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DIRECTIONAL WAVE MEASUREMENTS – SOUTHERN NORTH SEA

BY
C.H. CLAYSON

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Natural Environment Research Council

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Directional wave measurements - southern North Sea

C.H. Clayson

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ABSTRACT

This report concludes the work, carried out on behalf of the UK Department of Energy, on directional wave measurements in the southern North Sea.

It first summarises the coastal deployments of Datawell WAVEC buoys near Flamborough Head and Cromer, which are the subject of separate data reports.

It then describes the technical and operational aspects of a WAVEC - Mother Buoy system which was developed to acquire data in real time from situations remote from land. The limited data set acquired from a development of this system in the Outer Silver Pit area (south of the Dogger Bank) are presented.

Extensive details of the technical aspects of the work are appended for completeness and to form a basis for any further operation or development of the system.

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SUMMARY

This report, which concludes the commissioned work on Directional Wave Measurement in the Southern North Sea, first summarises the coastal WAVEC measurements at Flamborough Head and Cromer. It then describes the technical and operational aspects of a WAVEC-Mother Buoy system which was used to acquire data from the outer Silver Pit area (south of the Dogger Bank). The limited data set obtained are presented. Extensive details of the technical aspects of the work are appended for completeness in the event of continuation of the development of the Mother Buoy system.

1. INTRODUCTION

The work described in this report is a continuation of initial work, commissioned by the Department of Energy, on the evaluation and familiarisation trials of a directional wave buoy by the Taunton laboratory of IOS during 1984. These trials demonstrated the feasibility of obtaining high quality directional wave data in moderate continental shelf depths over a radio telemetry range of up to 30 km. It was originally envisaged that these trials, held off the Pembrokeshire coast, would lead to a programme of measurements off the Outer Hebrides and the Scilly Isles. However, the Department's interest in directional data lay in the Southern North Sea. A factor, albeit of short term importance, in establishing a North Sea site with some urgency was the imminent operation of the SIR-B Space Shuttle flown synthetic aperture radar imagery mission; the programmed use of this equipment included orbits covering part of the Southern North Sea.

The single WAVEC buoy, manufactured by Datawell bv, of Haarlem, The Netherlands, which had been procured for the initial evaluation trials was clearly insufficient, on its own, to allow operational measurements over a period of years. The procurement of two more WAVECs, with the necessary associated mooring equipment and receiving/processing equipment, was therefore initiated in January 1985. The equipment was delivered in March 1985.

A primary purpose of the deployment of directional wave sensors was understood to be the provision of data for wave modelling in the Southern North Sea, the need being to define boundary conditions along the Northern boundary (along an East-West line south of the Dogger Bank). Possible sites were limited by buoy telemetry range and a survey revealed three possible initial sites off the East Yorkshire coast: these were West Sole, Rough and INOUT 30 (a mooring used during JONSDAP 76 off Flamborough Head). The Flamborough Head site was selected, mainly on the grounds of easy access to the receiving equipment for service and data collection. This was to prove a fortunate choice in the light of subsequent requirements for intercomparisons with other systems (h.f. radar, a Marex buoy and a surface current measuring buoy). The nominal position of this site was 54°15'N, 0°03'E. The site was, however, subject to fishing activities, but these are a widespread problem in the North Sea and elsewhere so far as survival of moorings is concerned.

The intention was to establish a second site on the East-West line, perhaps in the Indefatigable area. However, approaches to platform operators, with a view to the installation of telemetry receiving equipment and data logging equipment, failed to meet with any success. It was, therefore, decided to establish a second WAVEC site at a position off Cromer, to measure the wave field after it had propagated over the banks south of Dogger. At the same time, it was decided to investigate the possibility of producing a buoy system which could be used at sites remote from land, using long range (possibly satellite) telemetry equipment. This work was commissioned in September 1985. The current report primarily covers the period September 1985 - December 1987, although reference is made to the previous work, of which it is a continuation. The work covered included:

1. The maintenance of the Flamborough head WAVEC and of the associated receiving station at Thornwick Bay.
2. The deployment of a WAVEC off Cromer and the establishment/maintenance of an associated receiving station.
3. The modification of a MAREX buoy hull (owned by the Department) for on board processing/satellite telemetry of wave data acquired from a nearby WAVEC buoy.
4. The recording of observations for subsequent analysis.

Subsequent amendments in connection with 1 and 3 were that

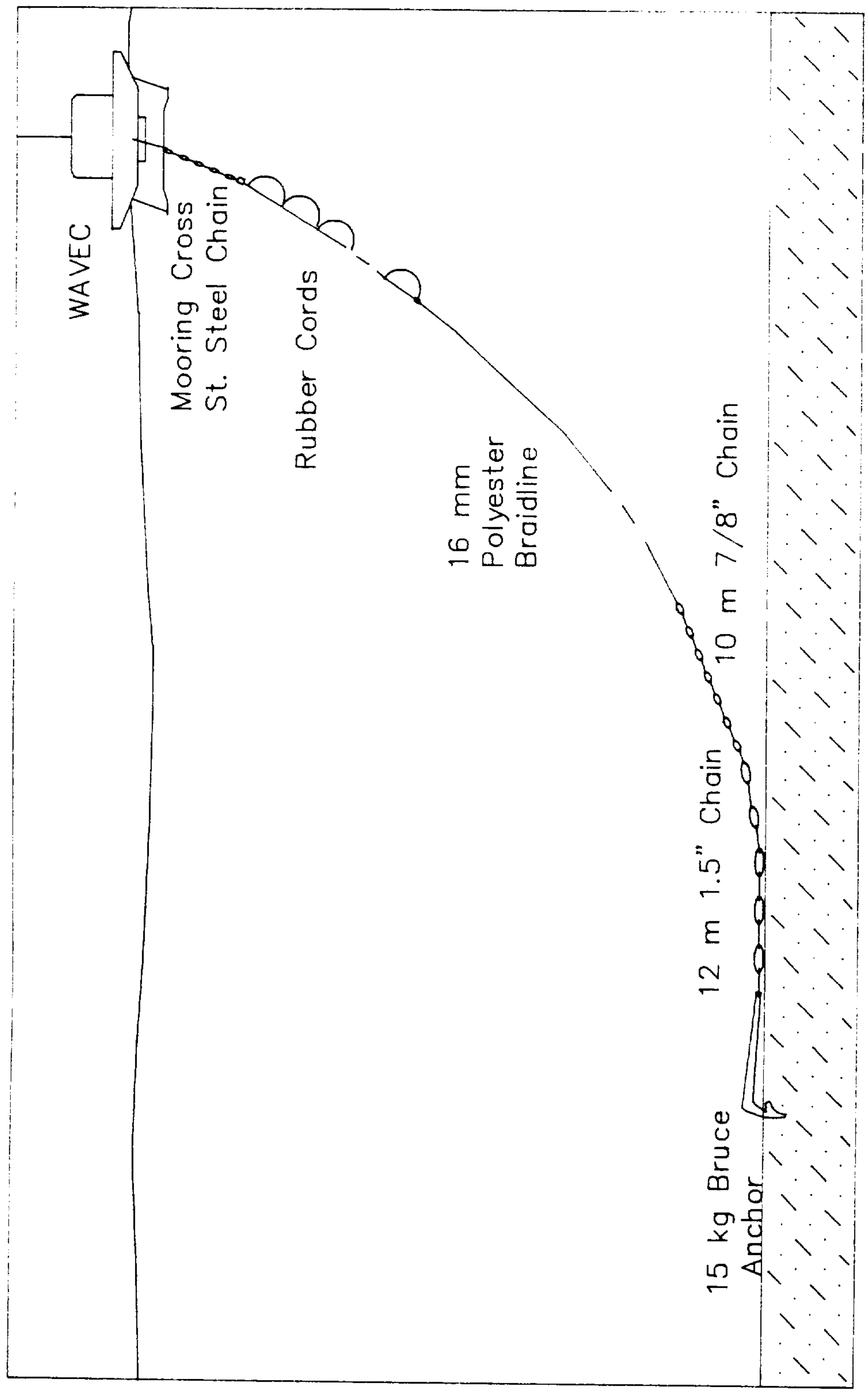
5. The MAREX ("mother") buoy should be tested in conjunction with the Cromer WAVEC.
6. The Flamborough Head buoy should be removed and deployed in conjunction with the "mother" buoy at a site 54°N 2°E.

2. WAVEC OPERATIONS

2A. Operation of the Flamborough Head WAVEC Buoy and Receiving Station

The site chosen for the Flamborough buoy was 54°13.7'N, 00°01.7'E; this was 7.7 nautical miles from Flamborough Head lighthouse on a bearing of 030° true. The mean depth at the site was 51 m; the sea bed was a mixture of sand, broken shell and stones, giving a good anchorage with the combination of heavy chain and a Bruce digging anchor that was used (figure 1). A survey of possible vessels for deploying and servicing the mooring resulted in the use of the m.f.v. 'Janet M' for all operations. This vessel, based in Bridlington, was owned by the secretary of the National Fishermen's Organisation; it was

Figure 1



Standard WAVEC Mooring Configuration

hoped that good relations with fishermen could be maintained by this contact. In practice, the buoy is thought to have been trawled a number of times; the intensity of fishing activities in the North Sea presents considerable hazards to any small buoy mooring.

Two possible sites were identified for the associated receiving station: these were the Flamborough Head lighthouse installation and a remote cottage at Thornwick Bay, about 1 mile North West of Flamborough Head. Whilst the former would have provided a reliable power source and suitable accommodation, there were doubts regarding the level of radio interference that might have been experienced due to transmitters on site. The site at Thornwick Bay was, therefore, utilised. A small space inside was rented to accommodate the receiver, computer and tape drive equipment; the quarter-wave whip receiving aerial with ground plane rods was mounted on a guyed scaffold pole in the garden. Although this site was very remote, it was close to the coastal footpath. During the operational period of this receiving station the receiving aerial was vandalised on one occasion, the cable and pole being sawn through and the aerial removed. Other problems were interruptions of the mains power, usually due to thunderstorms in the vicinity, and failures of the Columbia tape drive unit. This unit necessitated a number of service visits and resulted in a considerable reduction of the data return for this station. Data Technology Tracker 1600 units (functionally equivalent to the Columbia) were used for the Cromer receiving station and for transcription at Wormley; these were completely reliable. The Thornwick Bay receiving station was 7.2 nautical miles from the WAVEC site and was approximately 70 m above sea level near the edge of the cliff top. Arrangements were made for the tape cartridges to be changed at regular intervals and posted back to IOS for translation.

The history of the Flamborough Head WAVEC deployments and receiving stations is given in Table 1, below.

Table 1

Flamborough Head WAVEC and DIREC Installations

Date	Event
4th October 1984	WAVEC No. 22009 deployed using m.f.v. 'Janet M'. Receiving station set up using DIREC No. 23004. Frequency 29.825 MHz. Strong signals received but receiver would not lock on.
8th October 1984	Mr Gerritzen of Datawell was contacted re. the problem.
10th October 1984	Mr Gerritzen visited the Thornwick Bay site with test equipment and diagnosed a faulty channel resulting in the frame sync. code (all '1s') being transmitted twice per scan. This necessitated return of the buoy to Datawell.
16th October 1984	WAVEC No. 22009 recovered using m.f.v. 'Janet M'. Buoy towed back to Bridlington. Instrument canister returned to IOS(T).
29th October 1984 -1st November 1984	WAVEC transported to Datawell by van by E.J. Moore and C.H. Clayson for examination and repair and discussions re. problems. Faulty amplifier replaced. Fault arises from operating transmitter with lid off, causing latent fault in integrated circuit type uA776. This fault results in latch up at a later date.
6th December 1984	WAVEC No. 22009 redeployed, using m.f.v. 'Janet M'.
7th March 1985	WAVEC No. 22009 found adrift (trawled).
17th March 1985	WAVEC No. 22009 redeployed, using m.f.v. 'Janet M'.
21st March 1985	WAVEC No. 22009 reported adrift again. Could not be picked up due to bad weather.
28th March 1985	WAVEC No. 22009 sighted by Belgian trawler in Force 10, 15 miles off Hornsea.
10th April 1985	WAVEC No. 22012 deployed, using m.f.v. 'Janet M'. Frequency 29.725 MHz. DIREC No. 23009 substituted for 23004.
16th April 1985	WAVEC No. 22009 recovered by m.f.v. 'Grimsby Gladness'. Reward paid for recovery (£200).

3rd June 1985	HP85 at Thornwick Bay locked up, possibly due to thunderstorm.
6th June 1985	Receiving installation repowered up, returning to normal operation.
w.e. 18th August 1985	WAVEC No. 22012 mooring thought to have been damaged at this time (Dutch herring fleet was in the area at the time).
16th October 1985	WAVEC No. 22012 recovered, using m.f.v. 'Janet M'.
23rd October 1985	WAVEC No. 22009 deployed, using m.f.v. 'Janet M'.
3rd December 1985	Reported loss of signal at receiving station.
6th December 1985	Buoy reported on station and in good condition.
10th December 1985	Receiving station visited. Aerial found to have been vandalised. Jury rigged.
c. 9th February 1986	WAVEC No. 22009 adrift (reported off station).
12th February 1986	Radio contact lost.
14th February 1986	WAVEC No. 22009 recovered by Whitby lifeboat. Reward paid for recovery (£200). Mooring cross damaged.
27th February 1986	Attempted deployment aborted due to bad weather.
7th March 1986	WAVEC No. 22012 deployed, using m.f.v. 'Janet M'.
c. 10th May 1986	WAVEC No. 22012 adrift (reported off station).
2nd June 1986	WAVEC No. 22012 recovered off Lemvig, Denmark. Reward and repatriation arranged by agents.
August 1986	Receiving station at Thornwick Bay removed.

Calibrations of the two WAVECs used were carried out as follows: WAVEC No. 22009 - October 1984 and June 1985 at Datawell, Haarlem and June 1986 at Hydraulics Research Ltd., WAVEC No. 22012 - March 1985 at Datawell, Haarlem. Calibrations were all within 1% of the nominal values, so that the nominal values were used in processing the data.

As will be noted from Table 1, there were four occasions where the Flamborough Head WAVEC went adrift and a further occasion where the mooring was damaged. Inspection of the remains of any mooring components that were recovered suggested that cutting of the mooring as a consequence of trawling activities was the likely cause of these events. The mooring used in each case was of the standard type shown in figure 1. Modifications subsequently introduced by Datawell include the use of stainless steel chain links between the buoy and mooring cross, a single attachment point on the mooring cross centre, a 1.5 metre stainless steel chain between mooring cross and rubber cord terminal, and the use of two lengths of stiffer rubber cord to give greater elongation in areas where high currents are experienced. These modifications were incorporated in the later Cromer buoy moorings.

2B. **Operation of the Cromer WAVEC Buoy and Receiving Station**

The site chosen for the Cromer buoy was 53°04'N, 01°31'E; this was approximately 11 miles from the Cromer HM Coastguard lookout on a bearing of 035° true. The lookout formed an ideal site for the receiving station. The mean depth at the buoy site was 31 metres; the sea bed was a mixture of sand, shell and gravel, giving a good anchorage. The deployments, maintenance and recoveries of buoys used for this site were subcontracted to Hydraulics Research Ltd. IOS were still operating the Flamborough Head buoy, using the WAVEC, serial number 22009, procured for initial evaluation and one of the two WAVECs, serial number 22012, procured in March 1985. The other of these (serial number 22011) was not sufficient on its own for a routine operational system. The specification for the subcontracted operation therefore required the hire of a second set of equipment (backup buoy and mooring equipment). The technical specification for the subcontracted operation is included in Appendix A, Annexes A to P.

The receiving station was set up and maintained by IOS, with the assistance of the local HMCG staff, tape cartridges being posted at intervals to IOS for translation. The receiving antenna was a quarter-wave whip with ground plane rods, set on a guyed scaffold pole (as at Flamborough Head). Since this was within a fenced compound no interference by the public was expected or, in the event, experienced. The coaxial feeder was run underground into the Coastguard lookout via a gooseneck. The DIREC receiver, HP85B computer and Data Technology Tracker 1600 cartridge tape drive system were installed within the lookout.

The history of the Cromer WAVEC deployments and receiving station operations is given in Table 2, below.

Table 2
Cromer WAVEC and DIREC Installations

Date	Event
12th November 1985	H.R. Ltd took delivery of "IOS" WAVEC No. 22011.
21st-22nd November 1985	"IOS" WAVEC No. 22011 and HR WAVEC No. 22025 calibrated at HR Ltd, using swinging arm calibrator to Datawell design.
4th December 1985	WAVEC No. 22011 deployed, using m.v. 'Dawn Flight'. DIREC No. 23004 installed in HMCG lookout.
12th December 1985 -9th June 1986	11 checks on buoy position/condition made by various vessels operated by Warbler Shipping.
11th June 1986	WAVEC No. 22011 recovered and WAVEC No. 22025 deployed, using m.v. 'Putford Tern'.
19th June 1986	WAVEC No. 22025 recovered by m.v. 'Stirling Liberty' near platform 4829B (data still being received at Cromer).
24th June 1986	WAVECs No. 22011 and 22025 calibrated at HR Ltd.
17th July 1986	WAVEC No. 22011 deployed, using m.v. 'Chudleigh' using modified mooring.
5th August 1986 -3rd December 1986	8 checks on buoy position/condition made by various vessels of the Warbler fleet.
11th December 1986	WAVEC No. 22011 recovered by m.v. 'Liberty Moon' near platform 4829B (data still being received at Cromer, but Hz channel faulty).
9th January 1987	WAVEC No. 22025 calibrated at HR Ltd.
22nd January 1987	WAVEC No. 22025 deployed, using m.v. 'Chudleigh'.
13th February 1987 -12th June 1987	6 checks on buoy position/condition made by various vessels of the Warbler fleet.
21st July 1987	WAVEC No. 22025 recovered, using m.v. 'Dawn Flight'.

7th August 1987	WAVEC No. 22025 calibrated at HR Ltd.
12th August 1987	WAVEC No. 22011 calibrated at HR Ltd.
14th August 1987	WAVEC No. 22011 returned to IOS(W).
30th September 1987	WAVEC No. 22009 deployed, using m.v. 'Dawn Sky' (IOS deployment).
5th October 1987	DIREC No. 23009 substituted from No. 23004.
9th December 1987	WAVEC No. 22009 recovered, using m.v. 'Dawn Sky' (IOS recovery).

A complete account of the calibration procedures and results is given in the associated report on the data gathered at the Cromer station (Clayson and Ewing, 1988).

2C. **Data Collection, Translation and Banking**

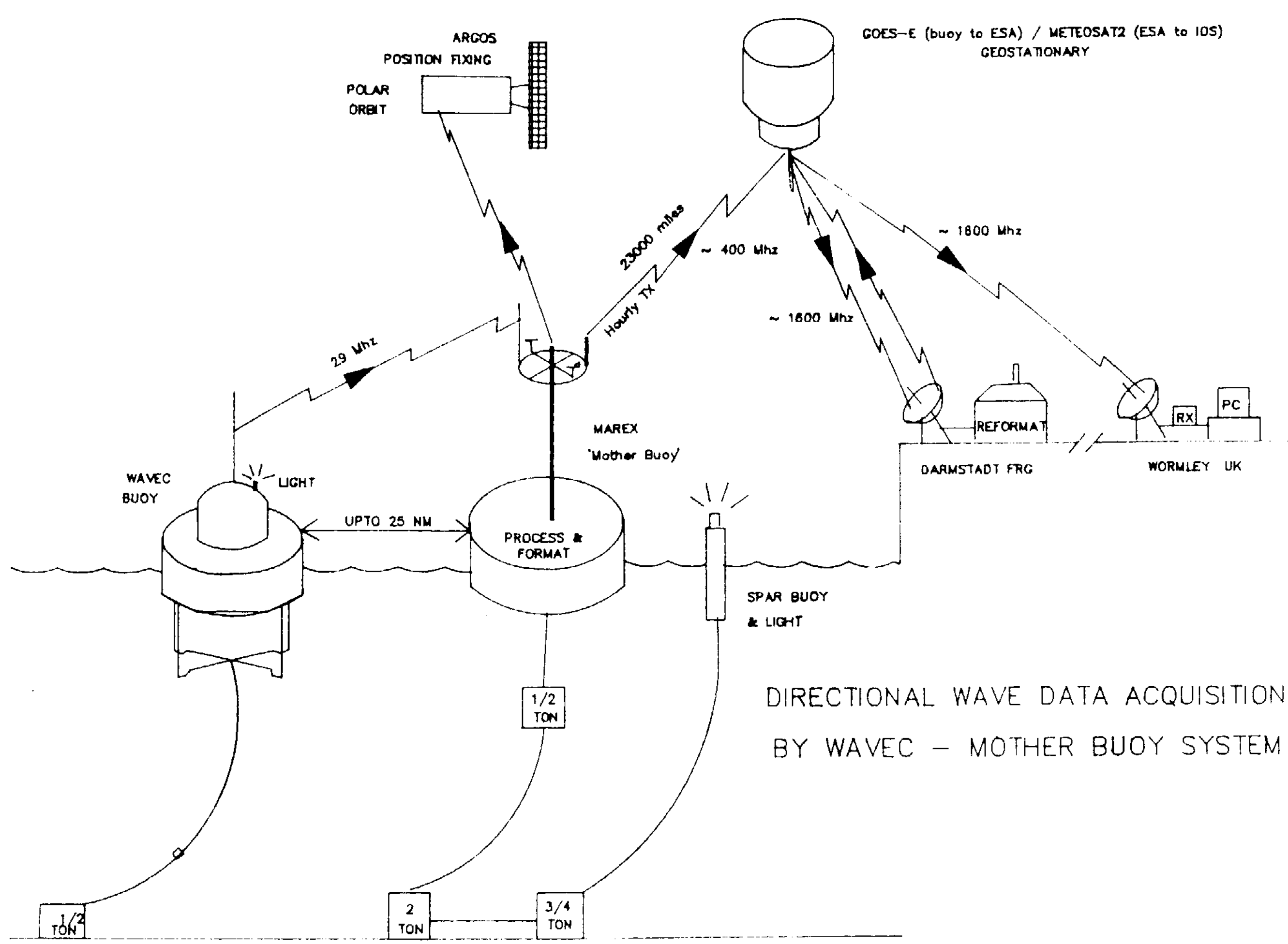
The WAVEC/DIREC telemetry and processing system has been described in the Cromer Report (CLAYSON and EWING, 1988) in some detail which will not be duplicated here. Briefly, the receiving station processor and controlling microcomputer produced tape files, at 1½ hourly intervals, containing housekeeping data and the full set of 9 co- and quadrature spectra of heave displacement, North-South slope and East-West slope. The 128 spectral estimates in each spectrum were produced by averaging the results of nine spectral analyses of 200 second ensembles at 1.28 Hz sampling rate, giving estimates with 18 degrees of freedom at 0.005 Hz intervals. Pairs of this set of 128 estimates were further averaged in the HP85B control microcomputer, giving 64 estimates with 36 degrees of freedom at intervals of 0.01 Hz. The estimates are centred on frequencies of 0.0075 Hz, 0.0175 Hz, 0.0275 Hz, ..., 0.6275 Hz. The zero frequency estimate was replaced by parameterised data in the recorded file format. Each file consisted of 6804 ASCII bytes. The Columbia and Tracker 1600 cartridge drives recorded the data files in ECMA 46 standard format. The cartridges were posted in standard Jiffy bags to IOS for processing. The Flamborough Head data cartridges were checked and translated onto ½" computer compatible magnetic tape using a replay system at IOS (Bidston) (now the Proudman Oceanographic Laboratory). The Cromer data cartridges were checked and translated to files on a microcomputer Winchester disk drive at Wormley; these files were then transferred to the IBM mainframe computer at Wallingford via the network and subsequently archived on ½" computer compatible tape.

At the time of writing of this report, all the Cromer data from 7th December 1985-30th June 1987 have been processed and banked in the MIAS data bank. The Flamborough Head data, covering the period January 1985-May 1986, inclusive, have been reformatted to MIAS directional wave data format and banked. Reports on data from selected periods during the Flamborough Head WAVEC deployment have been prepared and submitted; these include the WAVEC/MAREX S100/IOS P-R buoy intercomparison period (April-May 1985) (CLAYSON, 1985) and the WAVEC/Marconi OSCR h.f. radar/IOS surface current buoy intercomparison period (March 1986) (EWING, 1986). Selected parameterised data were also produced for Sir William Halcrow and Partners Ltd, in connection with the Holderness coastal erosion study project. A complete report on the Flamborough data will be produced during 1989.

3. THE MOTHER BUOY CONCEPT

The mother buoy concept (Figures 2 and 3) was developed in response to requirements for the acquisition of high quality directional wave data from sites remote from land, or from usable platforms. The initial survey (PITT, 1984) of commercially available instruments concluded that the WAVEC buoy, manufactured by Datawell bv of Haarlem, The Netherlands, was the best pitch-roll buoy currently available for routine directional wave measurements. This assessment was made with reference to (above all) likely accuracy of data, convenience of use and cost. Since then, one further contender has become commercially available recently - the Seatex Wavescan metocean data buoy; this was the subject of a short report to the Department (CLAYSON and EWING, 1986). The choice of the WAVEC has subsequently been vindicated by operational experience which has demonstrated the reliability of both buoy and receiving equipment. However, the WAVEC data telemetry system is, in common with all comparable low power h.f./v.h.f. radio telemetry equipment, subject to range limitations. For reliable operation, a range of less than about 35 km is to be preferred. Line of sight range, R, is given by $R \simeq \sqrt{Dh}$, where h is the height of the receiving antenna and D is the diameter of the Earth; for 50 m receiver height, R = 18 km. Refraction due to the change in water vapour content of the atmosphere with height above the sea normally allows the signals to travel considerably further than line of sight. However, attenuation of the ground wave rises with frequency and is considerable at the higher h.f. band frequencies where an efficient radiating antenna becomes a feasible proposition for small buoys.

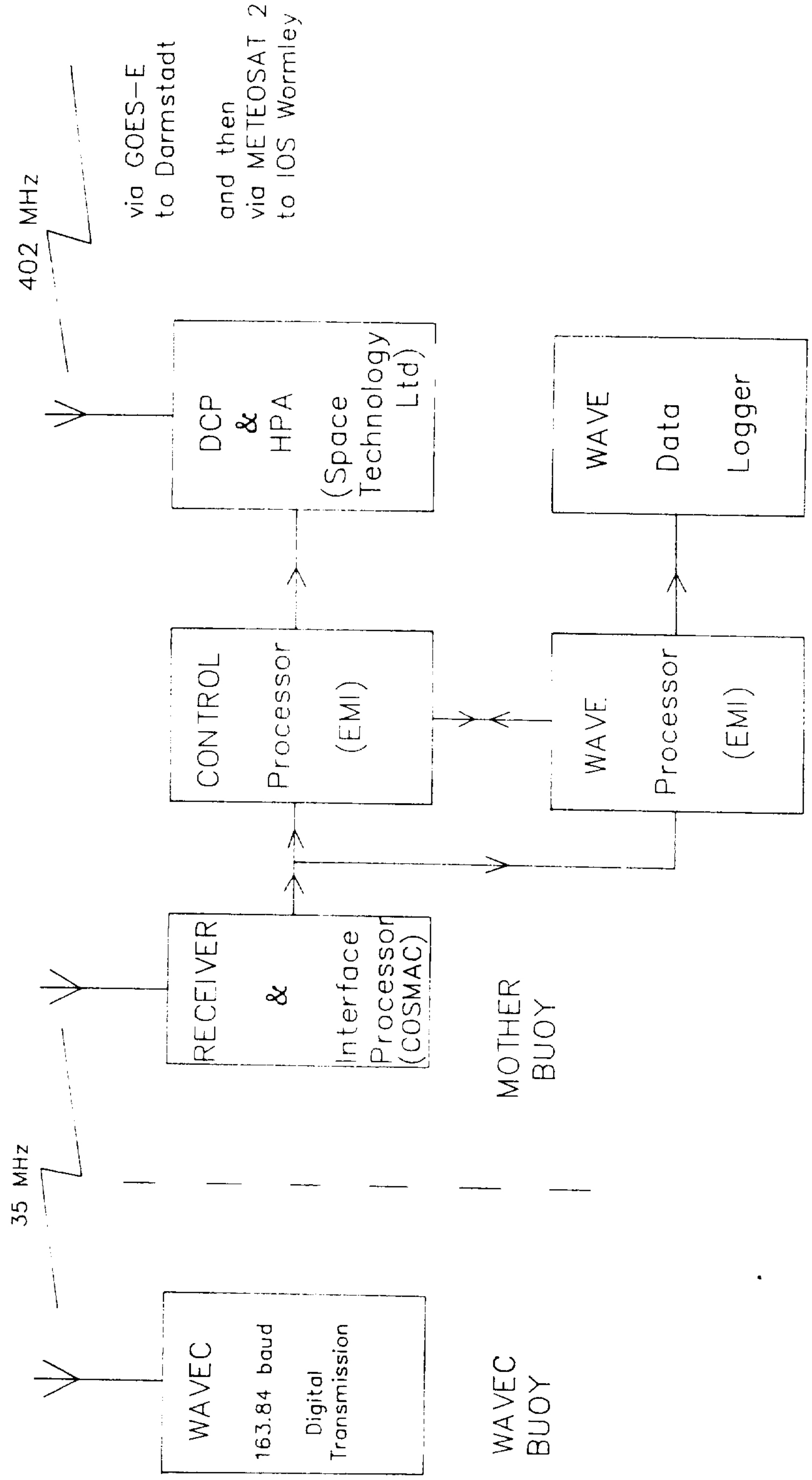
Figure 2



DIRECTIONAL WAVE DATA ACQUISITION

BY WAVEC – MOTHER BUOY SYSTEM

Figure 3



WAVEC – MOTHER BUOY TELEMETRY/PROCESSING

The use of sophisticated modulation schemes can result in an adequate degree of data reliability over longer ranges, as demonstrated by the 'Piccolo' system on DB1, but these are not practical for small buoys. Neither, due to the higher power demands, is telemetry via geostationary communications satellites; there is simply not enough capacity in the hull of a WAVEC, or similarly sized buoy, to accommodate the batteries required for a 6 month deployment. Manufacturers such as Nereides, Bergen Ocean Data Systems and Seatex have, therefore, adopted on board recording of data (raw or processed), together with transmission of a limited set of processed data parameters via the polar-orbiting satellites used in the ARGOS system. This decreases the transmitter power demands by nearly two orders of magnitude, allowing operation for 6 months or 1 year from a reasonably sized battery. However, the resulting restrictions on the nature of the data that are available in (near) real time are undesirable on two grounds - first that the buoy, with the unabridged set of on-board recorded data, may be lost or the recorder may fail, and second that the limited quantity of processed data parameters that may be passed via the ARGOS system is insufficient to monitor data quality adequately. Both problems could result in the loss of unacceptably large quantities of data.

The use of a buoy large enough to accommodate equipment and batteries for near real time telemetry via geostationary satellite, whether this is a commercially operated system such as Inmarsat Standard C or a "free" system made available for the use of the metocean community such as Meteosat/GOES, is one solution to the problem.

The metocean pitch-roll buoys DB2 and DB3 operated by EMI for UKOOA are an example of how directional wave data may be acquired reliably, albeit at high cost. The Marex DS17 buoy, developed from the S100 buoys produced by Marex for the Department for the South Uist project, is another, less expensive solution. The performance of these buoys as directional wave measuring sensors was, however, not ideal due to the constraints of the three point mooring system used on DB2 and DB3 and of the single point + stabilising counterweight system used on the Marex buoys. The former is believed to be currently the subject of investigation: the latter was the subject of intercomparisons carried out at Freshwater Bay, I.O.W., against an IOS pitch-roll buoy (McCARTNEY, 1984), and off Flamborough Head, against a Wavec and an IOS pitch-roll buoy (CLAYSON, 1985). Although the results of modifications carried out to the mooring system prior to this intercomparison resulted in significant improvements, IOS did not consider the nett buoy response to be wholly suited to the Department's requirements. It is understood that further modifications in weight distribution carried out prior to use of the buoy in the WADIC intercomparison, mounted by the IKU near the Edda platform, have resulted in improved performance; the results of this intercomparison experiment are, however, not yet generally available.

In view of the rather disappointing performance of the Marex hull/mooring in the Flamborough Head trials, it was agreed that a study should be made of the feasibility of using a Wavec buoy as a proven high quality sensor in conjunction with a nearby "Mother" buoy, which would process the directional wave data, record it onboard, and transmit the full set of processed data via geostationary satellite to a ground station, whence the data would be relayed to IOS. The wave-following performance of the "Mother" buoy would be immaterial and it was proposed to use the unmodified Marex S100 hull, owned by the Department. Authorisation to proceed with this development was finally agreed in mid September 1985.

The concept of the "mother-daughter" buoy system was quite simple but its practical realisation was not straightforward. Firstly, although the use of geostationary satellites appeared to offer virtually unlimited data capacity, there was only one system currently available which offered ease of access and minimal running costs: this was the geostationary meteorological satellite network, which includes Meteosat and GOES. This system, whilst being 'user-friendly' towards the metocean community, imposed restrictions upon the data rate and format. Although the system was (and still is) relatively underused, each data collection platform (DCP) transmitter is normally allocated only one time slot during each hour, of approximately one minute duration. During this time slot, after a lengthy sequence of synchronisation and identification, the DCP can send a maximum of 650 characters of data. For operational reasons, only characters from the International Alphabet no. 5 restricted character set are allowed. This includes the numbers 0 to 9, capital letters A to Z, a restricted set of punctuation marks and CR, LF.

Consequently, when digital information is to be transmitted, the most practical compact format is to send the data as ASCII versions of the hexadecimal characters 0-9, A-F. Two characters are, therefore, required to send an 8 bit binary byte.

Furthermore the message is restricted to a WMO code format, if it is to be disseminated via the GTS (Global Telecommunications System used by the WMO). It was considered preferable, on balance, to use this format in case arrangements to receive the data by direct relay at IOS proved unsatisfactory. The WMO format is not very efficient for the transmission of spectral wave data, however, and three consecutive hourly transmissions were needed to send one complete (3-hourly) directional spectrum. This is just adequate, in terms of sea state variability in the North Sea. In addition to the spectral data, the format includes meteorological parameters, housekeeping parameters and, most important, quality check data, as will be detailed below.

The processing system was, therefore, required to perform complete directional spectral processing at 3-hourly intervals and simpler (H_s, T_z type) processing hourly. The processed data, together with processed meteorological and housekeeping data was then to be assembled in the required message format for transfer to the DCP transmitter in time for the hourly transmission time slots. Although meteorological data acquisition did not form part of the Department's requirements, it was considered that, at the least, wind speed/direction should be monitored as a check on wind wave data and for possible use in modelling.

The wave data inputs to the processor had to be derived from the transmitted WAVEC digital data. The WAVEC sensors consist of heave (acceleration, which is normally double-integrated to displacement for transmission), pitch angle (actually sensed as sin (pitch angle)), roll angle (actually sensed as sin (roll angle)) and three orthogonal magnetometer components H_x, H_y, H_z where x is the buoy roll axis, y is the buoy pitch axis and z is the buoy vertical (normal to the plane of the float). These sensor outputs are analogue voltages which are first anti-alias filtered, using accurately matched filters, sampled (together with buoy battery voltage) using simultaneously strobed sample/hold circuits, sequentially digitised to 12 bit offset binary format (zero = 2048 digits, + full scale = 4048 digits, - full scale = 48 digits) and then sequentially transmitted, together with a sync. word and 21 error correcting bits, in a 106.21 BCH code. The sampling frequency is 1.28 Hz (crystal controlled). Note that the full range 0-4097 digits is not used since 4097 is reserved for the sync word. The serial data stream which is transmitted, using frequency shift keying (f.s.k.) has the format shown in figure 4 for each cyclically repeated scan. The data scales are as follows:-

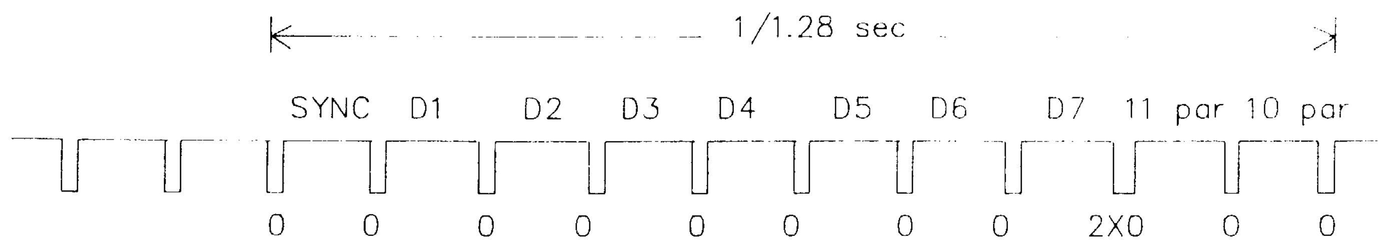
heave	2048 + 1 x heave (cm) digits (±20 m full scale)
H_x, H_y, H_z	2048 + 40 x magnetic intensity (A/m) (±50 A/m full scale)
pitch, roll	2048 + 2000 x sin (rotation angle) (sin(±90°) full scale)
battery	2048 - 36.68 x voltage (10 to 26 volts normal range)

In order to minimise development costs, a standard Datawell radio receiver, pcb F, as used in the DIREC receiver, was adopted for reception of the WAVEC transmissions. This demodulates the data, storing each 12 bit word of data, together with status information, in a 16 bit buffer and generating an interrupt as it is received. The buffer contents are multiplexed on to a single data line under control of an external device (e.g. processor).

The development of a low power microcomputer to interface with the receiver board, carry out the necessary computations to derive the North-South and East-West slopes, spectrally analyse the heave and the two slope time series, compute the 9 co- and quad-spectra, average the spectral components and to format the data for transmission via Meteosat, would have been technically possible in-house but was considered inadvisable due to the lack of uncommitted skilled manpower. It was, therefore, decided to put this part of the system out to tender to the only two manufacturers known to have experience in developing systems approximating to the required specification, i.e. Thorn EMI Defence Systems Division at Woking and Marex at Cowes. At the time of the tendering exercise, EMI had accumulated a considerable amount of operating experience with the processing system used in DB2 and DB3; Marex were in the

Figure 4

Wavec Telemetry Format (FSK)



SYNC : 12 X '1's (BAUD RATE : 163.84)
D1 : 12 bit HEAVE
D2 : 12 bit Hx
D3 : 12 bit Hy
D4 : 12 bit Hz
D5 : 12 bit PITCH
D6 : 12 bit ROLL
D7 : 12 bit BATTERY (changed to HEAVE ACCELERATION)
11 par + 10 par : 21 bit parity check (106.21 BCH code)

process of developing a new 16 bit processor version of the 12 bit data handling system used in their metocean data buoys, under contract to EXXON. Upon preliminary discussion with EMI it soon became apparent that any significant departures from the specification of the existing DB2/3 system would result in unacceptably high software development costs. A specification was produced which satisfied the IOS requirements whilst requiring only relatively minor changes in certain features of the EMI software.

4. DESIGN OF THE MOTHER BUOY PROCESSING SYSTEM

The ideal solution to interfacing the Datawell receiver to the EMI processors would have been a direct digital serial interface. However, it was apparent that this would have required substantial modifications to software that involved critical timings, with associated expense and uncertain outcome. Consequently, it was decided to design in-house an interface to convert the Datawell receiver outputs to analogue heave, pitch, roll and two-component magnetometer signals, to simulate the standard directional wave sensor suite of DB2/3 i.e. Datawell Hippy (heave, pitch and roll) sensor and Brookes and Gatehouse Halcyon 2 two-component fluxgate compass. A further minor complication was that the EMI hourly estimates of H_s and T_z were derived, using non spectral techniques, from a heave displacement signal, whereas the spectral data were derived from a heave acceleration signal. The heave data transmitted by the WAVEC are normally displacement although the acceleration signal is available within the buoy. Although it would have been technically possible to obtain an acceleration signal from a heave signal, or vice versa, after the receiver stage in the mother buoy, this would have been most undesirable in the event of transmission errors. It was, therefore, decided to transmit heave acceleration instead of battery voltage in channel 7. This necessitated the design, installation and testing (see Appendix B) of an additional matched anti-alias filter. The scale factor used was 2048 + 1 x heave acceleration (cm/sec^2) (± 10 m/sec^2 full scale). Details of the interface between the Datawell pcb F and the EMI processor are given in Appendix C.

The EMI directional wave sensor sampling rate of 1.28 Hz is software generated from a crystal controlled oscillator clock source. Similarly the

WAVEC sampling rate of 1.28 Hz is hardware generated from a crystal controlled oscillator clock source in the buoy. The two sources will not maintain exact synchronisation but will drift slowly due to temperature effects, crystal ageing, etc. Additionally, since the EMI rate is software generated, the instantaneous rate is subject to small variations in software execution time, although the average rate is determined by the crystal source. This will result in a small increase in noise level in the low frequency end of the spectrum on occasions when the EMI and WAVEC sampling times have a particular time relationship, due to "lost" samples. There are 2560 samples of each time series in an EMI processed "record", of duration 2000 seconds. If the relative stability of the two clock sources is better than 1 part in 2560, there should not be more than one lost sample, due to timing conflict, per "record"; such a loss has very little effect on the spectral data (checked by simulation). In practice the two clock sources were measured, in the laboratory, to be within approximately 1 part in 10^5 so that timing conflict should only occur about once in every 21.7 hours.

The EMI processing system consists of two interconnected microcomputer systems, using NSC800 processors: these are referred to as the Control Processor and the Wave Processor. The processors run off separate power supplies, derived from battery supplies of nominally 7.2V (the C5 supply), 7.2V (the W5 supply) and a common 14.4V supply (the CW15 supply). The C5 supply is regulated to a 5V logic supply for the Control Processor, the W5 supply is regulated to a 5V logic supply for the Wave Processor. The CW15 supply is converted to two separate ±15V supplies for the Control and Wave Processor analogue circuits by two dual output DC/DC convertors. The Control Processor is powered continuously; it performs signal conditioning for meteorological sensors, sampling of met. sensor and heave displacement signals, battery supply voltages and housekeeping parameters. It processes the meteorological and heave sampled data and assembles this, together with housekeeping data and wave data produced by the Wave Processor, into data bases appropriate to supply data to the Meteosat transmitter (DCP) and to the Argos transmitter (PTT). It also records the housekeeping and parameterised meteorological data on a Sea Data 633M cassette drive if required (not included in the IOS system). Finally, it provides a controlled charging supply for the DCP secondary batteries and controls the power up cycle of the Wave Processor.

The Wave Processor is powered down other than for acquisition and processing of directional wave data: this takes approximately 40 minutes out of every 3 hour interval. The wave data signals consist of analogue voltages representing heave acceleration, pitch, roll, sin (heading), cos (heading), as described above. The voltage scaling used in the interface results in

+10V for 4048 Wavec digits
0V for 2048 " "
-10V for 48 " "

for the heave, pitch and roll channels,

and +8.1V for sin 90°/cos 0°
0V for sin 0° or 180°/cos 90° or 270°
-8.1V for sin 270°/cos 180°

for the sin (heading), cos (heading) channels.

The Wave Processor samples the five channels using analogue multiplexor and fast 12 bit A-D convertor. The delay between sampling of the first and last channel in a scan is negligible in terms of phase shift at the Nyquist frequency of 0.64 Hz. The data are then acquired and processed as 5 ensembles of 512 samples each of h, p, r, sin ψ, cos ψ, i.e. as 5 sections of 400 seconds duration. The data are subjected to a number of quality checks, which result in the raising of flags if they fail; these flag bits are as follows:-

Table 3

Quality Flag Bit Allocations

(A) Heave Acceleration

(a) static (defined to be within ±20mV (±4 cm/sec^2) over 9 sequential values)
- more than 3 occurrences Q11,1
- more than 30 occurrences Q11,2

(b) high limit exceeded (>+9.8V (+19.6 m/sec^2))
- more than 3 occurrences Q10,1
- more than 30 occurrences Q10,2

(c) low limit exceeded (<-9.8V (-19.6 m/sec^2))
- more than 3 occurrences Q10,4
- more than 30 occurrences Q10,8

(d) >4 RMS (>4 x standard deviation of the ensemble)
- more than 3 occurrences Q11,4
- more than 30 occurrences Q11,8

(B) Pitch

(a) static (defined to be within ±20mV (±6.9 minutes of arc) over 9 sequential values)
- more than 3 occurrences Q9,1
- more than 30 occurrences Q9,2

(b) high limit exceeded (>+5V (+30°))
- more than 3 occurrences Q8,1
- more than 30 occurrences Q8,2

(c) low limit exceeded (<-5V (-30°))
- more than 3 occurrences Q8,4
- more than 30 occurrences Q8,8

(d) >4 RMS (>4 x standard deviation of the ensemble)
- more than 3 occurrences Q9,4
- more than 30 occurrences Q9,8

(C) Roll

(a) static (defined to be within ±20mV (±6.9 minutes of arc) over 9 sequential values)
- more than 3 occurrences Q7,1
- more than 30 occurrences Q7,2

(b) high limit exceeded (>+5V (+30°))
- more than 3 occurrences Q6,1
- more than 30 occurrences Q6,2

(c) low limit exceeded (<-5V (-30°))
- more than 3 occurrences Q6,4
- more than 30 occurrences Q6,8

(d) >4 RMS (>4 x standard deviation of the ensemble)
- more than 3 occurrences Q7,4
- more than 30 occurrences Q7,8

(D) Heading

(a) change of >60° from previous value
- more than 3 occurrences Q4,4
- more than 30 occurrences Q4,8

If either heave acceleration, pitch or roll fail a check more than 30 times in any of the first three ensembles, that ensemble is rejected and a flag is raised (flag bits Q12,1 → 8 and Q13,1 for ensembles 1 → 5 respectively. The last two ensembles are always used for recording/transmission, irrespective of errors, for diagnostic purposes and testing.

Processing of the time series (for accepted ensembles) is as follows:-

(1) The pitch and roll inputs are converted, using the heading ψ (derived from $\sin^{-1}\left[\frac{\sin\psi}{\sqrt{\sin^2\psi + \cos^2\psi}}\right]$ to allow for any scaling errors in the $\sin\psi$ and $\cos\psi$ signals) to North-South and East-West slopes ζ_x and ζ_y.

(2) The data is spectrally processed in 5 ensembles, each of 512 samples each of ζ, ζ_x and ζ_y (series 1, 2 and 3 respectively).

(a) a split cosine bell window function is applied to each time series within the ensemble to reduce spectral leakage

$$W(n) = \tfrac{1}{2}\left(1 - \cos\frac{10\pi n}{512}\right) \qquad 1 \leqq n \leqq 51$$
$$= 1 \qquad 52 \leqq n \leqq 461$$
$$= \tfrac{1}{2}\left(1 - \cos\frac{10\pi(513 - n)}{512}\right) \qquad 462 \leqq n \leqq 512$$

(b) the DFT of each windowed ensemble of each series is calculated using an FFT algorithm.

(c) the 9 co- and quad-spectral estimates C_{11}, C_{22}, C_{33}, C_{12}, Q_{12}, C_{13}, Q_{13}, C_{23}, Q_{23} are calculated. Note, these are all real numbers (C_{11}, C_{22} and C_{33} being +ve, the remainder having signs depending upon the phase angles between heave acceleration, pitch and roll and upon the direction of wave propagation). The estimates are for 256 frequencies at 0.0025 Hz spacing.

(d) the estimates are averaged over non-overlapping groups of 4 estimates, omitting the 0^{th}, 1^{st}, 254^{th} and 255^{th} harmonics. This results in 63 estimates at 0.01 Hz intervals, from 0.00875 Hz centre frequency to 0.62875 Hz centre frequency.

(e) the above processing is carried out for each of the 5 ensembles, if they meet the quality check criteria, and the estimates are then summed over the number of ensembles accepted. If less than 5 ensembles are accepted, the averages are normalised to give the same scaling as for 5 accepted.

These nine cross spectra, over 63 frequencies, comprise the basic set of directional spectra which are passed to the control processor, together with quality check data (flags Q6 - Q13).

48 estimates of each cross spectrum (0.00875 Hz → 0.47875 Hz) plus 3 further averaged estimates (0.50875, 0.55875, 0.60875), each obtained by averaging over 5 non overlapping estimates from the above set of 63, are recorded on the processed wave data cassette logger together with identification data, date, time, quality flags, computed parameters H_s, T_z, H_{swell}, T_{swell}, Θ_{1swell}, Θ_{2swell}, H_{wind}, T_{wind}, Θ_{1wind}. The recorded format is given in Appendix D.

The parameters are derived as follows:

$$H_s = 4 \times \left(\sum_{0.03875}^{0.47875} \frac{C_{11}(f)}{(2\pi f)^4} \right)^{\frac{1}{2}}$$

This value is multiplied by $(0.875)^{-\frac{1}{2}}$ to correct for the windowing.

$$T_z = \left(\frac{\sum_{0.03875}^{0.47875} C_{11}(f)}{\sum_{0.03875}^{0.47875} f^2 C_{11}(f)} \right)^{\frac{1}{2}}$$

H_{swell}, T_{swell}, H_{wind}, T_{wind} are calculated similarly, but using the restricted spectra from 0.04375 Hz → 0.21875 Hz (swell) and from 0.20875 Hz → 0.26875 Hz (wind) respectively. The swell direction Θ_{1swell} is calculated as the weighted mean of the directions at three frequencies including the peak of the heave displacement spectrum and the swell spread Θ_{2swell} is similarly calculated from spreads. The wind wave direction Θ_{1wind} is the mean direction over the band 0.20875 to 0.26875. The derived parameters are also passed to the control processor. Raw wave data, in the form of time series, can also be recorded at intervals of 93 hours, if required, on a separate cassette logger. This facility was not used, however. After transfers of data from the wave processor to the control processor and to the tape logger(s) are complete, the wave processor is powered down to save on battery consumption.

The control processor holds the complete set of directional wave spectral data and the parameterised data in a data base (storage area). The transmission of the spectral data requires three (hourly) transmissions via Meteosat. The wave processor is activated at (GMT) times (3N - 1) hours + 20 mins (N = 1, 2, ..., 8) for a period of 40 minutes. The spectral data are, therefore, available for use between 3N hours and 3(N + 1) hours. The C_{11} and C_{22} spectral estimates between 0.04875 Hz and 0.44875 Hz (41 for each spectrum) are transmitted in the 3N hours + T time slot, where T is the allocated transmission time (18-19 minutes for the GB/IOS2 allocation for this equipment). The C_{33} and Q_{12} spectral estimates are transmitted in the (3N + 1) hours + T time slot and the Q_{13} and C_{23} spectral estimates are transmitted in the (3N + 2) hour + T time slot. The C_{12}, C_{13} and Q_{23} estimates are not transmitted although they are recorded on the processed wave data tape; the estimates C_{12} and C_{13} are ideally zero and, if finite, are due to phase shifts in the buoy heave vs slope response (nominally 90° phase relationship). Q_{23} is also ideally zero and, if finite, is due to asymmetry in slope response with buoy azimuth. The transmitted data format is given in Appendix E.

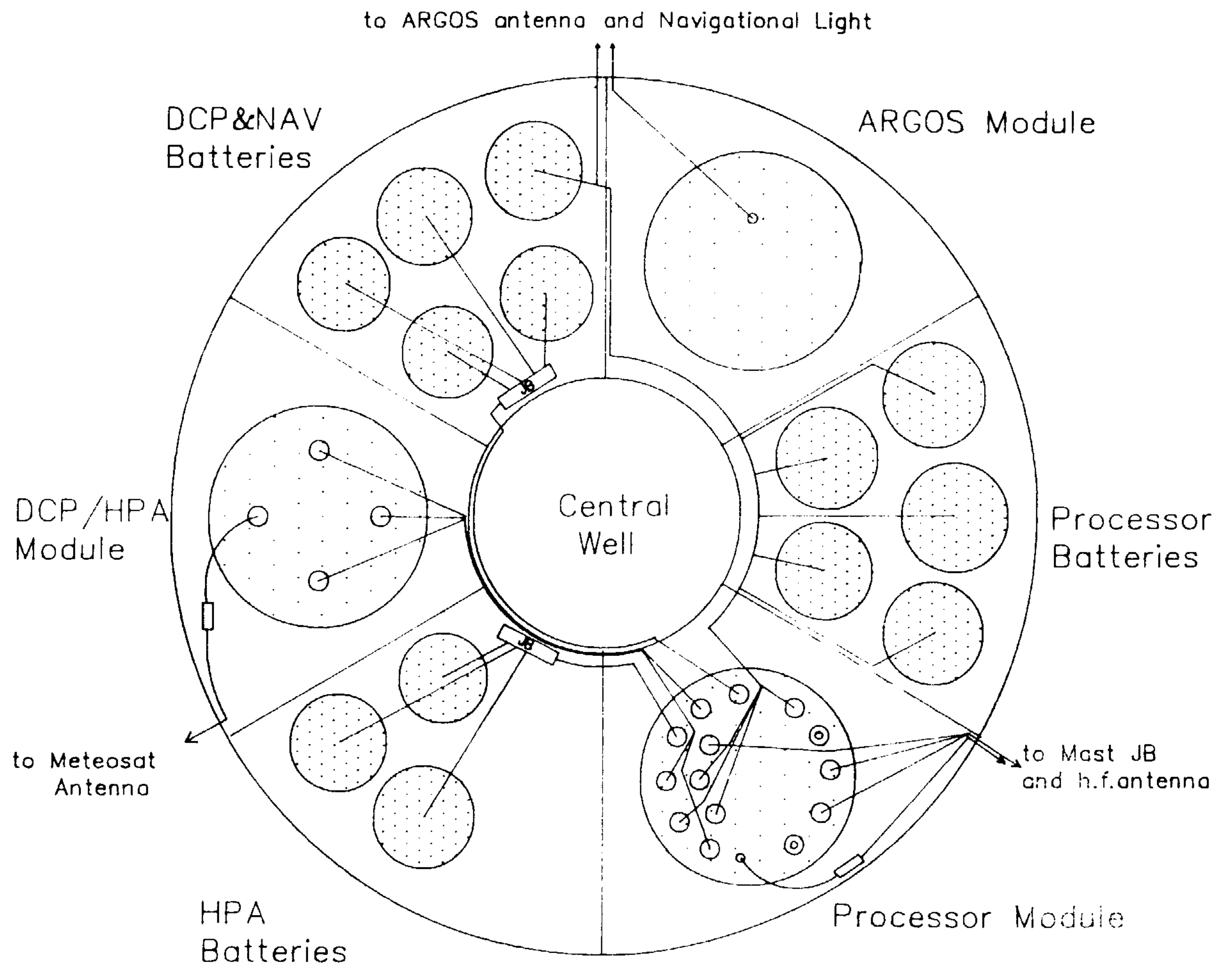
Both the control and the wave processor have RS 232 ports for communication using an external terminal. This is necessary for test purposes and for setting up the control processor clock initially. The minutes of the latter are, incidentally, reset to 19 minutes past the hour at the end of each DCP transmission, i.e. to (T + 1) minutes past the hour: this ensures synchronization of data gathering with the DCP real time clock, which is very accurate. A battery powered VDU terminal with LCD display was procured: this allows safe monitoring and control of the processors (and of the interface processor) whilst the buoy is out on deck of the deployment/recovery vessel. The procedure for setting and testing the control processor clock is given in Appendix F, together with details of the procedures for monitoring the processed data stores and digitised data buffers. The monitoring that is possible in the case of the wave processor is limited to examination of the instantaneous digitised values of the wave signals from the WAVEC via the COSMAC receiver interface. Details of this and of the COSMAC monitor output are given in Appendix G.

5. Design and construction of the hardware

The design centred round the use of the spare Marex S100 hull owned by the Department. This was slightly larger than necessary but offered a convenient working platform. It was decided to adopt a similar modular packaging/ interconnection system to that employed by Marex. The equipment owned by the Department included an Eidsvoll Argos PTT in a modular housing with primary batteries and a charging system for the stack of Ni Cd cells which supplied the PTT. This supply system was used to give a stable source of sufficient current capacity to power the transmitter with its high peak current/low mean current cycle. The PTT ID was 04120 and arrangements were made with Service Argos for this PTT ID to be transferred to an existing IOS experimental program number (0296). The PTT was not suited to transmission of data from the EMI Argos data base without further interfacing; this was not undertaken since the main function required was position fixing in this instance.

The buoy hull "hold" allowed for a further 3 large modules, if required, together with a total of 15 small modules (see Figure 5). The latter are normally battery packs. The EMI processors were supplied in card frames, mounted on a front panel including all external connectors, for test purposes. The card frames were remounted on a chassis in a configuration which would fit a standard-sized large module. It was also possible to mount the processed wave data Sea Data recorder and the DIREC receiver pcb F together with the associated COSMAC interface processor in the same module, thereby greatly minimising external connections. The receiver pcb was mounted in a diecast alloy box, so as to screen it from the noise generated by the digital processor circuitry. The COSMAC processor cards were mounted in a mother board/card frame adjacent to the Sea Data 633M 800 drive. The latter is a version of the 633M drive which is compatible with the NSC 800 microprocessors used in the EMI system. Apart from using a separate motor/head supply battery, it derives its power from the EMI wave processor +5V logic supply.

Figure 5



MAREX BUOY CABLE RUNS

AND MODULE ARRANGEMENT

Interconnections between the processors and external devices were routed via terminal blocks (Appendix H) for ease of testing. The decision was taken to use Electro connectors for all watertight bulkhead and external in-line connections (with the exception of r.f. coaxial connections). The use of connectors with a limited number of contacts resulted in the use of a large overall number of connectors, but was convenient in that a complex, inflexible, cable harness was not required and that modular testing was simpler (Appendix I).

The geostationary satellite (Meteosat) telemetry transmitter was housed in a separate module. This equipment consisted of two diecast alloy housings, together with secondary batteries of the sealed gel spirally-wound Cyclon type. Two series packs, each of 6 x 5.0 Ah cells were used to give a 12V supply for the DCP and a 24V supply for the HPA. The DCP unit comprises the accurate real time clock, digital processor for acquisition of the data from the EMI control processor and the low power 402.1255 MHz transmitter for regional channel 9, giving a nominal output of 4 to 8 watts. The data interface was of the synchronous 100 baud type for compatibility with the EMI equipment. The DCP also has a socket for connection to a special synchroniser unit. The latter, which is also processor driven, is used to set the real time clock in the DCP and to carry out various monitoring/control functions. The synchroniser has an LCD readout and an RS 232 printer output which can be used to obtain a hard copy of transmitted or test data.

The HPA unit is a high power u.h.f. amplifier, giving 40 to 60 watts output into 50 ohms. This power level is necessary when the 6805/200 omnidirectional antenna is used, whereas the 4 to 8 watt DCP output is sufficient if the 6805/100 directional antenna is used. The latter is, however, only suitable when motions of the platform do not exceed its 40 degree beamwidth. Whilst this is permissible in the case of a 3-point-moored buoy such as DB2 or DB3, it is not permissible with a single-point mooring as used on the Marex buoy.

Three Electro connectors were used on the transmitter module. These were for data transfer, charging current to the secondary batteries and monitoring of the secondary battery voltages. A cable gland was used in the lid for the low loss 50 ohm coaxial feeder to the antenna. An in-line connector module was constructed to allow disconnection of the transmitter module from the feeder running up inside the buoy mast. This connector module used N-type in-line connectors within a nylatron split housing with glanded cable entries and O-ring seals. A similar connector module was used on the feeder from the WAVEC quarter wave whip antenna to the receiver in the processor module. There were, therefore, three large modules (Argos, DCP/HPA and Processors).

6. Battery Packs

Thirteen battery packs were used, in total: these were housed in small modules. The battery packs were specified so as to allow sufficient capacity for 5 months operation. Three companies were asked to tender. The cheapest by far was the Danish company Hellesens who also had considerable experience in the military and marine fields. The specifications of the various types of pack are given in Table 4, below.

Table 4
Hellesens Battery Packs

Type	Function	Voltage (V)	Capacity (Ah)	Mean Current Drain (A)	Nominal Life (hrs)	Nominal Life (months)
1	C5 supply	7.5	750	0.189	3968	5.5
2	CW15 supply	14.4	375	0.097	3866	5.4
2	I15 supply	14.4	375	0.094	3989	5.5
2	NAV supply	14.4	375	0.009	41670	57.9
3	W5/I5 supplies	(a) 7.2	250	0.043	5814	8.1
	(a) (b)	(b) 7.2	250	0.053	4717	6.5
4	DCP	21.6	250	0.227	5464	7.6
(4 used in parallel, with series diodes, giving 1000 Ah capacity overall)						
5	HPA	21.6	250	0.183	4098	5.7
(3 used in parallel, with series diodes, giving 750 Ah capacity overall)						
6	COMP	21.6	250	0.014	17860	24.8

The battery packs were all made up from $LiSOCl_2$ R40 type cells, each of which provided 3.6V at 125 Ah. The packs were surrounded by vermiculite in the small module housings and pressure relief valves were included in the lids to prevent module explosion in the event of the cells venting. The connections to each pack were taken out through cable glands; Electro connectors were used on the free end of each cable tail. It must be emphasised that, although these particular cells have a good safety record and were professionally assembled in packs, Lithium batteries of this size are potentially a serious fire hazard and should be treated with great care. To ensure that the battery modules did not break loose within the buoy, close fitting plastic sleeves were installed to restrain their lower ends. The top rings of the battery modules were clamped down by the standard Marex locking arrangement.

The battery pack for the Sea Data motor drive and head drive supplies was made up from Duracell LO26SX Lithium Sulphur Dioxide 'D' cells. This was installed in the processor module itself. These cells have a nominal capacity of 8 Ah whilst 1.8 Ah is the manufacturer's figure for the required capacity to write a complete 450' tape. As will be described below, this battery failed to provide sufficient capacity.

7. Buoy Fitments

The Marex buoy required a number of relatively minor modifications for this application. A mast head sensor ring was procured from Marex to provide a means for mounting the h.f. receiving antenna for reception of the WAVEC signals, the ARGOS u.h.f. transmitting antenna and the Brookes and Gatehouse wind speed and direction sensors. A standard Kathrein h.f. receiving antenna was used, with ground plane rods. An adaptor was made to allow this to be mounted on one of the eight standard sensor fixing clamps used on the Marex sensor ring. The Brookes and Gatehouse sensors were fitted with polythene extension spigots to enable them to be fitted by the standard fixing clamps. The ARGOS antenna, as used previously by Marex, had a suitable base fixing. The fitting of the sensor ring to the mast necessitated the fitting of a short extension piece to the top of the mast by Marex. The mast head unit containing the flashing light fitted into this extension piece. The Meteosat u.h.f. antenna was mounted on top of the flashing light unit. The buoy heading sensor

(Brookes and Gatehouse Halcyon 2 two-component flux gate compass) which was required to give a reference for the wind direction sensor, was mounted on a small platform at a height of 3.9 metres above sea level. All sensors and antennas could be disconnected without removing the cables to the buoy holds. These cables were run down inside the mast, using foam plastic wads to prevent cable movement. The lower end of the mast fitted a socket on the tripod head, through which all the cables had to be fitted when the mast was stepped. The triangular junction box below the mast socket was modified so that the compass and wind sensor signals could be routed through it. The cables were then led down inside the U-section tripod legs, using cable ties, to the modules. The fixing of the battery modules within the holds has been described above. The three large modules were clamped down using standard Marex hooked studs, which were procured; this arrangement was found to work very well. Two battery junction boxes were constructed, with Electro bulkhead input connectors and a glanded output connector tail, to allow parallelling of the DCP and HPA battery packs. These junction boxes, which included series diodes and fuses, were strapped to the central frame bars in the hull. After final assembly and testing of the equipment, all cables were properly strapped down and the hold lids secured with cable ties.

8. System Testing

The proper testing of the component processors and telemetry transmitters was a long process. The processors were tested, individually, as fully as possible and they were then amalgamated and tested together, using signals transmitted by a static WAVEC buoy whose sensors were temporarily replaced by low frequency signal generators. When the receiver/interface processor/EMI processor combination had been shown to function correctly, these units were taken to Cromer for tests using the signals from the offshore WAVEC. For this purpose it was necessary to change the receiver frequency and to modify the interface processor software to route the received heave displacement signals to the heave acceleration analogue output. It would have been preferable to replace the Cromer WAVEC with one modified to transmit acceleration instead of battery voltage. Due to delays in the development programme, this would have necessitated additional expenditure in excess of £5000 and it was, therefore, decided to accept a slight uncertainty in the data.

This uncertainty results from the phase errors in the WAVEC double integrator which, in the normal DIREC processing, are corrected before any averaging of ensembles or spectral estimates is carried out. The EMI processor expects a correctly phased acceleration signal and the corrections can only be applied to the processed data after estimate and ensemble averaging has been carried out, which is not a sound practice.

After further laboratory testing the equipment was installed in the buoy hull and similar tests carried out using a static WAVEC as data source, but this time transmitting the data via Meteosat.

8A. **Interface Processor Testing**

Testing of both hardware and software was carried out. The "standard" COSMAC boards (processor, I/O, memory and H/W multiply) were tested using standard techniques and software exercising programs developed at IOS. The non standard boards were tested as follows. The power supply board was essentially similar to the EMI designed processor power cards and was tested using the EMI test specification. The six channel D-A convertor board was exercised using software synthesised ramps and exponential waveforms to check the operation of each D-A convertor (e.g. monotonicity, response time, etc.). The linearity and scale factor of each D-A was checked using a software stepped input to the convertors, whilst measuring the outputs with a precision digital voltmeter (see Appendix J). The Format board was connected to the DIREC pcb F and tested using standard laboratory test equipment (logic analyser, etc.).

The software was developed, as in Appendix C, using the FORTH nucleus in EPROM in the COSMAC system, by loading new word definitions over the RS 232 interface from the MPE FORTH development software running on an IBM PC (or ZENITH Z-100 after the MPE software had been successfully modified to run on the latter). The software was written using the MPE full screen editor and screens passed to the target processor. Each word was tested individually as it was added. Hardware switches were used to simulate data at the I/O ports to assist in testing of the software. For actual testing of the transformation resulting in the sine and cosine of the heading angle ψ, data values were loaded onto the stack using software rather than digital inputs. When the data processing functions had been fully verified in this way, the real time control/acquisition word START was developed, using a static WAVEC to transmit fixed data values to the DIREC pcb F and thence via the Format board to the I/O ports. This part of the software proved to be the most difficult to test properly, as might have been expected. Fortunately the speed of operation of the FORTH on the 1802 made it possible to include output of diagnostic data via the RS 232 whilst still carrying out the required processing and allowing a margin of time in hand in the processing cycle. It was, however, necessary to use 2400 baud data rate on the RS 232 so that serial output did not present an excessive overhead. Having tested the data acquisition and processing in this manner, it was then necessary to test the transfer of data to the EMI wave processor. At this stage it became evident that the EMI hardware/software generated sampling rate was in error by about 0.2% which resulted in a number of samples being lost over the 2560 sample record duration. This rate error was due to a faulty software counter which was present in the DB2 and DB3 systems also. In the case of DB2 and DB3, the error was not important, however. EMI were notified of this error and subsequently supplied new software in a replacement set of EPROMs. When these were installed, it was possible to check the control word START handshake, using the EMI synch. pulse, for any possible timing conflicts. The system appeared to function as expected so that the next step of transfer of simulated WAVEC data could be attempted. This is described in Section 8B.

8B. EMI Processor Testing

The main bulk of the EMI Control and Wave Processor testing was carried out at EMI's Woking establishment, according to a detailed test procedure which had been approved by IOS. Part of the testing was witnessed by the IOS Project Officer. This testing was carried out using the test facilities developed for testing the DB2 and DB3 systems. It had provisions for input of met. data using actual roof-mounted sensors, input of directional wave data using a two frequency signal source, with phase shifted slope signals. The facilities included Sea Data logger for test of processed wave tape interface and DCP/HPA for test of Meteosat interface. The EMI test specifications are given in the Thorn-EMI document D18D/TH/EAH/2451/07.10.86.

After acceptance, the EMI processors were rehoused at IOS into a chassis which would fit a "Marex style" large module. When this had been completed, the processors' functions were retested in the laboratory. The met. sensor processing was checked using the actual Brookes and Gatehouse sensors to be used on the Marex buoy, using a fan to simulate a fairly constant wind strength/direction. This testing enabled uncertainties in the polarities of various interconnections to be resolved (principally with regard to the compass/wind vane). The interface processor was then connected up and timing checks carried out as described in Section 8A, above. The scaling from the WAVEC sensors through the complete system to the EMI digital values was also checked. When the correct operation of the receiver/interface had been checked, an l.f. signal generator was connected into the WAVEC in place of the heave acceleration and displacement sensor outputs. This allowed a further check on the spectral processing, already tested at EMI, to ensure that no noise was introduced into the system by the telemetry/interfacing processes. It also allowed checks to be made on the scaling of the processed estimates.

Following the successful verification of the operation of the interface, a number of test records were made on the processed wave data Sea Data logger. It is worth pointing out, here, that all of the above checks on spectral data (as well as on processed met. data) were exceedingly protracted owing to the length of the processing and data output cycles. In a few cases, proceedings could be speeded up by alterations to the control processor real time clock, but even then the testing of the processors took an unexpectedly long time. The processed wave data tapes were translated, using a Sea Data model 12 reader interfaced to a Digidata double-buffered ½" tape drive. The translated data was then read back via an Acorn BBC microcomputer; printed outputs being obtained. This allowed a check to be made on the processed wave data format and the data could be checked against that held in the processor data base and read out into the pocket VDU terminal.

The EMI interface to the DCP and HPA acquired for use in this project was then tested. This required connection of the full system for charging the DCP and HPA secondary batteries from the Hellesens battery packs via the charging regulators in the EMI Control and Wave Processor power cards (1 regulator on each card).

The DCP u.h.f. output was connected into the HPA and a 15W (continuous rating) N-type 50 ohm dummy load was connected to the HPA output for initial tests. After the DCP and HPA had been powered up, it was necessary to set the DCP clocks. In order to safeguard against undesirable transmissions the DCP has two clocks. The primary clock, which can be set using the external synchroniser unit, reads hours, minutes, seconds, month, day, year. The secondary clock reads only the hour of the day and cannot be set directly; it is reset to zero and started when the primary clock passes through midnight and counts up one hour on each transmission during the day (other than on test transmissions initiated manually by the synchroniser TEST08 mode). A transmission (other than a test transmission) can only occur if the hours of the primary clock and secondary clock coincide. If, therefore, the DCP is powered up at, say 0900 hours, setting the primary clock to 0900 hours will leave the secondary clock set at zero hours and no transmissions will result. There are two ways to achieve correct time setting of both clocks; one is to power up the DCP and to set its primary clock just before midnight - this is not usually convenient. The second way is to use the "fast time" mode, as follows:

(a) the real time clock in the synchroniser is set to 23 hrs 55 minutes of the day before the current date;

(b) the DCP is powered up and synchronised to this time as explained in the DCP user manual;

(c) when the DCP clock has gone past midnight, thereby starting the secondary clock with time 00 hours, the DCP is set to fast time by means of synchroniser TEST05. The primary clock then runs at 30 x normal rate;

(d) when the DCP primary clock reaches the allocated time slot (18 minutes past the hour for the GBIOS2 equipment concerned), the clock reverts to normal speed for the duration of the transmission (approximately 1 minute);

(e) after the transmission, the clock reverts to "fast time" mode although it is necessary to reselect DCP TIME on the synchroniser to continue to monitor the DCP time (the synchroniser reverts to displaying its own time otherwise);

(f) processes (d) and (e) are repeated until the transmission occurs at a DCP primary time in the hour previous to the actual (GMT) current time. The DCP is then set to normal time by means of synchroniser TEST06;

(g) the synchroniser's own real time clock is then set to the exact current GMT time and it is used to set the DCP primary clock to GMT time.

Having set the DCP time in this way, the control processor is set to the same time as described in Appendix F. It is important that the DCP/HPA should not radiate any transmissions whilst the above process is being carried out, since they will not fall within the allocated time slot. A dummy load must be used, therefore. The HPA was then connected via a length of URM67 type, low loss coaxial cable to the antenna which was supported on a pole outside the building with a clear line of sight to the satellite GOES-E. The return transmissions via METEOSAT2 were then acquired by a local receiving station, acquired from Protolog Ltd, consisting of a 1.8 m diameter parabolic dish with feed, low noise preamplifier connected via approximately 50 m of URM67 coaxial cable to a down convertor/receiver. The latter produced a coherent binary phase modulated output which was passed to the Protolog SDUS message recovery unit. The latter decodes and stores the data from DCPs whose addresses are loaded in the SDUS unit message filter list. The stored messages are then read out into an Acorn BBC microcomputer via RS 232 and filtered into disk directories according to the originating DCP address. The resulting ASCII files (one per DCP per transmission) are then available for further decoding and processing as detailed below in Appendix K. Using this system, it was possible to check the content of data received at the ESA Darmstadt receiving station via GOES-E within about 2-3 minutes of transmission. The received data could then be compared with either the EMI Meteosat data base or the data transferred into the DCP. The latter could be monitored by using the synchroniser TEST09 mode with a serial printer or terminal connected to the synchroniser's RS 232 output.

After the correct operation of the Meteosat DCP/HPA had been verified, the processor module and DCP/HPA module were taken by van, together with the necessary battery packs, h.f. receiving antenna, pocket VDU and cabling to

Cromer to test the operation of the DIREC receiver/interface/EMI processors with actual "live" WAVEC data. A version of the interface software which used the heave displacement data to provide heave acceleration was used. The equipment was tested at two sites, one at Mundesley, the other adjacent to the Cromer coastguard lookout where the Cromer DIREC receiving/logging station was housed. The receiver crystal was replaced by the 38.825 MHz crystal necessary to tune to the Cromer WAVEC transmissions. Although good signals seemed to be received at Mundesley on a portable test set of IOS design (see Appendix L), there were occasional dropouts in the data as monitored via the interface processor 2400 baud output. Since no hard copy was available from the test set, it was not certain as to whether the receiving antenna was inadequate or whether the equipment was suffering from interference from a nearby marine radio station at Bacton. Consequently, having waited for a number of 3 hourly spectral processing periods to elapse without completely satisfactory results, it was decided to move the equipment to Cromer which, although slightly further from the buoy, was known to allow good reception. The equipment was set up again but it still suffered from very occasional dropouts which seemed to be a function of the exact location of the scaffold pole upon which the antenna was mounted. Since the ground was so dry, it is possible that an adequate earth was not being achieved and water was poured around the base of the pole in an attempt to improve matters. Due to the changes of site and the 3 hour repeat cycle, only two reasonably good intercomparisons resulted of the EMI system and of the DIREC system installed at Cromer (see Appendix M). The EMI system was set to process a 33 minute 20 second record which started at, nominally, the same time as the DIREC processing of a 30 minute record. The degrees of freedom for the estimates are respectively 40 (5 ensembles with averaging over four harmonics) for the EMI system, and 36 (9 ensembles with averaging over two harmonics) for the DIREC system. Thus about 80% of the estimates will be within ±30% of the true values. Due to the fact that heave displacement was analysed by the EMI system and that the sea state was quite low (H_s between 1.02 m and 0.66 m), the resolution in the heave spectrum, and in the heave x slope quadrature spectra, is rather coarse.

The agreement between the plots of normalised C_{11}, Θ_1 and Θ_2 against frequency for the two systems was good for the 1800 hrs records and fair for the 0900 hrs records. In both cases, the DIREC system measured a rather lower value of Θ_2 at the peak of the spectrum. This was almost certainly due to a combination of the uncorrected phase shift of the integrators in the EMI processing and of noise due to reception problems. The Θ_2 values from the EMI 0900 record are not valid in a band from 0.34875 Hz to 0.39875 Hz. This may have arisen from errors in manually recording the Meteosat data base contents. The computed H_s values from the EMI C_{11} spectra are 0.984 m for the 0900 hrs record and 0.674 for the 1800 hrs record. The Cromer DIREC H_s values were 1.02 m and 0.66 m, respectively. The maximum energy densities for the two EMI records were 0.973 and 0.490 m^2/Hz, c.f. 1.101 and 0.452 m^2/Hz for the DIREC records. The intercomparisons can, therefore, be looked upon as reasonably successful in view of the noise introduced by the reception problems. The software in the interface processor was then replaced by the version applicable to the modified WAVEC transmitting heave acceleration in the battery channel.

8C. **Testing of the Complete System**

The final stage of testing was to install all of the equipment in the Marex buoy to test for any possible electromagnetic compatibility problems, such as interaction between the various transmitters and receiver or pick up of interference by the sensors. This was carried out in the open in the IOS yard. The buoy was assembled completely with all cables routed and secured as for a deployment. The modified WAVEC (ex Flamborough Head) with heave acceleration in the battery channel was used to provide static signals. The system performed correctly apart from one detail: the receiver apparently overloaded due to the proximity of the WAVEC and it was necessary to remove the receiving aerial or the WAVEC aerial to achieve correct reception of data. Since the buoys were only a few metres apart and the receiver did not employ automatic gain control, this was not surprising. A second WAVEC at the frequency of the Cromer buoy (29.825 MHz) was also assembled in the vicinity and powered up. This did not appear to affect the reception of the desired signals. During the deployment all three of these buoys were to be in very close proximity on the deck of the deploying vessel.

The system was run for a number of days, with reception of good data via Meteosat. It was then disassembled to allow final preparation in the laboratory. At this point a fault occurred in the Meteosat module which resulted in one of the secondary batteries (the upper of the two series packs used to derive the 24V HPA supply) being completely flattened and which burnt out a number of connections in the DCP unit, as well as blowing up a number of integrated circuits. The units were returned to Space Technology Ltd for repair. The ST Ltd verdict was that the 24V supply must have become connected to the case via a link which was of lower resistance than the link from the 0V common to the case. It is not clear how this can have occurred or, indeed, when it occurred. After return of the equipment, the system was operationally retested in addition to the detailed testing conducted by ST Ltd. The equipment was then prepared for transport to Lowestoft.

9. Deployment of the Mother Buoy/WAVECs

The Cromer WAVEC contract with Hydraulics Research Ltd had been terminated at the end of June 1987. It had been hoped to retain this buoy in position while the Marex buoy and WAVEC were on station at 54°N 2°E so as to obtain directional data for testing a third generation wave model. It was, therefore, necessary to redeploy a WAVEC off Cromer in addition to the mother buoy system. Authorisations were sought from the relevant bodies and notices to mariners circulated to the relevant organisations (see Appendix N). Invitations to tender for the deployment operation were put out to three shipping companies. Tenders were received from Warbler Shipping and Seateam Shipping, the former being accepted on cost considerations. Mooring equipment for all three buoys was procured/serviced and prepared. Details of the mooring configurations are given in Appendix O.

The equipment was transported by articulated lorry to Lowestoft on 28th September 1987 and loaded on the vessel m.v. "Dawn Sky" using a hired mobile crane. The winches on the vessel were in the process of being refitted so that the intended departure of the vessel was delayed until 0900 hrs of the 29th. IOS personnel sailing were C.H. Clayson and I. Waddington. Since there was some doubt as to the success of the mother buoy system deployment operation, it was decided to deploy the mother buoy WAVEC first, followed by the Marex buoy and to deploy the Cromer buoy on the return journey. The site was reached at 1900 hrs of the evening of the 29th. Weather and sea conditions were quite good, there being about 1 metre of swell and only slight sea. The WAVEC was deployed using the standard deployment procedure (buoy first, anchor last).

The U-shaped Marex buoy mooring was then deployed. The main 2 tonne anchor clump was stopped off over the stern, with the Marex chain leg of the mooring and the counterweight ($\frac{1}{2}$ tonne clump) flaked out on deck with rope stoppers at each bight. The Marex buoy was launched with a short length of chain attached which could be coupled into the upper chain leg which was led round the stern. The crane was found to be inadequate for the job, having marginal lift to get the buoy over the side, despite assurances by the Warbler management that it would be adequate. When the buoy was finally in the water, the quick release on the crane hook would not operate at first and damage to the buoy mast structure was sustained, due to the buoy heave motion, because the crane jib could not be swung out the way as planned. The release eventually operated but the buoy had by then sustained the following damage: sensor ring slightly bent; one mast stay broken; compass sheared off and lost (sank); a number of mast stirrups sheared off. All antennas and met. sensors were undamaged, so it was decided to continue with the mooring.

The Marex buoy chain leg was run out under control of the stoppers but, as the weight of this chain came on the stopped off clump, the jerk resulted in the severance of a number of the strands of the wire ground line which ran from the winch over a snatch block to the 2 tonne clump. The end of the ground line was remade using bulldog clips and the clump lowered to the bottom. The spar buoy was then stopped off over the port quarter and the spar chain leg flaked out on the stern with its $\frac{3}{4}$ tonne clump and Bruce anchor. This was then run out under control of stoppers and the spar was slipped. An inspection of the Marex buoy was then made, using the vessel's work boat. The buoy was boarded and the broken stay removed; the remaining end of the compass cable (where the connector had sheared off) was taped up. The deployment strop was tied up. All appeared to be in order so, after taking position fixes on the buoys over a period to check that they were in fixed positions, the vessel departed for the Cromer site at 0100 hrs 30th September. The Cromer site was reached at about 0700 hrs and the coastguard was contacted to allow access of R. Pascal (IOS) to the receiving station to check the signals. The buoy was deployed using the standard procedure and, after checking reception, the vessel returned to Lowestoft. Personnel and equipment were disembarked and returned to IOS by van with R. Pascal on the afternoon of the 30th September.

Apart from the difficulties in deployment of the Marex buoy there were uncertainties in the procedure for establishing whether the system was operating correctly when deployed. In retrospect, the processed data quality flags should have been checked by taking the pocket VDU out to the Marex buoy after the buoys had gone through a complete processing cycle. Since the deployment was carried out in the dark, owing to the late sailing time, it was not considered justified to incur the risk to personnel of boarding the buoy for a second time in the dark; the cost of the ship time was also an ever present consideration.

10. Recovery of the Mother Buoy/WAVECs

After the buoys had been on station for a period of nearly two months, a second charter of the m.v. "Dawn Sky" was arranged to recover the buoys. The vessel had been working off Scotland so, to save cost, it was arranged to board the vessel in Grimsby on her return passage. The same personnel plus K. Goy boarded the vessel late evening of 24th November. The vessel sailed 0900 of the 25th after bunkering and reprovisioning. The weather was bad and forecast to become worse with winds up to force 10. Very slow progress was made towards the 54°N 2°E site. On the morning of the 26th the vessel was still about 25 miles off the site and was making only a knot or two in very heavy weather so it was decided, in view of the delay likely before any abatement of sea state, to abandon the attempt. The vessel ran back to Lowestoft, docking at 1900 hrs. Personnel were transported back to IOS by van the morning of 27th November.

A further charter was arranged and personnel joined the "Dawn Sky" at 1600 hrs on 8th December, sailing at 2200 hrs in fairly good weather. The site at 54°N 2°E was reached early morning of the 9th and the WAVEC recovered using towed grapnels to recover the bottom end of the rubber cord first. The rubber cord was in poor condition. The Marex buoy was then boarded, using the work boat, and new lifting strops were attached. The spar buoy was then attached to a line on the winch and pulled right up the stern ramp and along the deck. The chain leg was recovered using chain hooks on the winches and the $\frac{3}{4}$ tonne clump pulled up the ramp. The ground line was then attached to the winch, wound in, and the 2 tonne clump lifted. It was eased up onto the ramp using a separate line from a block on the A-frame to a small capstan. The chain leg to the buoy was then recovered using chain hooks. The buoy was then lifted inboard, again with difficulty, using the crane. The vessel then proceeded to the Cromer site, where the second WAVEC was recovered as above. The rubber cord was again in poor condition, having broken near the top fitment. The vessel then sailed for Lowestoft, docking at 2030 hours. The equipment was unloaded onto a lorry plus trailer on the morning of 10th December, using a hired mobile crane and personnel returned to IOS by 1530 hours.

11. Results

The results of the Cromer tests of the mother buoy system are summarised in Appendix M. The results from the actual offshore deployment were limited due to a combination of unfortunate events. When the buoys were first deployed, although all appeared to be well, monitoring of the Meteosat transmissions showed that quality checks on the wave data were failing due, presumably, to errors in reception of the telemetered data, although the WAVEC itself could have been at fault. However, after the buoys had been on station for approximately two weeks, this problem appeared to right itself, as evidenced by good data in a transmission received on 17th Octoober 1987 (after the passage of the "hurricane"). By this time, however, the Meteosat link had become unreliable and reception of data ceased altogether. This was later found to be due to water in the coaxial feeder cable to the antenna. It was also found, on recovery of the WAVEC, that the WAVEC glass reinforced plastic antenna had failed near the bottom and was probably making only intermittent contact: the g.r.p. had splintered axially and, although the rod was still in one piece when removed, it came apart when flexed slightly. The movement of the antenna is limited by the bore of the top hat (self righting) buoyancy module, when installed. The failure of the Meteosat link left the processed wave data cassette as the only hope for obtaining data after the h.f. telemetry problem righted itself.

Whilst a certain amount of data were recovered from the processed wave data cassette, failure of the motor/head drive battery pack cut short data recording on 12th October. The results are, therefore, based upon a number of tape records obtained during the period 7th-11th October. A summary of the quality check flags over this period is given in Appendix Q. All flags should ideally be zero, but it was considered worthwhile to process those records with less than two flag bits set.

These were 20 hrs 7/10/87, 05 hrs 8/10/87, 23 hrs 8/10/87, 02 hrs 9/10/87, 11 hrs 9/10/87, 20 hrs 9/10/87 to 05 hrs 11/10/87 incl., 11 hrs 11/10/87 to 17 hrs 11/10/87 incl. and 23 hrs 11/10/87.

The following records with more than 1 flag bit set also proved to be quite plausible when processed: 20/8/10, 17/9/10.

The statistics of the flag occurrences are worth noting. During the period 00 hrs 7/10/87 to 23 hrs 11/10/87, only one ensemble was rejected. However there were between 16 and 19 records where between 4 and 30 failures of the heave > 4 rms check, roll > high limit check, roll > 4 rms check, pitch > high limit check, pitch > 4 rms check occurred. By contrast there were only 6 records where the roll > low limit check and pitch > low limit check failed. There was only one record where a static value test failed, indicating that there were few hang ups in the interface. Plots of heave displacement energy, Θ_1, Θ_2 and check ratio R against frequency were made. Some of the records had very obvious low frequency energy of an f^{-4} type in the heave displacement energy spectrum, corresponding to more or less white noise in the acceleration energy spectrum. The effect of noise in the slope data is primarily to increase the computed directional spread Θ_2.

In order to remove the heave spectral noise, assuming it to be "white" in character, the displacement energy plots were examined to see at which frequency the first minimum arose, i.e. the frequency at which the genuine wave energy became significant. The energy of the acceleration estimates below that frequency was then averaged and this average energy was then subtracted from all of the estimates in the spectrum. If this resulted in a negative estimate, the estimate was set to zero. The process was also carried out for the two slope autospectra. This is a valid procedure in the case of the autospectra but not in the case of the cross spectra. The plots were then repeated using the "corrected" spectral estimates: these are included as Appendix P.

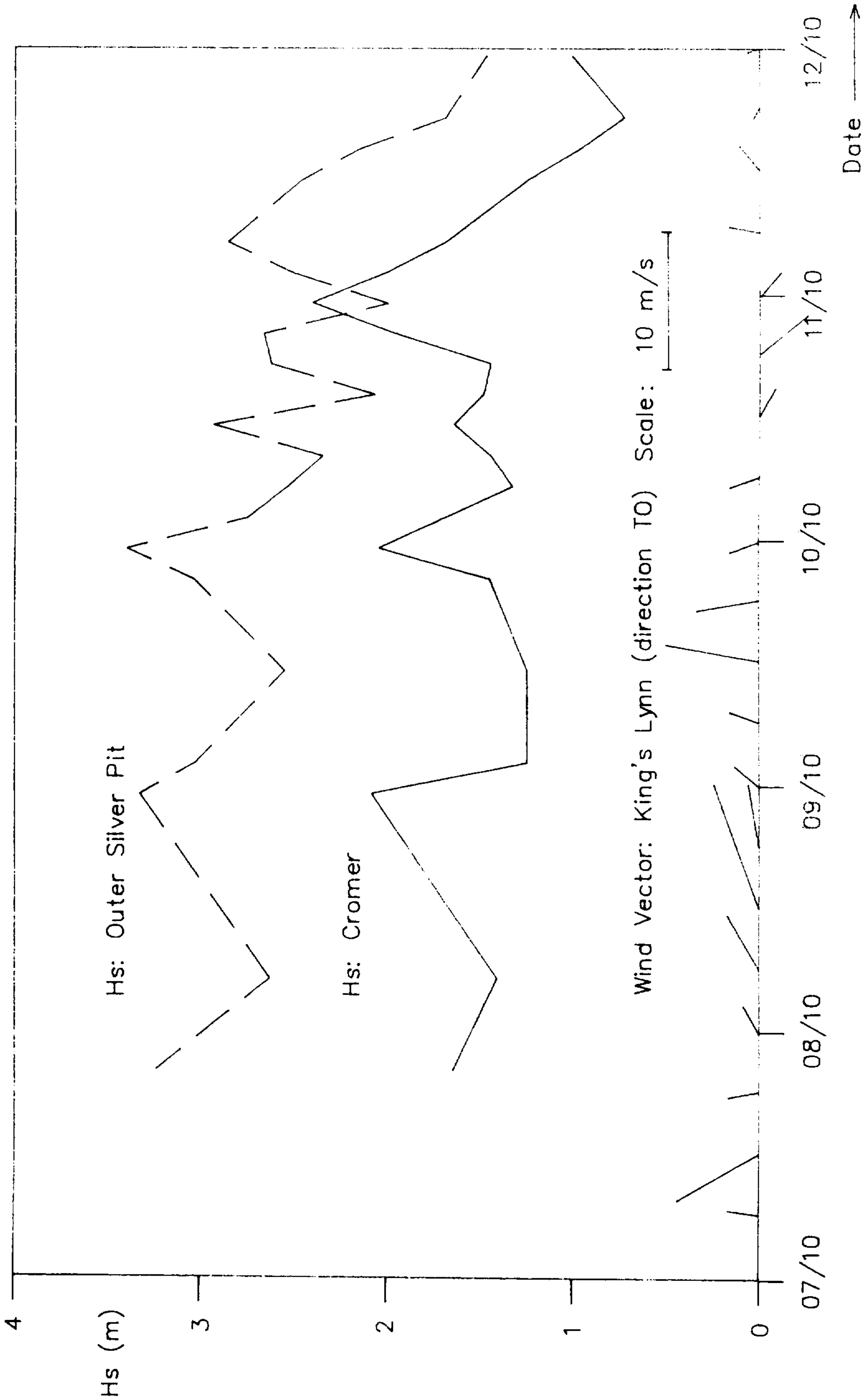
The resulting values of H_s and T_z were derived from the 0^{th} and 2^{nd} order moments of the corrected heave displacement energy spectrum: these are tabulated in Table 5, Appendix P.

The H_s values are also plotted in Figure 6, together with the wind vector as measured at King's Lynn. There is a clear correlation between the peaking of H_s at Cromer in the evening of 8/10/87 with the strong westerly (long fetch) winds that day and of the peaking of H_s at the Outer Silver Pit (54°N 2°E) site in the evening of 9/10/87 with the strong southerly winds (again, long fetch). Another peak in the Cromer H_s occurred at midnight 10/11th due to northwesterly winds blowing over a long fetch.

The correlation between the wind wave (0.20-0.26 Hz) mean direction and the King's Lynn wind direction is shown in Figure 7. There is an obvious correlation albeit lagged, probably due to the separation of the two sites.

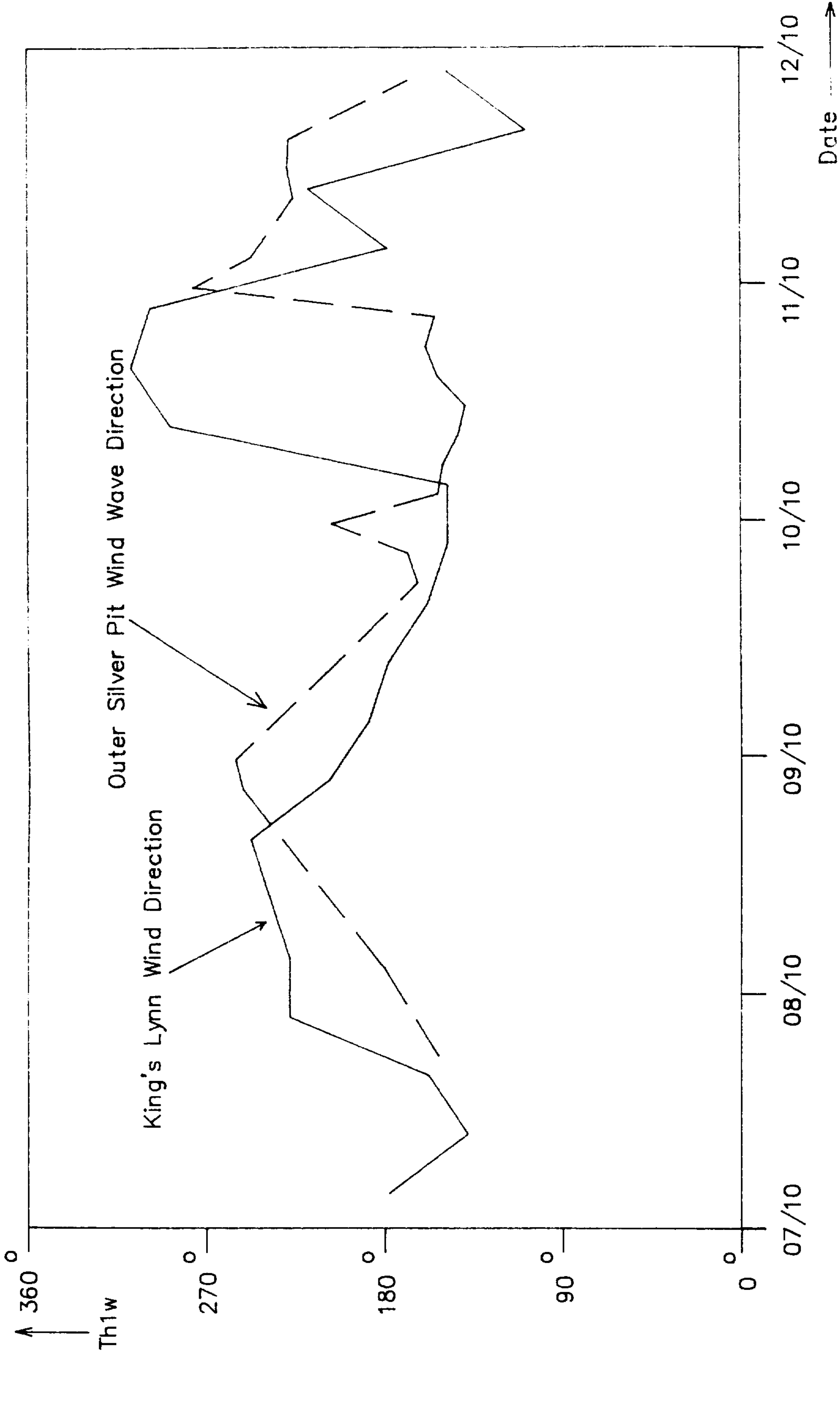
The nett data return from the deployments was very low but, for a first trial of the system, was sufficient to show that the concept was valid and that, apart from the necessity for minor amendments of a small number of constructional defects, a working system had been achieved. If the premature failure of the Sea Data motor/head drive battery pack had not occurred, it is likely that data would have been obtained over the whole of the deployment period although, due to the failure of the WAVEC antenna, some of that data would have been "noisy", resulting in increased values of spread.

Figure 6



Hs for Outer Silver Pit and Cromer and Wind Vector at King's Lynn

Figure 7


Outer Silver Pit Wind Wave Direction
King's Lynn Wind Direction
360°
270°
180°
90°
0°
0
Th1w
07/10
08/10
09/10
10/10
11/10
12/10
Date

12. CONCLUSIONS

Directional wave observations have been made in coastal situations, using WAVEC buoys telemetering to shore stations, with comparable reliability to one dimensional observations using WAVERIDER buoys. Handling of the WAVECs at sea, whilst requiring more care than for WAVERIDERs can be achieved with adequate safety using a 15 metre motor fishing vessel. On the numerous occasions when the buoys went adrift, whilst mooring failure can not be completely ruled out, fishing operations appear to have resulted in severance of the mooring rubber cord. Acquisition of directional data is, as would be expected, considerably more expensive than one dimensional data. The equipment, although reliable, has a much higher initial cost and, although deployment and recovery operations are no more expensive, serviceing and calibrating operations are more time consuming. Although the data are preprocessed in the shore station, later editing and banking also involve more effort than for one dimensional data.

The offshore measurements, using the WAVEC-Mother Buoy system showed that, despite the technical problems which resulted in poor data return, the concept of obtaining high quality data via a relay buoy was valid. With further attention to detail and to operational procedures, there is little doubt that such a system can be made to give as good a data return as a coastal buoy, albeit at considerably higher capital equipment and operational costs.

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APPENDIX A

Technical Schedules

The technical specification for the WAVEC operations included a number of annexes, which are listed below and are included both as a record and as a possible basis for similar operations in the future.

Annex	Subject
A	Equipment preparation
B	IALA special marks for ODAS
C	Transmitter realignment
D	WAVEC calibration
E	WAVEC double integrator response corr. factor
F	Equipment list
G	Mooring preparation
H	Diagram of standard mooring
J	List of components for standard mooring
M	Pre-deployment tasks
N	Deployment and retrieval
P	General considerations - loss of data, erroneous data, loss of buoy

ANNEX A

Equipment Preparation

A proper logbook detailing all non-trivial operations, checks, calibrations, repairs, etc., carried out on the Wavec and its associated equipment shall be kept. This shall be available for inspection by a duly authorised representative of the authority (NERC) at reasonable notice.

1. Wavec Handling

Instrument is to be handled carefully at all times, and it shall not be spun or rolled. Accidental damage, either actual or suspected, shall be reported to IOS, who shall decide if a check calibration is necessary; if so, calibration shall be performed as detailed in Annex D.

2. External

(i) Wavec canister shall be free of all but minor dents; wing attachment eyes shall be truly in line: antenna seating shall be clean and not corroded: threaded Delrin antenna base and top-nut shall be undamaged: rubber sealing ring and thin Delrin ring in antenna base shall be in good condition and undistorted: flashing light cable outlet shall be in good condition and the cable to the flashing light shall not be unduly chafed or have been pinched: all canister lid bolts shall be fitted with washers and tightened securely.

(ii) Glass housing for flashing light shall be neither chipped nor cracked: the flashing light pattern shall be in accordance with IALA recommendations (see Annex B). If the flashing light colour is blue white, a yellow filter shall be fitted inside the glass housing.

(iii) Wings and the related cunifer pins shall be free of any excessive distortion which may hinder assembly and prejudice the integrity of the assembled device: wing paintwork shall be in good condition and the surface of all parts in contact with the strainers, when assembled, shall be smooth: welds shall not show any sign of cracking or corrosion.

(iv) Strainers, float attachment bands and all hardware used in assembly of the buoy shall be in good condition: new split pins shall be used for securing the top band retaining rods.

(v) Float segments and the top float shall be in good condition: bonding of the bands shall not show signs of separation: the surface coating of the floatation material shall not be cracked or torn.

(vi) The procedure for assembly shown in the Wavec manual shall be followed closely: in particular, attention should be paid to the adequate tensioning of the float segment bands, to ensure that there is no possibility of the float segments working loose at sea: all shackles shall be properly moused with suitable seizing wire (of same material as shackles) or by means of nylon cable ties. No magnetic materials shall be attached within 2 metres of the canister.

(vii) Hoisting lines shall be made up according to the dimensions given in the Wavec manual: it is recommended that polypropylene rope of at least 3 ton breaking strength is used, except for the interconnecting line: temporarily attached steadying lines should also be provided to prevent the buoy from spinning when hoisting.

3. Internal

(i) The battery voltage, as measured in the junction box, shall be adequate for the required length of deployment, according to the table given in the Wavec handbook. Sealed dry cells manufactured by Leclanche, of Yverdon, Switzerland, shall be used. (These may be obtained from Datawell). The instructions for replacement, given in the Wavec handbook, shall be followed closely and care shall be taken that the pcb's are replaced with the arrow in the direction of the red marking on the canister.

(ii) During battery replacement, all silica gel contained within the Wavec shall be dried thoroughly, by heating to 130 degrees C for 12 hours, or until it is bright blue in colour. The Wavec shall then be kept sealed as much as possible.

(iii) The Wavec transmission frequency shall be determined in consultation with the Home Office prior to deployment. A crystal of the agreed frequency shall be fitted.

(iv) If the crystal referred to above is not fitted by the factory before delivery of the Wavec, the Wavec transmitter circuit shall be tuned for maximum output on the agreed frequency, as described in Annex C.

(v) No magnetic materials are to be introduced into the canister.

(vi) The lid seal O-ring, its groove and the flat sealing surface shall be cleaned and regreased with Vaseline or silicone grease just before the lid is finally refitted. The lid shall be replaced with the correct orientation, i.e. with the marked x-axis in line with the red dot on the inner side of the can.

4. On Recovery

(i) The buoy shall be cleaned of all marine growth, the metallic parts examined for corrosion and all parts examined for physical damage.

(ii) The Wavec canister shall be removed to a laboratory, dried and opened. It shall be inspected for water ingress, battery voltage state and cell leakage.

(iii) Before any electrical adjustments are made, the Wavec shall be calibrated. In the event of there being a fault with the electronics which makes a calibration impossible, the Contractor shall discuss the situation with the Superintending Officer before taking any remedial action on the fault. For calibration procedures, see Annex D.

(iv) Before re-deployment, the buoy shall be refurbished as specified in 1, 2 and 3 above.

ANNEX B

Special Marks

1. Definition of Special Marks: Marks not primarily intended to assist navigation but which indicate a special area or feature referred to in appropriate nautical documents, for example:

(i) Ocean Data Acquisition Systems (ODAS) Marks.
(ii) Traffic separation marks where use of conventional channel marking may cause confusion.
(iii) Spoil ground marks.
(iv) Military exercise zone marks.
(v) Recreation zone marks.

2. Description of Special Marks:

Colour:	Yellow
Shape:	Optional but not conflicting with navigational marks
Topmark (if any):	Single yellow 'X' shape
Light (when fitted):	Colour - yellow Rhythm - Group flashing (5) every 20 secs. Flash rate not to exceed 30 per minute.

(Notes: This Annex is copied directly from the IALA Supplement).

ANNEX C

Transmitter and Receiver Realignment

If it becomes necessary to change the operating frequency, new crystals have to be fitted to both transmitter and receiver, which then require precise realignment. This is relatively straightforward for a qualified technician, provided that he has the correct equipment (some special equipment is necessary).

In the event that a frequency change is required, the Datawell laboratory shall be consulted before any alterations or adjustments are carried out, and their instructions shall be followed precisely.

ANNEX D

Wavec Calibration

1. General

(i) The object of calibration is to provide a check on the absolute scaling of the Wavec buoy sensor outputs, which will subsequently be used in the analysis of the wave data. The sensor data are digitised in the buoy, unlike in the case of the simpler Waverider buoy, and each individual sensor circuit is adjusted by the manufacturer to give the correct scaling when the buoy leaves the factory. The nominal sensor calibrations are programmed into the Direc receiver processor memory permanently, so that all analyses performed by this unit depend upon the correct scaling of the sensor outputs in the buoy. It is also possible to record raw data from the receiver for further analysis and, in this case different calibrations can be applied. Processed data can also be corrected for changes in the calibration of the Heave sensor, but not for changes in the other sensors, in general.

(ii) The nominal calibrations for the sensors are given in the Wavec and Direc manuals and are summarised below.

Sensor	Data Range	Analogue Scaling (at junction box)	Digital Scaling (not incl. offsets)
heave	-2000 to +2000 cm	5 mV/cm	1 cm/digit
pitch	-90° to +90°	10sin (pitch)	0.0005/digit
roll	-90° to +90°	10sin (roll)	0.0005/digit
Hx,Hy,Hz	0 to 50 A/m	200 mV/A/m	0.025 A/m/digit
(Battery)	10 to 30V	______	-0.025V/digit

(iii) All checks on calibration shall be entered into the logbook referred to under equipment preparation, above, which shall be handed to IOS at the end of the contract.

(iv) Wavec buoys shall be calibrated by one of two methods, as described below. Method A shall be employed before and after every deployment: method B shall be employed at intervals of six months, normally at the routine maintenance intervals. If the calibration results produced by a method A calibration fall outside the range specified below, the Supervising Officer shall be informed before any action is taken to deploy the buoy concerned.

2. Method A

This is a test of the individual sensor calibrations by simple techniques and is based largely upon the method given in the Wavec manual. A Datawell Direc receiver and HP85 computer, or equivalent equipment, are required for monitoring the digital data transmitted from the buoy.

(i) The heave (displacement) channel shall be calibrated, approximately, by suspending the canister on springs, as detailed in the Wavec handbook, and subjecting it to near-sinusoidal vertical oscillations of at least 50 cm peak-peak amplitude, at a period of at least 2 seconds. The peak-peak output measured at the junction box test point shall be 5mV±0.2mV times the peak-peak displacement in cm. The peak-peak telemetered digital output shall be 1±0.04 times the peak to peak displacement in cm. Note, however, that at 1.28 Hz sampling rate it may take several cycles before samples of the exact peak and trough displacements are obtained.

(ii) The pitch channel shall be calibrated by inclining the buoy canister vertical axis at angles of ±90° to the vertical, whilst keeping the roll (x) axis vertical. This is illustrated in the Wavec handbook. The difference between the pitch output voltages (measured between pins 4 and 12 in the junction box) in these two orientations shall be 20V±0.4V. The difference between the digital values in the telemetered pitch output shall be 4000±80 digits.

(iii) The roll channel shall be calibrated by inclining the buoy canister vertical axis at angles of ±90° to the vertical, whilst keeping the pitch axis vertical. The difference between the roll output voltages (measured between pins 5 and 12 in the junction box) in these two orientations shall be 20V±0.4V. The difference between the digital values in the telemetered roll output shall be 4000±80 digits.

(iv) The platform offset shall be measured by the technique given in the Wavec handbook, that is by rotating the canister through 360° about its vertical axis in approximately 10 seconds and then observing the pitch and roll outputs over a period of about 20 minutes. The platform offset, measured as half the average of the peak to peak variations of the pitch and of the roll outputs at the junction box test points, over this 20 minute period, shall be less than 174mV (i.e. the equivalent of 1°).

(v) The compass shall be calibrated by measuring the three output components, H_x, H_y, H_z, with the canister rotated about its vertical axis to orientations of 0° to 350°, relative to magnetic North, in steps of 10°. This shall be carried out in a place which has been magnetically surveyed to ensure that the magnetic field horizontal component lies in a fixed direction (±½°) over an area 1 metre square. This survey shall be carried out using a North setting compass, accurate to 1/4°. No magnetic materials shall be allowed within 5 metres of this area whilst measurements are being taken.

The buoy canister shall be set with the x-axis (indicated on the lid) initially in line with the local magnetic North and with the buoy lid horizontal; the digital values of the three telemetered magnetic field components shall be noted. The canister shall then be rotated clockwise about its vertical axis (looking down on the lid) to an orientation of 10° and the digital values of the three field components again noted. This should be repeated at 10° steps up to an orientation of 350°. All orientations shall be correct to within ±0.5°.

The following checks shall be carried out on the measurements of the field components:

(a) the magnitude of the horizontal field component, obtained from the square root of the sum of the squares of the H_x and H_y values, shall be constant to within ±75 digits (or ±5 percent), whichever is the greater.

(b) the direction of the horizontal field component, obtained by taking $\tan^{-1}(H_y/H_x)$ shall agree with the orientation of the canister x-axis marking relative to magnetic North to within 1°.

(c) the value of H_z shall be constant to within ±10 digits (or within ±0.75 percent), whichever is the greater.

(d) in carrying out the above checks, the signed MONITOR data output from the DIREC receiver should be used.

In the event of the sensor package failing to meet any of the above calibration criteria, this fact shall be communicated to the Supervising Officer, who may then require that the canister shall be returned to the manufacturers for repair, at his discretion.

3. Method B

This method shall be used where a more rigorous check on the heave calibration is required, at six-monthly intervals.

(i) The canister shall be transported to a non-magnetic swinging arm calibration rig, similar to those installed at Datawell's Haarlem Laboratory and nearby manufacturing facility. A directional analysis is to be carried out, using the Direc receiver and HP 85A computer, or similar facilities, for each of at least six frequencies of rotation within the operating range of the swinging arm rig, with constant amplitude and direction of orbital motion.

Note that, at the present time, there are no facilities known, other than those at Datawell; any other facility may be used, if available, by agreement with IOS. The vertical displacement must be known to within 1% and must be greater than 1.5m.

(ii) The buoy sensor shall be calibrated at the following nominal rates of rotation, the actual rates being measured to better than 1%. Additional intermediate rates shall be included if time permits.

Rotation Speed (rpm)	1.5	2.5	3.5	6	10	15
Corresponding period (sec)	40	24	17.1	10	6	4

(iii) At least 30 seconds shall elapse after a speed change before the start of acquisition of a 200 second section of data for analysis, to allow for settling.

(iv) An analogue trace of heave displacement shall be produced and this shall be examined for mean line variation. If such mean line variation exceeds 0.3m (peak-peak) at a rotation period of 6 seconds, or 0.8m at 4 seconds, the sensor shall be rejected as faulty.

ANNEX E

Correction Factor for WAVEC Double Integrator Response (from 2 to 49.9 seconds period)

(sec)	0.000	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900
2.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
3.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
4.000	1.000	1.000	1.000	1.001	1.001	1.001	1.001	1.001	1.001	1.001
5.000	1.001	1.001	1.001	1.001	1.001	1.001	1.001	1.001	1.001	1.001
6.000	1.001	1.001	1.001	1.002	1.002	1.002	1.002	1.002	1.002	1.002
7.000	1.002	1.002	1.002	1.002	1.003	1.003	1.003	1.003	1.003	1.003
8.000	1.003	1.004	1.004	1.004	1.004	1.004	1.004	1.004	1.005	1.005
9.000	1.005	1.005	1.005	1.006	1.006	1.006	1.006	1.007	1.007	1.007
10.000	1.007	1.008	1.008	1.008	1.008	1.009	1.009	1.009	1.010	1.010
11.000	1.010	1.011	1.011	1.011	1.012	1.012	1.012	1.013	1.013	1.014
12.000	1.014	1.014	1.015	1.015	1.016	1.016	1.017	1.017	1.018	1.018
13.000	1.019	1.019	1.020	1.020	1.021	0.021	1.022	1.023	1.023	1.024
14.000	1.025	1.025	1.026	1.027	1.027	1.028	1.029	1.029	1.030	1.031
15.000	1.032	1.033	1.033	1.034	1.035	1.036	1.037	1.038	1.039	1.039
16.000	1.040	1.041	1.042	1.043	1.044	1.045	1.046	1.047	1.048	1.049
17.000	1.051	1.052	1.053	1.054	1.055	1.056	1.058	1.059	1.060	1.061
18.000	1.063	1.064	1.065	1.067	1.068	1.069	1.071	1.072	1.074	1.075
19.000	1.077	1.078	1.080	1.081	1.083	1.084	1.086	1.088	1.089	1.091
20.000	1.093	1.094	1.096	1.098	1.100	1.102	1.104	1.105	1.107	1.109
21.000	1.111	1.113	1.115	1.117	1.119	1.121	1.123	1.125	1.128	1.130
22.000	1.132	1.134	1.136	1.139	1.141	1.143	1.146	1.148	1.151	1.153
23.000	1.155	1.158	1.160	1.163	1.166	1.168	1.171	1.173	1.176	1.179
24.000	1.182	1.184	1.187	1.190	1.193	1.196	1.199	1.201	1.204	1.207
25.000	1.210	1.213	1.217	1.220	1.223	1.226	1.229	1.232	1.236	1.239
26.000	1.242	1.246	1.249	1.252	1.256	1.259	1.263	1.266	1.270	1.273
27.000	1.277	1.281	1.284	1.288	1.292	1.295	1.299	1.303	1.307	1.311
28.000	1.315	1.319	1.323	1.327	1.331	1.335	1.339	1.343	1.347	1.351
29.000	1.356	1.360	1.364	1.369	1.373	1.377	1.382	1.386	1.391	1.395
30.000	1.400	1.404	1.409	1.414	1.418	1.423	1.428	1.432	1.437	1.442
31.000	1.447	1.452	1.457	1.462	1.467	1.472	1.477	1.482	1.487	1.492
32.000	1.497	1.503	1.508	1.513	1.518	1.524	1.529	1.534	1.540	1.545
33.000	1.551	1.556	1.562	1.568	1.573	1.579	1.585	1.590	1.596	1.602
34.000	1.608	1.613	1.619	1.625	1.631	1.637	1.643	1.649	1.655	1.661
35.000	1.668	1.674	1.680	1.686	1.692	1.699	1.705	1.711	1.718	1.724
36.000	1.731	1.737	1.744	1.750	1.757	1.763	1.770	1.777	1.783	1.790
37.000	1.797	1.804	1.810	1.817	1.824	1.831	1.838	1.845	1.852	1.859
38.000	1.866	1.873	1.880	1.888	1.895	1.902	1.909	1.917	1.924	1.931
39.000	1.939	1.946	1.954	1.961	1.969	1.976	1.984	1.991	1.999	2.007
40.000	2.014	2.022	2.030	2.038	2.045	2.053	2.061	2.069	2.077	2.085
41.000	2.093	2.101	2.109	2.117	2.125	2.134	2.142	2.150	2.158	2.167
42.000	2.175	2.183	2.192	2.200	2.208	2.217	2.225	2.234	2.242	2.251
43.000	2.260	2.268	2.277	2.286	2.294	2.303	2.312	2.321	2.330	2.339
44.000	2.348	2.356	2.365	2.374	2.384	2.393	2.402	2.411	2.420	2.429
45.000	2.438	2.448	2.457	2.466	2.476	2.485	2.494	2.504	2.513	2.523
46.000	2.532	2.542	2.552	2.561	2.571	2.580	2.590	2.600	2.610	2.619
47.000	2.629	2.639	2.649	2.659	2.669	2.679	2.689	2.699	2.709	2.719
48.000	2.729	2.739	2.750	2.760	2.770	2.780	2.791	2.801	2.811	2.822
49.000	2.832	2.843	2.853	2.864	2.874	2.885	2.895	2.906	2.917	2.927

ANNEX F

Equipment List

1. Equipment to be initially supplied by the Authority

The following set of equipment shall be supplied by the Authority and may be collected from IOS by arrangement after the commencement of the contract:

(a) One WAVEC buoy, consisting of:-

Instrument Cylinder .... Weight 274 kg
Float Mounting Wings (complete
with fastening hardware) (4 off)......... Weight 4x37 kg
Topfloat .... Weight 60 kg
Float Segments (4 off) .... Weight 4x40 kg
Flashing Light
Whip Antenna

(b) Mooring Hardware, consisting of:-

Mooring Cross
(complete with strops) .... Weight 62 kg
Rubber Mooring Cord (with attached safety line)

(c) Note that other hardware necessary to complete the standard mooring configuration, described in Annexes G, H and J, shall be supplied by the contractor.

The buoy shall be initially supplied by the Authority with a complete set of batteries adequate for 6 months operation.

2. Equipment to be procured by the Contractor for back-up purposes

The following set of equipment shall be procured by the Contractor at the commencement of the contract and maintained as a back-up system. This system shall be used to replace the other buoy and mooring at the first routine maintenance, or earlier in the event of buoy loss or malfunction, as detailed in Appendix A, 2j. The original buoy and mooring equipment shall then be refurbished, or replaced if necessary, and maintained as the back-up set of equipment.

One WAVEC Buoy, consisting of:-

Instrument Cylinder
Float Mounting Wings (complete with fastening hardware) .... (4 off)
Topfloat
Float Segments .... (4 off)
Flashing Light
Whip Antenna

One Set of Mooring Hardware, including:-

Mooring Cross (complete with strops)
Rubber Mooring Cord (complete with safety line)
Rope, Chain, Anchor, etc. to complete mooring hardware to specification of Annex G.

3. Equipment to be returned to the Authority at the termination of the contract

Upon the completion of the contract, or its termination for any reason, the equipment listed under 1(a) and 1(b) above shall be returned to the Authority in accordance with Appendix A,2C and 4.

ANNEX G

Mooring Preparation

Standard Mooring

(i) The Wavec buoy shall be prepared as described in Annex A.

(ii) Annex H shows a diagram of the Standard Mooring, and Annex J lists each component. The mooring shall be prepared in accordance with these Annexes.

(iii) No dissimilar metal-metal contact shall be allowed.

(iv) All galvanised shackles shall be greased with salt water resistant grease, and moused with galvanised seizing-wire.

(v) No stainless steel shackle shall be greased but all shall be moused with nylon or similar rot-proof twine.

(vi) Used mooring components may be re-utilised. However, no appreciable corrosion of metal components shall be evident, no rope showing signs of chafe shall be used, no trawl float containing water shall be used, and the rubbercord shall exhibit no flaw other than superficial scratches or minor surface degradation.

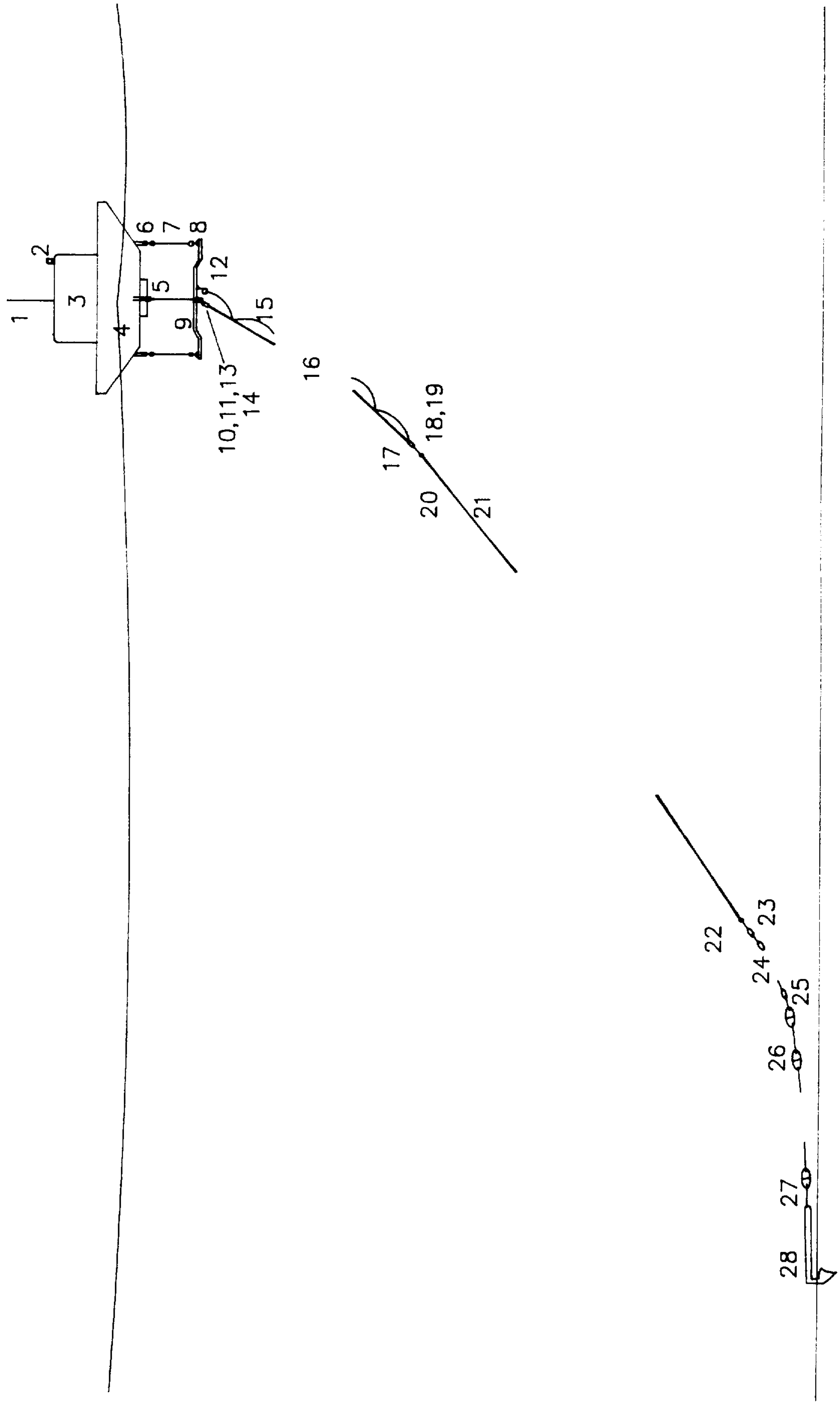
(vii) No natural fibre shall be used in mooring construction.

(viii) Patterns for the manufacture of nylon bushes may be supplied by IOS.

(ix) Advice on supplies of mooring components may be obtained from IOS.

ANNEX H

Figure 7a Mooring Details (WAVEC)



ANNEX J

Mooring Components

1. * Whip Antenna
2. * Flashing Light
3. * Self-Righting Float
4. * Segmented Float/Wing Assembly
5. * Instrument Canister
6. * Stainless steel shackle (1 of 4)
7. * Rope strop (1 of 4)
8. * Stainless steel shackle (1 of 4)
9. * Mooring Cross
10. * Mooring Cross Eye (part of 9)
11. * Stainless steel shackle
12. * Stainless steel shackle
13. Nylon Bush
14. * Rubbercord Terminal
15. * Safety Rope (attached to 16 at intervals)
16. * 15 metres Rubbercord
17. * Rubbercord Terminal
18. Nylon Bush
19. 26 cwt Shackles, galv. (2)
20. Mooring Line Termination
21. 50 metres Polyester Braidline (Mooring Line)
22. Mooring Line Termination
23. 26 cwt. Shackle, galv.
24. 10 metres Light Chain (7/8")
25. 37 cwt. Shackle, galv.
26. 12.5 metres Chain (1 3/8")
27. 37 cwt. Shackle, galv.
28. 15 kg Bruce anchor, with shackle to 27

* original equipment as supplied by Datawell

ANNEX M

Pre-deployment Tasks

General

(i) Experience to date suggests that the Wavec buoy and standard mooring has adequate survivability as far as the environment is concerned. The greatest hazards in the North Sea are likely to be accidental interference due to trawling activities and collision, both of which are likely to result in damage to the mooring and possibly the buoy. Intentional interference or theft are also possible, but less likely.

(ii) Whilst the foam floatation units of the buoy provide some protection for the central housing, great care should be exercised in handling the buoy from the deploying/recovering vessel. Moorings shall be prepared so that they are torque-free, and the buoy shall neither be rolled, nor be allowed to spin when being lifted.

(iii) Permission to deploy the Wavec within British territorial waters should be obtained from the following organisations:

(a) Department of Trade, Marine Division,
Sunley House,
90 High Holborn,
London WC1V 6LP

(b) Crown Estate Commissioners,
Crown Estate Office,
13-15 Carlton House Terrace,
London SW1Y 5AH

(c) The Home Office,
Radio Regulatory Department,
Waterloo Bridge House,
Waterloo Road,
London SE1 8UA
(but note that the IOS has an allocation for the frequency to be used)

(d) If Wavec is to be deployed near any Trinity House installation (buoy, lightship, etc.):
The Secretary,
Trinity House Lighthouse Service,
Trinity House,
Tower Hill,
London EC3N 4DH

It is suggested that the following are also informed:

(e) Ministry of Defence (H10),
Hydrographic Department,
Taunton,
Somerset.

(f) Inspectors of HM Coastguard for the area in which the buoy is to be deployed.

(g) The Manager, General Council of British Shipping
30/32 St Mary Axe
London EC3A 8ET

(h) Ministry of Agriculture,Fisheries and Food
Great Westminster House
Horseferry Road
London SW1

(iv) It is the responsibility of the Contractor to obtain the necessary authorities to operate Wavec installations.

ANNEX N

Deployment and Retrieval

1. It is the responsibility of the Contractor to arrange for the use of a suitable deployment/retrieval vessel. The vessel shall be fitted with position-fixing and depth measuring equipment, and lifting gear sufficient to lift the mooring and the buoy (see Appendix A,2h). Note, however, that it is possible, and may even be desirable if weather is bad, to tow the buoy out. In this event, the towing speed shall not exceed 4 knots.

2. Before the buoy and mooring are deployed, a site survey shall be performed to ensure that conditions are generally those to be expected from information given on the appropriate Admiralty chart. If conditions are not as expected it may be necessary to search locally for a suitable mooring point. The buoy should not be deployed more than half a mile from the nominal position, however. It may be necessary to alter the length of mooring components.

3. Buoy Preparation:-

(i) The buoy shall be assembled in accordance with Annex A, Sections 3 and 2, in conjunction with the WAVEC handbook provided by Datawell.

(ii) Note that the weight of the buoy, when assembled, is approximately 650 kg. The buoy should only be assembled within range of suitable lifting equipment or on a suitable trailer. When the buoy is lifted, it must not be allowed to spin, otherwise sensor damage may result.

(iii) The whip antenna is attached in between stages 2 and 3 of the procedure at the bottom of page 15 in the Datawell WAVEC handbook. The antenna socket must be dry and the antenna threaded base must be greased with silicone grease prior to fitting the antenna as per page 16 of the handbook.

(iv) Ensure that the float outer bands are adequately tensioned (see also Annex A, 2).

(v) The rubber mooring cord and its attached safety line should be attached to the mooring cross and the latter attached to the buoy, as per page 20 of the handbook.

(vi) Hoisting lines should be made up and attached to the four buoy hoisting eyes as per page 21 of the handbook.

(vii) The flashing light cable should be secured to the top float so as to prevent any chafing from occurring.

(viii) All shackles and other fasteners should be checked and moused or locked in the manners recommended in the handbook and in Annex A, 2(vi).

(ix) The mooring components should be prepared according to Annex G. The components should be connected together, starting with the anchor. The anchor should be placed so that it can be dropped over the side easily. The mooring should be flaked out so that there are no twists and no crossings so that it will run out freely when the anchor is dropped without applying torque to the buoy.

4. Buoy Deployment:-

(i) If the WAVEC is to be towed out to the mooring site, the towing line should be attached to one of the buoy hoisting eyes as shown on page 23 of the handbook. Alternatively, a towing bridle may be used, attached to two of the towing eyes, to reduce yawing of the buoy when under tow. Care should be taken not to induce any spin of the buoy by, for example, allowing it to roll its way along the side of the ship.

(ii) When a suitable site for the mooring has been located, a marker buoy can be deployed to form a quick visual reference point; this is especially useful if there is an appreciable tidal flow at the time.

If the buoy has been towed out to the site, it should be pulled in close to the ship and the mooring cross inspected to ensure that none of the four strops has caught round the end of its cross arm, and that the rubber cord is not caught up in the cross. The towing line/bridle should then be removed completely, but the hoisting lines left attached. The buoy should then be allowed to float clear, holding on to the rubbercord, while the ship heads slowly into wind/current.

If the buoy has been taken out to the site on the deck of the deploying vessel, it should then be lifted over the side on the hoisting line and lowered into the water. If possible the lifting equipment should give enough lift to lift the buoy, complete with the suspended mooring cross, over the rail, so as to avoid the danger of manually lifting the heavy mooring cross over the rail underneath the buoy. The mooring cross strops and rubber cord should then be inspected for snags, the lifting rope detached from the buoy's hoisting harness and the buoy allowed to drift off as described above.

(iii) The mooring anchor is then put over the side and lowered on the main mooring rope. When the anchor reaches the bottom, tension should be kept on the main mooring rope for as long as possible to pull out the ground chain and to dig the anchor in. The bight can then be released. A final inspection of the mooring cross should then be made to ensure that nothing has fouled.

5. Buoy Recovery:-

(i) Due to the dangerously high energy that can be stored in a fully stretched rubber cord, it is important that the buoy is not attached to the ship in any way before the bottom end of the rubber cord has been recovered and attached securely to the ship. This does not apply, of course, if the buoy is being recovered from a drifting state where the connection to the anchor has been severed.

(ii) In order to retrieve the bottom end of the rubber mooring cord, it is first necessary to grapple the rubber cord, well below the mooring cross. This can be achieved by towing a small anchor or grapnel astern and steaming in a circle past the buoy. If the anchor/grapnel is at a depth of between about 2 and 10 metres, this should allow a bight of the rubber cord to be hauled over the stern, but NOT attached permanently to the ship. Note that several grapnels should be available in case they become irretrievably caught in the safety line loops too near the mooring cross for recovery. The ship can then be manoeuvred over the cord until it can all be pulled on board. Great care is necessary to avoid fouling the propellor. The main mooring rope can then be attached to the ship and the rubber cord disconnected.

The use of divers to connect a line from the ship to the bottom termination of the rubber cord should be considered as a possible alternative to the above technique.

(iii) If the whole mooring is to be recovered, the main mooring rope can then be used to haul in the anchor. Alternatively, if the buoy is to be replaced with a back-up buoy, the back-up buoy's rubber cord can then be attached to the main mooring rope, the back-up buoy put in the water, floated off as in 4(ii), above, and the bight released. Note, however, that at the routine six month replacement intervals, the <u>whole</u> mooring is to be replaced in any case. Separate voyages will probably be necessary for the recovery and for the deployment, unless a large ship is used.

(iv) In order to attach a towing line or bridle to the buoy's hoisting eye(s), it is necessary for one person to board the buoy. This is not very satisfactory owing to the absence of any hand holds. It may be possible to devise a modification of the hoisting line harness so that one side of the harness can be unclipped to form a towing bridle which can then be attached to a towing line. Alternatively, the buoy can be lifted on board the recovery vessel, if weather permits.

(v) The complete mooring, when recovered, should be retained for inspection. The position at which the buoy is recovered should be logged.

ANNEX P

General Considerations

1. Loss of Data

(i) A break in service is usually detected first at the receiving station. In this case, IOS will be informed by their on-site agent and will decide whether the fault is at the shore station or inherent in the received signal.

(ii) If the received signal is faulty then IOS shall report the break in service to the Contractor. The Contractor shall, at the earliest opportunity, investigate the cause of signal loss, at the buoy site.

(iii) In the event of buoy loss or fault, the installation shall be renewed or repaired within not more than one month of the date of notification of the break in service by IOS.

(iv) If signal loss is caused by severe interference, and it is shown that other channels allocated for IOS use are free of interference, it may be necessary to change the frequency of operation. In this event, special instructions will be issued to the Contractor. In this case, the buoy shall be changed within one month of IOS notifying the Contractor or of providing an alternative transmitter crystal, whichever is the later. See Annex C.

2. Erroneous Data

(i) In contrast to the Datawell Waverider system, which uses a relatively simple buoy with a single sensor and a straightforward telemetry system, the more complex Wavec system has far more potential sources of faults. Limited experience so far suggests that the reliability of the Wavec system is not as high as that of the Waverider system.

(ii) The suspension of the Wavec accelerometer/pitch-roll sensor is similar to that of the Waverider accelerometer and necessitates the same handling precautions (restrictions on rotation) to prevent twisting of the fine wire ligaments. Such twisting will show up in the spectrally analysed data produced by the Direc receiver which will then show excessive energy levels at the low frequency end of the spectrum. Twisting of the suspension may be caused at sea by the buoy spinning as a result of contact with the side of a ship under way, or as a result of a capsize due to extreme breaking waves or a mooring defect. On being informed by IOS of excessive low frequency energy levels, the Contractor shall replace the buoy within one month. It shall not be re-used until the accelerometer suspension has been inspected for damage and necessary repairs and recalibration carried out. The above symptoms can also be caused by dampness on the electronics boards in the buoy and the bags of silica gel dessicant should be properly dried according to Annex A3 before deployment.

(iii) The buoy heading is sensed by a three-component flux gate sensor. The three field components are processed by the Direc to give the absolute value of the Earth's magnetic field and the stability of this value is continuously checked. Excessive fluctuations are flagged, indicating probable malfunction of the sensor or possible presence of magnetic materials in close vicinity to the sensor. In such an event, IOS shall notify the Contractor who shall replace the buoy within one month. It shall not be used again until the sensor has been checked and repaired, if necessary, according to Annex D2(v).

(iv) Further checks carried out by the Direc unit on the combined performance of the pitch, roll and heading sensors are: (a) a check on excessive rate of change of the computed buoy heading (more than 15°/second), and (b) a check on fluctuations of the computed inclination of the Earth's field to the horizontal. In the event of these checks indicating a fault with the one or both of the above sensors, IOS shall notify the Contractor who shall replace the buoy within one month. It shall not be used again until the sensors have been checked and repaired, if necessary, according to Annex A2.

(v) The buoy battery voltage is monitored and transmitted but is not, unfortunately, logged routinely with the processed data that is returned to IOS. IOS will, however, endeavour to check the indicated battery state when making service visits to the receiving station. It is the responsibility of the Contractor to ensure that the battery supply on deployment is adequate for the interval before the next scheduled service visit to the buoy (see Annex A3).

(vi) It should be emphasised that the success of the programme as a whole depends largely on the alacrity with which a functioning system is re-established in the event of failure or loss. IOS reserve the right to instruct the Contractor to replace the buoy at any time should this (in IOS's opinion) be necessary (see Appendix A clause 9(c) for conditions of payment in the event of loss or malfunction).

APPENDIX B

Modification of WAVEC to transmit heave acceleration

The WAVEC transmitted format is not amenable to the addition of channels so it was necessary to substitute acceleration for the battery voltage in channel 7. The 'active' signals are all passed through 7th order low pass active filters having the transfer function

$$|T(f)| = \frac{1}{\sqrt{1 + (f/0.6)^{14}}}$$

These "anti-alias" filters are required to prevent signal components having frequencies, f, above the Nyquist frequency (½ the sampling frequency of 1.28 Hz) from being aliased or folded back into the spectral estimates in the range 0-0.64 Hz. The filters must all be matched accurately, both in gain and in phase, so that the directional data, obtained as a result of taking co- and quadrature-spectra of the heave and slopes, are not affected. In adding a further 'active' signal, it was necessary to include an additional matched filter, since no filter was included as standard in the 'static' battery voltage channel.

The additional filter was made virtually identical to the existing filters, but with an additional input buffer amplifier since it was necessary to abstract the acceleration signal from a relatively high impedance point in the circuit prior to the double integrators (Junction of R72, R146, R174, R231 and C65, Datawell drg. no. 19-2-1-16/10).

The filter was made on a small printed circuit board which could be mounted adjacent to the existing active filter board in the WAVEC.

It was necessary to test the response of the filter and adjust it in accordance with recommended procedure communicated by Datawell. Since IOS did not have any suitable equipment for the accurate measurement of transfer function at frequencies in the range 0 to 1 Hz, a program was written for the Acorn BBC microcomputer which allowed logging of the filter input and output waveforms, using a standard low frequency sinusoidal signal generator as source. The program derived the amplitude transfer ratio by averaging pk-pk voltage readings and the phase shift by averaged corrected zero-crossing timings.

After testing to the recommended specifications the circuit was installed and the signals rerouted as appropriate. The existing channel filter responses were tested by the same method to ensure compatibility.

APPENDIX C

Design of the receiver interface hardware/software

The interface was required to accept data from the Datawell receiver (DIREC pcb F) and to convert it to analogue signals compatible with the EMI Wave Processor and Control Processor.

The Datawell receiver output consisted of a single data line, which was connected via multiplexors to the 12 data bits of a data word store and to 4 status bits in a separate store. The data bits could be selected by means of four address lines (inputs to the receiver board). The existence of a data word was signalled by the receiver producing an interrupt. The interrupts occur at intervals of approximately 79 mS. The interface between the receiver and the COSMAC processor is accomplished using a hard wired logic design referred to as the COSMAC "FORMAT" board (Figure 10). When the INTREQ line from the DIREC pcb F goes low, the latch controlling the IC3 reset is itself reset, enabling the counter IC3. This then counts clock cycles from the (nominally) 106 kHz astable clock source. When the IC3 count reaches 32, its Q6 output causes the latch to be set, inhibiting further counts. IC3 outputs Q2 to Q5 are used to address the DIREC pcb F data word multiplexor and the 16 bit addressable latch formed of IC5 and IC6 plus the three NAND gates (IC4) controlling the write disable lines. The DIREC 12 bit data word + 4 bit status word is, thereby, transferred to IC5 and IC6. The 12 data word bits from IC5 (Q4-Q7) and IC6 (Q0-Q7) are then combined with a three bit channel count from IC8 (reset by the $\overline{\text{sync}}$ status bit from IC5 (Q0) and counting the interrupts as received) and with a single "bit sync" status bit from IC5 (Q1) to form two output bytes at PLB and PLC.

The interrupt request from the DIREC pcb F is reset by a $\overline{\text{INTGNT}}$ output which pulses low at the end of the data transfer.

A strobe to signal the readiness of the two output bytes is also generated for data words 1 to 7 inclusive, i.e. for heave displacement, Hx, Hy, Hz, p, r and heave acceleration channels.

The FORMAT board also includes a latch (part of IC2) which is set by the EMI (end of scan) SYNC pulse and reset by the $\overline{\text{LDAC}}$ line going low. The latch

Figure 8

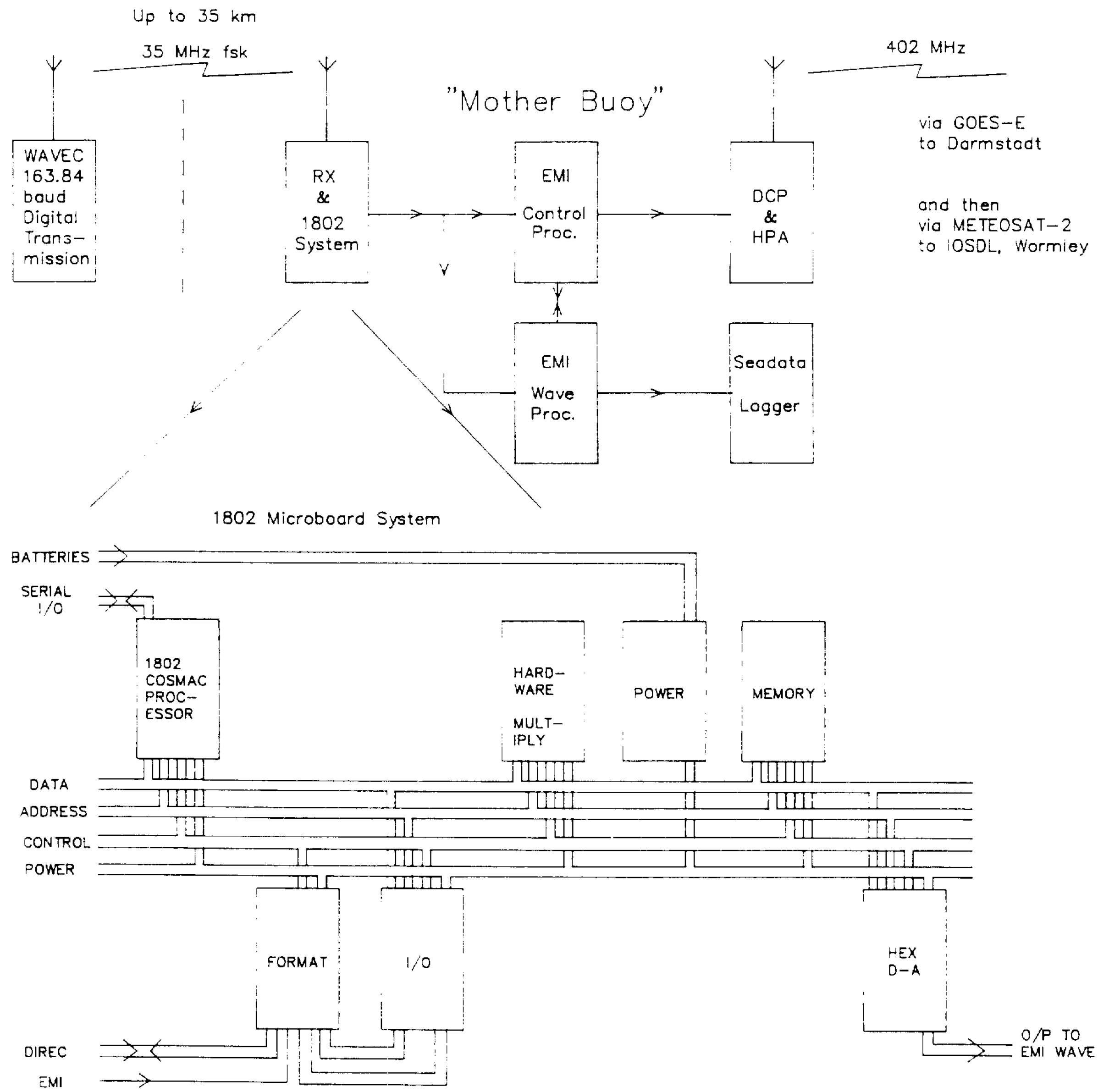

Up to 35 km
35 MHz fsk
402 MHz
"Mother Buoy"
via GOES-E
to Darmstadt
and then
via METEOSAT-2
to IOSDL, Wormley
WAVEC
163.84
baud
Digital
Trans-
mission
RX
&
1802
System
EMI
Control
Proc.
DCP
&
HPA
EMI
Wave
Proc.
Seadata
Logger
1802 Microboard System
BATTERIES
SERIAL
I/O
1802
COSMAC
PROC-
ESSOR
HARD-
WARE
MULT-
IPLY
POWER
MEMORY
DATA
ADDRESS
CONTROL
POWER
FORMAT
I/O
HEX
D-A
DIREC
EMI
O/P TO
EMI WAVE

Figure 9

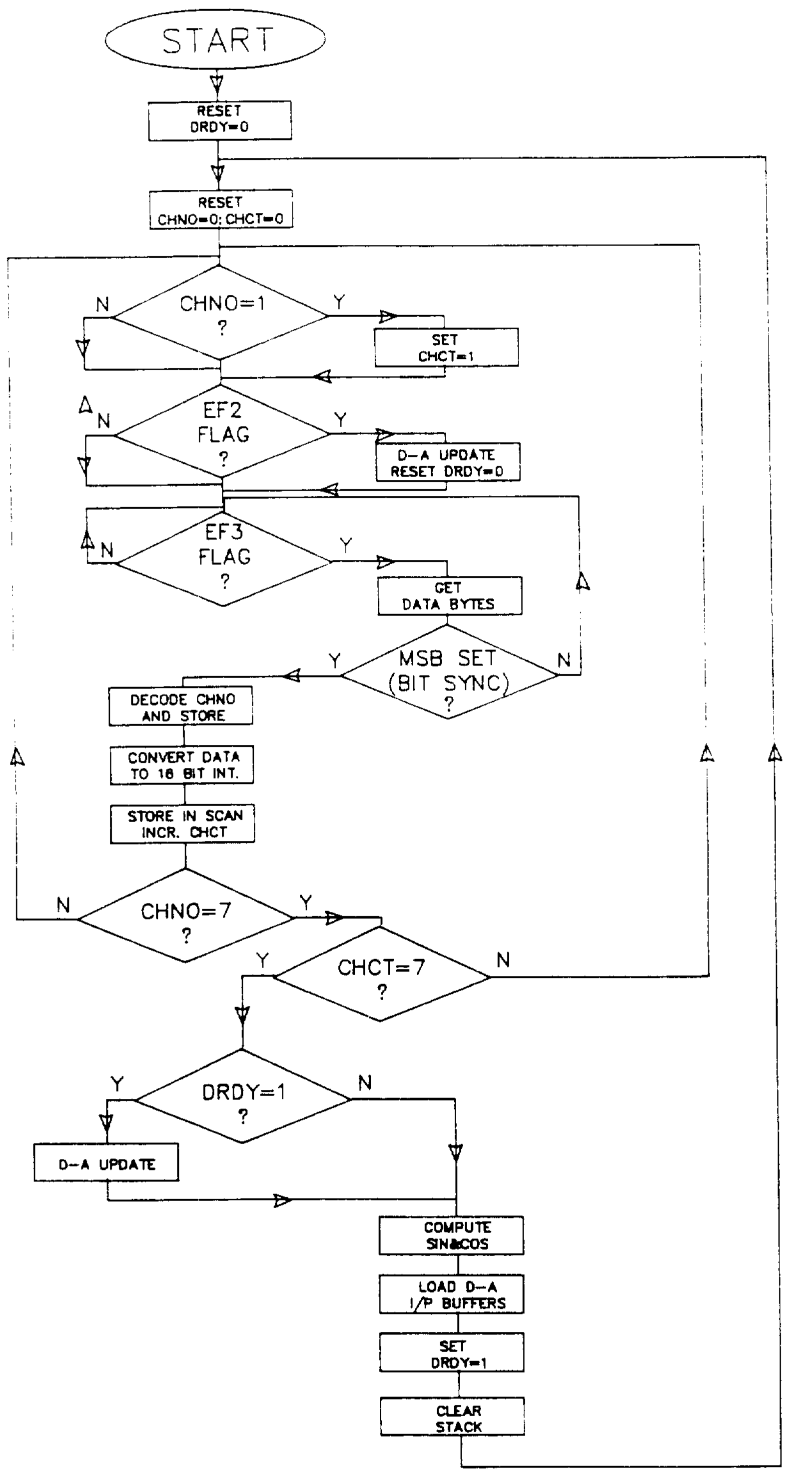
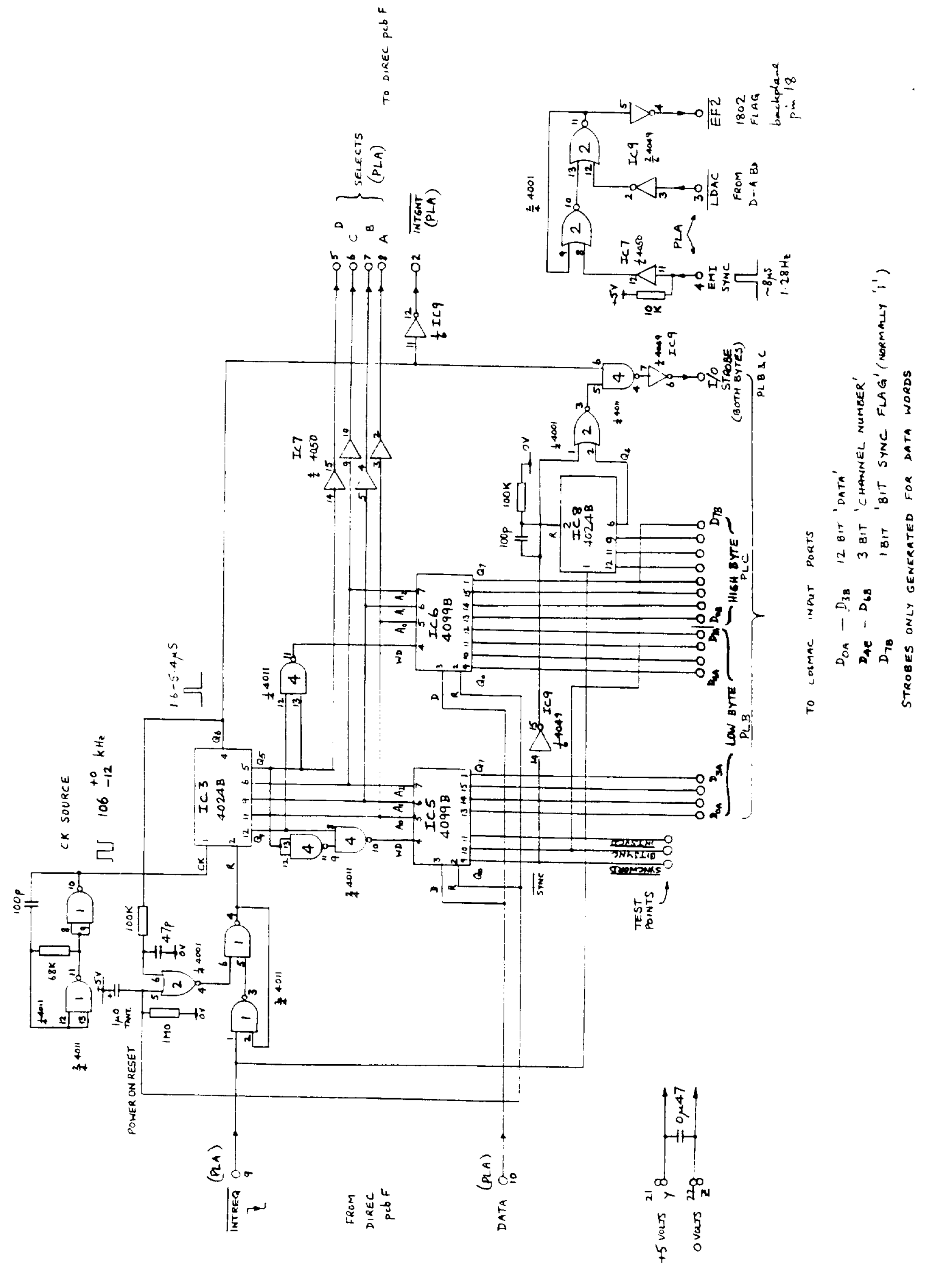

START
RESET
DRDY=0
RESET
CHNO=0: CHCT=0
CHNO=1
?
SET
CHCT=1
EF2
FLAG
?
D-A UPDATE
RESET DRDY=0
EF3
FLAG
?
GET
DATA BYTES
MSB SET
(BIT SYNC)
?
DECODE CHNO
AND STORE
CONVERT DATA
TO 16 BIT INT.
STORE IN SCAN
INCR. CHCT
CHNO=7
?
CHCT=7
?
DRDY=1
?
D-A UPDATE
COMPUTE
SIN&COS
LOAD D-A
I/P BUFFERS
SET
DRDY=1
CLEAR
STACK

Figure 10 Format Board



output sets the COSMAC $\overline{EF2}$ flag low. This flag is tested to determine whether an output update of the analogue outputs to the EMI wave processor should be initiated.

As described above, the two parallel bytes produced are as follows:

High Byte	D7B (msb)	BIT SYNC	(as indicated by DIREC pcb F - normally high)
	D6B)	CHANNEL NUMBER	(range from 0-7 although no
	D5B)		strobe is produced during
	D4B)		count 0)
	D3B)		
	D2B)	4 higher bits of 12 bit data word	
	D1B)		
	D0B (lsb))		
Low Byte	D7A (msb))		
	D6A)		
	D5A)		
	D4A)	8 lower bits of 12 bit data word	
	D3A)		
	D2A)		
	D1A)		
	D0A (lsb))		

The two bytes and strobe are connected to the two byte-wide input ports of the COSMAC I/O board (ref.*); when these are loaded the COSMAC $\overline{EF3}$ flag is set low. The Interface Processor block diagram is shown in Figure 8.

The software for the COSMAC processor was written in FORTH, using an MPE FORTH development system running on an IBM PC; its operation is described by a flow chart (Figure 9) and listing (Appendix R(a)). It includes a loop which tests for the $\overline{EF3}$ flag being low and, if so, reads in the two bytes. If bit D7B (BIT SYNC) is low, indicating loss of bit synchronisation in the receiver the processor continues in the loop testing $\overline{EF3}$. If BIT SYNC is high (good data), the bits D4B to D6B are extracted and stored in the variable CHNO (channel number). The 12 data word bits D0A to D7A and D0B to D3B are then converted to FORTH integer format and the zero offset of 2048 is subtracted. The signed decimal data is then stored in the array SCAN at location SCAN+2*(CHNO-1) (2 bytes required per single precision integer). The variable CHCT is then incremented; this variable which is set to 1 when channel number 1 is detected, thereafter counts the number of data words acquired. When the detected channel number CHNO reaches 7 and the channel count CHCT is also 7, a complete data scan has been acquired and the processor terminates the acquisition loop to begin processing/output of the data. If the CHNO and CHCT do not coincide, when CHNO = 7, there has been some error in acquisition and the processor continues with acquisition until this match is achieved.

In the processing/output cycle, the flag DRDY is first checked. This flag is set to '1' when data has been processed and output to the six D-A convertor <u>input</u> buffers. It is reset and the D-A output buffers are updated when a test of $\overline{EF2}$ shows that the EMI wave processor has finished its scan of the analogue inputs. If the processing/output cycle starts with DRDY set to 1 (i.e. data has been output to the D-A input buffers and new data is available for processing but the D-A output buffers have not yet been updated) the D-A output buffers are updated, setting the six analogue outputs to the new processed data values. The processing of the newly acquired (unprocessed) data then begins.

The processing of the Hx, Hy, Hz, p and r data, which are stored in the array at SCAN+2, SCAN+4, SCAN+6, SCAN+8 and SCAN+10, respectively (note, two bytes per variable), can be summarised by the following relations:

$$\sin\psi = \left[Hy + r'Hz + r'\,\frac{(p'Hx - r'Hy)}{1+\sqrt{1-p'^2-r'^2}}\right]/Hh$$

$$\cos\psi = \left[Hx - p'Hz - p'\,\frac{(p'Hx - r'Hy)}{1+\sqrt{1-p'^2-r'^2}}\right]/Hh$$

where ψ = buoy azimuth (heading) relative to magnetic North,

Hx, Hy, Hz are signed magnetometer readings, as stored in SCAN array,

p', r' are signed sin (pitch) and sin (roll), from p, r as stored in the SCAN array and then divided by 2000,

$Hh = \sqrt{Hx^2 + Hy^2 + Hz^2 - (p'Hx - r'Hy + Hz\sqrt{1 - p'^2 - r'^2})^2}$

In carrying out the above operations, it was necessary to maintain suitable scaling of the variables, since only a limited set of 16 bit/32 bit integer arithmetic operations are available in the FORTH kernel. It was necessary to minimise the execution time so that data could be processed and passed to the D-A input buffers in the interval between acquisition of data word 7 (heave acceleration) of one scan and data word 1 (heave displacement) of the succeeding scan; this interval is 305mS in length. The processing is accomplished by the FORTH words ENTER COMPUTE OUTPUT; the definitions of these words, and of the main control program word START, are given in the screen file listing (NUCLMOD.SCR Screens 93 to 96).

The word ENTER is used to set up the variables in the stack in a suitable order, this being (from the bottom upwards) 2000*Hx, p, Hz, p, 2000*Hy, Hz, r, r, Hx, Hy, Hz, p, r (top of stack). The word COMPUTE then executes PRANG. PRANG computes $\sqrt{4000000 - p^2 - r^2}$ (16 bit integer format) which is placed on top of the existing stack. Double precision arithmetic with a 32 bit → 16 bit square root word ROOT is used for this.

The word TRANS is then executed; this stores the result of PRANG in the variable ANGLE and computes Hz*ANGLE/2000, which is transferred below p, r at the top of the stack.

The word TRANS1 is then executed; this computes r*Hz/2000 and p*Hx/2000 which then occupy the top two positions of the stack above Hz*ANGLE/2000.

The word TRANS2 is then executed; this stores (p*Hx - r*Hy)/2000 in the variable HORIZ and (HORIZ + Hz*ANGLE/2000) in the variable HV (vertical field strength). It then computes the 32 bit result $Hx^2 + Hy^2 + Hz^2$).

The word TRANS3 is then executed; this stores the above 32 bit result in the double precision variable HABS2 (the square of the absolute field strength) and computes HABS2 - HV^2 in 32 bit form. It then computes the square root of this and stores it as the 16 bit variable HH (horizontal field strength). The stack then contains only the lowest eight of the original variables entered by ENTER.

The word TRANS4 is then executed; this loads HORIZ, 2000, 2000, ANGLE on to the stack and computes the 16 bit result HORIZ*2000/(2000+ANGLE) i.e. $(p'{*}Hx-r'{*}Hy)/(1+\sqrt{1-p'^2-r'^2})$ where p' = p/2000 and r' = r/2000. p' and r' are the true (normalised) values of sin (pitch) and sin (roll).

The word TRANS5 is then executed; this merely stores the result of TRANS4 in the variable HORN.

The word TRANS6 is then executed; this loads Hz, r, 2000, Hy on to the stack and manipulates the stack so as to compute the 32 bit result 2000*Hy+r*Hz+r*HORN.

The word TRANS7 is then executed; this loads HH and divides it into the 32 bit result of TRANS6 giving the result

$$\frac{2000 * [Hy + r'{*}Hz + \frac{r' * (p'{*}Hx - r'{*}Hy)}{1 + \sqrt{1 - p'r^2 - r'^2}}]}{\sqrt{Hx^2 + Hy^2 + Hz^2 + (p'{*}Hx - r'{*}Hy + Hz\sqrt{1 - p'^2 - r'^2})^2}}$$

This is equal to 2000 * $\sin\psi$ and it is stored in the variable SIN.

Finally, the word TRANS8 is executed. This loads 2000, Hx and computes 2000*Hx (32 bits). It then loads p, Hz and HORN, with stack manipulation so as to compute p*HORN and p*Hz (both 32 bits). It then sums 2000*Hx - p*Hz - p*HORN, loads HH and divides it into the summation, giving the result

$$\frac{2000 * [Hx - p'Hz - \frac{p' * (p'{*}Hx - r'{*}Hy)}{1 + \sqrt{1 - p'^2 - r'^2}}]}{\sqrt{Hx^2 + Hy^2 + Hz^2 + (p'{*}Hx - r'{*}Hy + Hz\sqrt{1 - p'^2 - r'^2})^2}}$$

This is equal to 2000 * cosψ and it is stored in the variable COS. The stack is then cleared.

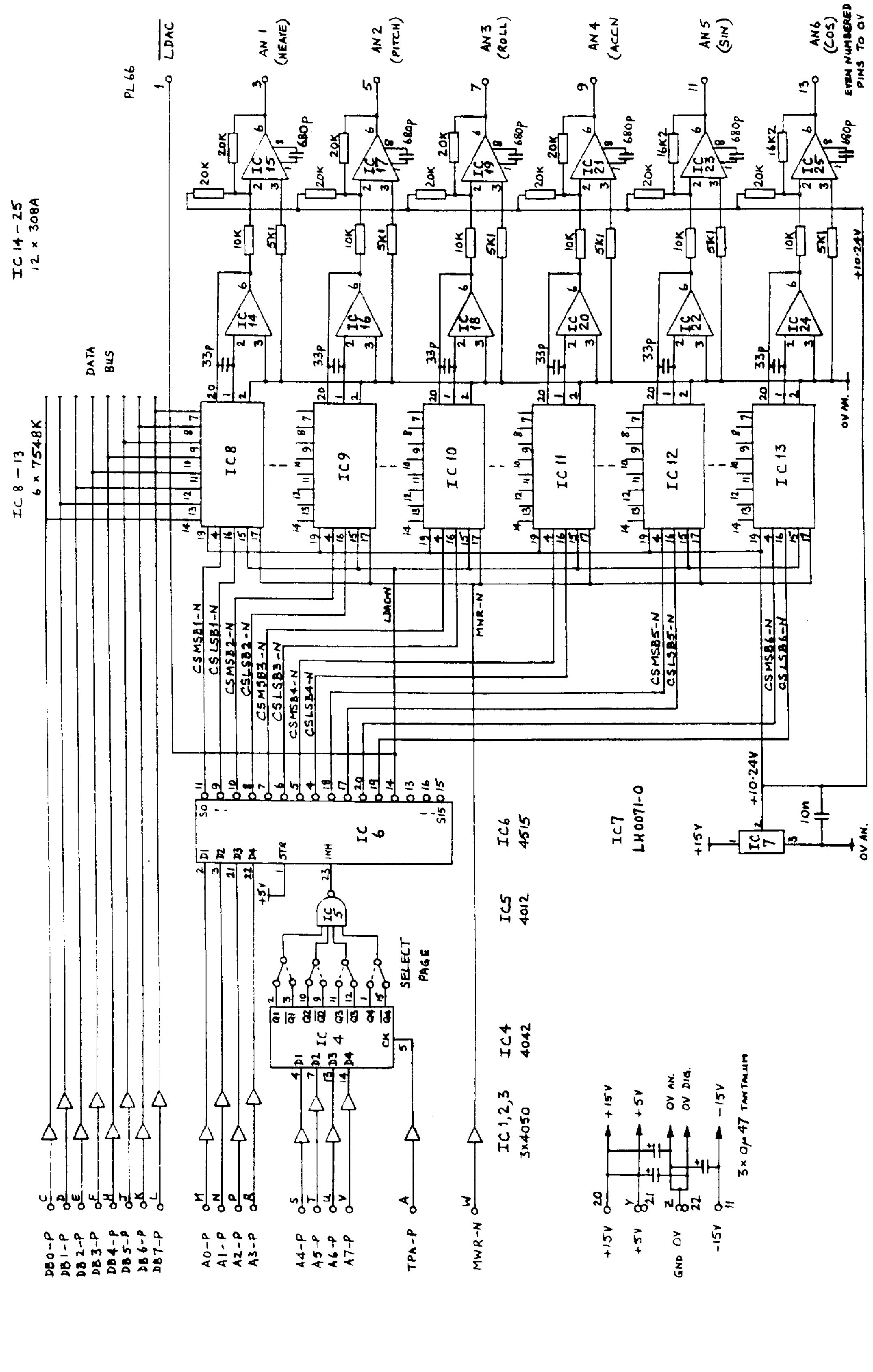
After the above sequence of operations, we have the original data values in the SCAN array and the computed sinψ and cosψ in variables SIN and COS. The required data for conversion to analogue outputs for the EMI wave and control processors is then loaded into the D-A convertor input buffers by executing the word OUTPUT. The six convertors used are 12 bit double buffered devices, type AD7548. Each 12 bit word is loaded as two bytes, using memory addressing of the individual convertors from address BUF0 to BUF0+11. The FORTH ! word for storing to memory writes the 16 bit integer to two successive memory locations, most significant byte first. A six channel D-A convertor board was designed with partial address decoding to operate the appropriate CS lines on the 7548s. The page (4 most significant bits of the address) is latched and decoded by a 4 input NAND gate via DIL selector switches. The least significant four bits of the address are decoded by a 4515 → 16 line decoder which is enabled when the page coincides with the DIL selected number. The decoder outputs 0 and 1 are used to select output channel 1 D-A m.s. byte and l.s. byte, respectively. Decoder outputs 2 → 11 similarly select channels 2 → similarly select channels 2 → 6 D-A m.s./l.s. bytes. The data bytes are loaded by the COSMAC MWR line.

The address for the channel 1 m.s. byte is given by the constant BUF0 which is set to 45056 (B000 hex). The page decoder DIL switches are therefore set to B (1011).

The above memory writing process sequentially loads the six D-A input buffers with heave displacement, p, r, heave acceleration, 2000*sinψ and 2000*cosψ. The D-A output buffers (to which the actual D-A convertor ladder switches are connected) are simultaneously updated by writing to memory location BUF0+12, which results in the 4515 output 12 going low, producing a LDAC operation.

The program development was carried out, using the PC based MPE FORTH development system, by writing the FORTH word definitions to screens of the screenfile WAVEC.SCR and then sending these screens to the 1802 processor which

Figure 11 Hex D-A Board



had the FORTH nucleus in EPROM. The software could then be tested interactively with the PC using simulated inputs to the I/O ports and flags. The FORMAT (DIREC pcb F-COSMAC interface) board was then installed in the COSMAC system and checked using a static WAVEC transmitting data to the DIREC pcb F.

The EMI processor sync was then connected and the system checked overall for timing compatibility. It was discovered, at this stage, that the EMI software controlled 1.28 Hz sampling rate was slightly in error. This required minor modification of the EMI software which was implemented in the form of replacement EPROMs.

The final requirement was to make the software start up automatically upon reset of the processor. This was done by replacing the word QUIT in the ABORT definition of the nucleus by START. The system, when executing a COLD start then executes START (after carrying out the necessary cold start operations, which include outputting the message "1802 fig-FORTH [stand-alone V 1.2]"<CR> to the 1802 serial output (RS232) port). A hardware watchdog timer board was made to reset the 1802, using the $\overline{\text{CLEAR}}$ line. This watchdog was triggered by the $\overline{\text{LDAC}}$ line so that, if the system hung up such that the analogue outputs were not updated for longer than about 4 seconds, the FORTH would be forced to do a cold start. This will happen if the data output from the receiver is missing or seriously faulty. The monitoring of the 1802 serial output, which normally consists of the channel data as received from the WAVEC (channels 1 to 7), clearly shows any such fault by the cold start message "1802 fig-FORTH ...".

When the COSMAC software had been finally verified as being operationally correct, the cross compiler in the MPE FORTH development system was used to produce a compiled version of the FORTH nucleus, plus the newly developed words for this application, in 1802 machine code. This was then transferred to EPROMs which were installed in the COSMAC memory board and the complete system was retested.

It was not considered necessary to carry out error detection/correction by using the 21 bits of parity check in the 106.21 BCH code, since the radio range would be less than a mile. Such error correction would have complicated the software considerably since no interval in the scan of duration more than 13 cycles of the 163.84 baud data rate (i.e. 79mS) would have existed for uninterrupted processing. A double input buffer with entry by DMA, rather than via input ports, would probably have been necessary. A hardware multiplier board was used to increase the speed of processing, with the standard FORTH words for the various multiplication and division operations being redefined to use the hardware multiplier. The other board required for the COSMAC system was a power supply board to provide the regulated +5V logic and ±15V analogue supplies. The -12V required by the DIREC pcb F receiver board was derived on the board from the -15V supply.

The total board complement and interconnection configuration of the COSMAC system is shown in Figure 8. The circuits of the specially developed COSMAC boards are shown in Figures 10-11.

The system is powered by two battery packs: these are the I5 supply (nominally 7.2V) and the I15 supply (nominally 14.4V). These supply the regulator for the +5V logic supply and the DC/DC convertor for the ±15V supplies, respectively. The mean current drains, including the DIREC pcb F amount to approximately 77mA and 120mA, respectively. The interface is powered continuously.

APPENDIX D

Processed Wave Data Cassette Format

Each record on the tape is in 16 bit (4 hexadecimal character) format, with the exception of the header. Each set of analysed data requires four records (each of 480 character length). The first record of the four has a 72 character header, made up as follows:-

Record 1	characters 1 to 3	F00	
	character 4	1	(record number)
	characters 5, 6	30	(identity number)
	characters 7, 8	HH	(hour of processing, in hex, e.g. 02, 05, 08, 0B, 0E, 11, 14, 17)
	characters 9, 10	DD	(day of month in hex)
	characters 11, 12	MM	(month of year in hex)
	characters 13, 14	YY	(year in hex, e.g. 57 = (19)87)
	characters 15, 16	00	(blank)
	characters 17, 18	0Q6	(zero and quality flag Q6)
	characters 19, 20	0Q7	(" " " " Q7)
	characters 21, 22	0Q8	(" " " " Q8)
	characters 23, 24	0Q9	(" " " " Q9)
	characters 25, 26	0Q10	(" " " " Q10)
	characters 27, 28	0Q11	(" " " " Q11)
	characters 29, 30	0Q12	(" " " " Q12)
	characters 31, 32	0Q13	(" " " " Q13)
	characters 33 to 36	0000	(blank)
	characters 37 to 40	HHHH	(H_s in hex)
	characters 41 to 44	TTTT	(T_z in hex)
	characters 45 to 48	HHHH	(H_{swell})
	characters 49 to 52	TTTT	(T_{swell})
	characters 53 to 56	DDDD	(Θ_{1swell})
	characters 57 to 60	SSSS	(Θ_{2swell})
	characters 61 to 64	HHHH	(H_{wind})
	characters 65 to 68	TTTT	(T_{wind})
	characters 69 to 72	DDDD	(Θ_{1wind})

The H, T, Θ_1 and Θ_2 parameters are in 16 bit binary with the following scaling factors:

Significant wave heights H_s, H_{swell}, H_{wind}
- units of 1/256 metres

Significant periods T_z, T_{swell}, T_{wind}
- units of 1/256 seconds

Directions Θ_{1swell}, Θ_{2swell}, Θ_{2wind}
- units of 1/25.6 degrees.

The remainder of record 1 is taken up by the C_{11} and C_{22} spectra

characters 73 to 276	C_{11} spectrum	(51 values, each of 4 hex characters)
characters 277 to 480	C_{22} spectrum	(51 values, each of 4 characters)

Record 2 has the four character header F002, followed by the C_{33} spectrum (51 values, each of 4 hex characters), the C_{12} spectrum (51 values, each of 4 hex characters) and the first 17 values of the Q_{12} spectrum (17 values, each of 4 hex characters).

Record 3 has the four character header F003, followed by the remaining 34 values of the Q_{12} spectrum (34 values, each of 4 hex characters), the C_{13} spectrum (51 values, each of 4 hex characters) and the first 34 values of the Q_{13} spectrum (34 values, each of 4 hex characters).

Record 4 has the four character header F004, followed by the remaining 17 values of the Q_{13} spectrum (16 values, each of 4 characters), the C_{23} spectrum (51 values, each of 4 characters) and the Q_{23} spectrum (51 values, each of 4 characters.

The 51 estimates in each spectrum are for the 48 frequencies 0.00875, 0.01875, 0.02875 ... 0.47875 Hz (averages over groups of 4 non-overlapping estimates from the original spectrum) and for the 3 frequencies 0.50875, 0.55875 and 0.60875 Hz (averages over 20 non overlapping estimates from the original spectrum).

The values are in 16 bit scientific notation. If the logged characters for a particular value are $C_1C_2C_3C_4$, then C_3 is the exponent, the most significant bit of C_4 is the sign ('1' = -ve, '0' = +ve) and the remaining 3 bits of C_4, together with C_1C_2 are the mantissa (11 bits). For example, if the value is A04C hex, the exponent is 4, the sign is -ve and the mantissa is 4A0 hex (1184 decimal). The estimate value is then $-1 \times 2^4 \times 1184$ or -18944 decimal. 1B23 would be $+1 \times 2^2 \times 795$ or +3180 decimal. The scaling of the spectral estimates is as follows:-

C_{11} - units of 9.91 millig^2/Hz
C_{22}, C_{33}, C_{23} and Q_{23} - units of 2.38 millirad^2/Hz
C_{12}, C_{13}, Q_{12} and Q_{13} - units of 4.86 milligmillirad/Hz

APPENDIX E

Meteosat Transmitted Data Format

line 1	BBXX <CRCRLF> (7 characters)
line 2	62030<SP>ddhh4<SP>99540<SP>10010<SP>46///<SP>/WdWs<SP>1+ATt<SP> 290RH<SP>4Pres<SP>5*Ptd<SPCRCRLF> (63 characters)
line 3	22200<SP>0+STt<SP>1ph<SPCRCRLF> (21 characters)
line 4	555<SP>$MHed<SP>q1to5<SP>C5:C1<SP>5:DCP<SP>COM:I<SP>15:RE<SP> C:NAV<SP>W5HPA<SP>I5DC2<SP>OffOn<SPSPSPCRCRLF> (69 characters)
lines 5 to 10	each nnnnn<SP>nnnnn<SP>nnnnn<SP>nnnnn<SP>nnnnn<SP>nnnnn<SP> nnnnn<SP>nnnnn<SP>nnnnn<SP>nnnnn<SP>nnnnn<SPCRCRLF> (6 x 69 characters)
line 11	Sd:Sp<SP>Sh:ph<SP>q6-10<SP>-13//<SP>S1to5<SP>BT///<SP>/////<SP> /////<SP>/////<SP>b-3PD<SP>Wg///<SPCRCRLF> (69 characters)

This comprises a total of 643 characters in the restricted International Alphabet no. 5. These mnemonics have the following significance:

line 1	WMO code for fixed buoy
line 2	62030 is buoy identifier dd is day number (decimal) in the month hh is GMT hour in the day (0-23) 99 is Latitude North code 540 is Latitude in tenths of degrees 10 is Octant 0→45°E 010 is Longitude in tenths of degrees Wd is Wind direction in tenths of degrees Ws is Wind speed in knots (other characters fixed format) + is sign of air temperature (0 zero or plus, 1 minus) ATt is air temperature in tenths of degrees C (N.B. sensor not fitted) RH is relative humidity % (sensor not fitted) Pres is air pressure in mbar (ignoring 1000 digit) *Ptd * = 4 for no change, = 2 for +ve trend, = 7 for -ve trend Ptd = pressure trend in mbar (sensor not fitted)

line 3	+ is sign of sea surface temperature
	STt is sea temperature in tenths of degrees C (sensor not fitted)
	\$p is wave period T_s in seconds
	\$h is wave height H_s in ½ metres e.g. 0 = 0 to 0.25, 1 = 0.25 to 0.75, 2 = 0.75 to 1.25, etc.
line 4	\$M is maximum wave height over last hour in ½ metres (as above)
	Hed is buoy heading in degrees rel. magnetic North
	q1to5 is quality flags Q1-Q5
	C5 is C5 battery voltage (control processor)
	C15 is CW15 battery voltage (control and wave processors)
	DCP is DCP (12V supply) Primary Battery voltage
	COM is compass battery voltage
	I15 is I15 battery voltage (COSMAC interface)
	REC is Sea Data motor drive battery voltage
	NAV is navigational light battery voltage
	W5 is W5 battery voltage (wave processor)
	HPA is ½ x sum of DCP (12V supply) secondary battery voltage and HPA (24V supply) primary battery voltage)
	I5 is I5 battery voltage (COSMAC interface)
	DC2 is DCP (12V supply) secondary battery voltage
	Off is DCP (12V) secondary battery voltage off load
	On is DCP (12V) secondary battery voltage on load
	Note that all voltages are in tenths of a volt in decimal form, e.g. 72 = 7.2 volts, except for "On" which is in hex, e.g. 7D = 12.5 volts.
lines 5 to 10	If the spaces, carriage returns (CR) and line feeds (LF) are removed, these lines contain spectral data in similar format to the processed wave data cassette. A "/" denotes the end of a spectrum. The spectra are transmitted as follows

3N(+T) hours	C_{11} followed by C_{22}
3N+1(+T) hours	C_{33} followed by Q_{12}
3N+2(+T) hours	Q_{13} followed by C_{23}

where N = 0, 1, ... 7 and T is time-slot in minutes. Note that the estimates are for 41 frequencies from 0.04875 Hz in steps of 0.01 Hz to 0.44875 Hz. They are decoded as in Appendix D.

line 11 Sd is swell direction Θ_{1swell} in tens of degrees rel. magnetic North

Sp is swell period T_{swell} in seconds

Sh is swell height H_{swell} in ½ metres (as above)

p is wind wave period T_{wind} in seconds

h is wind wave height H_{wind} in ½ metres (as above)

q6-10 is quality flags Q6 to Q10

-13 is quality flags Q11 to Q13

BT is board temperature

b-3 is jitter flags B1 to B3

PD is nav. light battery voltage drop on load

Wg is maximum wind gust in last hour in knots

Other parameters have no significance (sensors not fitted).

APPENDIX F

Control Processor Time Setting and Monitoring

1. Time Setting/Monitoring

The pocket VDU is set for 300 baud operation (DIL switches 1-10 set 1000110100) and connected to either the external (Electro) connector on the module lid or to the internal plug 15 on the chassis. The VDU is then set to duplex mode by keying CNTL LINE.

Key in Tdd<SP>MM<SP>yy<SP>hh<SP>mm<CR>

where dd is day number in the month (0-31)

MM is the month in the year (1-12)

yy is the year (omitting 19) e.g. 87

hh is the hour in the day (0-23)

mm is the minute in the hour (0-59)

To check the time, at any time, key in T<SP> or T<CR>. The time will then be displayed in the above format (omitting the T if T<CR> is used.

2. Monitoring of Analogue Channels/Battery Voltages

Key in chN, where ch is the channel number as given below, result M is displayed (decimal).

Parameter	ch. no.	Nominal Conversion Factor	to units of
zero offset	80	5(M-2047)	mV error
board temp.	81	(M-2047)/2	°C
sea temp.	83	M/41-35	°C
air pressure	84	M/6.83+600	mbar
air temp.	85	M/41-35	°C
humidity	86	M/17-82	%RH
wind dirn.	87	7M/40-360	°arc
wind speed	88	M/14-146	kt
compass cosψ	8A	} $\psi = \tan^{-1}\left(\frac{M(8B)-2047}{M(8A)-2047}\right)$	
compass sinψ	8B		°arc
heave displ.	8D	M/102.5-20	metres

Parameter	ch. no.	Nominal Conversion Factor	to units of
(DCP+HPA) secondary batteries voltage	8F	M/51.2-40	volts
C5 battery voltage	95	M/205-10	volts
CW15 " "	96	M/102.5-20	"
DCP primary "	97	M/51.2-40	"
compass "	98	M/102.5-20	"
I15 "	99	M/102.5-20	"
recorder "	9A	M/102.5-20	"
nav. light "	9B	M/102.5-20	"
W5 "	9C	M/205-10	"
I5 "	9D	M/205-10	"
DCP secondary & HPA primary "	9E	M/51.2-40	"
DCP secondary "	9F	M/102.5-20	"

Key in R for repeat readings of the same channel.

3. Monitoring of Control Processor Data Bases

Key in adr1,adr2M(<CR>) where adr1 is 4 hex character address of start of data, adr2 is 4 hex character address of end of data. <CR> may be needed if data occupies more than 2 lines on the pocket VDU.

The VDU displays ASCII character codes on the left of each line and the actual characters on the right (if printable - replaced by a dot if not printable). N.B. l.s. byte displayed before m.s. byte.

(a) Wave data (transferred from Wave Processor)

	address range
C_{11} (51 x 4 hex char. values)	89E0 to 8A31
C_{22} "	8A32 to 8A83
C_{33} "	8A84 to 8AD5
Q_{12} "	8AD6 to 8B27
Q_{13} "	8B28 to 8B79
C_{23} "	8B7A to 8BCB

(b) "Met. and Housekeeping Data"

	address range
compass sinψ	8EEB to 8EEC
compass cosψ	8EED to 8EEE
compass angle ψ	8C42 to 8C43
DCP secondary battery off load	89D4 to 89D5
" " " on load	89D6 to 89D7
nav. light battery drop on load	89B6 to 89B7
Q flags	89A5
S flags	89A0
B flags	8BCC
maximum wave height	89B2
running mean wind speed	8C06 to 8C0B
instantaneous wind speed	8CC6 to 8CC7
maximum wind gust	8CCA
wind average x 75	8CC4 to 8CC5
wind average final value	8975 to 8976
wind direction sensor	8CC2 to 8CC3
wind direction (referenced)	8977 to 8978
battery voltage C5	89BC to 89BD
" " CW15	89BE to 89BF
" " DCP pri.	89C0 to 89C1
" " compass	89C2 to 89C3
" " I15	89C4 to 89C5
" " recorder	89C6 to 89C7
" " nav. light	89C8 to 89C9
" " W5	89CA to 89CB

"	"	I5	89CC to 89CD
"	"	HPA1+DCP2	89CE to 89CF
"	"	DCP sec.	89D0 to 89D1

(c) Meteosat Data Base (in scientific/engineering units)

day, hour	909D to 90A0
board temp.	92EC to 92ED
air temp.	90BB to 90BF
sea temp.	90DC to 90E1
air pressure	90C6 to 90CB
pressure trend	90CC to 90D1
humidity	90C0 to 90C5
wind direction	90B6 to 90B7
wind speed	90B8 to 90B9
wind gust	930A to 930B
buoy heading	90F1 to 90F3
max. wave	90EF to 90F0
wave period	90E3 to 90E4
wave height	90E5 to 90E7
swell direction	92CE to 92CF
swell period	92D1 to 92D3
swell height	92D3 to 92D5
wind w. period	92D7 to 92D7
wind w. height	92D7 to 92D9
C5 voltage	90FB to 90FC
CW15 voltage	90FE to 9101
DCP primary voltage	9103 to 9105
compass voltage	9107 to 9109
I15 voltage	910B to 910E
recorder voltage	9110 to 9113
nav. light voltage	9115 to 9117
nav. volt drop	9307 to 9308
W5 voltage	9118 to 911A
DCP sec. + HPA pri. voltage	911B to 911D
IR voltage	911E to 9120
DCP secondary voltage	9121 to 9123

DCP sec. off load	9124 to 9127
DCP sec. on load	9128 to 9129
Q1 - Q5	90F4 to 90F9
Q6 - Q10	92D8 to 92DE
Q11 - Q13	92DF to 92E4
S1 - S5	92E5 to 92EA
B1 - B3	9303 to 9308

(d) ARGOS Data Base

Since data was not transmitted via ARGOS, the ARGOS PTT being used purely for location purposes, the data base has not been checked and no details will be given here.

APPENDIX G

Wave Processor and Interface (COSMAC) Processor Monitoring

1. Wave processor monitoring

The pocket VDU is set for 300 baud operation (DIL switches 1-10 set 1000110100) and connected to either the external (Electro) connector on the module or to the internal plug 5 on the chassis. The VDU is then set into duplex mode by keying CNTL LINE.

Key in ch N, where ch is the channel number as given below, result M is displayed (decimal).

Parameter	ch. no.	Nominal Conversion Factor	to units of
$\cos\psi$	8A	$\psi = \tan^{-1}\left(\frac{M(8B)-2047}{M(8A)-2047}\right)$	°arc
$\sin\psi$	8B		
heave accn.	8D	M/102.5-20	$metre/sec^2$
roll	8E	approx. M/36-57	°roll
pitch	8F	approx. M/36-57	°pitch

2. Interface processor monitoring

The pocket VDU is set for 2400 baud operation (DIL switches 1-10 set 1010011100) and connected to either the external (Electro) connector on the module or to the internal Molex connector on the interface processor card. The VDU is then set into duplex mode by keying CNTL LINE.

The VDU will then display continuously scans of the following data from the COSMAC processor.

Heavedispl<SP>Hx<SP>Hy<SP>Hz<SP>pitch<SP>roll<SP>Heaveaccn<CRLF>

It is not possible to examine the data in real time due to the rapidly changing LCD display. To examine the data, key CNTL EDIT to put the VDU offline and then use the SCROLL keys to examine the previously acquired data.

Appendix H

The following information is included, although it is tedious and routine, in order that this report can form the basis for a reference manual on the system.

Processor Module Terminal Block - Plug/Socket Connections

TB No.	SK/PL	Wire Colour	Function
A			Power Supplies and Monitoring
B			Meteosat, Argos and Digital Control
C			Wave and Met. Sensors

A1a	SK8D	YW/GN	C5 Monitor
A1b	SK8R	YW/GN	C5+ (to regulator)
A1e	PL14/1	YW/GN	C5+ (from battery)
A2a	SK8L	YW/RD	W5 Monitor
A2b	SK1A	YW/RD	W5+ (to regulator)
A2e	PL104/3	YW/RD	W5+ (from battery)
A3a	SK8M	YW/RD	I5 Monitor
A3b	SK60/7,8	YW/RD	I5+ (to regulator)
A3e	PL104/1	YW/RD	I5+ (from battery)
A4b	SK8T	WH/GN	C5- (to regulator)
A4c	A5c	WH/GN	Commoning Link
A4e	PL114/2	WH/GN	C5- (from battery)
A5a	A6a	WH/GN	Commoning Link
A5b	SK1C	WH/RD	W5- (to regulator)
A5e	PL104/4	WH/RD	W5- (from battery)
A6b	SK60/1,2	WH/BK	I5- (to regulator)
A6c	A13a	WH/BK	Commoning Link
A6d	SK60/15,16	WH/BK	Regulator Inhibit
A6e	PL104/2	WH/BK	I5- (from battery)
A7a	SK8E	OR/BN	CW15 Monitor
A7c	via 10k to A8c		
A8b	SK8S	OR/BN	CW15+ (to regulator)
A8e	PL105/1	OR/BN	CW15+ (from battery)
A9a	SK8G	OR/BLU	COMP monitor
A9c	VIA 10K TO A10C		
A10b	SK8W	OR/BLU	COMP+ (to contr.sw.)
A10e	PL114/3	OR/BLU	COMP+ (from battery)

A11a	SK8H	OR/BK	I15 Monitor
A11c	via 10k to A12c		
A12b	SK60/5,6	OR/BK	I15+ (to regulator)
A12e	PL105/3	OR/BK	I15+ (from battery)
A13b	SK8C	WH/BN	CW15- (to regulator)
A13c	A14c	WH/BN	Commoning Link
A13e	PL105/2	WH/BN	CW15- (from battery)
A14a	A15a	WH/BLU	Commoning Link
A14b	SK8X	WH/BLU	COMP- (to contr.sw.)
A14e	PL114/4	WH/BLU	COMP- (from battery)
A15b	SK60/3,4	WH/BK	I15- (to regulator)
A15c	A31b***	WH/BK	Commoning Link
A15e	PL105/4	WH/BK	I15- (from battery)
A16a	SK8F	OR/GN	DCP Monitor
A16c	via 30k to A17c		
A17b	SK8U	OR/GN	DCP+ (to regulator)
A17e	PL106A/1	OR/GN	DCP+ (from battery)
A18b	SK8V	GY/GN	DCP- (to regulator)
A18e	PL106A/2	GY/GN	DCP- (from battery)
A19a	C7e	GY/GN	DCP 2y Batt. Monitor
A19c	via 10k to A20c		
A20e	PL102/1	GN/OR	DCP 2y Batt. Monitor
A21b	SK10C	GN/OR	DCP 2y+ (from reg.)
A21c	SK10D	GN/OR	DCP 2y+ (from reg.)
A21e	SK101/1	GN/OR	DCP 2y+ (to battery)
A22b	SK10E	WH/OR	DCP 2y- (from reg.)
A22c	SK10F	WH/OR	DCP 2y- (from reg.)
A22e	SK101/2	WH/OR	DCP 2y- (to battery)
A23a	SK8N	OR/RD	HPA Monitor (1y)
A23c	via 30k to A24c		
A24b	SK1F	OR/RD	HPA+ (to regulator)
A24e	PL106B/1	OR/RD	HPA+ (from 1y batt.)
A25b	SK1G	GY/RD	HPA- (to regulator)
A25e	PL106B/2	GY/RD	HPA- (from 1y batt.)
A26a	SK10K	GN/RD	HPA Monitor (2y)
A26c	via 30k to A27c		
A27e	PL102/2	GN/RD	HPA Monitor (2y)
A28b	PL3G	GN/RD	HPA 2y+ (from reg.)
A28c	PL3H	GN/RD	HPA 2y+ (from reg.)
A28e	SK101/3	GN/RD	HPA 2y+ (to batt.)
A29b	PL3J	GN/OR	HPA 2y- (from reg.)
A29c	PL3K	GN/OR	HPA 2y- (from reg.)
A29e	SK101/4	GN/OR	HPA 2y- (to batt.)
A30a	SK8K	BN/BLU	NAV Monitor
A30c	via 5k1 to A31c		
A31e	PL106/1	BN/BLU	NAV+ (from batt.)
A31f	A35f	WH/BK	0V Common
A32e	PL106C/2	WH/BLU	NAV- (from batt.)
A34e	SK8J	RD/BK	RECORDER Monitor
A34f	via 10k to A36f		
A35b		BK	Sea Data Battery-
A35c	SK1L	WH/BK	0V COmmon

A36b	A37a	(link to sw. on)	Sea Data Battery+
A36c	SK1K	RD	Sea Data Supply+
A37a	see A36b		
A37b			Sea Data Battery+
B1b	PL11A	GY/BK	Clock Return (DCP)
B1e	SK103/1	GY/BK	Clock Return
B2b	PL11B	GY/BN	Alert Request
B2c	PL11F	GY/BN	Alert Request
B2e	SK103/2	GY/BN	Alert Req. (to DCP)
B3b	PL11C	GY/RD	Tx On
B3e	SK103/3	GY/RD	Tx On
B4b	PL11G	GY/BLU	Data In (from Proc.)
B4e	SK103/5	GY/BLU	Data In (to DCP)
B5b	PL11J	YW/RD	Data Return
B5e	SK103/6	YW/RD	Data Return (to DCP)
B6b	PL11K	YW/GN	Screen
B6e	SK103/4	YW/GN	Screen
B7b	PL11E	GY/OR	Clock (to Proc.)
B7e	SK103/7	GY/OR	Clock (from DCP)
B8b	SK14A	RD/BK	Clock (to Proc.)
B8e	PL102/3	RD/BK	Clock (from ARGOS)
B9b	SK14N	RD/BLU	Data (from Proc.)
B9e	PL102/4	RD/BLU	Data (to ARGOS)
B10b	SK14C	RD/BN	Enable (to Proc.)
B10e	PL102/5	RD/BN	Enable (from ARGOS)
B11b	SK14D	RD/GN	OV Common
B11e	PL102/6	RD/GN	OV Common
B12b	SK13L	WH/BLU	Wave On
B12e	PL3E	GN/BLU	Wave On
B13b	SK13N	BN/BLU	COMP On (Met.)
B13e	SK10B	BN/BLU	COMP On
B14b	PL3A	GN/BN	EM1 Sync
B14e	SK61/4	GN/BN	EMI Sync
B15b	SK13M	WH/GY	Hippy On
B16b	PL3C	GN/BN	COMP On (Wave)
B17b	SK15A	BK	Cont. Proc. Ser. i/p
B17e	SK112/1	BK	Cont. Proc. Ser. i/p
B18b	SK15C	WH	Cont. Proc. Ser. o/p
B18e	SK112/2	BK	Cont. Proc. Ser. o/p
B19b	SK5A	GY/BK	Wave Proc. Ser. i/p
B19e	SK112/3	BK	Wave Proc. Ser. i/p
B20b	SK5C	RD/BK	Wave Proc. Ser. o/p
B20e	SK112/4	BK	Wave Proc. Ser. o/p
B21b	SK67/4	RD/BN	Int. Proc. Ser. o/p
B21e	SK112/5	BK	Int. Proc. Ser. o/p
B22b	SK15B	BLU	Cont.Proc. OV Common
B22e	SK112/6	BK	OV Common
C1b	PL4E	WH/RD	Heave (to ContProc.)
C1e	SK66/3	WH/RD	Heave (fm Int.Proc.)
C2b	PL4C	WH/BK	Pitch (to WaveProc.)
C2e	SK66/5	WH/BK	Pitch (fm Int.Proc.)

C3b	PL4D	WH/BN	Roll (to WaveProc.
C3e	SK66/7	WH/BN	Roll (fm Int.Proc.
C4b	PL2Z	YW/GN	Sin (to WaveProc.
C4e	SK66/11	YW/GN	Sin (fm Int.Proc.
C5b	PL2Y	YW/RD	Cos (to WaveProc.
C5e	SK66/13	YW/RD	Cos (fm Int.Proc.
C6b	PL4F	WH/BLU	Accn (to WaveProc.
C6e	SK66/9	WH/BLU	Accn (fm Int.Proc.
C7b	SK8P	GY/GN	DCP 2y Monitor
C7e	A19a	GY/GN	DCP 2y Monitor
C8b	PL4G	WH/OR	OV Common
C9b	PL7E	GY/GN	10V Wind Vane
C9e	SK110/1	GY/GN	10V Wind Vane
C10b	PL7F	GY/BLU	OV Wind Vane
C10c	via 220k to C11c		
C10e	SK110/2	GY/BLU	OV Wind Vane
C11b	PL9A	GN/YW	Wind Vane o/p
C11e	SK110/3	GN/YW	Wind Vane o/p
C12b	PL9B	GN/RD	Wind Speed+ (fi
C12c	via 10uF to C13c		
C12f	via 150k to C14f		
C13b	PL9G	GN/BK	Wind Speed-
C13e	SK110/6	GN/BK	Wind Speed-
C14e	SK110/5	GN/BN	Wind Speed+
C15b	PL9C	RD	Compass R
C15c	PL9K	RD	Compass R
C15e	SK109/1	RD	Compass R
C16b	PL9D	GN	Compass G
C16c	PL9L	GN	Compass G
C16e	SK109/2	GN	Compass G
C17b	PL9E	BLU	Compass B
C17c	PL9M	BLU	Compass B
C17e	SK109/3	BLU	Compass B
C18b	PL9F	YW	Compass Y
C18c	PL9N	YW	Compass Y
C18e	SK109/4	YW	Compass Y
C19b	PL9H	WH/RD	Compass +
C19e	SK109/5	WH/RD	Compass
C20b	PL9J	WH/BK	Compass -
C20e	SK109/6	WH/BK	Compass -
C21b	PL7A	GY/BK	Air Temp OV
C21e	SK111/1	GY/BK	Air Temp OV
C22b	PL7B	GY/BN	Air Temp -
C22e	SK111/3	GY/BN	Air Temp -
C23b	PL7C	GY/RD	Air Temp +
C23e	SK111/4	GY/RD	Air Temp +
C24b	PL7D	GY/OR	Air Temp 2mA
C24e	SK111/2	GY/OR	Air Temp 2mA
C25b	PL7G	YW/RD	Hum. Ret.
C25e	SK111/5	YW/RD	Hum. Ret.
C26b	PL7H	YW/GN	AC Out
C26e	SK111/6	YW/GN	AC Out

C27b	SK13A	WH	0V
C27e	SK113/1	BK	0V
C28b	SK13B	WH/BK	Sea Temp -
C28e	SK113/2	BK	Sea Temp -
C29b	SK13C	WH/BN	Sea Temp +
C29e	SK113/3	WH/BN	Sea Temp +
C30b	SK13D	WH/RD	Sea Temp 2mA
C30e	SK113/4	WH/RD	Sea Temp 2mA
C31b	SK13H	OR	+15V
C32b	SK13J	WH/OR	+5V
C33b	SK13E	WH	0V
C34b	SK13F	GY	-15V
C35b	SK13K	WH/GN	Air Pressure
C36a	SK12A	WH/OR	Heave (to ContProc.)
C36b	SK12B	WH/BN	Heave (to ContProc.)
C36c	PL3L	YW/GN	Heave (fm WaveProc.)

Appendix I

Intercabling Details

The following information is included, although it is tedious and routine, in order that this report can form the basis for a reference manual on the system.

Cable 1   C5 and Compass Supplies - Processor Module to Battery Packs

From	To	Function	Length
SK114/1	PL145/1	C5+	1.5 m
SK114/2	PL145/2	C5-	
SK114/3	PL146/1	COMP+	1.5 m
SK114/4	PL146/2	COMP-	

Notes: SK114/1 is B51E4F-1, PL145 and 146 are each B51E2M-1 with 0.5 m tails extended with Metvinsmall 2c. Cable junction is at 0.5 m from SK114. C5 and COMP battery packs have B51E2F-1 connectors with 0.5 m tails glanded into the battery containers.

Cable 2   CW15 and I15 Supplies - Processor Module to Battery Packs

From	To	Function	Length
SK105/1	PL143/1	CW15+	1.5 m
SK105/2	PL143/2	CW15-	
SK105/3	PL144/1	I15+	1.5 m
SK105/4	PL144/2	I15-	

Notes: SK105 is B51E4F-1, PL143 and 144 are each B51E2M-1 with 0.5 m tails extended with Metvinsmall 2c. Cable junction is at 0.5 m from SK105. CW15 and I15 battery packs have B51E2F-1 connectors with 0.5 m tails glanded into the battery containers.

Cable 3   W5/I5 Pack - Processor Module to Battery Packs

From	To	Function	Length
SK104/1	W5+	W5+	1.5 m
SK104/2	W5-	W5-	
SK104/3	I5+	I5+	
SK104/4	I5-	I5-	

Notes: SK104 is B51E4F-1 with 0.5m tail. Tail (extended with Metvinsmall 4c) is glanded into battery container.

Cable 4 DCP Supply - Processor Module to DCP Junction Box

From	To	Function	Length
SK106A/1	DCPJB diode b+	DCP+	2 m
SK106A/2	DCPJB b-	DCP-	

Notes: SK106A is B51E2F-1 with 0.5 m tail. Tail (extended with Metvinsmall 2c) is glanded into DCP Junction Box.

Cable 5 HPA Supply - Processor Module to HPA Junction Box

From	To	Function	Length
SK106B/1	HPAJB diode b+	HPA+	1.5 m
SK106B/2	HPAJB b-	HPA-	

Notes: SK106B is B51E2F-1 with 0.5 m tail. Tail (extended with Metvinsmall 2c) is glanded into DCP Junction Box.

Cable 6 DCP 2y Battery Charging - Processor Module to DCP Module

From	To	Function	Length
PL101/1	SK121/1	DCP2y charge+	1.75 m
PL101/2	SK121/2	DCP2y charge-	
PL101/3	SK121/3	HPA2y charge+	
PL101/4	Sk121/4	HPA2y charge-	

Notes: PL101 is B51E4M-1, SK121 is B51E4F-1. The 0.5m tails are extended with Metvinsmall 4c.

Cable 7 DCP Supply Monitor - Processor Module to DCP Module

From	To	Function	Length
SK102/1	PL123/1	DCP2y+ monitor	1.75 m
SK102/2	PL123/2	DCP2y- monitor	
SK102/3	PL123/3	(ARGOS clock)	
SK102/4	PL123/4	(ARGOS data)	
SK102/5	PL13/5	(ARGOS enable)	
SK102/6	PL123/6	(ARGOS common)	
SK102/7	PL123/7	Spare	
SK102/8	PL123/8	Spare	

Notes: SK102 is B51F8F-1, PL123 is B51F8M-1. The 0.5 m tails are extended with Metvinsmall 12c.

Cable 8 Meteosat Digital Interface - Processor Module to DCP Module

From	To	Function	Length
PL103/1	SK122/1	Met. CLK Return	1.75 m
PL103/2	SK122/2	Met. Alert Reqst	
PL103/3	SK122/3	Met. Tx On	
PL103/4	SK122/4	Met. Screen	
PL103/5	SK122/5	Met. Data In	
PL103/6	SK122/6	Met. Data Return	
PL103/7	SK122/7	Met. CLK	
PL103/8	SK122/8	Spare	

Notes: PL103 is B51F8M-1, SK122 is B51F8F-1. The 0.5 m tails are extended with Metvinsmall 1c.

Cable 9 Navigational Light Supply - Processor Module to Battery Pack

From	To	Function	Length
SK106C/1	NAV Batt+	NAV+	1.5 m
SK106C/2	NAV Batt-	NAV-	
SK106C/1	SK141/1	NAV+	
SK106C/2	SK141/2	NAV-	

Notes: SK106C is B51E2F-1 with 0.5 m tail, SK141 is B51E2F-1 with 0.5 m tail extended with Metvinsmall 2c. Cable junction is 0.5 m from SK106C. Cable from junction to NAV battery container (glanded) is Metvinsmall 2c.

Cable 10 Compass - Processor Module to Mast Junction Box

From	To	Function	Length
PL109/1	SK200/2	Compass R	2.5 m
PL109/2	SK200/1	Compass G	
PL109/3	SK200/3	Compass B	
PL109/4	SK200/4	Compass Y	
PL109/5	SK201/3	Compass +	2.5 m
PL109/6	SK201/4	Compass -	
Screen	SK201/1		

Notes: PL109 is B51F8M-1 with 0.5 m tail extended with Metvinsmall 12c. SK200 and 201 are each B51F4F-1 with 0.5 m tails. Cable junction is 0.5 m from SK200 and 201.

Cable 11 Wind Sensors - Processor Module to Mast Junction Box

From	To	Function	Length
PL110/1	SK202/2	Wind Vane +10V	2.5 m
PL110/2	SK202/1	Wind Vane 0V	
PL110/3	SK202/3	Wind Vane Wiper	
PL110/4	Spare		
PL110/5	SK203/3	Wind Speed+	2.5 m
PL110/6	SK203/4	Wind Speed-	
Screen	SK203/1		

Notes: PL110 is B51F6M-1 with 0.5 m tail extended with Metvinsmall 6c. SK202 and 203 are each B51F4F-1 with 0.5 m tails. Cable junction is 0.5 m from SK202 and 203.

Cable 12 Mast Junction Box to Compass

From	To	Function	Length
SK204/1	SK210/A	Compass G	3 m
SK204/2	SK210/C	Compass R	
SK204/3	SK210/B	Compass B	
SK204/4	SK210/E	Compass Y	
SK205/1	Screen		
SK205/3	SK210/D	Compass +	3 m
SK205/4	SK210/F	Compass -	

Notes: SK204 and 205 are B51F4F-1 with 0.5 m tails. SK210 is RS466-624 fitted with Metvinsmall 6c. Cable junction is 0.5 m from SK204 and 205.

Cable 13 Mast Junction Box to Wind Vane Base

From	To	Function	Length
SK206/1	Yellow	Wind Vane +10V	5 m
SK206/2	Black	Wind Vane 0V	
SK206/3	Violet	Wind Vane Wiper	

Notes: SK206 is Electro B51F4F-1 with 0.5 m tail. Cable to sensor base is 7c as supplied with Wind Vane Mounting Base.

Cable 14 Mast Junction Box to Anemometer

From	To	Function	Length
SK207/1	Screen		
SK207/2	Spare		
SK207/3	Red	Anemometer+	5 m
SK207/4	Black	Anemometer-	

Notes: SK207 is B51F4F-1 with 0.5 m tail. Cable to sensor base is 2c as supplied with Anemometer Mounting Base.

Cable 15 Communications Ports - Processor Module to Pocket VDU

From	To	Function	Length
PL112/1	PL181/2	Control Proc. i/p	2 m
PL112/2	PL181/3	Control Proc. o/p	
PL112/3	PL182/2	Wave Proc. i/p	2 m
PL112/4	PL182/3	Wave Proc. o/p	
PL112/5	PL183/3	Interface Proc. o/p	2 m
PL112/6	PL181/7	Control Proc. OV	
PL112/6	PL182/7	Wave Proc. OV	
PL112/6	PL183/7	Interface Proc. OV	

Notes: PL112 is B51F6M-1 with 0.5 m tail extended with Metvinsmall 6c. The Metvinsmall cores are split out to PL181-3 (not waterproofed).

Cable 16 Navigational Light - Cable 9/SK141 to Nav. Light

From	To	Function	Length
PL141/1	SK191/1	NAV+	5.5 m
PL141/2	SK191/2	NAV-	

Notes: PL141 is B51E2M-1, SK191 is Seacon XSJ-2-CCP. Metvinsmall 2c is used to extend the 0.5 m tail of PL141 and is potted into the XSJ back-fitting.

Details are not included of the cables glanded into the battery packs, with the exception of Cables 3 and 9. All other battery pack connectors are B51E2F-1 with 0.5 m tails, glanded into the battery containers.

APPENDIX J

D-A Test Results

The six D-A convertors in the Interface Processor were tested for linearity by (a) applying a software generated ramp input (0 in steps of 1 to 4095 digits) and observing the differentiated D-A outputs and (b) applying set input values and recording the output readings obtained using an accurate digital voltmeter. In test (a) each D-A was observed on an oscilloscope using a.c. coupling so that on each increment of the D-A output a pulse of height equal to the D-A increment was produced. By adjusting the D-A ramp rate, so that the oscilloscope input coupling capacitor has time to charge to the new value of the D-A d.c. output before the next increment occurs, a pulse train with fixed base level can be achieved. Variations in the pulse amplitude over the full ramp sweep are a measure of the differential non-linearity of the D-A which is specified as $\pm\frac{1}{2}$LSB i.e. the pulse amplitude at final buffer amplifier output = 5 $\pm$ 2.5mV for heave displacement, heave acceleration, pitch and roll channels and 4.05 $\pm$ 2.025mV for sin (heading) and cos (heading) channels. In test (b) each D-A output was measured on a DVM for digital inputs of 0, 400, 800 ..., 4000 and for 2048 and 4095. The results were checked using a program for least squares fit to a straight line. These are given in Tables 7a to 7f below. The results of the least square fit (output in volts = A + B * digital input) are close to the nominal values of A and B. These are A = -10.24, B = 10.24/2048 = 5.000E-3 for the heave displacement, heave acceleration, pitch and roll channels (i.e. -10 volts for 0048 digits, 0 volts for 2048 digits and +10 volts for 4048 digits) and A = -8.2944, B = 8.2944/2048 = 4.050E-3 for the sin (heading) and cos (heading) channels (i.e. -8.1 volts for 0048 digits, 0 volts for 2048 digits and +8.1 volts for 4048 digits. The slopes, B, are all within 0.2% of the nominal values and the actual voltages are all within 0.5% of full scale of the nominal values.

Table 7a D-A Channel 0 Test

Date 12/01/1987

Linear: Y=A+B*X with A = -10.24146122
B = 5.004583587E-3

Coef of Correlation = 0.9999999043
Coef of Determination = 0.9999998086

X-ACT	Y-ACT	Y-EST	DIFF	% DIFF
0.000	-10.240	-10.241	-0.001	0.014
400.000	- 8.240	- 8.240	0.000	-0.005
800.000	- 6.240	- 6.238	0.002	-0.035
1200.000	- 4.230	- 4.236	-0.006	0.141
1600.000	- 2.236	- 2.234	0.002	-0.084
2000.000	- 0.233	- 0.232	0.001	-0.303
2048.000	0.006	0.008	0.002	32.099
2400.000	1.768	1.770	0.002	0.087
2800.000	3.770	3.771	0.001	0.036
3200.000	5.770	5.773	0.003	0.056
3600.000	7.780	7.775	-0.005	-0.064
4000.000	9.780	9.777	-0.003	-0.032
4095.000	10.250	10.252	0.002	0.023

Table 7b D-A Channel 1 Test

Date 12/01/1987

Linear: Y=A+B*X with A = -10.2418079
B = 5.000266592E-3

Coef of Correlation = 0.9999998733
Coef of Determination = 0.9999997467

X-ACT	Y-ACT	Y-EST	DIFF	% DIFF
0.000	-10.240	-10.242	-0.002	0.018
400.000	- 8.240	- 8.242	0.002	-0.021
800.000	- 6.240	- 6.242	0.002	-0.026
1200.000	- 4.240	- 4.241	-0.001	0.035
1600.000	- 2.244	- 2.241	0.003	-0.117
2000.000	- 0.242	- 0.241	0.001	-0.300
2048.000	- 0.003	- 0.001	0.002	-57.936
2400.000	1.758	1.759	0.001	0.047
2800.000	3.750	3.759	0.009	0.238
3200.000	5.760	5.759	-0.001	-0.017
3600.000	7.760	7.759	-0.001	-0.011
4000.000	9.760	9.759	-0.001	-0.008
4095.000	10.240	10.234	-0.006	-0.056

Table 7c D-A Channel 2 Test

Date 12/01/1987

Linear: Y=A+B*X with A = -10.25525869
B = 5.00129208E-3

Coef of Correlation = 0.999999831
Coef of Determination = 0.9999996619

X-ACT	Y-ACT	Y-EST	DIFF	% DIFF
0.000	-10.260	-10.255	0.005	-0.046
400.000	- 8.250	- 8.255	-0.005	0.057
800.000	- 6.250	- 6.254	-0.004	0.068
1200.000	- 4.250	- 4.254	-0.004	0.087
1600.000	- 2.255	- 2.253	0.002	-0.080
2000.000	- 0.254	- 0.253	0.001	-0.522
2048.000	- 0.014	- 0.013	0.001	-9.911
2400.000	1.746	1.748	0.002	0.106
2800.000	3.740	3.748	0.008	0.224
3200.000	5.750	5.749	-0.001	-0.020
3600.000	7.750	7.749	-0.001	-0.008
4000.000	9.750	9.750	-0.000	-0.001
4095.000	10.230	10.225	-0.005	-0.049

Table 7d D-A Channel 3 Test

Date 12/01/1987

Linear: Y=A+B*X with A = -10.25103731
B = 4.998915718E-3

Coef of Correlation = 0.9999998694
Coef of Determination = 0.9999997388

X-ACT	Y-ACT	Y-EST	DIFF	% DIFF
0.000	-10.250	-10.251	-0.001	0.010
400.000	- 8.250	- 8.251	-0.001	0.018
800.000	- 6.250	- 6.252	-0.002	0.030
1200.000	- 4.250	- 4.252	-0.002	0.055
1600.000	- 2.255	- 2.253	0.002	-0.099
2000.000	- 0.254	- 0.253	0.001	-0.313
2048.000	- 0.015	- 0.013	0.002	-11.614
2400.000	1.745	1.746	0.001	0.078
2800.000	3.740	3.746	0.006	0.158
3200.000	5.740	5.745	0.005	0.096
3600.000	7.750	7.745	-0.005	-0.064
4000.000	9.750	9.745	-0.005	-0.055
4095.000	10.220	10.220	-0.000	-0.005

Table 7e D-A Channel 4 Test

Date 12/01/1987

Linear: Y=A+B*X with A = -8.278811265
B = 4.04614101E-3

Coef of Correlation = 0.9999998223
Coef of Determination = 0.9999996447

X-ACT	Y-ACT	Y-EST	DIFF	% DIFF
0.000	-8.280	-8.279	0.001	-0.014
400.000	-6.660	-6.660	-0.000	0.005
800.000	-5.040	-5.042	-0.002	0.038
1200.000	-3.420	-3.423	-0.003	0.101
1600.000	-1.807	-1.805	0.002	-0.111
2000.000	-0.187	-0.187	0.000	-0.252
2048.000	0.007	0.008	0.001	9.793
2400.000	1.432	1.432	-0.000	-0.005
2800.000	3.051	3.0501	-0.001	-0.020
3200.000	4.660	4.669	0.009	0.190
3600.000	6.290	6.287	-0.003	-0.043
4000.000	7.910	7.906	-0.004	-0.054
4095.000	8.290	8.290	0.000	0.002

Table 7f D-A Channel 5 Test

Date 12/01/1987

Linear: Y=A+B*X with A = -8.254781574
B = 4.030244127E-3

Coef of Correlation = 0.999999783
Coef of Determination = 0.999999566

X-ACT	Y-ACT	Y-EST	DIFF	% DIFF
0.000	-8.260	-8.255	0.005	-0.063
400.000	-6.640	-6.643	-0.003	0.040
800.000	-5.030	-5.031	-0.001	0.012
1200.000	-3.410	-3.418	-0.008	0.249
1600.000	-1.809	-1.806	0.003	-0.144
2000.000	-0.195	-0.194	0.001	-0.362
2048.000	-0.002	-0.001	0.001	-57.920
2400.000	1.417	1.418	0.001	0.057
2800.000	3.030	3.030	-0.000	-0.003
3200.000	4.640	4.642	0.002	0.043
3600.000	6.250	6.254	0.004	0.066
4000.000	7.870	7.866	-0.004	-0.048
4095.000	8.250	8.249	-0.001	-0.011

APPENDIX K

The Local Meteosat Receiving Station

The receiving station consists of a 1.8 m parabolic antenna, with low noise preamplifier, mounted on the roof of the old block at IOS, so as to have a clear view of the satellite Meteosat 2 in geosynchronous orbit above the equator. The antenna was aimed by monitoring the gain control voltage from the down convertor receiver unit, which was temporarily operated on the roof using batteries. The antenna beamwidth is approximately 6° so that minor misalignment due to wind forces/lack of rigidity in the mounting base is not a serious problem. The antenna base was fixed to concrete pads (cast in situ) on the roof which had weight sufficient to balance the overturning moments calculated for 100 knot wind speed. The antenna was not disturbed by the "hurricane" of 16th October 1987 but, since electrical power was cut off for a period of about one week, no data was received during this period (the Cromer receiving station was similarly out of action due to power loss). The preamplifier is connected via approximately 50 m of URM67 low loss coaxial cable to the down convertor/receiver unit, which supplies d.c. power via the cable to the preamplifier. The receiver unit produces a coherent binary phase modulated output which is then processed by a message recovery unit to decode the digital data stream. Data transmissions are interposed between weather facsimile transmissions (WEFAX) from the satellite at intervals of 2-3 minutes. The microprocessor controlled message recovery unit then stores messages from those DCPs whose addresses are stored in the recovery unit, and outputs these upon demand via an RS232 port. The above equipment was put out to tender to the only two known UK manufacturers, Space Technology Ltd and Protolog Ltd. The Protolog tender was accepted, being considerably lower than the STL tender. The Protolog message recovery unit (MRU) incorporates storage space sufficient for 42 full length DCP messages with the capability for extension up to a maximum of 525 messages. It is, therefore, not necessary to have a dedicated computer to acquire and process the data from the MRU. Software was written in assembler and BASIC to allow interface of the MRU to an Acorn BBC microcomputer. This software ("MET.LOG") first loads any required DCP addresses into the MRU and compiles the list. It then polls the MRU at frequent intervals, using *S<CR>, to see if any new data has been received from a DCP on that list by comparing the number of filtered messages received by the MRU with the number already stored by the BBC micro. If new data has been received, the BBC then reads in the first line of the first message, using *L<CR>. It calculates the number of lines in the message from this header line data and then reads the message in, line by line. The data from the MRU is in the form of ASCII coded hex characters for each DCP (ASCII) byte. The data are reconverted to the original DCP ASCII (International character set 5) representation by calling the short assembly code routine ("conv."). The message in ASCII form is assembled in the buffer "data". The command *J0<CR> is then sent to the MRU to ensure that its pointer is at the start of the next message in its buffer or, if there are no more messages it sends the null response " M/<CRLF>".

The received message is then filed on disk in the appropriate directory. This is found by abstracting the two digit decimal channel number (chan%) from the header line. This channel number refers to the position of the DCP address in the list of selected addresses. The channel number is then used to select the directory title from a number of data statements. Using the hard disk drive under the BBC ADFS filing system allows up to 47 messages to be filed under each DCP directory: sufficient to cover an unattended weekend's operation. The program "MET.LOG" continues to acquire data from the MRU automatically until one of the DCP directories is full. It also allows manual intervention/communication with the MRU for a limited period during each program cycle, for test or diagnostic purposes.

A short program "MET.LIST" was written to allow examination of the files produced by "MET.LOG". This simply prints out all printable characters in the selected file. Another short program "MET.DBDEC" was written to decode the spectral data from DCP files in the EMI processor/WMO code format. This program simply generates files "C11, C22, C33, Q12, Q13, C23" in the RECORDS directory in decoded decimal integer format (i.e. not in engineering units). A final program "SPLOT" is then used to produce screen plots of displacement energy, Θ_1, Θ_2 and check ratio R against frequency and to produce a printed screen dump. The decoding and plotting programs are only intended for occasional use for monitoring data quality. For routine processing the data would have been transferred to the IBM mainframe via the network using the KERMIT file transfer system: in the event, the quantity of data acquired did not merit mainframe processing. Some data received via Meteosat 2 from DB2 and DB3 were monitored (with the permission of UKOOA) for the purpose of testing the software. The Proudman Oceanographic Laboratory's St Helena tide gauge station, also transmitting via Meteosat 2, was also monitored.

APPENDIX L

Design of Portable WAVEC Test Receiver

The standard DIREC receivers supplied by Datawell, in addition to requiring a separate terminal for data readout, are very heavy and bulky, due to the housing used to gain certification for use on platforms where electrical discharge is a hazard. It was considered necessary, after the initial abortive Flamborough Head deployment, to have some means of checking the transmitted signal from the WAVEC during deployment, with a radio range of, perhaps, 1-2 miles.

Datawell agreed to supply two radio receiver printed circuit boards (pcb F) used in the DIREC. These boards contain all the reception and demodulation circuits necessary to acquire each digital word as it is transmitted. The 12 bit word together with 4 status bits is available immediately after reception of the final bit of the word. An interrupt is produced to signal the availability of the word and the 16 bits are then output onto a single data line under bit address control of an external device.

A simple interface between the receiver board and a 4 hex digit liquid crystal display was designed (Figures 12, 13). The operation of this interface is as follows: the l.s.b. of the 16 bit data is a flag bit which is low when the data received is the sync. word and high otherwise. This l.s.b. is inverted and is clocked into an 8 bit serial to parallel register (IC2a and 2b) by the interrupt request line $\overline{\text{INTREQ}}$ going low. Thus a '1' will propagate through the register as successive channels are received; the position of the '1' gives the currently acquired channel (word) number. The register outputs are selected by a channel select switch so that when the required channel for display is available, the gated oscillator formed of two NAND gates (part of IC1), in conjunction with the binary counter IC5 which generates the bit addresses (A, B, C, D), clocks the data word into the 4 bit serial to parallel register IC3a. The outputs of this register are connected to the 7211 LCD decoder driver (IC7) hex input lines. The digit lines are strobed by the differentiated '1' to '4' decimal outputs from counter IC4, which is clocked on every 4th bit of the IC3a clock. After each word has been transferred to the interface and displayed as 4 hex digits, the counter IC5 resets the flip flop IC3b and gates off the bit clock oscillator (part of IC1).

Figure 12 Portable Receiver Schematic

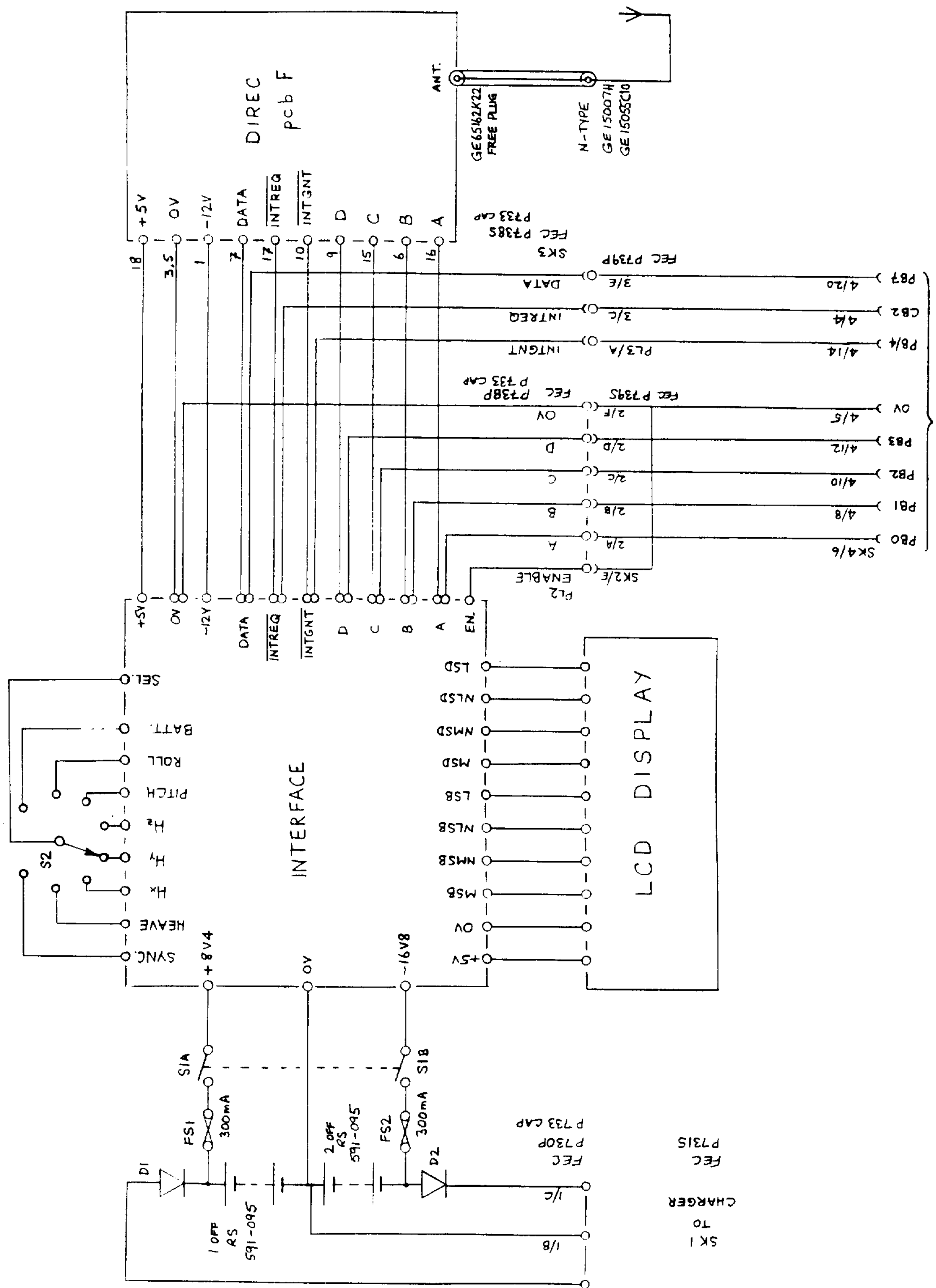
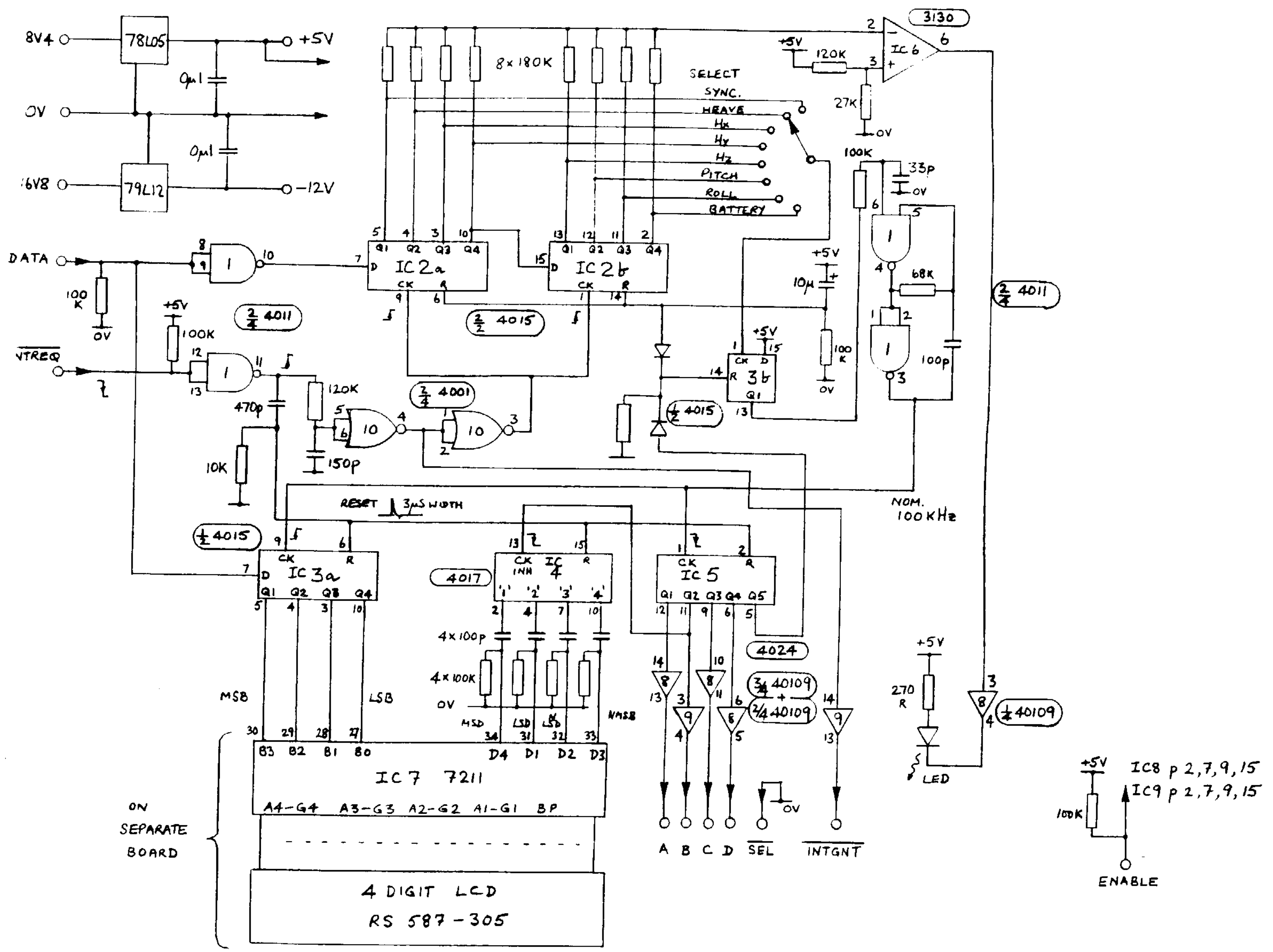


Figure 13 Portable Receiver-Interface Board



The channel number register (IC2a and 2b) outputs are connected via 180k resistors to the inverting input of the comparator IC6, whose noninverting input is set at 0.184 times the V_{DD} (+5V) supply voltage. Normally only a single output of IC2a and 2b will be high at any time, so that the voltage at the inverting input will be given by

$$\frac{180k/7}{180k + 180k/7} \times V_{DD}$$

$$\text{or } \frac{1}{8} V_{DD}$$

and the comparator output will remain high so that the LED is off. If, however, a fault in the buoy or transmission errors result in two synch. words being detected in a sequence of 8 channels, the voltage at the inverting input will rise to $\frac{180k/6}{180k/2 + 180k/6} \times VDD = 0.25\ V_{DD}$, or more, and the LED will be illuminated, indicating the fault.

In order to use this portable receiver for calibration purposes or more detailed testing of the buoy, the interface address line buffers (IC8 and 9) can be disabled by connecting the enable line low. This allows a separate microcomputer to gain control of the address lines of the receiver board. Software was written to allow the Acorn BBC microcomputer to acquire data from the receiver board and to display it in complete scans as well as to record the data on disk for further analysis. The BBC user port was software configured to provide 5 output lines to control the bit addressing and interrupt acknowledge line and 2 input lines for the interrupt request and data lines. This proved very useful for initial calibrations of the buoys when a full DIREC plus HP85B system was not available.

The portable receiver was housed in a splashproof housing with rechargeable NiCd cells. External splashproof connectors were used for cell recharging and for connection to the BBC microcomputer. A short rod aerial was included; this gave a useful range of up to about 5-6 miles. Two portable receivers were constructed for use on the Flamborough and Cromer WAVEC transmission frequencies of 29.725 and 29.825 MHz.

APPENDIX M

Meteosat Spectral Data and Derived Parameters from Cromer Trial 0900hrs 17/06/87
C11 in units of gΔ2/Hz, C22 and C33 in units of radΔ2/Hz, Q12 and Q13 in units of g.rad/Hz

Direction (Theta1) and Spread (Theta2) in degrees

Frequency	C11	C22	C33	Q12	Q13	Direction	Spread
0.04875	0.0000E0	3.0992E-5	1.6688E-5	0.0000E0	0.0000E0	indeterminate	
0.05875	0.0000E0	1.4304E-5	2.1456E-5	0.0000E0	0.0000E0	indeterminate	
0.06875	0.0000E0	1.9072E-5	1.6688E-5	0.0000E0	0.0000E0	indeterminate	
0.07875	0.0000E0	1.9072E-5	1.6688E-5	0.0000E0	0.0000E0	indeterminate	
0.08875	0.0000E0	2.8608E-5	1.6688E-5	0.0000E0	0.0000E0	indeterminate	
0.09875	1.4687E-6	3.3376E-5	1.9072E-5	1.8714E-6	1.8714E-6	45.0	67.7
0.10875	1.0801E-5	3.8144E-5	2.6224E-5	6.8087E-6	4.5391E-6	33.7	67.3
0.11875	7.6783E-5	5.0064E-5	4.2912E-5	3.5180E-5	3.2474E-5	42.7	53.3
0.12875	5.7295E-4	2.0026E-4	2.5986E-4	2.3222E-4	3.1811E-E	53.9	39.1
0.13875	2.0035E-3	9.2976E-4	4.9110E-4	1.1638E-3	8.6081E-4	36.5	30.5
0.14875	6.9341E-3	4.5153E-3	6.7706E-4	5.1039E-3	1.4267E-3	15.6	27.7
0.15875	8.9365E-3	5.1399E-3	1.2301E-3	6.1518E-3	2.2585E-3	20.2	29.4
0.16875	1.2775E-2	7.4762E-3	1.0418E-3	8.9185E-3	2.5193E-3	15.8	27.1
0.17875	1.0107E-2	6.8278E-3	8.0818E-4	7.7381E-3	1.0424E-3	7.7	27.0
0.18875	6.2536E-3	3.4854E-3	1.1729E-3	4.2526E-3	1.3264E-3	17.3	33.9
0.19875	6.9891E-3	4.6941E-3	6.9374E-4	5.1472E-3	5.9886E-4	6.6	32.0
0.20875	5.0446E-3	3.6737E-3	9.1307E-4	3.8217E-3	-1.1708E-4	358.2	36.7
0.21875	6.4012E-3	3.8382E-3	1.1801E-3	4.5823E-3	4.6833E-4	5.8	35.1
0.22875	1.0615E-2	5.0350E-3	8.5109E-4	6.7279E-3	-2.7113E-4	357.7	31.2
0.23875	6.7749E-3	4.2697E-3	1.1562E-3	4.5943E-3	2.1878E-5	0.3	39.9
0.24875	5.4996E-3	3.0038E-3	1.3493E-3	3.0161E-3	3.3248E-4	6.3	49.9
0.25875	6.3002E-3	2.4937E-3	1.1896E-3	3.3920E-3	-6.1672E-4	349.7	43.2
0.26875	5.3178E-3	3.4520E-3	1.3231E-3	3.5760E-3	-8.0392E-4	347.3	42.3
0.27875	5.6883E-3	2.5723E-3	1.2874E-3	2.8779E-3	-1.2376E-3	336.7	46.6
0.28875	1.2025E-2	2.0765E-3	1.5806E-3	1.7440E-3	-5.9201E-4	341.3	68.9
0.29875	7.3820E-3	3.9908E-3	3.1326E-3	3.9908E-3	-2.5863E-3	327.1	47.5
0.30875	1.4597E-2	2.9633E-3	3.9360E-3	2.3233E-3	-3.8965E-3	300.8	60.0
0.31875	1.2436E-2	3.8239E-3	6.0268E-3	4.7965E-3	-6.4343E-3	306.7	42.5
0.32875	1.6958E-2	4.6178E-3	4.8371E-3	3.8162E-3	-5.8073E-3	303.3	54.4
0.33875	1.0983E-2	3.6952E-3	1.1996E-2	3.8537E-3	-1.4600E-2	284.8	54.4
0.34875	6.3975E-3	5.7359E-3	7.2617E-3	4.0146E-3	-7.7024E-3	297.5	(17.7)
0.35875	8.4426E-3	5.7216E-3	1.3989E-2	3.4084E-3	-1.6647E-2	281.6	indeterminate
0.36875	8.8528E-3	4.1720E-3	1.1872E-2	2.6877E-3	-1.4822E-2	280.3	indeterminate
0.37875	8.5816E-3	4.7370E-3	1.7975E-2	1.7894E-3	-2.0674E-2	274.9	indeterminate
0.38875	1.1641E-2	3.8025E-3	9.5551E-3	2.0591E-3	-1.2500E-2	279.4	indeterminate
0.39875	9.7619E-3	3.3018E-3	5.9886E-3	2.7462E-4	-6.5298E-3	272.4	(45.4)
0.40875	0.0000E0	4.6440E-3	7.7766E-3	1.6352E-3	-8.5287E-3	280.9	indeterminate
0.41875	0.0000E0	5.5690E-3	5.8265E-3	1.0432E-3	-7.8070E-3	277.6	indeterminate
0.42875	0.0000E0	3.8096E-3	6.7038E-3	9.5248E-4	-8.2196E-3	276.6	indeterminate
0.43875	0.0000E0	4.2197E-3	8.0245E-3	1.4777E-3	-1.0639E-2	277.9	indeterminate
0.44875	0.0000E0	5.0255E-3	9.0354E-3	-1.2366E-3	-1.0511E-2	263.3	indeterminate

Note that, for the first 5 estimates, indeterminate values of direction and spread result from inadequate heave "acceleration" levels (displacement was actually input instead of acceleration and the results corrected by multiplying by (angular frequency)Δ4). Consequently the resulting C11, Q12 and Q13 estimates are below the threshold resolution. Similarly the last 5 estimates of C11 were zero, so that spreads could not be calculated. Noise affected the estimates between 0.34875 Hz and 0.39875 Hz to such an extent that the spread values are unreliable or indeterminate.

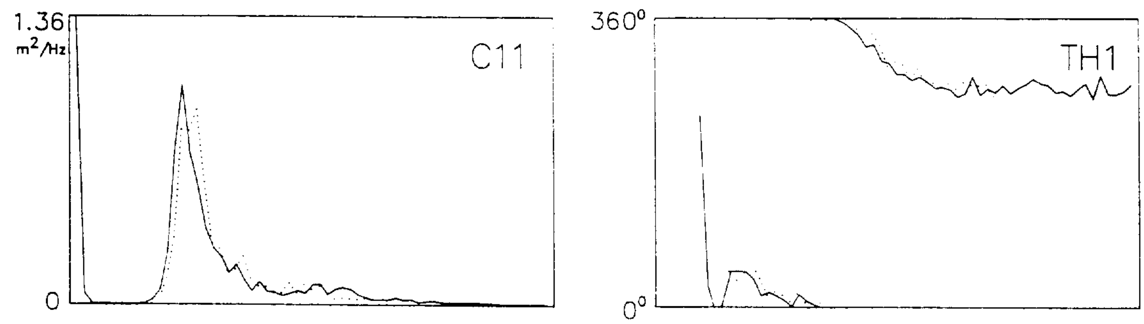
Meteosat Spectral Data and Derived Parameters from Cromer Trial 1800hrs 17/06/87
C11 in units of gΔ2/Hz, C22 and C33 in units of radΔ2/Hz, Q12 and Q13 in units of g.rad/Hz

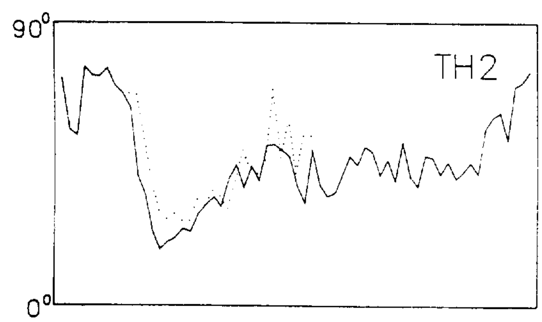
Direction (Theta1) and Spread (Theta2) in degrees

Frequency	C11	C22	C33	Q12	Q13	Direction	Spread
0.04875	0.0000E0	2.6224E-5	1.4304E-5	0.0000E0	0.0000E0	indeterminate	
0.05875	0.0000E0	2.3840E-5	1.4304E-5	0.0000E0	0.0000E0	indeterminate	
0.06875	0.0000E0	2.1456E-5	2.1456E-5	0.0000E0	0.0000E0	indeterminate	
0.07875	0.0000E0	1.9072E-5	2.1456E-5	0.0000E0	0.0000E0	indeterminate	
0.08875	9.5822E-7	1.9072E-5	2.1456E-5	0.0000E0	0.0000E0	indeterminate	
0.09875	1.1750E-5	1.9072E-5	2.1456E-5	3.7427E-6	1.8714E-6	26.6	72.8
0.10875	1.1499E-4	7.8672E-5	5.2448E-5	6.5818E-5	3.4044E-5	27.3	50.9
0.11875	6.2348E-4	4.4104E-4	9.5360E-5	4.2487E-4	1.3260E-4	17.3	38.9
0.12875	1.8334E-3	1.4948E-3	4.4819E-4	1.3074E-3	4.1991E-4	17.8	42.3
0.13875	2.9423E-3	1.5782E-3	7.4858E-4	1.8361E-3	1.1046E-3	31.0	34.5
0.14875	3.1910E-3	2.0431E-3	5.6739E-4	2.1358E-3	1.0148E-3	25.4	34.4
0.15875	2.4328E-3	1.9358E-3	4.0290E-4	1.7846E-3	4.9330E-4	15.5	38.3
0.16875	1.7159E-3	1.4662E-3	5.7216E-4	1.3498E-3	4.7544E-4	19.4	39.3
0.17875	2.0498E-3	1.3064E-3	6.4130E-4	1.4655E-3	6.1317E-4	22.7	36.7
0.18875	1.7251E-3	1.6736E-3	7.5096E-4	1.4768E-3	6.2216E-4	22.8	37.7
0.19875	1.0845E-3	8.3202E-4	4.0290E-4	6.4435E-4	1.9709E-4	17.0	52.4
0.20875	1.8184E-3	1.2182E-3	6.2461E-4	1.1122E-3	6.4392E-4	30.1	44.2
0.21875	1.2024E-3	6.9136E-4	7.5096E-4	6.2444E-4	2.3876E-4	20.9	56.9
0.22875	1.3956E-3	1.1705E-3	7.0566E-4	9.7405E-4	6.0250E-5	3.5	51.0
0.23875	1.9572E-3	1.3422E-3	8.9638E-4	1.1158E-3	2.2972E-4	11.6	54.7
0.24875	2.1289E-3	1.4900E-3	8.8208E-4	1.1281E-3	4.2748E-4	20.8	55.1
0.25875	2.6309E-3	2.4150E-3	9.0115E-4	1.5289E-3	5.7817E-4	20.7	54.1
0.26875	3.0618E-3	2.2529E-3	2.0169E-3	1.5524E-3	2.7721E-5	1.0	61.2
0.27875	2.2380E-3	2.7058E-3	1.9883E-3	1.1929E-3	-3.8769E-4	342.0	63.4
0.28875	4.9390E-3	4.6393E-3	3.2112E-3	3.0561E-3	-1.6800E-3	331.2	53.7
0.29875	4.3062E-3	5.5500E-3	4.5844E-3	3.3399E-3	-1.1476E-3	341.0	55.3
0.30875	4.4913E-3	7.4524E-3	5.1399E-3	3.9697E-3	-1.8328E-3	330.3	50.7
0.31875	5.1020E-3	4.6655E-3	6.6847E-3	3.4316E-3	-1.8328E-3	331.9	56.6
0.32875	4.8710E-3	9.5360E-3	3.9860E-3	4.9984E-3	-8.2962E-4	350.6	49.7
0.33875	3.8642E-3	4.4414E-3	4.0933E-3	1.8498E-3	-4.1841E-4	347.3	66.3
0.34875	6.1690E-3	8.6587E-3	3.4735E-3	4.5981E-3	-2.2407E-3	334.0	51.8
0.35875	5.3725E-3	5.3783E-3	5.2019E-3	3.3096E-3	-6.4216E-4	349.0	60.2
0.36875	5.9971E-3	6.6323E-3	4.1625E-3	2.7138E-3	-1.0438E-4	357.8	66.0
0.37875	7.9459E-3	8.8256E-3	3.0801E-3	3.9091E-3	-1.6517E-4	357.6	62.6
0.38875	9.8772E-3	6.1269E-3	3.4473E-3	3.2192E-3	1.2761E-3	21.6	65.0
0.39875	5.8572E-3	8.8208E-3	3.4377E-3	4.1193E-3	9.7642E-4	13.3	57.3
0.40875	7.7606E-3	6.5989E-3	5.4689E-3	3.3666E-3	-5.4507E-4	350.8	65.2
0.41875	7.5986E-3	2.4484E-3	3.9408E-3	1.6152E-3	5.7206E-4	19.5	70.4
0.42875	5.7412E-3	4.5463E-3	4.4390E-3	2.2930E-3	-4.9388E-4	347.8	66.5
0.43875	4.0064E-3	3.2518E-3	3.3471E-3	9.6049E-4	0.0000E0	360.0	73.1
0.44875	5.0107E-3	3.4735E-3	4.0671E-3	1.8550E-3	1.4685E-3	38.4	63.5

Note that, for the first 5 estimates, indeterminate values of direction and spread result from inadequate heave "acceleration" levels (displacement was actually input instead of acceleration and the results corrected by multiplying by (angular frequency)Δ4). Consequently the resulting C11, Q12 and Q13 estimates are below the threshold resolution.

Figures 14 a, b, c





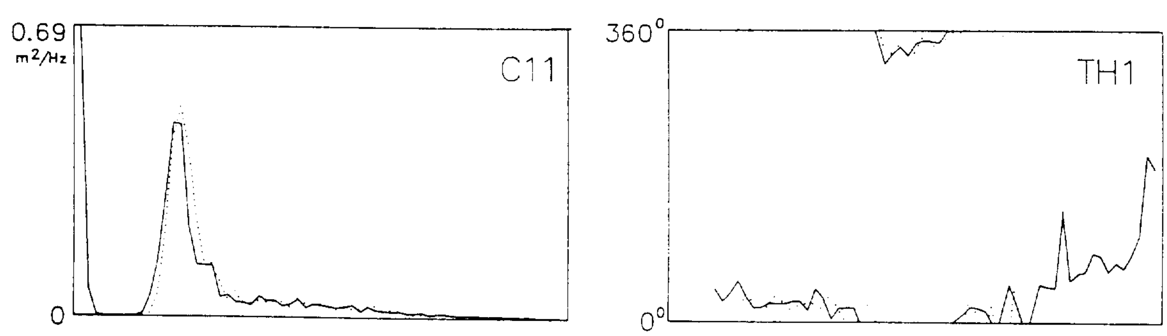
Cromer Wavec Data 0900hrs 17/06/87

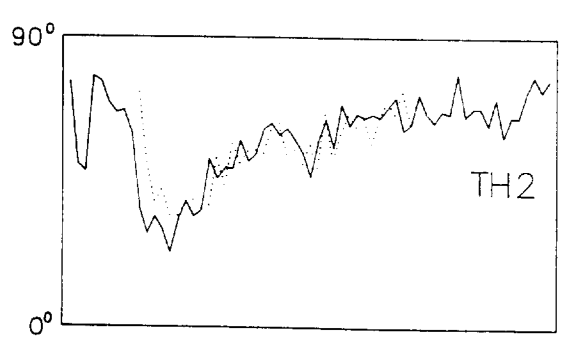
Full line: DIREC analysis

Dotted line: EMI analysis

Frequency Scale 0 to 0.64 Hz

Figures 15 a, b, c





Cromer Wavec Data 1800hrs 17/06/87

Full line: DIREC analysis

Dotted line: EMI analysis

Frequency Scale 0 to 0.64 Hz

APPENDIX N

Notices to Mariners, etc.

Approval to deploy the buoys was sought in each case from the Department of Transport, Marine Directorate and Trinity House Lighthouse Service. Notices to mariners were prepared and circulated to a wide range of interested parties, listed below, and the Hydrographer of the Navy was notified of deployment and recovery dates.

Circulation List

- Department of Transport, Marine Directorate
- Trinity House Lighthouse Service
- Nautical Charts Branch, Hydrographic Department
- Radio and Navigation Warnings, Hydrographic Department
- General Council of British Shipping
- Deputy Submarine Superintendent, Marine Division NP6
- Ministry of Agriculture, Fisheries & Food, Interference to Fisheries
- H.M. Coastguard, Regional Controller, Great Yarmouth
- National Federation of Fishermen's Organisations
- Harbour Masters of Lowestoft and Hull
- Great Yarmouth Port & Haven Commissioners
- Lowestoft Pilot Office
- Lowestoft Fishing Vessel Owners' Association

Figures 16 a, b

Notice to Mariners

Outer Silver Pit – West of Markhams Hole.

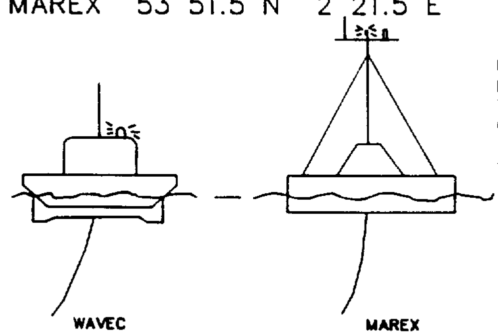
A hazard to shipping and fishing will be presented by a WAVEC wave measurement buoy and a MAREX meteorological buoy moored to the sea bed.
The WAVEC buoy is a 2.5 metre diameter discus buoy with a 1.5 metre high spherical top. The buoy is coloured yellow and contains a radar reflector. It carries a flashing yellow light, character FL(5) 20 seconds (5 flashes in 10 seconds, followed by 10 seconds off).
The MAREX buoy is a 3 metre diameter discus buoy with a 5 metre high mast fitted with wind sensors and aerials. The top surface of the buoy is coloured yellow. The mast carries a flashing yellow light, character FL(5) 20 seconds, as above.

To avoid fouling the moorings, we would be grateful if all vessels kept at least 5 cables (1000 metres) clear of the buoys.

Positions of the buoys: (from end Sept–end Dec 1987)

WAVEC 53° 52′ N 2° 21.5′ E

MAREX 53° 51.5′ N 2° 21.5′ E



INSTITUTE OF OCEANOGRAPHIC SCIENCES
Brook Road,
Wormley,
Near Godalming,
Surrey GU8 5UB
England

Notice to Mariners

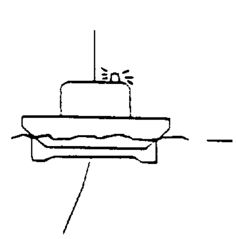
Wavec Buoy to the N.E. of CROMER.

A hazard to shipping and fishing will be presented by a Wavec wave–measuring buoy moored to the sea bed.
The WAVEC buoy is a 2.5 metre diameter discus buoy with a 1.5 metre high spherical top. The buoy is coloured yellow and contains a radar reflector. It carries a flashing yellow light, character FL(5) 20 seconds (5 flashes in 10 seconds, followed by 10 seconds off).

To avoid fouling of the mooring, we would be grateful if all vessels kept at least 5 cables (1000 metres) clear of the buoy.

Position of the Buoy :(from end Sept–end Dec 1987)

53° 04′ N 1° 31′ E



INSTITUTE OF OCEANOGRAPHIC SCIENCES
Brook Road,
Wormley,
Near Godalming,
Surrey GU8 5UB
England

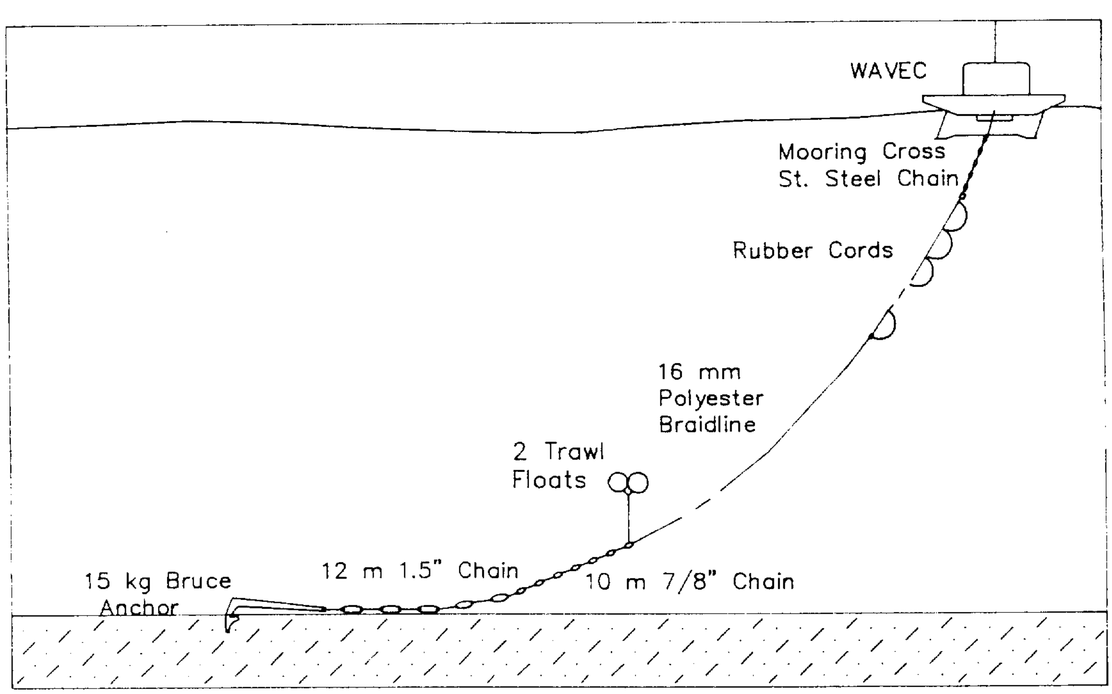
APPENDIX O

Mooring Configurations

"Standard" IOS moorings were used for all WAVEC buoy deployments carried out by IOS. The moorings by HR Ltd were generally similar except for the use of stainless chain below the mooring cross and two lengths of rubber cord for some of the moorings.

The mooring for the MAREX buoy was designed and deployed by I. Waddington of IOS. It performed well and showed little wear after the deployment period which included the "Great Storm" of 1987.

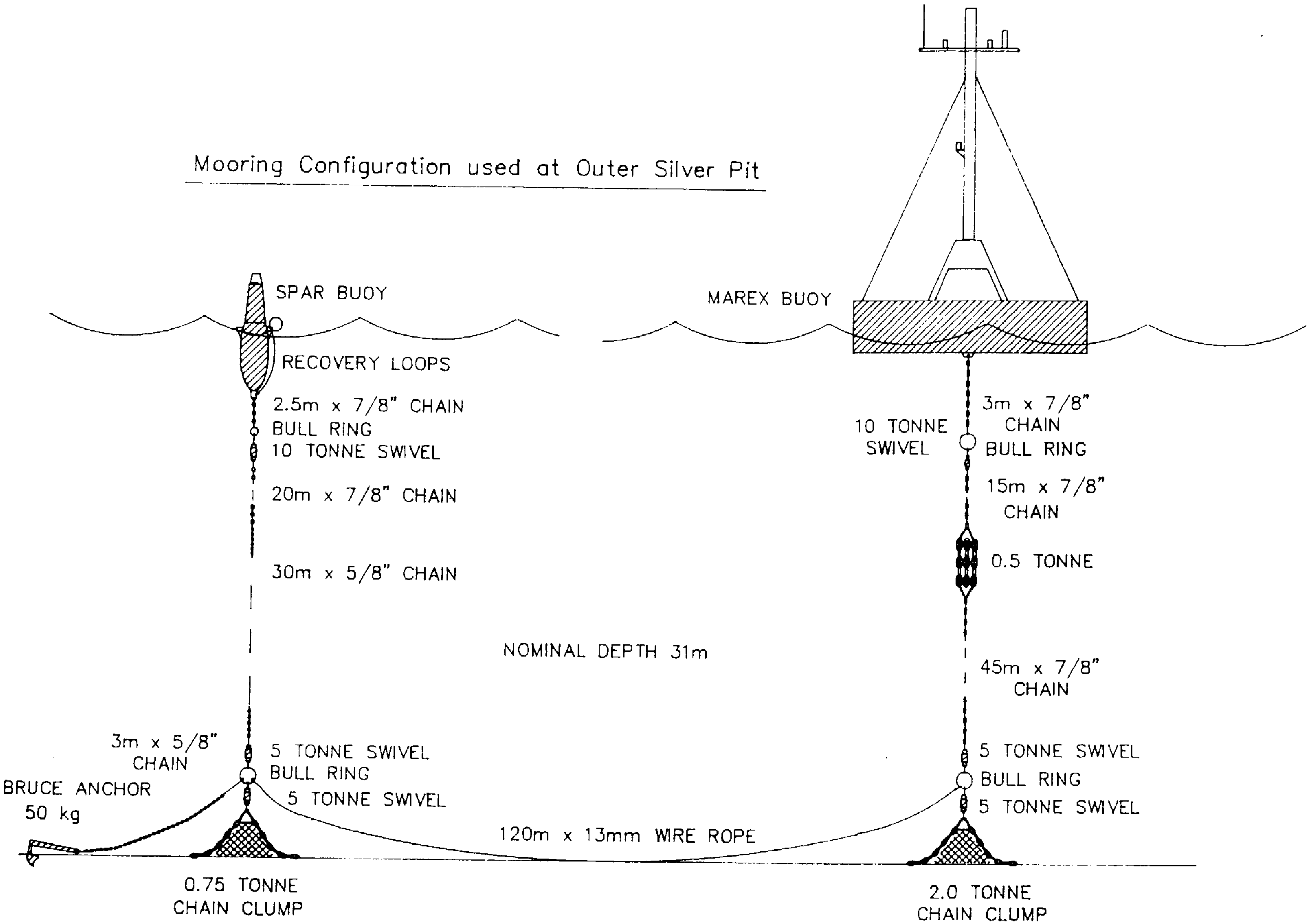
Figure 17



Standard WAVEC Mooring Configuration
used at Cromer and Outer Silver Pit

Figure 18

Mooring Configuration used at Outer Silver Pit



APPENDIX P

Data from Mother Buoy/Wavec at 54°N 2°E

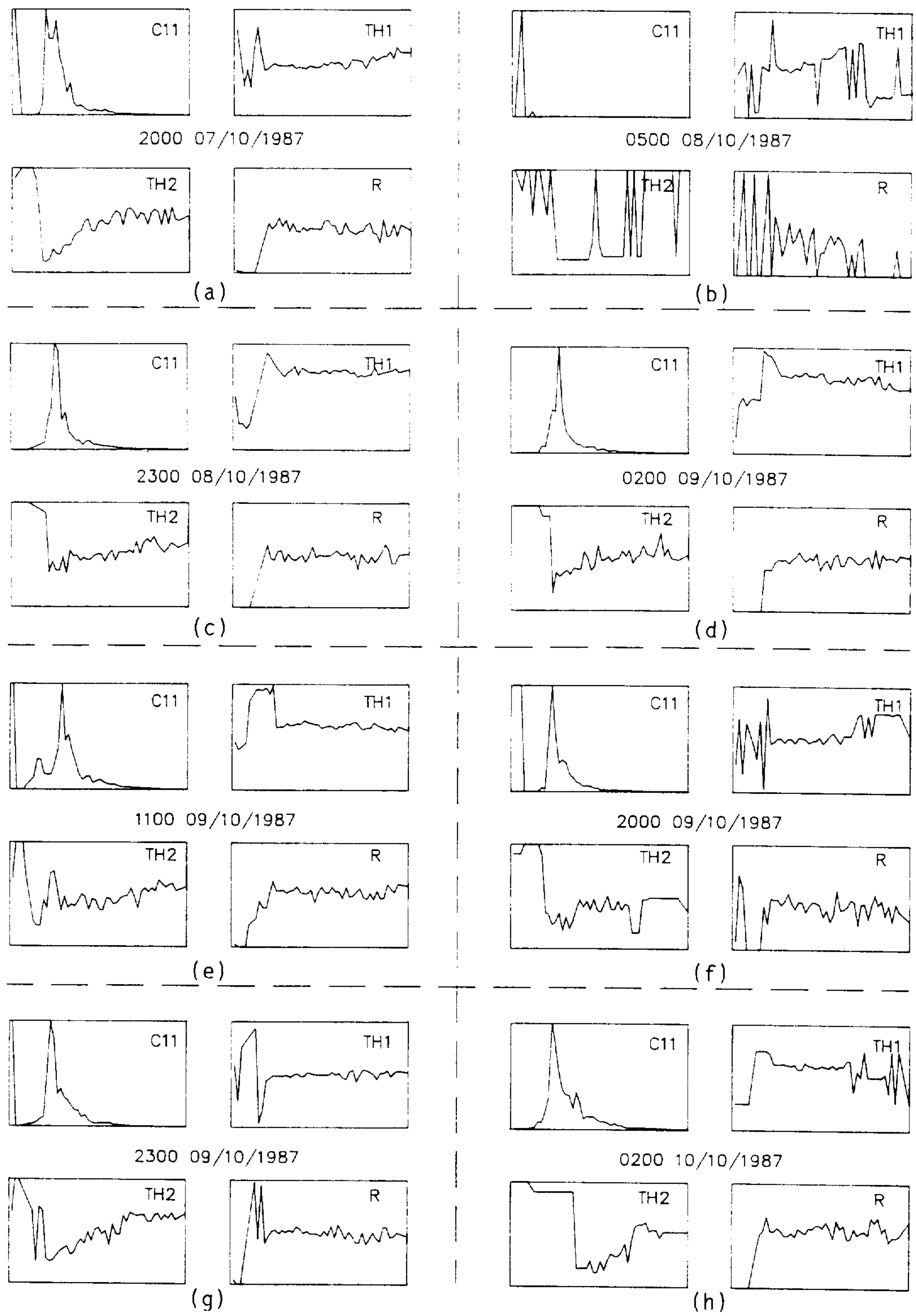
The data were translated from the Sea Data tape, reformatted into the auto- and cross-spectra and any white noise removed from the auto-spectra using programs PARTENTZ and NOISEOUT. The data were then analysed to give the parameters, for comparison with the Cromer Wavec data, given in Table 5 below. The data were also converted to spectra of displacement energy, C11, direction, Th1, spread, Th2, and check ratio, R; these were plotted and are shown in Figures 19-21, below. Of the error flagged records (NQ=1), 20/10/10 is apparently useable, the worst being 05/18/10.

Table 5

Summary of Outer Silver Pit Data with Cromer Wavec Hs values

Time/Date	NQ	Hs(CR)	Hs(OSP)	Tz	Tp	Ep	Th1p	Th2p	Rp	Th1w	Th2w	Rw	Notes
(hh/dd/mm)		(metres)	(metres)	(sec)	(sec)	(mΔ2/Hz)	(deg)	(deg)		(deg)	(deg)		
20/07/10	1	1.64	3.23	6.7	10.1	46	159.3	[illegible]	0.95	165.1	41.6	0.86	Th2p unrealistic?
05/08/10	1	1.40	2.62	9.5	17.0	98	116.5	50.3	5.23	192.3	28.1	0.46	Noisy, unreliable
23/08/10	0	2.08	3.32	6.1	7.8	62	275.9	31.2	1.06	264.0	43.1	0.99	Credible
02/09/10	0	1.24	3.02	6.0	7.2	62	262.8	28.8	0.96	268.0	44.3	0.96	Credible
11/09/10	0	1.24	2.54	5.5	6.7	28	214.2	30.5	1.09	221.0	38.4	1.02	Credible
20/09/10	1	1.44	3.03	6.6	8.4	60	170.4	[illegible]	0.94	175.1	36.0	0.80	Credible, low Rw
23/09/10	0	2.04	3.39	6.2	8.4	59	175.[illegible]	18.6	1.01	180.2	41.2	0.96	Credible
02/10/10	0	1.68	2.74	5.6	8.4	32	223.[illegible]	-	1.07	218.8	38.2	1.14	Th2p indeterminate
05/10/10	0	1.32	2.53	5.6	7.8	33	173.4	31.8	1.02	165.2	36.4	0.97	Credible
08/10/10	0	1.44	2.34	6.1	8.4	31	159.8	20.3	0.92	162.6	37.6	0.81	Low Rw
11/10/10	1	1.64	2.93	7.7	7.8	24	163.1	66.7	0.90	154.9	17.8	0.90	Noisy, Th2s unreliable
14/10/10	0	1.48	2.06	4.9	7.2	12	160.0	25.6	1.09	151.0	37.8	1.11	Credible
17/10/10	0	1.44	2.62	5.5	7.2	39	168.1	17.5	1.01	165.0	31.1	1.02	Credible
20/10/10	1	1.96	2.66	6.0	7.8	52	176.3	20.1	0.93	171.2	37.8	0.92	Credible
23/10/10	0	2.40	1.99	5.5	7.2	20	169.0	27.7	1.02	166.2	45.8	0.94	Credible
02/11/10	0	2.00	2.50	5.5	7.2	29	285.7	56.8	0.96	288.5	42.0	0.86	High Th2p, shift in Th1s follows wind
05/11/10	0	1.68	2.85	5.4	7.2	34	302.6	41.7	1.43	259.4	43.7	1.06	High Th1p, Rp
11/11/10	0	1.24	2.45	5.3	5.6	23	238.8	35.3	1.06	237.5	45.9	1.06	Credible
14/11/10	0	0.96	2.14	5.3	5.9	28	227.9	35.0	1.15	240.7	41.9	0.97	Credible
17/11/10	1	0.72	1.68	5.1	5.3	10	245.2	32.9	1.13	239.7	44.2	0.99	Credible
23/11/10	0	1.00	1.46	5.8	7.8	6	-	21.9	0.97	-	74.6	0.90	Tape data incomplete

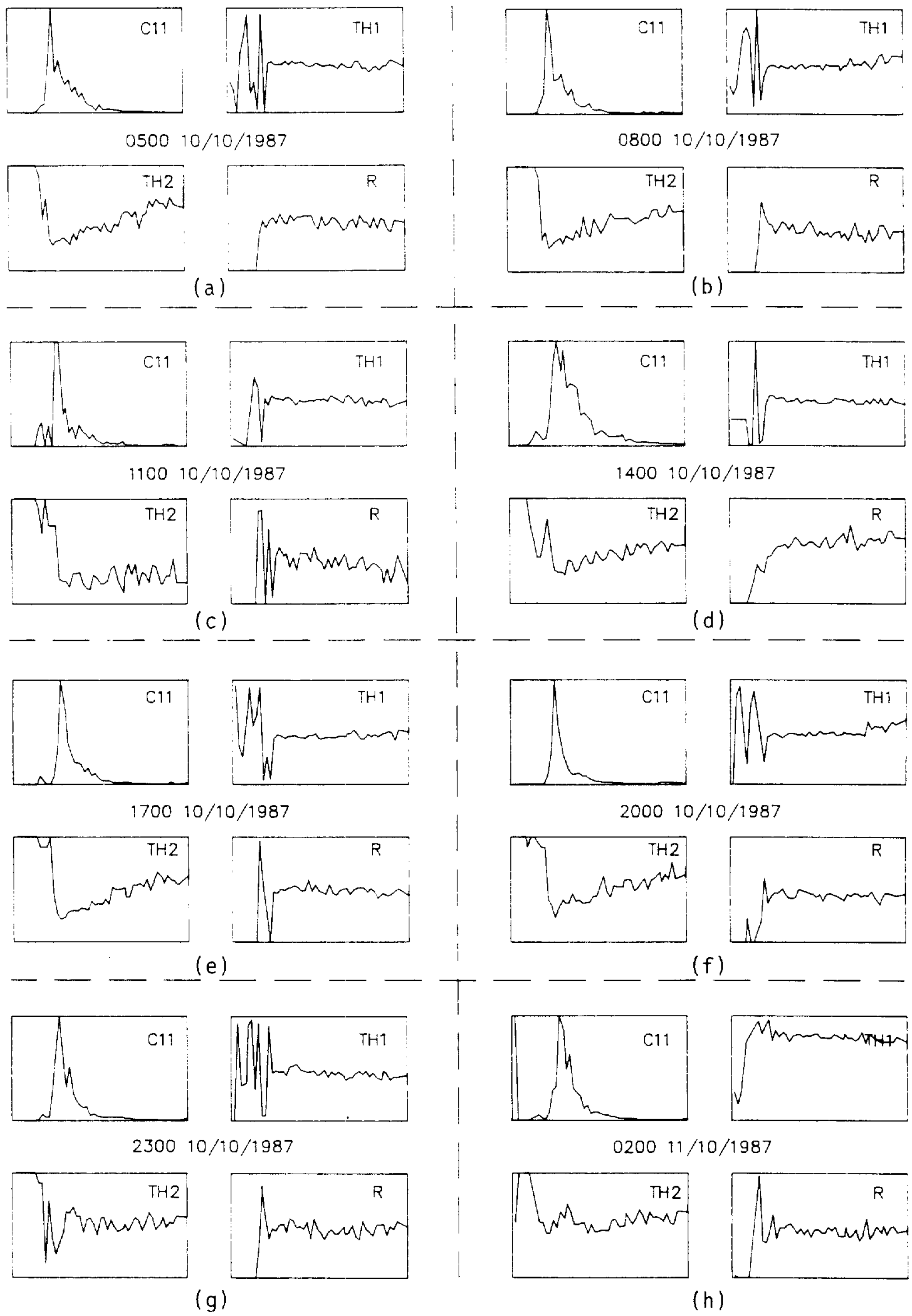
Notes:
Hs(OSP), Tz from spectral estimates 0.04875 to 0.60875 Hz
Tp is period of peak of displacement energy spectrum
Ep, Th1p, Th2p, Rp are, respectively, spectral density, mean direction, directional spread and check ratio at Tp
Th1w, Th2w and Rw are, respectively, mean direction, directional spread and check ratio averaged over the estimates 0.20875 to 0.25875 Hz, i.e. wind wave parameters.



Data from Outer Silver Pit

Freq: 0.04875–0.44875 Hz, C11 normalised, TH1 0 to 360°, TH2 0 to 90°, R 0 to 2

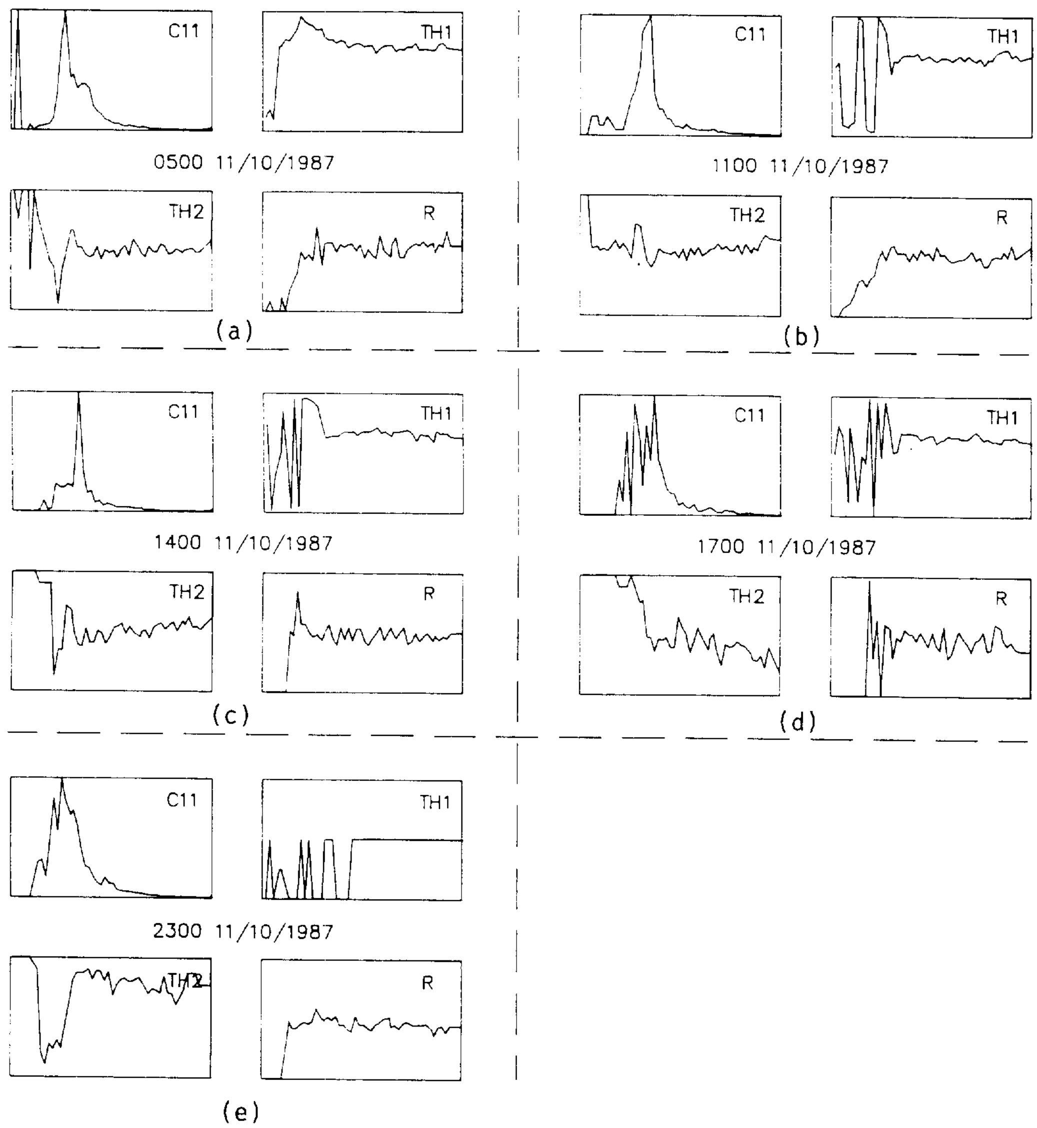
Figures 19 a-h



Data from Outer Silver Pit

Freq: 0.04875–0.44875 Hz, C11 normalised, TH1 0 to 360°, TH2 0 to 90°, R 0 to 2

Figures 20 a-h



Data from Outer Silver Pit

Freq: 0.04875–0.44875 Hz, C11 normalised, TH1 0 to 360°, TH2 0 to 90°, R 0 to 2

Figures 21 a-e

APPENDIX Q

Summary of Quality Flags for period 6th - 11th October 1987

(Flag Bits in order 8421)

Date	Time	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Total
06/10/87	02	0011	1100	0001	1100	0000	1100	0000	0000	9
	05	0001	0100	0101	0100	0000	0100	0000	0000	6
	08	0001	0100	0001	0100	0000	0100	0000	0000	5
	11	0001	0100	0001	0100	0000	0100	0000	0000	5
	14	0101	0100	0001	0100	0000	0100	0000	0000	6
	17	0001	0100	0001	0100	0000	0100	0000	0000	5
	20	0001	0100	0101	0100	0000	0100	0000	0000	6
	23	0001	0100	0101	0100	0100	1100	0000	0000	8
07/10/87	02	0101	0100	0101	0100	0000	0100	0000	0000	7
	05	0001	0100	0001	0100	0100	0100	0000	0000	6
	08	0101	0100	0001	0100	0000	1100	0000	0000	7
	11	0001	0100	0101	0100	0000	0100	0000	0000	6
	14	0001	0100	0001	0100	0000	0100	0000	0000	5
	17	0001	0100	0101	0100	0000	0100	0000	0000	6
	20	0000	0000	0000	0100	0000	0000	0000	0000	1
	23	0001	0100	0001	0100	0000	0100	0000	0000	5
08/10/87	02	0100	0000	0001	0100	0000	0100	0000	0000	4
	05	0100	0000	0000	0000	0000	0000	0000	0000	1
	08	0001	0100	0001	0100	0000	0100	0000	0000	5
	11	0001	0100	0101	0100	0000	1100	0000	0000	7
	14	0001	0100	0001	0100	0000	0100	0000	0000	5
	17	0101	0100	0101	0100	0000	0100	0000	0000	7
	20	0001	0100	0001	0100	0000	0000	0000	0000	4
	23	0000	0000	0000	0000	0000	0000	0000	0000	0
09/10/87	02	0000	0000	0000	0000	0000	0000	0000	0000	0
	05	0001	0100	0000	0000	0000	0100	0000	0000	3
	08	0001	0100	0001	0100	0000	0100	0000	0000	5
	11	0000	0000	0000	0000	0000	0000	0000	0000	0
	14	0101	0100	0001	0100	0000	0100	0000	0000	6
	17	0001	0100	0111	0000	0000	0000	1000	0000	6
	20	0000	0000	0000	0000	0000	0100	0000	0000	1
	23	0000	0000	0000	0000	0000	0000	0000	0000	0
10/10/87	02	0000	0000	0000	0000	0000	0000	0000	0000	0
	05	0000	0000	0000	0000	0000	0000	0000	0000	0
	08	0000	0000	0000	0000	0000	0000	0000	0000	0
	11	0000	0000	0000	0000	0000	0100	0000	0000	1
	14	0000	0000	0000	0000	0000	0000	0000	0000	0
	17	0000	0000	0000	0000	0000	0000	0000	0000	0
	20	0000	0000	0000	0100	0000	0000	0000	0000	1
	23	0000	0000	0000	0000	0000	0000	0000	0000	0
11/10/87	02	0000	0000	0000	0000	0000	0000	0000	0000	0
	05	0000	0000	0000	0000	0000	0000	0000	0000	0
	08	0001	0100	0000	0000	0000	0000	0000	0000	1
	11	0000	0000	0000	0000	0000	0000	0000	0000	0
	14	0000	0000	0000	0000	0000	0000	0000	0000	0
	17	0000	0000	0000	0000	0000	0100	0000	0000	0
	20	0001	0100	0001	0100	0000	0100	0000	0000	5
	23	0000	0000	0000	0000	0000	0000	0000	0000	0

APPENDIX R

Listings of Software Produced

The software falls into the following categories:

(a) Forth words for the Interface Processor, converting DIREC raw data to a form suitable for input to the EMI processors.

(b) Programs for translation of 3M tape cartridges to disk, editing and reformatting.

(c) Programs for listing and plotting results of (b).

(d) Programs for acquisition of data from Meteosat receiver onto disk, editing and reformatting.

(e) Programs for listing and plotting results of (d).

(f) Programs for editing and reformatting EMI processed wave data after translation from Sea Data cassette to disk.

(g) Programs for listing and plotting results of (f).

(h) Special versions to deal with Cromer DIREC/EMI intercomparison data.

(i) Programs for acquisition of data from portable test receiver, listing and plotting.

(a) FORTH Words for Interface Processor

```
( initialisation, allocation of RAM for array SCAN, etc. )
  DECIMAL
0 VARIABLE ANGLE 0 VARIABLE HORIZ 0 VARIABLE HV 0 VARIABLE DRDY
0 VARIABLE HH 0 VARIABLE HORN 0 VARIABLE SIN 0 VARIABLE COS
0 VARIABLE SCAN 20 ALLOT-RAM 0 VARIABLE CHNO 0 VARIABLE CHCT
  45056 CONSTANT BUFO

( minor manipulative words )
: PICK 1+ -2 * SP@ + @ ;
: 2SWAP ROT >R ROT >R ;
: 2OVER >R >R 2DUP R> R> 2SWAP ;
: GETD SCAN + @ ;

( ENTER sets stack up for main calculations )
( from bottom up, 2000*Hx,p,Hz,p,2000*Hy,Hz,r,r,Hx, Hy,Hz,p,r )
: ENTER 2000 2 GETD M* 8 GETD 6 GETD OVER 2000 4 GETD M*
6 GETD 10 GETD DUP 2 GETD 4 GETD 6 GETD 8 GETD 10 GETD ;
( ROOT, using ITER, is routine for 32 bit - 16 bit square root )
( by Newton's method )
: ITER 0 2OVER 2OVER DROP M/ ROT ROT 2DROP + 2/ ;
: ROOT 2DUP 2000 M/ SWAP DROP 1+ 12 DO ITER LOOP
  SWAP DROP SWAP DROP ;
```

```
( RES_3 calculates H_abs^2 = H_x^2 + H_y^2 + H_z^2)
: RES_3 DUP ROT DUP M* 2SWAP M* D+ ROT DUP M* D+ ;
( PRANG calculates ANGLE = root of 4000000 - p^2 - r^2)
: PRANG 2DUP DUP ROT DUP M* 2SWAP M* D + 4000000. 2SWAP D- ROOT ;
( TRANS calculates H_z*ANGLE/2000 )
: TRANS DUP ANGLE ! 3 PICK 2000 */ ROT ROT ;
( TRANS1 calculates r*H_y/2000 and p*H_x/2000 )
: TRANS1 4 PICK 2000 */ SWAP 5 PICK 2000 */ ;
( TRANS2 calculates HORIZ = (p*H_x  -r*H_y)/2000 ) 9
( and HV = HORIZ +H_z*ANGLE/2000 )
: TRANS2 SWAP - DUP HORIZ ! + HV ! RES_3 ;
( TRANS3 calculates HH = root of HABS2-HV*HV )
: TRANS3 HV @ DUP M* D- ROOT HH ! ;
( TRANS4,5 calculate HORN = HORIZ/(2000+ANGLE) )
: TRANS4 HORIZ @ 2000 DUP ANGLE @ + */ ;
: TRANS5 DUP HORN ! ;
( TRANS6,7,8 calculate SIN and COS )
: TRANS6 M* 2SWAP M* D+ D+ ;
: TRANS7 HH @ M/ SIN ! DROP ;
: TRANS8 HORN @ M* 2SWAP M* D+ D- HH @ M/ COS ! DROP ;

( COMPUTE is complete routine for SIN and COS calculation )
: COMPUTE ENTER PRANG TRANS TRANS1 TRANS2
  TRANS3 TRANS4 TRANS5 TRANS6 TRANS7
  TRANS8 ;
( output of data to D-A convertor )
: STORE SCAN + @ 2048 + SWAP BUFO + ! ;
: OUTPUT 0 0 STORE
  2 8 STORE
  4 10 STORE
  6 12 STORE
  SIN @ 2048 + BUFO 8 + !
  COS @ 2048 + BUFO 10 + ! ;
( LSCAN used for test only in acquisition loop )
( to output received data to RS232 )
: LSCAN 20 DO I SCAN + @ . CR 2 +LOOP ;

( acquisition/synchronisation loops )
: START 0 DRDY !
  BEGIN 0 CHCT ! 0 CHNO !
  BEGIN
  BEGIN CHNO @ 1 = IF CHCT ! THEN
( test for EMI sync - update D-As )     2 ?EF IF 0 BUFO 12 + ! 0
  DRDY ! THEN
  BEGIN
( test for received data word ready )
  BEGIN 3 ?EF UNTIL
( load l.s. and m.s. data bytes )
  64 1 P!
  SP! 2 P@ 4 P@ DUP 127 > UNTIL
( mask out CHNO )
```

```
  DUP 112 AND 2/ 2/ 2/ 2/ CHNO !
( mask out data and convert to 16 bit word )
  15 AND 256 * + 2048 -
( store in SCAN array, increment CHCT )
  CHNO @ 1- 2* SCAN + ! CHCT @ 1+ CHCT !
( until CHNO =7 )
  CHNO @ 7 = UNTIL
( and CHCT = 7 )
  CHCT @ 7 = UNTIL
( update D-As if EMI sync not received since last data scan )
  1 DRDY @ = IF 0 BUFO 12 + ! THEN
( compute SIN and COS and reset DRDY flag )
  COMPUTE OUTPUT 1 DRDY ! SP! AGAIN ;
```

Note: SCAN array holds the received data in the following order

SCAN+0 Heave Displacement m.s.byte

SCAN+1 Heave Displacement l.s.byte

SCAN+2 H_x m.s.byte

SCAN+3 H_x l.s.byte

SCAN+4 H_y m.s.byte

SCAN+5 H_y l.s.byte

SCAN+6 H_z m.s.byte

SCAN+7 H_z l.s.byte

SCAN+8 Pitch (p) m.s.byte

SCAN+9 Pitch (p) l.s.byte

SCAN+10 Roll (r) m.s.byte

SCAN+11 Roll (r) l.s.byte

SCAN+12 Heave Acceleration m.s.byte

SCAN+13 Heave Acceleration l.s.byte

Calculations use 16 bit and 32 bit precision, with appropriate normalisation of quantities, giving 16 bit offset binary SIN and COS outputs

i.e. BUFO+8 = m.s.byte of 2048*(1+sine(buoy heading))

BUFO+9 = l.s.byte of 2048*(1+sine(buoy heading))

BUFO+10 = m.s.byte of 2048*(1+cosine(buoy heading)

BUFO+11 = m.s.byte of 2048*(1+cosine(buoy heading) (b.1) Program TD - 3M Tape to Disk Transfer

```
  1REM 3M Tape to Disk Transfer Prog.
  2REM Alter skips in line 1230 to 17 for Flamborough 128 harmonic data
  5*DIR $.RECORDS
 10OSBYTE=&FFF4
 20OSFIND=&FFCE
 30OSBPUT=&FFD4
 40OSWRCH=&FFEE
 50MODE3
 60DIM data 256
 70DIM mc% 500
 80FOR opt%=0 TO 2 STEP 2
 90P%=mc%
100[
110OPT opt%
210.loop1
220LDA#&80:LDX#&FF
230JSR OSBYTE
240TXA
250BEQ rx
260.tx
270LDA#&91:LDX#0
280JSR OSBYTE
290CPY#&20
300BNE notctlq
310LDA#&11
320TAY
330.notctlq LDA#&8A:LDX#2
340JSR OSBYTE
350.rx
360LDA#&80:LDX#&FE
370JSR OSBYTE
380TXA
390BEQ loop1
400LDA#&91:LDX#1
410JSR OSBYTE
420TYA
430AND#&7F
440JSR OSWRCH
450CMP&85
460BNE notn
470STA&84
480LDA&81
490BNE test
500LDA#0:STA&80:LDA#1:STA&81:LDA&84
510JMP notn
520.test
530LDA&83
540BNE abort
550LDA&84
560LDA&84
```

```
570.notn LDX&80
580STA data,X
590CPX#&FF
600BEQ save
610.cont
620INC&80
630JMP loop1
640.save
650LDA&81
660BEQ cont
670LDX#0
680LDY&82
690.loop2
700LDA data,X
710JSR OSBPUT
720CPX#&FF
730BEQ setflag
740INX
750JMP loop2
760.setflag
770LDA#1:STA&83
780JMP cont
790.abort
800LDA#&8A:LDX#2
810LDY#19:JSR OSBYTE
820LDX#2:LDY#16:JSR OSBYTE
830LDY&82
840LDX#0
850.loop3
860LDA data,X
870JSR OSBPUT
880CPX&80
890BEQ end
900INX
910JMP loop3
920.end
930LDA#0:LDY&82
940JSR OSFIND
950RTS
960.init
970LDA#0:STA&80:STA&81:STA&82:STA&83
980LDA#15:LDX#0
990JSR OSBYTE
1000LDA#&80:LDX#0:LDY#&0B
1010JSR OSFIND
1020STA&82
1030CMP#0
1040BEQ abort
1045RTS
1050]
1060NEXT opt%
1070*FX2,2
```

```
1080*FX7,7
1090*FX8,7
1100*FX203,10,0
1110INPUT"Enter start file name",st$
1120st1$=LEFT$(st$,2):r%=VAL(RIGHT$(st$,4))
1130REPEAT
1140A$=st1$+STR$(r%):PRINT"File ";A$
1150A%=138:X%=2:Y%=14:CALL OSBYTE
1160 M=&0B00
1170$M=A$+CHR$(13)
1180K$="M"
1190VDU7:PRINT'"Press <SPACE BAR> to start"
1200?&85=ASC(K$)
1210CALL init
1212FOR V%=0 TO 5000:NEXT
1214*FX138,0,32
1220 CALL loop1
1230 FOR skip%=0 TO 7
1240A%=138:X%=2:Y%=14:CALL OSBYTE
1250FORN%=0 TO 3000:NEXT
1260NEXT skip%
1270PROCtitle
1280r%=r%+1
1290 UNTIL FALSE
1300DEF PROCtitle
1310CLS
1320X=OPENIN A$
1330B$="":C$=""
1340FOR N%=1 TO 252
1350B$=B$+CHR$(BGET#X)
1360NEXT
1370VDU2
1380PRINT'"File ";A$
1390PRINT B$
1391VDU3
1410CLOSE#X
1415FOR D%=1 TO 1000:NEXT
1420ENDPROC
```

(b.2) Program LFINS - Corrects LF characters after editing with WORDWISE-PLUS

```
  1REM Prog. to correct LF chars
  2REM in Wavec RECORD files after
  3REM editing by Wordwise Plus
 10DIM data 10000
 20DIM C 30
 30INPUT"ENTER FILE TO BE TRANFERRED",A$
 90X=OPENIN("$.RECORDS."+A$)
100L%=EXT#(X):PRINT"LENGTH OF FILE=";L%
110CLOSE#0
120$C="LOAD"+CHR$(34)+"$.RECORDS."+A$+CHR$(34)+STR$~data
130PRINT$C
140X%=C MOD 256
150Y%=C DIV 256
160CALL &FFF7
170FOR N%=0 TO L%:IF ?(data+N%)=124 ?(data+N%)=10
175NEXT
230$C="SAVE"+CHR$(34)+"$.RECORDS."+A$+CHR$(34)+STR$~data+CHR$(43)+STR$~L%
240X%=C MOD 256
250Y%=C DIV 256
260CALL &FFF7
270END
```

(b.3) Program DATMOD - Corrects faulty header time/date data

```
  1REM Program for altering faulty real time clock data
  2REM in header of Tape Cartridge Files
  3REM File must be in RECORDS Directory
  5*DIR $.RECORDS
 10 INPUT"FILE TO MODIFY ..CR",F$
 12IF F$="" F$=STR$(VAL(L$)+1):PRINTF$
 14L$=F$
 20X=OPENUP("CR"+F$)
 25W$=""
 30FOR A=68 TO 78
 40PTR#X=A
 50W$=W$+CHR$(BGET#X)
 60NEXT
 70PRINTW$
 90 INPUT"ENTER NEW DATE/TIME",E$
100 IF E$="" ELSE W$=E$
110FOR A=68 TO 78
120PTR#X=A
130BPUT#X,ASC(MID$(W$,A-67,1))
140NEXT
150CLOSE#X
160GOTO10
```

(b.4) Program MAIN4 - Produces dayfiles from individual $1\frac{1}{2}$ hourly files

```
  10REM Program to combine 16 Wavec Records into 1 Dayfile (ADFS version)
  20REM Output File on Winchester Directory DAYFILES
  30REM Input Files on Winchester Directory RECORDS
  40REM vn.4
  50*KEY 0 *DIR $.DAYFILES  M
  60*KEY 1 *DESTROY CR
  70*KEY 2 *DIR $.RECORDS  M
  80*KEY 3 *DIR $.WAVEC  M
  90*KEY 4 CH."$.WAVEC.MAIN4"
 100*KEY 5 CH."$.UTILITIES.A2ACOPY"  M
 110*KEY 6 *CLOSE  M
 120*KEY 7 *ADFS  M *MOUNT 0  M
 130 ON ERROR PROCerror
 140CLOSE#0
 150MODE7
 160DIM CON% 20
 170DIM C 20
 180DIM CON% 20
 190DIM D 20
 200V$=CHR$(255)
 210*LOAD"$.WAVEC.DUMFILE" 4C00
 220PRINTTAB(0,21)CHR$(151);STRING$(39,"p"):PRINTTAB(0,22)CHR$(130);CHR$(157);
    CHR$(135);
 225PRINT" f0   f1   f2   f3   f4   f5   f6"
 230PRINTTAB(0,23)CHR$(130);CHR$(157);CHR$(135);"DayF WIPE Recs Wvec RUN
    COPY CLOSE"
 240VDU28,0,19,39,0
 250PROCdate
 260CLS
 270VDU2:VDU1,12:PRINT TAB(0,0)"Day File Name: ";F$:PRINT:VDU3
 280X=OPENOUT("$.DAYFILES."+F$)
 290SF$="......":Q%=1:ND%=0
 300PRINTTAB(0,1)"Files transferred so far are :"
 310PROCblocks
 320PTR#X=EXT#X
 330FOR R%=Q% TO 16
 340PRINTTAB(0,10)" Enter Drive on which data is situated"
 350PRINTTAB(1,12)"Press <RETURN> for Current Drive (";ND%;")"
 360PRINTTAB(0,13)"( 99 for Dummy File/Missing Record )"
 370INPUT X$:IF X$<>"" ND%=VAL(X$)
 380IF ND%=99 PROCdummy:L%=149:PROCsave(&4C00):GOTO660
 390PRINT TAB(0,10)SPC(5);"Selected Source Drive is ";ND%;SPC(10)
 400IF ND%<>0 PROCdrive(ND%)
 410PRINTTAB(0,12)"    Enter filename for transfer";SPC(12)
 420PRINTTAB(0,13)SPC(38);
 430PRINTTAB(0,14)"Press <RETURN> for consecutive file"
 440 PRINTTAB(0,16)"(Last file was ";SF$;")"
 450INPUT X$
 460IF X$<>"" SF$=X$:GOTO 480
 470SF$=LEFT$(SF$,2)+STR$(VAL(MID$(SF$,3,4))+1)
```

```
480PRINTTAB(0,12)SPC(7);"Selected File is ";SF$;SPC(10)
490PRINTTAB(0,14)SPC(160);
500Y=OPENUP("$.RECORDS."+SF$)
510L%=EXT#Y
520CLOSE#Y
530IF L%<>6805 AND L%<>0 PRINTTAB(0,18)"Data File Wrong Length";
   :PROCdelay:GOTO 1260
540$C="LOAD"+CHR$(34)+"$.RECORDS."+SF$+CHR$(34)+" 3000"
550X%=C MOD 256
560Y%=C DIV 256
570CALL&FFF7
580IF ?&3008<>&0A PRINTTAB(0,17)CHR$(157);CHR$(132);"File contains instead of
   line feed"
585IF ?&3008<>&0A PRINTTAB(0,18)CHR$(157);CHR$(132);"Correct using prog. LFINS ";
   :END
590PROCtime
600$C=""
610FOR char=0 TO 16
620$C=$C+CHR$(?(&303E+char))
630NEXT
640IF $C=LEFT$($&4C3E,17) GOTO 650
645PRINTTAB(0,17)CHR$(157);CHR$(132);"File has wrong Date/Time"
   :PROCdelay:GOTO 1260
650PROCsave(&3000)
660SOUND1,-6,53+2*R%,2
670 RR%=R%-1
680PRINTTAB(10*(RR%MOD4),2+2*(RR%DIV4))CHR$(130);CHR$(157);CHR$(135);
   SF$;CHR$(156);
690FOR D%=0 TO 5000:NEXT
700PRINTTAB(0,14)SPC(200);
710NEXT
720CLOSE#0
730VDU2
740$C="INFO $.DAYFILES."+F$
750X%=C MOD 256
760Y%=C DIV 256
770PRINTTAB(0,17);
780CALL&FFF7
790VDU3
800END
810DEF PROCdate
820CLS
830PRINTTAB(5,11)"Format YYYY/MM/DD"
840INPUT TAB(0,10)"Enter date ",D$
850F$="C"+MID$(D$,3,2)+MID$(D$,6,2)+RIGHT$(D$,2)
860REM filename for day file
870 D$="*"+LEFT$(D$,4)+" "+MID$(D$,6,2)+"-"+RIGHT$(D$,2)
880REM for dummy file
890CLS
900ENDPROC
910DEF PROCdummy
920SF$="Dummy "
```

```
930PROCtime
940INPUT TAB(0,15)"Enter r.m.s. Height (cm) in Format NNNN",L$
950$&4C8E=L$
960ND%=0
970PRINTTAB(0,15)SPC(40)
980ENDPROC
990DEF PROCsave(S%)
1000?CON%=X
1010CON%!1=S%
1020CON%!5=L%-1
1030CON%!9=PTR#X
1040X%=CON% MOD 256
1050Y%=CON% DIV 256
1060A%=1
1070CALL&FFD1
1080H$=""
1090IF S%=&4C00 H$=H$+"Dummy"
1100FOR N1%=63 TO 78
1110H$=H$+CHR$(?(S%+N1%))
1120NEXT
1130VDU2:PRINTTAB(0,17)H$:VDU3
1140ENDPROC
1150DEF PROCdrive(D%)
1160$D="MOUNT "+STR$(D%)
1170X%=D MOD 256
1180Y%=D DIV 256
1190CALL&FFF7
1200ENDPROC
1210DEF PROCerror
1220IF ERR=&D6 GOTO 1250
1230IF ERR=&C4 GOTO 1260
1240CLS:PRINTTAB(1,10)"Error Number ";ERR;" at line ";ERL:END
1250PRINTTAB(0,17)CHR$(136)"File not found"
1260PRINTTAB(0,18)"Re-enter Drive and Filename";
1270SF$=LEFT$(SF$,2)+STR$(VAL(MID$(SF$,3,4))-1)
1280FOR Z%=0 TO 15000:NEXT
1290PRINTTAB(0,17)SPC(80);
1300Q%=R%:CLOSE#0
1310PROCdrive(0)
1320X=OPENUP("$.DAYFILES."+F$)
1330GOTO320
1340ENDPROC
1350DEF PROCblocks
1360FOR BL%=0 TO 15
1370PRINTTAB(10*(BL%MOD4),2+2*(BL%DIV4))CHR$(147);"wssssss{"
1380NEXT
1390ENDPROC
1400DEF PROCdelay
1410FOR D%=0 TO 5000:NEXT
1420ENDPROC
1430DEF PROCtime
1440hour=15*(R%-1)+5
```

```
1450IF hour MOD 10 >1 min$="30" ELSE min$="00"
1460hour=INT(0.1*hour)
1470IF hour<10 hour$="0"+STR$(hour) ELSE hour$=STR$(hour)
1480$&4C3E=D$+" "+hour$+":"+min$
1490?&4C4F=32
1500ENDPROC
```

(b.5) Program DUMFILE - Dummy file for filling gaps due to missing data files

The ASCII Dummy File WAVEC.DUMFILE is used by MAIN4 when there is no Spectral Data File available

```
wavec.dumfile
0000 4D 4F 4E 49 54 4F 52 0D MONITOR.
0008 0A 30 30 20 30 30 30 30 .00 0000
0010 20 30 30 30 30 20 30 30  0000 00
0018 30 30 20 30 30 30 30 20 00 0000
0020 30 30 30 30 20 30 30 30 0000 000
0028 30 20 30 30 30 30 20 30 0 0000 0
0030 30 30 30 0D 0A 43 51 20 000..CQ
0038 44 41 54 41 0D 0A 2A 31 DATA..*1
0040 39 38 36 20 4D 4D 2D 44 986 MM-D
0048 44 20 48 48 3A 4D 4D 20 D HH:MM
0050 5B 33 30 20 30 33 20 30 [30 03 0
0058 39 5D 0D 0A 30 30 30 30 9]..0000
0060 2C 30 30 30 30 2C 30 30 ,0000,00
0068 30 30 2C 30 30 30 30 2C 00,0000,
0070 30 30 30 30 2C 30 30 30 0000,000
0078 30 2C 30 30 30 30 2C 30 0,0000,0
0080 30 30 30 2C 30 30 30 30 000,0000
0088 2C 30 30 30 30 2C 30 30 ,0000,00
0090 30 30 0D 0A 30 ** ** ** 00..0...
```

(b.6) Program A2ACOPY - Fast copy of floppy disk ADFS data files to hard disk

```
  1REM Program for transferring Floppy Disk ADFS Cromer Files
  2REM to Winchester RECORDS Directory using only one
  3REM look at the Floppy Directory (saves Drive/Disk wear)
 10*ADFS
 20*MOUNT 0
 30MODE7
 40DIM buffer% 10000
 50DIM block% 30:DIM b% 40
 60DIM S%(47):DIM L%(47):DIM F%(47)
 70DIM cat$(47)
 80np%=0
 90MODE7
100CLS:PRINT SPC(3);CHR$(141);CHR$(131);CHR$(157);CHR$(132);
105PRINT"ADFS to ADFS File Transfer  ";CHR$(156);CHR$(137)
110PRINT SPC(3);CHR$(141);CHR$(131);CHR$(157);CHR$(132);
115PRINT"ADFS to ADFS File Transfer  ";CHR$(156);CHR$(137)
120INPUT TAB(0,10)"Enter ADFS Floppy Drive Number(4]5)",nd%
130INPUT"Enter Start File number: CR",n1%
140INPUT"Enter Finish File number: CR",n2%
150PRINT TAB(4,2)CHR$(131);CHR$(157);CHR$(132);"Copying CR";STR$(n1%);" to CR";
155PRINTSTR$(n2%);SPC(4);CHR$(156);CHR$(137):VDU28,0,24,39,3
160CLS
170PROCread(2,1280)
180PROCcat
190PROCfind
200PROCsort
210PROCtxfr
220GOTO90
230DEF PROCread(s%,n%)
240block%?0=0
250block%!1=buffer% AND &FFFF
260block%?5=&08
270block%?6=32*nd% OR s% DIV 65536:r%=s% MOD 65536
280block%?7=r% DIV 256
290block%?8=r% MOD 256
300block%?9=&00
310block%?10=&00
320block%!11=n%
330A%=&72
340X%=block% MOD 256
350Y%=block% DIV 256
360CALL&FFF1
370ENDPROC
380DEF PROCsave
390F$=LEFT$(cat$(F%(N%)),6)
400PRINT'CHR$(129);CHR$(157);CHR$(135);"Writing ";F$
410PRINT
420PROCfile
430np%=1
440ENDPROC
```

```
450DEF PROCcat
460FOR entry%=0 TO 46
470cat$(entry%)=""
480FOR c%=0 TO 9
490cat$(entry%)=cat$(entry%)+CHR$(?(buffer%+26*entry%+c%+5)AND&7F)
500NEXT
510NEXT
520ENDPROC
530DEF PROCfind
540FOR fn%=n1% TO n2%
550ff%=0
560PRINT'"Finding CR";STR$(fn%)
570FOR entry%=0 TO 46
580IF LEFT$(cat$(entry%),6)<>"CR"+STR$(fn%) GOTO 640
585fp%=entry%:PRINT'"Position ";fp%+1;" in catalogue":ff%=1:ffp%=buffer%+26*fp%
590S%(fn%-n1%)=?(27+ffp%)+256*?(28+ffp%)+65536*?(29+ffp%)
600PRINT"Start Sector=";S%(fn%-n1%);
610L%(fn%-n1%)=!(23+ffp%)
620PRINT" Length=";L%(fn%-n1%);" bytes"
630F%(fn%-n1%)=fp%
640NEXT
650IF ff%<>1 PRINT"Not Found!"
660NEXT
670FOR d%=0 TO 15000:NEXT
680ENDPROC
690DEF PROCtxfr
700CLS
710FOR N%=0 TO n2%-n1%
720bl%=L%(N%)
730l%=1+(bl% DIV 256)
740PRINT'CHR$(130);CHR$(157);CHR$(135);"Reading";LEFT$(cat$(F%(N%)),6);
745PRINT" (";STR$(l%);" sectors)"
750s%=S%(N%)
760PROCread(s%,bl%)
770PROCsave
780NEXT
790ENDPROC
800DEF PROCsort
810CLS:PRINTTAB(16,12)"SORTING"
820IF n2%-n1%=0 ENDPROC
830REPEAT
840flag%=0
850FOR pos%=0 TO n2%-n1%-1
860IF S%(pos%)>S%(pos%+1) PROCswitch
870NEXT
880UNTIL flag%=0
890ENDPROC
900DEF PROCswitch
910temp%=S%(pos%):S%(pos%)=S%(pos%+1):S%(pos%+1)=temp%
920temp%=L%(pos%):L%(pos%)=L%(pos%+1):L%(pos%+1)=temp%
930temp%=F%(pos%):F%(pos%)=F%(pos%+1):F%(pos%+1)=temp%
940ENDPROC
```

```
 950DEF PROCfile
 960$b%=":0.$.RECORDS."+F$+CHR$(13)
 970block%?0=b% MOD 256
 980block%?1=b% DIV 256
 990block%!2=0
1000block%!6=0
1010block%!10=buffer% AND &FFFF
1020block%!14=(buffer%+bl%) AND &FFFF
1030A%=0
1040CALL&FFDD
1050ENDPROC
```

(b.7) Program DADCOPY - Fast copy of floppy disk DFS data files to hard disk

```
  1REM Program to transfer Floppy Disk DFS Files
  2REM to Winchester RECORDS Directory using only one
  3REM look at the Floppy Catalogue (saves Drive/Disk wear)
 10*ADFS
 20*MOUNT 0
 30ON ERROR IF ERR=17 CHAIN"$.WAVEC.MAIN4" ELSE REPORT
 40DIM buffer% 8000
 50DIM block% 30:DIM b% 40
 60DIM S%(30):DIM L%(30):DIM F%(30)
 70np%=0
 80MODE7
 90CLS:PRINT SPC(3);CHR$(141);CHR$(131);CHR$(157);CHR$(132);
 95PRINT"DFS to ADFS File Transfer  ";CHR$(156);CHR$(137)
100PRINT SPC(3);CHR$(141);CHR$(131);CHR$(157);CHR$(132);
105PRINT"DFS to ADFS File Transfer  ";CHR$(156);CHR$(137)
110INPUT TAB(0,10)"Enter DFS Drive Number(0]3)",nd%
120INPUT"Enter Start File number: CR",n1%
130INPUT"Enter Finish File number: CR",n2%
140PRINT TAB(4,2)CHR$(131);CHR$(157);CHR$(132);"Copying CR";STR$(n1%);
145PRINT" to CR";STR$(n2%);SPC(3);CHR$(156);CHR$(137):VDU28,0,24,39,3
150CLS
160*DISC
170PROCread(0,0,2,0)
180PROCcat
190PROCfind
200PROCsort
210PROCtxfr
220GOTO 80
230DEF PROCread(tr%,s%,n%,off%)
240block%?0=nd%
250block%!1=(buffer%+off%)AND&FFFF
260block%?5=3
270block%?6=&53
280block%?7=tr%
290block%?8=s%
300block%?9=&20+n%
310A%=&7F
320X%=block% MOD 256
330Y%=block% DIV 256
340CALL&FFF1
350ENDPROC
360DEF PROCsave
370PROCsel
380F$=MID$(cat$,fp%-7,7)
390PRINT'CHR$(129);CHR$(157);CHR$(135);"Writing ";F$;" ADFS"
400PRINT
410PROCfile
420np%=1
430ENDPROC
440DEF PROCcat
```

```
450cat$=""
460FOR c%=8 TO 255
470cat$=cat$+CHR$(?(buffer%+c%))
480NEXT
490ENDPROC
500DEF PROCfind
510FOR fn%=n1% TO n2%
520PRINT'"Finding CR";STR$(fn%)
530fp%=INSTR(cat$,"CR"+STR$(fn%))+7
540PRINT'"Position ";STR$(fp%/8);" in catalogue"
550S%(fn%-n1%)=256*(?(buffer%+&106+fp%)AND&03)+?(buffer%+&107+fp%)
560PRINT"Start Sector=";S%(fn%-n1%);ffp%=buffer%+fp%
570L%(fn%-n1%)=4096*(?(&106+ffp%)AND&30)+256*(?(&105+ffp%))+?(&104+ffp%)
580PRINT" Length=";L%(fn%-n1%);" bytes"
590F%(fn%-n1%)=fp%/8
600NEXT
610FOR d%=0 TO 15000:NEXT
620ENDPROC
630DEF PROCtxfr
640CLS
650FOR N%=0 TO n2%-n1%
660fp%=8*F%(N%)
670off%=0:soff%=0
680bl%=L%(N%)
690l%=1+(bl% DIV 256)
700PRINT'CHR$(130);CHR$(157);CHR$(135);"Reading";MID$(cat$,fp%-7,7);
705PRINT" (";STR$(l%);" sectors) DFS"
710REPEAT
720tr%=(S%(N%)+soff%) DIV 10
730s%=(S%(N%)+soff%) MOD 10
740IF soff%+10>l% n%=l%-soff% ELSE n%=10-s%
750PRINT"Track:";STR$(tr%);:PRINTTAB(10)"Sectors:";STR$(s%);"]";STR$(s%+n%);
760PROCread(tr%,s%,n%,off%)
770off%=off%+256*n%
780soff%=soff%+n%
790PRINT TAB(24)"Sector Total:";soff%
800UNTIL soff%=l%
810PROCsave
820NEXT
830ENDPROC
840DEF PROCsort
850CLS:PRINTTAB(16,12)"SORTING"
860IF n2%-n1%=0 ENDPROC
870REPEAT
880flag%=0
890FOR pos%=0 TO n2%-n1%-1
900IF S%(pos%)>S%(pos%+1) PROCswitch
910NEXT
920UNTIL flag%=0
930ENDPROC
940DEF PROCswitch
950temp%=S%(pos%):S%(pos%)=S%(pos%+1):S%(pos%+1)=temp%
```

```
 960temp%=L%(pos%):L%(pos%)=L%(pos%+1):L%(pos%+1)=temp%
 970temp%=F%(pos%):F%(pos%)=F%(pos%+1):F%(pos%+1)=temp%
 980ENDPROC
 990DEF PROCsel
1000IF np%<>0 PROCfurther:ENDPROC
1010*ADFS
1020ENDPROC
1030DEF PROCfurther
1040*ADFS
1050ENDPROC
1060DEF PROCfile
1070$b%=":0.$.RECORDS."+F$+CHR$(13)
1080block%?0=b% MOD 256
1090block%?1=b% DIV 256
1100block%!2=0
1110block%!6=0
1120block%!10=buffer% AND &FFFF
1130block%!14=(buffer%+bl%) AND &FFFF
1140A%=0
1150CALL&FFDD
1160*DISMOUNT
1170ENDPROC
```

(c.1) Program MOD - Plots E, Theta 1 and Theta 2 vs frequency from data files created by TD

```
   1REM Program to plot Displacement Energy (C11)
   2REM Mean Direction (Theta1) and Directional Spread (Theta2)
   3REM against frequency, from 0 to 0.64Hz
  10MODE4
  30DIM MC% 300
  40DIM data 110
  50DIM header 260
  60DIM D 20
  70VDU23,239,0,0,1,1,1,1,0,0
  80VDU23,240,0,24,37,37,29,9,16,0
  90VDU23,241,6,201,41,38,32,32,192,0
 100VDU23,242,0,152,165,153,165,165,152,0
 110VDU23,243,0,60,133,137,17,33,160,0
 120VDU23,244,0,3,4,0,3,4,7,0
 130VDU23,245,0,24,161,57,165,165,24,0
 140VDU23,246,0,3,4,1,0,4,3,0
 150VDU23,247,0,0,1,0,0,0,0,0
 151VDU23,248,0,24,36,36,36,36,24,0
 152VDU23,249,248,128,128,241,130,130,250,2
 153VDU23,250,0,0,0,70,169,169,169,166
 154VDU23,251,0,0,0,34,20,8,20,162
 160OSBGET=&FFD7:OSFIND=&FFCE:OSWRCH=&FFEE
 170FOR opt%=0 TO 2 STEP 2
 180P%=MC%
 190[.init
 200OPT opt%
 210LDA#&40:LDX#0:LDY#&0B
 220JSR OSFIND
 230STA&0B10
 240CMP#0
 250BEQabort
 260LDX#0:LDY&0B10
 270.head
 280CLC
 290JSR OSBGET
 300BCC store
 310JMP abort
 320.store
 330STAheader,X
 340CPX#251
 350BEQ abort
 360INX
 370JMP head
 380.read
 390LDX#0:LDY&0B10
 400.energy
 410JSR OSBGET
 420 STAdata,X
 430CPX#103
```

```
440BEQ fin
450INX
460JMP energy
470.abort
480RTS
490.fin
500RTS
510]
520NEXT opt%
530M=data:N=&0B00
540$D="DIR $.RECORDS"
550X%=D MOD 256
560Y%=D DIV 256
570CALL &FFF7
580CLS
590INPUT TAB(0,10)"Enter Run Number alphabetic prefix (e.g. CR)",P$
600INPUT"Enter Start Run Number suffix (e.g. 203)",n1
610INPUT"Enter Finish Run Number suffix (e.g. 217)",n2
620CLS
630@%=&10309
640FOR N%=n1 TO n2:$N=P$+STR$(N%)+CHR$(13)
660CLS
670PRINT TAB(13,31)"Plotting ";$N;
675PRINTTAB(30,30)"Ch.Ratio";
680VDU5
682RESTORE
685FOR p%=0 TO 2
690PROCsquare(p%)
695NEXT
697VDU4
700CALL init
710PROCheadwr
720VDU4
725C11M=1E-4*VAL(LEFT$($(header+240),10))
727cscale=1000/C11M
730FOR HARM%=2 TO 126 STEP 2
740omg=0.101936799*(0.01*PI*HARM%)^2
745REM i.e. omega squared over 'g'
750CALL read
760REM IFHARM%<6 GOTO0820
770C11=1E-4*VAL(MID$($data,5,10)):A11=C11*omg^2
775REM  converts C11 to metres squared per Hz, giving A11 in 'g' squared per Hz
777REM 0.25E-6 required since slopes have scaling factor of 2000
780C22=0.25E-6*VAL(MID$($data,16,10))
790C33=0.25E-6*VAL(MID$($data,27,10))
800omg=omg*0.5E-5
805REM 0.5E-5 converts heave slope cross spectra to metres x radians per Hz
810C12=-VAL(MID$($data,38,10))*omg
820Q12=-VAL(MID$($data,49,10))*omg
830C13=VAL(MID$($data,60,10))*omg
840Q13=VAL(MID$($data,71,10))*omg
850C23=-0.25E-6*VAL(MID$($data,82,10))
```

```
860Q23=-0.25E-6*VAL(MID$($data,93,10))
870den=SQR(A11*(C22+C33)):A1=Q12/den:B1=Q13/den:A2=(C22-C33)/(C22+C33)
   :B2=2*C23/(C22+C33)
880R=SQR(A11/(C22+C33))
885PRINTTAB(30,31)R;
890IF A1>0 TH1=DEG(ATN(B1/A1))
900IF B1<0 TH1=DEG(ATN(B1/A1))+360
910IF A1<0 TH1=180+DEG(ATN(B1/A1))
920IF A2>0 TH12=DEG(ATN(B2/A2))
930IF A2<0 TH12=DEG(ATN(B2/A2))+360
940IF A2<0 TH12=180+DEG(ATN(B2/A2))
950C1=SQR(A1*A1+B1*B1):S1=C1/(1-C1):TH2=DEG(SQR(2-2*C1))
960C2=SQR(A2*A2+B2*B2):S2=(1+3*C2+SQR(1+14*C2+C2*C2))/(2*(1-C2))
970REM Only C11, TH1 and TH2 plotted but other parameters calculated in case
   required
985PROCplot(0,C11*cscale)
990PROCplot(1,2.778*TH1)
995PROCplot(2,11.11*TH2)
1000NEXT
1005PRINT TAB(24,24)CHR$(249);CHR$(250);CHR$(251);"=";C11M
1007PRINT TAB(13,31)SPC(18);
1010CLOSE#0
1020IF p% MOD 4<>3 AND N%<>n2 GOTO1120
1060*LOAD"$.UTILITIES.DUMPCL" 0A00
1065PRINTTAB(30,30)SPC(9);:PRINTTAB(30,31)SPC(9);
1070CALL&0A00
1080X%=D MOD 256
1090Y%=D DIV 256
1100CALL &FFF7
1110VDU2,1,12,3
1120NEXT
1130END
1140DEF PROCsquare(p%)
1150READx%,y%
1160MOVEx%,y%:PROCsq(p%)
1170ENDPROC
1220DEF PROCplot(p%,y)
1230GCOL4,1
1240GOTO (1250+10*p%)
1250PLOT69,96+4*HARM%,552+0.432*y:ENDPROC
1260PLOT69,752+4*HARM%,552+0.432*y:ENDPROC
1270PLOT69,96+4*HARM%,70+0.432*y:ENDPROC
1290ENDPROC
1300DEF PROCheadwr
1320PRINT TAB(24,18)"Cromer Wavec"
1325PRINT TAB(24,19) LEFT$($(header+63),16)
1326PRINT TAB(24,21)"C11, Theta1 and"
1327PRINT TAB(24,22)"Theta2 vs Freq."
1328PRINT TAB(24,24)"0 to 0.64 Hz"
1330ENDPROC
1340DEF PROCsq(p%)
1350PLOT1,512,0
```

```
1360PLOT1,0,-432
1370PLOT1,-512,0
1380PLOT1,0,432
1385IF p%=0 GOTO1455
1387IF p%=2 GOTO1451
1390PLOT0,-96,-416:VDU32,239,241
1400PLOT0,-96,108:VDU32,240,241
1410PLOT0,-96,108:VDU247,242,241
1420PLOT0,-96,108:VDU244,243,241
1430PLOT0,-96,108:VDU246,245,241:PLOT0,416,-24:PRINT"Th1"
1450ENDPROC
1451PLOT0,-96,-416:VDU32,239,241
1452PLOT0,-96,432:VDU32,240,241:PLOT0,416,-24:PRINT"Th2"
1454ENDPROC
1455PLOT0,-96,-416:VDU32,32,248
1456PLOT0,-96,432:VDU249,250,251:PLOT0,416,-24:PRINT"Cl1"
1457ENDPROC
1460 FOR T%=0 TO 2000:NEXT:CLS
1500DATA 96,984,752,984,96,502,752,502
```

(c.2) Program WAVSER3 - Plots series of up to 16 consecutive Energy Spectra from data files

```
  1REM Program to plot time series of Energy Spectra
  2REM (up to 16 in number (1 day's worth))
  3REM with optional rescaling and screendump
 10*DIR $.RECORDS
 20MODE1
 30scale=0.05
 40N%=10
 50DIM MC% 300
 60DIM T$(30)
 70DIM data 20
 80DIM D 20
 90OSBGET=&FFD7:OSFIND=&FFCE:OSWRCH=&FFEE
100FOR opt%=0 TO 3 STEP 3
110P%=MC%
120[.init
130OPT opt%
140LDA#&40:LDX#0:LDY#&0B
150JSR OSFIND
160STA&0B10
170CMP#0
180BEQabort
190LDX#0:LDY&0B10
200.head
210CLC
220JSR OSBGET
230BCC store
240JMP abort
250.store
260CPX#251
270BEQ abort
280INX
290JMP head
300.read LDX#0:LDY&0B10
310.start
320CLC
330JSR OSBGET
340BCC put
350JMP abort
360.put
370CPX#3
380BEQ stuff
390INX
400JMP start
410.stuff
420LDX#0:LDY&0B10
430.energy
440JSR OSBGET
450 STAdata,X
460CPX#9
```

```
470BEQ gash
480INX
490JMP energy
500.gash
510INX
520LDA#13
530STA data,X
540INX
550LDA#10
560STA data,X
570LDX#0
580.fill
590JSR OSBGET
600CPX#89
610BEQ fin
620INX
630JMP fill
640.abort
650RTS
660.fin
670RTS
680]
690NEXT opt%
700M=data:N=&0B00
710x%=0:y%=0
720CLS
730INPUT TAB(0,10)"Enter Run Number alphabetic prefix (e.g. CR)",P$
740INPUT"Enter Start Run Number suffix (e.g. 203)",n1
750INPUT"Enter Finish Run Number suffix (e.g. 217)",n2
760CLS
770x%=0:y%=0
780FOR N%=n1 TO n2:$N=P$+STR$(N%)+CHR$(13):PRINT TAB(0,0) $N
790X=OPENIN("$.RECORDS."+$N)
800F%=BGET#X
810IF F%<>77 CLOSE#X:GOTO 950
820H$=""
830FOR B%=1 TO 250
840H$=H$+CHR$(BGET#X)
850NEXT
860T$(N%-n1)=MID$(H$,63,16)
870CLOSE#X
880CALL init
890MOVE x%,y%
900FOR HARM%=2 TO 126 STEP 2
910CALL read
920IFHARM%<6 GOTO940
930E%=VAL($data):PLOT5,8*HARM%+x%,scale*E%+y%
940NEXT
950y%=y%+50
960CLOSE#0
970NEXT
980PRINT TAB(0,0)"Energy Spectra"
```

```
 990PRINT TAB(0,1)"Cromer"
1000M%=0:REPEAT:PRINT TAB(0,2)T$(M%);:M%=M%+1:UNTIL T$(M%)<>""
1010PRINT TAB(17,2)" to ";
1020M%=n2-n1:REPEAT:PRINT TAB(21,2)T$(M%);:M%=M%-1:UNTIL T$(M%)<>""
1030PRINT TAB(0,3)"Scale OK <Y/N>?":V$=GET$
1040IF V$="Y" OR V$="y" GOTO 1110
1050REPEAT
1060PRINT TAB(0,3)"Scale ";scale;" Larger <L> or Smaller <S> or OK <Y> ?":V$=GET$
1070IF V$="L" OR V$="l" scale=scale*2
1080IF V$="S" OR V$="s" scale=scale/2
1090UNTIL V$="Y" OR V$="Y"
1100GOTO760
1110VDU2:PRINT:PRINT TAB(0,0)"Energy Spectra"
1120PRINT TAB(0,1)"Cromer"
1130M%=0:REPEAT:PRINT TAB(0,2)T$(M%);:M%=M%+1:JNTIL T$(M%)<>""
1140PRINT TAB(17,2)" to ";
1150M%=n2-n1:REPEAT:PRINT TAB(21,2)T$(M%);:M%=M%-1:UNTIL T$(M%)<>""
1160PRINT
1170PRINT TAB(0,3)"Scale=";scale;"   Time increases up paper";SPC(25)
1180VDU3
1190PRINTTAB(0,0)SPC(160)
1200*LOAD"$.WAVEC.DUMPCL" 0A00
1210CALL &0A00
1220VDU2,12,3
1230END
```

(c.3) Program DUMPCL - Screen dump routine for FX-80 dot matrix printer

The Machine Code Routine WAVEC.DUMPCL is used by MOD and WAVSER3 for producing Screen Dumps.

```
WAVEC.DUMPCL
0000 A9 1D 20 EE FF A9 00 A2 ). n.)."
0008 04 20 EE FF CA D0 FA A9 . n.JPz)
0010 5A 85 79 A9 0B 85 7A A9 Z.y)..z)
0018 02 20 EE FF A2 00 A9 24 . n.".)$
0020 85 70 A9 0B 85 71 A5 70 .p)..q%p
0028 18 69 06 85 70 95 7F E8 .i..p..h
0030 90 02 E6 71 A5 71 95 7F ..fq%q..
0038 E8 E0 10 90 E9 A9 FF 85 h'..i)..
0040 72 A9 03 85 73 A9 87 20 r)..s).
0048 F4 FF C0 03 B0 01 C8 98 t.@.0.H.
0050 6A B0 0B A9 04 8D 29 0B j0.)..).
0058 A9 02 85 8F D0 09 A9 08 )...P.).
0060 8D 29 0B A9 05 85 8F A0 .).)...
0068 00 A2 03 20 02 0B A9 00 .". ..).
0070 85 70 85 71 A0 03 A2 04 .p.q .".
0078 20 02 0B A2 04 8A 48 A2  .."..H"
0080 70 A0 00 A9 09 20 F1 FF p .). q.
0088 A9 0B A0 00 A2 74 20 F1 ). ."t q
0090 FF 68 AA A5 75 29 07 0A .h*%u)..
0098 95 7A A5 72 38 E9 04 85 .z%r8i..
00A0 72 B0 02 C6 73 CA D0 D5 r0.FsJPU
00A8 A4 8F A9 00 85 76 A2 04 $.)..v".
00B0 8A 48 B5 7A AA B5 7F 85 .H5z*5..
00B8 77 B5 80 85 78 B1 77 18 w5..x1w.
00C0 65 76 85 76 68 AA CA F0 ev.vh*Jp
00C8 06 06 76 06 76 90 E1 A5 ..v.v.a%
00D0 76 20 0C 0B 88 10 D3 18 v ....S.
00D8 AD 29 0B 65 70 85 70 90 -).ep.p.
00E0 02 E6 71 A5 71 C9 05 F0 .fq%qI.p
00E8 0D A9 10 18 65 72 85 72 .)..er.r
00F0 90 89 E6 73 B0 85 A9 0A ..fs0.).
00F8 20 0C 0B A5 73 30 18 4C  ..%s0.L
0100 6E 0A B1 79 20 0C 0B C8 n.1y ..H
0108 CA D0 F7 60 48 A9 01 20 JPw'H).
0110 EE FF 68 20 EE FF 60 A0 n.h n.'
0118 07 A2 04 20 02 0B A9 03 .". ..).
0120 20 EE FF 60 00 00 00 00  n.'....
0128 00 00 00 00 00 00 00 00 ........
0130 00 02 01 00 02 01 00 01 ........
0138 03 00 02 03 00 01 00 00 ........
0140 02 00 03 01 03 03 02 03 ........
0148 02 03 02 01 03 01 02 01 ........
0150 02 01 02 01 03 03 03 03 ........
0158 03 03 1B 41 08 1B 4C C0 ...A..L@
0160 03 1B 74 ** ** ** ** ** ..t.....
```

(c.4) Program MODFL - Prints summarised directional wave parameters

```
 10REM Program derives Hs, Tp,Th1p,Th2p parameters from WAVEC data files
 20REM and prints out summary information
 30REM Files must be 64 averaged harmonics
 40MODE7
 50DIM N 30
 60INPUT TAB(0,10)"Enter Run Number alphabetic prefix (e.g.CR)"
 70INPUT TAB(16,12),P$
 80PRINT TAB(0,14)"Enter Start Run Number suffix (e.g. 203)"
 90INPUT TAB(16,16),n1
100PRINT TAB(20,18)"Enter Finish Run Number suffix (e.g. 217)"
110INPUT TAB(16,20),n2
120VDU2:PRINT''''
130PRINT TAB(0,4)"Year";SPC(2);"Month-Day";SPC(2);"Hr(GMT)";SPC(3);"Hs";SPC(6);
140PRINT"Tp";SPC(6);"THp";SPC(5);"Emax";SPC(4);"Spr"
150PRINT
160VDU3
170VDU28,0,23,39,8
180CLS
190VDU2
200IF n2=0 THEN n2=n1
210@%=&20207
220 FOR N%=n1 TO n2
230$N="LOAD"+CHR$(34)+"$.RECORDS."+P$+STR$(N%)+CHR$(34)+" 3600"
240X%=N MOD 256
250Y%=N DIV 256
260CALL&FFF7
270H$=""
280FORN1%=0 TO 251
290H$=H$+CHR$(?(&3600+N1%)):NEXT
300IF LEFT$(H$,1)="M" GOTO 340
310CLOSE#0
320PRINT"Missing Record"
330GOTO 490
340CMAX=0
350FOR HARM%=2 TO 126 STEP 2
360PROCenergy
370IF C11>CMAX AND HARM%>6  CMAX=C11:HP=HARM%:hp=HP+1
380NEXT HARM%
390CLOSE#0
400PROCtp
410PROCemax
420PROCthp
430PROCspr
440PROChs
450@%=&01020206
460PRINTMID$(H$,64,4);SPC(4);MID$(H$,69,5);SPC(5);MID$(H$,75,5);FNJUST
   (hs);SPC(1);
470PRINTFNJUST(tp);SPC(2);FNJUST(THP);SPC(1);FNJUST(EMAX);SPC(1);FNJUST(SPR)
480@%=&10
490NEXT
```

```
500PRINT''''
510VDU3:END
520DEF PROCtp
530tp=1/(.005*hp)
540ENDPROC
550DEF PROCemax
560EMAX=1E-4*CMAX
570ENDPROC
580DEF PROCthp
590PROCcalculate
600THP=TH1
610ENDPROC
620DEF PROCspr
630SPR=TH2
640ENDPROC
650DEF PROChs
660hs=0.04*VAL(MID$(H$,230,10))
670ENDPROC
680DEF PROCcalculate
690omg=0.00101936799*(0.01*PI*hp)^2
700D$="":DN$=""
710FORN2%=1 TO 104
720D$=D$+CHR$(?(&3600+147+52*HP+N2%)):DN$=DN$+CHR$(?(&3600+251+52*HP+N2%))
730NEXT
740C11=CMAX:A11=C11*(omg^4)/(9.81^2)
750C22=0.5*(VAL(MID$(D$,16,10))+VAL(MID$(DN$,16,10)))
760C33=0.5*(VAL(MID$(D$,27,10))+VAL(MID$(DN$,27,10)))
770Q12=-0.5*(omg^2)*(VAL(MID$(D$,49,10))+VAL(MID$(DN$,49,10)))/9.81
780Q13=0.5*(omg^2)*(VAL(MID$(D$,71,10))+VAL(MID$(DN$,71,10)))/9.81
790C23=-0.5*(VAL(MID$(D$,82,10))+VAL(MID$(DN$,82,10)))
800den=SQR(A11*(C22+C33)):A1=Q12/den:B1=Q13/den
810IF A1=0 TH1=180-90*SGN(B1)
820IF A1>0 TH1=DEG(ATN(B1/A1))
830IF B1<0 TH1=DEG(ATN(B1/A1))+360
840IF A1<0 TH1=180+DEG(ATN(B1/A1))
850TH1=TH1-6.475
860IF TH1<0 TH1=TH1+360
870C1=SQR(A1*A1+B1*B1):TH2=DEG(SQR(2-2*C1))
880 ENDPROC
890DEF PROCenergy
900C$="":CN$=""
910FOR ch%=0TO 9
920C$=C$+CHR$(?(&3600+147+52*HARM%+5+ch%)):CN$=CN$+CHR$(?(&3600+251+52
   *HARM%+5+ch%))
930NEXT
940C11=0.5*(VAL(C$)+VAL(CN$))
950ENDPROC
960DEF FNJUST(p)
970p$=STR$(p)
980z=INSTR(p$,".")
990sp$="":FOR n=0 TO 4-z:sp$=sp$+" ":NEXT
1000=sp$+p$
```

(d.1) Program LOG - Meteosat Receiver to Disk Transfer

```
  1REM Program to acquire Meteosat Messages from Protolog MRU
  2REM (Message Recovery Unit)
  3REM Enters IDs of Dogger Bank Unit (IOS2), DB2A/B, DB3A/B and Bidston TG (IOS1)
  4REM Files messages in ADFS Directories
  5REM Use MET.LIST to list Files
 10 ON ERROR PROCerror
 20DIM data 800
 30 DIM C 30
 40DIM D 2
 50DIM MN$(10):DIM CT%(10)
 60DIM MC% 50
 70DIM FC%(10)
 80VDU23,255,255,255,255,255,255,255,255,255
 90MODE3
100CLS:R$="Y":@%=&10
110PROCinit
120PROCassemble
130CLS
140PROCselect
150*FX15,0
160REPEAT
170PROCsend("SO")
180PROCreceive
190COLOUR 0:COLOUR 129
200IF MID$(ST$,2,1)<>"S" COLOUR128:ST$=STRING$(60,"0")
210IF MID$(ST$,9,1)="1" CA$="OFF " ELSE CA$=" ON "
220VDU28,0,24,79,0
230PRINTTAB(29,21)"Status Information:-"
240PRINTTAB(0,22)"Carrier ";CA$;TAB(15);CHR$(255);"nrbad";FNstat(37);TAB(30);
245PRINTCHR$(255);"nrgood ";FNstat(44);TAB(45);CHR$(255);"nrfilt";FNstat(50);
   TAB(60);CHR$(255);
250NF%=VAL(FNstat(50)):PROCsend("S1"):PROCreceive
255IF MID$(ST$,2,1)<>"S" COLOUR128:ST$=STRING$(60,"0")
260PRINT"nrferr ";FNstat(5);TAB(75);CHR$(255)
270PRINTTAB(0,23)"nrabort ";FNstat(11);TAB(15);CHR$(255);"nrslip";FNstat(18);
   TAB(30);
275PRINTCHR$(255);"nrcrcc ";FNstat(24);TAB(45);CHR$(255);"testtot";FNstat(31);
   TAB(60);
277PRINTCHR$(255);"testerr ";FNstat(37);TAB(75);CHR$(255);
280COLOUR 1:COLOUR 128
290PRINT TAB(31,14)"Messages received: ";NF%:PRINT TAB(31,16)"Messages filed:
   ";mc%
300VDU28,0,24,79,0
310COLOUR 0:COLOUR129:PRINTTAB(0,20)SPC(27);"METEOSAT LOGGING SYSTEM";SPC(28);
315PRINTTAB(0,19)"Files created:-";CHR$(255);
320FOR list%=1 TO 10
325IF MN$(list%)="" GOTO330 ELSE PRINT MN$(list%);"";CT%(list%);"(";
   FC%(list%)+CT%(list%);")";CHR$(255);
330NEXT
340COLOUR 1:COLOUR 128:VDU28,0,18,79,0
```

```
350PROCdelay
360IF NF%>mc% CLS:PROCmessage:PROCsave
370PROCmanual
380PROCdelay
390UNTIL FALSE
400END
410DEF PROCinit
420*FX15,0
430FOR S%=0 TO 10:MN$(S%)="":CT%(S%)=0:NEXT
440mc%=0
450*FX2,1
460*FX7,4
470*FX8,4
480VDU28,0,20,79,0
490ENDPROC
500DEF FNdec($D)
510CALL conv
520=?&80
530DEF PROCsend(M$)
540M$="*"+M$+CHR$(13)
550FOR N%=1 TO LEN(M$)
560A%=138:X%=2:Y%=ASC(MID$(M$,N%,1)):CALL&FFF4
570NEXT
580ENDPROC
590DEF PROCreceive
600ST$=""
610REPEAT
620IF ADVAL(-2)>0 THEN ST$=ST$+CHR$(GET)
630UNTIL RIGHT$(ST$,1)=CHR$(10)
640ENDPROC
650DEF PROCmessage
660ptr%=0
670PROCsend("L")
680PROCreceive
690PRINTST$;
700E%=LEN(ST$)-1
710FOR N%=0 TO E%
720?(data+N%)=ASC(MID$(ST$,N%+1,1))
730NEXT
740ptr%=N%
750 chan%=VAL(MID$(ST$,7,2))
760date$=MID$(ST$,24,3)+MID$(ST$,28,2)
770E%=INT(0.5+(VAL(MID$(ST$,38,3)))/16)
780FOR L%=1 TO E%
790PROCsend("L")
800PROCreceive
810PRINTST$;CHR$(11);
820FOR CH%=9 TO 43 STEP 2
830IF MID$(ST$,CH%,1)=CHR$(32) CH%=CH%+1
840byte%=FNdec(MID$(ST$,CH%,2))
850 ?(data+ptr%)=byte%:ptr%=ptr%+1
860IF MID$(ST$,CH%,2)=CHR$(47)+CHR$(13) CH%=43:ptr%=ptr%-1
```

```
870NEXT
880PRINT
890NEXT
900PROCsend("J0")
910PRINTST$
920ENDPROC
930DEF PROCselect
940RESTORE 1540
950REPEAT
960READ AN$
970READ ID$
980READ MN$:IF VAL(AN$)<100 MN$(VAL(AN$))=MN$
990IF LEN(AN$)>2 PROCcompile:PRINTAN$:PROCdelay:ENDPROC
1000PROCsend("D"+AN$+"/"+ID$)
1010PROCreceive
1020IF R$="Y" OR R$="y" GOTO 1050
1030$C="CDIR $.MET."+MN$
1040X%=C MOD 256:Y%=C DIV 256:CALL&FFF7
1050IF VAL(AN$)<100 FC%(VAL(AN$))=FNfind(MN$)
1060IF FC%(VAL(AN$))=47 CLS:PRINTTAB(15,12)"Directory $.MET.";MN$;
    "is FULL":PROCend
1070UNTIL AN$="999"
1080$C="DIR $":X%=C MOD 256:Y%=C DIV 256:CALL&FFF7
1090ENDPROC
1100DEF PROCsave
1110IF chan%=0 ENDPROC
1120RESTORE (1550+10*chan%)
1130READ MN$
1140$C="SAVE"+CHR$(34)+"$.MET."+MN$+"."+date$+CHR$(34)+""+STR$µdata+" +"+STR$µptr%
1150X%=C MOD 256:Y%=C DIV 256:CALL &FFF7
1160CT%(chan%)=CT%(chan%)+1
1170mc%=mc%+1
1180ENDPROC
1190DEF PROCmanual
1200*FX15,0
1210*FX2,0
1220*FX229,0
1230CLS
1240PRINTTAB(10,12)"Press space bar to enable 20 sec of communication with
    Protolog"
1250IF INKEY(1000)=-1 GOTO1370
1260CLS
1270TIME=0
1280*FX2,2
1290REPEAT
1300A%=138:X%=2
1310IF ADVAL(-1)>0 AND ADVAL(-3)>0 THEN Y%=GET:CALL&FFF4
1320*FX2,1
1330IF ADVAL(-2)>0 THEN VDU GET
1340*FX2,2
1350UNTIL FALSE OR TIME=2000
1360CLS
```

```
1370PRINTTAB(10,12)"Enter revised count of filed records if required";SPC(15);
1380T$="":TRY%=1
1390REPEAT:G$=INKEY$(200):PRINTG$;:T$=T$+G$:TRY%=TRY%+1:UNTIL TRY%=5
1400IF T$<>"" mc%=VAL(T$)
1410*FX2,1
1420*FX229,1
1430*FX15,0
1440CLS
1450ENDPROC
1460DEF PROCdelay
1470FOR N%=0 TO 10000
1480NEXT
1490ENDPROC
1500DEF PROCcompile
1510PROCsend("C"):PROCdelay
1520*FX21,1
1530ENDPROC
1540DATA01,1680231C,DOG,02,1681719A,DB2A,03,1681811E,DB2B,04,16819268,DB3A
1545DATA05,1681A7F2,DB3B,06,16814400,BIDS,999,00000000,DUMM
1550DATA"DUMM"
1560DATA"DOG"
1570DATA"DB2A"
1580DATA"DB2B"
1590DATA"DB3A"
1600DATA"DB3B"
1610DATA"BIDS"
1620DEF PROCerror
1630PRINT"ERROR LINE ";ERL;"  ERROR CODE ";ERR
1640*FX2,0
1650*FX229,0
1660END
1670ENDPROC
1680DEF PROCassemble
1690FOR opt%=0 TO 2 STEP 2
1700P%=MC%
1710[
1720OPT opt%
1730 .conv
1740 LDA D
1750 AND#&7F:ROL A:BPL dec1
1760 ADC#&12
1770 .dec1
1780 AND#&1E:ROL A:ROL A:ROL A:STA&80
1790 LDA D+1:AND#&7F
1800 ROL A:BPL dec2
1810 ADC#&12
1820 .dec2
1830 AND#&1E:ROR A:ADC&80
1840 STA&80
1850 RTS
1860]
1870NEXT
```

```
1880ENDPROC
1890DEF FNstat(N%)
1900=STR$(FNdec(MID$(ST$,N%,2))+256*FNdec(MID$(ST$,N%+3,2)))
1910DEF FNfind(D$)
1920IF D$="" flag%=0:GOTO1990
1930$C="DIR $.MET."+D$:X%=C MOD 256:Y%=C DIV 256:CALL&FFF7
1940D%=&1205
1950FOR file%=0 TO 47
1960IF file%=47 =file%
1970IF (?(D%+26*file%) AND &7F)=0 Z%=file%:file%=47:flag%=1  ELSE flag%=0
1980NEXT
1990IF flag%=1 =Z% ELSE =0
2000DEF PROCend
2010*FX2,0
2020*FX229,0
2030END
2040ENDPROC
```

(d.2) Program LIST - Lists formatted Meteosat Data

```
  1REM Program to list files generated by MET.LOG
 10INPUT"ENTER FILE TO BE LISTED",F$
 20X=OPENIN(F$)
 21M$=""
 22FOR CH%=1 TO 61
 23M$=M$+CHR$(BGET#X)
 24NEXT
 25PTR#X=&004B
 26PRINTM$
 28REM E%=VAL(MID$(M$,38,3))
 30REM FOR CH%=1 TO E%
 35REPEAT
 40X%=BGET#X
 45IF X%>128 X%=X%-128
 50 IF X%>31 AND X%<128 PRINTCHR$(X%);:GOTO80
 70 IF X%=13 OR X%=10 PRINTCHR$(X%);:GOTO80
 80REM NEXT
 85UNTIL EOF#X
 90PRINT
100*CLOSE
110END
```

(d.3) Program DBDEC - Reformats 3 x Hourly Metosat messages to directional spectra C11 ... etc.

```
    1REM Program to abstract Spectral Data from
    2REM three consecutive Meteosat Files
    3REM starting with a 3*N hour file (N=0 to 7)
    4REM Spectra are saved in $.RECORDS.C11 . . etc. as appropriate
    5REM
   10INPUT"ENTER FILENAME OF FIRST DB TYPE FILE ",F$
   20IF VAL(RIGHT$(F$,2)) MOD 3 >0.1 PRINT"NOT A 3-HOUR START FILE!":GOTO 10
   30 FOR F%=0 TO 2
   40HR$=STR$(VAL(RIGHT$(F$,2))+F%)
   50IF LEN(HR$)=1 HR$="0"+HR$
   60FF$=LEFT$(F$,LEN(F$)-2)+HR$:PRINT"Processing ";FF$
   70X=OPENIN(FF$)
   80RESTORE(10000+F%)
   90FOR SP%=1 TO 2
  100READ SP$,off%
  110Y=OPENOUT("$.RECORDS."+SP$):PTR#X=off%
  120SPEC$=""
  130FOR N%=1 TO 202
  140M%=BGET#X AND &7F
  150IF (M%>47 AND M%<71) SPEC$=SPEC$+CHR$(M%)
  160NEXT
  170IF LEN(SPEC$)<>164 PRINT"ERROR":END
  180FOR N%=0 TO 160 STEP 4
  190exp=2^(VAL(MID$(SPEC$,N%+3,1)))
  200char4=FNhex(MID$(SPEC$,N%+4,1))
  210IF char4>7 sign%=-1:char4=char4-8 ELSE sign%=1
  220MANT=sign%*(256*char4+16*FNhex(MID$(SPEC$,N%+1,1))+FNhex(MID$
     (SPEC$,N%+2,1)))
  230spec%=exp*MANT
  240PRINT#Y,spec%
  250NEXT
  260CLOSE#Y
  270NEXT
  280CLOSE#X
  290NEXT
  300PRINT"Done"
  310END
  320DEF FNhex(S$)
  330IF ASC(S$)>57 S$="1"+CHR$(ASC(S$)-17)
  340=VAL(S$)
10000DATA "C11",&00EB,"C22",&01BA
10001DATA "C33",&00EB,"Q12",&01BA
10002DATA "Q13",&00EB,"C23",&01BA
```

(e.1) Program CPLOT2 - Plots E, Theta 1 and Theta 2 vs frequency from files created by DBDEC

```
  1REM Plots E, theta1, theta2 vs freq
  2REM for data files C11,C22,C33,etc in
  3REM RECORDS directory.
  4REM NB. Version for Meteosat data (41 harmonics)
  6MODE1
  7PRINT"DB or Marex (D or M)":R$=GET$:CLS
  8IF R$="M" fudge%=-1:sc%=4 ELSE fudge%=1:sc%=1
 10@%=&20205
 20U=OPENIN("$.RECORDS.C11")
 30V=OPENIN("$.RECORDS.C22")
 40W=OPENIN("$.RECORDS.C33")
 50 X=OPENIN("$.RECORDS.Q12")
 60Y=OPENIN("$.RECORDS.Q13")
 70PROCsquare(140,512,"C11"):PROCsquare(660,512,"TH1")
 75PROCsquare(140,0,"TH2"):PROCsquare(660,0,"R")
 80MAX=0
 85lastc=0
 90FOR N%=1 TO 41
 95afreq=2*PI*(0.04875+0.01*(N%-1))
100INPUT#U,C11
105C11=sc%*C11
110IF C11/(afreq^4)>MAX AND N%>2 MAX=C11/(afreq^4)
120NEXT
130PTR#U=0
140FOR N%=1 TO 41
145afreq=2*PI*(0.04875+0.01*(N%-1))
150INPUT#U,C11:INPUT#V,C22:INPUT#W,C33:INPUT#X,Q12:INPUT#Y,Q13
155C11=C11*sc%:Q12=Q12*SQR(sc%):Q13=Q13*SQR(sc%)
160IF C11=0 TH2=90:GOTO200
170den=SQR(C11*(C22+C33)):IF den=0 GOTO 240
180Q12=fudge%*Q12:Q13=fudge%*Q13:A1=Q12/den:B1=Q13/den
190C1=SQR(A1^2+B1^2):IF C1>1 C1=lastc ELSE lastc=C1
195TH2=DEG(SQR(2-2*C1))/90
200DIRN=FNDIR(Q13,Q12)
205IF (C22+C33)=0 C22=1
210x1=140+12.5*(N%-1):x2=660+12.5*(N%-1):x3=x1:x4=x2
220y1=512+500*C11/(MAX*afreq^4):y2=512+500*DIRN/360:y3=512*TH2
225y4=256*SQR(C11/(C22+C33)):IF y4>500 y4=500:IF y1>1012 y1=1012
230PROCplot(1,x1,y1):PROCplot(2,x2,y2):PROCplot(3,x3,y3):PROCplot(4,x4,y4)
240NEXT
250*CLOSE
260*LOAD"$.WAVEC.DUMPCL" 0A00
270 CALL &0A00
275VDU2,1,12,3
280END
290DEF FNDIR(P,Q)
300IF Q=0 AND P<0 =270
310IF Q=0 AND P>=0 =90
320IF Q<0 =180+DEG(ATN(P/Q))
```

```
330IF P<0 =360+DEG(ATN(P/Q)) ELSE =DEG(ATN(P/Q))
440DEF PROCsquare(m%,n%,T$)
445VDU5
450MOVE m%,n%
460PLOT1,500,0:PLOT1,0,500
470PLOT1,-500,0:PLOT1,0,-500
475PLOT0,400,470:PRINTT$:VDU4
480ENDPROC
490DEF PROCplot(s%,x,y)
500IF N%=1 GOTO 530
505IF NOT (s%=2 AND ABS(y-lasty2)>250) GOTO 510
506MOVE lastx2,lasty2:DRAW lastx2,512+500*INT((lasty2-262)/500)
507lasty2=512+500*INT(y/512-.5)
510ON s% GOTO 511,512,513,514
511MOVE lastx1,lasty1:GOTO520
512MOVE lastx2,lasty2:GOTO520
513MOVE lastx3,lasty3:GOTO520
514MOVE lastx4,lasty4
520PLOT5,x,y
530ON s% GOTO 531,532,533,534
531lastx1=x:lasty1=y:ENDPROC
532lastx2=x:lasty2=y:ENDPROC
533lastx3=x:lasty3=y:ENDPROC
534lastx4=x:lasty4=y:ENDPROC
```

(f.1) Program DIGIDEC - Reformats EMI processed wave tape data to directional spectra C11 ... etc.

```
  1REM Program to abstract Spectra from an edited
  2REM SeaData Processed Wave tape
  3REM The SeaData tape must be translated to 1/2" Digidata tape
  5REM and each file then transferred to a BBC file, e.g. 23/10/11
  6REM The file must then be edited using Wordwise
  7REM into a new file containing only the spectral data
  8REM from the F001 to F004 records
  9REM
 10INPUT"Enter Full File Name for Decomposition"',F$
 15VDU2:PRINTF$:VDU3
 20X=OPENIN(F$)
 30FOR SP%=0 TO 8
 40READ SP$
 50PTR#X=SP%*204
 60Y=OPENOUT("$.RECORDS."+SP$)
 70FOR N%=1 TO 51
 75WD$=""
 80FOR CH%=1 TO 4
 90WD$=WD$+CHR$(BGET#X)
100NEXT
110exp%=2^FNhex(MID$(WD$,3,1))
120char4=FNhex(MID$(WD$,4,1))
130IF char4>7 sign%=-1:char4=char4-8 ELSE sign%=1
140MANT=sign%*(256*char4+16*FNhex(MID$(WD$,1,1))+FNhex(MID$(WD$,2,1)))
150C%=exp%*MANT
160PRINT#Y,C%
165PRINTC%
170NEXT
180CLOSE#Y
190PRINT"END OF SPECTRUM"
200NEXT
210PRINT"FINISHED"
220CLOSE#X
230END
240DATA "C11","C22","C33","C12","Q12","C13","Q13","C23","Q23"
300DEF FNhex(S$)
310IF ASC(S$)>57 S$="1"+CHR$(ASC(S$)-17)
320=VAL(S$)
```

(f.2) Program PARTENTZ - Computes H_s from C11 spectrum from n^{th} harmonic upwards

```
10REM Calculates Hs of Full C11 spectrum
20REM and of spectrum with low frequency
30REM errors cut out
40DIM A%(60)
50F$="$.RECORDS.C11"
60@%=&1040A
70PRINTCHR$(14)
80PRINT"  FREQ";SPC(6);"ENERGY"
90X=OPENIN(F$)
100SP%=0
110FOR N%=1 TO 51
120INPUT#X,A%(N%)
130IF N%<49 w=2*PI*(.01*N%-.00125) ELSE w=2*PI*(.50875+.05*(N%-49))
140PRINTw/(2*PI),A%(N%)/w^4
150NEXT
160PRINT"END OF SPECTRUM"
170PRINT"FINISHED"
180CLOSE#X
190INPUT"Enter lowest harmonic for Hs calc.",n1%
200energy1=0:energy2=0:energy3=0:energy4=0
210FOR N%=1 TO 51
220IF N%>3 AND N%<49energy1=energy1+A%(N%)/(2*PI*(.01*N%-.00125))^4
225IF N%>3 AND N%<49energy3=energy3+A%(N%)/(2*PI*(.01*N%-.00125))^2
230IF N%>48 energy1=energy1+5*A%(N%)/(2*PI*(.50875+.05*(N%-49)))^4
235IF N%>48 energy3=energy3+5*A%(N%)/(2*PI*(.50875+.05*(N%-49)))^2
240IF N%>(n1%-1) AND N%<49energy2=energy2+A%(N%)/(2*PI*(.01*N%-.00125))^4
245IF N%>(n1%-1) AND N%<49energy4=energy4+A%(N%)/(2*PI*(.01*N%-.00125))^2
250IF N%>48 energy2=energy2+A%(N%)/(2*PI*(.50875+.05*(N%-49)))^4
255IF N%>48 energy4=energy4+A%(N%)/(2*PI*(.50875+.05*(N%-49)))^2
260NEXT
265tz1=2*PI*SQR(energy1/energy3):tz2=2*PI*SQR(energy2/energy4)
270REM PRINT"energy ratio",100*energy2/energy1
280PRINT"Hs from TOTAL ENERGY",4*SQR(9.537E-6*energy1);SPC(2);
290PRINT"Hs from PART ENERGY",4*SQR(9.537E-6*energy2)
295PRINT"Tz from TOTAL ENERGY",tz1,'"Tz from PART ENERGY",tz2
300PRINTCHR$(15)
310VDU3
320END
330DATA "C11","C22","C33","C12","Q12","C13","Q13","C23","Q23"
340DEF FNhex(S$)
350IF ASC(S$)>57 S$="1"+CHR$(ASC(S$)-17)
360=VAL(S$)
```

(f.3) Program NOISEOUT - Removes "white noise" from C11, C22 and C33 spectra as determined by average of 1[st] to n[th] estimates

```
  1REM Removes (assumed) white noise from Spectral Data
  2REM by averaging spectral level over frequencies
  3REM below significant wave spectrum
  4REM (i.e. breakeven harmonic number)
 10INPUT"ENTER BREAKEVEN HARMONIC NUMBER",n1%
 20DIM A%(60)
 22FOR S%=1 TO 3
 24READ SP$
 30 X=OPENUP("$.RECORDS."+SP$)
 40SUM%=0
 50FOR N%=1 TO n1%-1
 60INPUT#X,SP%
 70SUM%=SUM%+SP%
 80NEXT
 90AV%=INT(0.5+SUM%/(n1%-1))
100PTR#X=0
110FOR N%=1 TO 51
120INPUT#X,A%(N%)
130A%(N%)=A%(N%)-AV%
140IF A%(N%)<0 A%(N%)=0
150NEXT
160PTR#X=0
170FOR N%=1 TO 51
180PRINT#X,A%(N%)
190NEXT
200CLOSE#X
210NEXT
220DATA "C11","C22","C33"
```

(g.1) Program CPLOT3 - Plots E, Theta 1 and Theta 2 vs frequency from files created by DIGIDEC

```
  1REM Plots E, theta1, theta2 vs freq
  2REM for data files C11,C22,C33,etc in
  3REM RECORDS directory.
  4REM NB. Version for Proc. Wave Tape data (51 harmonics)
  6MODE1
  7PRINT"DB or Marex (D or M)":R$=GET$:CLS
  8IF R$="M" fudge%=-1:sc%=4 ELSE fudge%=1:sc%=1
 10@%=&20205
 20U=OPENIN("$.RECORDS.C11")
 30V=OPENIN("$.RECORDS.C22")
 40W=OPENIN("$.RECORDS.C33")
 50 X=OPENIN("$.RECORDS.Q12")
 60Y=OPENIN("$.RECORDS.Q13")
 70PROCsquare(140,512,"C11"):PROCsquare(660,512,"TH1")
 75PROCsquare(140,0,"TH2"):PROCsquare(660,0,"R")
 80MAX=0
 85lastc=0
 90FOR N%=1 TO 51
 95IF N%<49 afreq=2*PI*(0.00875+0.01*(N%-1)) ELSE afreq=2*PI*(0.50875+0.05*(N%-49))
100INPUT#U,C11
105C11=sc%*C11
110IF C11/(afreq^4)>MAX AND N%>2 MAX=C11/(afreq^4)
120NEXT
130PTR#U=0
140FOR N%=1 TO 51
145IF N%<49 afreq=2*PI*(0.00875+0.01*(N%-1)) ELSE afreq=2*PI*(0.50875+0.05*(N%-49))
150INPUT#U,C11:INPUT#V,C22:INPUT#W,C33:INPUT#X,Q12:INPUT#Y,Q13
155C11=C11*sc%:Q12=Q12*SQR(sc%):Q13=Q13*SQR(sc%)
160IF C11=0 TH2=90:GOTO200
170den=SQR(C11*(C22+C33)):IF den=0 GOTO 240
180Q12=fudge%*Q12:Q13=fudge%*Q13:A1=Q12/den:B1=Q13/den
190C1=SQR(A1^2+B1^2):IF C1>1 C1=lastc ELSE lastc=C1
195TH2=DEG(SQR(2-2*C1))/90
200DIRN=FNDIR(Q13,Q12)
205IF (C22+C33)=0 C22=1
210x1=140+10*(N%-1):x2=660+10*(N%-1):x3=x1:x4=x2
220y1=512+500*C11/(MAX*afreq^4):y2=512+500*DIRN/360:y3=512*TH2
225y4=256*SQR(C11/(C22+C33)):IF y4>500 y4=500:IF y1>1012 y1=1012
230PROCplot(1,x1,y1):PROCplot(2,x2,y2):PROCplot(3,x3,y3):PROCplot(4,x4,y4)
240NEXT
250*CLOSE
260*LOAD"$.WAVEC.DUMPCL" 0A00
270 CALL &0A00
275VDU2,1,12,3
280END
290DEF FNDIR(P,Q)
300IF Q=0 AND P<0 =270
310IF Q=0 AND P>=0 =90
320IF Q<0 =180+DEG(ATN(P/Q))
```

```
330IF P<0 =360+DEG(ATN(P/Q)) ELSE =DEG(ATN(P/Q))
440DEF PROCsquare(m%,n%,T$)
445VDU5
450MOVE m%,n%
460PLOT1,500,0:PLOT1,0,500
470PLOT1,-500,0:PLOT1,0,-500
475PLOT0,400,470:PRINTT$:VDU4
480ENDPROC
490DEF PROCplot(s%,x,y)
500IF N%=1 GOTO 530
505IF NOT (s%=2 AND ABS(y-lasty2)>250) GOTO510
506MOVE lastx2,lasty2:DRAW lastx2,512+500*INT((lasty2-262)/500)
507lasty2=512+500*INT(y/512-.5)
510ON s% GOTO 511,512,513,514
511MOVE lastx1,lasty1:GOTO 520
512MOVE lastx2,lasty2:GOTO 520
513MOVE lastx3,lasty3:GOTO 520
514MOVE lastx4,lasty4
520PLOT5,x,y
530ON s% GOTO 531,532,533,534
531lastx1=x:lasty1=y:ENDPROC
532lastx2=x:lasty2=y:ENDPROC
533lastx3=x:lasty3=y:ENDPROC
534lastx4=x:lasty4=y:ENDPROC
540IF s%=2 lastx2=x:lasty2=y:ENDPROC
550IF s%=3 lastx3=x:lasty3=y:ENDPROC
560IF s%=4 lastx4=x:lasty4=y:ENDPROC
```

(g.2) Program PPAR - Prints summarised directional wave parameters

```
 10REM Derives parameters
 20REM from data files C11,C22,C33,etc in
 30REM RECORDS directory.
 40REM NB. Version for TAPE DATA (51 estimates)
 50REM chains digidec
 60MODE3
 70PRINT"DB or Marex (D or M)":R$=GET$:CLS
 80IF R$="M" fudge%=-1:sc%=4 ELSE fudge%=1:sc%=1
 90@%=&20205
100U=OPENIN("$.RECORDS.C11")
110V=OPENIN("$.RECORDS.C22")
120W=OPENIN("$.RECORDS.C33")
130 X=OPENIN("$.RECORDS.Q12")
140Y=OPENIN("$.RECORDS.Q13")
150MAX=0
160lastc=0
170energy=0:velenergy=0
180FOR N%=1 TO 51
190IF N%<49 afreq=2*PI*(.01*N%-.00125)
200IF N%>48 afreq=2*PI*(.50875+.05*(N%-49))
210INPUT#U,C11
220IF N%>48 C11=C11*5
230IF C11/(afreq^4)>MAX AND N%>4MAX=C11/(afreq^4):fmax=afreq:nmax%=N%
240IF N%>4energy=energy+9.537E-6*C11/(afreq^4):velenergy=velenergy+9.537E-6*C11/
   (afreq^2)
250NEXT
255PTR#U=0:PTR#V=PTR#U:PTR#W=PTR#U:PTR#X=PTR#U:PTR#Y=PTR#U
260tz=2*PI*SQR(energy/velenergy)
270FOR N%=1 TO nmax%
280afreq=2*PI*(0.01*N%-.00125)
290INPUT#U,C11:INPUT#V,C22:INPUT#W,C33:INPUT#X,Q12:INPUT#Y,Q13:C11=C11
   *sc%:Q12=Q12*SQR(sc%):Q13=Q13*SQR(sc%)
300den=SQR(C11*(C22+C33)):IF den=0 GOTO 355
310Q12=fudge%*Q12:Q13=fudge%*Q13:A1=Q12/den:B1=Q13/den
320C1=SQR(A1^2+B1^2):IF C1>1 C1=lastc ELSE lastc=C1
330TH2=DEG(SQR(2-2*C1))
340DIRN=FNDIR(Q13,Q12)
350IF (C22+C33)=0 C22=1
355NEXT
360VDU2
370PRINT4*SQR(energy);SPC(2);tz;SPC(2);2*PI/afreq;SPC(2);9.537E-6*C11/
   (afreq^4);SPC(2);
380PRINTDIRN;SPC(2);TH2;SPC(2);SQR(C11/(C22+C33));SPC(2);
390Q12sum=0:Q13sum=0:th2sum=0:Rsum=0
400PTR#U=100:PTR#V=PTR#U:PTR#W=PTR#U:PTR#X=PTR#U:PTR#Y=PTR#U
410FOR N%=21 TO 26
420afreq=2*PI*(0.01*N%-.00125)
430INPUT#U,C11:INPUT#V,C22:INPUT#W,C33:INPUT#X,Q12:INPUT#Y,Q13:C11=C11
   *sc%:Q12=Q12*SQR(sc%):Q13=Q13*SQR(sc%)
440den=SQR(C11*(C22+C33)):IF den=0 GOTO 490
```

```
450Q12=fudge%*Q12:Q13=fudge%*Q13:A1=Q12/den:B1=Q13/den
460C1=SQR(A1^2+B1^2):IF C1>1 C1=lastc ELSE lastc=C1
470TH2=DEG(SQR(2-2*C1))
480Q12sum=Q12sum+Q12:Q13sum=Q13sum+Q13:th2sum=th2sum+TH2:Rsum=SQR
   (C11/(C22+C33))+Rsum
490NEXT
500DIRN=FNDIR(Q13sum,Q12sum)
510PRINTDIRN;SPC(2);th2sum/6;SPC(2);Rsum/6
520VDU3
530*CLOSE
540CHAIN"DIGIDEC"
550DEF FNDIR(P,Q)
560IF Q=0 AND P<0 =270
570IF Q=0 AND P>=0 =90
580IF Q<0 =180+DEG(ATN(P/Q))
590IF P<0 =360+DEG(ATN(P/Q)) ELSE =DEG(ATN(P/Q))
```

(h.1) Program MTABL2 - Prints summarised directional wave parameters

```
 10REM Lists spectral estimates and derived parameters
 20REM from data files C11,C22,C33,etc in
 30REM REC10.SP1 or SP4 directory.
 40REM Signs of Q12,Q13 reversed to account for
 50REM +disp up).
 60VDU2,1,15,1,48,3
 70@%=&10306
 80INPUT"Enter REC10 directory (SP1 or SP4)",SP$
 90IF SP$="SP1" T$="0900" ELSE IF SP$="SP4" T$="1800" ELSE GOTO 80
100SP$="$.REC10."+SP$
110MODE3
120VDU2:VDU1,27,1,45,1,1
130PRINT"EMI Processed Spectral Data and Derived Parameters from Cromer Trial";
140PRINTT$;"hrs 17/06/87";:VDU1,27,1,45,1,0:PRINT'
150PRINT"C11 in units of g";:VDU2,1,27,1,83,1,0,1,50,1,27,1,84
160PRINT"/Hz, C22 and C33 in units of rad";:VDU2,1,27,1,83,1,0,1,50,1,27,1,84
170PRINT"/Hz, Q12 and Q13 in units of g.rad/Hz"'
180PRINT"Direction Th1(M) and Spread Th2(M) from M = 1st and 2nd order
   angular harmonics ";
190PRINT"in degrees (zero when incalculable"':VDU1,27,1,45,1,1
200PRINT"Frequency";SPC(4);"C11";SPC(9);"C22";SPC(9);"C33";SPC(9);"Q12";
   SPC(9);"Q13";
210PRINTSPC(9);"C23";SPC(7);"Th1(1)";SPC(2);"Th1(2)";SPC(2);"Th2(1)";SPC(2);
   "Th2(2)";
220VDU1,27,1,45,1,0:PRINT'
230U=OPENIN("$.REC10.SP1.C11")
240V=OPENIN("$.REC10.SP1.C22")
250W=OPENIN("$.REC10.SP1.C33")
260X=OPENIN("$.REC10.SP1.Q12")
270Y=OPENIN("$.REC10.SP1.Q13")
280Z=OPENIN("$.REC10.SP1.C23")
290FOR N%=1 TO 41
300 FREQ=2*PI*(.01*(N%-1)+.04875)
310INPUT#U,C11:INPUT#V,C22:INPUT#W,C33:INPUT#X,Q12:INPUT#Y,Q13:INPUT#Z,C23
320C11=C11*(9.91E-6)*FREQ^4:C22=C22*2.384E-6:C33=C33*2.384E-6
330Q12=Q12*(4.861E-6)*FREQ^2:Q13=Q13*(4.861E-6)*FREQ^2:C23=C23*2.384E-6
340IF C11=0 TH21=0:TH22=0:FLAG=1:GOTO 390 ELSE FLAG=0
350den=SQR(C11*(C22+C33)):IF den=0 GOTO 510
360A1=Q12/den:B1=Q13/den
370C1=SQR(A1^2+B1^2):IF C1>1 C1=lastc ELSE lastc=C1
380S1=C1/(1-C1):TH21=DEG(SQR(2/(S1+1)))
390A2=(C22-C33)/(C22+C33):B2=2*C23/(C22+C33):C2=SQR(A2^2+B2^2)
400S2=(1+3*C2+SQR(1+14*C2+C2^2))/(2*(1-C2)):IF S2<=-1 GOTO 410 ELSE TH22=DEG
   (SQR(2/(S2+1)))
410DIRN2=0.5*FNDIR(2*C23,(C22-C33))
420DIRN1=FNDIR(Q13,Q12)
430IF (C22+C33)=0 C22=1
440@%=&20508:PRINTFREQ/(2*PI);SPC(2);
450@%=&10508:PRINTC11;SPC(2);C22;SPC(2);C33;SPC(1);
460PRINTFNsp(Q12);Q12;SPC(1);FNsp(Q13);Q13;SPC(1);FNsp(C23);C23;
```

```
470IF (DIRN1-DIRN2)>90 AND (DIRN1-DIRN2)<270 DIRN2=DIRN2+180
480IF (DIRN2-DIRN1)>90 DIRN2=DIRN2-180
490IF DIRN2<0 DIRN2=DIRN2+360
500@%=&20108:PRINTDIRN1,DIRN2,TH21,TH22
510NEXT
520*CLOSE
530VDU2,1,12,3
540END
550DEF FNDIR(P,Q)
560IF Q=0 AND P>0 =90
570IF Q=0 AND P<0 =270
580IF Q=0 AND P=0 =0
590IF Q<0 =180+DEG(ATN(P/Q))
600IF Q>0 AND P>0 =DEG(ATN(P/Q)) ELSE=360+DEG(ATN(P/Q))
610DEF FNsp(num)
620IF LEFT$(STR$(num),1)<>"-" =" " ELSE=""
```

(h.2) Program MUNDESLY - Plots E, Theta 1 and Theta 2 vs frequency
from results of Cromer EMI tests

```
 10REM Plots E, theta1, theta2 vs freq
 20REM for data files C11,C22,C33,etc in
 30REM RECORDS directory.
 40REM Signs of Q12,Q13 reversed to account for
 50REM +disp up).
 60REM Uses Printmaster ROM GDUMP (DUMPCL calls in brackets)
 70@%=&20205
 80MODE0
 85INPUT"Enter Time of Record (e.g. 09:00)",T$
 87CLS
 90U=OPENIN("$.RECORDS.C11")
100V=OPENIN("$.RECORDS.C22")
110W=OPENIN("$.RECORDS.C33")
120 X=OPENIN("$.RECORDS.Q12")
130Y=OPENIN("$.RECORDS.Q13")
140PROCsquare(96,552,"C11"):PROCsquare(752,552,"TH1"):PROCsquare(96,70,"TH2")
150PRINTTAB(50,19)"Cromer Wavec Data"
160PRINTTAB(50,21)"EMI Processor"
170PRINTTAB(50,23)"1987 06-17 09:00"
180PRINTTAB(50,24)"C11, Th1, Th2 vs Freq"
190PRINTTAB(50,26)"0 to 0.45 Hz"
200MAX=0
210lastc=0
220FOR N%=1 TO 41
230INPUT#U,C11
240C11=9.91E-6*C11
250IF C11>MAX AND N%>7 MAX=C11
260NEXT
270PTR#U=0
280FOR N%=1 TO 41
290 FREQ=2*PI*(.01*(N%-1)+.04875)
300INPUT#U,C11:INPUT#V,C22:INPUT#W,C33:INPUT#X,Q12:INPUT#Y,Q13
302C11=C11*(9.91E-6)*FREQ^4:C22=C22*2.384E-6:C33=C33*2.384E-6
304Q12=Q12*(4.861E-6)*FREQ^2:Q13=Q13*(4.861E-6)*FREQ^2:C23=C23*2.384E-6
310IF C11=0 TH2=1:FLAG=1:GOTO360 ELSE FLAG=0
320den=SQR(C11*(C22+C33)):IF den=0 GOTO 410
330A1=Q12/den:B1=Q13/den
340C1=SQR(A1^2+B1^2):IF C1>1 C1=lastc ELSE lastc=C1
350TH2=DEG(SQR(2-2*C1))/90
360DIRN=FNDIR(Q13,Q12)
370IF (C22+C33)=0 C22=1
380x1=144+11.6*(N%-1):x2=800+11.6*(N%-1):x3=x1:x4=x2
390y1=552+432*C11/(MAX*FREQ^4):y2=552+432*DIRN/360:y3=70+432*TH2:y4=70
   +216*SQR(C11/(C22+C33))
395IF y4>502 y4=502:IF y1>984 y1=984
400PROCplot(1,x1,y1):PROCplot(2,x2,y2):PROCplot(3,x3,y3)
410NEXT
420*CLOSE
430REM *LOAD"$.WAVEC.DUMPCL" 0A00
```

```
440REM CALL &0A00
450*GDUMP 0 0 1 1
460REM VDU2,1,12,3
470END
480DEF FNDIR(P,Q)
490IF Q=0 AND P>0 =90
500IF Q=0 AND P<0 =270
510IF Q=0 AND P=0 =0
520IF Q<0 =180+DEG(ATN(P/Q))
530IF Q>0 AND P>0 =DEG(ATN(P/Q)) ELSE=360+DEG(ATN(P/Q))
540DEF PROCsquare(m%,n%,T$)
550VDU5
560MOVE m%,n%
570PLOT1,512,0:PLOT1,0,432
580PLOT1,-512,0:PLOT1,0,-432
590PLOT0,400,400:PRINTT$:VDU4
600ENDPROC
610DEF PROCplot(s%,x,y)
620IF NOT (N%=1 OR (FLAG=1 AND s%=4)) GOTO 630
625 ON s% GOTO 642,644,646,648
630IF NOT (s%=2 AND ABS(y-lasty2)>216) GOTO 640
635MOVE lastx2,lasty2:DRAWlastx2,552+432*INT((lasty2-232)/432):lasty2=552
   +432*INT(y/432-.5)
640ON s% GOTO 641,643,645,647
641MOVE lastx1,lasty1:PLOT5,x,y
642lastx1=x:lasty1=y:ENDPROC
643MOVE lastx2,lasty2:PLOT5,x,y
644lastx2=x:lasty2=y:ENDPROC
645MOVE lastx3,lasty3:PLOT5,x,y
646lastx3=x:lasty3=y:ENDPROC
647MOVE lastx4,lasty4:PLOT5,x,y
648lastx4=x:lasty4=y:ENDPROC
```

(h.3) Program NEWMOD3 - Version of MOD to plot DIREC data in same format as output of MUNDESLY

```
  1REM vn of MOD to plot C11, Th1 and Th2
  2REM from Cromer WAVEC DIREC Processed Data
  3REM in same format as MUNDESLY EMI Processed Data
 10MODE0
 20DIM last(3)
 30DIM MC% 300
 40DIM data 110
 50DIM header 260
 60DIM D 20
 70OSBGET=&FFD7:OSFIND=&FFCE:OSWRCH=&FFEE
 80FOR opt%=0 TO 2 STEP 2
 90P%=MC%
100[.init
110OPT opt%
120LDA#&40:LDX#0:LDY#&0B
130JSR OSFIND
140STA&0B10
150CMP#0
160BEQabort
170LDX#0:LDY&0B10
180.head
190CLC
200JSR OSBGET
210BCC store
220JMP abort
230.store
240STAheader,X
250CPX#251
260BEQ abort
270INX
280JMP head
290.read
300LDX#0:LDY&0B10
310.energy
320JSR OSBGET
330 STAdata,X
340CPX#103
350BEQ fin
360INX
370JMP energy
380.abort
390RTS
400.fin
410RTS
420]
430NEXT opt%
440M=data:N=&0B00
450$D="DIR $.RECORDS"
460X%=D MOD 256
```

```
470Y%=D DIV 256
480CALL &FFF7
490CLS
500INPUT TAB(0,10)"Enter Run Number (e.g. CR6798)",P$
510INPUT"Enter Time of Record",T$
520CLS
530@%=&10309
540$N=P$+CHR$(13)
550CLS
560PRINT TAB(13,31)"Plotting ";$N;
570VDU5
580RESTORE
590FOR p%=0 TO 2
600PROCsquare(p%)
610NEXT
620VDU4
630CALL init
640PROCheadwr
650VDU4
660C11M=1E-4*VAL(LEFT$($(header+240),10))
670cscale=1000/C11M
680FOR HARM%=2 TO 90 STEP 2
690omg=0.101936799*(0.01*PI*HARM%)^2
700CALL read
710REM IFHARM%<6 GOTO0820
720C11=1E-4*VAL(MID$($data,5,10)):A11=C11*omg^2
730C22=0.25E-6*VAL(MID$($data,16,10))
740C33=0.25E-6*VAL(MID$($data,27,10))
750omg=omg*0.5E-5
760C12=-VAL(MID$($data,38,10))*omg
770Q12=-VAL(MID$($data,49,10))*omg
780C13=VAL(MID$($data,60,10))*omg
790Q13=VAL(MID$($data,71,10))*omg
800C23=-0.25E-6*VAL(MID$($data,82,10))
810Q23=-0.25E-6*VAL(MID$($data,93,10))
820den=SQR(A11*(C22+C33)):A1=Q12/den:B1=Q13/den:A2=(C22-C33)/(C22+C33)
   :B2=2*C23/(C22+C33)
830R=SQR(A11/(C22+C33))
840IF A1>0 TH1=DEG(ATN(B1/A1))
850IF B1<0 TH1=DEG(ATN(B1/A1))+360
860IF A1<0 TH1=180+DEG(ATN(B1/A1))
870C1=SQR(A1*A1+B1*B1):S1=C1/(1-C1):TH2=DEG(SQR(2-2*C1))
880PROCplot(0,C11*cscale)
890PROCplot(1,2.778*TH1)
900PROCplot(2,11.11*TH2)
910NEXT
920PRINT TAB(13,31)SPC(18);
930CLOSE#0
940IF p% MOD 4<>3 GOTO 1020
950REM*LOAD"$.UTILITIES.DUMPCL" 0A00
960REMCALL&0A00
970*GDUMP 0 0 1 1
```

```
 980X%=D MOD 256
 990Y%=D DIV 256
1000CALL &FFF7
1010VDU1,12,3
1020END
1030DEF PROCsquare(p%)
1040READx%,y%
1050MOVEx%,y%:PROCsq(p%)
1060ENDPROC
1070DEF PROCplot(p%,y)
1080GCOL0,1
1090ON (p%+1) GOTO 1100,1120,1170
1100MOVE96+5.689*(HARM%-2),last(p%):IF HARM%<=10last(p%)=552+0.432*y:ENDPROC
1110PLOT5,96+5.689*HARM%,552+0.432*y:last(p%)=552+0.432*y:ENDPROC
1120MOVE752+5.689*(HARM%-2),last(p%):incr=552+0.432*y-last(p%):cx%=75
    2+5.689*HARM%:cy%=552+0.432*y
1130IF HARM%>10 AND ABS(incr)<300 PLOT5,cx%,cy%:last(p%)=cy%:ENDPROC
1140IF HARM%>10 AND incr>0 PLOT5,cx%,552:last(p%)=984:ENDPROC
1150IF HARM%>10 PLOT5,cx%,984:last(p%)=552:ENDPROC ELSElast(p%)=cy%:ENDPROC
1160IF HARM%>10 AND incr>0 PLOT5,cx%,552:last(p%)=984:ENDPROC ELSE IF
    HARM%>10 PLOT5,cx%,984:last(p%)=552:ENDPROC ELSElast(p%)=cy%:ENDPROC
1170MOVE96+5.689*(HARM%-2),last(p%):IF HARM%<=10last(p%)=70+0.432*y:ENDPROC
1180PLOT5,96+5.689*HARM%,70+0.432*y:last(p%)=70+0.432*y:ENDPROC
1190ENDPROC
1200DEF PROCheadwr
1210PRINT TAB(50,19)"Cromer Wavec Data"
1220PRINT TAB(50,21)"DIREC Processor"
1230PRINT TAB(50,23)"1987 06-17 ";T$
1240PRINT TAB(50,24)"C11, Th1, Th2 vs Freq"
1250PRINT TAB(50,26)"0 to 0.45 Hz"
1260ENDPROC
1270DEF PROCsq(p%)
1280PLOT1,512,0
1290PLOT1,0,-432
1300PLOT1,-512,0
1310PLOT1,0,432
1320IF p%=0 GOTO1380
1330IF p%=2 GOTO1360
1340PLOT0,416,-24:PRINT"Th1"
1350ENDPROC
1360PLOT0,416,-24:PRINT"Th2"
1370ENDPROC
1380PLOT0,416,-24:PRINT"C11"
1390ENDPROC
1400 FOR T%=0 TO 2000:NEXT:CLS
1410DATA 96,984,752,984,96,502,752,502
```

(i.1) Program DIREC - Displays real time channel data from portable receiver

```
  1REM Program to display WAVEC data on screen
  2REM No logging is performed
 10init=&C00:byte=init+400:DIM array 8192
 15!&80=array:?&80=0:?&81=?&81+1
 20IRQ2V=&0206
 30FOR I%=0 TO 3 STEP 3
 40P%=init
 50[OPT I%
 60.init LDA#int MOD 256:STA IRQ2V
 70LDA#int DIV 256:STA IRQ2V+1
 80LDA#&1F:STA&FE62
 90LDA#&7F:STA&FE6E
100LDA#&88:STA&FE6E
110LDA#0:STA&FE6C:STA&FE60:LDX#0
120LDA#&1F:STA&FE60:RTS
130.int PHA:TXA:PHA:TYA:PHA
135LDA#0:STA byte+1:STA byte+2
140LDY#&1F:TAY
150.read1 CPY#&17:BEQ read2
160ASL byte
170STY&FE60
180LDA&FE60:BPL end1:INC byte
190.end1 DEY:JMP read1
200.read2 CPY#&13:BEQ read3
210ASL byte+1
220STY&FE60
230LDA&FE60:BPL end2:INC byte+1
240.end2 DEY:JMP read2
250.read3 CPY#&0F:BEQ exit
260ASL byte+2
270STY&FE60
280LDA&FE60:BPL end3:INC byte+2
290.end3 DEY:JMP read3
300.exit LDA#0:STA&FE60:LDA#&FF:STA byte+3
310ROR byte+2:BCS end4:ROL byte+2:JSR&FFE7:LDA#&30:ADC byte+2:JSR&FFEE
320.end4 LDA#&10:STA&FE60
340PLA:TAY:PLA:TAX:PLA:RTI
350]
360NEXT I%
370MODE3
380VDU23;8202;0;0;0;
390@%=&07
400CALL init
410CLS
420IF ?(byte+3) PRINT 16*?byte+?(byte+1);:?(byte+3)=0
430GOTO420
```

(i.2) Program LOG1 - Logs data from portable receiver to floppy disk

```
  1REM Program to acquire WAVEC data and store it on disk
  2REM For DFS filing system
  3REM Option for saving all channels or just wave data channels
  9MODE3
 10init=&A00:byte=&C00:DIM array 5120
 12INPUT"How many sections of data to be acquired (each of 256 bytes)",s%
 13IF s%>20 PRINT"Too many, maximum 20":GOTO12
 15!&80=array:?&80=0:?&81=?&81+1:!&84=!&0206:?(byte+6)=?&81+s%
 17start=256*?&81
 20IRQ2V=&0206
 30FOR I%=0 TO 3 STEP 3
 40P%=init
 50[OPT I%
 60.init LDA#int MOD 256:STA IRQ2V
 70LDA#int DIV 256:STA IRQ2V+1
 80LDA#&1F:STA&FE62
 90LDA#&7F:STA&FE6E
100LDA#&88:STA&FE6E
110LDA#0:STA&FE6C:STA&FE60:STA byte+4:STA byte+5
120LDA#&1F:STA&FE60:RTS
130.int PHA:TXA:PHA:TYA:PHA
135LDA#0:STA byte+1:STA byte+2
140LDX#&1F:TAX
150.read1 CPX#&17:BEQ read2
160ASL byte
170STX&FE60
180LDA&FE60:BPL end1:INC byte
190.end1 DEX:JMP read1
200.read2 CPX#&13:BEQ read3
210ASL byte+1
220STX&FE60
230LDA&FE60:BPL end2:INC byte+1
240.end2 DEX:JMP read2
250.read3 CPX#&0F:BEQ exit
260ASL byte+2
270STX&FE60
280LDA&FE60:BPL end3:INC byte+2
290.end3 DEX:JMP read3
300.exit LDA#0:STA&FE60:LDA#&FF:STA byte+3
310ROR byte+2:BCS end4:ROL byte+2:JSR&FFE7:LDA#&30:ADC byte+2:JSR&FFEE
315LDA byte+4:BNE end4:LDA#0:STA byte+5:LDA#1:STA byte+4
320.end4 LDA byte:LDY byte+5:STA(&80),Y:INY
325LDA byte+1:STA(&80),Y:CPY#&FF:BNE midpage:INC&81:LDA byte+6:CMP&81:BEQ reset
330.midpage INY:STY byte+5:LDA#&10:STA&FE60
340PLA:TAY:PLA:TAX:PLA:RTI
345.reset LDA#&FF:STA byte+6:LDA#&08:STA&FE6E:LDA#&17:STA&FE6E
347JMP midpage
350]
360NEXT I%
380VDU23;8202;0;0;0;
```

```
385 REM ON ERROR REPORT:CALL reset
390@%=&07
391CLS
393PRINT'"Base address &";~start
395PRINT"Press SPACE to start sampling":a$=GET$
400CALL init
410CLS
420IF ?(byte+3) PRINT 16*?byte+?(byte+1);:?(byte+3)=0
430IF ?(byte+6)<&FF GOTO420
440PRINT'"Finished Sampling"
450PRINT'"Do you want to save data on disk<Y/N>":R$=GET$
460 IF R$="Y" OR R$="y" PROCsave
470END
1000DEF PROCsave
1005FOR T%=0 TO 5000:NEXT
1007*FX15,1
1010INPUT"Enter File Name for data to be saved",F$
1020PRINT"Drive 0 or 1 (enter 0 or 1)":D$=GET$
1030IF D$="1" GOTO 1040 ELSE GOTO 1050
1040*DRIVE 1
1045GOTO 1052
1050*DRIVE 0
1052PRINT"All channels to be saved <Y> or just heave,hx,hy,hz,pitch,roll <N>":R$=GET$
1054IF R$="Y" OR R$="y" flag=TRUE ELSE flag=FALSE
1060X=OPENOUT F$
1065PRINT#X,s%,flag
1070 FOR N%=0 TO 256*s%-1 STEP 2
1071IF flag GOTO 1080
1072pos%=N% MOD 20
1074 IF pos%<2 OR pos%>13 GOTO 1090
1080PRINT#X,(16*?(start+N%)+?(start+N%+1))
1090NEXT
1100CLOSE#X
1110*DRIVE0
1120ENDPROC
>*SPOOL
```

(i.3) Program RECOVER - Lists data acquired by LOG1

```
  1REM Program to list acquired WAVEC data files
  2REM Using DFS filing system
 30@%=&7
 40DIM C 20
 50INPUT"Enter File to be read",F$
 60INPUT"Enter Drive number",D$
 70$C="DRIVE"+D$
 80X%=C MOD 256
 90Y%=C DIV 256
100CALL &FFF7
110X= OPENUP F$
120INPUT#X,s%,flag
130PRINT"There are ";s%;" sections in this file"
140IF flag PRINT"All channels are present" ELSE PRINT"Only sensor channels
   are present"
150VDU2
160M%=(256*s%-1) DIV 20
170PRINT"File ";F$
180DIM h%(M%),hx%(M%),hy%(M%),hz%(M%),p%(M%),r%(M%)
190IF flag DIMsync%(M%),batt%(M%),par1%(M%),par2%(M%)
200 PRINT SPC(3);"Heave";SPC(3);"Hx";SPC(5);"Hy";SPC(5);"Hz";SPC(4);
210PRINT "Pitch";SPC(2);"Roll"
220FOR N%=0 TO M%-1
230IF flag GOTO 270
240 INPUT#X,h%(N%),hx%(N%),hy%(N%),hz%(N%),p%(N%),r%(N%)
250 PRINT h%(N%),hx%(N%),hy%(N%),hz%(N%),p%(N%),r%(N%)
260GOTO310
270 INPUT#X,sync%(N%),h%(N%),hx%(N%),hy%(N%),hz%(N%)
280INPUT#X,p%(N%),r%(N%),batt%(N%),par1%(N%),par2%(N%)
290 PRINT sync%(N%),h%(N%),hx%(N%),hy%(N%),hz%(N%)
300PRINT p%(N%),r%(N%),batt%(N%),par1%(N%),par2%(N%)
310NEXT
320CLOSE#X
330VDU3
```

(i.4) Program PLOTWA - Plots time series acquired by LOG1

```
  1REM Program to plot WAVEC data acquired using portable Rx
  2REM Using DFS filing system
 10MODE0
 20DIM ch%(10),param%(10)
 30INPUT"Enter File to be read",F$
 40INPUT"Enter Drive number",D$
 50IF D$="0" GOTO 80
 60*DRIVE1
 70GOTO 90
 80*DRIVE0
 90X=OPENIN F$
100INPUT#X,s%,flag
110CLOSE#X
120PRINT"There are ";s%;" sections in this file"
130IF flag PRINT"All channels are present" ELSE PRINT"Only sensor channels
   are present"
140M%=(256*s%-1) DIV 20
150PRINT'"Enter channels to be displayed"
160PROCselect
170GCOL0,1
180CLS
185VDU5
190FOR CH%=0 TO m%-2
210X=OPENIN F$
220INPUT#X,s%,flag
230FOR N%=0 TO M%-1
240IF flag GOTO 300
250FOR para%=1 TO 6
260 INPUT#X,data%
270IF para%=ch%(CH%) dispdata%=data%
280NEXT para%
290     GOTO340
300FOR para%=0 TO 9
310 INPUT#X,data%
320IF para%=ch%(CH%) dispdata%=data%
330NEXT para%
340IF N%=0 MOVE0,0.25*dispdata%-16:PRINT STR$(ch%(CH%)):MOVE0,
   0.25*dispdata%:GOTO 360
350PLOT5,N%*1279/(M%-1),0.25*dispdata%
360NEXT N%
370CLOSE#X
380NEXT CH%
385VDU4
390END
400DEF PROCselect
410PRINT"-terminate with number>10"
420m%=0
430REPEAT:INPUT ch%(m%):m%=m%+1:UNTIL ch%(m%-1)>10
440ENDPROC
```

(i.5) Program PLATOFF - Plots HIPPY sensor offset angle after 360° rotation about vertical axis

```
  1REM Program to display platform offset of Hippy Sensor
  2REM Requires record of data to be made
  3REM using rotation of Hippy about Vertical Axis
  4REM as per Datawell Handbook
 10MODE0
 20@%=&7
 30INPUT"Enter File to be read",F$
 40INPUT"Enter Drive number",D$
 50INPUT"Enter scale (pixels/digit)",scale
 60IF D$="0" GOTO 90
 70*DRIVE1
 80GOTO 100
 90*DRIVE0
100X= OPENUP F$
110INPUT#X,s%,flag
120PRINT"There are ";s%;" sections in this file"
130IF flag PRINT"All channels are present" ELSE PRINT"Only sensor channels
   are present"
140CLS:VDU5
142MOVE0,512:DRAW1279,512
144MOVE640,0:DRAW640,1023
150FOR ring%=10 TO50 STEP 10
160rad=scale*ring%
170MOVE640,rad+512:PRINTring%
180MOVE640,rad+512
190FOR t%=0 TO 20
200theta=PI*t%/10
210PLOT5,640+rad*SIN(theta),512+rad*COS(theta)
220NEXT
230NEXT
240VDU4
250M%=(256*s%-1) DIV 20
260IF flag DIMsync%(M%),batt%(M%),par1%(M%),par2%(M%)
270FOR N%=0 TO M%-1
280IF flag GOTO 310
290 INPUT#X,h%,hx%,hy%,hz%,p%,r%
300GOTO320
310 INPUT#X,sync%,h%,hx%,hy%,hz%,p%,r%,batt%,par1%,par2%
320IF N%=0 MOVE640+scale*(p%-2048),512+scale*(r%-2048)
330PLOT5,640+scale*(p%-2048),512+scale*(r%-2048)
340NEXT
350CLOSE#0
```