SERI/TP-257-3663
UC Category: 261
DE9000317

PC-Based PCM Telemetry Data Reduction System Software

D. A. Simms

February 1990

Prepared for the
36th ISA International
Instrumentation Symposium
Denver, Colorado
7-10 May 1990

Prepared under Task No. WE011001

Solar Energy Research Institute
A Division of Midwest Research Institute

1617 Cole Boulevard
Golden, Colorado 80401-3393

Prepared for the
U.S. Department of Energy
Contract No. DE-AC02-83CH10093

Printed in the United States of America
Available from:
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Price: Microfiche A01
Printed Copy A03

Codes are used for pricing all publications. The code is determined by the number of pages in the
can be found in the current issue of the following publications which are generally available in most libraries: *Energy Research Abstracts (ERA)*; *Government Reports Announcements* and Index (*GRA* and I); *Scientific and Technical Abstract Reports (STAR)*; and publication NTIS-PR-360 available from NTIS at the above address.

PC-Based PCM Telemetry Data Reduction System Software

D. A. Simms

Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

ABSTRACT

The Solar Energy Research Institute's (SERI) Wind Research Program is using pulse code modulation (PCM) telemetry systems to study horizontal-axis wind turbines. SERI has developed a low-cost PC-based PCM data-acquisition system to facilitate quick PCM data analysis in the field. The SERI PC-PCM system consists of AT-compatible hardware boards for decoding and combining PCM data streams and DOS software for control and management of data acquisition. Up to four boards can be installed in a single PC, providing the capability to combine data from four PCM streams direct to disk or memory.

This paper describes the SERI Quick-Look Data Management Program, which is a comprehensive software package used to organize, acquire, process, and display information from PCM data streams. The software was designed for use in conjunction with SERI's PC-PCM hardware described in a related paper. Features of the Quick-Look program are highlighted, including those which make it useful in an experiment test environment to quickly examine and verify incoming data. Also discussed are problems and techniques associated with PC-based PCM data acquisition, processing, and real-time display.

INTRODUCTION

PCM-encoded telemetry data systems provide highly accurate measurements over a wide dynamic range with low noise (Strock 1983). These systems are ideal for collecting data relating to the study of wind turbines, especially in multiple-turbine wind parks. Typical test installations require multiple-channel measurements taken from a variety of different locations. These can be grouped into three basic categories: Turbine rotating, turbine non-rotating, and meteorological.

In the rotating-turbine frame, measurements are made on the turbine blades, blade attachments, and hub. Typical parameters include strain-gauge bending moments and torsion, airfoil surface pressure distributions, total dynamic pressure, and blade pitch angle. These measurements provide data to determine blade aerodynamic and structural loads.

In the nonrotating turbine frame, measurements characterize machine performance and determine turbine loads. This requires data from the turbine nacelle and tower, such as generator power production, tower bending, azimuth and yaw angles, and rotation speed.

To determine characteristics of the wind at a turbine or wind park, meteorological conditions are measured. Anemometers are used to measure near-field horizontal and vertical wind shear. This requires many channels of wind speed and wind direction data from local upwind anemometer arrays. Atmospheric stability measurements are also important in evaluating characteristics of wind park inflow and outflow. This requires far-field atmospheric boundary layer measurements, including anemometry, temperature, barometric pressure, and dewpoint.

In an effort to increase accuracy, simplify instrumentation and reduce noise, data are digitized and encoded into PCM streams as close to the measurement source as possible. The streams are then telemetered to a convenient central receiving location and recorded on multi-track tape. Streams from the rotating frame can be transmitted over an RF link or conducted through slip rings. Local streams are usually conducted through cables, and far-field streams are most easily transmitted.

Figure 1 depicts the current "Combined Experiment" (Butterfield 1989) under way at SERI, sponsored by the U.S. Department of Energy (DOE), to provide detailed measurements on a 10-meter, 3-bladed horizontal-axis wind turbine. The objectives of the experiment are to develop an understanding of how turbulent inflow affects unsteady aerodynamics, fatigue loads, and yawed operation loads. The experiment uses seven PCM streams for data collection. Three streams are recorded in the rotating frame, two from local inflow, one from the turbine/tower, and one from far-field meteorology. Characteristics of the streams are summarized in Table I.

PCM data streams from the Combined Experiment are recorded on wide-band tape and postprocessed on an extensive laboratory-based telemetry data-reduction system (Fairchild Weston 1985). Figure 2 shows the complete data processing path used to reduce PCM data recorded in the

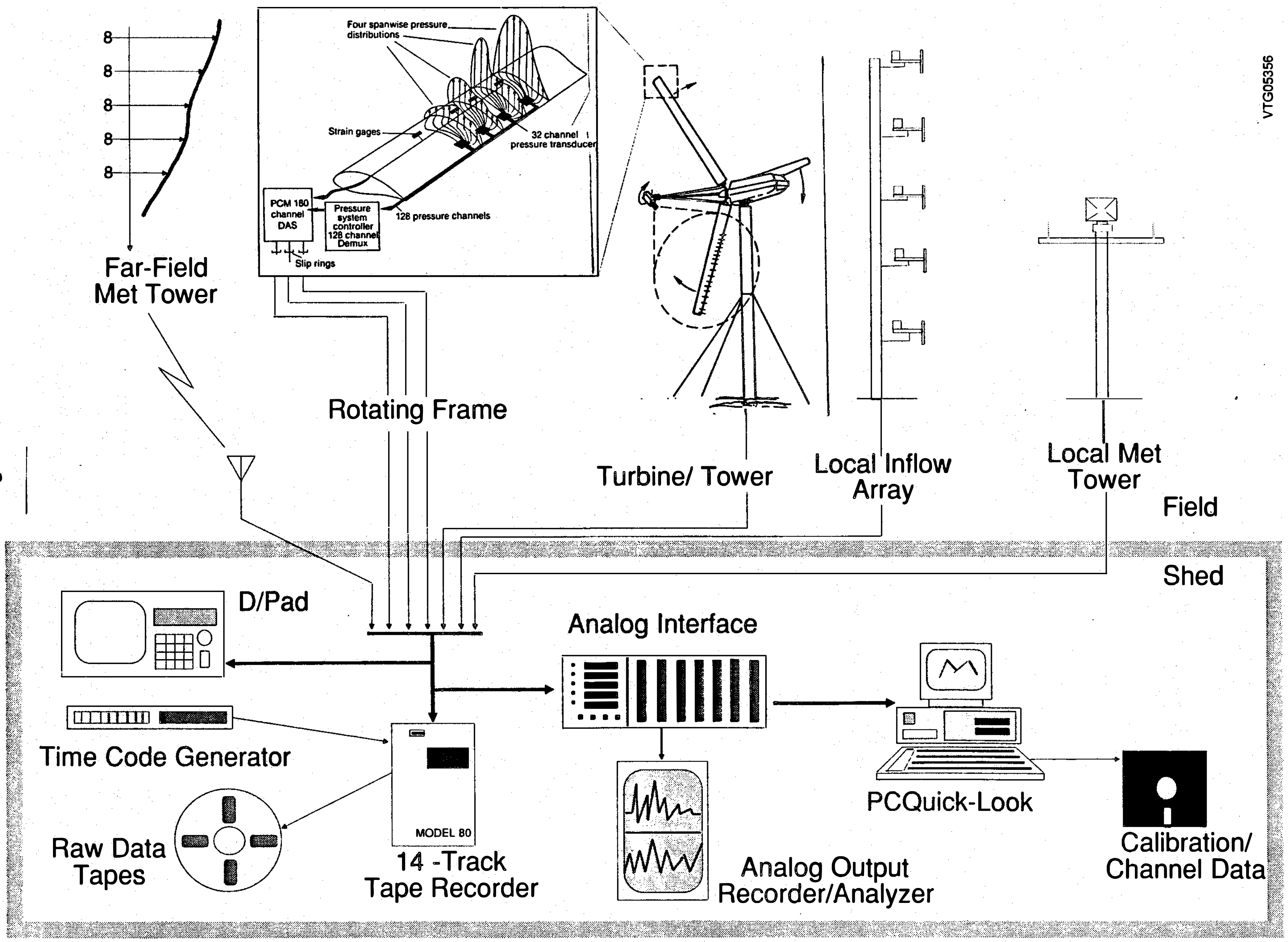

Figure 1. Combined Experiment PCM Streams

VTG05356-B

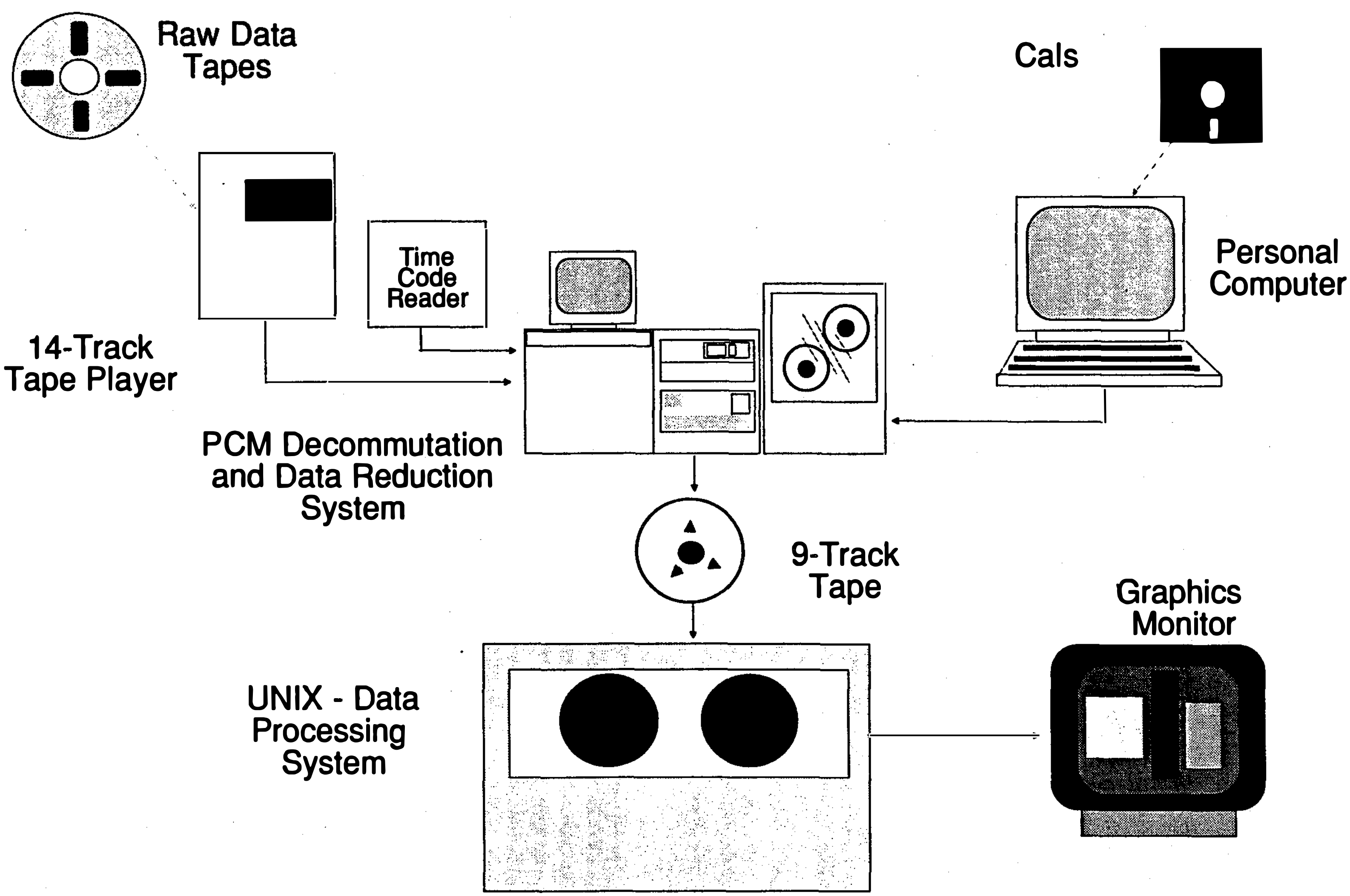

Figure 2. Full PCM data reduction and processing

field. This system processes all recorded data, providing them in digital format for use in subsequent data analysis on a UNIX-based computing system.

Table I. Combined Experiment PCM Configurations

PCM #	Bit rate (Kbit/s)	Sample rate (Hz)	Number of channels	Sample interval (msec)	PCM source location
1	7.5	34.72	16	28.8	Far met
2	15	69.44	16	14.4	Inflow
3	60	277.78	16	3.6	Local met
4	400	520.83	62	1.92	Rotor
5	400	520.83	62	1.92	Rotor
6	400	520.83	62	1.92	Rotor
7	60	277.78	16	3.6	Turbine

SERI's wind program is also conducting various other field tests in an effort to assist wind industries in the United States to improve reliability and performance of wind turbines. Some current studies include wind park inflow-outflow characterization and advanced airfoil testing. These tests are not as comprehensive as the Combined Experiment described above. They are typically of short duration, designed with one or two specific objectives in mind. Data collection needs are on the order of 50 channels with 10-Hz maximum bandwidth. A typical test layout is shown in Figure 3. Multichannel hub-mounted rotor packages (McKenna 1990) facilitate rotating frame measurements from multiple turbines.

One area of field testing in which we were severely limited was the ability to provide quick-look data processing and display. We needed multiple-stream decoding, derivation of parameters from all channels (across PCM streams), graphic display, data storage, and a means to rapidly update calibration coefficients. We also needed the ability to monitor long-term meteorological conditions for evaluating current test status. These field capabilities are essential, because debugging using laboratory-based postprocessing is inefficient and impractical. We could not find a commercial system with these features which could be inexpensively duplicated at our many test sites. We therefore decided to develop our own PC-based PCM system which could provide the required field test capabilities. The system consists of PCM decoding hardware boards (Simms and Butterfield 1990) and a custom quick-look PCM data management software program.

OVERVIEW OF THE QUICK-LOOK PROGRAM

The Quick-Look program is a comprehensive software package designed to manage data from multiple incoming data sources. It is used on a DOS-based PC interfaced with peripheral PCM decoders in an experiment test environment. The major objective in developing the program was to provide a way to quickly examine data from PCM streams in the field. Other objectives include on-line channel data base management, hardware debugging capability, and automated calibration procedures.

Menus are presented to the user enabling quick selection of desired options. Each menu contains a title, followed by lines listing current available options. The user uses the arrow keys to move a highlighted bar up and down to select the desired operation. From there, another level of menu options may appear, or option execution may begin.

The main program menu presents the user with options which are summarized in Table II. These options identify all the basic features of the Quick-Look program.

Table II. Quick-Look Program Features

Hardware Set-Up Define all parameters related to interfacing the PC with peripheral PCM decoding devices.
PCM Configuration Data Base Data base in which to define and maintain the characteristics of all potential incoming PCM streams.
Channel Data Base Data base in which to define and maintain information associated with all measured data channels.
Derived Parameter Data Base Data base in which to establish and organize ancillary derived channel equations.
Acquire Data Select channels, monitor current conditions, collect data and store it in a disk file.
Display Recorded Data Comprehensive graphical or alphanumeric display of previously recorded data sets.
Channel Calibration Multiple channel data processor using least squares linear regression to generate calibration coefficients.
File Maintenance System to organize and catalog experiment-associated data files and channel data bases.
Test Event Log To record the sequence of experiment events.

Typical components of PC-based data acquisition systems common to both the Quick-Look system and most commercial data acquisition systems are not described here. This report concentrates on the particular capabilities of the Quick-Look program related to quick handling of PCM data in the field and conducting calibrations. Although this program was developed to allow the PC to be interfaced with PCM data, the capabilities for data management outlined here could be applied to other types of telemetry-based experiment data handling systems as well.

VTG05356-C

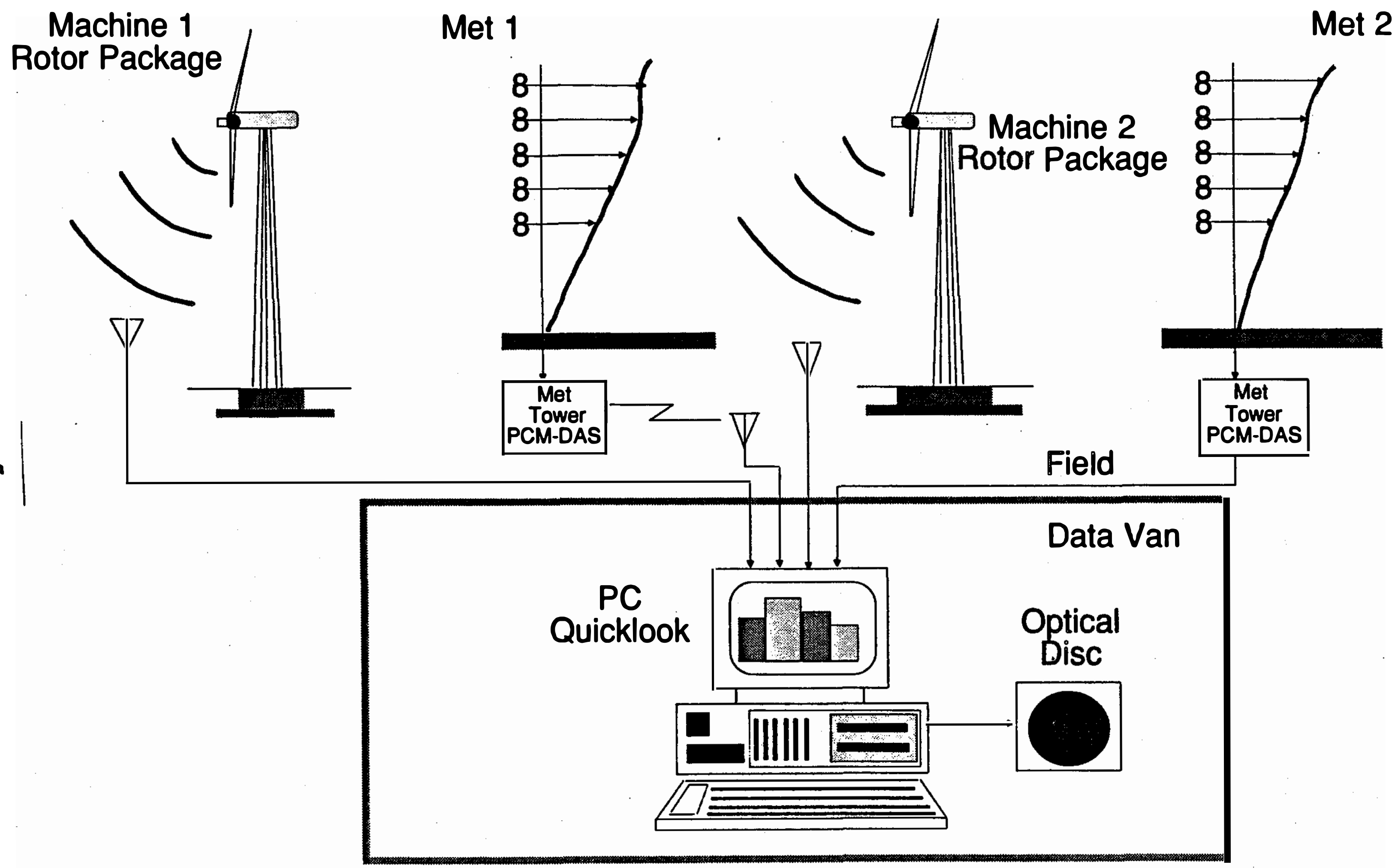

Figure 3. Wind farm multiple-machine/met tower PCM scenario

LIMITATIONS OF PC-BASED DATA PROCESSING

A basic premise of the Quick-Look program is that the PC cannot process all incoming data in real time. Because of DOS and CPU limitations, data collection and data processing are not done at the same time. These tasks could be combined if incoming data rates are sufficiently slow. However, for most of our applications, we have found that the typical PC cannot concurrently do both adequately. If the processes are independent, then the CPU can be fully dedicated to each task separately. This allows access to higher-rate incoming data and provides greater data-processing capability.

To compensate for the limitations imposed by the PC, two techniques can be used to effectively reduce the quantity of incoming data to a manageable level. First, the PCM data streams can be periodically sampled at a controllable rate. This allows the PC's CPU to selectively alternate between data acquisition and processing. Second, data can be recorded to disk or memory over a given duration of time, and then postprocessed.

These data-reduction techniques impose restrictions that the user must be aware of, and they may not be appropriate in certain situations. For example, transients may be missed, or aliasing could be introduced. To provide data values representative of existing conditions, the data segments should be stationary time history records (Bendat and Piersol 1980). The Quick-Look program provides many features which allow evaluation of time series data. It is up to the user to ensure that the data segments are sufficiently long and statistically meaningful to produce adequate results.

For most of our quick-look requirements, the limits imposed by the PC-based system are not of concern. In our typical field experiments, we have found this system to be extremely useful, especially for monitoring current conditions and conducting channel calibrations. We do not, however, use this system as a substitute for full data processing. Usually, all PCM data streams are recorded independently of this system to provide complete data sets for comprehensive postprocessing, as shown in Figure 2.

INTERFACING A PC TO THE PCM DATA STREAMS

The main function of the Quick-Look program is to interface a PC with PCM data. This requires some type of PCM decoding hardware with the ability to transfer data into a PC. The data transfer can be done in a variety of ways, such as through a simple but slow serial communication port, or complex but fast direct memory access (DMA) buffers. The PCM decoding hardware can be outside or inside the PC.

This report assumes that PCM data are provided to the Quick-Look program through a PC-based PCM-decoding hardware system developed by SERI (Simms and Butterfield 1990). The Quick-Look program could support other PCM decoders if appropriate interface drivers were provided; however, some of the software features described here depend on unique capabilities provided by the SERI decoding system.

The SERI PC-PCM decoding system consists of printed circuit boards (APEX Systems Inc. 1988) that fit directly inside the chassis of a PC/AT or compatible computer, and basic control software. PCM data are decoded on the board and DMA transferred to PC memory or disk. One board can decode one PCM stream at a time. Up to four boards can be installed into a PC, permitting data from four streams to be simultaneously combined. The Quick-Look program builds all data files necessary for setting up PC-PCM boards, and overlays control software to accomplish data acquisition.

The full complement of four boards in a PC allows the Quick-Look program to manage data from up to 16 PCM streams. Each board has four inputs, and can be quickly reconfigured to cycle through the inputs to grab-sample data from different PCM streams. Various combinations of cyclic or concurrent acquisition can be used. Maximum data-collection rates vary, depending on hardware limitations and other variables which are discussed in following sections. The boards support standard-format Inter-Range Instrumentation Group (IRIG)-compatible PCM streams with bit rates in the range of 1000 to 800,000 bits/sec, and a maximum of 64 data words (including sync) per frame. Assuming 12-bit data resolution, channel sample rates from of 1.3 to 33,000 Hz are possible.

The Quick-Look program assumes that each channel of input data is a time history record, and that each record has a constant sample rate. However, because data can originate from multiple PCM streams of varying rates, channels may have different sample rates. Data are transmitted to the program through arrays either in memory or on disk files. If multiple PC-PCM boards are used, then data from up to four PCM streams can be collected simultaneously. All incoming data are meshed into a single file. After they are collected, they are then decoded for display by the Quick-Look program. If a single PC-PCM board is used, it is still possible to cycle through and monitor up to four PCM streams; but simultaneous acquisition from multiple streams is not possible. Software decoding of subcommutated or supermultiplexed PCM data is not supported.

To keep track of up to 16 PCM inputs, the Quick-Look program provides a location matrix into which the user assigns incoming PCM streams to their respective input locations. When data are requested from a particular PCM stream, the program uses the matrix to determine how to set up acquisition so that the correct PCM streams are accessed.

During acquisition of PCM data, all values are based on raw "counts" which are derived from binary data words that have been decoded from the PCM data streams. Data resolution is determined by the number of bits used to represent each measured data value. We typically use 12-bit resolution, which is 1 part in 2^{12}, corresponding to count values ranging from 0 to 4095.

The Quick-Look program interprets the raw count values provided by the PCM decoding hardware and converts them to engineering units. As described above, because of the potentially large amount of incoming data and the limitations of the PC, the Quick-Look program does not acquire and process the data simultaneously. It uses techniques of contiguous or sampled acquisition to reduce the volume of incoming data to a manageable level. These techniques are described in following sections.

CONTIGUOUS DATA ACQUISITION

In contiguous data acquisition, data streams are recorded as time history record blocks, with no gaps. Data from up to four streams can be simultaneously acquired to a disk file up to the limit of available disk space. The data blocks are then postprocessed using features of the Quick-Look program or other data analysis programs.

While contiguous data collection is occurring, no other process can run. After the block of data is acquired, summary statistics are presented on the monitor display. From these, the user can decide whether the data set meets the necessary criteria.

The required number of samples is specified by the user as a time duration. The total resulting number of data points depends on bit rate, number of streams, and channels per stream. Large quantities of data are not practical in this mode. Upward from 50,000 individual data values start to become difficult because

- *Disk storage resources are quickly exhausted.* Raw data are input to the program in an efficient binary integer format. However, to produce practical data sets, they are converted to engineering units and copied to an ASCII file in 80-column E12.3 format with corresponding time. This is very readable (and printable), but not storage efficient.

- *It takes a long time to process.* It is CPU intensive to decode and sort the raw binary data, especially for multiboard acquisition. Data from the PCM streams are intermeshed in one binary file as they are acquired. Each data value is encoded with a "tag" which identifies the stream and channel it came from. The tag has to be removed from the data and used for sorting. The raw data values usually require conversion to engineering units. Slower-rate data are interpolated to the rate of the fastest stream. The final data file is chronologically organized as a time series, with each record consisting of a time value followed by data values from each requested channel for that time.

REAL-TIME DATA MONITORING

Sampled data acquisition is used to provide real-time data-monitoring capability. The incoming PCM streams are periodically sampled to acquire small segments of contiguous data. The segments are quickly processed and displayed to show current conditions. The process is continuously repeated. Up to 135 channels from any combination of incoming PCM streams can be displayed. Each representative value for each channel is determined by averaging 1 to 10,000 contiguous samples. The user selects channels for display and defines an appropriate averaging interval.

Data monitoring is a cyclic repetitive process which is controlled by the Quick-Look program. This is shown in Figure 4, and can be described in three basic steps:

1. PCM-stream data acquisition is initiated to obtain data segments from each requested channel. The Quick-Look program overlays an independent data-capture program which initializes the PCM decoding boards, locks onto the PCM streams, and initiates data capture. All PCM streams containing requested channels are sampled to obtain enough contiguous data frames for the required averaging interval. Data are written to RAM disk, and control is returned to the Quick-Look program.

2. The Quick-Look program reads data from RAM disk and sorts by requested channel. Mean and standard deviations are calculated for each channel from the total number of samples in the sample period. PCM data in units of counts can be converted to engineering units using the slope and offset from the channel data base. If derived channels are requested, calculations are performed using equations from the derive-channel data base. Any combination of derive channels and measured channels can be displayed.

3. Resulting values are displayed on the screen in either raw PCM counts or engineering units. The main reason for displaying counts is for conducting calibrations. The screen display is an alphanumeric representation of the current conditions for the requested set of data channels. The program monitors in pages of 15 channels each. Only one page is displayed at a time. The user can easily select from among several pages by keying the desired page number. All pages are updated simultaneously after each set of data is processed. Each channel is displayed beginning with channel number, name, and units from the channel data base, followed by the current mean and standard deviation.

For example, selected channels would be displayed on the monitor in the following format:

```
201:Anemometer #1 (m/s).......1.067E+01 (2.502E-01)
307:Power Supply (volts)......2.502E+00 (6.745E-02)
402:Bending Moment (N-m)......5.678E+02 (3.456E+01)
.                             .
.                             .
.                             .
```

The first digit of the channel number identifies the PCM stream, and the next two digits identify the data word. The mean and standard deviation values continuously change as data monitoring cycles. The monitor display may lag behind real time by a few seconds, depending on calculation overhead. For the Combined Experiment data streams of Table I, practical data monitor update rates of 1-10 seconds were easily achievable.

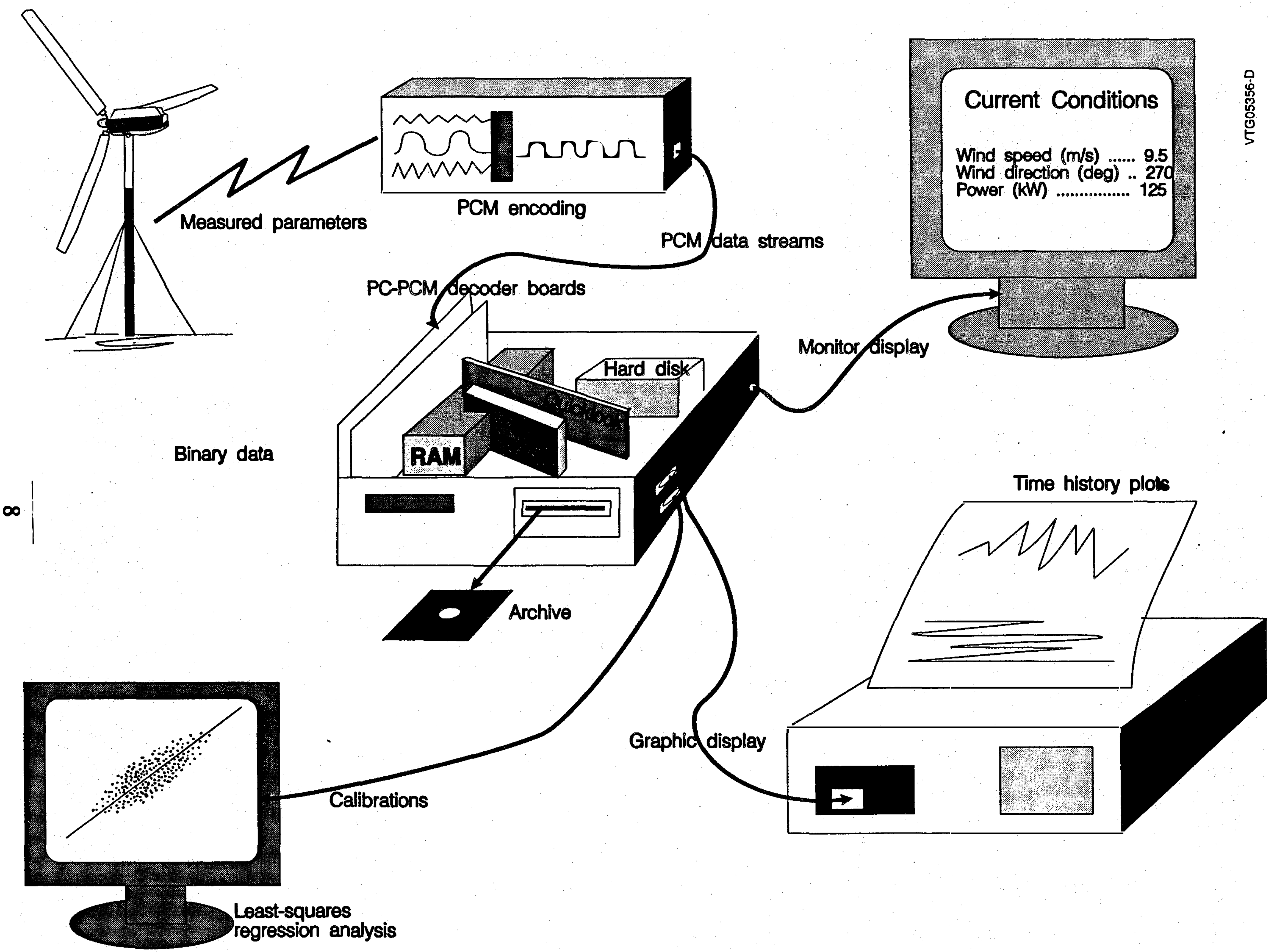

Figure 4. Quick-Look program data flow

At any time during data monitoring, data collection can be initiated via a user-entered keystroke. This causes monitor-displayed mean and standard deviation values to be permanently recorded in an ASCII disk file. The data monitor will continue to update, and will note that data collection is in progress. The collection can be suspended and restarted at any time. Upon termination of data monitoring, collection is stopped, and mean values for the entire period are calculated. These are inserted at the beginning of the data file, and the file is closed and saved. The user is notified of the file name, shown the file for browsing, and has the option of printing a copy.

DATA MONITORING FEATURES

Typically, the monitor displays current rapidly changing conditions. The current values are calculated by averaging contiguous samples. Another level of averaging is also possible. A parallel monitor display is available to show long-term averaged values, determined from the current condition values. Keystrokes are used to toggle between the long- and short-term displays. For long-term averaging, current display values are summed for each channel (measured and derived) over the averaging period. At the end of each period the sums are divided by the number of scans, and the average display is updated. The user defines an appropriate long-term averaging period (typically in minutes).

Because up to 135 data channels can be monitored, it would be impractical to expect the user to re-enter the list of desired channels each time he or she wants to monitor data. To overcome this, the program provides a means to define and save collections of display channels. A user-defined name is associated with each collection. The user assembles a collection of channels and the Quick-Look program adds it to a list of available selections. When data acquisition is initiated from the main menu, the user is presented with a menu containing the list of all available collections of channels and selects the appropriate one using the arrow keys. It is also possible to modify an existing collection, delete obsolete ones, and define new ones.

For real-time data monitoring, a range-check feature exists which highlights the display when a value is out of range. The user enters the maximum and minimum allowable values for a particular channel in the channel data base. If a value is outside the range, then it is displayed with a conspicuous red background.

Another type of real-time data monitor is provided in the form of a graphic bar-chart display. This can be invoked at any time during alphanumeric data monitoring via a user-entered keystroke. Up to 62 measured channel values are graphically displayed as bar graphs on the screen. The Quick-Look program sets up the bar-chart display with the desired PCM stream configuration and channels. The bar-chart monitor shows data in units of counts and can be used on only one PCM stream at a time. Its display update rate is very fast, typically many times per second. It is useful for quickly checking a large number of channels at once, because dead channels are readily detected and easily identified.

FACTORS AFFECTING DATA MONITOR RATES

The rate at which the data monitor display updates itself is affected by many factors. Some depend on which program options the user selects. Others are inherent in the hardware. Some of the factors are

1. CPU speed of the PC
2. Number of channels to display
3. Number of scans to average for each sample
4. Whether engineering unit conversion is done
5. Whether derived parameters are calculated
6. Overhead of the PC-PCM board capture software
7. Bit rate of the incoming PCM stream(s)
8. PCM stream consistency and quality
9. Whether data is captured to RAM or hard disk
10. Whether simultaneous or cyclic acquisition is used
11. Whether data collection is occurring.

DATA BASE OF PCM STREAM CONFIGURATION

The Quick-Look program provides a form into which a set of configuration parameters defining each PCM stream can be input. The parameters are then used to set up decoding hardware to access streams whose channels are requested. The configuration parameters are

1. PCM stream title
2. Number of data words per frame (data channels)
3. Number of sync words per frame
4. Binary sync bit pattern
5. Bit rate in bits/sec
6. PCM data format (Bi-phase L or NRZ)
7. Signal polarity
8. Bits per word
9. Samples to average.

DATA BASE OF CHANNEL PARAMETERS

A data base is kept for each channel of each PCM stream. A maximum of 70 channels per stream is allowed. The data base consists of a set of user-definable parameters and corresponding data. For the Combined Experiment, the following parameters fields are used:

1. Channel description
2. Sensor location
3. Sensor type
4. Sensor ID number
5. Anti-alias filter setting
6. Sample rate
7. Engineering data units
8. Slope (engineering units per count)
9. Offset (engineering units)
10. Range maximum
11. Range minimum
12. Reference channel for calibration
13. Low, zero (mid) and high calibration values
14. Flag to print mean values to a log file
15. Date and time of latest revision

Parameters 2 - 6 are available for bookkeeping purposes, and other than for comprehensive printouts they are not used elsewhere in the program. Values do not have to be entered in these fields. Parameters 1 and 7-14 are used in various other places in the software. Values may need to be entered in these fields depending on the program option selected.

The channel data base option of the Quick-Look program provides access to these parameters for any channel on any PCM stream. The user is presented with a form on the screen that displays current parameter values, which can easy be updated or modified. If any changes are made, a new version of the data base file is written, and becomes the current version. Parameter 15 is updated automatically if any changes are made in any field.

Previous versions of the channel data base are retained so that a history of the channel, including calibration coefficients, is available. The program allows previous versions to be easily recovered. This is especially useful for postprocessing raw PCM data recorded on tape, allowing ready access to data values in correct engineering units.

DERIVED CHANNEL DATA BASE

A data base of all derived channels is maintained by the Quick-Look program. A derived channel can be a function of many channels from multiple PCM streams. When the user selects the derived-channel data base option, a simple form is presented in which the channel description and derive equation are entered. The equation may contain constants, functions, or measured channel numbers. Upon completion, the derived-channel information is saved and made available for use either in monitoring or generating data files.

RAPID MULTICHANNEL CALIBRATION CAPABILITY

Only linear engineering unit conversions are provided, one slope and offset pair for each channel. The slopes and offsets can be input manually into the channel data base, if known. They can also be generated based on measured data obtained during "calibration runs" and automatically inserted into the channel data base. It is possible to quickly generate and update calibration coefficients for many channels from many PCM streams simultaneously. There are four options for calibration runs:

1. 3-level high/mid/low calibration data
2. 2-level high/low calibration data
3. 1-level zero cals (determines offset only)
4. A function of another "reference" data channel

For the first two options, PCM count data are collected at the constant calibration levels for a short duration of time and stored in a file. The channel data base contains a value in engineering units which should coincide with the measured count value at each level. The count data are read from a file and compared to the reference values. A least squares regression line is generated from which a slope and offset are found, and correlation statistics are calculated.

For the third option, count values corresponding to the channel zero (or any known level) are stored to a file. The data base zero value is used as a reference, and a new offset is calculated.

For the fourth option, engineering unit data are concurrently measured from a "reference channel" used to generate coefficients for the channels to be calibrated. The relation between the reference channel and the channel to be calibrated is limited to a simple user-defined mathematical function entered in the channel data base. A least-squares regression line is generated to obtain the relation between the two variables. This allows a "ramp" calibration to be done, in which the data values are distributed over a wide range, as opposed to discrete known levels.

Upon completion of a calibration run, the user is presented with a page of summary regression statistics, other information pertinent to the least-squares fit, and new calibration values. The user can opt to accept or decline the calibration coefficients based on these statistics. He or she can also set up criteria that automate the acceptance process using defined tolerances. For example, the user can identify acceptable ranges of standard error and correlation coefficient. If the regression statistics are within the ranges, calibration coefficients are automatically accepted and inserted in the data base. This provides a means to quickly calibrate many channels. It has proven very useful in the Combined Experiment, in which calibrations of 128 pressure channels are required every five minutes of testing.

EVENT LOG FILE

The Quick-Look program provides a means for maintaining a log of events that occur during an experiment. The user can set up a log file at any time. The log feature automatically notes when data acquisition occurred and summarizes channels used and mean data values during the interval. If any changes are made in the channel data base, then it is noted in the log that a new version was generated. If any channels are recalibrated, their new calibration coefficients and regression statistics are included in the log. The user can easily enter comments, which will be time stamped.

QUICK REVIEW OF RECORDED DATA

Upon completion of data collection to a file, the file is immediately available for review. It is presented to the user, and can be scanned and printed. Channel values can also be easily displayed using included graphics programs. Two- or three-dimensional plot capability is available. Basically, all the user has to do is select a data file, plot type, and desired channels. Available plot types are

- 2-D time series plots. Channel data are plotted on the ordinate axis with time on the abscissa. Axes maximum and minimum are automatically chosen based on data range. Channel data are plotted in appropriate units. A legend that uses the channel name to identify each curve is automatically included. Up to 10 channels of data can be displayed on one graph.

- 2-D X-vs.-Y plots. Channel data are plotted on both axes for comparison. A legend is generated from the name of each Y-axis channel to distinguish among multiple comparisons. Up to 10 comparisons can be displayed on one graph.

- Custom 2-D plots. This option provides the user with some flexibility to generate custom-format plots.

- 3-D plots of time-vs.-channel-vs.-data value. This option provides a quick way to look at time series from many similar channels simultaneously. Time is plotted incrementally on the X axis. (It is assumed that the scans occur at even intervals of time.) Selected channels are plotted on the Y axis incrementally in the order in which they were selected. The data value magnitudes are plotted on the Z axis. The XYZ values are shown as a surface in three dimensions. Any deviation among channels is readily noticeable on the plot surface. Appropriate surface display depends on the particular data set, and display options are available to improve the view.

CONCLUSIONS

The Quick-Look program is a comprehensive software package designed to manage data from multiple incoming data sources. It provides a way to quickly examine field data in an experiment test environment. Program menus allow easy access to options that facilitate organization, acquisition, processing, and display of information from many PCM data streams.

The program presumes that a PC cannot process all incoming data in real time. It compensates for this by using techniques to reduce the quantity of incoming data to a manageable level. The data-reduction techniques impose limitations that the user must be aware of, and they may not be appropriate in certain situations. However, for most of our quick-look requirements, the imposed limitations are not of concern.

In our typical field experiments, we have found the Quick-Look program to be extremely beneficial, especially for real-time monitoring and conducting multichannel calibrations. The ability to grab contiguous time-series data blocks from multiple streams allows access to high-rate phenomena. Graphic review features provide the test engineer with a means to quickly interpret results. Data bases providing histories of channel configurations and calibration coefficients are essential for accurate postprocessing of recorded raw data sets.

ACKNOWLEDGMENTS

This work was sponsored by the U.S. Department of Energy's Wind/Oceans Technology Division, and was conducted by the Wind Research Branch at the Solar Energy Research Institute. Development of the program described in this report could not have been carried out without the support of Sandy Butterfield and Neil Kelley.

REFERENCES

APEX Systems, Inc., *PCM Decoder Card Manual* (1988), APEX Systems, Inc., Boulder, Colorado.

Bendat, J. S., Piersol, A. G., *Engineering Applications of Correlation and Spectral Analysis*, A Wiley-Interscience Publication, John Wiley & Sons, New York, 1980.

Butterfield, C. P., *Aerodynamic Pressure and Flow Visualization Measurements from a Rotating Wind Turbine Blade*, Proceedings of the Eighth ASME Wind Energy Symposium, Vol. 7, January 1989, pp. 245-255.

Fairchild Weston Systems, Inc. (February 1985), *PCM Data Collection and Reduction System for the Solar Energy Research Institute: Operating Manual*, Fairchild Weston Systems, Inc., Sarasota, Florida.

McKenna, E., *The Wind Research/Cooperative Field Data Acquisition System*, to be published by the Solar Energy Research Institute in 1990.

Simms, D. A., Butterfield, C. P., *PC-Based PCM Telemetry Data Reduction System Hardware*, Proceedings of the 36th International Instrumentation Symposium, May 6-10, 1990, Denver, Colorado, Instrument Society of America.

Strock, O. J., *Telemetry Computer Systems: An Introduction*, Instrument Society of America, 1983, Prentice-Hall Inc. Englewood Cliffs, New Jersey.