STORED PROGRAM DECOMMUTATION TECHNIQUES

R. J. GALPIN and R. C. MABE
Analysis Systems Department
Federal Systems Division
IBM Corp.
Gaithersburg, Md.

Summary The application of core storage elements directly in the ground station data path could add greatly to the solution of increasing telemetry input data load problems. Decommutator control information loaded into these elements at mission set up time allows complete front end control by the main processor. Indeed, more complex formats such as PCM sub-subframes could be handled, depending only on the extent and sophistication of the control routine. Prestoring FM muliplexer addresses on prescribed sequences with a selectable rate clock can provide a discriminator sampling scheme approaching the theoretical in terms of sample rates relating to signal frequencies. The data content is again only limited by the degree of sophistication of the control program. In general, these control programs are just extensions of the main processor. By using storage devices external to the processor, however, the dynamic decommutation can be performed in a fairly optimum manner without the high I/O data transfer from the computer.

A second function provided by the core memory in the telemetry data stream is data identification. Particular preassigned bits stored with the control information can be attached to the telemetry data word as this word is transferred from the front end. These flag bits can be used to route the particular sample to the main processor or to display equipment for quick look purposes. Unique flag bits may also be used to key any special data handling required on that particular sample, such as attaching a time tag or selecting a special subroutine in the main processor.

Introduction Telemetry ground station data handling requirements are becoming increasingly complex. Range users are considerably more sophisticated now than 10 years ago and demand more data, higher rate data, and usable results more quickly than before. Ground station users are also expecting greater equipment performance. Station setup time and mission turnaround time are now important evaluation parameters to a potential system user. To meet these increasing data handling requirements, the industry has been guided into the field of automated equipment. From the old patch panel and thumbwheel ground station equipment, numerous units aimed at handling more data faster and with less human intervention have evolved. Tunable discriminators, variable rate multiplexer-A/D convertors, and stored program PCM decommutators are examples. Almost all of this new equipment is provided with a computer Interface for both static setup and dynamic mid-mission change capability. This computer control of the front end seems to be successfully addressing the rapid station turnaround problem. The problem that remains–how to handle and distribute the increased data streams–is slightly more complex. The basic idea presented here is to insert small core storage elements in the data path between the decom equipment and the computer. The flexibility of the core memory allows this device to be used both for control purposes in the front end and for data rate buffering. Control information such as dynamic word length data can be stored for PCM. For FM, prestoring multiplexer addresses in various sequences can greatly enhance the sampling scheme. Source identification bits and routing tags can be stored along with the front end control information for distribution to the appropriate end device. Finally, a portion of the core can be assigned as a buffer to absorb data rate peaks from the front end and to act as a data smoother-for more efficient data transfer to the main processor.

The telemetry ground station data handling growth problem is serious. Most general purpose processors cannot, and should not, accept telemetry data at the present front end equipment rate capabilities. A better way must be found to work the front end equipment efficiently and still utilize the central processor for the computing load, not just data handling.

Problem Definition The basic problem to be solved by a telemetry ground station is the acquisition and presentation, in a meaningful form, of data from a remote source. Orginally, many systems were hardwired for a particular program and either required extensive modification or were rendered useless if any ‘major program changes occurred.

These problems were solved, to a great extent, by the adoption of telemetry standards. Now, the user that operates within these standards finds a wide selection of equipment that will meet his requirements. Flexibility has been further enhanced by the incorporation of programmable patch boards for data selection and routing.

Prior to the advent of the computer, the basic presentation of data has been in the form of strip chart and oscillograph recordings and quick-look type displays. These methods were sufficient when the amount of data telemetered was relatively small and slow and when a high degree of accuracy was not required.

Figure 1 depicts two methods of acquiring and displaying PCM data. In the hardware method, format flexibility is provided by being able to select bit rate, frame length, frame sync pattern, etc. The patchboard decommutator provides the flexibility to route selected data to the display devices. This method is sufficient for some applications, but has disadvantages for others:

a. Data rates must be relatively slow due to the response of the analog display equipment and the operator observance of the digital displays.
b. Data is displayed in raw form, and no provision is made for further analysis (except by analyzing strip chart recordings).
c. Mission reconfiguration is relatively slow due to complete manual setup.
d. A replay of the mission would have to be derived from an analog tape that may not exactly duplicate the original data.
e. No provision is made for data quality (sync status) monitoring (a sync status line could be recorded on the strip chart for low rates).
f. Time resolution is relatively coarse, even if a time code is recorded on the chart.
g. Data words must be of common size.

The software method utilizes a bit synchronizer to condition and reconstruct the data and to provide a noise-free bit stream to a computer. The computer performs the serial-to-parallel conversion, acquires word (if used), frame, and subframe sync, and identifies data by word location within the frame. Selected data may then be linearized, have its limits checked, be averaged, and be converted to engineering units. The raw or processed data, as selected by the program, is provided to the various display devices. Several advantages are offered by this method:

a. Highly accurate data may be provided by use of the computer printer.
b. Data has the necessary computations performed to relate readily useful engineering/performance data.
c. Data provided as quick-look information is in a more useful form.
d. Reselection of data to the display devices may be accomplished dynamically through the computer operations console.
e. Mission configuration is accomplished by the loading of new mission. parameters through a card reader, tapes, or a paper tape reader.
f. Much higher data rates may be meaningfully presented.
g. Real time decision making may be performed either directly by the computer program or by presenting a set of parameters for operator action.
h. Data words may be variable in size.
i. The system can provide the final report of the mission in the form of printouts, charts, graphs, etc., within a short period after the end of the mission.

Even though the result of the software method provides a desirable solution to the problem, it has several disadvantages:

a. The prime reason for using a computer is the speed and accuracy at which it can perform computations. If the functions, such as serial-to-parallel conversion, synchronization, are performed in the computer, the available computation time must be reduced.
b. All data may not require real time processing. The software approach required all data to be input to the computer. This also reduces available computer time.
c. The total composite throughput rate of the system is determined by the speed of the data, the quantity of the data, and amount of computation required. Any means of reducing redundant data, or parameters that are not required at this time, leaves more time to perform computations; and the throughput rate of a given system is proportionally increased. This also means that a smaller processor may be used to perform a given job.

Figure 2 depicts a typical PCM application utilizing a general purpose processor, standard telemetry front end equipment, and a stored program decommutator (SPD). The SPD controls the length of each data word/syllable, time tags the data, monitors synchronization status (search, check, lock), identifies the data, buffers peak data, and selectively routes data to the display system or processor.

The heart of the SPD is a core memory that is loaded via the processor prior to a mission and that may be dynamically changed during a mission. Figure 3 depicts a typical memory address allocation. A 2048 address memory is used in this application. Each address from 0 through 511 is assigned to a main frame segment, providing a main frame length of 512 words. Two independent subframes are provided. Addresses 512 through 1535 are assigned to each segment of the subframes, providing two subframes of 512 frames each. Addresses 1536 through 2047 are assigned as rate buffers. This provides 512 addresses of temporary storage for data in excess of the input rates of the processor. The front end equipment consists of standard bit, frame, and subframe synchronizers. These units perform the same function as they did in the hardware method. The units depicted are capable of selecting all format parameters via computer instruction. This feature provides rapid mission configuration and reduces mission turnaround time to a minimum. The frame and subframe synchronizers acquire synchronization on the respective patterns and provide the rate pulses and synchronization status to the SPD.

Figure 4 depicts a typical memory control word. The information consists of word length (bits per syllable, syllables per word, and bits per last syllable), subframe 1 and 2 segment identification, computer entry tag and source ID, and display tag and DAC address.

Once the SPD and front end have been loaded from the computer and the serial PCM wavetrain has been applied to the bit synchronizer, the frame synchronizer searches for the proper sync pattern. When the proper sync pattern is detected, the SPD will advance one memory location per word. As each control word is extracted from memory, the word length information is provided to the frame synchronizer. The frame synchronizer truncates the serial data into parallel data of the proper number of bits. This data word is provided to the SPD, and the next word length is requested. The computer entry tag is then examined. If the tag is on, the data word and source ID are stored in the rate buffer. If the display tag is on, the data and the display address are provided to the display system. The data is then displayed on the addressed digital display or converted and displayed on strip charts, meters, etc.

As each control word is extracted from memory, the subframe 1 and 2 bits are also examined. If one of these bits is on, memory will be addressed again, under control of the respective subframe counter. The contents of this location will be used to route and identify the data sample.

All data tagged for computer entry is stored in the rate buffer section of memory. The rate buffer is addressed by the computer program for input to the computer. The capacity of the rate buffer depicted is 512 words. The computer would be required to empty the rate buffer once per 512 data samples; otherwise data would be lost and an overflow alarm generated.

Another feature incorporated into the SPD is data quality monitoring (synchronization status). Once per frame, the status lines of the frame and subframe synchronizers (search, check, lock) are sampled, encoded into a digital word, uniquely identified, and input to the rate buffer. This also serves as a reinitialization point, if the frame synchronizer should revert to search. The SPD also provides for data time tagging. Depending upon the application and the resolution required, the time sample may be taken once per frame and input in the same fashion as the sync status word. If a more finite resolution is required, the timing system may be sampled once per data word and input to the rate buffer with the data.

The system utilizing the SPD offers all the advantages of the software method, but allows a much smaller general purpose computer to be utilized. The tasks such as sync acquisition, sync maintenance, and serial-to-parallel conversion are provided by standard telemetry equipment. The SPD performs the functions of sizing the data, selecting data (telemetry data, time, status) for direct input to the display system, and selecting and buffering data selected for computer input. The general purpose processor performs the arithmetic functions, the front end and SPD setup, digital recording, and display of processed data.

PAM/PDM Applications To adapt the previously discussed PCM system to PAM/PDM applications, the front end would be replaced by a PAM/PDM synchronizer that incorporates an A/D converter. The SPD performs the same functions, except the word length information is not required.

The front end synchronizes the data stream and converts each channel to a digital word of the required resolution. The SPD selectively routes the data to the processor and display system, buffers peak data, identifies and time tags the data, and monitors sync status.

FM Applications An FM system that inputs data to a computer requires the same functions of data identification and routing. The FM ground station must also time division multiplex the discriminator outputs. Each output must be sampled at a high enough rate to ensure proper data reconstruction. This rate is determined by the bandwidth of each channel. If the rate is too high, over-sampling will occur; and redundant data is introduced to the system.

If only constant bandwidth subcarriers are employed, the available bandwidth of each channel is the same. In this case, the channels could be sampled sequentially using a single sampling rate.

If proportional bandwidth subcarriers are employed, the bandwidths vary from a few cycles to several kilocycles. To use the sequential method, the sampling rate would have to be a multiple of the widest channel. This could result in up to 1000 samples of data from a channel, where I sample would have sufficed.

The stored program decommutator in an FM system actually commutates the data. The word length information of the PCM system is replaced by a discriminator address. Each memory location now contains information regarding which data to sample, how to identify it, and what to do with it.

In operation, the computer would select a basic sampling rate (performed by SPD static storage) and start the SPD. The SPD extracts the first memory address, digitizes the selected discriminator, and routes the data as specified. The next memory address is extracted, and the same functions are performed. In this fashion, the computer would load a table that optimized the sampling rate of each channel to a value that allowed data reconstruction, but reduced oversampling to a minimum. Subframes could also be utilized to further optimize sampling.

In addition to the routing flag information, each telemetry data sample could have attached a unique identification word. This ID tag would identify that particular sample for all further data handling. The ID tag could be used as a D/A converter address for raw data or as a means of tracing that telemetry data through the processing loop. By use of the routine flags and the ID trays, both of which could be loaded prior to the mission or changed in midmission, a great deal of front end flexibility is provided in using the main processor in selection of the data to be input in selecting the processing routine, and in maintaining telemetry data integrity throughout the system.

The final function provided by the insertion of a core memory into the data stream is data buffering. When the telemetry data word rate exceeds that of the processor I/O speed, buffering is required. By assigning a section of the online core to rate buffering, it is possible to operate under the above conditions for short periods of time. Obviously, this time duration is directly proportional to the amount of core required. It is feasible, however, to consider an average data word rate on a frame basis that is within the processors I/O capability but that contains points of peak data rates that must be buffered. Use of the online core for this purpose again allows the main program access to possibly critical data without the high I/O data exchange or special interrupt handling.

The online core memory or stored program telemetry documentation technique described above should provide a key to the solution of the increasing data input requirements of present telemetry ground station systems.

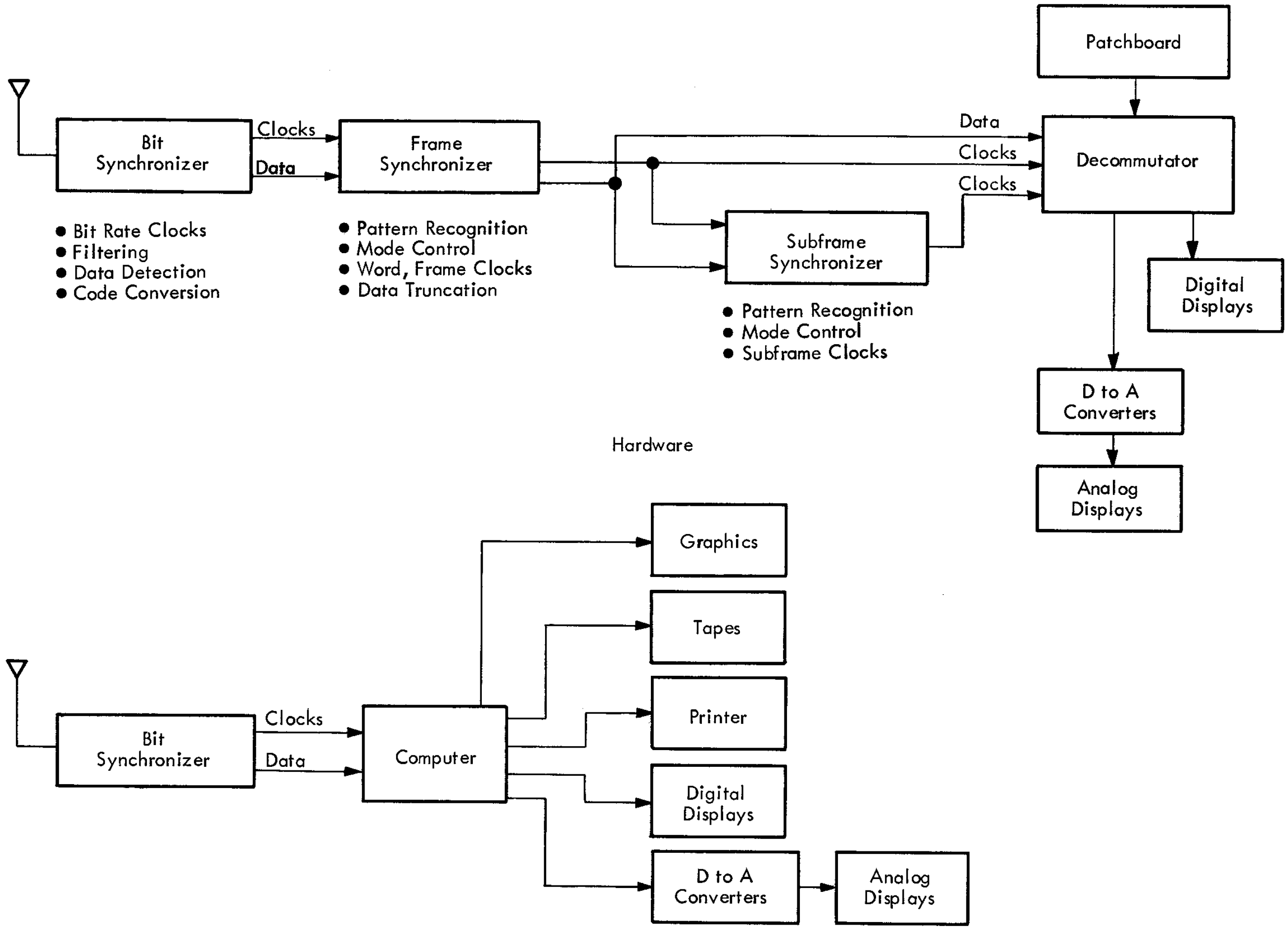

Fig. 1 - Software

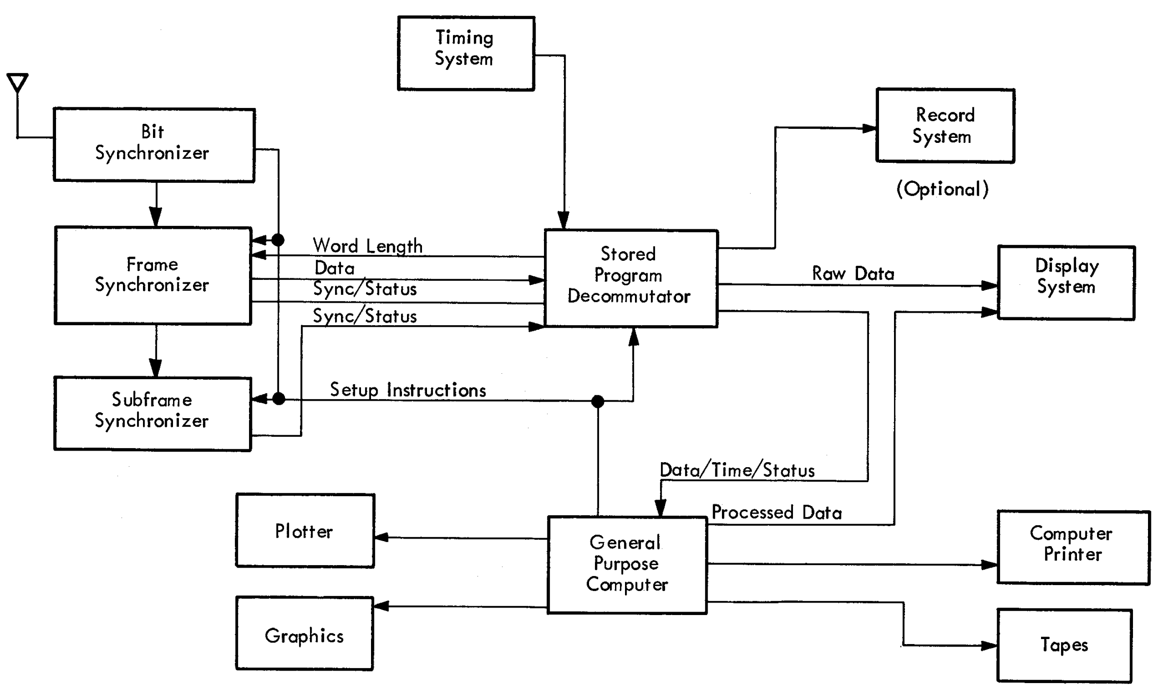

Fig. 2 - Typical PCM Application

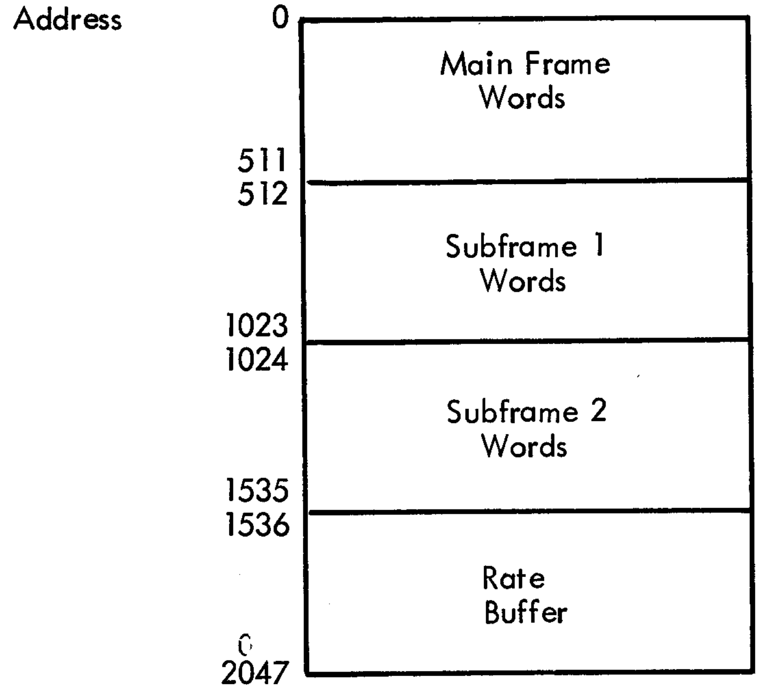

Figure 3. Typical Address Allocation

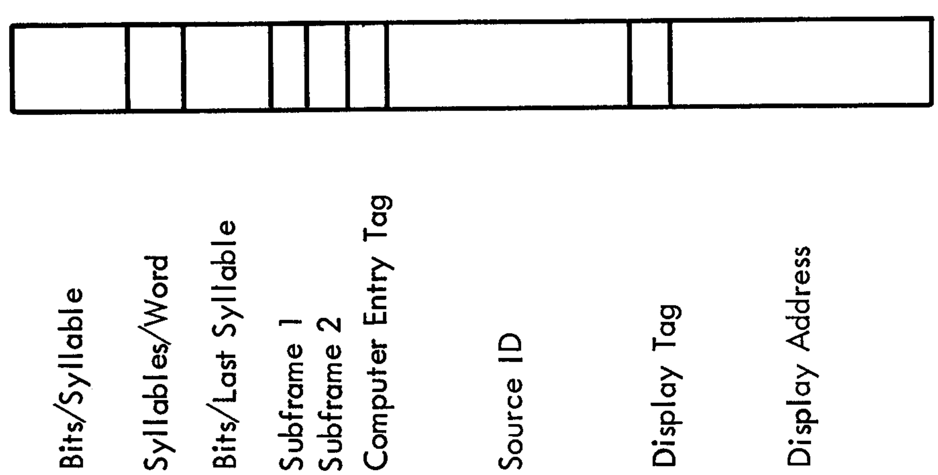

Fig. 4 - Typical Memory Control Word