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I.O.S.

SYMINEX RADAR WAVE RECORDER ON FRIGG PLATFORM

Assessment of performance based on the results of the 3 month comparison with a Waverider - 1979/80

by

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1. INTRODUCTION

1.1 General

The United Kingdom Offshore Operators Association funded a 3-month comparison between a Syminex wave-recording radar mounted on the Frigg Platform in the North Sea and a standard Datawell Waverider moored nearby. Syminex analysed and reported on the data (see below) and this showed significant discrepancies. IOS was asked by UKOOA to investigate and comment on the cause of these. The Secretary of the UKOOA Oceanographic Committee, Mr W B Woollen, has taken a considerable interest in this investigation and is therefore a joint author of this report.

1.2 The following evidence has been used.

(a) The Syminex reports to UKOOA:

		Syminex Report No.
	November 1979) Addendum)	569/80
	December 1979	619/80
	January 1979	620/80
	Synthesis report) Addendum)	933/80
(b)	General description of the radar system	587/80

(c) Correspondence with Syminex followed by a visit to the Syminex offices and laboratories in Marseille on 19 December 1980. At this meeting, apart from the authors, the following were present:

Mr Cavanie of CNEXO

Mr P Ansquer, Technical Director, Syminex

Mr A Baudry, Syminex

Mr R Carton, Elf-Aquitaine (Paris)

With other staff of Syminex at various times.

2. GENERAL

The firm of Syminex were very helpful and gave us all the information and assistance we requested, although it was not possible to speak to the designer of the equipment and, as a result, some points of detail about its operation were not clarified. However, these mainly concerned features (such as target velocity measurement) not directly related to the wave recording function.

The general principle of the radar is one which is well established (see Section 5. below). So far as the authors could tell from a rather cursory inspection it is well engineered.

It had been designed in the first instance as an aircraft radar altimeter then adapted as a berthing aid for supertankers, and finally as a wave recorder. The method of working is more complex than appears at first sight and is probably more so than would have been necessary if the instrument had been designed as a wave recorder in the first place. However, on balance, the advantage of using an instrument which is basically a proven and reliable design probably outweighs the disadvantage of its not being specifically designed for the present application.

3. THE EVIDENCE FOR THE FAULT

3.1 Examination of individual waves

Three individual large waves shown in the radar records available to us before the meeting on 19 December 1980 are obvious errors. These are:

(1) November Report page 29 at 402 s (the wave at 682 s can also be shown to be impossible)

(2) December Report page 28 at 750 s.

(3) A test record given us by Syminex dated 1 February 1979 @ 1500 hours has several impossible waves on it (at the time of the record the sea state was severe).

The second case referred to above was printed out in an expanded form at the meeting on 19 December 1980. Syminex agreed that the evidence indicated that this was a false wave.

Having identified this type of error, inspection of the records showed several other waves which seem to have the same general appearance.

Inspection of the numerical data printed in the reports led us to believe that the radar records for 0900 and 1200 hours on 13 December would show this fault rather obviously. They were the two highest sea states for the 3 month period as recorded by the radar, and show large discrepancies in waveheight compared with the Waverider results.

At the meeting Syminex willingly agreed to print out various records as requested. Unfortunately it took some time to organise this and only a limited number could be done, particularly because our thinking on how to analyse them developed as we were able to see more detail, requiring particular portions of the records to be printed on greatly expanded timescales.

The wave which we examined in most detail is shown in the attached figure (0900 hours 13 December at 345 s: complete with the notes made on it at the meeting!). It shows a crest nearly three times as high as the troughs on either side of it. While we cannot say that this is absolutely impossible, it is unlikely. Further, the downward velocity on the rear-slope of the wave (approximately 9 m/s) is greater than the upwards velocity on the front slope (approximately 7 m/s): both figures are very high. The downwards velocity on the rear slope as it passes through the mean water level is approximately 5.5 m/s, which is considerably greater than the theoretical particle velocity for a wave of this height and period. Taken together, these features make it reasonably certain that this wave is falsely recorded. One or two other large waves on this record also appear unlikely, but we did not have time to examine them in detail.

3.2 Statistical evidence

Syminex agree that the radar records for the 18, 19 and 20 November (which are all on the same tape) are faulty. If one looks through the plots of Hs in the Synthesis Report* and neglects these faulty values, it becomes clear that if one considers only values of Hs below about 4 m, there is no evidence for any difference in calibration of the two instruments: one could certainly see a 5% difference, and probably a 3% difference.

Note also the scatter of the points. Neglecting the false points referred to above, in the whole data set (printed on page 75 of the summary report) for values of Hs below 5 m there is not a single point whose ratio of Hs radar/ Hs buoy is outside the limits 0.75 and 1.25. But look at the three highest values of Hs as recorded by the radar (0900 hours, 1200 hours and 1500 hours on 13 December): the comparisons are as follows:

Time	Buoy Hs (m)	Radar Hs (m)	Ratio
0900	8.9	12.0	1.35
1200	9.4	12.9	1.37
1500	9.4	10.0	1.06

The likelihood of getting the first two of these discrepancies from random sampling errors is individually small. Getting all three in successive records at the height of the worst storm recorded is virtually impossible on a random chance basis.

Thus, the statistical evidence points to the discrepancies occurring only at high sea-states.

*Hs = 4 $\sqrt{m_0}$ has been chosen because it is the best conditioned waveheight parameter

4. THE PERFORMANCE OF THE WAVERIDER BUOY

Waverider buoys move approximately with the water particles and this has the effect of broadening the crests and narrowing the troughs in steep seas relative to a fixed surface height recorder. Thus, the fact that the radar records show sharper crests than the buoy records is not in itself evidence of errors.

Syminex state that Waverider buoys "are well known for cutting the crests of the waves" (personal letter) and this is implied also by the remark at the top of page 202 of the Synthesis Report. Such "crest-cutting" certainly occurs when strong currents are running, but at the Frigg Field the maximum springs tidal current is approximately 0.5 knots, which is negligible in this context. So far as the authors are aware, with the type of mooring described by Syminex in these conditions, there is no evidence that crest-cutting is significant. However, it would be difficult to detect and no one has examined such an installation visually for a long period during a severe storm.

5. THE RADAR INSTRUMENT

5.1 The principle of operation

The details, many of which were described to us, are commercially confidential, but the broad principle of operation is a well established one and can be quoted here.

A radar signal is transmitted vertically downwards from a parabolic antenna with a 3^{o} beamwidth. The frequency is in the region of 12 G Hz (wavelength 2.5 cm). This frequency is swept between a lower and an upper limit. Thus, the echo received from the sea-surface, which is delayed in time by the order of 100 nanoseconds, is different from the frequency being transmitted. In the Syminex radar this beat frequency is kept constant by feedback to the ramp generator, and this analogue control voltage is the primary output of the wave recorder.

These f m transmissions take up only a small proportion of the available time. Between them a fixed frequency C W is transmitted allowing the doppler shift due to the velocity of the target to be measured. This is not at present used in the wave recording made.

Prior to the visit the authors were sent report No 587/80 dated 9 April 1980 by Syminex giving a general description of the radar wave meter. From the information given in this report the authors were surprised that the claimed resolution could be achieved. At the meeting, it became apparent that considerable changes had, in fact, been made, and in particular that the sweep range of frequency (which largely governs the resolving power) had been approximately trebled.

5.2 Possible mechanisms for producing the errors

Discussion of the principle of operation of the radar produced several suggestions as to possible mechanisms for the observed mode of failure. It was agreed that the most likely was a loss of lock of the range-tracking circuits due to a low signal strength return.

It was pointed out by the authors that in most circumstances the echo was probably composed of the sum of reflections from a large number of facets on the water surface, leading to a Rayleigh probability distribution for the echo amplitude. This gives a one in a thousand chance that the echo power would be one thousandth of its mean value. Further, published information shows that with a moderately rough surface, if the radar beam is tilted 30^{o} relative to the sea surface then the average returned power is reduced by a factor of between 100 and 1000. These two effects taken together suggest that as the wave slope becomes steeper there is an increasing chance of the radar echo falling either below the control range of the automatic gain control ("AGC") or below background noise.

It is worth mentioning that we were told that the AGC range is 1000:1 in amplitude, which does not appear to be adequate for this application.

6. CONCLUSIONS

By inspection of the time-series plots of the radar output and of the statistical comparisons, the instrument appears to be measuring waves correctly for most of the time. However, it is occasionally giving false outputs which are difficult to detect and correct by normal quality control techniques, and whose form is particularly unfortunate. The errors enhance the height of an occasional high crest and (less obviously) the depth of an occasional low trough. Thus, the statistics of the highest waves are distorted in a way which produces a spurious overestimate. Of the three highest values of Hs during the 3 months as measured by the radar, we consider that two are overestimated by at least 20%.

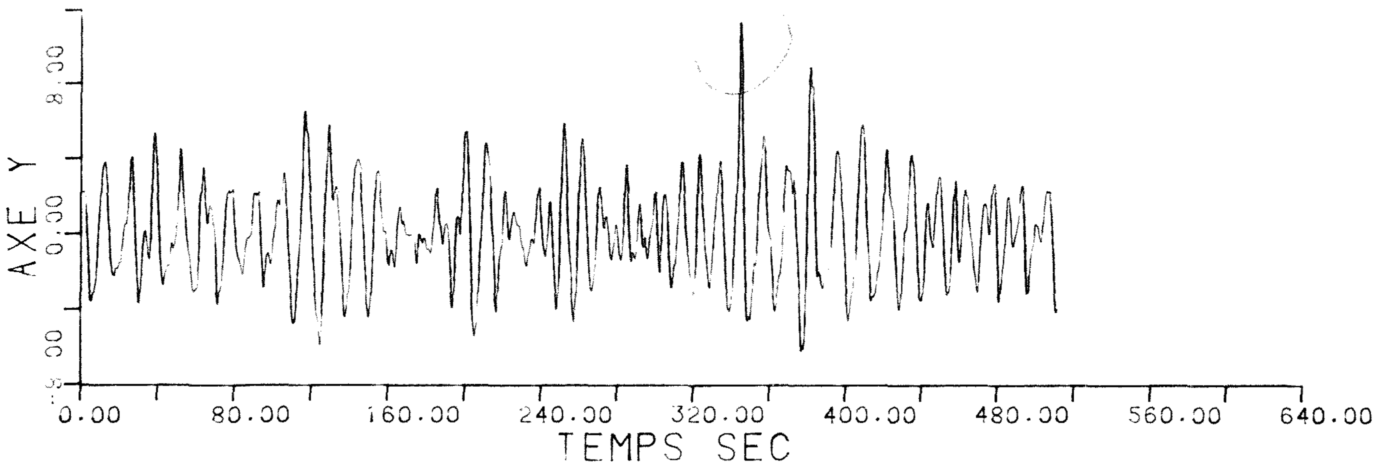
The evidence for the exaggeration of high waves was agreed by Syminex and possible reasons for it were discussed. Syminex will prepare proposals to investigate the problem.

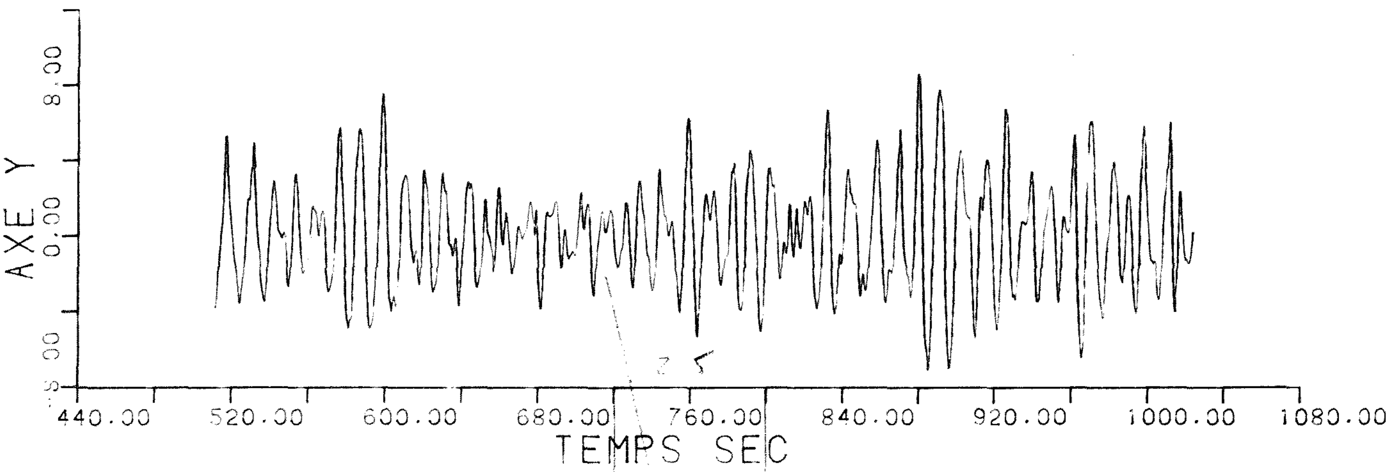
The radar will also give trouble when there is only a smooth swell running, but the occasions when this happens are likely to be few and comparatively unimportant statistically.

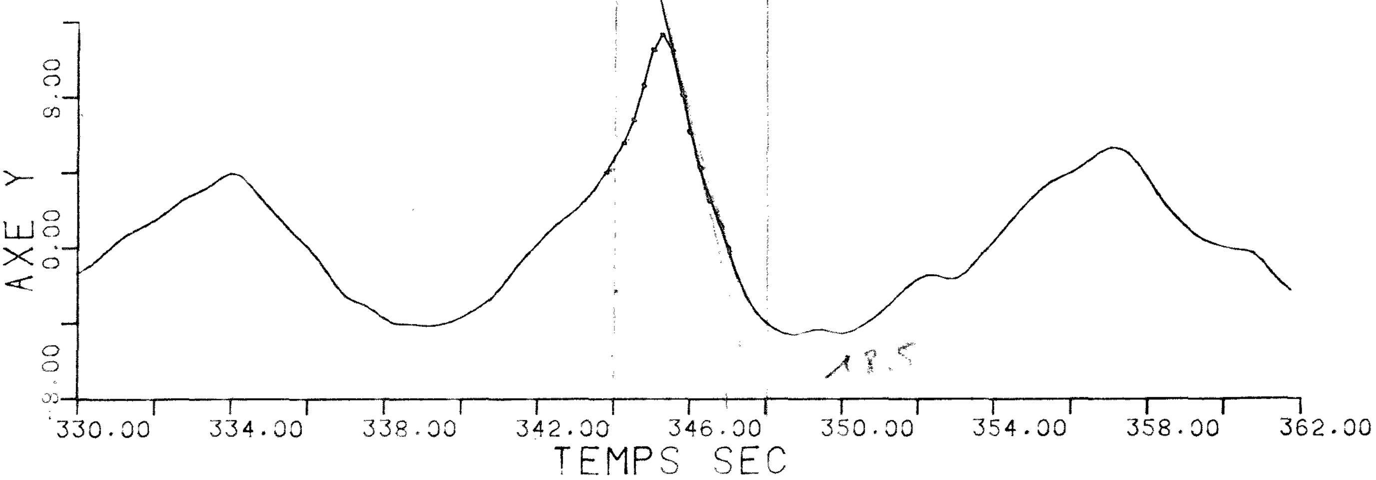
7. PROPOSALS FOR FURTHER INVESTIGATION

Syminex stated that they would explore means for checking on the mechanism producing the errors. One possible means is to investigate the control voltage in the AGC line of the receiver which would require an extra cable to be laid from the instrument on QP1 to the recorder on TP1. Other means would involve tests in the laboratory with moving targets. We presume the Elf will organise the finance for this work, although nothing was said explicitly.

13 Dec 79 0900 Hrs. RADAR







5 mm ≡ 1m

16/5 mm = 3.2

28/3.2 = 8.75 m