

AN OCEAN ACOUSTIC DATA ACQUISITION AND PROCESSING SYSTEM
BASED ON THE APTEC COMPUTER SYSTEMS 2400 INPUT/OUTPUT COMPUTER

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ABSTRACT

An ocean acoustic data acquisition and processing system is discussed. The system is based on the Aptec Computer Systems 2400 I/O Computer (IOC) and is controlled by a DEC VAX 11/730 minicomputer running the VMS operating system. The system utilizes a High Density Digital Recorder (HDDR), an FPS 5205 Array Processor, a number of fixed disks, a Lexidata color display, a QMS laser printer, and a 9-track tape unit. Real-time processing performed with the system includes 1) the collection of HDDR time series data, 2) the computation and storage of selected time-to-frequency FFT bins, cross-spectral matrices, and FFT-beamformer outputs, 3) the plotting of hydrophone power vs. time, and signal power vs. frequency and azimuth, and 4) the backing up of processed data and maintenance of logs of the data. The VAX remains relatively free to perform other concurrent tasks since the Aptec system handles items 1 and 2 above. Data rates used are 16 channels at 1500 Hz, and 128 channels at 699 Hz.

INTRODUCTION

An ocean acoustic data acquisition and processing system was developed by the Applied Ocean Acoustics Branch and Large Aperture Acoustics Branch of NRL in the spring of 1985. [1] That system was based on a DEC VAX 11/750 minicomputer and was used successfully at sea and in the lab. The system performed real-time processing on about 50 hydrophone channels at about 1 kilohertz per channel. In order to process higher data rates, off-load the VAX for post processing and other tasks, and reduce the size and weight of the system, a new system was developed based on an Aptec IOC and a VAX 11/730. The IOC provides for higher data rates and off-loads the VAX, and the switch from a VAX 11/750 to an 11/730 reduces the size and weight of the processing system. Although the data rates have increased and modifications to hardware and software were necessary, the data processing algorithms have remained virtually the same on the new system.

HARDWARE

Refer to figure 1.

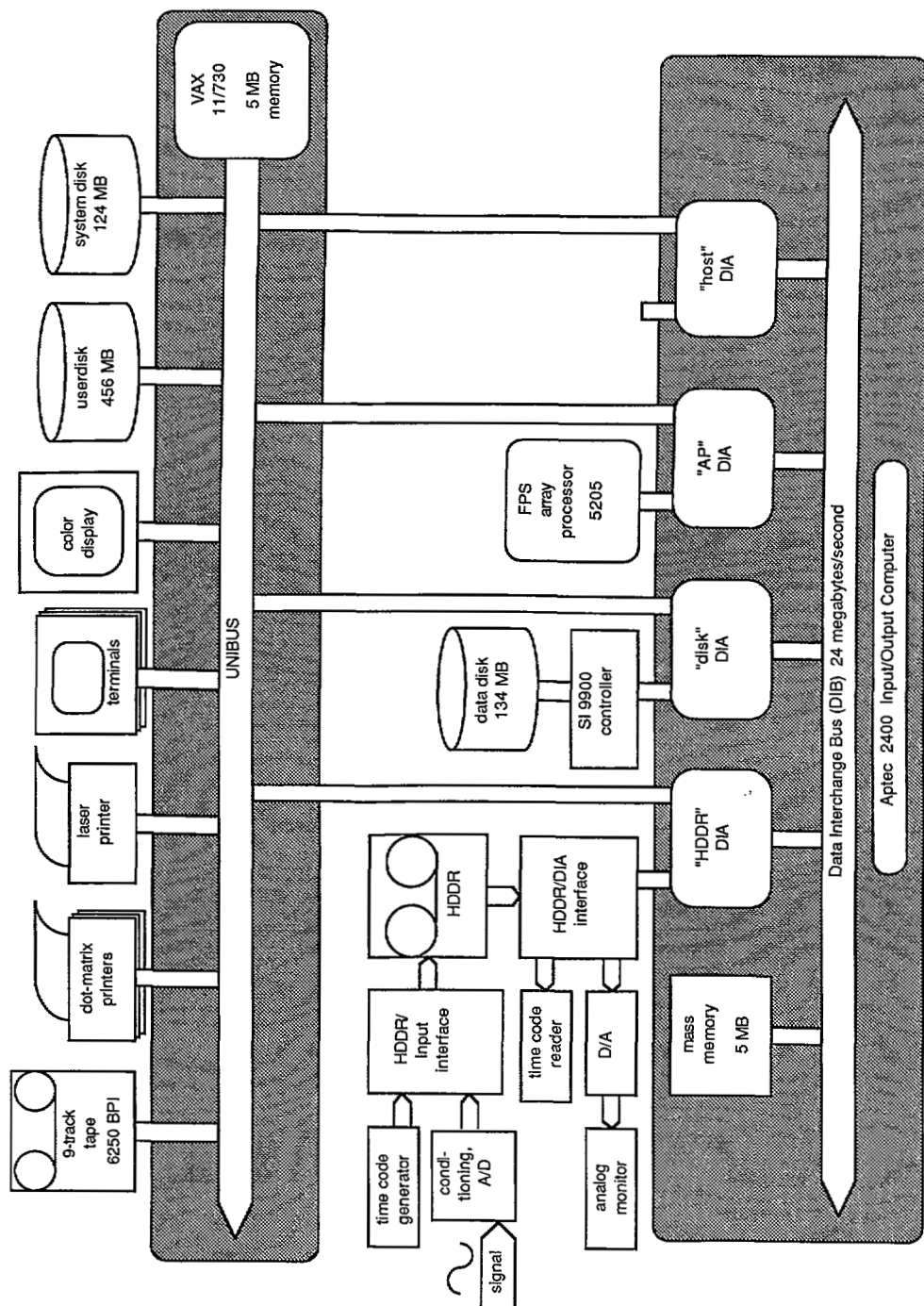
The main hardware components of the system are a VAX 11/730 with 5 megabytes (MB) of memory and an Aptec 2400 IOC. The other integral components are an HDDR, an FPS model 5205 Array Processor (AP) with 512 K bytes of System Common Memory (SCM), a Winchester 134 MB (formatted) disk drive, a Lexidata LEX 90 color display unit, and a custom HDDR/Aptec interface board. Also in use are a 9-track tape drive, a QMS model 800 Lasergrafix laser printer used for post processing output, a DEC RA80 124 MB system disk, a DEC RA81 456 MB user disk, a System Industries model 9900 disk controller, various terminals, and DEC LA50 dot matrix personal printers.

Within the IOC are 5 MB of Aptec Mass Memory (MM), a 24 MB/second Data Interchange Bus (DIB), a DIB controller, and 4 independently programmable processor boards known as Data Interchange Adapters (DIA). One DIA is allocated as a "host DIA" which synchronizes communication with the VAX. Another DIA is allocated to control data transfers between MM and the Winchester disk via the 9900 disk controller. We will refer to this DIA as the "disk DIA" and the Winchester disk - logically separated into 2 units - as the "Aptec disks." The third DIA loads incoming HDDR (or real-time) data into Aptec MM from the custom interface board. We will refer to this DIA as the "HDDR DIA." The fourth DIA interfaces between the AP and MM and has two mutually exclusive modes (determined by software) of operation: time-series data collection mode or first-pass processing mode. In time-series data collection mode, this DIA demultiplexes input time-series data directly to the Aptec disks. In first-pass processing mode, this DIA demultiplexes input time-series data from MM to the AP, retrieves processed results from the AP, and stores the data on the Aptec disks. We will refer to this DIA as the "AP DIA."

DATA FLOW

After amplification, anti-alias filtering, and digitizing, the input signal from all hydrophones is recorded on HDDR tape along with synchronization, time-code, and environmental information. The HDDR utilizes a read-after-write

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SYSTEM CONFIGURATION

figure 1.

feature which allows the HDDR DIA to load input data into the IOC MM in real-time immediately after it has been stored on tape.

There are two modes of operation: time-series data collection mode and first-pass processing mode.

In time-series mode, the AP DIA demultiplexes selected channels of this input data, typically in "frames" of 4096 samples per channel, from MM to "time" files on the Aptec disks.

In first-pass mode, selected channels of the input data are demultiplexed into the AP SCM by the AP DIA. This "frame" of data typically consists of 4096 sample points per channel. The AP performs a fast Fourier transform (FFT) on these selected channels and saves user-selected frequency lines. The AP DIA then moves the line data from SCM to MM, then from MM to "line" files on the Aptec disks. Concurrently, the AP performs FFT beamforming on these same lines and averages the results over a specified number of data frames. If the averaging is complete after this frame, the AP DIA moves these averaged beams from SCM to MM, then from MM to "beam" files on the Aptec disks. Again concurrently, the AP calculates a cross-spectral matrix for each line in this frame and the results are averaged over a specified number of frames. If the averaging is complete after this frame, the AP DIA moves these averaged cross-spectral matrices from SCM to MM, then from MM to "cross-spectral" files on the Aptec disks. It is the operator's choice whether or not to perform the beam and/or cross-spectral calculations.

In either time-series mode or first-pass mode, there is a file transfer program running on the VAX. This transfer program detects when Aptec disk files (time, line, beam, and/or cross-spectral files) are full and copies completed files from the Aptec disks to a user disk, allowing the Aptec disk files to be re-used. This additional buffering reduces the real-time burden on the VAX.

When moved to a user disk, the line files are then used in a program running on the VAX to display shade plots of hydrophone power vs. hydrophone number vs. time. These plots are produced on a DEC LA50 dot-matrix personal printer.

The beam files, after being moved to the user disk, may be used at operator request in another program which runs on the VAX to produce color plots of frequency vs. azimuth (FRAZ) vs. time. These plots are produced on a Lexidata color display.

As data files are written to the user disk, a monitor program runs on the VAX and detects when the amount of free disk space on the user disk is low. When this occurs, the program notifies the operator to back up the oldest data files to 9-track tape and delete them from disk, thus creating free disk space for new data files.

To keep track of this activity, a logging program runs on the VAX to keep a permanent record of the time, line, beam, and cross-spectral files produced and stored on 9-track tape.

OPERATION AND SOFTWARE

Refer to figure 2.

The data collection and processing is initiated by VAX/VMS Digital Command Language (DCL) "command procedures" that start the necessary programs on the VAX, which in turn start the necessary IOC and AP programs. There is one main Fortran program running on the VAX for each mode: time-series data collection mode or first-pass processing mode. Once data processing has been initiated, it can continue indefinitely until stopped, paused, or restarted by the operator. If there is a break in the input data stream, the software will spin and wait for more input, then continue.

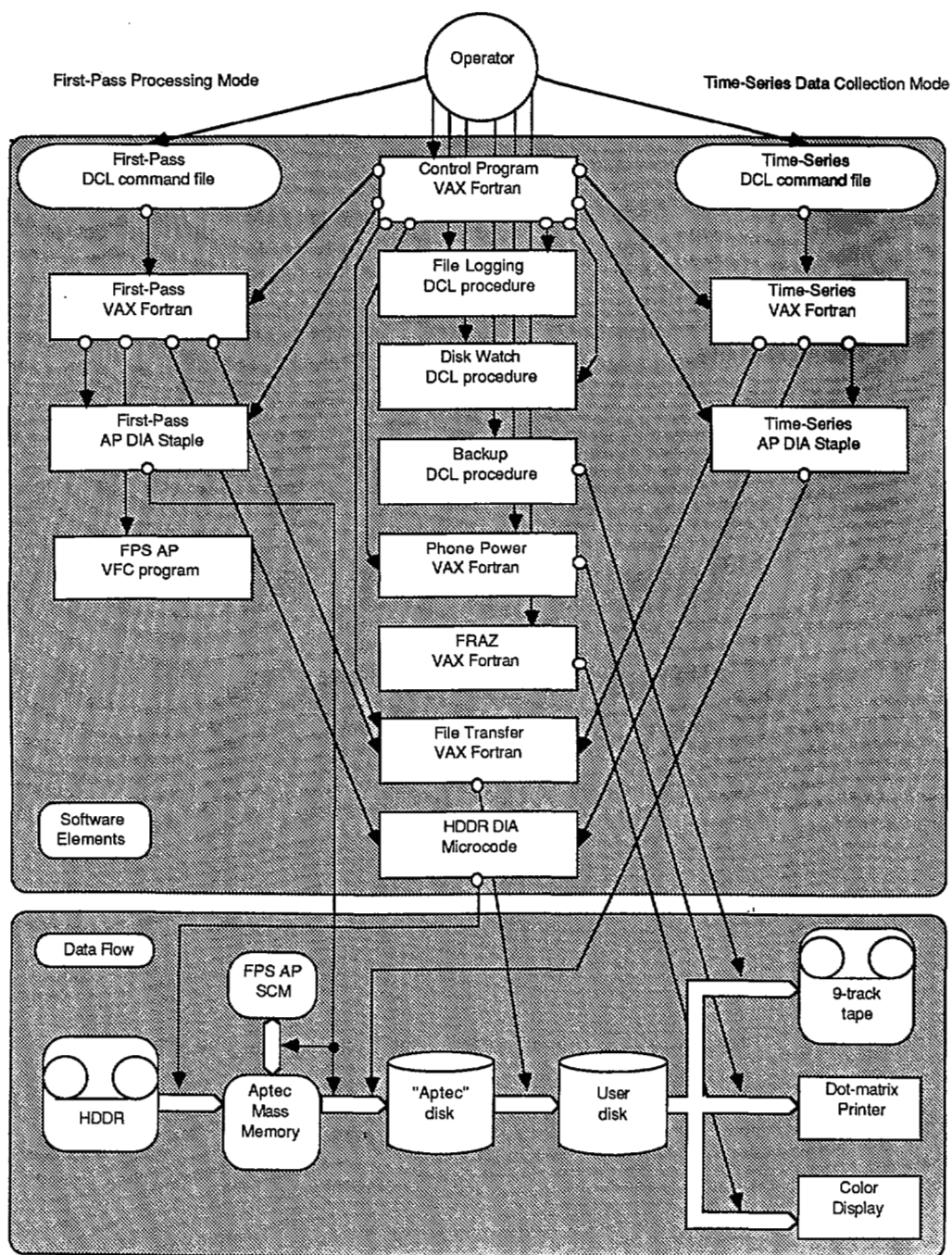
Aptec software uses the standard VMS Files-11 file structure to manage Aptec disks and their files so they may be accessed transparently through VMS. Also, Aptec uses the Files-11 structure to manage Aptec mass memory. In this way, mass memory "looks like" a Files-11 disk with Files-11 files and may be accessed via standard VMS I/O routines. Aptec software also allows these disk and mass memory files to be accessed by byte so that Aptec software can use the files as RAM.

In the initialization stage of either mode, files are created on the Aptec disks to hold demultiplexed and processed data. "Time", "line", "beam", and/or "cross" files are created to hold time-series data, line data, beamformed output, and cross-spectral output, respectively. These files are made permanent for the duration of the data collection and processing run. The system fills these Aptec disk files with data and then copies the files to the user disk, allowing the Aptec disk files to be re-used. In this way, the Aptec disk files act as buffers for completed data files.

The first step in the data processing, for either mode, is the real-time storage of time-series data into Aptec MM by microcode running in the HDDR DIA. Aptec provides a standard "monitor" program which runs in any DIA. This monitor can be expanded with custom routines. In our case, the standard monitor was expanded with data collection routines written in Aptec microcode. This microcode interfaces with the custom HDDR/DIA interface and buffers input data into MM. This hardware/software configuration can store data at rates of between 80 K samples/second and 800 K samples/second. This same microcode is used for either mode of operation.

In time-series mode, the HDDR DIA microcode is started by the main time-series Fortran program running on the VAX. In first-pass processing mode, the HDDR DIA microcode is started by the main first-pass processing Fortran program running on the VAX.

In time-series mode, the input data in MM is demultiplexed to time files on the Aptec disks by code running on the AP DIA. This code is written in a "Fortran like" Aptec language called Staple (STructured Application Language and Executive) and runs continuously during the data collection and



SOFTWARE CONTROL OF DATA FLOW

figure 2.

processing run. The Staple is initiated by the main Fortran time-series program.

In first-pass mode, the input data in MM is demultiplexed into the SCM of the AP by a different Staple program running on the AP DIA. This Staple program also runs continuously and is initiated by the main Fortran first-pass program.

Only one of these Staple routines can run at any given time.

In either mode, when the HDDR DIA microcode has filled an MM buffer with input data, it sends an interrupt to the main Fortran program on the VAX. (The standard Aptec host DIA monitor program was enhanced by NRL to provide this interrupt.) The main Fortran then sets a "flag" word in MM for the Staple running in the AP DIA. This flag signals the Staple to demultiplex the full buffer. Staple then processes the buffer and the cycle repeats on the next full buffer.

In first-pass mode, a program written in FPS VFC (Vector Function Chainer) code is started by the main first-pass Fortran and runs in the AP continuously while "handshaking" with the AP DIA Staple. After the AP DIA Staple moves a frame of data from MM to SCM, it notifies the AP VFC which, in turn, calculates selected frequency lines. The VFC notifies Staple when it is finished with the line calculations and Staple then copies the line data from SCM to MM, then from MM to line files on the Aptec disks. While the transfer of line data is under way, the VFC beamforms the lines (if beamforming is desired by the operator). If beamform averaging is complete on this frame of data, the VFC notifies Staple which in turn copies the beamformer output from SCM to MM, then from MM to beam files on the Aptec disks. If cross-spectral matrix calculations are desired by the operator, the VFC performs the calculations on this same frame of lines. These cross-spectral calculations proceed in parallel with the transfers of line and beam data to the Aptec disks. If the cross-spectral matrix averaging is complete on this frame, the VFC notifies Staple which in turn copies the cross-spectral matrices from SCM to MM, then from MM to cross files on the Aptec disks. The VFC then waits for another frame of input data from Staple and the cycle repeats.

In either mode, the main Fortran program "spawns" a file transfer Fortran routine on the VAX which detects completed files on the Aptec disks and copies them to the user disk, thus allowing the Aptec disk files to be re-used as file buffers. The AP DIA Staple sets flag words in MM to signal when a file is complete. The file transfer Fortran monitors these flags. When the transfer routine detects a set flag, it copies the corresponding Aptec disk file to the user disk, extracting the starting time code of the data from MM (where it was stored by the AP DIA Staple) and using it as part of the permanent file name.

In first-pass mode, two Fortran graphics display programs are used to assist in data monitoring. The first, the phone-power monitor, uses the processed

line files to plot gray-shade intensity levels of received phone power as a function of time. This information is displayed on a dot-matrix printer and is continually updated as new line files are copied from the Aptec disks to the user disk. The operator has a choice of plotting the total power for each channel and/or only the power contained in a given frequency line. This type of display can be used to determine bad channels, as well as the intensity of the acoustic field.

The second display is that of power as a function of frequency and azimuth or FRAZ. This Fortran program reads data from the beam files and uses it to create a color intensity plot on a Lexidata display unit. In order to take advantage of code previously written for a Ramtek color display, Ramtek-to-Lexidata conversion routines were written. In this way, the system can either be used with a Lexidata in the field or, with the code re-linked, a Ramtek in the lab. When running this program, the operator can select different subsets of channels, which represent different sonar apertures, and plot time histories of frequency and bearing spectra. This is useful for determining the relative position and history of an acoustic source. To free the operator from manually entering start and stop times, this routine automatically finds past and "future" data by using the computer-generated logs of processed files.

For either mode, operator DCL command procedures spawn a "file-logging" DCL procedure that automatically maintains logs of the processing of files, and a "disk watch" DCL procedure which notifies the operator when free space on the user disk becomes low. Upon notification of low disk space, the operator will run a "backup" DCL command procedure to automatically back up data files to 9-track tape after which they may be deleted. The backup command procedure uses the computer-generated logs to keep track of what files have already been backed up and what files should not be deleted until used by the phone-power or FRAZ programs.

Unless told otherwise by the operator, the system processes data continuously. To control the different processes, the operator runs a Fortran "control" program on the VAX. This control program allows the operator to: pause processing immediately, pause processing when the current files are done, resume processing, stop processing immediately, or stop processing when the current files are done.

SYSTEM FLEXIBILITY AND ENHANCEMENTS

This system is flexible in a number of respects and can be expanded and enhanced without affecting the existing system. The VAX 11/730 may be replaced by any Unibus VAX, or a Q-Bus or BI-Bus VAX equipped with a Unibus adapter, with no modifications to hardware or software. In the lab, the 11/730 is replaced by a VAX 11/750 with 8 MB of memory to provide more processing power.

Aptec Mass memory can be expanded to allow more processing buffers and the elimination of the Aptec

disks by enabling the AP DIA Staple and VAX Fortran to buffer data directly to the user disk files. This enhancement is currently under development.

To provide more processing power, additional DIAs and DIPs may be added to the system, along with more disks, APs, input sources, etc. These additions should produce relatively little drain on the VAX.

Similar to the DIA, the DIP (Data Interchange Processor) is used in similar systems at NRL. Whereas the DIA's private bus uses standard Unibus protocol to interface Unibus devices to the Aptec and perform data transfers up to (theoretically) the 3 MB/second limit of the Unibus, the DIP is used to attach custom devices to the Aptec which adhere to the DIP private bus hardware/software protocol. The DIP private bus is capable of transfer rates of up to 12 MB/second. Present input data rates of the system can be increased by replacing the HDDR DIA with a DIP and replacing the HDDR/DIA interface with a different custom interface board. This particular configuration has been developed by the Large Aperture Acoustics Branch of NRL and is in use successfully in a similar system developed by the Applied Ocean Acoustics Branch of NRL. Possible data rates of this configuration are 0 to over 1 million samples/second.

SUMMARY

The system was used at sea and is presently running in the lab to further process data gathered during the experiment. Modifications and enhancements to the system, including the elimination of the need for the disks attached to the Aptec, the replacement of the host VAX 11/730 with a VAX 11/750 clustered to another 11/750, both in full use, and the ability to handle higher input data rates via an input DIP instead of a DIA, are presently under development. Future plans call for enhancements of the user interface and data monitoring displays.

ACKNOWLEDGMENTS

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REFERENCES

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