USE OF ID-1 HIGH DENSITY DIGITAL RECORDING SYSTEMS FOR TEST RANGE SUPPORT

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ABSTRACT

The Space and Missile Systems Center at Vandenberg AFB has integrated ID-1 high bit rate helical scan digital recorders into the ground based and mobile telemetry receiving and processing facilities. The systems are used for recording higher bit rates than those available with the current IRIG standard longitudinal wideband and double density instrumentation magnetic tape recorder/reproducers. In addition to the 400 Mbps digital recorders, the systems consist of high-speed multiplexer/ demultiplexers and multi-channel bit synchronizers for recording numerous telemetry data links and sources on a single recorder. This paper describes the system configurations and compares recording capabilities with those of the previous generation instrumentation magnetic tape recorder/reproducers.

KEY WORDS

High Density Digital Recorders, Test Range Support, Multiplexers/Demultiplexers, and Bit Error Rates.

INTRODUCTION

The primary data recording devices used by the test ranges over the past 40 years have been analog instrumentation magnetic tape recorder/reproducers. These recorders began with bandwidths of 100 kHz at 60 ips and evolved to the current bandwidths of 4 MHz at 120 ips (double density) or 240 ips (wideband). As the PCM bit rates of the telemetry data from the test vehicles has increased; these recorders have become inadequate to meet mission recording requirements. In 1993, the Range Commanders Council Telemetry Group (RCC/TG) added 19-mm Digital Cassette Helical Scan Recording Standards to IRIG Document 106, Telemetry Standards. The format is as specified in the American National Standard For Information Systems (ANSI) 19-mm Type ID-1 Recorded Instrumentation Digital Format, ANSI X3.175-1990. Since the Ranges have multi-channel recording requirements, multiplexer/demultiplexers were also added for recording multiple data channels on these single-channel recorders. In 1996, the systems were further enhanced with the addition of submultiplexers/subdemultiplexers for recording of additional digital data.

SYSTEM DESCRIPTION

The High Density Digital Recording (HDDR) systems discussed in this paper are the Metrum/Datatape LP 400 Digital Recorders with the Alliant Techsystems Analog/Digital Adaptive Recorder Input/Output (ADARIO) multiplexer/demultiplexer. The systems also include a Veda 16-channel PCM bit synchronizer that inputs to an Alliant Techsystems 16-channel submutliplexer. A laptop computer controls the systems. Two HDDR systems have been integrated into the facility at the Vandenberg Telemetry Receiving Station (VTRS), the Pillar Point Air Force Station (PPAFS) and the Telemetry Analog Equipment Room (TAER). Also, one system is available in the Mobile Telemetry Receiving Station (MTRS) number 2. A block diagram of the system is shown in Figure 1.

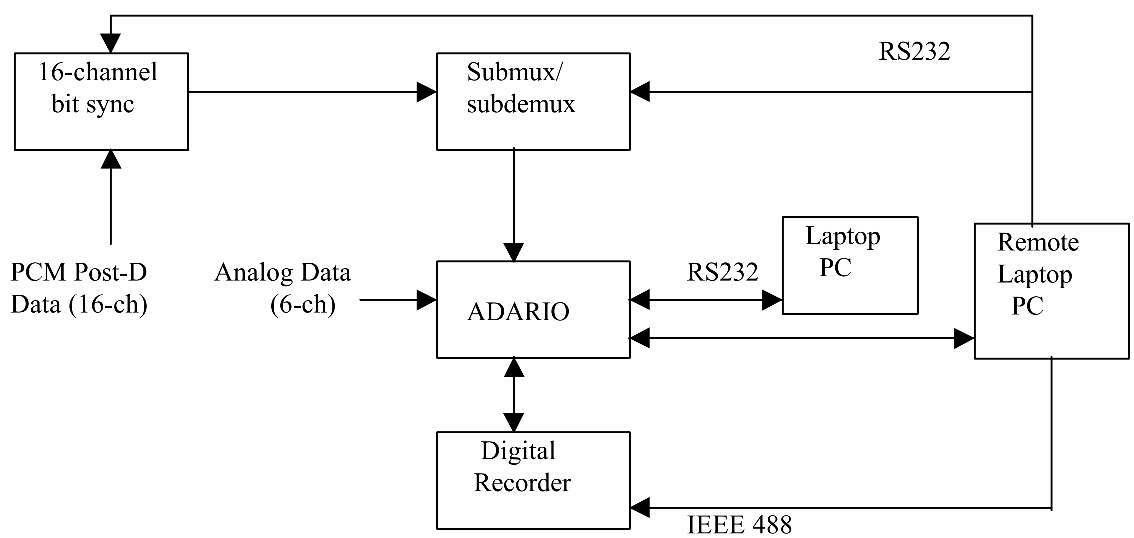

Figure 1: HDDR System Block Diagram

The systems have both digital and analog inputs. The submultiplexer will accept up to 16 digital inputs of post-detection PCM data with bit rates up to 25 Mbps for each channel, up to a total aggregate rate of 256 Mbps. The submultiplexer is inputted to channel 1 of the ADARIO. The ADARIO channels will also accept up to 6 additional analog or digital data streams. Each analog channel can be digitized up to maximum rate of 400 Mbps. Of course, the total aggregate rate of all channel inputs can not exceed the 400 Mbps of the digital recorder.

The laptop PC shown in Figure 1 was delivered as part of the system and can be used for local setup of the ADARIO and the recorder. The remote laptop PC was added to the system by Federal Services Corporation and is used to configure the complete system, including the bit synchronizer, submux/subdemux, ADARIO, and tape recorder. The configurations are achieved by using the menu-based controls in the software. The software allows the user to establish channel parameters such as filter bandwidth, sample size, clock source, and the coupling that is required to record the incoming signal. System self-checks are also initiated from the remote PC.

The recorder in the test range configuration has four speeds with aggregate rates of 50, 100, 200 and 400 Mbps, which are equal to tape speeds of 3.31 to 26.1 ips. The 19-mm medium and large cassettes are used on the test range. This results in recording times using the large cassette of from 30 minutes to 4 hours. The recorder contains error correction circuitry that performs error-protection encoding of the data before recording and error-detection and error-correction of the reproduced data. The error protection uses a double-encoded Reed-Solomon protocol, levels 4 and 5, interleaved by row and column transposition in each of two data memory blocks. Each memory block is dedicated to one scan of wideband data. This produces corrected bit-error-rates (BER) of less than 1 error bit per 10^{10} data bits (excluding tape defects) with raw uncorrected input BER of about 1 error bit per 10^{6} data bits.

The analog instrumentation magnetic tape recorder/reproducers discussed in this paper are standard wideband and double density recorders meeting the requirements of IRIG Document 106-99, Telemetry Standards. The recorders are currently on line at VTRS, PPAFS, TAER and the MTRS 1 and 2. The wideband recorders are Ampex Model 3030's in the 14-track interlaced head configuration. The recorders have a maximum bandwidth of 4 MHz at 240 ips tape speed. The double density recorders are Datatape Model 3700J's and Racal Storehorses in the 14-track in-line head configuration. The maximum bandwidth is 4 MHz at 120 ips. The majority of the recordings are predetection, were the IF of the receiver is downconverted to a frequency within the bandwidth of the recorder. For analog recorders, this has several advantages including recording at the earliest point in the data stream in case of equipment failures, ability to optimize equipment settings during playback, elimination of the recorder DC response problems, and less susceptibility to tape dropouts. The first two advantages also apply to the HDDR systems, however predetection recording with the HDDR systems uses much more of the recording capacity than does post-detection recording.

TEST RESULTS

There are several missile programs scheduled for support by the test range that have recording requirements that can not be adequately met with our current analog instrumentation magnetic tape recorder/reproducers. These include the Titan IVB program, National Missile Defense (NMD) program, Multi-Service Launch System (MSLS) program and Atlas IIA program.

Titan IVB. Tests were conducted at VTRS and MTRS 2 to evaluate the capability to record Titan IVB telemetry data. The requirement is to post-detection record the 3.277 Mbps NRZ-L PCM telemetry data on our Double Density Instrumentation Magnetic Tape Recorders at a bit error rate of $1x10^{-6}$ or better. The HDDR systems and Wideband Instrumentation Recorders were also tested as a comparison. At the request of the Titan IVB program engineers, the tests were conducted using a BER test set with a pseudo-random pattern of 2047 bits set to average the errors over a 3-minute period. No noise was added to the data at the input. The test configuration is shown in Figure 2.

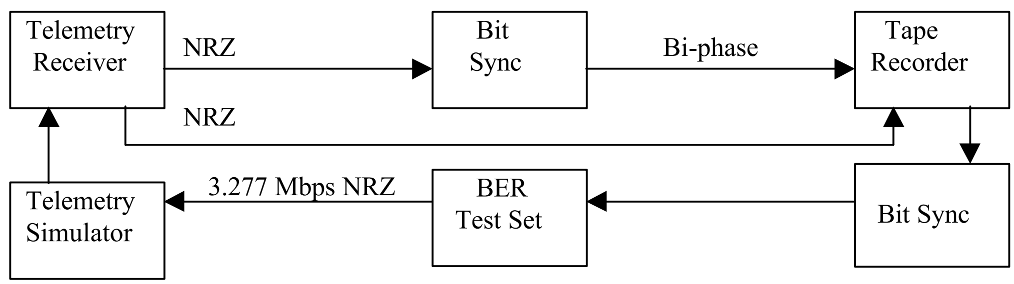

Figure 2: Titan IVB Test Configuration

The test results are shown in Figure 3. The vertical axis in the figure indicates the BER and the horizontal axis indicates time. The horizontal test result lines represent the average BER reading over several 3-minute intervals and the vertical lines indicate large error bursts (over 10,000 errors).

Test # 1 was an average of 6 BER reading using the Datatape 3700J double density (DD) at VTRS and 3 reading using the Racal DD in the MTRS 2. The reading varied from $2x10^{-5}$ to $9x10^{-6}$, excluding error bursts, with no significant difference between the Datatape and Racal recorder results. Test # 2 was a repeat of test # 1, with the input code changed from NRZ-L to Bi-Phase-L. The BER reading varied from $2x10^{-5}$to $4x10^{-7}$, with the average as shown. There were no large bursts of errors resulting in an error overflow indication.

Test #3 was using the Ampex 3030 Wideband (WB) Instrumentation Recorder at 240 ips. The recorder was able to record the 3.277 Mbps NRZ-L data with no errors over the three 3-minute periods. The recording was also error free at 120 ips.

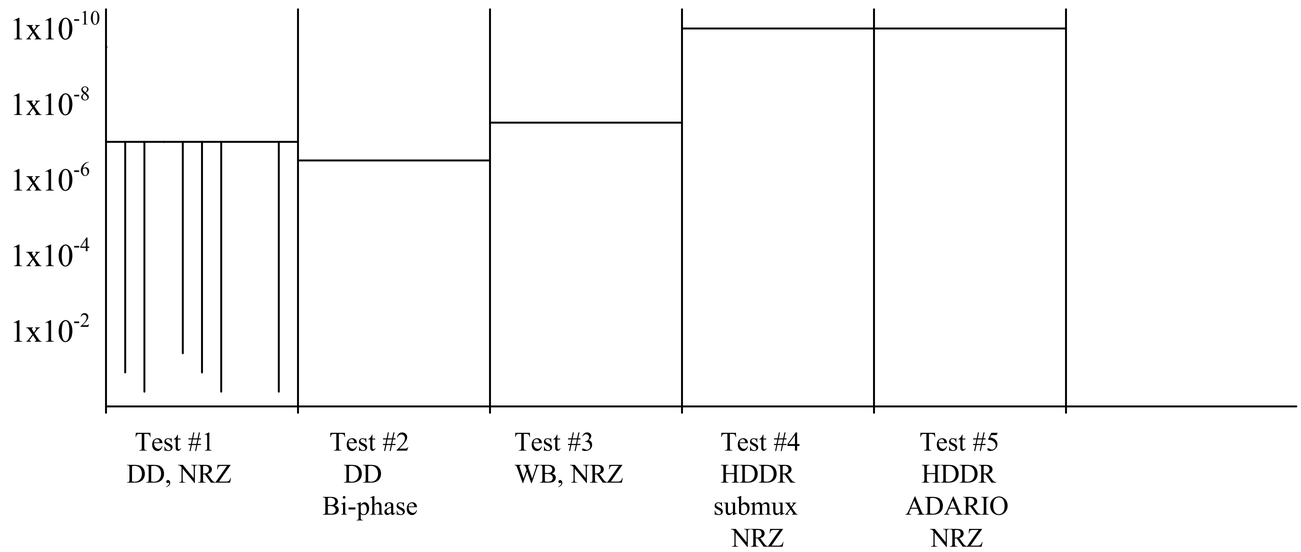

Figure 3: Titan IVB Test Result

Test # 4 was using two different HDDR systems with inputs into channels 1, 2, and 3 of the submultiplexer. Initially, there were one or two bursts of errors during each 3-minute period of recording and reproducing the NRZ-L data, causing the error count to be out of tolerance. This was corrected by using a new tape, which resulted in no errors over the three 3-minute periods.
Test # 5 was a repeat of the previous test, but with the input to the ADARIO multiplexer analog channel 2. The result was still no errors over the three 3-minute periods.

NMD and MSLS Programs. Both of these programs require support of 10 Mbps NRZ telemetry data streams. Tests were conducted on the HDDR systems at VTRS, PPAFS, TAER and the MTRS 2 by recording the 10 Mbps on all 16 channels of the submultiplexer. The test configuration is shown in Figure 4. The data could be recorded and reproduced with no errors introduced by the recording process when a dropout free tape was used. The relative humidity in the test facility was critical in finding dropout free tapes. The bit rate was too high to record on the analog recorders.

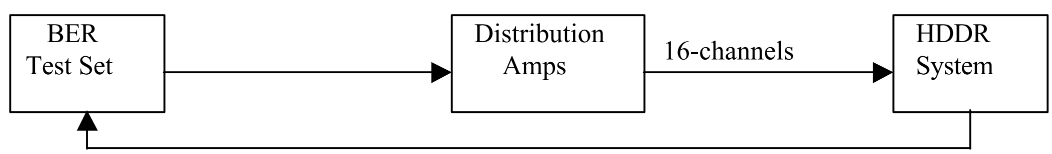

Figure 4: NMD and MSLS Test Configuration

Atlas IIA. Tests were conducted at VTRS to evaluate the capability to record Atlas IIA telemetry data. The requirement is to predetection record the telemetry link containing the I and Q channel PCM data

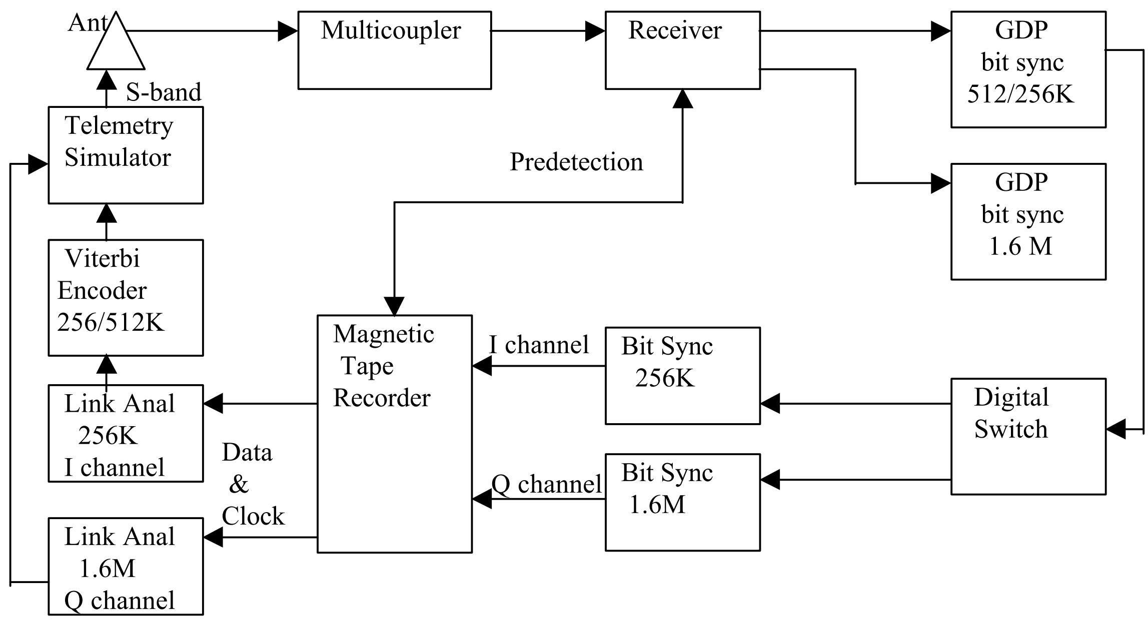

Figure 5: Atlas IIA Test Configuration

on our analog instrumentation magnetic tape recorders at a bit error rate (BER) of $1x10^{-6}$ or better. The I channel is 256 Kbps NRZ that is Viterbi Encoded and the Q channel is 1.6 Mbps NRZ. The I and Q channels are then QPSK modulated onto the S-band carrier. A predetection downconversion frequency of 2.1 MHz was used. The test configuration is shown in Figure 5.

Both the wideband and double density instrumentation magnetic tape recorders were tested, along with the HDDR system. In addition to predetection, the post-detection capability was evaluated by recording the outputs of the I and Q channel bit synchronizers.

Test #1 was predetection recording of clean data using the HDDR system with input into the ADARIO multiplexer analog/digital channel #1. The reproduced data was found to be error free. The signal-to-noise ratio (SNR) was then lowered until the Q channel showed a BER of 1×10^{-6} with the recorder in the bypass (e to e) mode. Upon recording and playback, no additional errors were introduced. The SNR was lowered further until the I channel was at an error rate of 1×10^{-6}. This was at a 6 dB lower SNR than the Q channel due to the Viterbi encoding improvement. Upon playback, it was found that the predetection recording process still did not introduce any additional errors.

Test #2 was recording noisy NRZ data, that is noise was added until the Q channel showed a BER of 1×10^{-6} without the recorder in the loop. The I and Q data was post-detection recorded using channels 1 and 2 of the submultiplexer. The recording did not add any errors due to the recording process.

Test #3 was predetection recording of clean data on the Datatape 3700J double density recorder at a tape speed of 120 ips. Although the data from the recorder did not look bad on an oscilloscope, lock of the demodulator in the playback receiver was erratic and the data was not usable. Test #4 was predetection recording of clean data on the Ampex 3030 wideband instrumentation recorder at a tape speed of 120 ips. The results were the same as the double density recorder, with no usable data.

Test #5 was recording clean post-detection data on the double density recorder with the I and Q

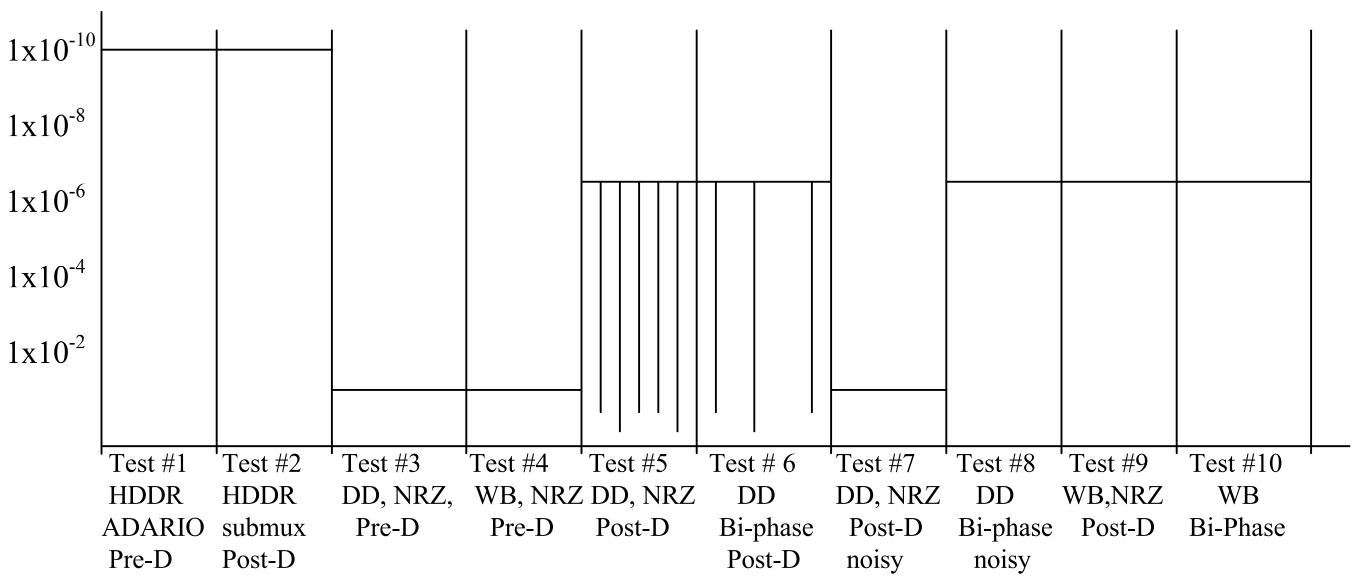

Figure 6: Atlas IIA Test Results

channels on separate recorder tracks. The TTL outputs of NRZ data were recorded from the individual bit synchronizers. Both tracks showed bursts of errors every 5 to 10 seconds due to tape dropouts.

Test #6 was recording clean post-detection data on the double density recorder, but recording the bi-phase I and Q channel outputs of the bit synchronizers. The bursts of errors on both channels occurred less frequently, about every 30 seconds.

Test #7 was recording post-detection data on the double density recorder, but with noise added until the Q channel showed a BER of 1×10^{-6} without the recorder in the loop. When recording and reproducing the NRZ data, both channels had very high error rates and where unusable. Switching to bi-phase resulted in excellent data with no errors introduced by the recording process as seen by the Test # 8 results.

Test #9 and #10 were a repeat of test #7 and test #8, but using the Ampex 3030 Wideband Instrumentation Recorder at 120 ips. The recorder was able to record and reproduce both the NRL and bi-phase data with no errors added by the recording process.

TEST SUMMARY

The Titan IVB 3.277 Mbps telemetry data can be recorded on the HDDR systems without any data errors provided a good tape is used. It was found that the relative humidity in the facility has a big effect on the tapes and is critical to low error rates. A relative humidity from 45 to 60 percent is recommended. Either recording through the submultiplexer or directly on an ADARIO channel provides excellent results. Use of the wideband instrumentation magnetic tape recorders also provided acceptable results.

Post-detection recording of the Titan IVB NRZ data on the double density recorders is not acceptable.
The loss in recorded output level is inversely related to the recorded wavelength, i.e., there is a 55 dB signal loss for every wavelength separation of the tape from the head. Since double density recording is at ½ the wavelength of wideband recording, the effects of tape dropouts are much more severe. The problem is compounded by the recorder head track width of 25 mils for double density verses 50 mils for wideband. Recording the Titan IVB 3.277 Mbps data on the double density recorders in the NRZ format results in several bursts of errors during each 3 minute period that put the error rate above the required $1x10^{-6}$. Using the standard Range procedure of measuring the error rate over each million bit period and accepting occasional error bursts due to tape dropouts indicates that the tape and recorder are performing as expected. Translating the code from NRZ-L to Bi-Phase-L improved the data because the Bi-Phase-L code is less effected by tape dropouts due to a transition each bit period.

The HDDR systems are the only recorders on the Range that can record the 10 Mbps PCM data stream required by the NMD and MSLS programs.

Predetection or post-detection recording of the Atlas IIA data on the HDDR system provides error free data. However, predetection recording on the wideband or double density recorders will not provide usable data. Post-detection recording of the separate I and Q channels of NRZ may provide acceptable results, but is susceptible to tape dropouts. Recording the NRZ data may also be a problem on the analog recorders due to low-end frequency response if long strings of ones or zeros are present in the data stream. Post-detection recording the bi-phase output of the bit synchronizers does provide acceptable data.

CONCLUSIONS

The Range User should be encouraged to use the new HDDR recorders, rather than the analog recorders. If analog recorders are the only systems available for playback by the Range User, then the wideband recorders, rather than double density recorders, should be used. When double density recorders are the only type available, then the NRZ PCM data should be translated to bi-phase for recording, along with a backup recording using the HDDR or wideband systems.

The HDDR systems are the only recorders on the Range that will meet the predetection recording requirement of the Atlas IIA program. Converting to the bi-phase format at the output of the bit synchronizers and post-detection recording the I and Q channels on either the double density or wideband instrumentation recorders is also acceptable. Post-detection recording of the NRZ I and Q channels is not recommended. The HDDR systems are also the only recorders on the Range that will meet the 10 Mbps NMD and MSLS program recording requirements. When using the HDDR systems, the tapes are critical, including the relative humidity at the recording facility.

ACKNOWLEDGMENT

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