TELEMETRY DATA
VIA
COMMUNICATIONS RELAY

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ABSTRACT

This paper responds to a test range engineer's need to relay one or more channels of various types of telemetry data from a remotely-located receiving station to the central telemetry station at range headquarters for real time processing and display. Several types of data are identified, and specific equipment and technology for multiplexing, transmission, and demultiplexing up to eight streams from a variety of sources is discussed.

The widely-used T3 communications link, also known as DS-3, can relay data via satellite, microwave link, or other high-speed path at 44.736 megabits per second, of which about 95% can be actual telemetry data; other standard links operate at lower aggregate rates. Several links and rates are discussed, with emphasis in the high-rate T3 link.

OPERATING SCENARIO

On a typical test range for analysis of performance of a vehicle, the size and layout of the range are such that it is impossible to acquire data by radio link in real time at a central telemetry site during the entire test. Consequently, it becomes highly desirable if not mandatory that secondary receiving sites be linked to the central site in real time by high-speed data link, and that one or several data channels be transferred over that high-speed link in real time. The link may be a commercial-grade coaxial cable, fiber optics line, microwave link, or communications satellite link.

Generally, it is impractical or impossible to put telemetry data directly onto a commercial grade link. The link data rates, impedances, and protocol are totally incompatible with our normal PCM telemetry data. Further, there is sometimes the need to handle other types of telemetry than PCM, and/or to merge and transfer data from two or more channels simultaneously.

SPECIFIC IMPLICATIONS OF THIS SCENARIO

Analysis of the operating scenario as outlined above led our company to generate a set of specific design goals which defined a product for use on the T3 communications link. These goals included the following

1. Link Interface: Because the equipment must interface with a commercial or military communications system (namely the T3 link), it was a specific requirement to generate and receive the exact signal levels, work into and out of the exact impedances, and use the exact protocol required by that link. Further, it must operate at the specified bit rate (44.736 megabits per second, with plus or minus 0.002% tolerance)

   The data rate requirement meant that the equipment must generate filler words when the composite input rate is too low, and must eliminate input channels per prearranged rules when the composite input rate is too high.

   The transmission code on T3 is alternate mark inversion, with bipolar three-zero substitution.

2. Efficient Use of Bandwidth: Because the equipment must be efficient in use of data bandwidth, it must function properly without excessive overhead bits such as synchronization patterns. An optimum design was defined as using no more than 5% of the bandwidth for overhead.

3. Bit Count Integrity: Because data position in telemetry data streams determines the meaning of the data, each channel must be protected from bit slips and other bit count errors in the face of data link errors. The design goal for mean time between bit slips or other bit count errors on a link with a bit error rate of 10^{-3} is two days.

4. Bit Rate Accuracy: Because the system must preserve also the individual bit rates to make the output compatible with telemetry decommutation equipment and/or other data handlers, the equipment must regenerate each channel's bit rate very accurately. The goal was to add no more than 0.2% jitter on any channel.

5. Self-configuring: The data multiplexer equipment is often in an unattended remote area. Since the inputs may change from time to time, and since there will be no operator on site, the equipment must be self-configuring after basic setup.

6. Loopback Testing: Because users must have assurance of proper operation before live data is transferred, the design goal was to provide a loop-back capability in the product, such that operating integrity of the multiplexing equipment and especially the data link could be proven in a confidence check

7. Number of Channels: Because a range user may have several data streams for transmission on a single communications link, the equipment design goal was to merge up to 2, 4, 6, or 8 streams as configured in hardware

8. Data Variety: Because some range data is not in a PCM telemetry formal, the equipment design goal was (possibly with available external synchronizers, encoders, and /or formatters) to handle a variety of data types, including at least PCM, PAM, FM, analog and discrete data, and MIL-STD-1553 avionics bus data.

9. Status: Because a system operator must have continuous health evaluations on this critical element of range instrumentation, the design goal was to monitor and present status information at the remote multiplexer and the local demultiplexer, and to relay the remote status information to the local site with data.

10. Diagnostics: Because self-diagnostics are necessary for rapid fault detection, the goal was to incorporate such capability into the equipment.

11. Space: Because space is often at a premium in a range station, the equipment design goal was to keep the height of each unit no greater than 5-1/4 inches.

12. Logistics: Because the logistics budget is important to any telemetry user, the design goal was to use a minimum number of module types in each multiplexer and in each demultiplexer, and to use the identical module in both devices whenever possible.

DESIGN RESULTS

Working from the design goals discussed above, to meet the typical range of operational scenarios, a development team designed a product known as the EMR 8245 Asynchronous Multiplexer/Demultiplexer. This device, now in production, performs as follows:

1. Link Interface: The product interfaces correctly to the T3 link at the sending and receiving ends.

2. Efficient Use of Bandwidth: The unit uses no more than 5% overhead; this includes tile frame synchronization pattern and the status and alarm bits.

3. Bit Count Integrity: The unit meets the design goal of not more than one bit slip or other bit count error in two days, even with a link so poor that it has a bit error rate of 10^{-3}.

4. Bit Rate Accuracy: The equipment reproduces the original bit rate, adding no more than 0.2% jitter.

5. Self-Configuring: The devices are totally self-configuring after basic conditions are defined by the operator. Using the per-module setup capabilities, an operator defines:

- The basic mode for each box: multiplexer or demultiplexer

- For each data channel input:
  - On or off
  - Differential or single-ended
  - Shield: connected to chassis or signal ground
  - Randomizer: on or off

- For the link input:
  - Balanced or unbalanced output
  - Binary three-zero substitution encoder: on or off
  - Shield: connected to chassis or signal ground

- For the link output:
  - Balanced or unbalanced input
  - Binary three-zero substitution decoder: on or off
  - Shield: connected to chassis or signal ground
  - Link input or external NRZ and clock inputs (and for external input, the termination)

- For each data channel output:
  - On or off
  - Differential or single ended
  - Shield: connected to chassis or signal ground
  - Derandomizer: on or off

- General:
  - Diagnostics: on or off
  - Frame length: normal or shortened
  - Air flow audible alarm: enabled or disabled

6. Loopback: A loopback feature in the demultiplexer mode takes data from the link. buffers it, and routes it to an output connector. This data can then be "looped back" to the sending site via a second link so that the link may be tested. This loopback feature is normally used with the Multiplexer in the self-test mode, so that the data content is known and testable.

7. Number of Channels: The devices merge and separate up to 2 channels, 4 channels, 6 channels, or 8 channels, based on the number of dual channel modules which are installed.

8. Date Variety: Even though each channel of input data must be in a serial digital format, other types of data are accepted after external preparation. These include, for example:

   - FM telemetry, using a tunable digital multiplex discriminator.

   - Analog and/or discrete data, using a multiplexer/encoder.

   - PAM telemetry, using a PAM synchronizer/encoder.

   - MIL-STD-1.553 Avionics Bus data, using an all-bus-instrumentation-system to collect data per the new IRIG 106 standard format.

9. Status: The multiplexer compiles and provides status locally, as well as sending it in the data stream to the demultiplexer. That status includes:

   - Channel on/off, each of 8 channels

   - Mux/Demux mode setting

   - Power on (switch setting and presence of power)

   - Bandwidth alarm if the link bandwidth is exceeded by incoming data

   - Diagnostics pass/fail

- Air flow alarm if there is insufficient flow, of cooling air
- Status from a secondary multiplexer unit.

The demultiplexer provides as outputs all of the above-listed conditions from the remote multiplexer. Also, it compiles and provides the same types of status conditions where they are applicable for a demultiplexer. Finally, it provides:

- Frame sync condition
- Signal quality (acceptable/unacceptable)

The more meaningful status conditions are displayed on the front panel, or generate audible alarms. These include:

- Channel activity (each of 8 channels):
  - Clock inactive (no indicator)
  - On, and suitable quality (green indicator)
  - On, but poor quality, or not allocated due to excessive bandwidth (red indicator)
  - Switched off (flashing red)
- Signal quality from the link (frequency deviation and level):
  - Suitable (green indicator)
  - Questionable (red indicator)
- Frame synchronizer status at demultiplexer:
  - Locked (green indicator)
  - Searching for the pattern (red indicator)
- Air flow reduction to a danger level:
  Audible alarm at the unit with the problem (and if it is the multiplexer, this alarm will sound also at the demultiplexer station)
- Diagnostics
  - Not being tested (no indicator)
  - Operation is verified (green indicator)
  - Diagnostics failure (red indicator)
- Power
  - Off (no indicator)
  - On (light is illuminated in the switch)

10. Diagnostics: Because of the internal microprocessor, the unit has switch-selectable diagnostic modes. It has stand-alone test capability when configured as a multiplexer or as a demultiplexer. It has also the capability to perform a system test when a multiplexer and demultiplexer are connected together, either directly or through an external communications link.

    A switch on the mux/demux module initiates the multiplexer health test. The module drives a BITE signal to cause each dual channel module to generate its own clock source with its clock regenerator circuitry. A unique data pattern generator is selected based on the channel number as the data source. The mux/demux module performs its normal functions, multiplexing and formatting the data, and tests the record lengths against programmed limits. The module also sequentially tests the data from each stream by demultiplexing and comparing the data to a stored sequence.

    The same switch on the mux/demux module is used to put a demultiplexer in the self test mode. When the link/sync module detects the BITE signal, it selects a simulated multiplexed serial format instead of live data. This is similar to the stream generated by the multiplexer when it is in the self-test mode. This data is frame synchronized and passed to the mux/demux module. The processor checks the record sizes of the various channels against stored values. The module also passes the data to the appropriate channels on the dual channel modules for further processing. The modules output the data, and the processors check the channel for correct rate and monitor the FIFO fullness to verify proper channel operation. The data at the output of the FIFO is tested by the processor to verify the data path integrity.

11. Space: The multiplexer and demulliplexer are packaged identically. Each is rack-mounting, using only 5-1/4 inches of vertical space.

12. Logistics: A fully-configured multiplexer has:

    One link output interface module
    One multiplexer module
    Four dual-channel input modules

    A fully configured demultiplexer has:

    One link input interface module
    One demultiplexer module
    Four dual-channel output modules

Due to the dual-mode designs in all modules, however, the user needs only three module types to provide complete replacement capability:

One link/sync module
One multiplexer/demultiplexer module
One dual-channel inpuVoutput module

OTHER APPLICATIONS

Of necessity, this paper is pointed toward one type of communications link (T-3) and one generic application (telemetry data merging and transfer). The same general technology is useful under other scenarios as well, such as:

1. Other communications links: A companion set of units are available for the lower-speed commercial communications links:

   DS-1
   DS-1C
   DS-2
   DS-A
   Or any user-supplied rate between 56K bits/second and 12.928 Mbits/second.

   Alternatively, the lower-rate equipment can serve as input/output channels in a T3 system.

2. Other types of data: Outside the telemetry field, many data transfer scenarios can be enhanced by the same technology described here.

3. Data storage on rotary-head tape recorder: The need for data channel merging, efficient generation of a single-bit-rate stream, and efficient data separation on playback make this same technology adaptable very conveniently to the record/reproduce needs of a rotary-head recorder.

ILLUSTRATIONS

Figures 1 and 2 show front and rear views of an Asynchronous Multiplexer/Demultiplexer, to emphasize the degree to which the units are self-configuring. Figure 3 is a simplified functional diagram of one unit in the multiplexer mode and a second unit in the demultiplexer mode.

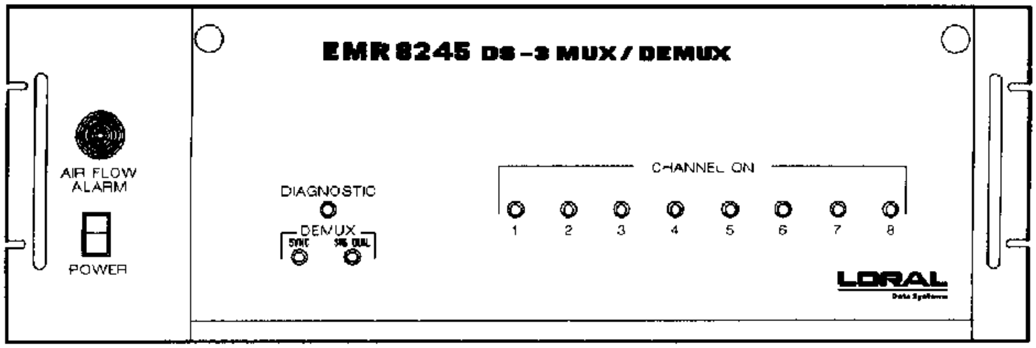

Figure 1. Front View of Asynchronous Multiplexer/Demultiplexer

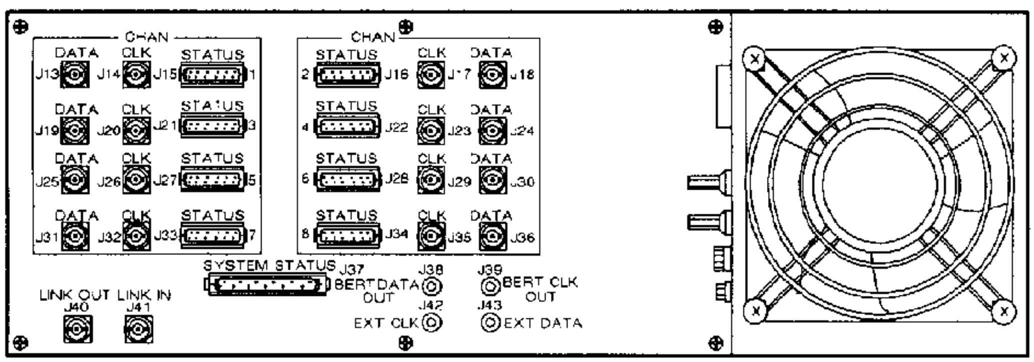

Figure 2. Rear View of Asynchronous Multiplexer/Demultiplexer

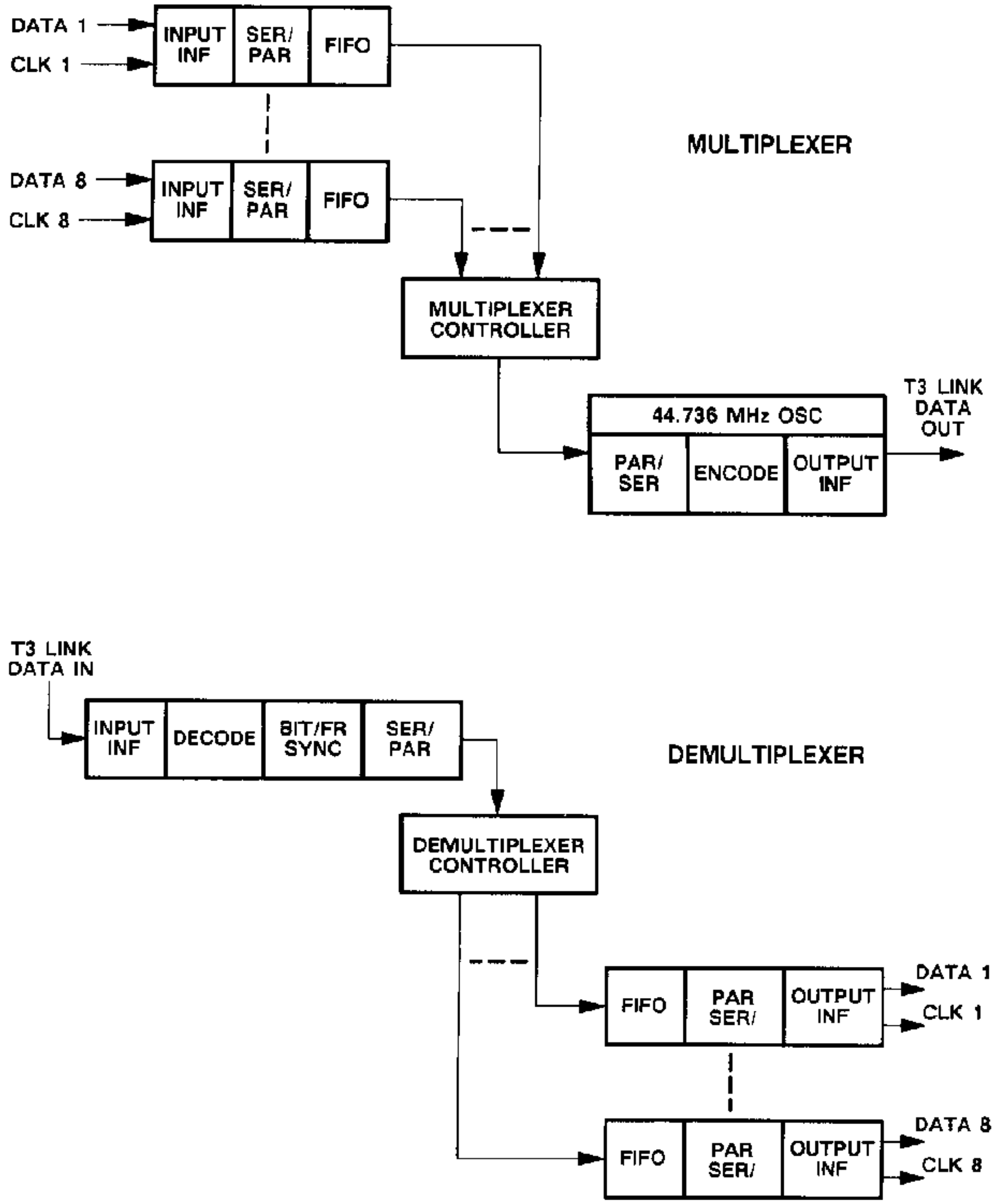

Figure 3. Functional Diagram of a Pair of Asynchronous Multiplexer/Demultiplexer Units