AUTOMATIC TESTING OF INSTRUMENTATION MAGNETIC TAPE RECORDER/REPRODUCERS

Kenneth O. Schoeck
Western Space and Missile Center
Range Systems Instrumentation
Telemetry, Bldg. 8500
Vandenberg AFB, CA 93437

George M. Kobylecky
Federal Electric Corporation
P.O. BOX 1886, IC400
Vandenberg, AFB, Ca 93437

ABSTRACT

Over the past few years, small desktop computers have been used more and more to control test equipment in various instrumentation evaluation applications. Computer control not only greatly reduces test time, but provides more consistent results by eliminating variations in individual test techniques.

This paper describes a computerized system at the Western Space and Missile Center (WSMC), Vandenberg AFB, CA designed to automatically conduct IRIG compatible tests of instrumentation magnetic tape recorder/reproducers, analyze and print out the results. The system features remote or manual control of the various recorder types. Tests include harmonic distortion, frequency response, signal-to-noise ratio, flutter, time base error, interchannel time displacement error, intermodulation distortion, crosstalk and slot noise. The first six tests can be run individually or as a complete set designated as a “System” test.

INTRODUCTION

WSMC uses over forty instrumentation magnetic tape recorder/reproducers for telemetry support of launch and various other operations. Several brands of wideband (2 MHz and 4 MHz) recorders in seven and fourteen track configurations are available. During periodic preventive maintenance checks, some recorders or individual tracks require major adjustments, while others require little or none. Also, the technicians use their own favorite method of setting up the recorders, which may or may not conform to IRIG standards or Range policy.

In an effort to speed up these tests and obtain more uniform results, an Automatic Recorder and Data Evaluation System (ARDES) was developed. The ARDES conducts a complete set of recorder tests, prints the results and indicates which parameters are out of

tolerance. The maintenance technicians can then concentrate their efforts on problem areas. Test results are fully documented for review by management. The ARDES also runs certain engineering tests used during recorder acceptance that normally take a long time (interchannel time displacement error, crosstalk and slot noise).

HARDWARE

The hardware required to implement a system of this type includes a desktop computer (32K memory) for controlling the other test equipment and recorders, signal source and measurement devices and a printer or other device for recording the results. A switching matrix and a device for remotely controlling the recorder is also needed.

A function generator is the primary test signal source. A second unit is required for the intermodulation distortion tests. Signal level measurements are made using a spectrum analyzer and automatic synthesizer. Flutter is measured with a flutter meter modified for semi-automatic readings (front controls have to be set manually) and a digital voltmeter (plug-in to counter). A counter is used for time interval measurements.

Transfer of control signals between the controller and the test equipment and digital data from the measurement device to the computer is accomplished via an interface bus conforming to IEEE 488 requirements. Circuitry that interprets the control signals, commands and data on the interface bus is incorporated within the individual test equipment and within a plug-in at the computer end.

SOFTWARE

The ARDES computer programs are stored on a magnetic tape cartridge and are transferred into the computer memory from the tape deck in the controller. There are separate programs for each test (harmonic distortion, frequency response, etc), as well as self test, control, tolerance and initialization programs.

SELF TEST

The self test program internally checks the system and components in the test configuration. Equipment anomalies and indications of possible problems are noted. This program operates independently. All other programs operate through the control program.

CONTROL

The control program prints out recorder test headings, including information inputted by the operator. This includes the date, recorder type and serial number, number of tracks, tape speed and a list of the selected recorder tests to be conducted.

The operator may select either automatic or manual recorder control. In the automatic mode, start, stop, record, rewind, forward and the tape speed are automatically controlled by ARDES. A recorder remote control capability must be available and connected. In the manual mode, the operator is cued when to start the recorder, rewind, etc.

The program asks the operator if there are any tolerance changes. Any tolerance changes apply to the completion of current tests; the standard test tolerances in the tolerance program remain unchanged.

Tests of the instrumentation tape unit commence automatically upon completion of test selection by the operator. The last step performed by the Control program, which is currently stored in computer memory, is to load from the computer magnetic tape the program for the first test selected by the operator. If the system test is selected, the first test in the system test sequence is loaded. Upon completion of the first test, the program for the next test selected is loaded into computer memory. This process continues until all tests selected have been run. The last step of the last test program run loads the Control program back into computer memory. At this point, the operator is given the option of conducting additional tests or ending the program and automatically restoring all equipment to the manual mode of operation.

TOLERANCE

The tolerance limit program is a listing of default tolerance limits. It is accessed by the control program at the start of the test.

INITIALIZATION

The intitialization program provides the operator with reference signals to be used for adjusting bias, record and reproduce levels for specified tracks of the recorder.

The program requests the operator to indicate the desired reference signal(s) (bias, record/reproduce level, or both) and track number, or to indicate completion of the intitialization procedures. “Bias” is an upper bandedge signal and “record/reproduce” level is a one-tenth upper bandedge signal at the selected tape speed. If there is an input error, the input request is repeated. A summary of the operator input requests is printed.

SYSTEM TESTS

After the proper record and reproduce levels are set using the initialization program, a systems test can be conducted. These tests are run per IRIG standards. The equipment is automatically calibrated for each test. The tests are run and the results are printed together with “Out of Tolerance” if such is the case.

The reference signal is a one-tenth upper bandedge sinewave, except the 240 ips flutter and ITDE (all speeds) which use one-twentieth upper bandedge. Hardware is being developed to use one-tenth upper bandedge for flutter measurements at 240 ips.

Since recorder specifications are based on the results obtained by the present IRIG manual measurements, a great deal of time was spent correlating manual and automating readings. Variables effecting the readings were the length of the sample taken, difference is in input and output impedances, filter characteristics and setting times of various pieces of equipment. Tradeoffs had to be made between the optimum correlation of results and the time required to run the test. In the final configuration, a systems test requires about 25 minutes for a 14-track recorder, with recording time of less than 15 minutes. System tests can be completed on one pass of a 9200 foot reel of tape at all speeds but 240 ips. For 240 ips, the operator is cued when to change tapes.

For harmonic distortion, frequency response and signal-to-noise ratio, ten readings of each signal are made for use in determining the results. The ten readings cover a period of approximately 100 milliseconds. This period is independent of tape speed; it depends on specturm analyzer response time, data transfer time and computer program times. For time base error and interchannel time displacement error, the first 40 readings are discarded. The 500 readings are taken for measurement purposes, with 95% (2 - Sigma) comprising the printed results.

HARMONIC DISTORTION

First the test equipment is calibrated at the fundamental, the second harmonic and third harmonic. Then the tape recorder track under test is connected and the system calibration conducted at the fundamental frequency. The signal input is kept at the fundamental and the voltage measurements are made at the second and third harmonics.

When measuring the fundamental for both the equipment and the system calibration, readings that are less than one-half of the nominal input level are disregarded. In the event that 200 of these low readings are encountered in succession, the track number and “NO SIGNAL” are printed out and the program proceeds to the next track to be tested.

FREQUENCY RESPONSE

Test measurements are made at 400 hertz at upper bandedge, and at various frequencies in between that correspond to specific wavelengths. Thus, except for the lowest frequency of 400 hertz, all other frequencies are dependent on the tape speed selected.

An ARDES equipment calibration at all frequencies used in the test is first completed and the results are stored. The test configuration includes the interwiring of the signal source, the tape unit track under test and the voltage measurement instrument. A system calibration of the track is made at the reference frequency, then measurements are made at the vaious frequencies up to and including upper bandedge.

In order to conserve tape, the calibration and measurements are stored and the test process is repeated until all tracks selected have been tested. The tape recorder is then stopped and the results are printed.

The average measurement determined for a particular frequency with the tape unit in the test configuration is corrected by subtracting the ARDES equipment calibration at that frequency. The result obtained for a particular frequency is output relative to the result obtained at the reference frequency.

If insufficient signal (less that .5 Volts rms) is available for measurement at the reference frequency during ARDES equipment calibration, “CALIBRATION ERROR” is printed and an equipment calibration correction of 0 is applied.

If insufficient signal is available for measurement during system calibration for a particular track, the track number is printed after “NO SIGNAL-TRACKS”.

SIGNAL-TO-NOISE RATIO

The ARDES test instruments are calibrated at the reference frequency. Then the first tape unit track to be tested is connected and system calibration for the track is conducted at the reference frequency. A short to instrument ground is applied to the record input under test. The noise voltage output by the track is measured in increments covering the bandwidth of the recorder at the test speed. The individual readings are corrected for instrument calibration and then summed. The noise measurement obtained for the track is corrected for spectrum analyzer characteristics.

For either instrument of system calibration, ten voltage readings are made. For noise measurements, one reading is made for each 8.9 kilohertz of the tape recorder bandwidth at the test speed.

The ten kilohertz bandwidth setting of the spectrum analyzer is equivalent to a noise power bandwidth of 8.9 kilohertz. The voltage measurement in the band is converted to power and summed for all bands measured. The resulting sum is converted back to dB and a correction factor of 2.5 dB is added. (1.05 dB is attributed to envelope detection and 1.45 dB to log shaping).

Readings are made at approximately 100 millisecond intervals. The number of readings taken is proportional to tape unit bandwidth; thus, the test time is proportional to tape speed. The average tape sampling time per reading is less than ten milliseconds.

FLUTTER

The flutter test requires that the operator set up the flutter meter as instructed on the computer's printer. The electrical zero of the flutter meter is determined for correction of flutter measurements. The tape unit is connected into the system in the record/playback mode and flutter is measured for two selected tracks.

In the system test, an odd and an even track near the center of the tape head are tested. When run individually, the operator selects the two tracks. The flutter unit output that is used for measurements is the internal input to the unit's meter. This output, under computer control is digitized by the digital voltmeter plug-in to the counter. The counter serves as the controlling interface for command and data transfer; the flutter unit does no have a computer interface.

For the determination of the electrical zero of the flutter meter, 50 readings are taken with no input to the flutter unit. The average of these readings is stored as the electrical zero correction. With the tape unit in the record/reproduce mode, the test signal is recorded on the first test track and the reproduced output is verified and connected to the flutter unit input. The DVM is set to read and twenty seconds are allowed for flutter meter settling. Thirty readings are discarded. One hundred additional readings are made. The average (2 - Sigma) of these readings, after correction for electrical zero, is the flutter measurement. The printed output includes the two tracks tested, the flutter in % measured for each track, and "Out of Tolerance" when this condition applies.

TIME BASE ERROR (TBE)

Time base error for one odd and one even track is measured. In the system test, tracks four and five of a seven track or tracks seven and eight of a fourteen track tape recorder are tested; otherwise, an odd and an even track selected by the test conductor are tested. The tape unit's record reference signal is recorded on the first track tested. The tape is rewound to the test starting point. On playback in the tape mode, the tape signal is connected to the

A input of the frequency counter; it is also connected into the reproduce reference of the tape unit. The record reference, whether originating in the tape unit or ARDES, is routed to the B input of the counter. The time interval between the two signals is measured. This is used in calculating the time base error.

The printed outputs of the TBE program are the track number tested, the TBE in microseconds and the maximum and minimum time intervals measured and used. Results for two tracks are printed out. If any result is not within specified tolerance limits, “Out of Tolerance” is also printed.

INTERCHANNEL TIME DISPLACEMENT ERROR (ITDE).

The frequency of the signal used to measure ITDE is ten kilohertz at tape speed(s) of 15 inches per second and S ÷ 1.2 kilohertz at othe speeds. This signal is simultaneously recorded on the outside tracks of the odd head stack. The tape is rewound to the starting point and then played back. The time displacement between the zero crossing of the signal on one track and the same point on the other track is read repeatedly on a counter capable of measuring time interval. These readings are used to determine the ITDE. The process is repeated for the outside tracks of the even head stack.

The printed output of the ITDE program includes the test frequency, the tracks tested and the ITDE in microseconds. Results for odd outside and even outside tracks, together with “Out of Tolerance”, if applicable, are printed.

INTERMODULATION DISTORTION (IMD)

Intermodulation distortion is not part of the systems test, but may be called up by the operator. It is run per IRIG standards. The IMD test is run in the record/reproduce mode. A signal at a frequency of ten percent of upper bandedge for the selected speed is used as the reference. The system is first calibrated at the reference frequency. Then a signal at .45 of the reference frequency is resistively mixed with another signal of the same level but at a frequency of .55 of the reference. Measurements of the reproduced output signal are made at frequencies of .1, .35, .65 and .9 of the reference. The outputs of the two function generators are fed to respective 75 ohm resistors and then to the record bus. The spectrum analyzer is set at the frequencies, in turn, at which intermodulation levels are measured. Thirty voltage readings are taken and discarded. Ten additional voltage readings are made. The highest of the last ten readings is used in calculating intermodulation distortion.

The printed output of the IMD test program includes the track number, the two test frequencies used and the distortion measured at frequencies corresponding to five different combinations of the two test frequencies.

CROSSTALK

Crosstalk is called up individually by the operator. It is run per IRIG Standards at two kilohertz and upper bandedge. Each track is first calibrated at two kilohertz and at the upper bandedge frequency relative to the response at ten percent of the upper bandedge frequency. This calibration is performed in the record/reproduce mode. For tracks tested, a two kilohertz signal is recorded at the same level as used for calibration (one volt rms). This is repeated for a signal at upper bandedge.

The tape is rewound beyond the point at which the two kilohertz test signal was recorded. The tape is moved forward in the reproduce mode. When the two kilohertz signal on the track tested is detected, the highest output of every other track is measured at two kilohertz. The process is repeated for the upper bandedge. When the test process is completed for all tracks, the tape recorder is stopped and the results are printed out. The program then proceeds to the next test requested or to control. For each calibration, ten voltage readings are made. For crosstalk measurements, ten voltage readings are made at two kHz and at upper bandedge for each track. Each reading takes less than 100 milliseconds. Approximately 1000 milliseconds of tape time is used for the ten samples used in determining results.

The printed output of the crosstalk program is the reference track number and the crosstalk measurement obtained for each other track at two kHz and upper bandedge. This result is in dB down from the signals recorded on the reference tracks. “Out of Tolerance” is printed if such is the case.

SLOT NOISE

Slot noise is called up individually by the operator. The program measures the noise in a slot that corresponds to a bandwidth of one kilohertz. Beside track selection, the test conductor must select one of four different options: (a) all slots starting at a counter frequency of five kilohertz and ending at the upper bandedge; (b) slots centered at frequencies (maximum of 50) selected by the operator; (c) all slots (5 kHz to upper bandedge center frequencies) in which the noise measured exceeds a limit that is specified for the test; and (d) a combination of b and c.

The computer program utilized is divided into three segments. The first part described above handles the requests to and inputs from the operator. If the all slot option A is selected, the second part of the program is loaded; if not, the third part of the program is loaded.

For all options, a system calibration is made for the track tested. This serves as the reference. The input to the track is shorted and output noise voltages are read for all slots between five kilohertz and upper bandedge or one megahertz, whichever is less. The tape recorder is then stopped. The synthesizer is set to make 1000 steps of one kilohertz, 500 each side of 505 kilohertz. The analyzer is set for a one kilohertz bandwidth. The synthesizer is then set to start a single sweep. The voltage is read on the analyzer at five kilohertz, the synthesizer steps one kilohertz and sets the center frequency of the analyzer at six kilohertz. The process continues until all of the noise measurements required in the current pass are completed. If more than one pass is required, the center frequency of the synthesizer is increased one megahertz for each succeeding pass.

Noise measurements are made as in the first pass except that the starting frequency is altered by one megahertz. For calibration, an input signal level of one volt rms into 75 ohms is utilized. For noise measurements, the input is shorted to ground.

The output for option A is the center frequency and the relative noise level measured for each one kilohertz slot starting at five kilohertz and ending at upper bandedge. The option B output consists of the center frequencies specified by the operator and the relative noise level measured in the respective one kilohertz slot. In option C, only those center frequencies at which the relative slot noise level exceeds a limit set by the test conductor and output together with the noise measured. Of the frequencies specified in option D, only those for which the relative noise level exceeds the specified limit are printed.

SUMMARY AND CONCLUSIONS

ARDES has been developed as a tool for conducting recorder preventive maintenance and acceptance tests. Further refinements are being made to follow-on systems, such as completely automating the flutter tests and shorting test times. For example, a signal-to-noise ratio measurement across the recorder bandwidth is taken instead of sweeping across the frequency band and summing the results. Test time for specific measurements have to be increased in some cases when dealing with various manufacturers recorders due to the dynamics of tape movement to insure sampling data over the correct interval on tape. Trouble-shooting programs are also being developed to allow variations in the test parameters, automatic repeat of tests, etc.

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