

# **AN OPERATIONAL VIDEO TAPE RECORDING SYSTEM UTILIZING IRIG STANDARD 129-73 [1] SEGMENTED HELICAL SCAN RECORDING FORMAT**

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## **Summary**

### **Part I. An Operational Video Tape Recording System**

An Operational Video Tape Recording (OVTR) system has been developed which fulfills the requirements of the USAF prime specification ASD/ENACC-73-4. The system is comprised, in part, by a highly versatile MIL-E-5400 Airborne Video Recorder and Remote Control Unit which are designed to produce high band [2], [3] video recordings in the environments encountered on deployment in jet fighter aircraft. The companion ground system consists of a video recorder/reproducer for playback of mission tapes and a video Discassette® recorder/reproducer with slow motion/stop action capability for complete analysis of the recorded data. The system design incorporates multi-line rate flexibility to provide record capability of video signals from a multitude of electro-optical sensors including FLIR, LLTV and scan converted radar. The high band performance of the OVTR system makes it suitable for utilization with numerous weapon systems such as PAVE TACK, TISEO, MAVERICK, WALLEYE, HOB0 and PAVE SPIKE and various airborne ASW applications.

### **Part II. Expanded Capability for a Wide Range of Instrumentation Applications**

The OVTR system is easily expanded in capability to enable the recording of any type of instrumentation data that fits within a 6.5 MHz bandwidth, such as an 8 mB/s serial digital stream, radar, spread spectrum or other down converted communications data.

The system features continuous data reproduction capability with no switching transients resulting from sequentially recombining the segmented scan data. The very precise time-base stability and high linearity are key performance factors in enabling the handling of these signals with extremely high fidelity.

Further extensions in bandwidth, SNR and time-base stability are under development. Predictions are made on expected performance improvements.

Other developments to extend the versatility of the transport systems will be discussed.

**Introduction.** In mid 1973, the Air Force Systems Command, Aeronautical Systems Division, conducted an exhaustive study of the various commands' (TAC, SAC, ATC, Joint Services) applications and requirements for Airborne Imagery Recording Systems. These requirements indicated need for a system capable of recording multi-line rate, wideband, video formatted data from a multitude of electro-optical sensors including TISEO, MAVERICK, WALLEYE, HOBO, PAVE SPIKE and scan converted radar. Further, it was necessary that the recording system possess the capability for deployment in high performance aircraft environments, such as are encountered on F4, A7, F111, B1 and B52, with the ability of rapid access to the recorded data for mission debriefing. System concepts for an operational videotape recorder (OVTR), definitized by the prime specification ASD/ENACC-73-4, represented the culmination of this survey.

The system requirements, defined by the prime specification, were for a highly versatile airborne video recorder with MIL-E-5400/MIL-STD-454 characteristics, and a ground-based reproducer with reliable interchange capability for reproduction of tapes from numerous airborne recorders. Stop-action display of video data, video and audio dubbing and audio editing were necessary features of the system as were reliability and maintainability for logistics support. Slow motion display was considered a desirable but not required feature. The application of existing off-the-shelf hardware to the extent possible was considered desirable to avoid cost and risks of new product design/development.

A survey of the industry conducted by AFSC/ASD revealed there was no stock imagery recorders) or recording system(s) that possessed the combination of features which would meet the OVTR requirements; i.e. bandwidth, signal/noise, multi-line rate capability with no adjustments, size, weight, power and immunity to the required environments.

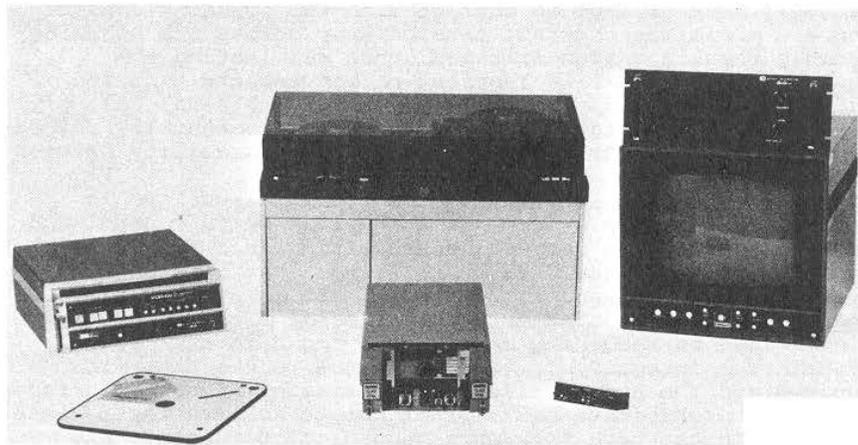
In October of 1973, an RFP was issued by ASD to several U.S. companies and a bidder's conference was held on 20 November 1973 at WPAFB, Ohio. Proposals were received in January of 1974 and evaluated by ASD between January and April of the same year. In addition to the proposals, an evaluation of base line equipment supplied by the competing bidders was conducted. In June of 1974, OVTR contracts were awarded to two of the competing bidders to develop video tape recording systems in accordance with the prime specification.

In January of 1976, prototype systems were delivered to the Air Force for flight test evaluation. Concurrently, environmental qualification, reliability demonstration and maintainability demonstration tests were conducted. The text of this paper describes one of these systems, which utilizes the IRIG standard 129-73 segmented helical scan recording format, its unique characteristics and exceptional performance.

## **Part I**

### **Operational Video Tape Recording System**

The Echo Science operational video tape recorder system is comprised of an airborne video recorder and remote control unit (RCU), a ground video tape recorder/reproducer, a video Discassette® recorder/reproducer (VDR), a video monitor and an audio amplifier/monitor (See Fig. 1).



**ECHO SCIENCE OPERATIONAL VIDEO TAPE RECORDING SYSTEM**  
**Figure 1**

These equipments constitute a high performance imagery recording system capable of record and playback of any video formatted data (60 fields/s, 30 frames/s) including electro-optical sensors, low light level television (LLTV), forward looking infrared sensors (FLIR), and scan converted radar. The airborne and ground VTR record format affords one wideband video channel and two auxiliary audio/data channels. Video and audio dubbing as well as audio editing are features of the VTR system, while the VDR provides slow motion/stop action record and playback capability.

Two very significant features of the airborne and ground video tape recorder (VTR) system provide the performance and flexibility necessary to comply with the requirements of the prime specification. First, the utilization of the IRIG 129-73 Standard Video Tape Recording Format and attendant segmented helical scan recording technique affords great latitude in selection of writing speeds to achieve the bandwidth and signal/noise

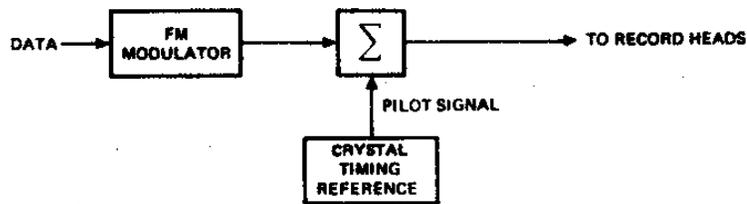
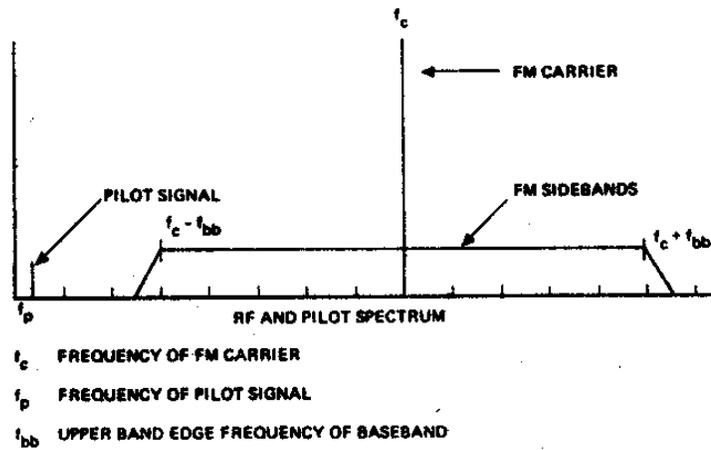
performance associated with quadruplex recorders, while retaining the simplicity, low cost, and reliability of non-segmented helical scan recorders [4], [5].

The small size and mass of scanning assembly components and the short span of unsupported tape in the scanning area combine to minimize the susceptibility of the VTR record format to distortions imposed by vibration and acceleration forces and dimensional changes which occur with variations in temperature. The rotational inertia of the scanning head drum is small, tending to minimize the sensitivity of the airborne VTR to rotational velocity errors which can be introduced by environmental acceleration forces. Additionally, the small area of tape in contact with the scanning assembly mandrels minimizes the tape tension drop across the scanning assembly resulting from friction, thus eliminating the requirement for air film lubrication between the tape and mandrels as required on some rotary head recorders. All of these parameters relate directly to an environmentally rugged airborne recorder, as well as good interchangeability between recorders.

Secondly, a pilot timing control technique is utilized in the OVTR system, to accomplish servo control and electronic time base correction, resulting in a video time base stability of less than  $\pm 25$  ns relative to an internal crystal timing reference. Because of the relatively high frequency of video data, extremely precise timing control must be exercised in recording and reproducing data off tape to maintain the integrity of the data. Due to the precision required and the non precise characteristics of magnetic tape, it is cost prohibitive and impractical to achieve the necessary control with the tape transport mechanical components and electromechanical servos alone, particularly in light of the airborne record environment. An electronic time base corrector (ETBC) thus serves to eliminate those time displacement errors introduced by the tape transport in the record and reproduce modes, which are not corrected by the servos.

The standard video (TV) approach to time base correction is a baseband time base corrector which utilizes the video horizontal sync for timing control. The multi-line rate requirements of OVTR, however, significantly complicate this approach to timing control. The pilot system utilized in the Echo Science OVTR airborne and ground based system, which is entirely independent of line rate, is based on recording a pilot reference frequency with the video data, and in playback, the pilot is extracted, compared to an internal crystal controlled timing reference, and the resulting error signal processed in a baseband ETBC to achieve time base correction.

In the record mode, a pilot signal at a frequency lower than the lowest significant sideband of the fm spectrum (157.5 KHz) is derived from a stable crystal reference and added to the frequency modulated signal at the output of the modulator before the record heads. This is shown schematically in Figure 2. The pilot signal is recorded at an amplitude



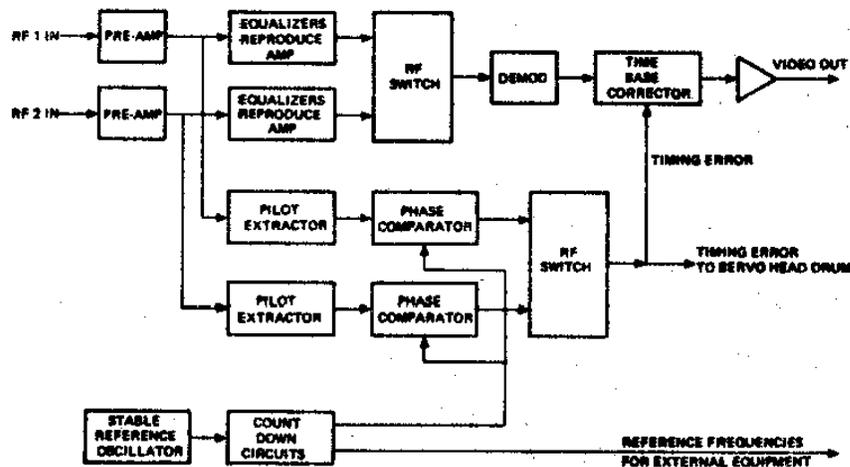
PILOT TIMING CONTROL, RECORD MODE

Figure 2

which is approximately 7% of the fm carrier. The fm carrier, which is recorded at subsaturation level, acts as a bias with which to linearly record the pilot signal.

The pilot signal accompanies the fm carrier and sidebands (RF) through the record and reproduce process and thus experiences all the time base perturbations that are experienced by the RF. During the reproduce mode, the pilot signal from each head channel is filtered from the RF and phase compared to a crystal reference signal in the ground reproducer. An error signal is thus derived, whose voltage amplitude at each sample time is directly proportional to the composite record/reproduce time displacement error, relative to the crystal reference. See Figure 3.

The combined error signals from the two head channels provides timing control information to the head drum servo and the tension servo. The combined error signal is also applied to the ETBC, in which the delay of a voltage variable delay line is adjusted by the error signal. The ETBC provides final time displacement correction to remove those errors outside the bandwidth of the head drum servo and to assure that the reproduced video signal timing relationships are preserved.



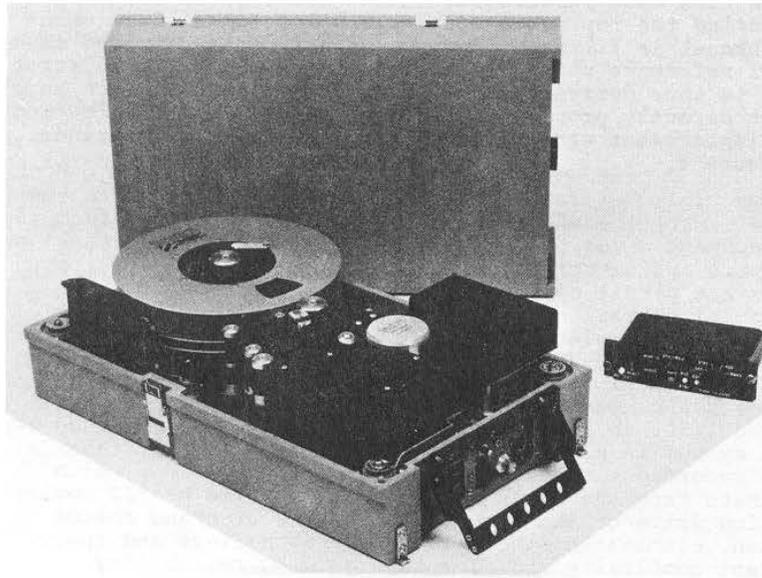
## OVTR GROUND-BASED VIDEO RECORDER/REPRODUCER REPRODUCE MODE

Figure 3

### Airborne Video Tape Recorder

The Echo Science Model WR-702 Airborne Video Recorder and Remote Control unit comprise the airborne portion of the OVTR system. The WR-702, depicted in Fig. 4, consists of a lower case to which the entire tape transport and associated electronics are attached by means of vibration isolators, the upper case and a lower access plate. The lower case is the primary external structure and contains provisions for mounting the WR-702 in the aircraft. The rotary head scanning assembly, tape drive mechanisms, tape guiding components and signal, control and power electronics all attach to the tape transport. An upper case which contains provisions for forced air cooling of the unit attaches to the lower case and is easily removed for rapid access to the magnetic recording tape and the top of the tape transport. The access plate, which attaches to the lower case, is provided for accessibility to the underside of the tape transport. The three section case provides a rigid structure to withstand the severe vibration and shock environments. The WR-702 recorder fits entirely within the specified OVTR envelope of 6 in. x 11 in. x 18 in. All handles, latches, connectors and controls are recessed within the envelope dimensions.

The WR-702 is designed to provide specified performance under the adverse environments normally encountered in aircraft. Composite gaskets between mating enclosure faces protect the interior of the WR-702 and tape from sand, dust, dirt, rain, salt atmosphere and humidity, all of which are degrading to magnetic tape recording performance and recorder life. These composite gaskets also provide electromagnetic shielding to minimize the effects of EMI radiation and to reduce the susceptibility of the WR-702 to external radiation. A diaphragm-activated, double-acting breather valve on the



**Figure 4**

upper case section relieves pressure differentials greater than 1.5 lb/in<sup>2</sup> to permit operation at altitudes up to 70,000 ft. A dessicator mounted in the upper case section prohibits exposure of the magnetic tape to relative humidities in excess of 40%, thus minimizing hygroscopic expansion of the tape which can create excessive tension errors in playback.

The internal temperature of the WR-702 is regulated to facilitate operation in ambient environments ranging from -54°C (-65°F) to +71°C (160°F). Temperature regulation is necessary to protect the magnetic tape from exposure to temperatures outside the range of 5°C (41°F) to 55°C (131°F) which can create excessive tension errors in playback and result in failure of the magnetic tape oxide binder and backing material. Thermostatically controlled blanket heater elements on the tape transport maintain the internal temperature of the WR-702 above 5°C. A cold plate type of heat exchanger is integrally incorporated in the upper case for cooling air provisions. Cooling air at 1.0 lb/min flow rate, 1.0 in. of water pressure drop and any supply inlet temperature below 30°C (86°F) provides sufficient cooling to allow extended periods of operation of the WR-702 in a 71°C environment. The cooling plenum is so configured that heat dissipation is achieved without the need for directing cooling air through the inside of the recorder. This permits the WR-702 to operate with cooling air of poor quality (uncontrolled humidity, dust, dirt, etc.) with no degradation in performance as might occur if the magnetic tape were exposed to such contaminants.

Vibration isolation of the WR-702 is designed to achieve minimum torsional oscillations of the tape transport and to reduce the effects of natural resonances on video time displacement error. The isolators not only protect the tape transport and electronics from

severe shock and vibration forces but permit operation under conditions of a  $\pm 10g$  sinusoidal vibration environment with no performance specification deviations.

The WR-702 utilizes NAB or SMPTE standard 8-1/2 in. diameter precision reels to provide 45 minutes of record time. The reels are concentrically mounted with the supply reel located 1.500 in. below the take-up reel. A closed loop tape drive system is employed to isolate the portion of tape in which recording is accomplished from perturbations which originate from the reels and reel drive. The WR-702 employs friction drive of the tape by means of a urethane coated capstan, eliminating the need for pinch rollers and their inherent complexity and poor tape guiding reliability. Elevation transfer of the tape is accomplished entirely on the scanner. Entry and exit guides on the scanning assembly are tilted in such a manner that the tape rises 1.500 in. as it passes around the scanner. The geometry of the scanner establishes the static helix angle. This geometry combined with the longitudinal tape speed of 12.5 in/s and direction of the head wheel rotation define the format of the video track recorded on tape. Precision rotating and fixed tape path elements provide accurate and uniform tape guiding to assure proper tracking and to minimize forces on the tape which might otherwise result in premature tape failure and reduced tape life.

The WR-702 utilizes a single permanent magnet DC motor to drive the scanner and the tape. The scanner, capstan and reels are driven from the motor by means of a series of pulleys coupled by polyester belts. This results in a simple and reliable drive system with minimum power consumption (under 75 W steady state in record mode). The scanner and capstan are directly driven by the motor via belt coupled pulleys.

The reel drive is provided from the capstan through belt coupled pulleys. To achieve bidirectional operation for rewind, a clutch cluster is driven through a reduction belt from the capstan. Two pulleys, concentrically mounted on the clutch cluster, provide drive to one or the other (depending on direction of travel) of the reel pulleys by means of reduction belts. The pulley that is not driven is locked via a roller clutch to ground. Because the reel speed varies with tape pack radius, it is not possible to drive the reel at a constant rotational speed. Also, because it is desirable to maintain constant tape tension as the tape is wound onto the take-up reel, a constant torque wind is undesirable. Rather it is desirable that both the torque and speed of the reel be controlled to produce a constant tension wind. To accomplish this an idler in the take-up reel belt drive, which is spring loaded to produce the necessary reel drive belt tension, is mechanically coupled to the take-up tension arm around which the tape wraps. The force exerted on the arm by the tape works through the mechanical advantage of the take-up tension linkage to subtract from the idler spring force exerted on the reel drive belt. This in turn controls the torque exerted at the reel, as well as the speed of the reel (through controlled belt slippage) to maintain constant tape speed and tension. A similar mechanical servo-mechanism is utilized on the supply reel. However, in record, the supply reel belt is locked to ground by

the clutch cluster so that there is no drive to the reel. The supply tension arm in conjunction with the supply servo linkage, operates to provide controlled belt slippage and hold-back torque to the reel to allow the capstan to pull the tape from the reel at constant speed and tension. In rewind, the direction reversal of the motor causes the clutch cluster to reverse the action of the supply and take-up reels. The tension servo linkages operate in the same manner for either controlled drive tension or controlled hold-back tension. Supply and take-up tape tensions are servo controlled in this manner to within one ounce of tension over a full tape pack.

The WR-702 electronics consist of interchangeable EMI filters and power supply modules, signal circuitry and control logic. The interchangeable power supply modules facilitate operation from power sources of 28 VDC, 115 VAC, 400 Hz, single phase or 230 VAC, 400 Hz, single phase. Companion EMI filters for the different supplies serve to provide suitable protection from electromagnetic radiation and susceptibility. These modules are easily replaced to allow rapid conversion to alternate power sources.

The WR-702 signal circuitry consists of video AGC, modulator and record driver circuits and audio record circuits. The AGC functions on input video signals in the range of 0.2V to 4.0V black to peak white and automatically adjusts the level to produce a 1.0V composite video signal. The WR-702 employs a frequency modulation recording technique for video wherein a center carrier is frequency modulated by the signal to be recorded. The carrier frequency, 8.0 MHz for the WR-702, corresponds to 0 VDC or blanking level [2], [3]. In this technique, signal levels in excess of 0 VDC deviate the carrier frequency, in proportion to the input signal DC voltage level, a certain percentage in one direction. Signal levels below 0 VDC deviate the carrier in proportion to the signal level a certain percentage in the opposite direction. An AC input signal deviates the carrier alternately on both sides of the center frequency, at a rate equal to the frequency of the applied signal. Thus, the frequency of the frequency modulated carrier is directly proportional to the DC voltage of the video signal in the time domain. Frequency modulation of the input video signal is achieved in the modulator by a voltage controlled multivibrator. The video input to the modulator is clamped to 0 VDC on the back porch. The carrier of 8.0 MHz utilized in the WR-702 corresponds to this level. Active video from 0 VDC to 0.8 VDC will deviate the carrier from 8.0 to 10.0 MHz in proportion to the signal level and rate of change of the video information. The video sync at -0.3 volts DC deviates the carrier from 8.0 to 7.06 MHz. The output of the modulator is thus a frequency modulated signal that deviates from 7.06 to 10.0 MHz. This signal is applied to a video record driver in which a switching (square wave) driver functions as the record amplifier to deliver a constant current, with respect to frequency, drive to the record heads.

A linear recording technique is utilized for the audio/data channels. The input audio signal from a switch-selected impedance matching network is amplified in a differential amplifier

circuit having preset level adjustment. High frequency equalization is provided by a series circuit that boosts record current to compensate for head response drop off at the higher frequencies. Similar compensation is provided for the low frequencies by a shunt circuit. The AC coupled audio signal is then applied through a constant current source record driver. At the output of the driver is a parallel tuned bias trap which presents a high impedance to the 60 KHz bias signal preventing distortion of the driver output signal.

The WR-702 control logic consists of the RCU circuits which initiate the various function commands, a pulse-width modulated, phase locked servo and motor drive amplifier (MDA) and a reference generator on which all of the timing reference signals are derived from a hybrid crystal oscillator. In addition to the recorder operation commands, standby, record and rewind, the RCU features an audio tone event marker which when depressed records a 3 KHz tone on audio channel 2. An electro-optical end-of-tape (EOT) sensor located on the transport senses a clear leader on the end of the tape and inhibits a logic gate supplying power to the MDA when this leader is detected, thus stopping the motor. This prevents the tape from being completely transferred to the take-up reel, assuring the rewind function will always be operable. Additionally, a microswitch senses the supply tape tension arm and causes the recorder to revert to standby under conditions of broken or unloaded tape. A tape remaining counter is provided on the RCU for a visual indication of the minutes of record time remaining. Record confidence indicators on the front panel of the WR-702 and on the RCU provide verification that the recorder is functioning properly in record mode.

The speed of the motor is accurately controlled by the servo and MDA. A pulse-width modulated drive is utilized for maximum efficiency and minimum power consumption. An electro-optical emitter and receiver sense the scanner rotational velocity at a once around rate, 180 rev/s. This tachometer signal is compared to a 180 Hz reference signal in a phase comparator and an error voltage is generated which is proportional to the phase difference. A pulse width modulator, operating at a 15.75 KHz rate, varies the duty cycle of rectangular pulses to the motor in proportion to the tachometer error voltage. An MDA feedback, proportional to motor current, is summed with the phase comparator error voltage to cause a more rapid response of drive motor torque to the tachometer phase error.

## **Ground Video Record/Reproduce System**

The WRR-712 video recorder/reproducer, companion to the WR-702, consists of a single portable unit, in which is contained all of the record/playback functions and controls, signal, control and power circuitry, and magnetic tape transport. This single unit possesses all of the functions and requirements of the OVTR ground playback system except for the slow motion/stop action capability provided by the VDR-1W Discassette® recorder and

the video monitor capability provided by a multi-line rate video monitor. Because of its portability, the WRR-712 recorder/reproducer and associated OVTR ground playback equipment is easily deployed on the flight-line, in debriefing rooms or any other area in which rapid access is required for playback of mission tapes.

The WRR-712 possesses all of the functions and performance afforded by the WR-702 for recording of wideband video formatted data. The WRR-712 also contains the circuitry and controls necessary for playback of recorded tapes, including separate scanner and capstan servos, tape tension servo and electronic time base corrector (ETBC). The transport drive and associated circuitry of the WRR-712 are similar in concept to that of the WR-702. A single motor and belt coupled pulleys provide drive in the record mode. The closed loop tape drive, tape guiding elements and mechanical tape tension servos are all similar to those employed on the WR-702.

In reproduce mode, however, tape drive is uncoupled from scanner drive and separate phase-locked loop servos control scanner and capstan drives independently. The scanner servo phase error voltage is derived from the reproduced pilot signal and an internal crystal reference on the WRR-712.

The reproduced pilot is also utilized by the tape tension servo, which electromechanically controls supply tape tension to cause it to be the same as that at which it was recorded. The tension servo also corrects for expansion and contraction of the tape which occurs when the temperature and/or humidity environments are different in record than in reproduce. A second motor on the WRR-712 independently controls capstan, hence tape speed. A control track recorded longitudinally on tape by a fixed head is reproduced by the WRR-712 and phase compared with a reference to servo the capstan. The reproduced pilot is also utilized by the ETBC to accomplish final time displacement error correction and provide a video time base stability of  $\pm 25$  ns.

The VDR-1W provides storage capacity for 400 frames of video data (200 each side) on each cassette and features step rates of 1, 3, 6, 10 and 15 frames/s in addition to stop motion. A VDR sync output from the WRR-712 provides timing reference information for the VDR to facilitate multi-line rate operation.

The Echo Science OVTR System has been thoroughly tested and meets or exceeds the characteristics and performance required by the prime specification. A highly sophisticated rotary head recording format, simple tape transport drive system, and unique timing accuracy control technique combine to provide a system of exceptional

performance and ruggedness with a predicted reliability far above the specified OVTR requirements.

## **Part II**

### **Expanded Capability for a Wide Range of Instrumentation Applications**

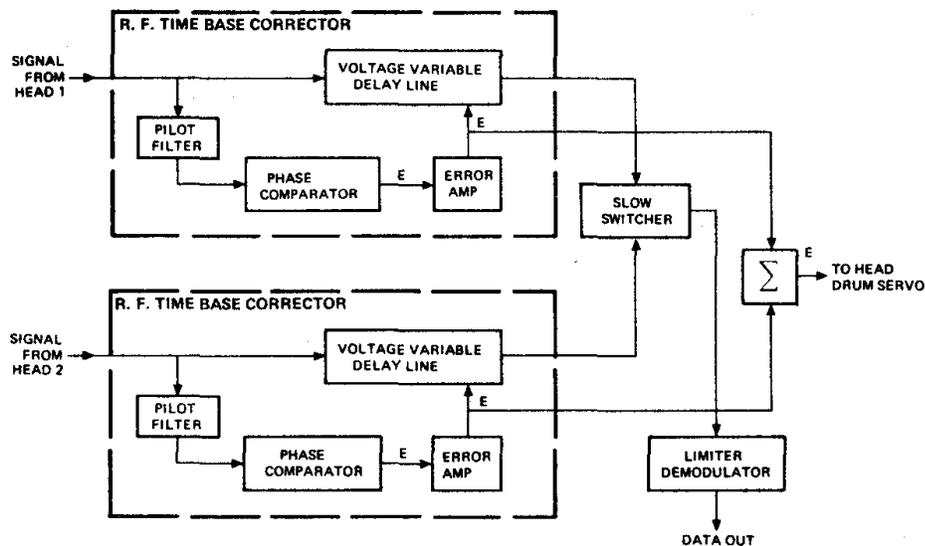
#### **Expanded Capabilities Currently Available**

At the outset of the design phase of the OVTR equipment, a project ground rule was established to continually keep in mind provision for growth capability in the system versatility without compromising configuration, development costs or recurring costs as they related to the specific requirements of the OVTR contract. As a result of following this philosophy, it is possible to replace three printed wiring cards in the Model WR-702 OVTR Airborne Recorder and convert it to a Model WR-721 Advanced Airborne Video Recorder (AAVR), companion to the Echo Science Model WRR-421 transient free [6], [7] Universal Instrumentation Video Recorder (UIVR). In this configuration the recorder can record any type of data whose spectrum fits within the 6.5 MHz bandwidth of the recorder.

As in the case of the OVTR application, a pilot signal derived from the internal timing reference is recorded in a region of the spectrum not used by wanted fm data sidebands. In this case the pilot signal is 250 KHz. This pilot signal, during the reproduce mode on the Model WRR-421, is phase compared to the 250 KHz derived from the timing reference (See Figure 5). The combined error signals from the two head channels are used to control the head drum servo and tape tension servo, and the error signal for each head channel is applied to its corresponding time base corrector through which the associated RF signal is passed. The delay of the voltage variable delay line is adjusted by the error signal, and as the RF signals emerge from their respective delay lines they are in a time base corrected state relative to the crystal reference and to each other.

The next step is to slowly switch (during approximately a 50 us period) from one channel to the other during the redundant period at the beginning of one head scan and the end of the other. Time base correction is achieved to the extent that the fm signals from each head channel are within 90° of phase or less, relative to each other. The resulting phase transient is small and when the continuous carrier is demodulated the spurious signal in the baseband during the time of head switching is several dB below the system noise. The time base stability achieved is within  $\pm 20$  ns relative to the internal crystal reference.

Many DOD needs for recording various ECM, ECCM, ESM and other intelligence data require this wide bandwidth and high degree of time base stability performance to enable the desired quality of data analysis.



**TRANSIENT FREE RECORDER/REPRODUCER  
MODEL WRR-421 REPRODUCE MODE**

**Figure 5**

To further extend this capability, other equipments have been developed to broaden the base of applications which can be served.

Many applications exist which require simultaneous recording and subsequent reproduction of two separate wideband channels of data with a very precise time correlation. A recorder/reproducer Model WRR-441 has been developed having two 6.5 MHz wideband channels with the same performance specifications as the Model WRR-421 and an interchannel time displacement accuracy of 50 ns P-P.

Although many airborne recording applications are satisfied by record only airborne systems, with surface reproduction, some missions require reproduce in flight. To serve these needs a recently developed product, the WRR-521 is now available which is only 0.85 cubic ft., weighs 45 lbs., and has a 6.5 MHz record capability for one hour. The system has immediate playback capability with a 5 MHz bandwidth or these tapes can be played back on a Model WRR-421 meeting full bandwidth and other specifications, such as dynamic range and time base stability.

**Future Capabilities**

Advanced studies have been conducted at a head-to-tape scanning speed of 2100 in/s, which demonstrate feasibility of providing equipment using these same mechanical transports with significant extension in bandwidth, dynamic range and further improved time base stability. Table I is a matrix of predicted analog performance trade-offs. Playing time on a 10-1/2 inch NAB reel is 45 min. at the 2100 in/s writing speed.

	SNR P-P/rms	Time base Stability	Intermodulation Distortion
6 MHz	50 dB	$\pm 3$ ns	-40 dB
10 MHz	43 dB	$\pm 20$ ns	-25 dB
12 MHz	41 dB	$\pm 20$ ns	-23 dB
15 MHz	37 dB	$\pm 20$ ns	-20 dB

**PREDICTED ANALOG PERFORMANCE  
TABLE I**

There are an ever increasing number of applications requiring the digitizing of 6 MHz bandwidth (for example) analog data for telemetry or analysis. This calls for serial bit rates up to 120-150 Mb/s. Feasibility tests in the laboratory at 2100 in/s writing speed and .005 in. track width indicate a bit rate of 40 Mb/s per single channel can be achieved with a data reliability of better than  $1 \times 10^{-6}$ .

The number of wideband channels can be increased to four by placing 8 heads equidistant around the scanning head wheel. Each pair of heads  $180^\circ$  apart on the drum comprise a wideband channel. Such a system will have a throughput capability of 160 Mb/s and an area storage density of 2 Mb/in<sup>2</sup>. A 10-1/2 in. NAB reel of one inch width tape would have a playing time of 11.25 min.

Systems such as these would represent a substantial step in the direction of mass memory throughput rates and economies in initial cost and cost of operation. They would have the same size, weight and power advantages as the currently available systems described earlier.

### REFERENCES

- (1) IRIG Standard 129-73, "Standard Video Tape Recording Format", 1973.
- (2) M. O. Felix, C. H. Coleman, P. W. Jensen, "FM Systems of Exceptional Bandwidth" IEEE Intermag Recording Conference, 1964.
- (3) M. O. Felix, H. Walsh, "FM Systems of Exceptional Bandwidth" Proc. IEEE Vol. 112, No. 9, September 1965.

- (4) S. S. Damron, "Applications and Economic Considerations Affecting the Selection of High Environment Video Recorder Systems", Symposium on Military Airborne Video Recording Requirements, Utilization and Techniques, sponsored by Society of Photo-Optical Instrumentation Engineers, Dayton, Ohio, April 1973.
- (5) D. J. Cochran, A. R. Maxey, "Compact Video Tape Recorders of Exceptional Performance and Reliability", Symposium on Military Airborne Video Recording Requirements, Utilization and Techniques, sponsored by Society of Photo-Optical Instrumentation Engineers, Dayton, Ohio, April 1973.
- (6) E. K. Kietz, "Transient-Free and Time-Stable Signal Reproduction From Rotating-Head Recorders". National Space Electronics Symposium Record, 1963, Miami Beach, Florida, Paper 4.3.
- (7) J. D. Taylor, "What We Do and What We Need", Symposium on Military Airborne Video Recording Requirements, Utilization and Techniques, sponsored by Society of Photo-Optical Instrumentation Engineers, Dayton, Ohio, April 1973.