Development of a New IRIG Standard Flight Recorder

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ABSTRACT

An IRIG standard flight recorder has been developed that is based on half-inch helical scan technology. The recorder was developed by combining the data channel of existing ground-based recording systems with transport technology used in both flight test and operational fighter aircraft environments.

The design goal was to achieve cross play compatibility with the defined IRIG 106.6 tape format. Significant margins were provided in the design to maintain compatibility with tapes recorded in fighter aircraft environments. Operation at up to 50,000 feet, a temperature range of -40°C to +55°C, and vibration sources to Mil Spec 5400T are requirements in this environment.

How these technical problems were overcome during the development of this recorder is addressed in this paper.

KEY WORDS

Flight Recorder, Recording, Recording Technology, Airborne Instrumentation, Flight Test, IRIG

INTRODUCTION

A flight test recorder was designed to meet mid-range recorder performance needs. The goal of this work was to produce a flight test recorder that is format compatible with existing ground station recorder-reproducers and adheres to the IRIG 106.6 tape format standard.

The recorder, the Model 32HE, was developed by combining the data channel of an existing ground-based recording system with a transport and related control technology that is used in both flight test and operational fighter aircraft environments. In an era of budgetary constraints and economic pressures, this combination of two technologies from existing equipment was a cost effective approach in achieving the technical goals.

The data channel design was derived from a 64 megabit per second ground station recorder. This includes everything from the external connector to the media and includes input/output circuits, memory arrays, ECC electronics, formatter, pre-amplifiers, bit synchronization, equalization, head drivers, and head technology. Although all of these functions are working designs in a lab environment recorder, the designs had to be migrated to meet the requirements of a harsher environment and a much smaller physical space.

The remaining technology was adapted from an existing mission video recorder. The most significant component of this technology is the helical scan transport, but several other critical subsystems were also derived from the mission recorder. This includes the mechanical design of the chassis, the heat dissipation system, and other elements related to the transport such as the motors, motor control, and servo systems. This group of technologies had to be translated to meet the requirements of a digital recorder operating in a high performance jet fighter aircraft environment.

From a system perspective, the development strategy was simply to combine the two sets of technology into a new recorder. Although several system engineering hurdles could be anticipated, especially the integration of two previously independent designs, the main problems were an outcome of attempting to record a digital stream of data at a 100 kilobit per inch density in the jet fighter environment.

IRIG 106.6 TAPE FORMAT

A major goal of the design was to achieve format compatibility with the IRIG 106.6 tape format standard. This standard specifies two related track pitches as shown in Figure 1. The E format has 58 x 10^{-6} (μm) tracks on 80 μm centers. The B format specifies 32 μm tracks on 40 μm centers. Both the E and B formats may be recorded at approximately 50 kilobit per inch or 100 kilobit per inch densities. All these versions of the format are used in existing ground station recorder-reproducers.

These formats are usually supported in one of two ways. The first method has two heads mounted 180 degrees apart on the rotating upper cylinder of the scanner. For example, a two head upper cylinder using 58 μm heads could be controlled to write two tracks on 80 μm centers during each rotation of the cylinder. This would be compatible with the E format. The second method uses four head with a pair of heads mounted 180 degrees apart. An upper cylinder with four 32 μm heads mounted with two sets of heads 180 degrees apart is an example of the second implementation. Each rotation in this example would result in four tracks being written as shown in the bottom part of Figure 1.

Also note that with proper control of the data channel, a B format recorder can reproduce the E format since the single rotation tape offset is the same for both implementations.

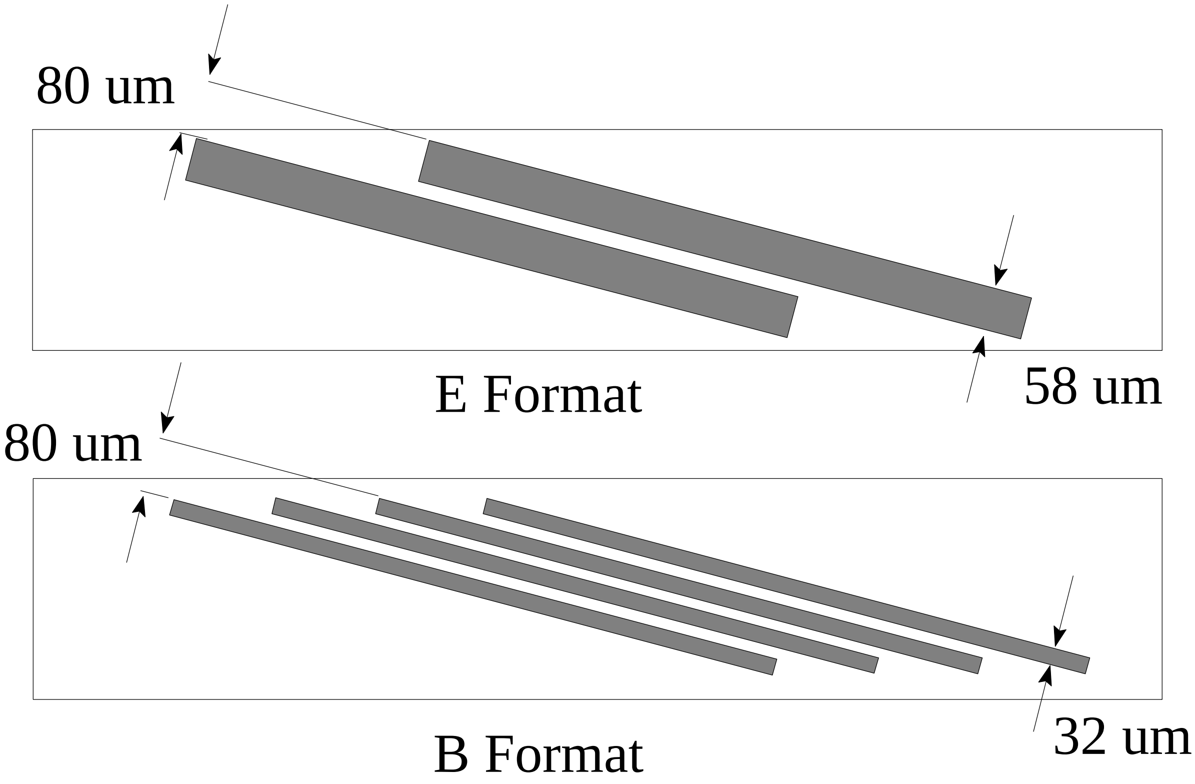

Figure 1
IRIG 106 Track Format

JET AIRCRAFT ENVIRONMENTAL REQUIREMENTS

The format requirements outlined above have been implemented in lab environment recorders with a high degree of success. The environment in a modern jet fighter aircraft is much more severe in several areas. The most challenging requirements for a recorder are the temperature, vibration, and altitude requirements.

The temperature range that test equipment must meet is -40°C to +55°C. Most laboratory recorders are specified to operate in a range of +5°C to +40°C. The extended temperature range poses difficulties for electronics, heat dissipation, media performance, and the electromechanical-magnetic systems involved in writing data on tape.

The vibration requirements that must be met are represented by the vibration curves in MIL-SPEC 5400T. There are several elements of a recorder that can be affected by vibration including component mounting and circuit card mounting. However, the effect of vibration on track straightness and track spacing are the most difficult to control.

The final significant requirement posed by the jet aircraft environment is operation to an altitude of 50,000 feet. This requirement, of course, translates into operation at a reduced atmospheric pressure. For the most part, this has negligible effect on electronic or mechanical operation. However, a helical scan tape recorder's operation depends on the presence of an air bearing that exists at the head to tape interface as the magnetic head travels across the tape.

How some of these problems were resolved is discussed below. Particular attention is given to tape format issues.

DESIGN STRATEGIES

Any tape drive design achieves the environmental requirements outlined above by careful design in the signal system, the geometry of the mechanical design of the tape transport, and the servos. The discussion below describes the design considerations that were necessary to accomplish the environmental requirements, but concentrates on specific areas that were critical in achieving crossplay of the IRIG 106.6 tape format.

The underlying strategy was to use the margins that are inherently available in the IRIG 106.6 tape format and implement a servo design capable of maintaining those margins. Additionally, it was necessary to isolate the unit as much as possible from the added effects of temperature, vibration, and altitude.

Referring again to Figure 1, note that the E format has a track width of 58 μm and the B format has a track width of 32 μm. In order to assure the widest possible margins across the extremes of the environment it was decided to use the E format to record data on the airborne recorder and use a B format ground station to reproduce data. This provides an additional 26 μm of margin in the track. A centered head could drift 13 μm and still be 100% on recorded signal.

The worst case allowable margins are determined by this system level strategy. In order to meet these margins the design of the recorder's geometry attempted to keep the track tolerances to a minimum. Table 1 gives a list of the mechanical elements that contribute to the track geometry. Each of these elements was allocated a maximum allowable effect on the track straightness, calculations were made to determine the effect of tolerances, and then tolerances assigned to each mechanical part. When the transport was constructed each of these parameters were then measured.

Static Environment	Temperature	Vibration
Helical head width tolerance	Head height to helix D.C. shift	Head deflection
Head dihedral	Cylinder diameter helix angle	Slant post deflection
Head penetration	Head width	Capstan shaft radial deflection
Upper scanner diameter	Head protrusion	Linear head
Helix angle	Tape dimensions	Baseplate
Scanner eccentricity	Scanner tilt	Spool/cassette
Head height		Inlet guide
Slant post		
Cylinder azimuth		
Cylinder tilt		
Cylinder pitch		
Catcher post skew		
Tension variation		
Capstan shaft runout		

Table 1
Tape Position Design Elements

The remaining subsystems important in achieving the track format are the servo systems. Figure 2 is a block diagram of the scanner servos, one of the servo systems. This servo system is a digital system using an Analog Devices Digital Signal Processor (DSP) ADSP2101. The DSP is programmable via an EPLD. Its software performs the control algorithms to drive each phase of the motors with a synthesized current profile. The feedback is provided from an optical encoder that is mounted on the scanner. This provides position and velocity information allowing a track reference pulse and control pulse to be generated for other parts of the recording system. The Motor Driver Assembly (MDA) is a switched mode current drive that provides independent closed loop control of the current in each of the motor phases as required by the servos. The MDA is able to supply up to 1 amp into any phase to support high servo gain. The switching system keeps the power consumption of the assembly very low.

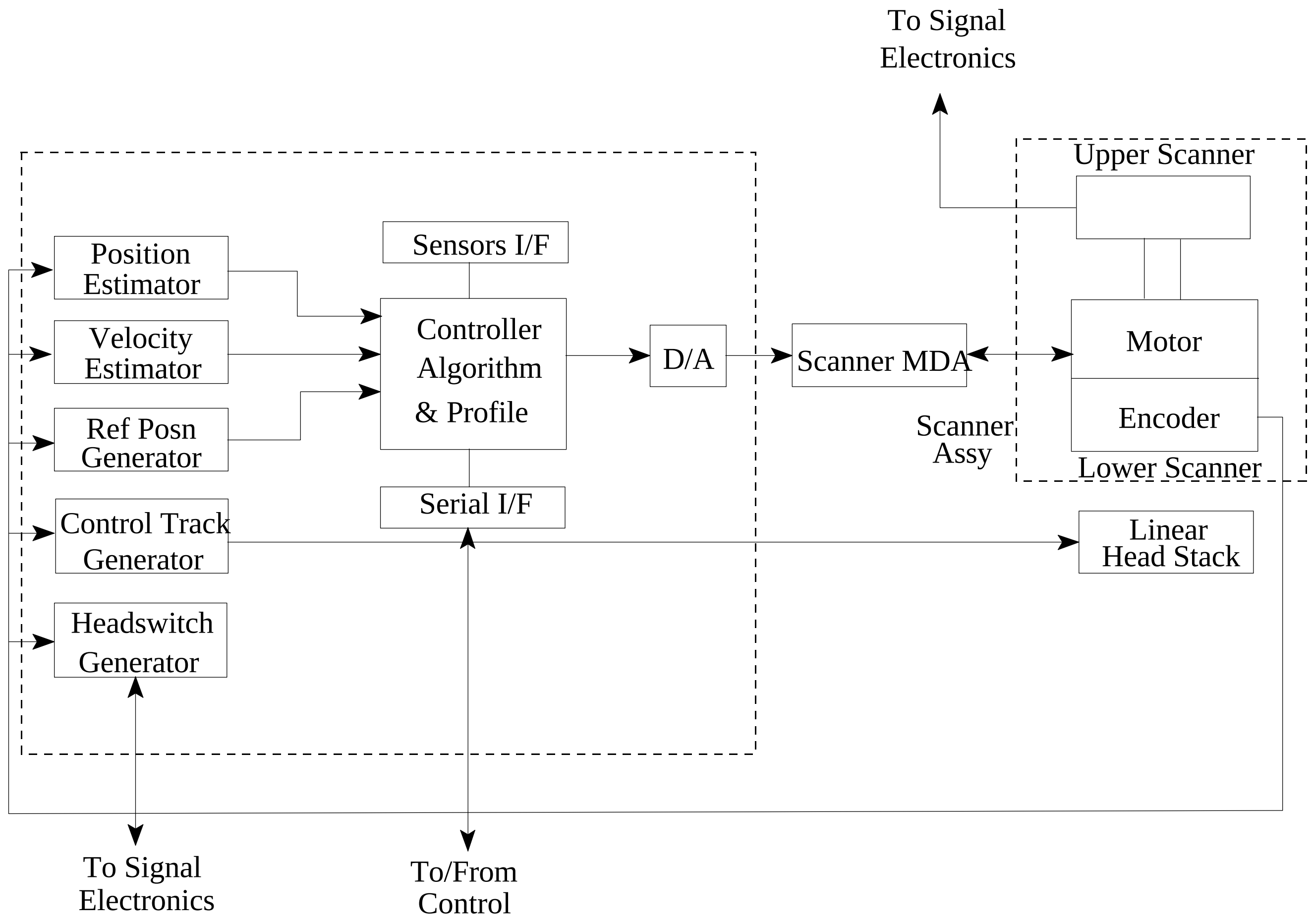

Figure 2
Scanner Servo Subsystem

The motor assemblies are precision mechanical components. Their bearings provide sufficient pre-load and rigidity to maintain system accuracy within the environmental extremes. The motor assemblies also contain the motor and feedback transducers. In order to satisfy control requirements in the environmental range, customized motors were designed. These motors are toroidal servo motors that are cogging free. The combination of these motors, the synthesized drive, and the mechanical accuracy of the assemblies provides for very smooth delivery of torque to within +/- 1 gram. Similarly, the feedback transducers also had high bandwidth and accuracy requirements because of the environmental demands. To satisfy these requirements custom designs were implemented that provided high sample rates and accuracy.

TEST RESULTS

The design approaches described above were tested as part of the final unit in environmental chambers. Figure 3 is a plot of track deviation measured across a group of 240 tracks on a segment of recorded tape. The recording was done at 55°C. The worst case track deviation is about 6 μm, and is well within the +/- 13 μm safety margin. Figure 4 is a similar plot taken during a vibration test. The results of this test show a worst case deviation of about 5 μm, again well within the safety margin. These results show that narrower track widths could be supported.

CONCLUSION

These results, and the results of many similar tests, demonstrate that the design approaches described in this paper produce a recorder capable of supporting the IRIG 106.6 tape format. Although the environmental requirements are severe, the management of the signal system, mechanical geometry, and control systems provide enough margin to meet the tape format specification. Enough margin is present to consider smaller track width implementations. This provides encouragement for future designs of higher performance flight test recorders using the same IRIG 106.6 tape format.

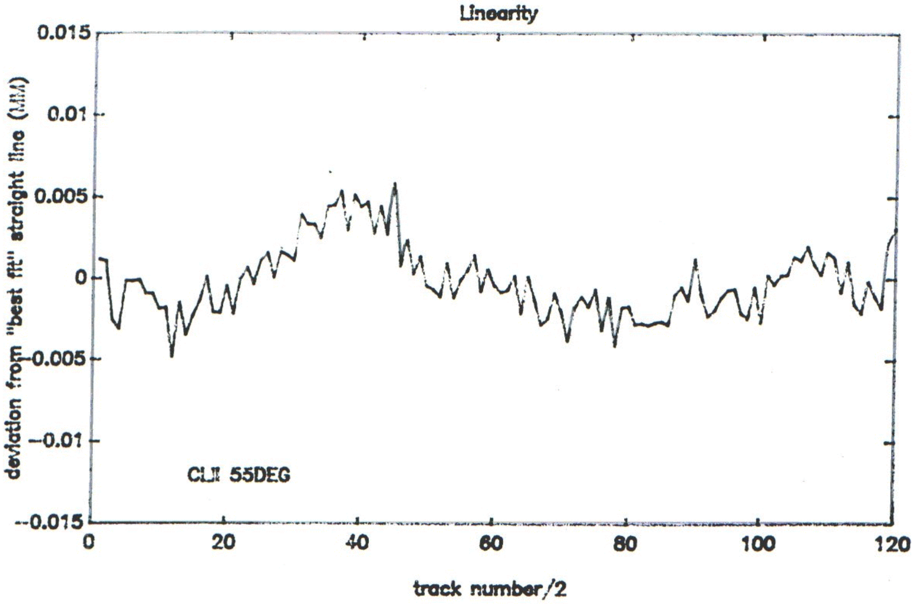

Figure 3
Track Deviation at 55°C

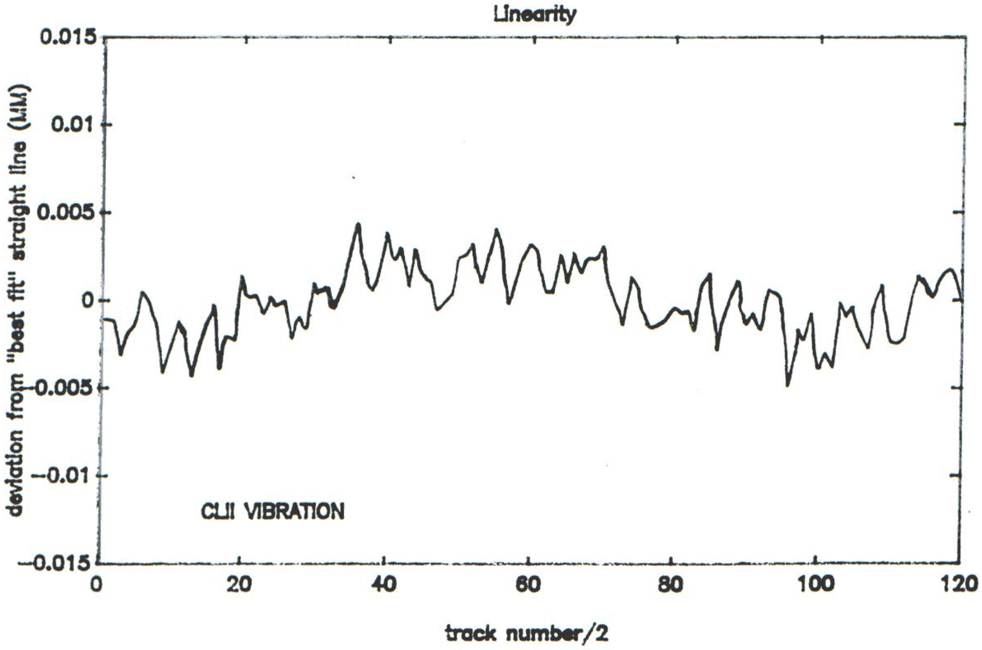

Figure 4
Track Deviation under Vibration