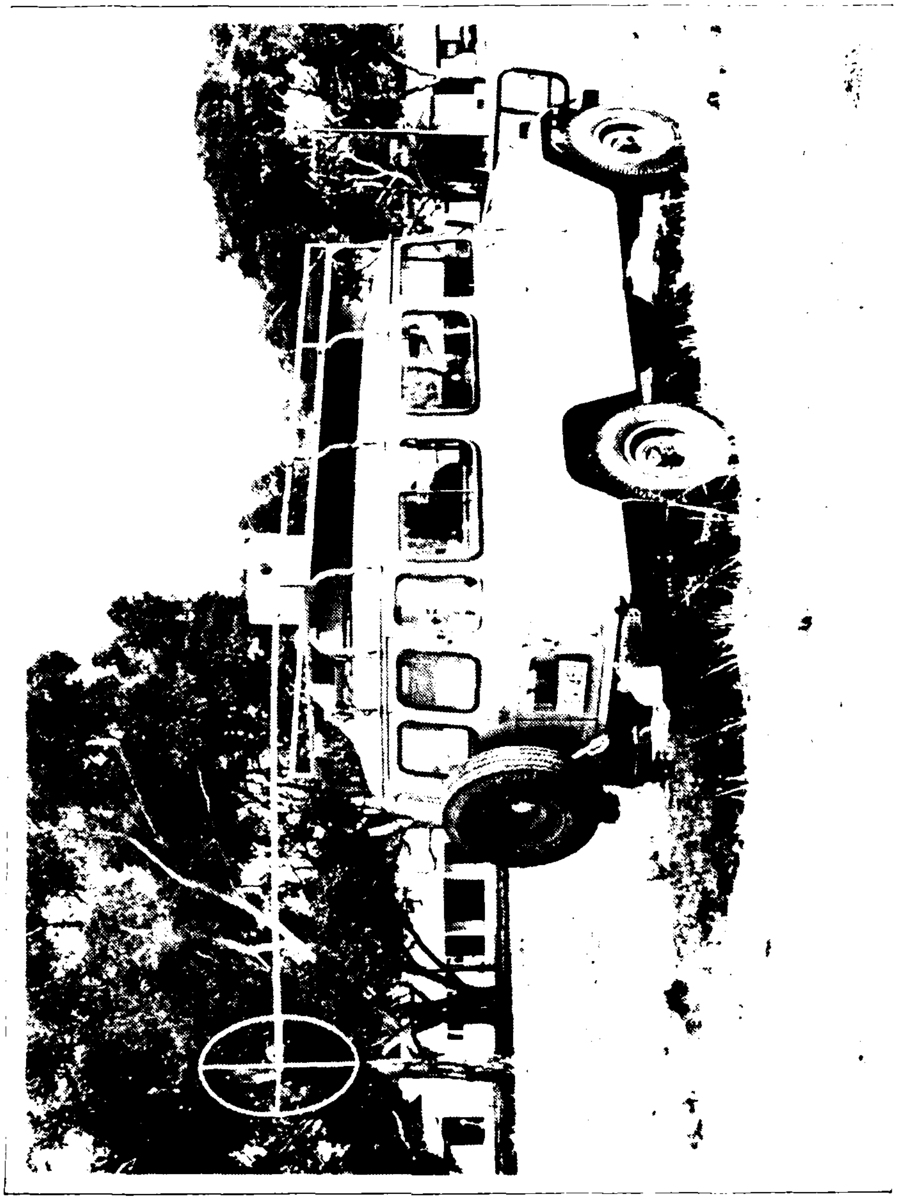


Figure 5. Toyota Land Cruiser

Figure 4. Ford D700 truck

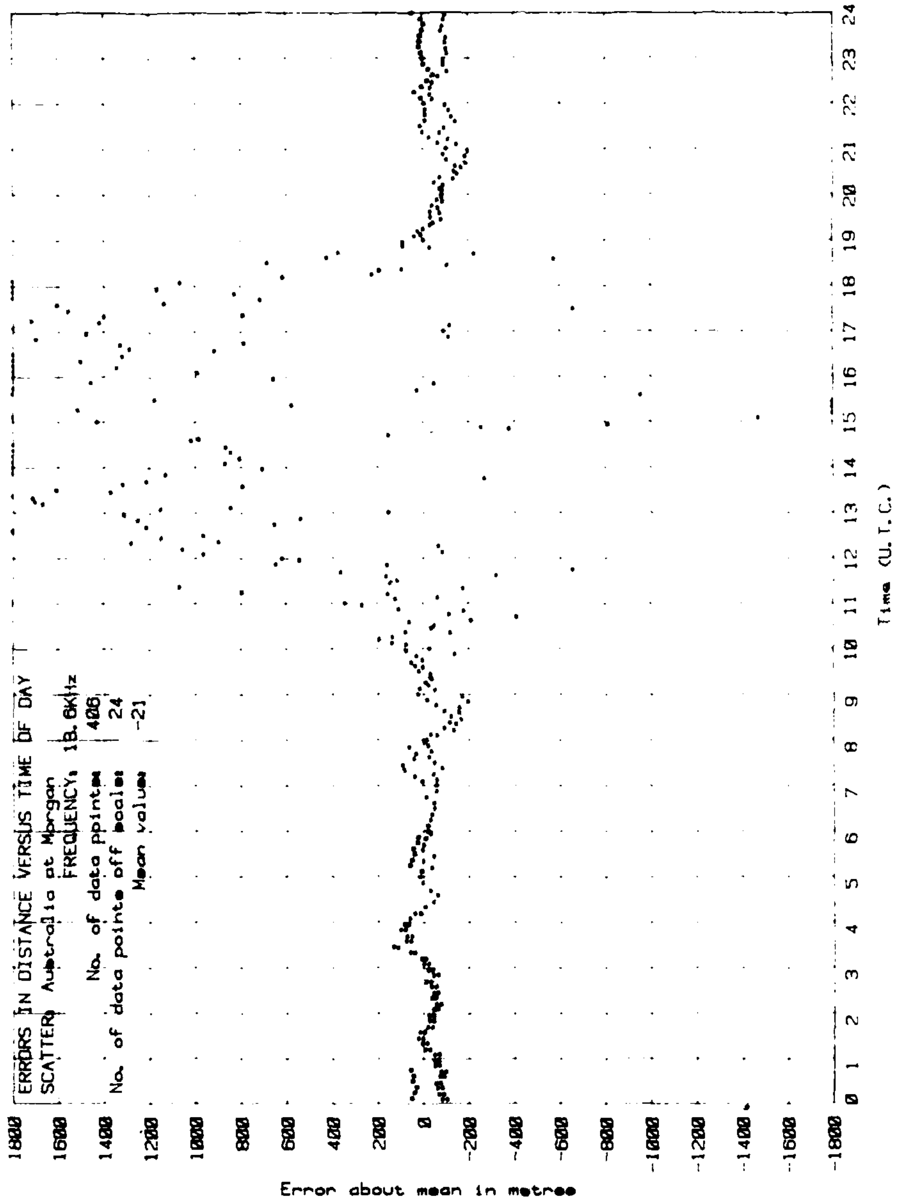


Figure 5. Scatter of errors in distance at Morgan (Australia 13.6 kHz)

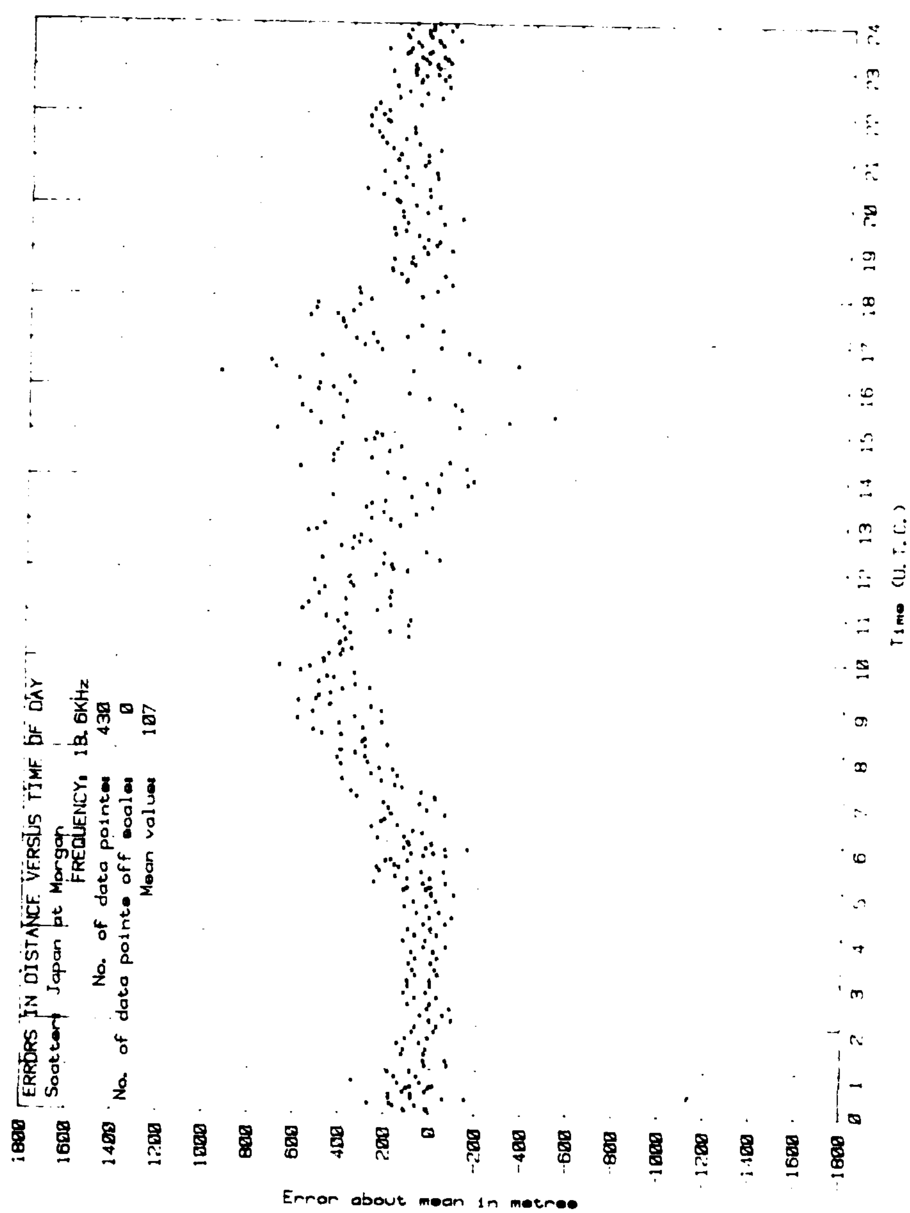


Figure 6. Scatter of errors in distance at Morgan (Japan 13.6 kHz)

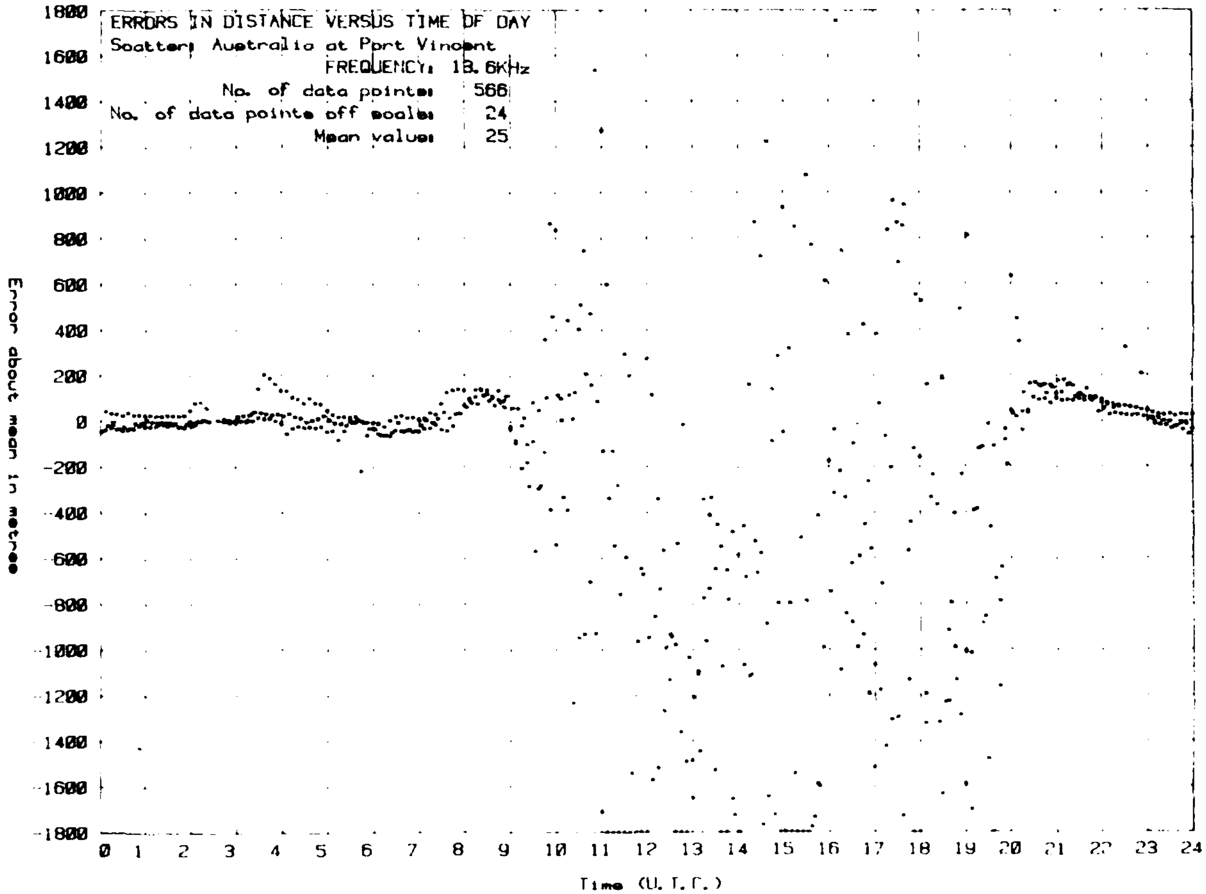


Figure . Scatter of errors in distance at Port Vincent (Australia 13.6 kHz)

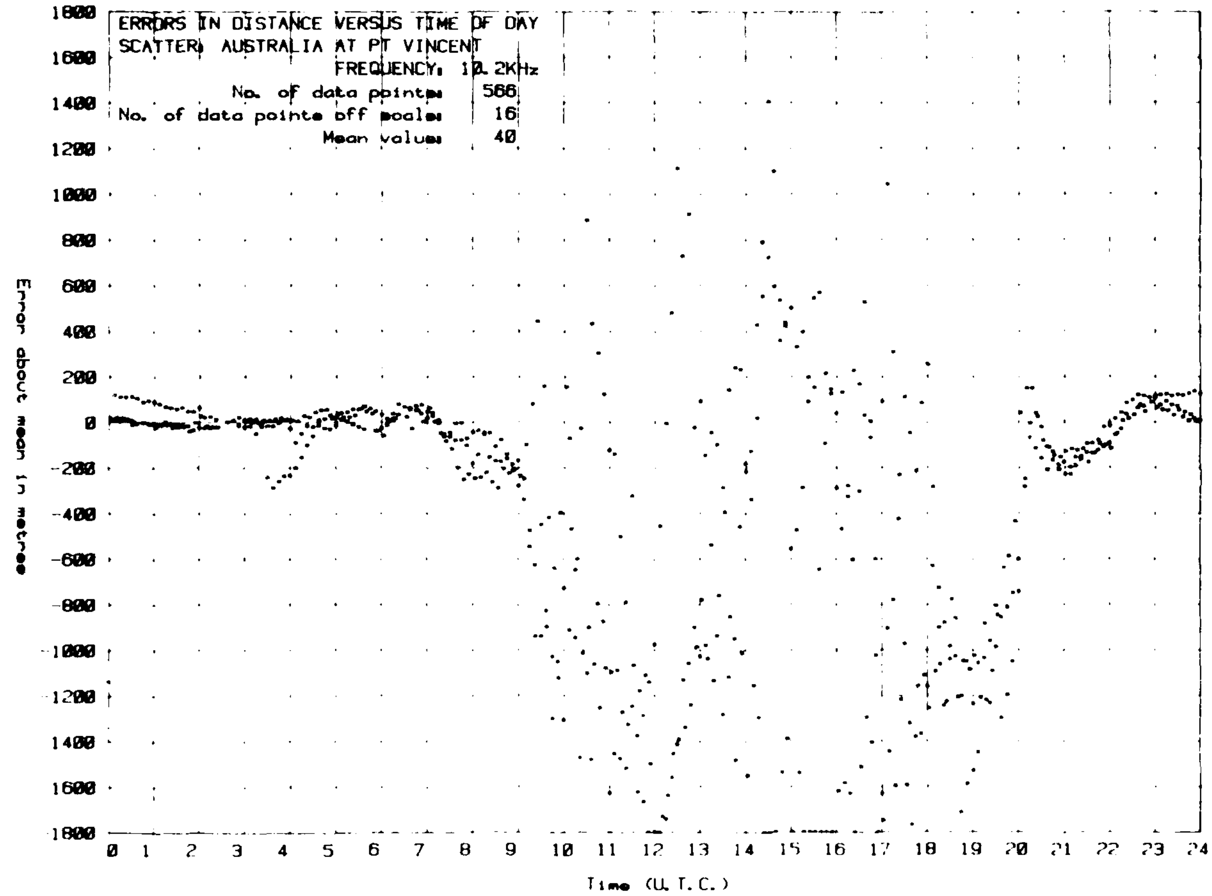


Figure 8. Scatter of errors in distance at Port Vincent (Australia 10.2 kHz)

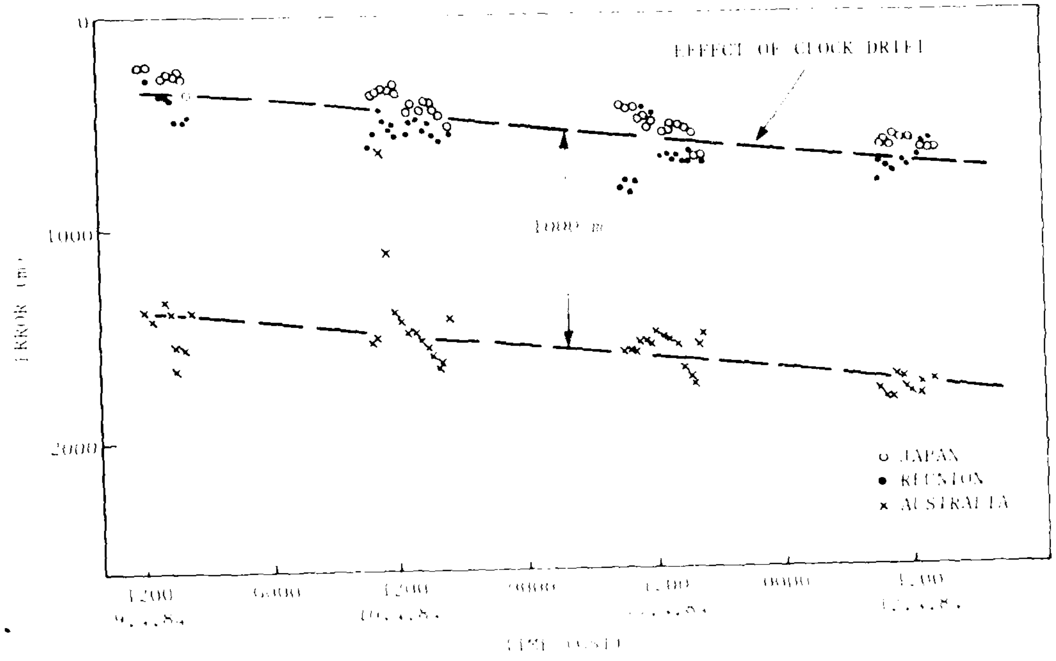


Figure 9. Radial range error [illegible]

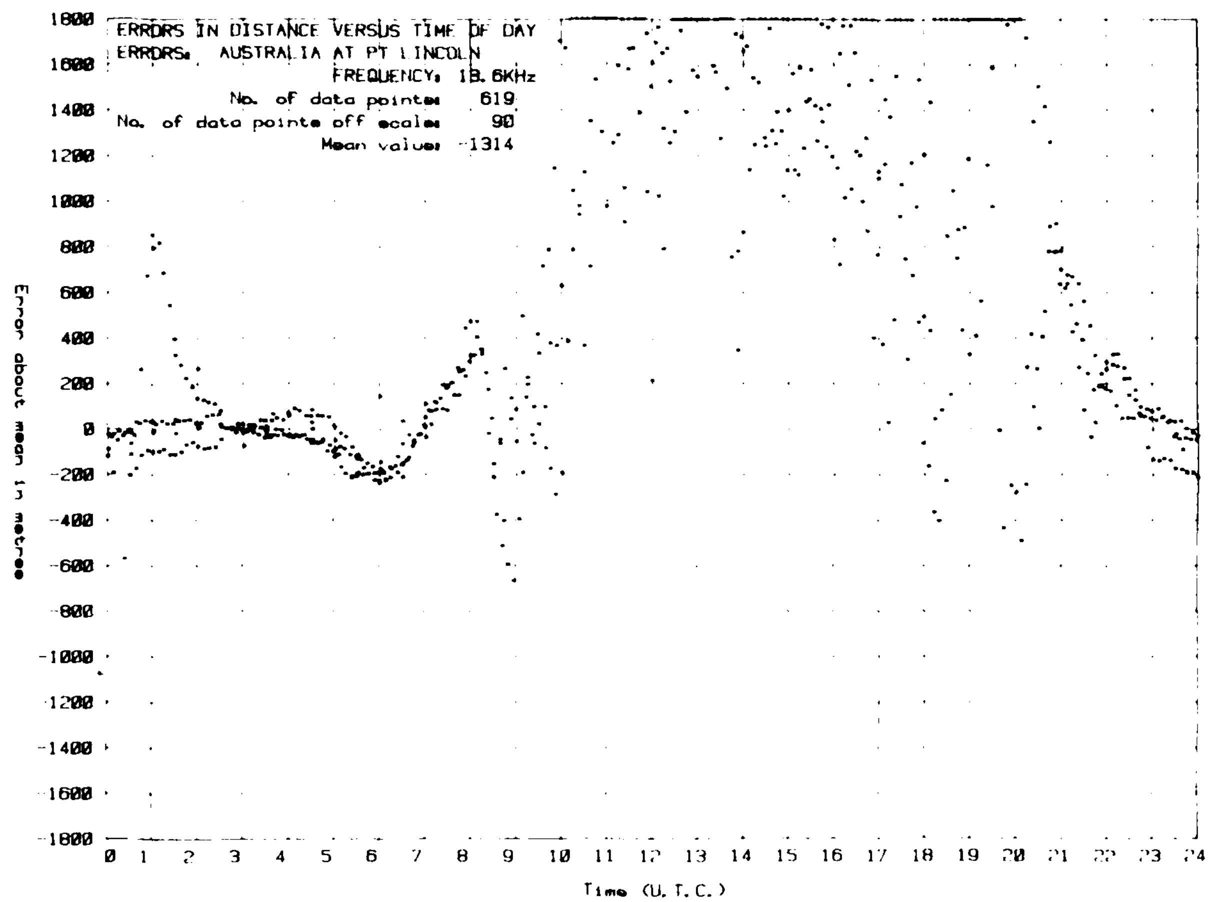


Figure 10. Scatter at Port Lincoln (Australia 13.6 kHz)

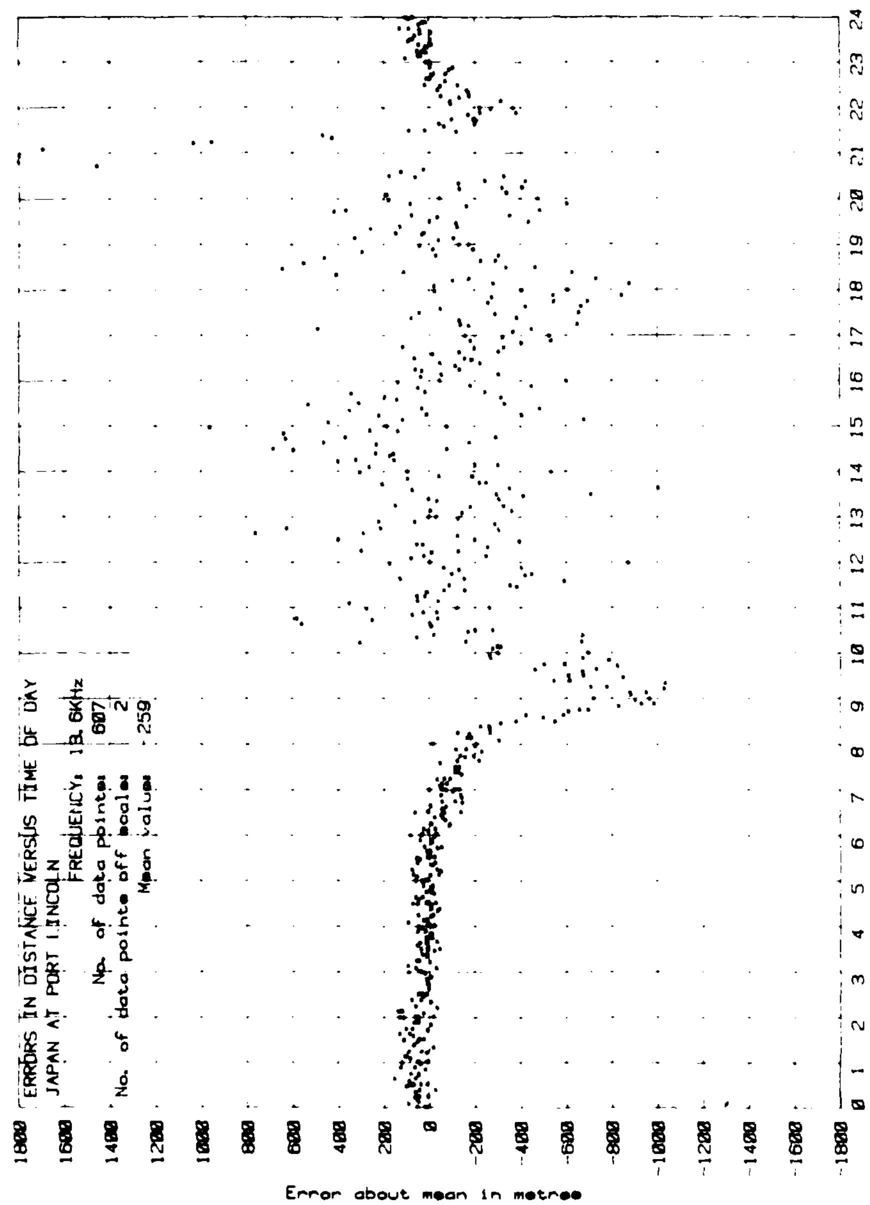


Figure 11. Scatter at Port Lincoln (Japan 13.6 kHz)

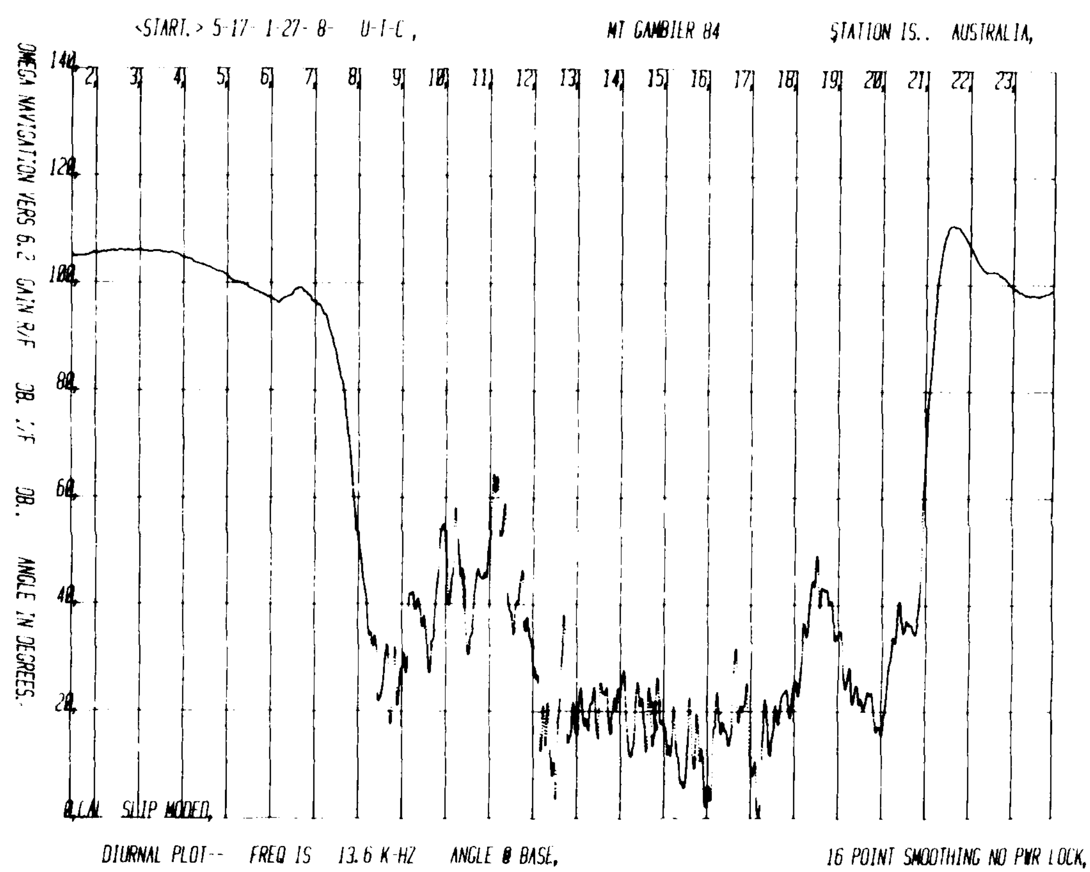


Figure 12. Typical diurnal for Australia at Salisbury on 10.2 kHz

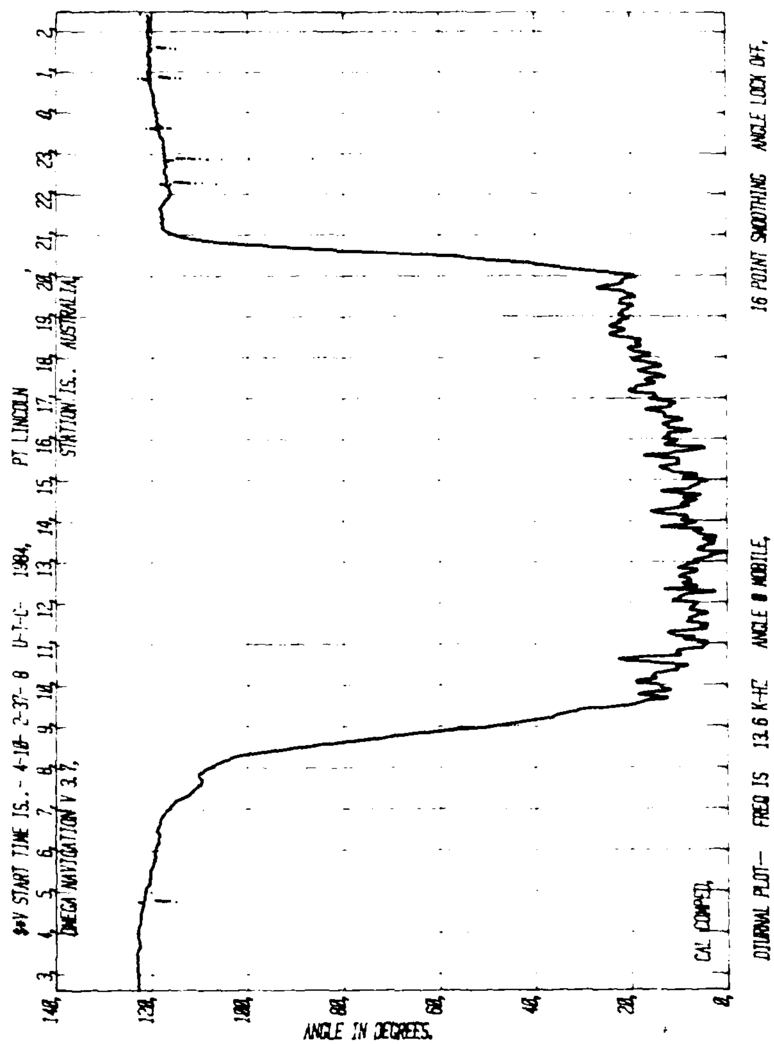


Figure 13. Diurnal for Australia at Port Lincoln on 13.6 kHz

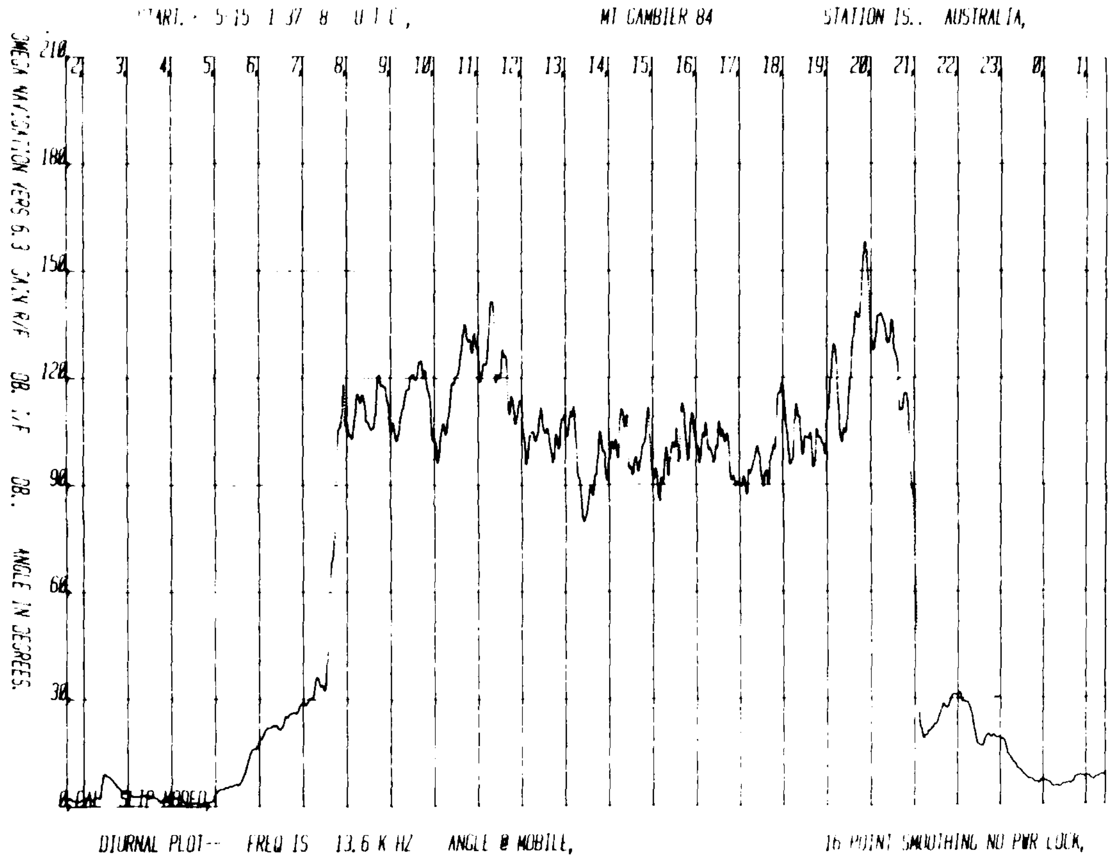


Figure 14. Diurnal for Australia at Mount Gambier [illegible]

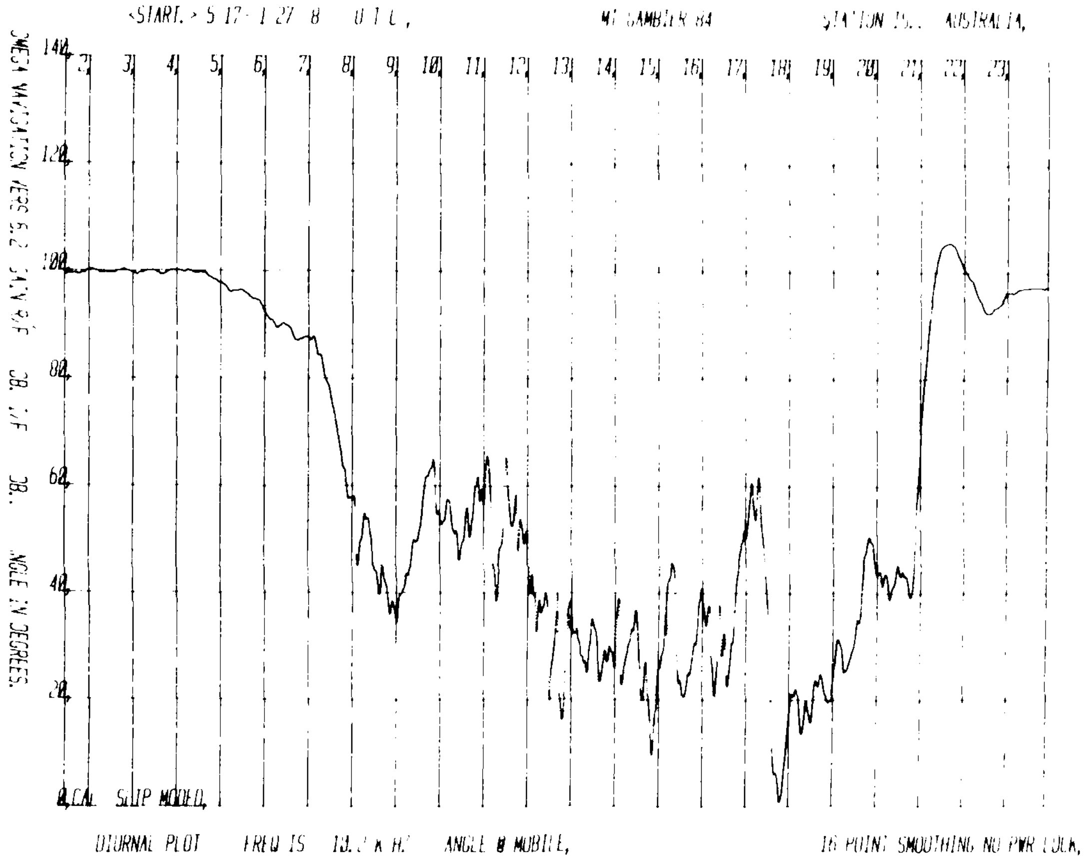


Figure [illegible]. Typical diurnal for Australia at [illegible]

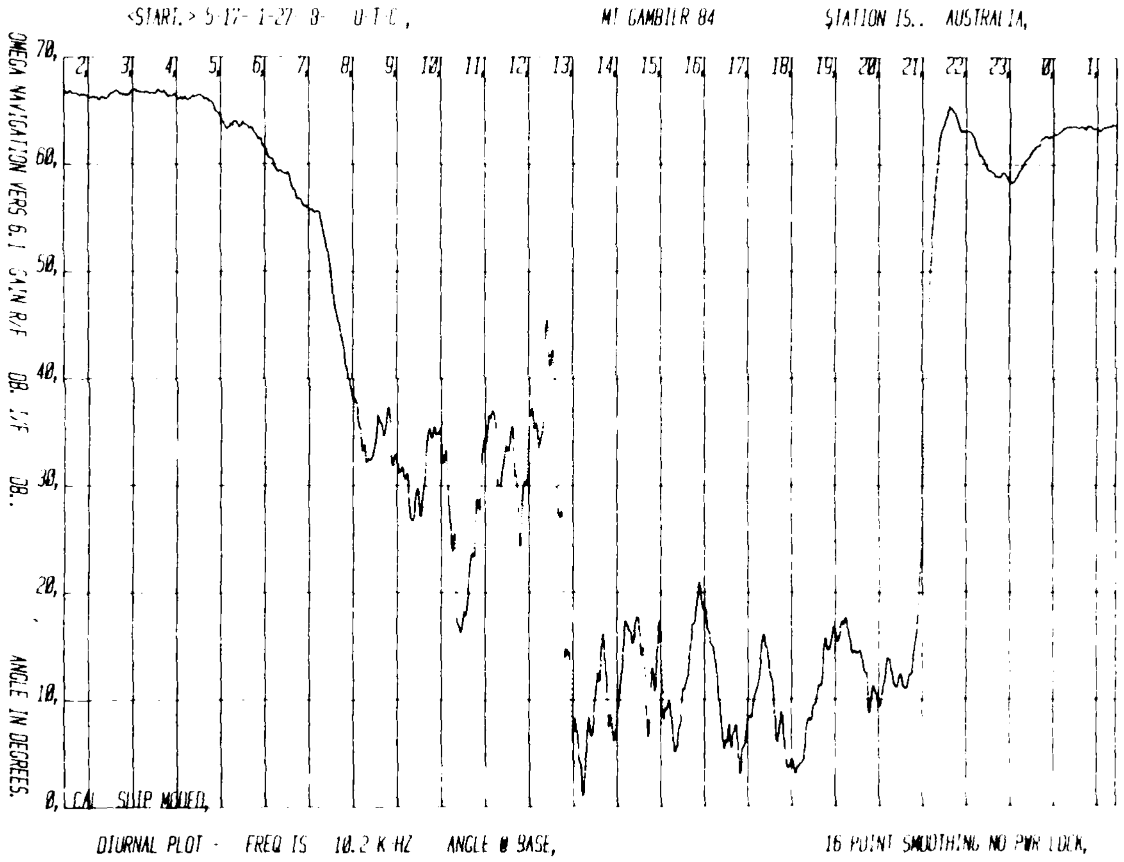


Figure 16. Diurnal for Australia at Mount Gambier on 10.2 kHz

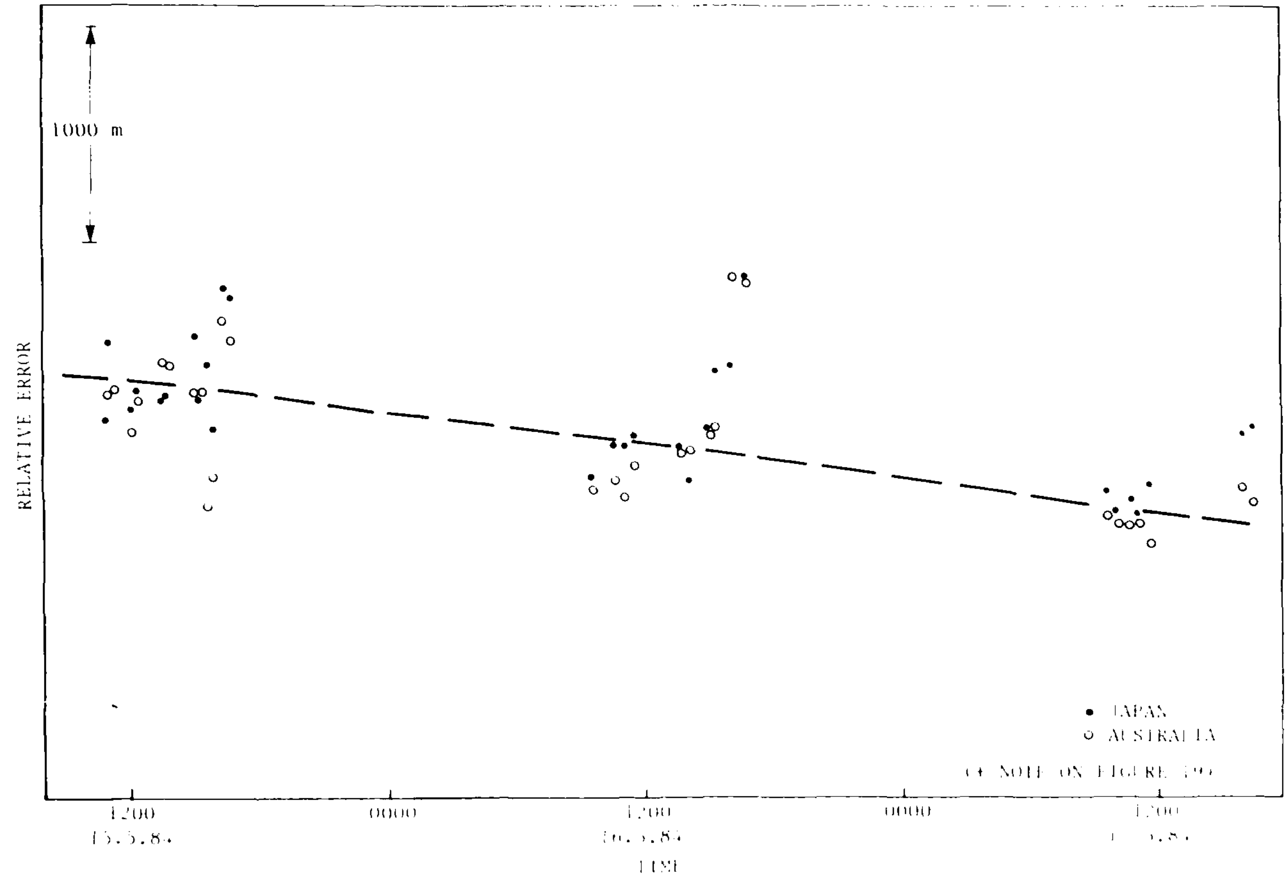


Figure 1[illegible]. Errors - Australia relative to Japan 13.6 kHz

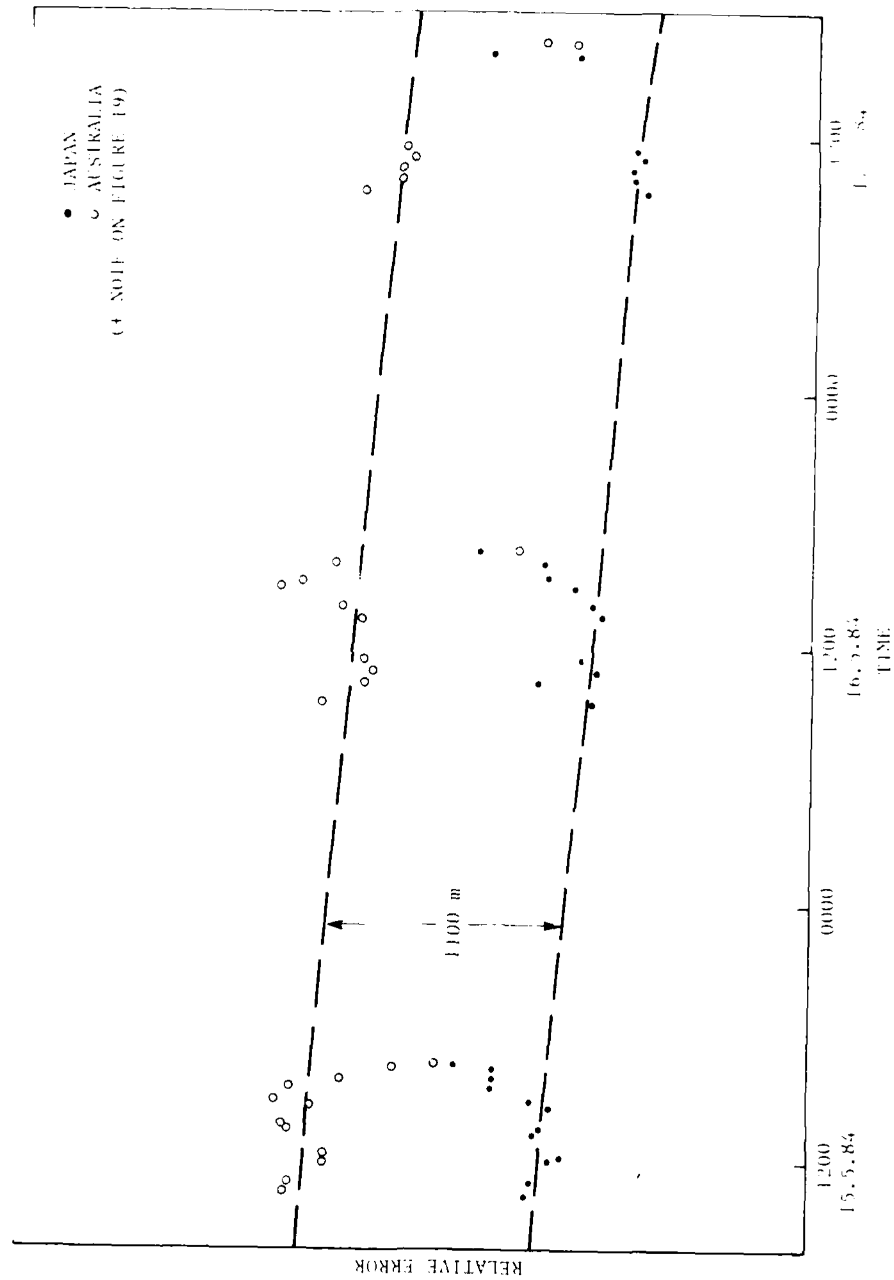


Figure 18. Errors - Australia relative to Japan 11.3 kHz

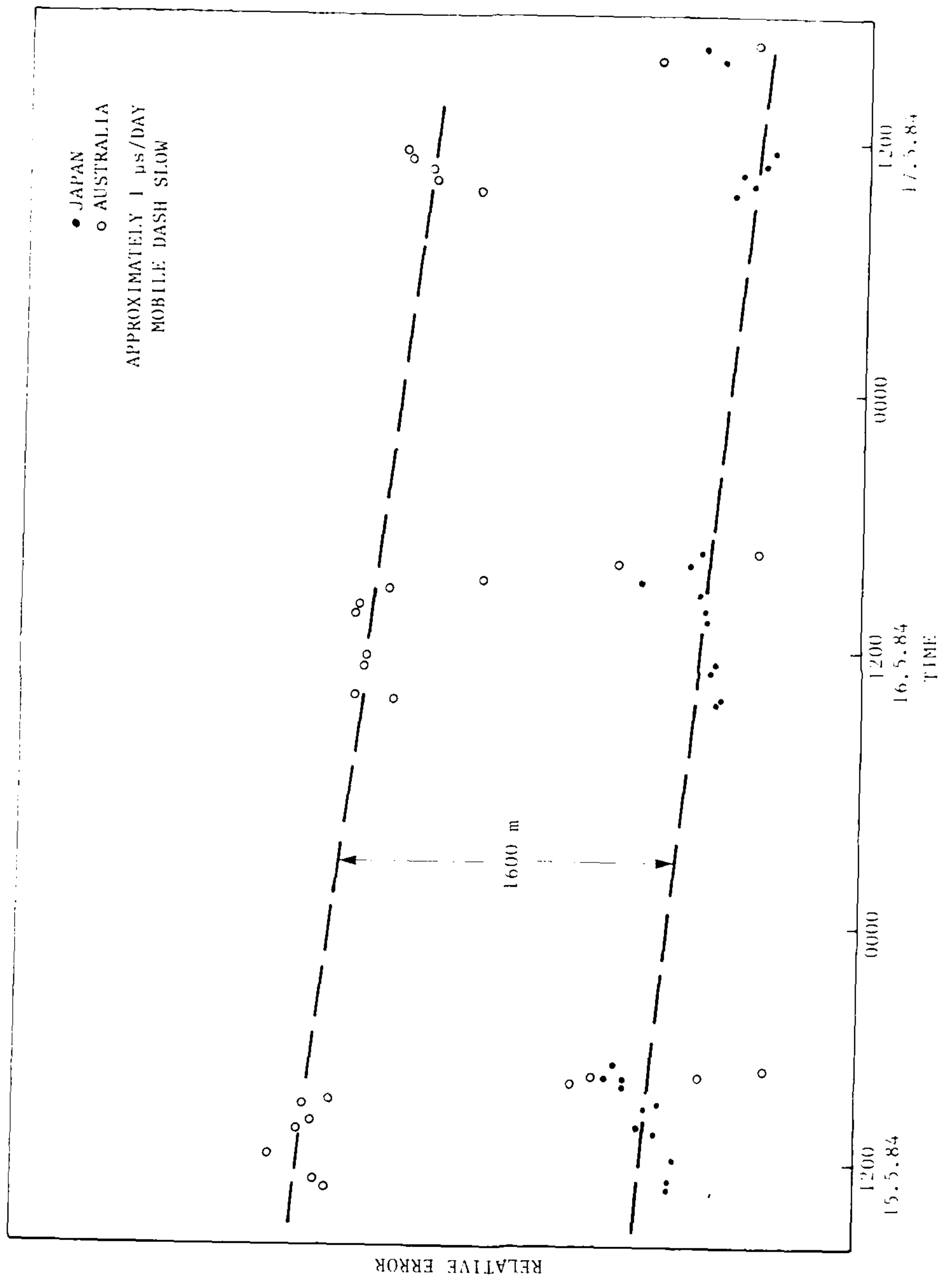


Figure 19. Errors - Australia relative to Japan 10.2 kHz

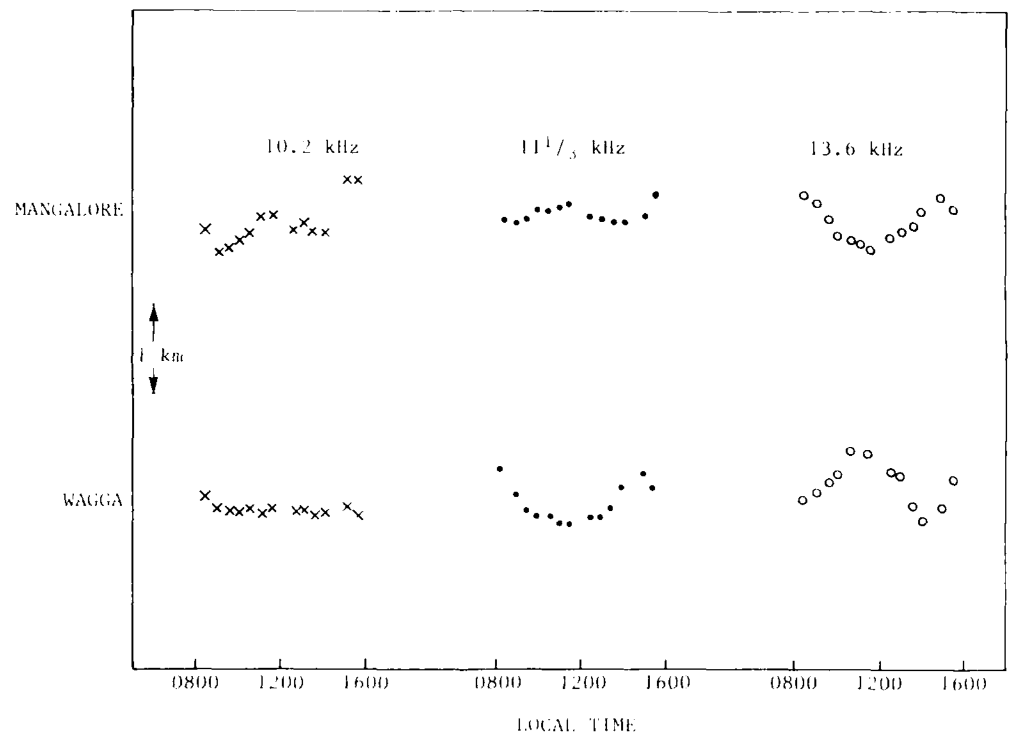


Figure 20. Diurnals for Omega Australia - Wagga/Mangalore

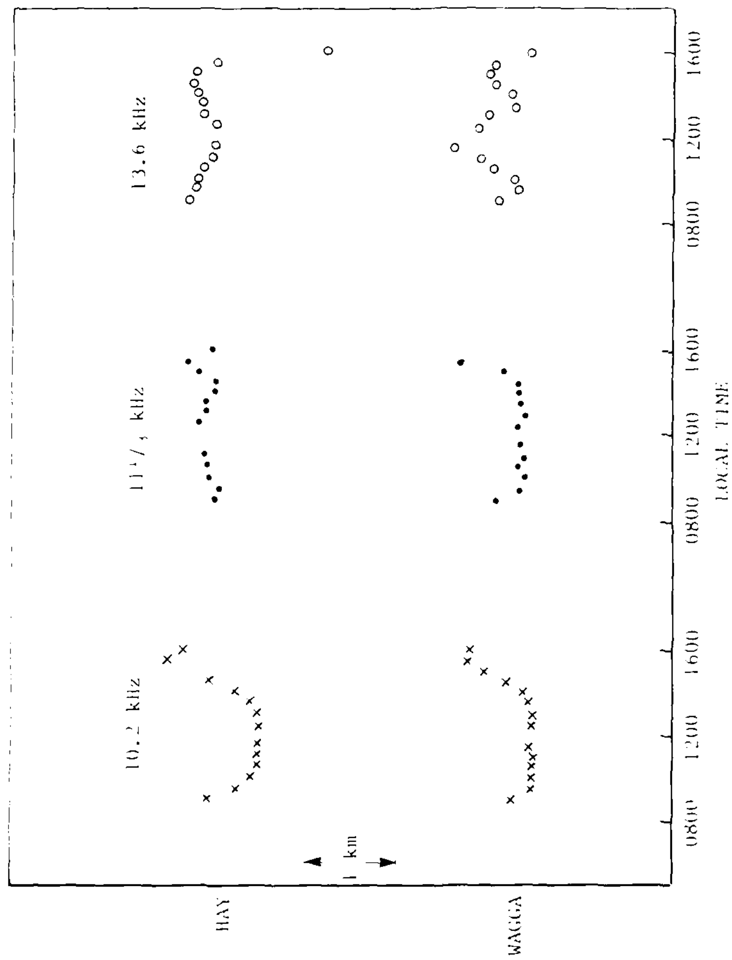
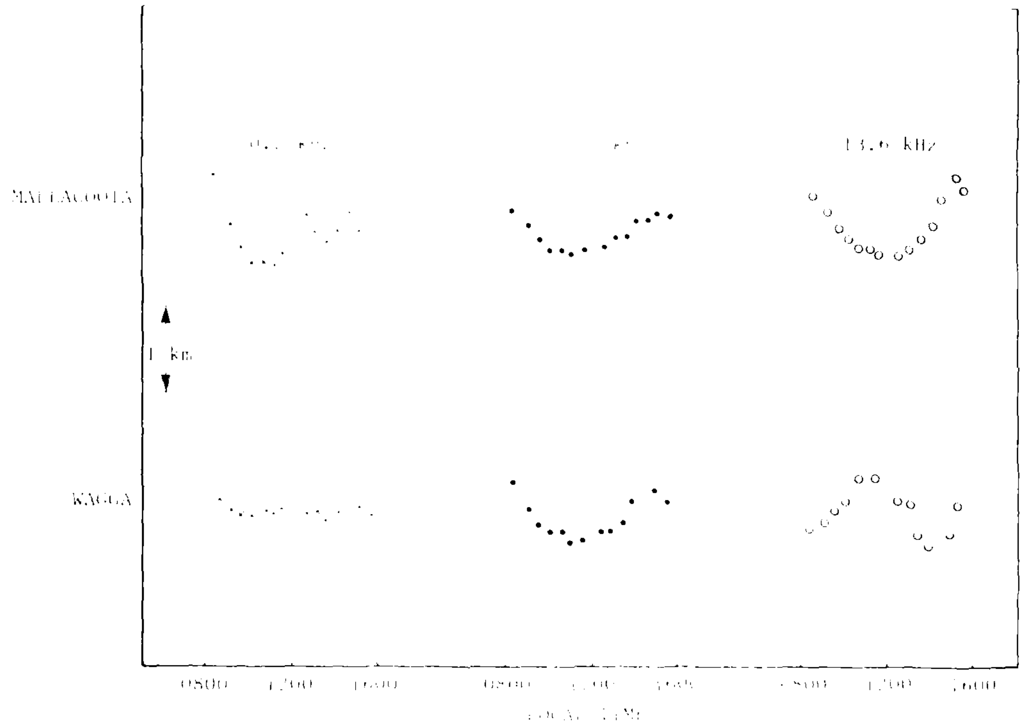


Figure 21. Diurnals for Omega Australia - Wagga/Hay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WAGGA
1 km
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0800 1200 1600
0800 1200 1600

[illegible]

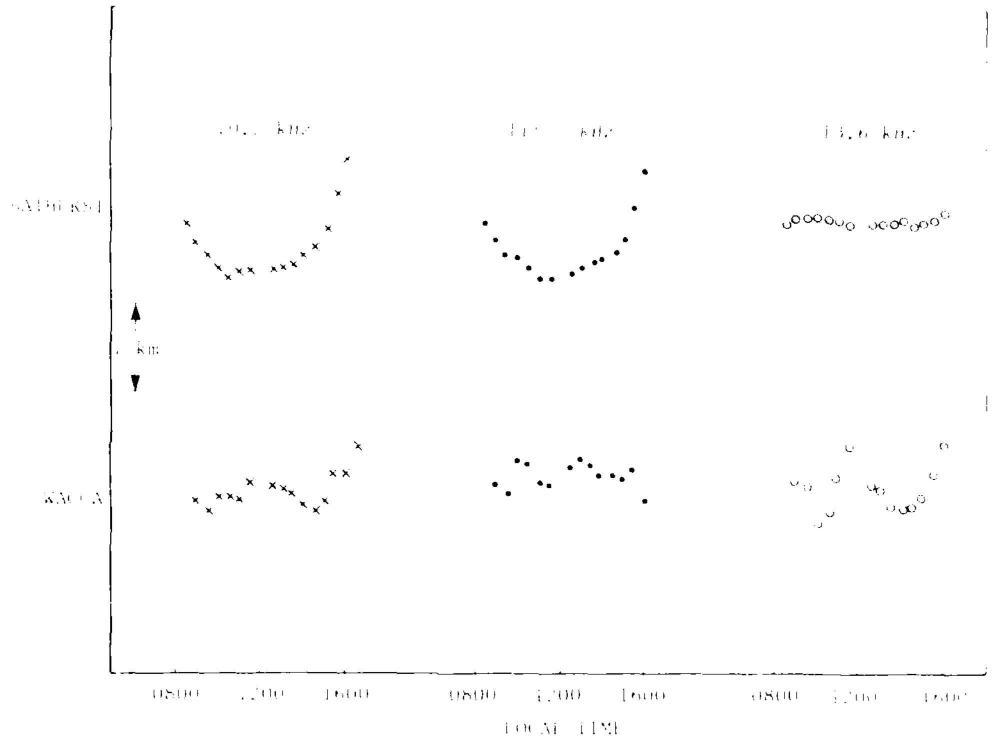

Figure [illegible]. Diurnals for Omega Australia - Wagga Bathurst

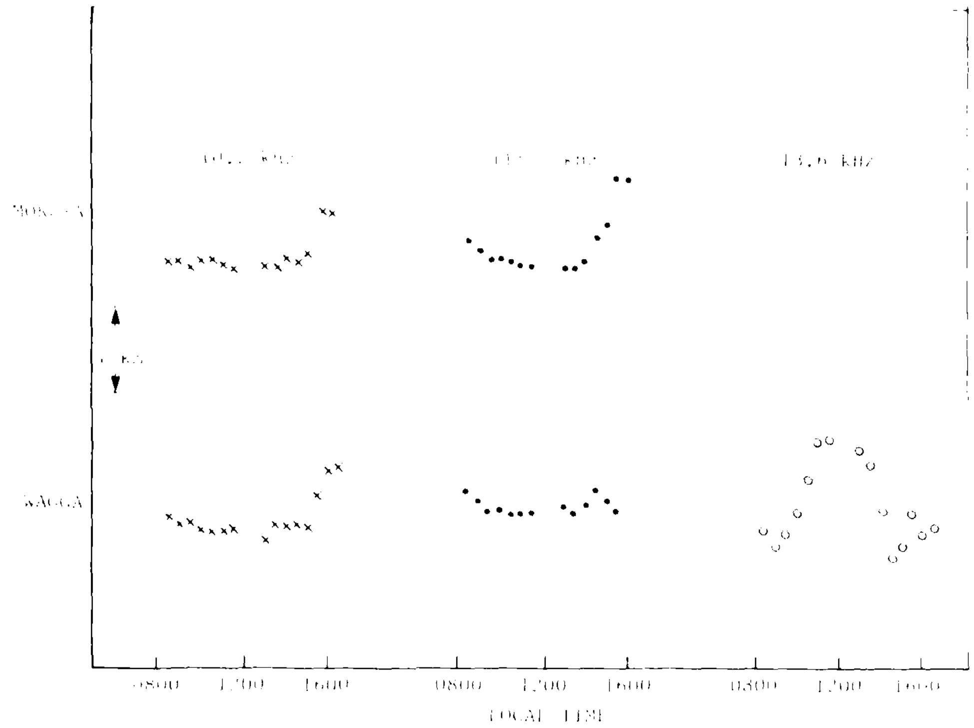

Figure 24. Diurnals for Omega Australia - Wagga Moruya

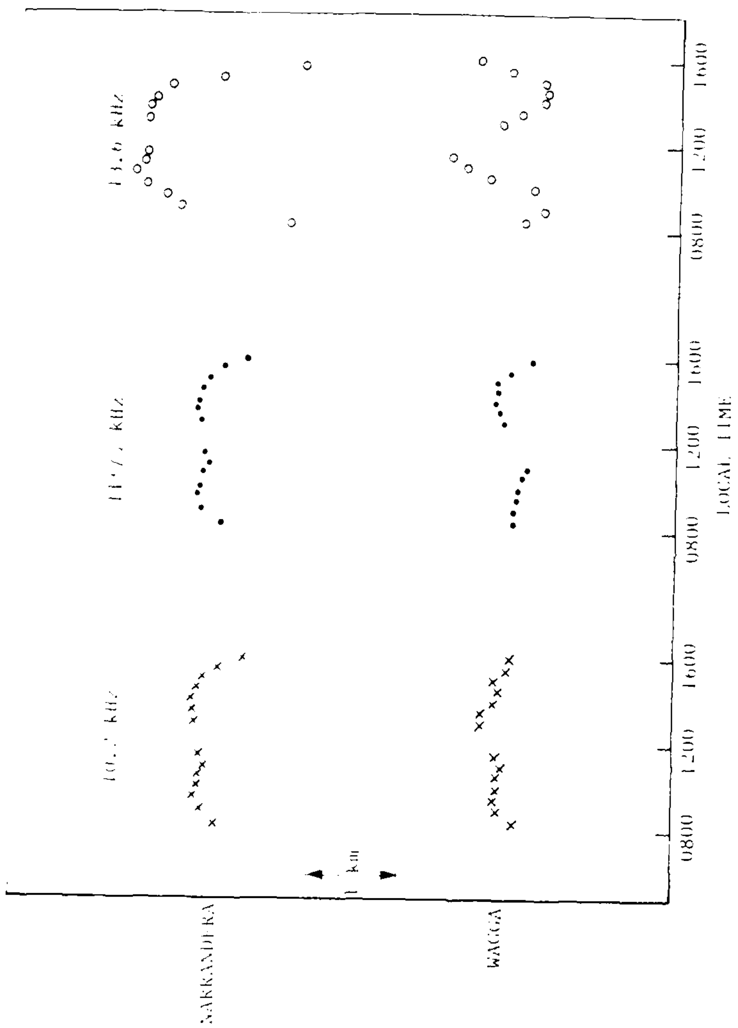

Figure 25. Diurnals for Omega Australia - Wagga/Narrandera

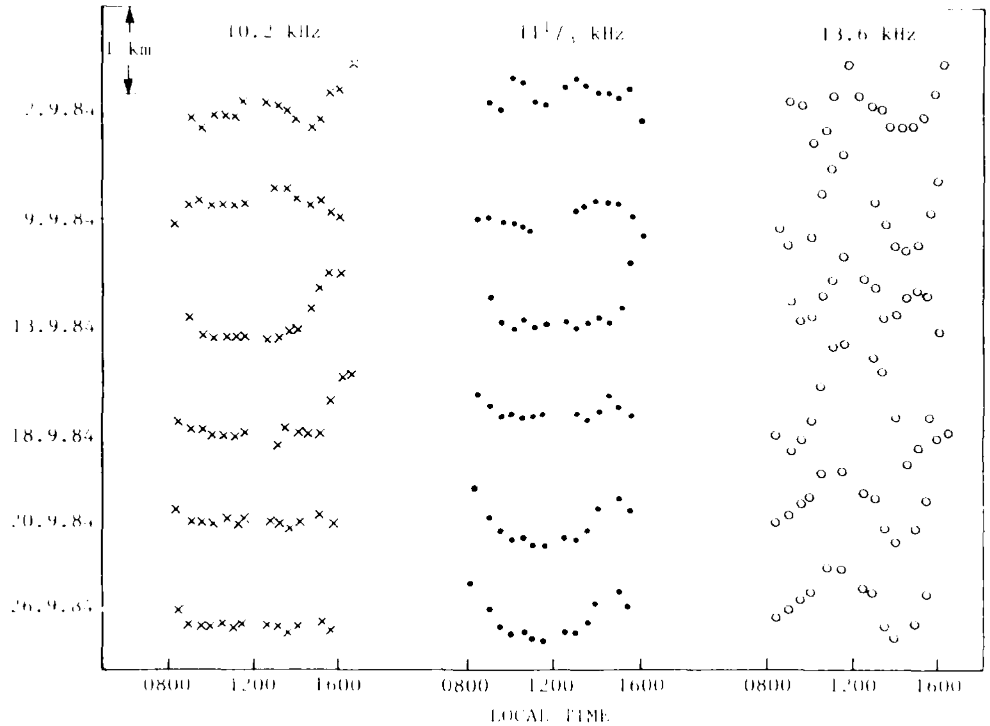

Figure 26. Diurnals for Omega Australia - Wagga

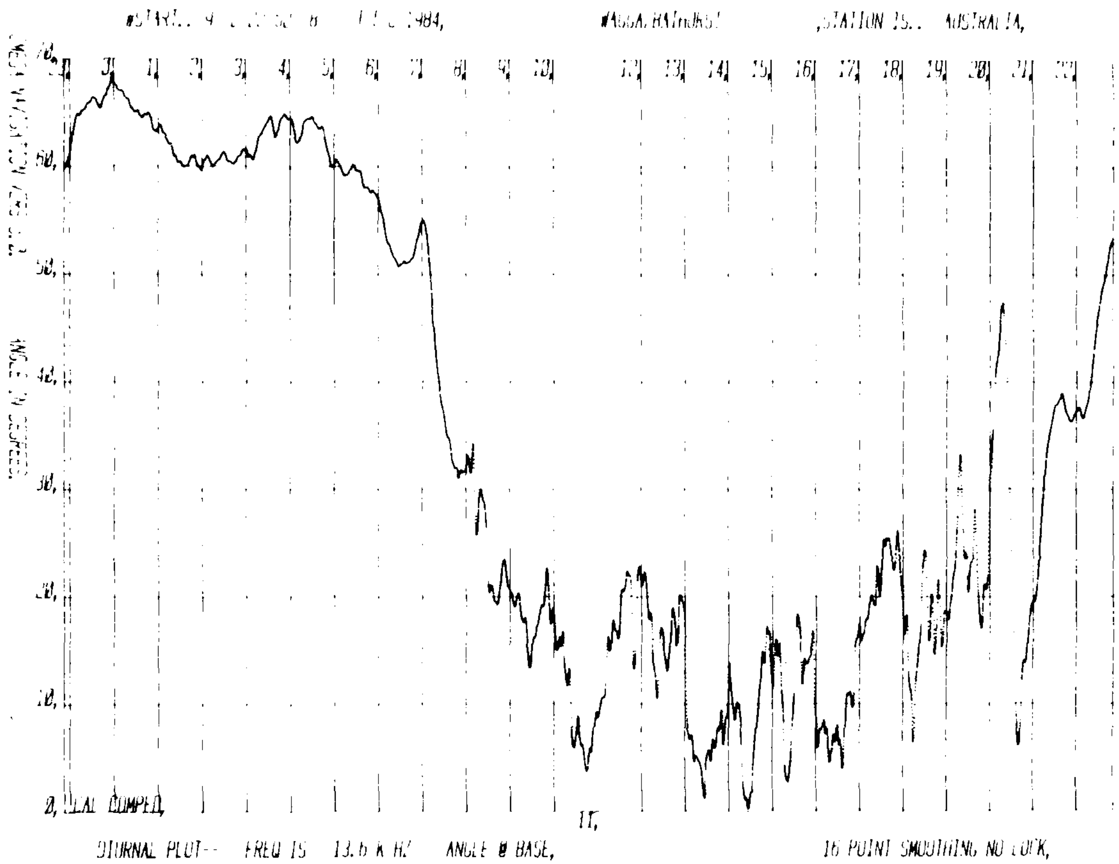

Figure 27. Diurnal at Wagga - Australia 13.6 kHz

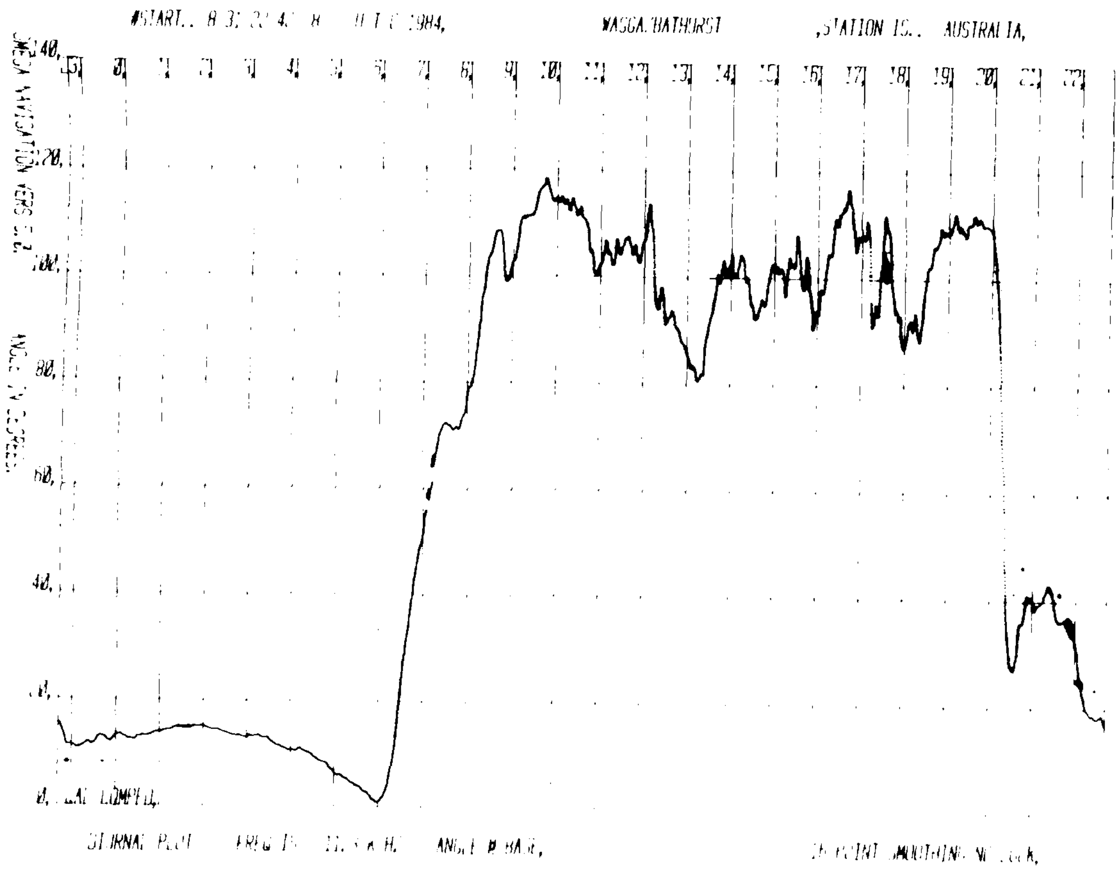

Figure [illegible]8. Diurnal at [illegible] - Australia [illegible]

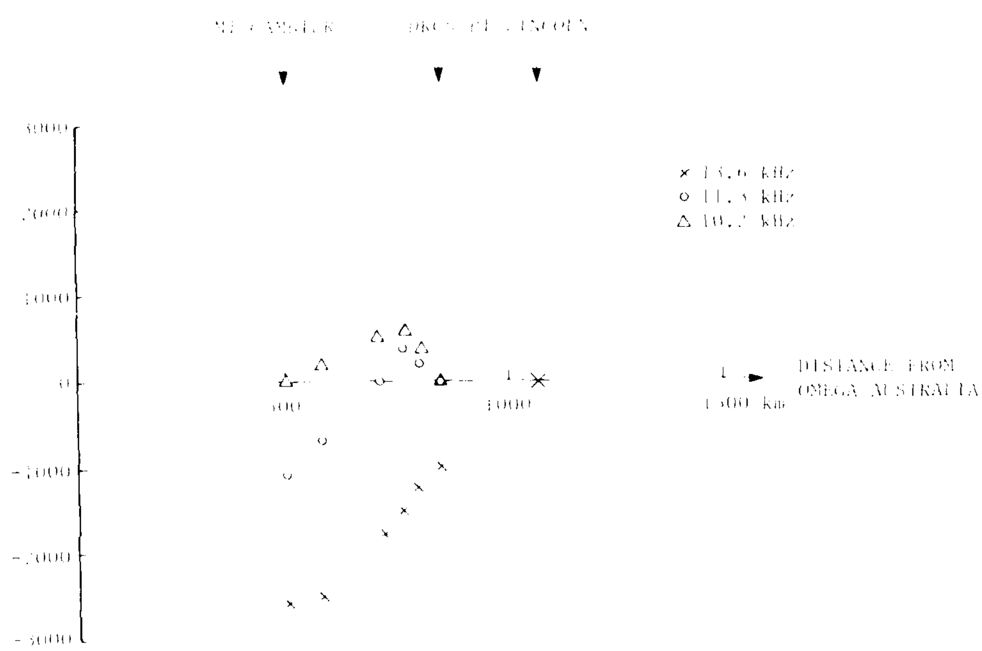

Figure 29. Error in distance measured from Port Lincoln in the direction of Omega Australia

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DOCUMENT CONTROL DATA SHEET

Security classification of this page: UNCLASSIFIED

1 DOCUMENT NUMBERS		2 SECURITY CLASSIFICATION	
AR Number	AR-004-971	a. Complete Document	Unclassified
Series Number	ERL-0423-TM	b. Title in Isolation	Unclassified
Other Numbers		c. Summary in Isolation	Unclassified

3 TITLE

ASSESSMENT OF THE DIFFERENTIAL TECHNIQUE FOR LAND NAVIGATION WITHIN 1000 km OF OMEGA AUSTRALIA

4 PERSONAL AUTHOR(S)	5 DOCUMENT DATE
J.H. Silby	July 1987
	6.1 TOTAL NUMBER OF PAGES: 36
	6.2 NUMBER OF REFERENCES: 5

7.1 CORPORATE AUTHOR(S)	8 REFERENCE NUMBERS
Electronics Research Laboratory	a. Task: DST 84/077
	b. Sponsoring Agency:
7.2 DOCUMENT SERIES AND NUMBER	9 COST CODE
Technical Memorandum 0423	127

10 IMPRINT (Publishing organisation)	11 COMPUTER PROGRAM(S) (Title(s) and language(s))
Defence Research Centre Salisbury	

12 RELEASE LIMITATIONS (of the document)

Approved for Public Release.

Security classification of this page: UNCLASSIFIED

Security classification of this page UNCLASSIFIED

13 ANNOUNCEMENT LIMITATIONS (of the information on these pages)

No limitation

14 DESCRIPTORS

a EJC Thesaurus Terms

Omega navigation
Surface navigation
Navigational aids

b Non-Thesaurus Terms

15 COSATI CODES

0076D

16 SUMMARY OR ABSTRACT
(if this is security classified, the announcement of this report will be similarly classified)

Navigation section of Radio Group, Electronics Research Laboratory was required to investigate the behaviour of the Australian Omega transmissions within Australia. This paper reports the approach used to undertake this investigation at points within the area of modal interference and the results obtained. Conclusions are drawn on the efficacy of using the Omega Australia transmissions in the differential mode in the areas investigated and comment is made on the use of differential Omega for land navigation in Australia drawing also on the results of trials reported previously.

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