F16 MID-LIFE UPGRADE INSTRUMENTATION SYSTEM SOLVING THE PROBLEM OF SPACE IN THE AIRCRAFT AND IN THE RF SPECTRUM

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ABSTRACT

The older F16 jet fighters are currently being flight tested to evaluate the upgraded electronics for aircraft avionics, flight control and weapons systems. An instrumentation system capable of recording three different video signals, recording four Military-Standard-1553B (Mil-Std-1553B) data streams, recording one PCM stream, transmitting the PCM stream, and transmitting two video signals was needed. Using off the shelf equipment, the F16 instrumentation system was design to meet the electronic specifications, limited available space of a small jet fighter, and limited space in the S-Band frequency range.

KEY WORDS

Data To Video Encoding, Video Compression, Airborne Telemetry Systems

INTRODUCTION

The basic problem that face most engineers designing a telemetry package is the limitations of physical space to install the hardware without sacrificing performance. At the same time, transmitting the data to a telemetry ground station within a specified bandwidth can also place restrictions on the hardware chosen. The F16 Combined Test Force (CTF) faced this challenge and found several off-the-shelf black boxes that integrated together to form a package that met all of our space requirements and was able to operate in a narrow transmitted bandwidth.

THE LIMITATIONS OF PHYSICAL SPACE IN THE F16

The initial design requirements stated that the instrumentation system must record 4 separate Military Standard 1553B (Mil-Std-1553B), data streams with redundant busses, and two Pulse Coded Modulation (PCM) Manchester 2 Bi-Phase-Level (Bi-O-L) data streams at a bit rate of 750,000 bits per second. The desired recording time is 2 hours.

The first challenge is to overcome the recording time associated with analog recorders. According to the Inter-Range Instrumentation Group standards 106-96 (IRIG 106-96), a standard wide-band analog recorder should run at 60 inches per second (ips) to accurately record 1MegaBytes per second (MBps). At 60 ips, a standard 16 inch diameter reel will have an average recording time of 42 minutes. Changing tape quality to Double-Density from standard wide-band will permit a tape speed of 30 ips, giving you a nominal recording of 84 minutes. This option was not acceptable because it did not meet the 120 minutes of recording time required. A standard, off-the-shelf analog recorder occupies about 3 cubic feet of space making multiple recorders not an acceptable option.

The solution was to use two off-the-shelf black boxes to convert the Mil-Std-1553B or Pulse Code Modulation (PCM) data to a standard National Television System Committee (NTSC 525) monochrome video format and then record the video signal on an off-the-shelf video recorder. Using a standard Hi-8mm video tape, a recording time of two hours or 15.84 Gigabits of data can be achieved. Merlin Engineering Works, manufactures a data-to-video encoder, ME-981, capable of converting a PCM or 1553B data stream into a standard NTSC video signal. The data-to-video encoder is a small, 0.1 cubic feet, with no adjustments or calibration required.

The encoder utilizes a proprietary error correction circuit to mitigate the effects of data loss due to tape dropouts. The V3 (Vector Cube) three-dimensional, seven level error detection and correction scheme uses cyclic redundancy check (CRC) bits to find and correct parity errors in the data and perform the bit correction during playback operations.

The F16 uses three data-to-video encoders to convert four streams of 1553B redundant A/B busses and two PCM streams into a standard video signal. This signal is fed into an off-the-shelf TEAC V-83AB-FS, Triple Deck, HI-8mm videocassette airborne tape recorder (ref. Figure 1).

The V-83AB-FS is physically one recorder that contains three electronically independent tape decks. It occupies less than one-half cubic feet of volume and weighs less than 20 lb. Each deck is capable of recording on a standard HI-8mm cassette for a minimum of 2 hours with a signal to noise ratio of greater than 43 dB[3]. Recorder control is accomplished in the aircraft via two discrete signals, record and stop. On the ground an RS422 control line to a portable computer controls the recorder for preflight and postflight operations and troubleshooting.

An engineering question that arises, “Why can’t I record the data directly onto the video recorder?” The answer is that the video recorder is expecting to receive an NTSC video signal. The recorder automatic gain control (AGC) and logic circuits are timed off of the video sync pulse. In some of the older video recorders with a single helical recording head, a head gap time, a non-recording period, is present and will cause data loss. The V-83AB-FS two recording heads overlap each other to accomplish uninterrupted recording.

Analysis of this airborne system yields a nominal bit error rate of less than one error in 10^9 bits and 2.2 hours of usable recording time. Total system power draw is a maximum of 180 watts while occupying less than 1 cubic foot and weighing less than 40 pounds. This solution has been implemented into the F16 Mid-Life Upgrade program and is working to designed specifications.

THE LIMITATIONS OF THE RF SPECTRUM

The second major problem that the F16 MLU program faced was the limitations of available RF bandwidth to transmit aircraft video. The F16 contains three aircraft video signals that need to be transmitted real-time mission evaluation and safety, Heads Up Display (HUD), left Multi-Functional Display (MFD), and right MFD. These video signals are standard NTSC formats and therefore occupy an RF bandwidth of almost 4MHz each. Using an off-the-shelf Enerdyne Technologies, ENC1000A94, Color Video Compression Encoder to compress and digitize the video signal prior to transmission (ref. figure 2) yields an RF bandwidth approximately 750 KHz. The compression scheme is the Enerdyne proprietary Adaptive Digital Video Standard Compression (ADVS) algorithm working in conjunction with the Discrete Cosine Transform method defined in the ETI-TP093 DCT standard for Digital Transmission of Color Television Images[4].

The MFD is not a fast updating display and therefore can be sampled by the slave encoder unit at a rate of 4 frames per second verses the NTSC rate of 30 frames per second and then converted to a 250 KBps PCM data stream. The HUD video is sampled at 10 frames per second by the encoder master unit which results in a 409 KBps PCM stream. Multiplexing the two video/PCM streams within the encoder master unit results in a slim 714KBps PCM stream. Figure 3 is an actual Spectrum Analyzer screen of the RF carrier.

The spectrum analyzer graph reveals a real RF bandwidth, -3dB down from the top, of under 800Khz. The -25dB RF bandwidth is approximately 1.6Mhz. Premodulation filters are used before the transmitter of 750KHz to keep the harmonics and sidebands down to acceptable levels.

In practical applications, the HUD transmitted video is sampled at one-third the rate of normal television and this creates a “strobed” or jerky looking picture. This creates no noticeable data loss during postflight analysis. The picture is crisp and clear not smeared. A video time inserter is used to help mark and correlate aircraft time with range time. The accepted resolution of the overlaid IRIG time is 150 milliseconds. The slower MFD scan rates are almost unnoticeable when displaying the radar data.

CONCLUSION

The limitations of physical space in the F16 jet fighter was effectively solved using an off-the-shelf data-to-video encoder and recording the video data on an off-the-shelf Hi-8mm triple deck. The space savings of 67%, 2 cubic feet, was achieved without sacrificing data quality.

The limitations of the RF bandwidth was solved using an off-the-shelf video compression unit. The savings of RF bandwidth is 80% over one NTSC signal. The transmitted video signals occupy a bandwidth of under 800 MHz and a savings of approximately 90% is realized.

References

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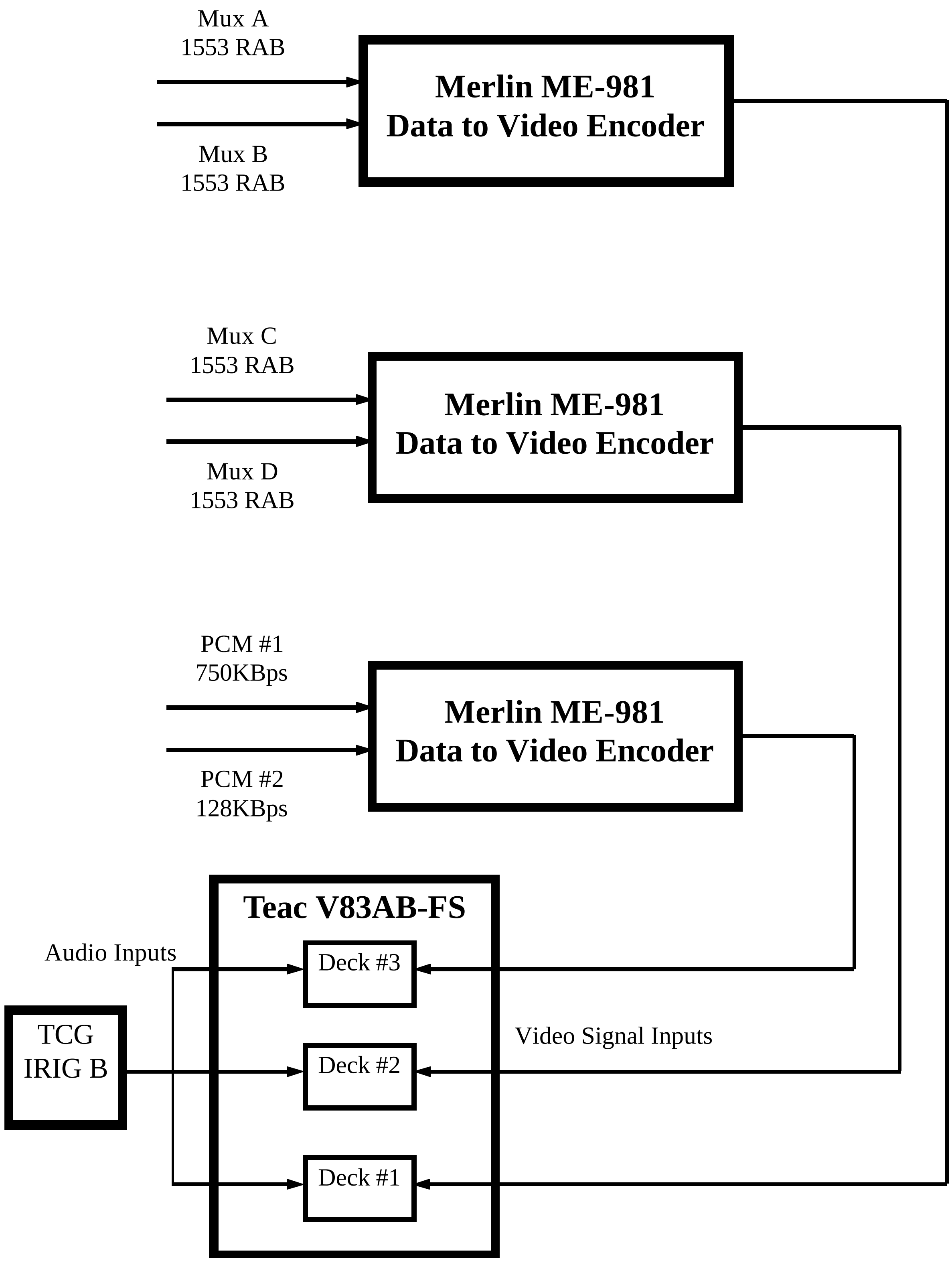
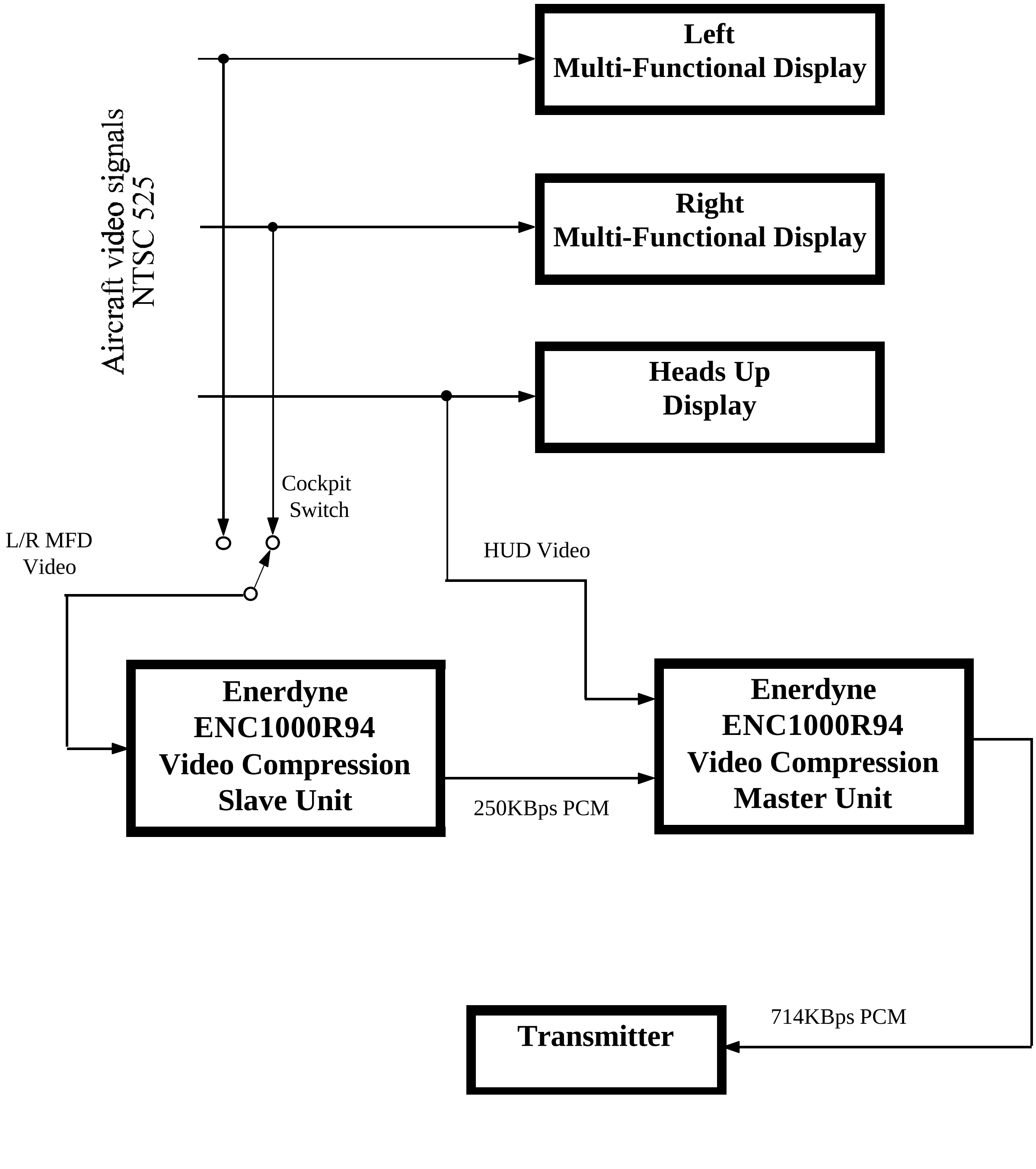
Data Recording Block Diagram

Figure 1



Video Compression Block Diagram

Figure 2



Spectrum Analyzer Graph of Video RF Carrier
Figure 3