TELEMETRY RECORDING AND REDUCTION EQUIPMENT FOR SHIPBOARD SUPPORT OF MISSILE EXERCISES

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ABSTRACT

Evolving growth in Navy ship-to-air missile design has resulted in a need for larger quantities of telemetry information with increasing emphasis on digital telemetry. This has inherently led to the requirement for telemetry processing equipment that is adaptable to these changing missile telemetry data formats. The design for the Telemetry Recording and Reduction Equipment (TRRE), that incorporates today's technology into a compact, real-time analysis tool for shipboard use, is presented in this paper.

The TRRE was designed to process both the Pulse Amplitude Modulation (PAM) telemetry data formats of existing missile designs and the Pulse Code Modulation (PCM) data formats of evolving missile designs. The TRRE design minimizes the required operator interace through preprogrammed telemeter formats and programmable decommutation tables. A microprocessor is utilized in the design to program the decommutation hardware configuration.

INTRODUCTION

E-Systems is currently producing the AN/SYR-1 Communication Tracking Set which serves as the downlink receiver and processor for TARTAR and TERRIER combat weapon systems. When not required for downlink, either of its two channels can be used to receive telemetry. The TRRE utilizes this existing telemetry reception capability to provide recording of telemetry data and real-time display of telemetered functions. The TRRE is also compatible with other telemetry receivers. The TRRE's input configuration showing the two telemetry channels from the AN/SYR-1 receivers, plus time-of-day and ship's audio inputs, is depicted in Figure 1.

The TRRE design seeks to combine simplicity of operation with the flexibility required for missile telemetry data analysis. Digital technology is used where possible to enhance adaptability to new telemeters while maintaining compatibility with existing missile formats.

The following sections describe the TRRE performance characteristics, system components, system operation, and the program status.

TRRE PERFORMANCE CHARACTERISTICS

The TRRE design specification required the capability to record and process the telemetry signal formats of 15 Navy telemeters, the majority of which represent Standard Missiles. These formats fall into three basic categories: PAM, PAM with digitized words, and PCM. The PAM telemeters transmit samples of about 50 analog telemetry functions at 25,000 samples per second. The digital PAM telemeters also use a PAM format, but at the rate of 41,667 samples per second; in addition, a new aspect of these formats was the inclusion of digital words (3 bits per channel) from the on-board (missile) guidance computer. The new PCM telemeters transmit over 200 functions at rates greater than 25,000 bits per second. All three formats contain a Doppler Video (DV) signal which provides additional flight analysis data.

The TRRE is capable of being initialized before launch should only a tape recording be required or if crew members will not be available to operate the system during a missile flight. The system will then detect when the input from either receiver channel contains a valid telemetry signal and will automatically start the tape recorder. To perform post-flight data reduction, the analyst configures the decommutation process by simply selecting a previously entered display assignment set. These display sets are stored in nonvolatile memory and are easily, modified.

The TRRE design provides space for additional circuits, allowing adaptability to future telemeter requirements. Circuits are partitioned such that additional hardware can be incorporated with a minimum impact. To the maximum extent practical, the hardware configuration is controlled by easily modified microprocessor firmware.

Intended for shipboard use, the TRRE is designed to military specifications. Except for the commercial oscillograph, parts and materials have been selected from military qualified parts lists or tested to military specifications. The TRRE has passed extensive temperature, shock, vibration, and electromagnetic tests. It is compact and conforms to safety and human engineering guidelines.

SYSTEM COMPONENTS

The TRRE system consists of two signal processing chassis, a magnetic tape recorder, and an oscillograph, all contained within a 74-inch high cabinet (see Figure 2). Interfaces are provided for an external printer and spectrum analyzer. A design goal was to limit chassis depth to support consideration for mounting in transportable cases.

Data Processor

The telemetry signal processing is divided into two separate chassis. The Signal Conditioner Unit (SCU) primarily contains analog circuitry which receives the telemetry video signal, performs the filtering and detection functions, and converts the telemetry data into a digital format. The Controller Decommutator Unit (CDU) contains the microprocessor based, digital hardware which decommutates the selected missile functions, and formats the data for output to the oscillograph and printer. These circuits are contained on a total of twenty-six 8-inch by 8-inch printed circuit boards designed by E-Systems. The chassis have space and reserve dc power for 22 additional boards.

Magnetic Tape Recorder

A permanent record of received telemetry signals is produced on analog tape by an AN/USH-24 tape recorder. This recorder was specified as part of the TRRE equipment. Two channels of telemetry data can be recorded on its one-inch magnetic tape, and then played back for post-flight processing. The track allocations are presented in Table I.

Table I. AN/USH-24 Track Allocations

- PAM (2 tracks)	- Time Code (IRIG-B)
- DV (2 tracks)	- Audio (operator & ship’s audio)
- FM DV/PCM Composite (2 tracks)	- Servo Reference (internal to recorder)
- PCM Detected (BI-Ø) (2 tracks)	- Spare (3 tracks)

Oscillograph

The Honeywell Model 1858 oscillograph (strip-chart recorder) was specified as part of the TRRE equipment. This 18-channel oscillograph provides the primary means of data display. Two channels are dedicated for time code and discriminated DV, ten channels can be programmed to display any telemetered missile functions, and six channels can be programmed to display bi-level missile functions only. The channel assignments are entered via the CDU front panel keypads. Calibration voltages can be applied to each oscillograph trace to provide scaling references.

Printer Interface

An auxiliary means of data display is provided by an RS-232/MIL-STD-188C interface, which permits the generation of numerical, hard-copy printouts by an external printer. Since most ship-board telemetry data anlysis can be accomplished from the oscillograph, a printer is not provided as an integral component of the TRRE. For those exercises requiring printouts an analyst can connect an external printer to the TRRE. The advantages to be realized from a numerical printout, as compared to the oscillograph display, include:

- A higher degree of accuracy and resolution is provided for a function value.

- Certain types of digital functions can be more easily analyzed from a numerical printout.

Up to 18 missile functions can be displayed on the printout. A heading at the beginning of each printout identifies the date, missile type, and the functions being displayed. The selected functions are printed at the rate of one sample per second.

Spectrum Analyzer Interface

The majority of the DV data reduction is accomplished using spectrum analysis techniques. An external interface is provided for connecting the filtered DV signal to a spectrum analyzer. Since data reduction is normally performed at land based sites and not onboard ship, a spectrum analyzer is not provided as part of the TRRE.

SYSTEM OPERATION

The TRRE's primary purpose onboard ship is to document the missile firing by making a telemetry recording and providing "quick-look" analysis capability at the completion of the flight. Selected missile functions can be monitored on the oscillograph during the flight to indicate missile performance, including DV. In the event of an anomaly, the TRRE recording can be played back for more in-depth analysis of telemetered functions. With such a range of uses, it was necessary to provide many features to simplify the system operation for the operator-analyst, while still providing a flexible analysis tool.

Select and Process Modes

Before data processing is begun, the TRRE is configured for the specific test requirements. To accomplish this, the TRRE is placed in the Select mode from the front panel of the CDU. In the Select mode, the operator selects the appropriate telemetry format using the CDU keypads, and can assign telemetered functions to as many as 16 oscillograph traces and 18 printer columns. Special printer formats can be enabled for telemeters incorporating burst data functions which require detection and buffering. Once such a set of configuration parameters has been entered into the CDU, it can be saved in non-volatile memory for future use. Up to 50 such sets can be stored and quickly recalled. If only a recording of a missile flight is required, the operator need only enter the telemeter format number.

When the TRRE is placed in the Process mode, the information provided in the Select mode configures the TRRE hardware and firmware to perform the desired processing and display. The format number defines the input signal type (PAM or PCM), data rates, frame size and filter requirements. A control on the CDU selects the input signal source, either directly from the external receiver or playback from tape. The decommutator is loaded with control words that define the processing and display of the selected missile functions.

PAM/DV and DV/PCM Modulation Formats

To be compatible with both PAM and PCM input signals, the TRRE uses digital decommutation and processing techniques. Both PAM and PCM are converted to digital words and tagged with a channel address corresponding to its position in the data frame. This address is used to store the data in a frame buffer from which the printer output is derived, and is used by the real time oscillograph decommutator to select and route the data to the desired oscillograph trace.

The DV signal, which occupies different frequency bands for PAM and PCM formats, has two output destinations. After filtering (to separate it from the composite telemetry data), it is output to the spectrum analyzer interface. It is also routed to a digital discriminator whose transfer function is programmed from the missile format number. The discriminated DV signal is then displayed on a dedicated channel of the oscillograph.

Data Display

The two telemetry data display devices are the oscillograph and the printer. High sample rates of some telemetered functions (up to 5000 samples per second) prevented the use of a general purpose processor for real-time decommutation of oscillograph data. Instead the decommutator utilizes Schottky logic circuitry and a 24-bit control word to process and route the data in real time. Under control of this Decommutator Control Word (DCW), a telemetry data sample may be split into 1-bit functions (events); it can be accumulated with other samples to produce higher resolution words (multi-levels); it can be changed from a 2’s complement form to offset binary (sign bit complement); and its full scale range on the oscillograph can be modified. Information designating the processing requirements is automatically incorporated into the appropriate DCW when a telemetry function is selected for output to the oscillograph.

The printer output allows telemetered function values to be monitored at a once-per-second-rate. Event state changes can also be monitored continuously and burst mode data displayed without loss of samples or resolution. To accomplish this, each frame of digitized data is buffered and made available to the microprocessor. The selected function values are read, processed, and converted to a decimal number and output to the printer along with status flags and time-of-day.

Signal Flow

The major functional blocks and signal flows within the TRRE are summarized in Figure 3. The telemetry signals from the receiver are switched by the controller to the appropriate recorder channels. Direct signals from the receiver, or playback signals from the recorder, are filtered and passed to the analog signal processing circuits. Programmed from the controller, this analog block derives synchronization timing, perfoms DV processing, and outputs digitized data and addressing to the digital decommutator. Here, the data words are buffered for use in outputs to the printer, and selected functions are processed and routed to specified oscillograph channels. The microprocessor based controller interfaces with the operator via the CDU front panel, formats the printer output, and controls the overall system configuration.

PROGRAM STATUS

The Pre-production TRRE system has successfully completed an environmental and electromagnetic qualification test program. The equipment was installed on the USS MAHAN in February 1982, and is presently supporting New Threat Upgrade (NTU) testing.

Through the playback of missile flight tapes, integration of the TRRE with inert operational missiles (IOM), and the use of PAM/PCM/DV signal simulators, the TRRE has demonstrated its compatibility with the telemetry formats for which it was designed. System performance testing with the AN/SYR-l has indicated useful PCM data (BER of 3×10^{-4}) will be provided at the maximum range of the AN/DKT-53 telemeter.

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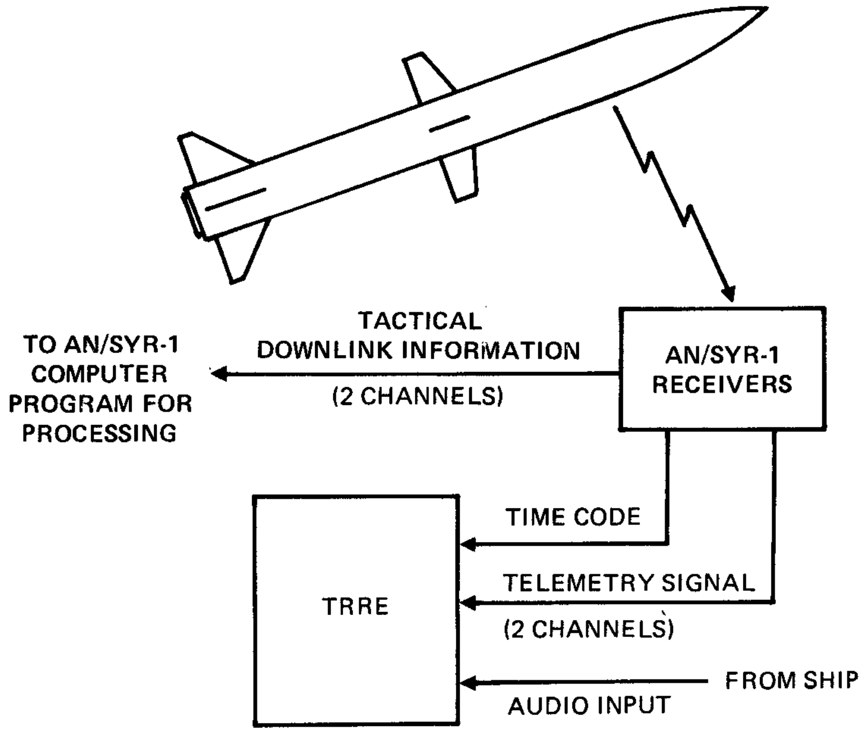

Figure 1. Shipboard Telemetry System

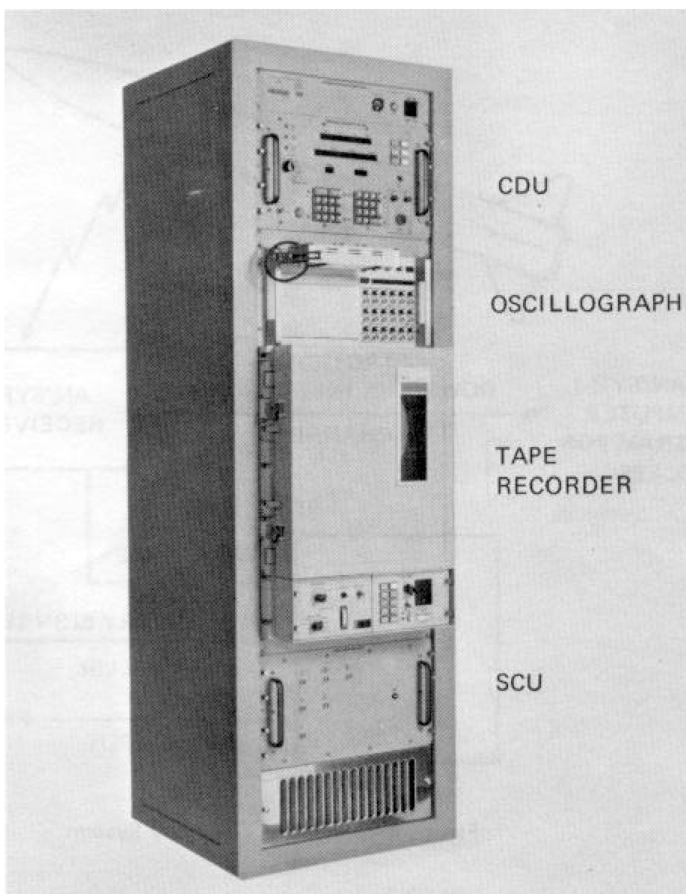

Figure 2. The TRRE System

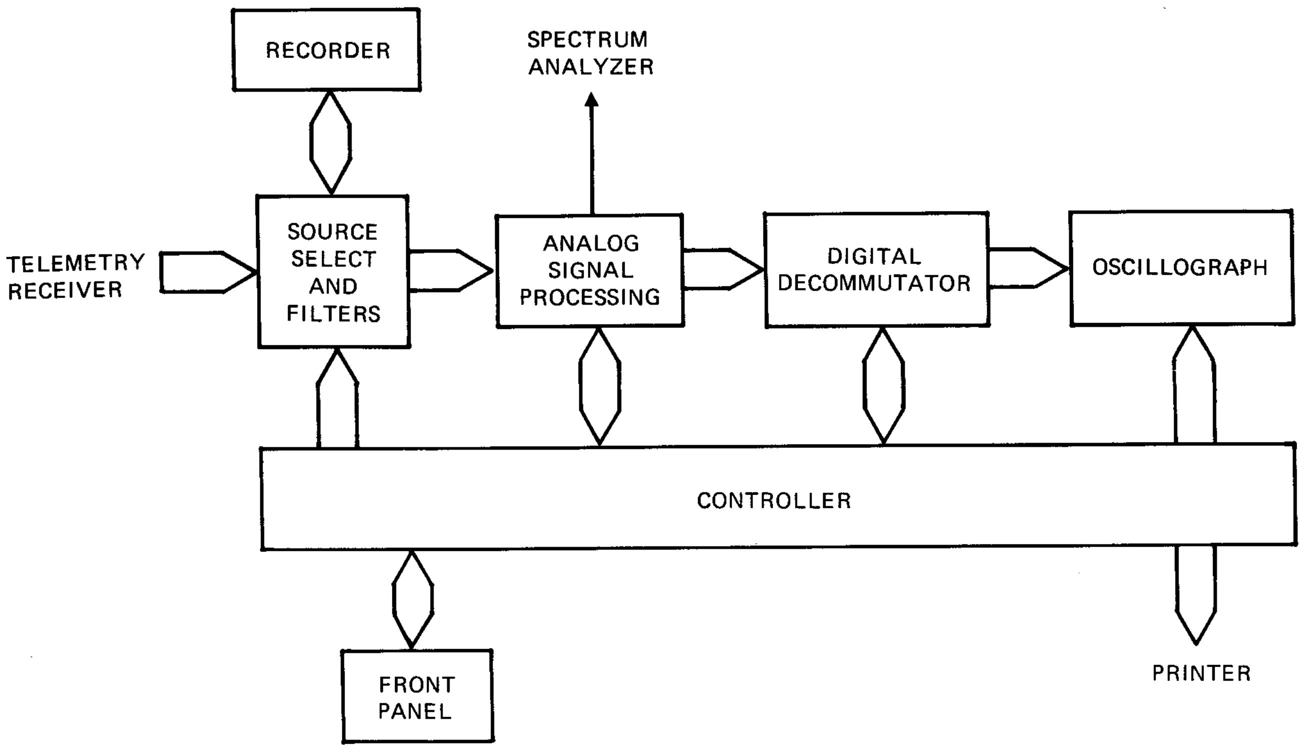

Figure 3. TRRE Functional Block Diagram