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APPLETON LABORATORY NEWSLETTER

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Dr. G. H. Stafford, C.B.E., F.R.S.

Staff will be glad to learn that Dr. G. H. Stafford, Director of the Rutherford Laboratory, has been elected to Fellowship of the Royal Society:

> "for his studies of nucleon scattering and his leadership of the Rutherford Laboratory in its support of particle physics and in the diversification of its activities."

In 1957 when the Rutherford Laboratory came into being, Dr. Stafford was appointed Head of the PLA Group, became responsible for the high energy physics programme on Nimrod in 1963 and became Deputy Director in 1966. For many years he has had a close association with CERN, becoming the UK Delegate and Vice-President to the Council in 1973, and Chairman of the Scientific Policy Committee in 1978. Dr Stafford was appointed Director of the Rutherford Laboratory in 1969 and received the honour of CBE in 1976.

We offer our congratulations to him on achieving this mark of the scientific world's appreciation of his work.

REMOTE SEA-SURFACE MONITORING BY HIGH-FREQUENCY RADAR

There are various mechanisms responsible for movement of the sea surface of which the wind is the most obvious. Waves generated by the wind fall into two categories depending on their wavelength. There are surface gravity waves propagating under the restoring force of gravity with wavelengths from about 10 cm to 1 km. There are also capillary waves travelling under the restoring force of surface tension; these have wavelengths less than about 1 cm. In the deep oceans the surface gravity waves are in equilibrium with the driving wind. When these waves move away from the area where they were originally excited, or after the wind has dropped, their character changes, and they lose the short wavelength components becoming known as 'swell'. This 'swell' is capable of travelling great distances without modification. Also present in the oceans are tides which are very large-scale motions caused by the gravitational attractions of the sun and moon. In addition there are near-surface sea currents, being the general transport in a given direction of the water mass over a large region. Wind-driven waves and near-surface sea currents are unaffected by temperature gradients present in deep water but inshore these gradients can lead to a circulation which alters the surface patterns. Also close inshore both currents and waves are modified by bottom topography effects.

Information on waves and surface currents is required in many disciplines, including meteorology, oceanography, wave and tidal energy extraction and marine engineering. Little is known about these sea parameters although their importance in such fields as the management of coastal waters, global-resource monitoring and weather predictions is becoming increasingly recognised.

Historically, the earliest studies have been concerned with wave height measurements by visual observation using a graduated fixed staff. A more modern alternative technique involves a pressure transducer mounted on the sea floor in which variations in the pressure of the column of water above are translated into wave heights.

However, both these methods are restricted to use in shallow waters. In the deep oceans, accelerometers mounted on buoys are deployed and the wavelength data acquired are either recorded aboard the buoy for subsequent analysis or else telemetered to shore; the telemetry equipment often restricts the operating range from the receiving site to some tens of kilometres.

Wave direction is either determined visually or deduced from measurements derived from an array of pressure sensors. With visual observations it is possible to determine the wave direction of two intermingled swell components as well as that of the wind waves which are assumed to be greatest in the wind direction. Also estimates can be formed of the periods of the waves i.e. the time for sequential wave crests to pass a fixed point.

Conventional methods of measuring currents involve meters moored at depths greater than 10 m in order to provide results which are not influenced by the individual waves; surface values have to be inferred indirectly. In addition there are the data-acquisition problems mentioned above for waveheights. Other techniques used for measuring these surface - sea currents, such as drifting buoys, involve aircraft or ships to plot their progress. This type of measurement is both expensive and time-consuming for small return in terms of current data obtained.

Much greater quantities of wave and current data may be collected by radio-sensing techniques such as those involving microwave radiometers and scatterometers, synthetic-aperture radar and side-looking radar. Aircraft measurements using one or more of these instruments can provide information from a substantial area of sea over limited flight duration. The corresponding measurements with a satellite would involve greater temporal and areal coverage but many days elapse between repeated surveys of the same sea area. However, satellite systems require several years of preparation, costs are high and there is no guarantee of continuous successful operation after launch. SEASAT-A demonstrates the difficulties encountered. This satellite was placed in orbit around the Earth on 22nd June 1978 with a planned programme of sea-state measurements lasting several years, but its power system failed prematurely. Fortunately nine weeks of data were obtained which it is believed are of great potential interest.

Remote sensing by high-frequency radar is an attractive alternative means of monitoring wind waves and surface-sea currents since it provides good spatial and temporal coverage. Pilot studies in the UK, USA and Australia using sky-wave and ground-wave high-frequency radars have demonstrated the feasibility of obtaining sea-state data from the spectral analysis of the returned signals. For sky-wave measurements radiowaves in the frequency range 2 - 30 MHz are transmitted from a land-based site and are reflected from the 'mirror-in-the-sky' ionosphere onto the sea area under investigation. A fraction of the energy incident on the sea surface is scattered back along the same path (backscattered) to a receiving site coincident with or close to the transmitter. In this way coverage to several thousand kilometres range is possible. Ground-wave high-frequency radars, operating in approximately the same frequency range, use transmitting and receiving sites erected as close to the sea-land boundary as possible to give the greatest sea coverage; although the radiowaves travel round the Earth's curvature, by diffraction into the shadow region beyond the horizon, such installations are restricted to ranges of the order of 100 kilometres.

Theoretical basis for the technique and information provided

The sea surface can be imagined as consisting of a chaotic distribution of wind-driven waves of different wavelengths and directions superimposed on some regular features such as the 'swell' from a distant storm. Wind-driven waves may be quantified by their wave-energy spectra. The directional spectrum indicates mean wave energy as a function of wavelength and direction. The wavelength containing most energy increases with increasing wind speed. The maximum wavelength present is that for which the wave speed equals the wind speed. The radiowave frequencies used for the sky-wave technique are determined by the properties of the ionosphere in order to give illumination of the areas of interest but it turns out that the corresponding wavelengths are of the same order of magnitude as those seawaves likely to be present most of the time. Choice of frequency for the ground-wave technique is a compromise between sea area coverage which is greater the lower the frequency and antenna efficiency and directivity which increases with frequency. The motion of the seawaves manifests itself as the translation of frequency (Doppler shift) of the received back-scatter from that of the transmitted signal. The scattering mechanism is the diffraction grating or Bragg effect akin to that which arises in holography or X-ray studies of crystalline structures. The received backscatter consists predominantly of returns from those two components in the chaotic seawave spectrum whose wavelength is half that of the incident radiowave and which travel directly towards or away from the radar. At this wavelength the backscatter returns from successive crests reinforce constructively whilst in comparison returns from other wavelengths and directions are negligible. These two dominant components are called the advance and recede seawave terms and due to the wave motion they are Doppler-shifted almost equally about the signal frequency to form two 'Bragg' spectral lines. They can be resolved by Fourier analysis.

Fig 1 shows idealised Doppler spectrum produced in this way indicating a principal negative Doppler shift corresponding to a receding seawave. The mean of the two spectral line frequencies has an offset from the transmitter frequency (shown as zero on the Doppler frequency scale of the figure) proportional to the radial component along the antenna bore sight (the line between the scattering area and the radar) of the sea-current velocity. Also indicated in the figure are higher-order lines due to hydrodynamic interaction between seawaves of different wavelengths and directions. Additionally there is a background continuuum produced by multiple scatter in which the radiowaves are received after scattering from one seawave crest to another.

From such spectral data and using existing algorithms based on simple empirical relationships between waves and winds, estimates may be derived of surface-wind directions and surface-wind speeds. A model is available which relates the angle between the predominant wind direction and the radar boresight to the ratio of the amplitudes of the advance and recede spectral lines. Another algorithm relates the wind speed to the sum of the amplitudes of the two first-order lines, measured from the lowest level of the continuum between these two lines. Alternatively the wind speed may be estimated from a relationship between wind speed and the width of the dominant first-order line.

Recent theoretical work, based on ground-wave measurements, has demonstrated the possibility of deriving sea-state information from the higher order lines by a spectral-inversion process without resorting to the empirical relationships mentioned above. Application of this work to the sky-wave measurements presents some difficulty in that the higher-order line widths are sometimes less than the broadening which arises from ionospheric perturbations, such as fluctuations in electron density. This means that sky-wave data may not always be equally useful. However, until operational tests have been carried out it remains to be seen how often the data are not corrupted in this way.

<u>Proposed new UK synoptic-monitoring facility</u>

In a collaborative venture the Appleton Laboratory and Birmingham

University are setting up a facility based on the sky-wave technique with which it is planned to make daily measurements over a large area of the North Atlantic for a one year period. If this proves successful it is possible that a permanent national facility will be established.

Use is to be made of an existing backscatter radar transmitter and antenna system situated in South West England. The antenna is a linear array of vertical monopoles extending over a length of 300 metres; it provides a beam which is narrow in azimuth (6^{o} at 10 MHz) and may be steered, over an angular range of $\pm 30^{o}$ relative to a westerly direction. Assuming surveillance out to a ground range of 6000 km figure 2 shows the area of the North Atlantic thereby covered. The transmitter radiates pulses of 100 kW peak power with a pulse width of 500 microseconds to provide a range resolution of 75 km. The transmitter is capable of being operated at a series of frequencies between 4 MHz and 32 MHz. The pulse repetition rate is 20 Mz so that the unambiguous slant range is 7,500 km.

Time gating of the received backscatter, referenced to the transmitter pulse, determines the range to the sea-scatter area. A total of 64 consecutive range-gated samples for each transmitted pulse are digitised and stored. Storage for up to 1024 amplitude values, corresponding to an acquisition duration of 51.2s, for each of the 64 range gates is available. The time series for each range gate will be spectrally processed on-line by a hardware fast Fourier transform unit and the resultant spectra transferred in digital form to a dedicated minicomputer. On the mini computer the spectra will be processed to extract surface wind direction and where possible surface wind speed and surface sea-current results for each range gate at each azimuth. On completion of an area scan these results are to be plotted in near real-time onto appropriate map displays.

Preliminary studies

In view of the need to assess the capabilities of the system every opportunity is being taken to collaborate with other workers carrying out ground-truth experiments. Comparisons with results obtained by conventional methods are of great value in validating the techniques. Analysis of one such ground-truth experiment, using several sets of shipborne data, in an area off NW Scotland is at present being undertaken. Preliminary findings are encouraging but it is clear that further studies of ionospheric effects are needed. In particular the use of ionospheric predictions, for frequency management of the radar to give surveillance of desired target areas and for ionospheric modal identification to relate slant path and ground ranges, needs optimisation.

Assuming that these problems can be resolved the remote sensing of sea-state by high-frequency sky-wave radar shows promise and will at least under favourable ionospheric conditions be capable of providing wind data from an area which at present has only limited coverage by other means.

(This article will shortly appear in the Central Office of Information publication 'Spectrum' which enjoys world-wide distribution through British Embassies, Consulates etc.)

Idealised Doppler spectrum

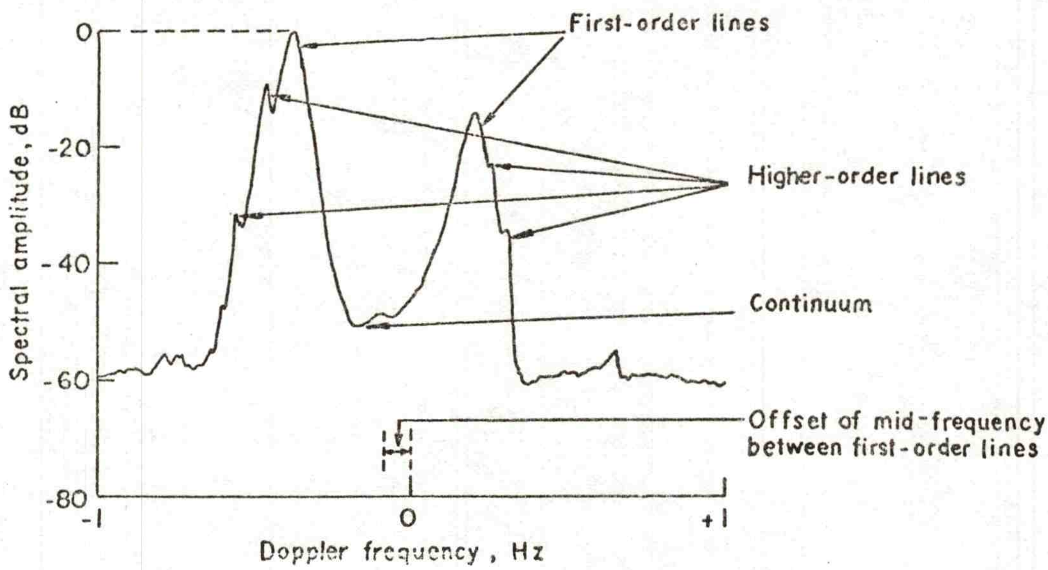
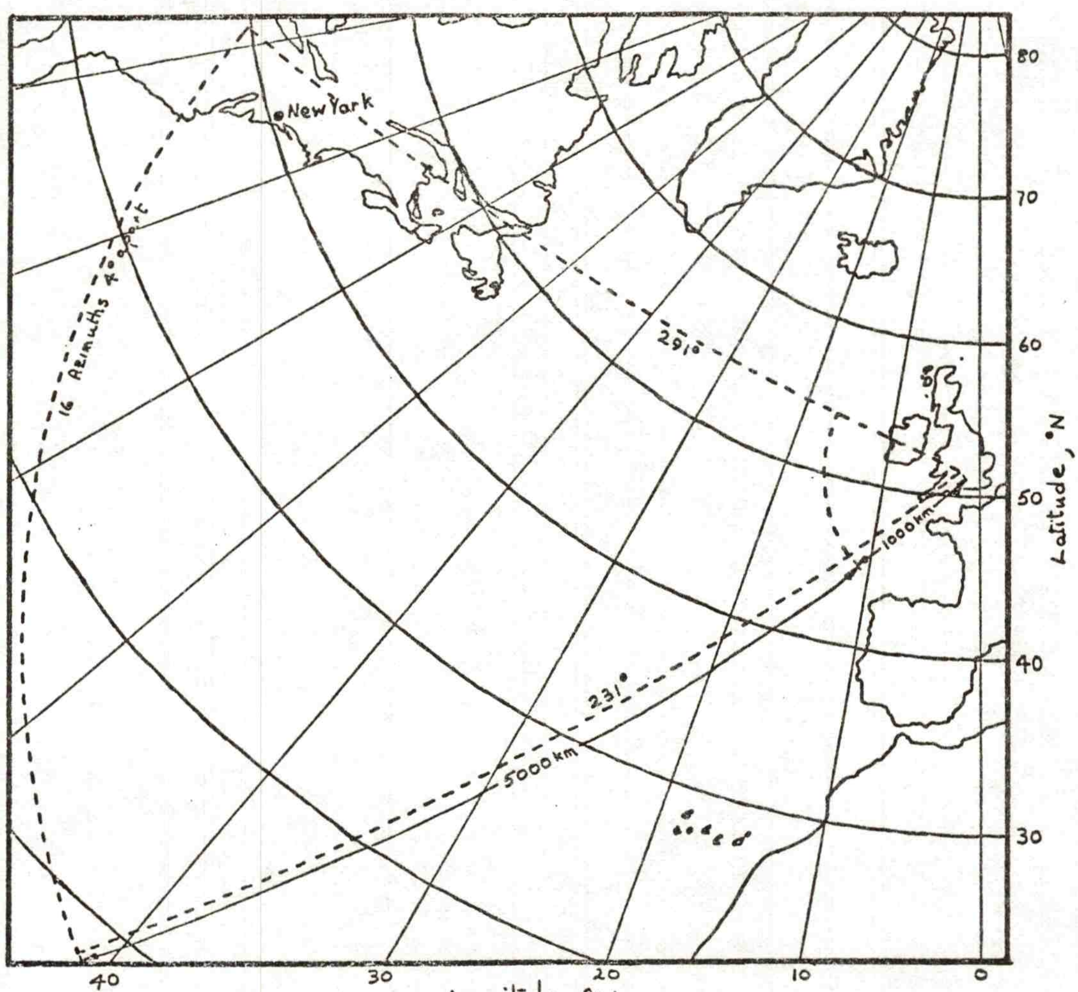


Figure 1



Area of North Atlantic covered

Figure 2

Staff News

Congratulations to :

Alan and Barbara Buck on the birth of their son, Philip Nathan, on 15th February, 1979.

H. C. Bevan	now P.S.O.

Welcome to :

Mrs. B. Danbury	C.A.
Mrs. I. M. Broadhead	C.A.
Mrs. A. K. Kapur	C.O.
H. Nykamp	S.C.S.
Miss J. T. Varlet	C.O.
C. F. Dale	S.C.S.
S. Hale	S.O. (Culham)
Miss A. M. Nicole	Pers. Sec.
L. F. O'Connor	S.C.S.
Mrs. M. E. Oliver	C.O. (Culham)

Resignations, Retirements etc.

Mrs. J. Coombes	A.S.O.
R. A. Bohlander	S.S.O.
P. Springate	S.O.
Mrs. C. Brooks	C.O.
J. F. R. Braby	S.O.
J. T. King	E.W.II
Mrs. J. A. Murray	Typist
Mrs. J. Sandal	Cas. Wkr.
Mrs. A. J. Garner	C.O. (Culham)

Obituary

Mr. A. E. Lawder

Staff were very sorry to learn of the sudden death, recently, of Mr. Albert Lawder, who retired from the Laboratory only last year. To his wife, Gladys, and to his family, colleagues here offer their deepest sympathy.

Sports Day

Thursday, 28 June 1979 is going to be the Sports Day, the venue being Chiswick as before.

Following events are included :-

- Angling
- Bowls
- Cricket
- Football
- Hockey
- Netball
- Tennis
- Tug-of-war

So get into action now for the day.

Hari Shah.

Letter to the Outstations

Dear Colleagues,

On present form, the Hounds of Spring seem a bit too dozy to be worth carrying one's shirt at the dogtrack. However there are grounds for hope. Faint, foreign, 'phone calls now instantly conjure up the racket of the lawn mower just beneath one's window - a sure token of the season.

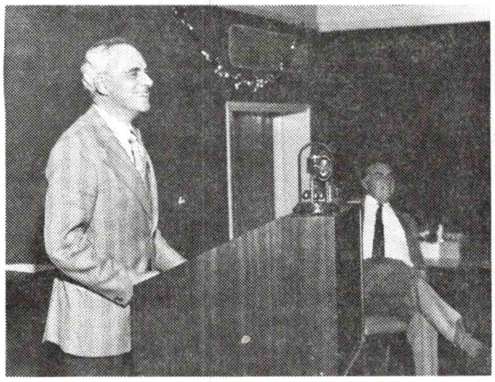
Another sign is less readily interpreted. One swallow does not, we know, make a summer - but how about one duck? What senior oracle can read that riddle.

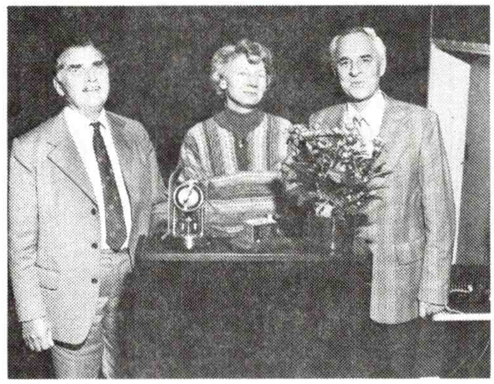
The creature has, I'm told, settled comfortably enough on a nest near D Spur; eggs have been seen but no explanation has been forthcoming. Maybe it's just a case of a smart bird getting first option on desirable premises. Whatever the motive, all wish it well and those of a practical turn of mind have provided food. From this office we can help but little, save in one particular. 'Beware Oranges'. This useful, if cryptic, advice is offered to the fowl with all good wishes from,

Yours sincerely,

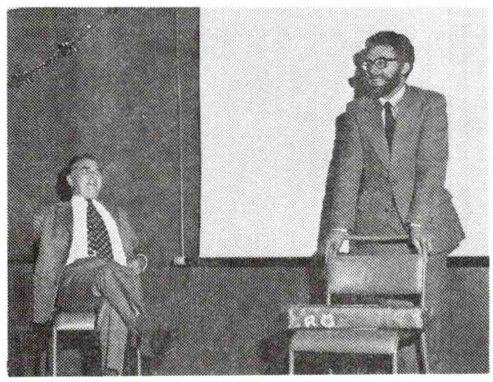
THE EDITOR.

RETIREMENT PRESENTATIONS

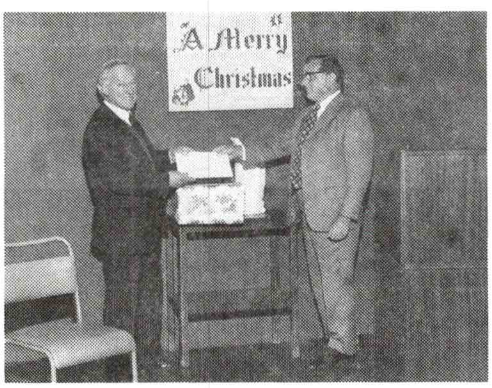




Mr. B. N. Harden



Mr. D. E. Mortimer



Mr. V. A. W. Harrison

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INTERNAL MEMORANDA

NIL