Naval Model Testing Using Fiber Optics and Parallel Processing

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Background

The David Taylor Research Center has a large complex of model basins and carriages to satisfy a wide variety of Hydrodynamic requirements. Technical support is furnished to US government design agencies, the maritime administration, and private organizations. Support involves both experimental and analytical programs related to every type of ship and craft.

The stability, control, and maneuvering characteristics of submarines can be determined by performing free running radio control experiments. These experiments and analytical methods used are to investigate submarine motion.

A requirement arose to operate the radio controlled model (RCM) in a towing tank housed in a building 3200 feet long. This tank is located 1500 feet from the building that houses the data collection and control system mainframe computer. A unique communications, command, and control system has been developed to run experiments using the RCM.

System Configuration

It is necessary in carrying out hydrodynamic experiments to send telemetry data acquired from sensors on the model to the VAX computer and commands from the VAX to the RCM. The model and carriage operate in a building over a distance of 1000 feet. It is also desirable to communicate by voice between the carriage and the computer. A system configuration diagram is shown in Figure 1.

Data are transmitted from the model to the moving carriage and then retransmitted to a stationary receiver at the end of the basin. This transmission is particularly difficult since the building is narrow and highly reflective of RF signals. These data are sent to the VAX in building 18. It is important to preserve the quality of the data along the entire path.

A decommutator is used to recover and process measurement data from the vehicle. The mainframe VAX computer is used by many other users for simulations. It is desirable to perform as much of the real time test processing in a decom to off load the VAX so the latter can serve the other users. The decom ideally should multiplex and format incoming data, display the data, and output control and status signals. This decom should be capable of operating by itself without the mainframe. This would permit the model to be tested for functionality and to be calibrated without tying up the users on the mainframe.

System Description

Command, communication, and control systems often interact with vehicles which are remote from the computer mainframe cluster. Microwave is often used in these systems. Optical fiber is rarely used, but has a distinct benefit for our communications link. Parallel processing is used ahead of the VAX. Separate processors are employed for multiplexing incoming data streams, reformatting and scaling the data, processing (averaging, mapping, etc.), displaying data as graphs, tables, and bar charts, directing the data into the desired output order, and controlling the bidirectional data path to the mainframe. The advantage is to off load the VAX of many processing demands. Parallel processing is required for the processing speed demands of the real time application.

Data and Command Links

RF Segment

The telemetered data are transmitted from the model to the carriage and the commands are sent from the carriage to the model via RF links. The maximum distance is 500 feet over the water and a maximum depth of 36 feet into the basin. The RF signals can penetrate the water because it is fresh water which is resistive. This is much deeper than equivalent RF penetration in sea water. The sea water is salty which makes it conductive and prevents as much RF penetration as in the fresh water.

Microwave Segment

Communication between the moving carriage and the stationary shore has been difficult since there are many reflections and resulting multipath transmissions. Radio transmissions have been used with some success, however data and voice dropouts occur frequently with such systems. A narrow beam microwave system was installed to minimize the multipaths. The main lobe is on the axis of travel of the carriage. Reflections from objects in the building are minimized since the beam is only 3 degrees wide and the building is several thousand feet long. The frequency is 22 GHz (K band), while the power output is 100 mw which is more than enough range for our requirement of 2000 ft.

Fiber Optic Segment

The data, command, and voice signals have to be sent from the microwave receiver to the computer facility 1.3 km away. This is done via fiber optic cable using relatively simple data modems at each end.

The reasons for selecting fiber are:

1. Low electronic cost

2. Low maintenance cost

3. Reduced interference from noise

4. Secure communications

Low Electronic Cost

Fiber has only a few dB of loss per km when properly terminated, there is no need for amplification or equalization in the middle of the run as with coax cable. The cost of fiber is greater than coax, but when future expansion capabilities are included, the overall system cost is less.

Low Maintenance Cost

The maintenance cost for the fiber electronics is considerably less than for coax. Circuitry for coax is often outdoors in the middle of a run in weather proof enclosures which are exposed to the elements. The latter will require costly maintenance over the years whereas the fiber modems are inside buildings and not exposed to the elements.

Reduced Interference From Noise

There is significant electronic noise from motors and AC equipment where models are tested, as there is in many environments where data transmission takes place. Optical fiber will not pick up electrical noise whereas coax with its related circuitry and connectors can receive this interference.

Secure Communications

Finally, since optical fiber doesn't radiate electromagnetic or optical signals, it is secure. It is virtually impossible for anyone to tap into the data being sent in a clandestine fashion.

Communications Link

There is a requirement for two way voice communication between the carriage and the computer facility. Voice signals are multiplexed with the data and command signals. These signals come from voice powered headsets. The carriage voice signals are added to the telemetry data by summing and filtering analog circuitry. Then the data and voice are separated at the computer by appropriate filters. The computer voice signal is frequency division multiplexed onto the command link by a voltage controlled oscillator (one of the command link tone oscillators). The closed loop gain must be kept lower than one or the whole system will oscillate. Another critical item is to limit the voice peaks so that they don't saturate the opamps thereby causing the telemetry signal to lose sync.

Previous Generation Decom and Custom Multiplex Circuitry

This model has used telemetry and command signals for well over a decade. The decom uses pulse code modulation (PCM) and a significant amount of custom circuitry. The model has an acoustic tracking system to record its position. The custom built digital multiplexer and buffer combine the telemetry and parallel tracker signals so they can be sent to the computer. The decom/tracker output goes into a custom built first in first out (FIFO) memory which outputs directly to the computer. When dropouts occur in the telemetry stream the FIFO memory is cleared and data is no longer sent to the mainframe.

The model is run from a control console manually by operators to test the hardware. The previous generation decom is dumb and only passes the telemetry data to the Sigma 9 computer. Consequently the Sigma 9 has to run in real time for the test preventing other computer users from using the system.

Decom - Front End Requirements

The decom is being replaced along with the computer. The following are the communications, multiplexing, and processing requirements on the new decom:

1. Merge the parallel tracker data with the serial telemetry stream.

2. Output the data to the VAX,

3. Stop sending data to the VAX when the telemetry stream is interrupted during dropouts. Restart sending the new data when the stream restarts after the dropout.

4. Perform # 3 in the event that a dropout occurs in the tracker parallel data stream.

5. Input the command data from the VAX.

6. Convert these commands to analog signals for output to the command link.

7. Covert data from both the data link and the VAX to analog signals for strip chart recorders.

8. Format and display the data in 7.

9. Do all of the above in real time.

10. Receive data from the model and transmit commands for testing and calibration barefoot without the VAX.

11. Perform the above with as little additional custom hardware as possible.

12. Provide the capability to reconfigure the system with software in lieu of redesigning custom hardware.

Advanced Decommutation System

The system chosen to accomplish the above is the Loral Advanced Decommutation System, the ADS 100. This system merges incoming data streams, formats and performs mathematical computations on the data, and distributes the data for output to different ports in real time while displaying the data various ways. The system can perform this in real time because each group of operations is performed on a module in parallel. Each module is a processor card on a 4 million bit per second bus.

The telemetry data is received by one card in parallel with the tracker data being received by another card. Each of the data words is assigned an address or a tag. This tag allows each of the data words (parameters) to be sent to specific modules for processing and output. For example the RCM telemetry parameters can be routed to the display. The tracker words can be grouped together with the telemetry words after the latter has been inverted.

This system utilizes a general purpose 8086, and parallel bit slice AMD 2900 processors. The 4 Mbps MUXbus is managed by and the modules are controlled by the latter as described above. The 8086 is used for overhead functions. An example would be to create a menu to set up and specify a telemetry parameter. Different parameters are set up for each module such as PCM prime, parallel input, and processed parameters.

The processed parameters can perform many types of processing including averaging, masking, logical, mapping, etc. Any of the above parameters can be displayed on the CRT in the form of a data page, graph, or bar chart. The general purpose processor performs the display operations. In addition, processing can be accomplished by writing programs using sequences of parameters. These programs can perform many data analyses in real time. The only constraint is the ability of the compressor to keep up in real time. Nevertheless, programs of reasonable length can be run with our data rates. Our PCM frame contains 64 words and is sent at 100 frames/sec. Additional compressors can be added to the MUXbus to run additional real-time processing in parallel. Consequently, the effect is that longer parameter sequences, or programs can be run.

PCM dropouts are handled automatically by the decom. When either bit sync or frame sync detection is lost, the decom stops sending parameters to the system MUXbus. Once the PCM stream has reestablished itself, and the decom has regained “lock” on the stream, then parameters are once again passed to the MUXbus and distributed to the computer.

The system includes both A/D converters and DAC’s. The former inputs analog control signals whereas the latter outputs analog control signals and analog signals for the strip chart recorders. The strip chart recorders can display signals coming into the decom, A/D’s, parallel ports, and from the computer.

All of the above is done in real time and is fully setup by programming the menus. There is no external custom hardware that has to be built or reconfigured. In fact the system is easy to reconfigure through the menus. Additional modules can be added as well as another expansion chassis for future system growth.

Summary

The new system will provide a capability not attainable with our previous generation system. The new decom performs many of the processing tasks that the VAX would otherwise have to provide permitting additional users access to the VAX. The data link has performed with very few data dropouts on our initial tests preserving the hydrodynamic data quality. The system will enable the RCM to operate in a basin remote from our computer facility building providing additional hydrodynamic experiment capability.

References

From David Taylor Research Center:

Richard Nigon - Chief RCM Design Engineer
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Joan Lewis - Chief Systems Analyst
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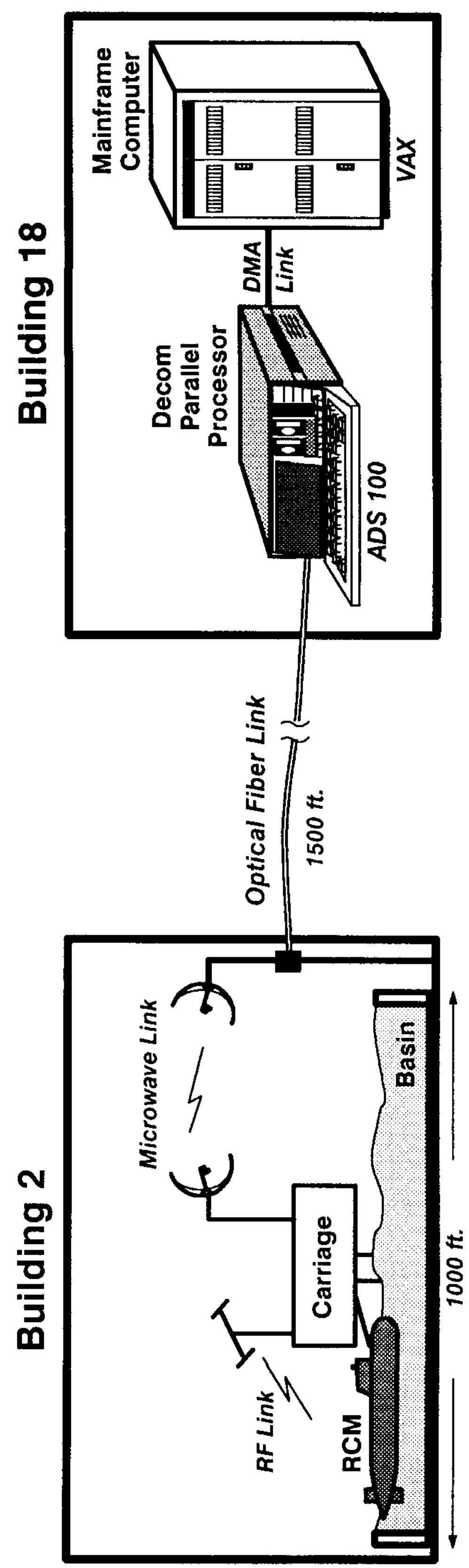

Figure 1. RF-Microwave-Fiber Link