THE APPLICATION OF HIGH-SPEED PROCESSORS TO PROPAGATION EXPERIMENTS USING EXPLOSIVES

by

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ABSTRACT The possibility of analysing explosive signals directly, without an intermediate recording system, offers large improvements in the quality and rapid availability of results from acoustic propagation experiments. The requirements for a ship-borne system to process a number of broad-band channels simultaneously and present information in both frequency and time domains are examined, together with some practical aspects of implementing such a system using currently available general-purpose array processors.

INTRODUCTION

Explosive charges have been used for many years in measurements of acoustic propagation in the ocean. In a typical experiment charges are dropped at regular intervals from a moving ship or aircraft, and the acoustic signals are received on hydrophones deployed from a stationary ship. Explosive charges are simple to use, and can be arranged to detonate at virtually any depth; the acoustic output is very stable and covers a wide frequency range. Provided the signals at the receiving points are sufficiently above the local background noise they can be analysed to reveal the distribution of energy from each shot in both frequency and time. Finally, absolute transmission loss data can be obtained by comparing the received energy levels with the known source level of the explosion.

MEASUREMENT OF EXPLOSIVE SIGNALS

In early systems for measuring received energy the hydrophone signals were taken through band-pass filters, usually one octave wide, and the output of each filter was connected to some square-law device followed by an integrating circuit. Each discrete arrival of energy from a shot should appear as a step in the output of the integrator. In practice, due to the limited dynamic range of the squaring and integrating circuits, these systems were quite difficult to operate - particularly in varying propagation conditions when the received levels can change appreciably from one shot to the next. Furthermore the measurement of many hydrophone channels in many frequency bands requires an inconveniently large amount of equipment, with increased risk of losing data.

TAPE-RECORDING EXPLOSIVE SIGNALS

It has now become general practice to tape-record the hydrophone signals and make detailed measurements from the tape recording after the experiments at sea have been completed. The equipment on board the receiving ship is designed primarily to acquire good recordings of the signals from all the hydrophone channels. A typical FM instrumentation tape recorder running at 15 inches per second has a nominally flat response from zero to 10 kHz, with a quoted signal-to-noise ratio of about 50 dB. The achievable signal-to-noise performance is however restricted by the following factors :

(a) The recording has to be made somewhat below maximum permitted level, to avoid overloading and wasting the shot.

(b) The explosion provides a very "peaky" waveform, so that if the gain is correctly set for the highest peak most of the recording is well below the maximum level.

(c) The spectral distributions of the signal and the tape system noise are different, so that when the recording is analysed into octave or third-octave bands the signal-to-noise ratio is worse in some bands than others.

Spectral shaping before recording can be applied to compensate for (c) but because the spectrum of the signal varies with the distance from the source any such compensation must be a compromise, and at very long ranges the high-frequency part of the signal is invariably lost. Simple high-frequency pre-emphasis must be used with caution due to the tendency of FM tape systems to produce large noise levels at the bottom as well as the top of their frequency range; in these circumstances the use of high-frequency emphasis to improve the long-range signals can result in the loss of low-frequency data at short ranges.

FM recording systems have been used successfully by AUWE for a bandwidth ratio of 100 (100 Hz to 10 kHz) but this is near the limit for a single channel. For larger bandwidth ratios it would be necessary to divide the range by filtering and to record the sub-bands on separate tape channels.

The explosive signals recorded at sea are analysed in the laboratory into one-third octave bands by replaying through filters and squarer/integrator circuits, or through a digital analyser based on the fast Fourier transform. In the latter case the third-octave levels are obtained by summing the power spectrum between the frequency limits of each band. In this replay process the operator is required to identify the recorded explosion signals and to position the analysis time-window correctly for each hydrophone channel; every shot is replayed as many times as necessary to obtain measurements on all channels.

DIRECT DIGITAL ANALYSIS

Sufficient has been said above to indicate the problems of tape-recording explosive signals for wide-band measurements. General-purpose digital hardware now available offers the possibility of performing continuous on-line frequency analysis of broad-band hydrophone signals. The remainder of this paper discusses how such a processing system can be organized for use on board ship in a propagation experiment using explosive charges. The advantages of such a system are :

(a) The distortions due to tape-recording are avoided.

(b) The signals can be captured and processed in a much greater dynamic range - over 90 dB for 16-bit sampling.

(c) The processed data in the form of one-third octave energy levels can be stored very compactly on digital tape.

The processing system will be made to perform Fourier transforms on successive blocks of each hydrophone signal, convert the spectral data into third-octave band levels for each block, and store this information either continuously throughout the experiment or for a sufficient length of time before and after each shot. The "intelligent" selection of the blocks containing the shot energy will be made by the experimenter; it should be possible to do this on board ship and obtain propagation loss information during the experiment. All the third-octave data will be retained on digital tape for further study if required, and this data will not be affected by any selection made on board ship.

During an explosive run the main task for the operators will be to monitor the hydrophone signals and select gain settings for each shot to give suitable peak levels at the inputs to the processor; this is much the same as setting gains for tape-recording, but with greater latitude in dynamic range, and fast peak-level indicators developed for tape-recording can be used. Signal pre-amplifiers with digitally-controlled gain are available nowadays, but in an explosive run automatic gain setting by program would probably raise more problems than it solves; manual gain control will therefore be retained, with automatic input of the gain settings to the processor.

SYSTEM SPECIFICATION

It is proposed to construct a system using a Digital Equipment Corporation PDP 11-34 minicomputer as host to a Floating Point Systems AP 120 B array processor (Figure 1).

The initial specification provides for 8 signal channels to be analysed into 20 third-octave bands from 100 Hz to 10 kHz, using an A/D sampling rate of about 25 kHz for each channel followed by Fourier transformation in the AP 120 B in 8192-point blocks. The total input rate to the processor is 200,000 16-bit samples per second; it has to perform 25 8192-point transforms per second, plus squaring and summing between band limits. This getting near the limit for one AP 120 B.

The Fourier transform frame size is dictated by the need to get enough spectral lines in the lowest third-octave band; an 8192-point transform will provide a spectral resolution of about 3 Hz, which gives seven lines in the 100 Hz band. Using this block size the processor will produce 20 band levels for each channel three times per second - a total output rate of about 500 numbers per second.

This third-octave data is passed to the PDP 11 and stored on standard digital tape. It will be possible for the operator to control which portions of the data stream are stored, but with the relatively low data rate it is probably simpler and safer to store it all. A single magnetic tape will accommodate continuous data from 8 channels for about 10 hours.

A selection of third-octave data will also be fed to paper and/or CRT outputs to enable the operator to monitor the data from the processor and observe the arrival of each explosion signal. The PDP 11 has two cartridge disk stores to support these activities, as well as the operating system software.

A system of time-coding the stored data blocks is obviously required, and perhaps some means for the operator to key in auxiliary information (for example if a hydrophone channel is faulty). The methods of meeting these needs, and some questions of overall system control, are still under consideration.

The input and output specifications quoted above match those of an existing hybrid system using FM recording and off-line Fourier processing, so that side-by-side testing of the new system will be possible. After that it is intended to improve the specification, increasing the time resolution for the high-frequency bands, and also extending the frequency range downwards. The increased frequency range can be obtained purely by software; decimating the data in the processor and Fourier transforming in longer time-windows will permit third-octave analysis down to 10 Hz - or lower still if required.

DISCUSSION

J.W.R. Griffiths Has the speaker considered using digital filtering to get the third-octave outputs directly, rather than via an FFT?

J.S. Pyett Yes, this has been discussed. I think it would be useful if we only needed one or two filters, but with a bank of 20 to 30 filters it is probably easier by FFT processing, using available software.

R. Seynaeve It appears that you will need 2 x 64 Kwords of buffering space for the input data. Can the AP120B store data in half words to save memory?

J.S. Pyett All the AP120B arithmetic is 38-bit floating-point. We will have at least 128 Kwords of data memory and that memory is 38 bits wide.

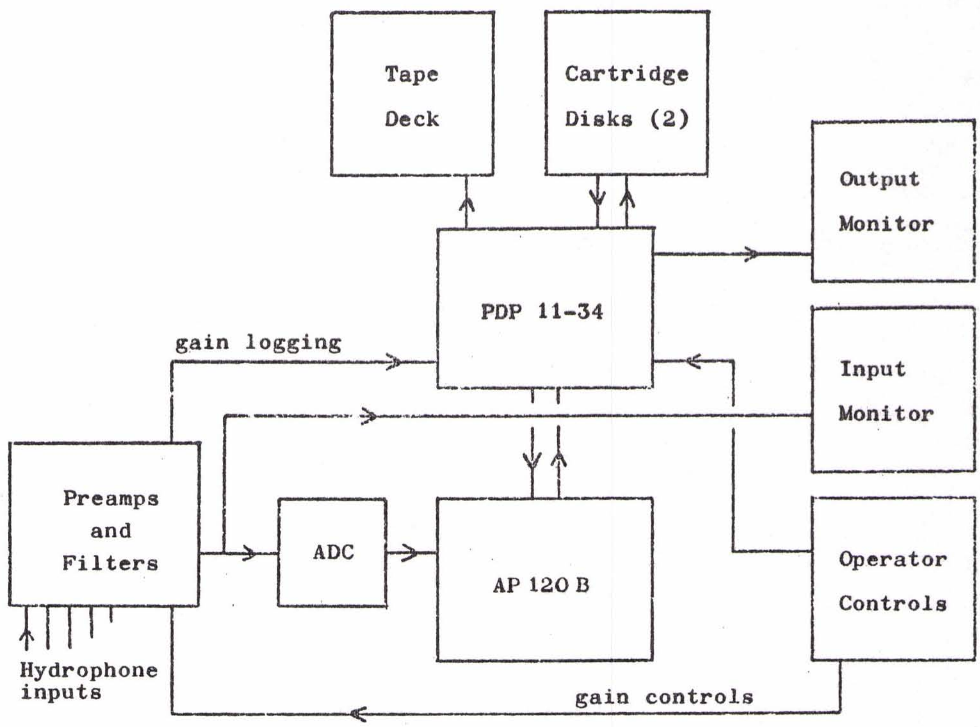

FIG. 1 BLOCK DIAGRAM OF SHIPBORNE PROCESSING SYSTEM