AN AUTOMATED TESTING SYSTEM FOR A TELEMETRY TRACKING SYSTEM

TED A. MARSH
INSTRUMENTATION DIRECTORATE
WHITE SANDS MISSILE RANGE, NM

ABSTRACT

White Sands Missile Range (WSMR) has developed an Advanced Transportable Telemetry Acquisition System (TTAS-A) which utilizes a dedicated computer system for antenna control. The Automated Testing System (ATS), an integral part of this system, is the subject of this paper.

The ATS consists of hardware and software designed to provide fully automated testing of the radio frequency (RF) and servo subsystems for validation purposes. The RF subsystem tests are designed to evaluate, measure, and display RF performance parameters such as receiving system Figure of Merit and RF system sensitivity. The servo subsystem tests are designed to evaluate and display the stability and response characteristics of the servo subsystem. Tests are accessed via a keyboard, and extensive use of menus makes the software easy to learn and use. The test equipment is controlled entirely by the computer, and hard copies of all test results are available on the system printer.

INTRODUCTION

The requirement for an ATS was developed over a number of years as a result of special operational scenarios and the concern over whether the WSMR TTAS's can accommodate those scenarios. Tracking numerous targets, in an environment that requires frequent movement and setup, dictated the need for an ATS for validation. A series of tests have been designed to evaluate the performance of the TTAS-A's RF and servo subsystems.

The RF subsystem tests are designed to evaluate and measure the design parameters required to satisfy the operational requirements of the TTAS-A. These tests consist of measurements of RF system sensitivity, receiving system Figure of Merit, receiving system gain characteristics and Tracking Error Gradient. Additionally, an antenna pattern test can be performed to determine the feed/antenna geometry and to ensure the Focal Length/Diameter (F/D) ratio has not changed due to transport of the TTAS-A.

The servo subsystem tests are designed to determine the stability and response characteristics of the servo system. The tests include constant velocity, constant acceleration, small and large step response and tachometer gradient test.

DESIGN CRITERIA

The ATS was designed to provide fully automated testing with as little operator intervention or input as possible. The following discussion covers the design criteria for the software and hardware aspects of the ATS.

The software was to be easy to use and understand, with extensive use of menus and prompts so that even a first-time user would be able to execute tests with little or no training. Test results were to be plotted graphically, or displayed in tabular form on the video monitor, with a hard copy option to print data or plots on the system printer.

The time each test takes to run was to be minimized without jeopardizing the integrity of the test. If a setup parameter could be set by software rather than input by an operator, it should be set by software to reduce the risk of erroneous data entry and to speed up the test. Any positioning of the antenna during the course of a test was to be under computer control.

The hardware, to be fully remote-controllable by the computer, consists of the RF test equipment (sweep oscillator, power meter, and frequency counter), telemetry receivers, the Signal Distribution Panel (SDP) which routes the RF and IF signals through the test system, the video monitor, and the system printer. The equipment was to be controlled either by the IEEE-488 parallel interface bus (also called the GPIB, General Purpose Interface Bus) or by a serial interface bus.

DESIGN IMPLEMENTATION

The test equipment used in the ATS has IEEE-488 capability and is fully remote-controllable from the GPIB. Figure 1 shows a simplified block diagram of the ATS hardware configuration. The Hewlett Packard model 8350B sweep oscillator was selected as a signal source because of its high rate modulation capability, a factor which may become critical in future requirements. The power meter being used is a Boonton model 4200 and the frequency counter is a Hewlett Packard model 5343A. The ATS also controls two Microdyne 1200 telemetry receivers through the GPIB.

The SDP was built in-house specifically for use in the TTAS-A. The SDP's function is to route RF and IF signals from the test equipment to the antenna feed or to the test equipment from the RF System. The SDP eliminates the need for manual patching, by automatically routing the RF signal to the appropriate piece of test equipment, according to which test is being conducted. A signal flow diagram of the SDP is shown in figure 2, and table I contains the SDP component list. The SDP is controlled by the computer using a relay board which routes the 28-volt source to the on-board switches and attenuators.

Table I. SDP COMPONENT LIST

AT1, AT2:	Programmable Attenuators
PS1:	28V dc Power Supply
DC1:	Directional Coupler
HY1 - HY3:	Hybrid Signal Dividers
J1 - J8:	N-type Connectors
MT1, MT2:	Power Sensors
RY1 - RY5:	Relay Switches
SW:	Power Switch
TB1, TB2:	Terminal Boards

The TTAS-A's test line cables were then measured to account for the line losses in the test system. These line losses were entered into a file to be accessed by the ATS software when certain tests are run. The effects of the test cables are factored out in calculations to ensure that only the RF system is tested.

The ATS software was developed in C language, using the National Instruments (NI) GPIB-1014P GPIB board. Software development began with the GPIB drivers, which interface the test equipment to the GPIB board. NI provided C language drivers which performed the basic input and output functions associated with the interface bus. This software is being used with some modifications. The in-house developed GPIB drivers constitute an interfacing medium between the ATS software and the specific items of test equipment. They accept a high level GPIB command and translate it to be compatible with the GPIB board. The GPIB board then relays the message to the appropriate pieces of test equipment, each of which has its own control protocol.

The ATS programs, which actually run the RF and servo system tests, were then developed based on the functional requirements. The tests were developed in a modular fashion as much as possible in order to aid in debugging and to allow for repeated use of functions among programs. The graphics software interfaces with the

ATS software through the data files generated by the individual ATS tests. After a test is run and the data has been acquired and reduced, the data, along with pertinent information such as date and time, is placed on data files on the system's ram disk. The ATS program then calls the appropriate graphics program, which accesses the new data, and plots or prints the data. Additionally, the graphics programs can access the data directly (without running the actual test) if data from a previously executed test exists in the appropriate ram disk data file. The graphics routine displays the most recent data taken by a test, regardless of when that test was performed.

ATS TESTS

The ATS tests were designed to have as much standardization as possible from test to test. For example, extensive use was made of functions or modules which could be used by more than one test, similar menu structures, and similar initializing routines. This modular approach was helpful in keeping the software easier to read and manage. The common features of the ATS tests will be discussed now, and specific discussions of individual tests will follow.

The ATS tests are accessed by the operator from the ATS main menu. The operator can select either RF tests or Servo tests, and the resulting submenus are summarized in table II.

Table II. ATS TESTS

RF TESTS	SERVO TESTS
SUN TRACKING	STEP RESPONSE
ANTENNA	CONSTANT VELOCITY
TRACKING ERROR	CONSTANT ACCELERATION
NOISE FLOOR	TACHOMETER GRADIENT
GAIN/SYSTEM	
SWEPT FREQ/AMPLITUDE	

From the submenus the individual tests can be selected, at which time the system goes into an initialization phase. During this phase, the computer checks to insure that the pedestal has been unstowed and that pedestal power has been applied. If either has not been accomplished the computer gives the operator a message to check the stow pins or the pedestal power switch. The computer then puts the antenna in the center of the cable wrap in order to avoid driving the antenna into an azimuth limit during testing. This is the extent of the initialization procedure for the Servo tests.

During the execution of the RF tests, the initialization procedure is extended to include selection of RF system polarization for the test being run, selection of bore site to be used (if appropriate), selection of receiver frequency and IF bandwidth being used, and an inquiry of test equipment which will be used by the test being run. If the test equipment needed for the selected test does not respond to the inquiry, the operator is informed as to which item(s) of test equipment is not responding, and the test is aborted.

A feature which is common to most of the RF tests is the verification of the presence of a signal source before the autotrack mode of operation is selected. To accomplish this, the antenna is commanded to a point in the quiet sky (no signal source within 30 degrees), whereupon a signal strength reading from the telemetry receiver is recorded. The antenna is then commanded to point at the signal source, whereupon the signal strength is compared to the quiet sky signal strength reading. If the signal source reading is not at least 3 dB higher than the quiet sky reading, the operator is alerted, and the test is aborted. This check prevents the antenna from going into autotrack on a source which either has not been turned on, or has been erroneously designated as a source by the operator.

Another feature used by some RF tests is the sun position verification, which utilizes a routine to calculate the look angles to the sun using the date, time, and antenna position (stored in nonvolatile RAM in the computer). The sun position angles are tested to ensure that they are within the limits, to allow both valid measurements and antenna movement. Specifically, if the sun angle is not at least 30 degrees above the horizon, the operator is alerted that test results may not be valid and is given the choice to continue or abort the test. If the sun angle is above 85 degrees, which is the upper elevation limit of antenna, the test is aborted and the operator is instructed to wait for a lower sun angle. If the sun angle is below the horizon, the operator is instructed to wait for the sun to rise before attempting to track it.

TEST DESCRIPTIONS

Sun Track Test

The Sun Track test autotracks the sun and compares actual antenna angles with calculated pointing angles to the sun. The purpose of the Sun Track Test is to verify that the Autotrack tracking mode is operational in all three servo bandwidths. The test also yields standard deviation measurements for each bandwidth of the azimuth and elevation position angles during the sun track, which can be indicative of a degradation in the system.

Noise Floor Measurement

The Noise Floor Measurement test measures the system noise floor and calculates the RF System sensitivity for any receiver IF bandwidth required for mission support. The test also allows the operator to set threshold levels for the Antenna Control Unit, and to perform a strip chart calibration on the RF system.

Swept Frequency vs. Amplitude Test

This test measures and plots the amplitude response of the system's RF channels for any frequency range input by the operator. The Swept Frequency vs. Amplitude Test is designed to establish and periodically verify the overall System Gain for all RF bands used by the system. The preselector filters and triplexers are also tested to ensure they are providing adequate isolation for each band.

Antenna Pattern Test

This test plots the antenna pattern of the TTAS-A by stepping the antenna plus-and-minus 15 degrees across a bore site. The Antenna Pattern test is designed to graphically display the response of the feed/antenna. The test can be used to validate the system response and overall reliability during premission setup. An example plot of the Antenna Pattern test is shown in figure 3.

Tracking Error Gradient

The Tracking Error Gradient test determines the error gradient of the feed and the tracking error demodulator. The test can be run in azimuth only, elevation only, or both for either right or left circular polarizations.

Gain/System Temperature Test

The purpose of the Gain/System Temperature (G/T) test is to determine the TTAS-A's Figure of Merit. The information derived from this test establishes the RF system sensitivity, system noise figure, system temperature and antenna gain. The procedure used for the G/T measurement and subsequent calculations closely follows that set forth in IRIG Document 118-89, Test Methods for Telemetry Systems and Subsystems, under the Solar Calibration using Linear Receiver Method test. An example of the G/T test results can be seen in figure 4.

Servo Step Response Test

This test steps the antenna either 1 degree (small step) or 5 degrees (large step) and plots position vs. time. The purpose of the small Servo Step Response test is to determine the relative stability in the linear response region of the servo system. The small and large step tests determine the maximum overshoot, the rise time and the settling time of the system. The large step response can also be used to determine the maximum angular velocity and acceleration for each bandwidth in both azimuth and elevation.

Servo Constant Velocity Test

This test moves the antenna at a constant velocity and plots error vs. time. The purpose of the Constant Velocity test is to determine the relative stability and the error overshoot of the servo system. The test is also used to verify that the error overshoot does not exceed the beamwidth of the antenna. The test can be run in each servo bandwidth in both azimuth and elevation.

Servo Constant Acceleration Test

This test moves the antenna at a constant acceleration and plots error vs. time. The purpose of the Constant Acceleration test is to determine the relative stability and the acceleration constant (K_a) of the servo system. The test determines the steady state position error overshoot, the rise time and the settling time of the system. The test can be used to verify that the error overshoot does not exceed the beamwidth of the antenna for each servo bandwidth, in both azimuth and elevation. See figure 5 for an example of the test results.

Tachometer Gradient Test

This test drives the antenna at several constant velocities and simultaneously measures the tachometer output to verify that the tachometer output is linear with respect to angular velocity.

CONCLUSION

The use of automated testing in telemetry antenna systems has proven to be an effective performance verification, troubleshooting and maintenance tool. The automated tests provided for the TTAS-A have been designed to: Require little or no setup time, Be simple to run, and Require as little operator input and intervention as possible. As a result the ATS provides the operator with an efficient, quick, accurate, and repeatable method of diagnosing and evaluating both general and specific characteristics of the TTAS-A's RF and servo subsystems.

ACKNOWLEDGEMENTS

The author would like to acknowledge the members of the team which developed the Advanced TTAS: Phillip D. Sharp, Henry B. Stephenson, Marcelo V. Rosales, James E. Tillett, Michael J. Hart, James W. Cutler, Daniel C. Bissell, Vaughn L. Bourget, and Moises Pedroza. Thanks to Helene Essary for her editorial assistance.

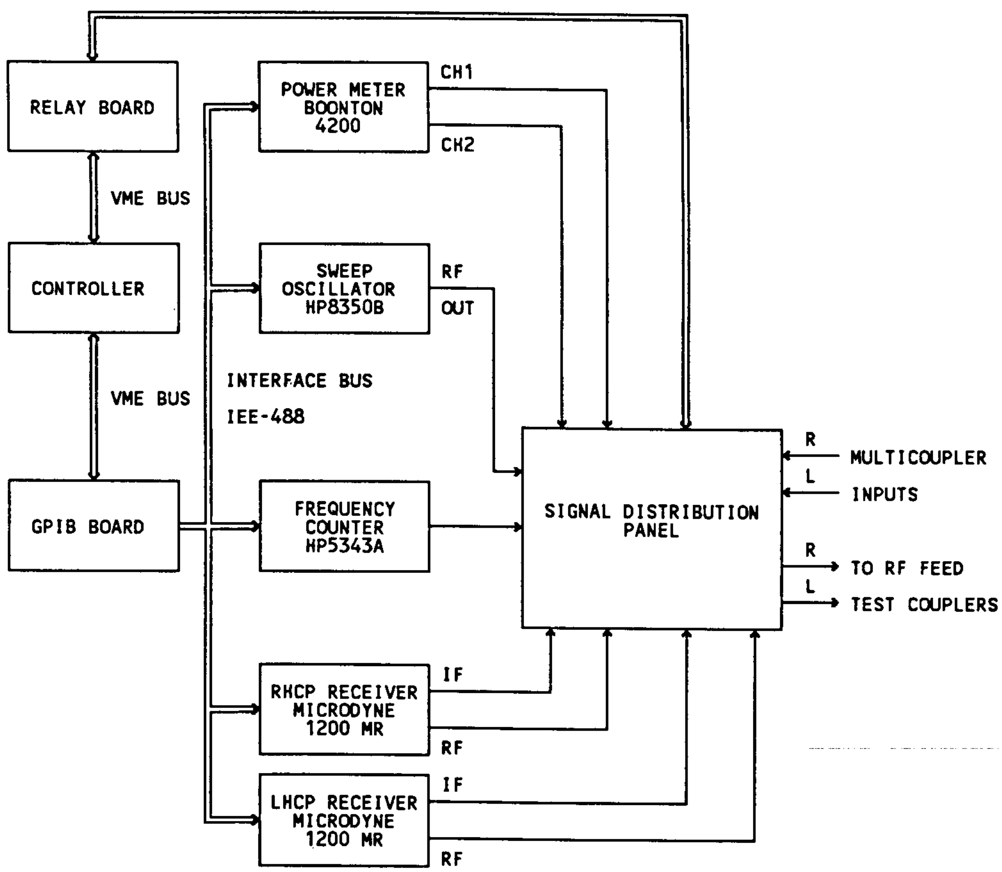

Figure 1. ATS Simplified Block Diagram.

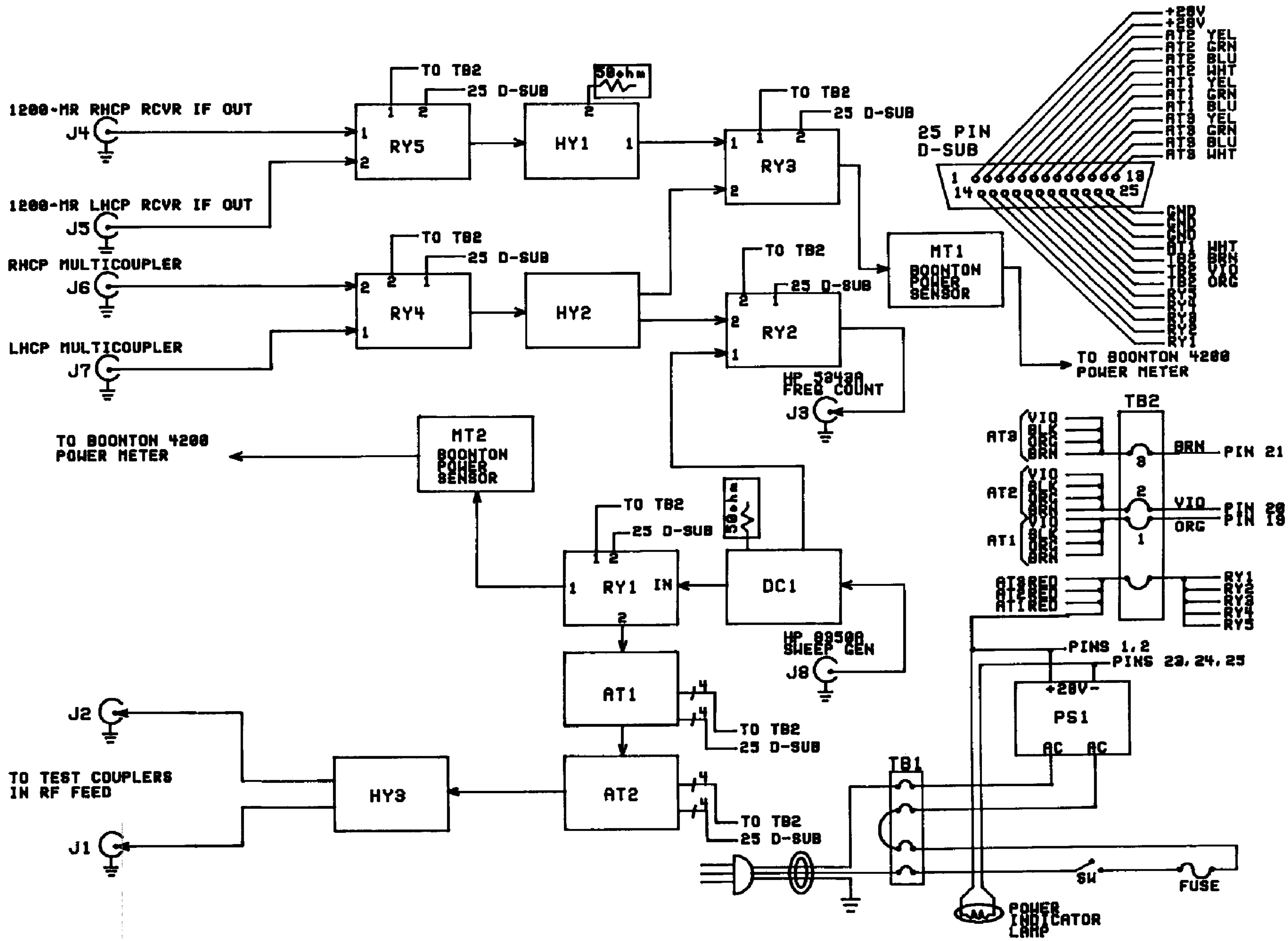

Figure 2. Signal Distribution Panel Signal Flow Diagram.

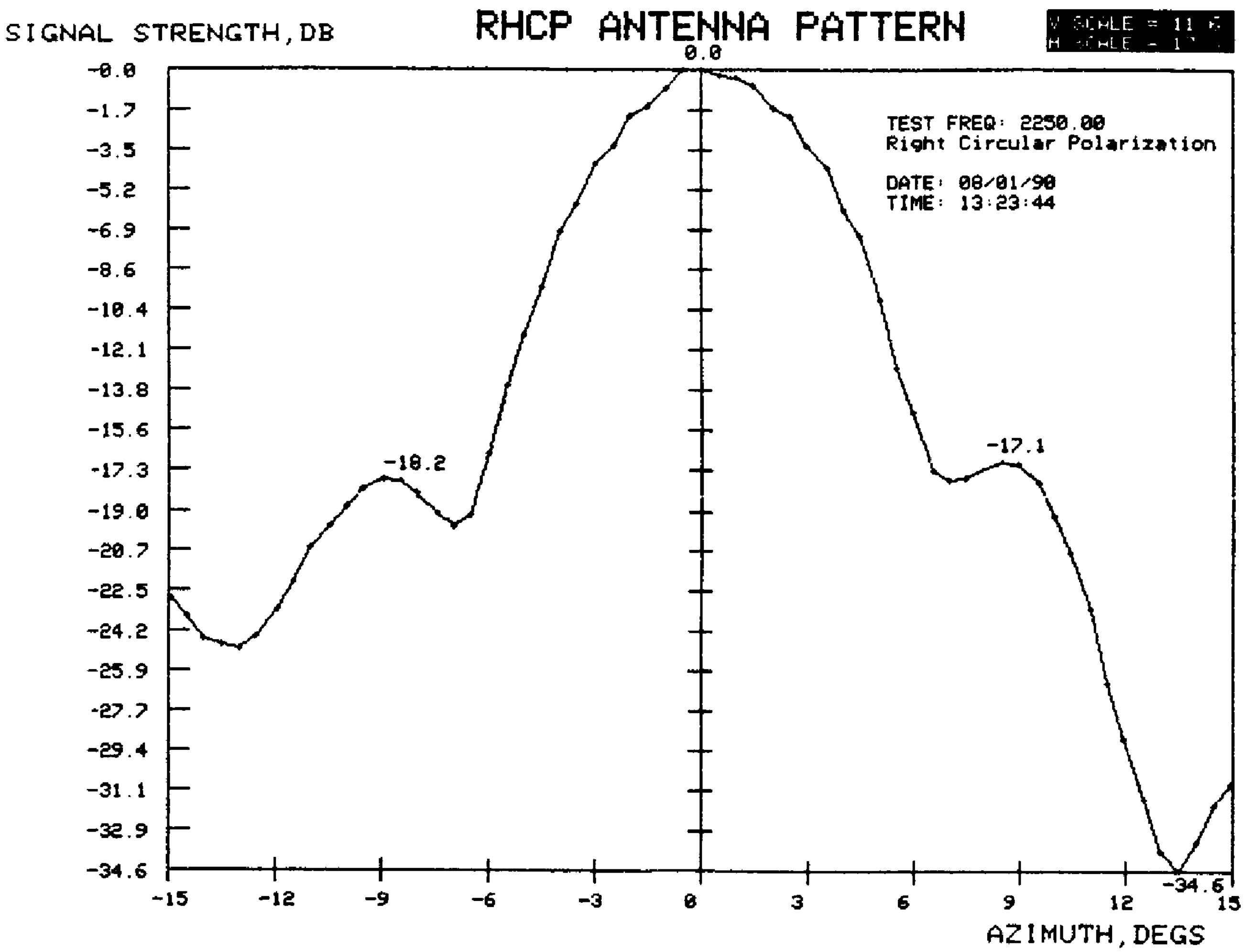

Figure 3. Antenna Pattern Test Results.

SYSTEM CALIBRATION

POLARIZATION:	LCP
G/T:	8.75 DB/DEG K
Y-FACTOR:	9.24
SOLAR FLUX:	192.54 FLUX UNITS
SYSTEM SENSITIVITY:	-117.15 DBM
SYSTEM TEMPERATURE:	279.27 DEG K
ANTENNA GAIN:	33.21 DBI
IF BANDWIDTH:	0.50 MHZ
TEST FREQUENCY:	2250.0 MHZ

Figure 4. Gain/System Temperature Test Results.

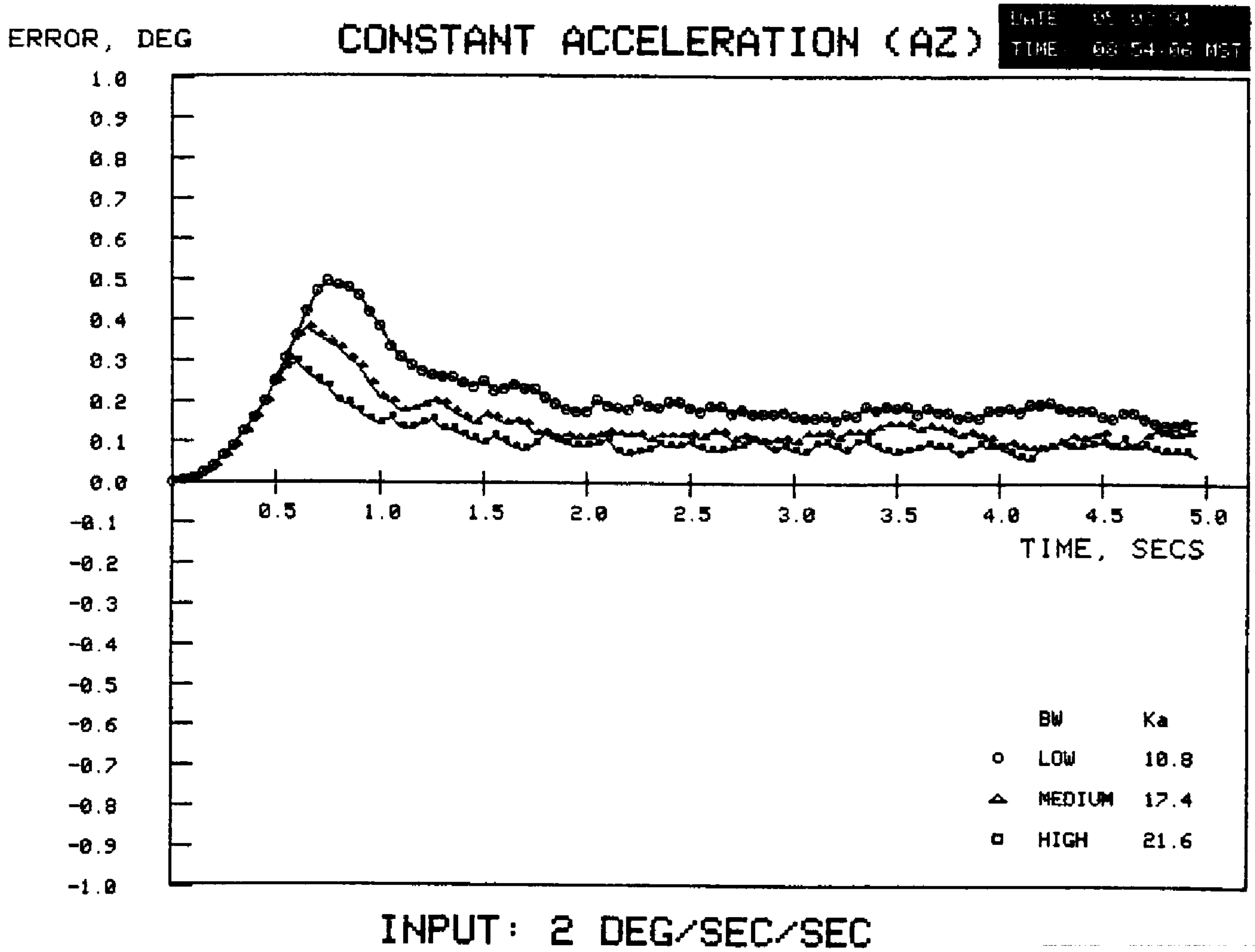

Figure 5. Constant Acceleration Test Results.