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SHUTTLE ORBITER KU-BAND RADAR/COMMUNICATIONS SYSTEM DESIGN EVALUATION

DELIVERABLE TEST EQUIPMENT EVALUATION

Contract No. NAS 9-15795B

Task #3 Interim Report
(JSC Technical Monitor: E. B. Walters)

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1.0 INTRODUCTION

As per NASA Contract NAS 9-15795, Task 3, this report reviews and evaluates the Hughes Aircraft Company's Ku-band test equipment which will be delivered to both the Avionic Development Laboratory (ADL) and the Electronic System Test Laboratory (ESTL). This test equipment was previously known as the Deliverable Test Equipment (DTE); however, the present nomenclature is the Deliverable System Test Equipment (DSTE).

The DSTE is capable of performing system level developmental testing of the Ku-Band Integrated Radar and Communications Equipment and is functionally organized into LRU test panels similar to the Ku-band system with the addition of · microcomputer system, a Ku-band signal conditioner, power control panel and general-purpose test equipment. Figure 1 is a functional block diagram of the DSTE.

The Hughes test philosophy entailed a cost-effective approach wherein the LRU test equipment would be readily adapted for use in the DSTE. Three individual panels, the EA-1 LRU, the EA-2 LRU and the SPA LRU test panel, were developed and are being used as the primary signal sources and signal detection circuits for the respective LRU's. Upon completion of the EA-1, EA-2 and SPA LRU testing, the three LRU test panels were integrated into a console to form the basis of the DSTE.

While the DSTE is capable of operating in an RF link mode where radiation is coupled between the Ku-band system antenna and a simulated TDRS satellite, the more typical operational mode is to use the Ku-band Test Signal Conditioner (TSC). The TSC provides numerous functions but, essentially, the TSC upconverts the simulated forward link data generated by the EA-1 test panel or the simulated radar target return signals generated by the EA-2 test panel to Ku-band frequencies. The upconverted signals are, in turn, injected into the deployed assembly (DA) via RF connectors. Also, the TSC demodulates the return link QSPK or FM signal which is input into the SPA test panel for data comparison and validation.

The DSTE utilizes a power control panel that monitors the voltage and current supplied to the Ku-band system. The power control panel provides protection circuitry to guard against bus reversal, overvoltage and short-circuit conditions, and provides the logic circuitry to perform the power-up/down procedures.

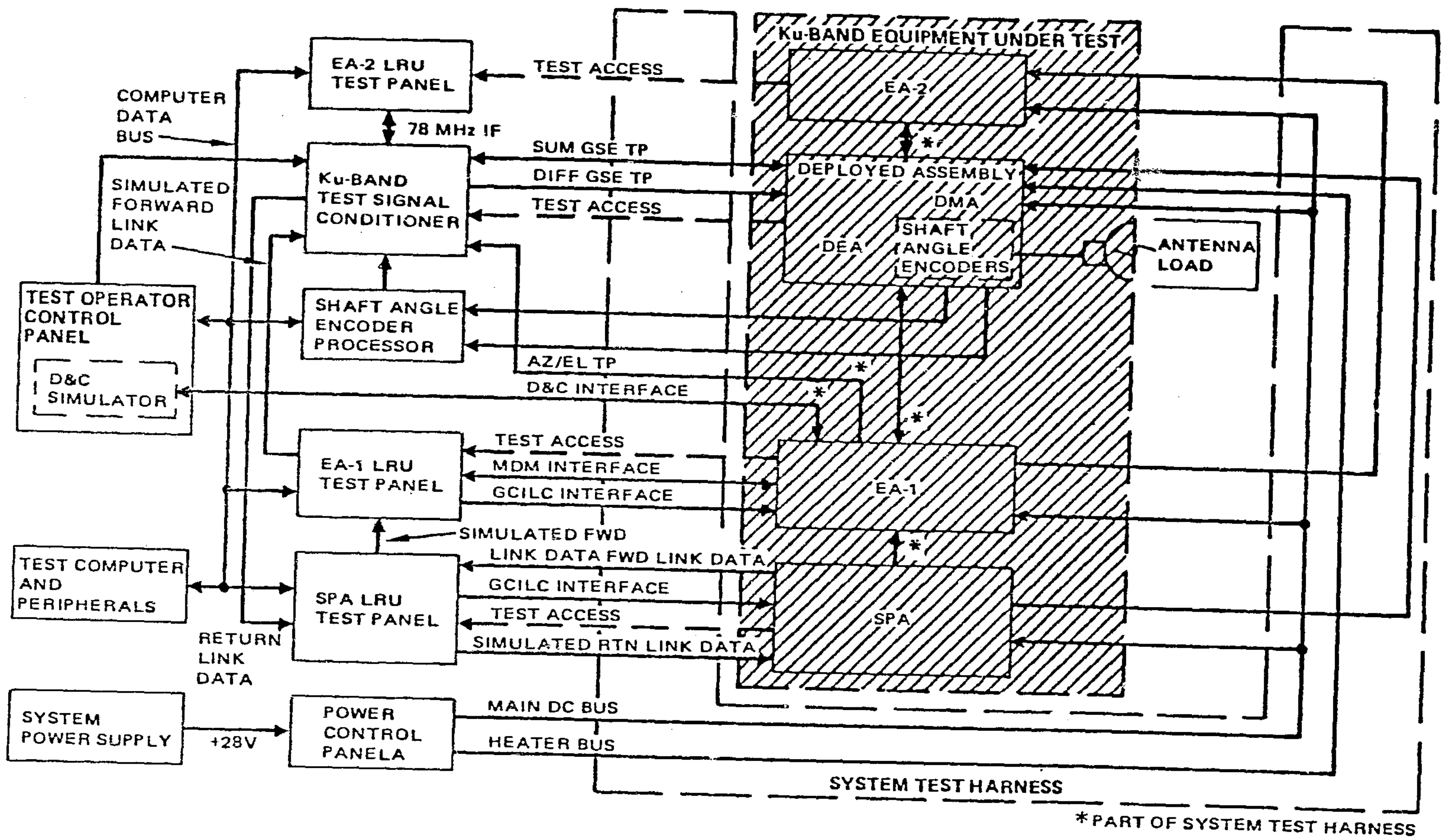

Figure 1. DSTE Functional Block Diagram

The last major features of the DSTE are the test operator interface and the test computer system. The DSTE is basically semiautomatic, with primary control of the test operations by the test operator. The test computer primarily performs the role of monitoring nonreal-time functions, data logging, and management of the Ku-band system operating modes. The test computer system includes a minicomputer, a dual floppy disc system, a hard disc system (ESTL only), a CRT display terminal, a high-speed line printer, and a test control/computer interface panel.

The DSTE was built into a modularized configuration being grouped functionally to minimize intercabling and to facilitate system and LRU level testing. Figure 2 shows the DSTE physical configuration which consists of the following:

(1) A three-and-one-half bay console housing the three LRU test panels (EA-1, EA-2 and SPA), power supplies, the system-unique panels (power control, test operator panel and shaft angle encoder processor), commercial measuring equipment and the test computer system. Note: The ESTL configuration will be a four-bay console so that the hard disc system and additional cooling blowers may be added.

(2) A mobile stand for mounting the DA LRU and housing the TSC panel.

(3) A two-bay, low-boy console with cold plates for mounting the EA-1, EA-2 and SPA LRU's.

(4) A line printer on a stand.

(5) An additional three-bay console for user-supplied commercial test equipment.

Since the DSTE is semiautomated, Hughes generated a number of computer programs to test the Ku-band system. The 14 communications mode tests and the 17 radar mode tests and described in detail in Hughes document TP32090-001, "Subsystem Development Test Procedures for the Ku-Band Integrated Radar/Communications Equipment," dated October 23, 1979. The 31 test modules will be discussed in greater detail later in this report.

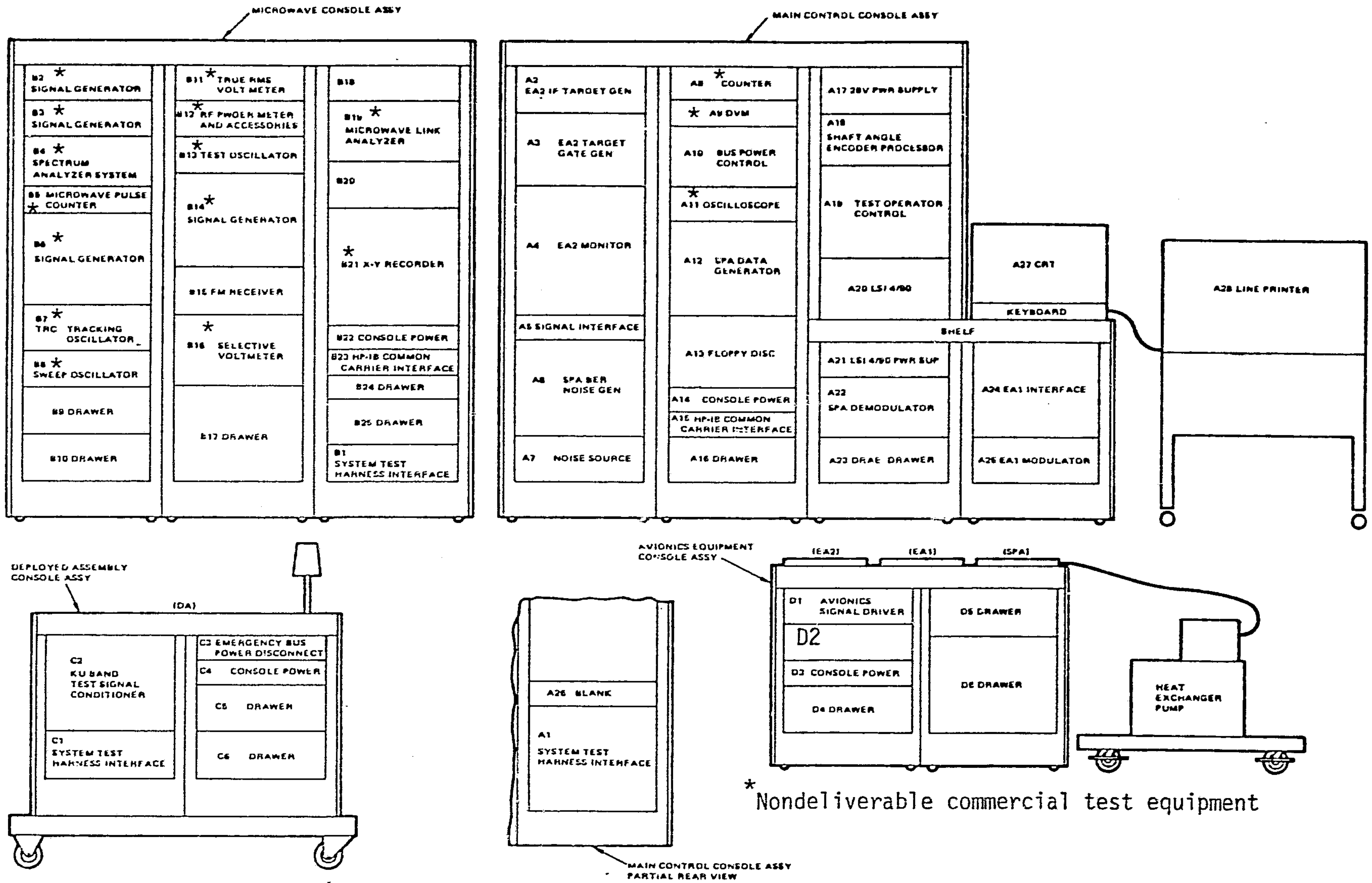

Figure 2. DSTE Configuration

Note: The ESTL DSTE will consist of a four-bay main control assembly so that additional cooling blowers and hard disc system may be added.

2.0 APPROACH

To date, there is no existing document describing the DSTE in detail. So, in order to understand the capabilities, a number of documents were reviewed. First, there is Hughes document HS237-528, "Verification Plan for Ku-Band Integrated Radar and Communications Equipment," dated September 14, 1979. This Hughes document, which is sometimes referred to as "TM01," is a Rockwell contractually required plan that permits Rockwell to evaluate the Hughes method of verifying the Ku-band system requirements. In TM01, a number of system tests are described, and there is a discussion of the system test equipment (STE). The STE is similar to, but not the same as, the DSTE.

Second, there is Hughes document TP32090-001 (previously mentioned) that describes the 31 test modules. This specification will be used in this report to determine the basic capabilities of the DSTE.

Third, Hughes document TP32012-074, "Ku-Band Sell-Off Test Procedure," dated May 19, 1980, is used to sell off the ADL and ESTL DSTE's. This procedure outlines which of the 31 test modules will be used for sell-off.

Fourth, Rockwell document MC409-0025, "Integrated Communications and Radar Equipment, Ku-Band," Rev. B with changes, dated July 21, 1978, is the Ku-band system specification. This document describes in detail all of the system requirements and methods that must be used to verify compliance to the specification.

The basic approach was to generate a matrix to compare the Ku-band system requirements as detailed in the Rockwell specification to the 31 test modules described in TP32090-001. Ideally, the modules should test a majority of the Rockwell system requirements. In this same matrix, the modules used for DSTE sell-off will also be identified.

3.0 FINDINGS

The first task was to determine exactly what each of the 14 communications test modules and the 17 radar test modules actually verify. This was accomplished by reviewing TP32090-001 and TM01.

3.1 Test Module Descriptions

The reader must remember that originally there were no requirements for Hughes to perform system testing. The 31 test modules were intended for system developmental tests only. When system testing was eventually required, these modules were used to test the system, even though they were not initially designed for that task.

3.1.1 Communications Test Module Descriptions

3.1.1.1 Communications power up/down consumption

The Ku-band communications subsystem power up/down sequence will be tested to verify that the subsystem responds properly to the standby and power on modes.

The test begins with the system switched to COMM STDBY from the OFF condition. MDM status bits will be verified for correct mode. In the COMM STDBY mode, the following power will be measured:

(1) Avionics power
(2) DA power
(3) HTR power.

Upon completion of the standby power measurements, the system will then be commanded to COMM ON. The antenna unstowing procedure, along with initialization of the angle designation register, will be verified via the MDM pitch and roll data and the shaft angle encoder data. With the antenna in the unstowed condition, the following power will be measured:

(1) Avionics power
(2) DA power
(3) HTR power.

Upon completion of the power measurement, the antenna stowing procedure will be verified via MDM pitch and roll data and discrete signals (BOOM STOW ENABLE I and II--high). The system will then be commanded off and the avionics and DA currents measured.

3.1.1.2 Communications subsystem slant range

The purpose of this test is to demonstrate the capability of the Ku-band system to acquire and lock on to a TDRS simulated signal.

The test consists of transmitting a 13.775 GHz CW signal from an antenna located atop the south end of Hughes building #355 (Bird House) to the Ku-band system located in the radome-enclosed area in building #358.

The Ku-band system antenna is manually slewed until a maximum reading occurs, indicating that the DA antenna is pointing at the simulated target. The Ku-band antenna is then positioned away from the simulated target, but within the 10° half-cone search angle. Search is initiated in GPC ACQUISITION antenna steering mode, and the Ku-band system capability to acquire and lock up on the simulated target is verified. Search is visually verified by the antenna motion. After the antenna motion has stopped, system status is verified by reading the MDM status.

3.1.1.3 Forward link signal strength test

The objective of this test is to verify the Ku-band communications subsystem capability to provide acceptable conditioned AGC voltage representing communications signal strength.

The Ku-band communications subsystem input signal level will be varied and the corresponding signal strength voltage measured. The signal level will be input at the DA test access connector and the MDM-3 signal strength voltage measured at the signal interface panel.

3.1.1.4 Forward link tracking threshold test

The tracking threshold level for the specified modulation types will be verified for the communications subsystem, as follows:

(1) Unmodulated carrier
(2) Data modulation on the carrier
(3) PN modulation on the carrier
(4) Data and PN modulation on the carrier.

The test starts with the Costas and PN (when PN is present loops tracking a known input signal of sufficient strength to cause lock-on. The signal level will be reduced by 0.5 dB steps and held constant for 60 seconds. The point where each loop loses lock will be recorded (does not apply to the PN loop when PN is absent).

3.1.1.5 Forward link acquisition time test

Acquisition and lock-on time for the Costas loop, PN loop, frame synchronization and data present (lock-on and dropout) are measured for the following classes of forward link input signals:

(1) Unmodulated carrier
(2) Data modulation on the carrier
(3) PN modulation only on the carrier
(4) Data and PN modulation on the carrier.

The forward link acquisition time measurements are made on an electronics counter set for time interval measurement. Unless otherwise specified, each test is repeated 10 times for the high input signal level (upper C/N range) and 100 times for the low input signal level (lower C/N range).

(1) The Costas loop acquisition and lock indication (within 330 ms) after the input signal is applied is measured for all four specified modulation types. Test is performed in mode 1.

(2) The PN loop acquisition and lock indication (within 10 seconds) after the input signal is applied is measured for the PN modulation on carrier and data and PN modulation on carrier modulation types. Test is performed in mode 1.

(3) Frame synchronization acquisition within two seconds after PN acquisition when PN data are present and within two seconds after Costas lock when PN data are not present is measured. Test is performed in mode 1.

(4) The time for the data present signal to go high, within two seconds after PN lock is acquired when PN data are present and within two seconds after Costas lock when PN data are not present, is measured. The test is performed in mode 2 and at rates of 32 kbps and 216 kbps.

(5) The data present signal drop-out time ($\leq$ 11 seconds) for data interrupt on the forward link will be measured. The test is performed in mode 2 and at the 216 kbps rate. The test is repeated 10 times with high input signal rate.

3.1.1.6 Forward link acquisition BER tests

Acceptable BER for the communications forward link input signal levels and output data RMS jitter will be verified.

The bit error for various forward link input signal levels is measured on the electronic counter. Signal detection is verified at the start of each test and the bit error measured at the end of 60 seconds. The test is performed for data modulation on carrier and data and PN modulation on carrier. The mode 1, NSP 1 forward link output data RMS jitter is measured on the electronic counter set for time interval measurement.

3.1.1.7 Functional test (return link)

The return link functional test objectives are as follows:

(1) To verify acceptable signal isolation and correct configuration for return link data channels in response to management commands.

(2) To verify acceptable signal conditioning in response to an asymmetrical HDR clock.

The functional tests will be conducted as follows:

(1) Signal isolation and correct configuration will be verified by injecting 125 kHz square-wave signal into two of the SPA return link data channels while the third or selected data channel is provided with the normal signal. The output signal shall be verified for the selected normal signal and rejection of the nonselected signals. The test will be repeated for all combinations of the return link data channels and selectable data source.

(2) Acceptable signal conditioning in the face of clock asymmetry will be verified by first using an HDR clock with +20% asymmetry and insuring that the HDR bit stream output of the DA does not exceed 10% asymmetry. The test will be repeated for -20% HDR clock asymmetry.

3.1.1.8 BER test (return link)

The communications return link BER test objective is to verify acceptable BER levels for all return link digital channels for normal and abnormal inputs (asymmetrical convolutional encoder clock).

Generally, BER can be determined directly by comparing the bit stream out of the test device to the bit stream fed into the test device and dividing the number of times a bit error occurs (extra bit due to noise or loss of bit due to noise) by the total number of input bits occurring during the time period of observation. However, because the BER for the return link is normally too low to determine directly in a reasonably short time period, a known amount of noise will be injected into the test channel in order to raise the BER.

By measuring the BER corresponding to each of several known levels of noise, then plotting these points, the resulting curve can be extrapolated to obtain the S/N ratio corresponding to a BER of 10^{-6}. This S/N ratio shall not be different from an S/N ratio measured for the calibration configuration by more than a specified amount.

Additionally, the BER test will include measurement of BER for the HDR channel 3, mode 1, clock in response to asymmetry in the convolutional recorder clock signal.

3.1.1.9 Communications mode antenna stow/unstow test

The antenna is deployed to its unstowed position and directed to the zenith, where roll and pitch gimbal encoder angles are verified. The antenna is then directed to the stowed position and the roll and pitch encoders are verified for the gimbal's stowed angular values.

3.1.1.10 Communications mode obscuration zone test

The antenna's obscuration area is verified using values for roll and pitch gimbal angles computed from the data in the obscuration boundary table.

3.1.1.11 Communications mode antenna stability test

The antenna's drift rate in inertial stabilization and the antenna's drift and pointing accuracy in body stabilization are measured. The antenna's angular position is set for different pointing designates and the accuracy is checked. After two minutes at each pointing designate, the antenna's angular position is again read. From this data, the drift rates in inertial stabilization mode and the angular drift in body stabilization mode are computed.

3.1.1.12 Communications mode antenna slew test

The antenna's manual fast and slow slew rates are checked in elevation (up and down directions) and in azimuth (left and right directions). A plot is made to verify the antenna search scan.

The antenna wraparound rate is checked at various beta gimbal positions. The antenna is positioned 5° from the alpha gimbal stop and directed to go to a position 5° on the other side of the alpha gimbal stop. Since the gimbal cannot go through its stop, the gimbal whips around at the super slew rate to the designate angle. This rate is measured to verify that it is within the slew maximum and minimum tolerances.

3.1.1.13 Communications mode target acquisition and track test

The target acquisition and track functions of the antenna servo system are performed to verify angular track accuracy, the main scan TDRS acquisition and track stability requirements, the low signal level TDRS acquisition requirements and the loss in antenna gain during TDRS track. The resultant data is either processed by the test equipment computer or analyzed off-line to determine requirements compliance.

3.1.1.14 Communications antenna scan volume

Proper response to an invalid start scan commanded during GPC DESIG, MANUAL, GPC ACQ and AUTOTRACK antenna steering modes is verified. The operator then selects either the ambient scan volume test or the thermal vacuum scan volume test. These tests use the X-Y plotter to record the antenna scan trajectory for off-line analysis. Parameters to be verified off-line are: number of scan circles, scan volume, 30% scan overlap, scan time, scan dwell time and scan rates. The thermal vacuum scan volume test consists of a search scan at each of four scan centers. The scan centers in (ALPHA, BETA) are (0,0), (45,0), (-75,0) and (0,45). The search cone is 20°. The ambient scan volume test consists of a 20° scan cone.

3.1.2 Radar Test Module Description

3.1.2.1 Radar power up/down consumption

The Ku-band radar subsystem power up/down sequence will be tested to verify that the subsystem responds properly to the standby and power-on modes.

The test begins with the system switched to RADAR STDBY from the OFF condition. MDM status bits will be verified for correct mode. In the RADAR STDBY mode, the following power will be measured: avionics power, DA power and HTR power. Upon completion of the standby power measurements, the system will then be commanded to RADAR ON. The antenna unstowing procedure, along with initialization of the angle designation register, will be verified via the MDM pitch and roll data and the shaft angle encoder data. With the antenna in the unstowed condition, the following power will be measured: avionics power, DA power and HTR power. Upon completion of the power measurement, the antenna stowing procedure will be verified via MDM pitch and roll data and discrete signals (BOOM STOW ENABLE I & II--HIGH) from the system.

The system will then be commanded off and the avionics current and DA current measured.

3.1.2.2 Radar self-test

The radar self-test begins with an invalid start command. The response is noted and is followed by a correct initiation of the self-test mode. The test operator evaluates the response of the D&C displays while the DSTE evaluates the S/T information available at the MDM. The combined evaluations determine the self-test validity.

Available to the operator at his discretion is a printout of all the MDM data that was taken during S/T by the DSTE.

3.1.2.3 Antenna stow/unstow test

The antenna is commanded to execute the stow and unstowing process. Along with visual verification, the stow and unstow angle positions are measured and verified against known values.

3.1.2.4 Antenna obscuration zone test

The obscuration profile for the A side is checked out. The antenna is positioned to seven locations, five of which are in the obscuration area. The scan warn limit indicator on the MDM and D&C outputs are monitored for the correct responses.

3.1.2.5 Antenna stabilization test

This portion consists of several tests. The drift rate in the inertial stabilization mode and the antenna drift while in the Orbiter stabilized mode are measured and verified to be within specification. The slew modes are verified by measuring the antenna slew rate for both fast and slow rates in the azimuth and elevation planes. Finally, the antenna is scanned about the -Z axis in a 12° cone.

3.1.2.6 Radar target track test

This test verifies radar target tracking in both angle-tracking and nonangle-tracking modes. The passive mode is used in both tests.

The Ku-band radar subsystem signal strength indicator is dynamically exercised by varying the input signal level. In addition, the transmitted signal strength indicator is characterized by measuring the response to all three transmitter power settings.

3.1.2.7 Radar antenna scan volume test

Proper response to invalid start scan commanding during GPC DESIGNATE, MANUAL, GPC ACQUISITION and AUTOTRACK antenna steering modes is verified. The operator then selects either the ambient scan volume test or the thermal vacuum scan volume test. These tests use an X-Y plotter to record the antenna scan trajectory for off-line analysis. Parameters to be verified off-line are: number of scan circles, scan volume, 30% scan overlap and scan time of one minute maximum. The thermal vacuum scan volume test consists of five scan cones for each of three scan centers. Scan centers (pitch, roll) are (0,0), (30,30) and (-30,-30). Search cones are approximately 60, 50, 40, 20 and 10°. The ambient scan volume test consists of a 10° scan cone centered at (0,0).

3.1.2.8 Radar waveform test

This test verifies the radar waveform design by measuring the pulse width, PRF, power and frequency management of the transmitted waveforms. These parameters are obtained from 19 operator-selectable tests. These tests are derived from appropriate combinations of GPC DESIGNATE and MANUAL operation in the active or passive modes for both search and track, along with designating the range. A simulated target return is provided to obtain the track waveforms. In addition, the frequencies of the 156 MHz (T.O. reference) and 49.2 MHz (range clock reference) signals are measured.

3.1.2.9 Radar range accuracy test

This test module verifies the radar subsystems's measurement of range in the active and passive modes. Two verification approaches are provided: developmental and acceptance. The developmental approach uses many data samples (1000 nominal, but operator controlled) to determine the statistical mean, variance and three sigma values of the data. These computer-calculated statistical reports are then compared to the system specification values. The acceptance approach uses a single data sample which is compared to the combined random and bias specification values. Fourteen range accuracy tests make up the test module. The tests are configured to verify the radar subsystem's measuring capability through the specified regime of operation.

3.1.2.10 Radar range rate accuracy test

This test module verifies the radar subsystem's measurement of range rate in the active and passive modes. Two verification approaches are provided: developmental and acceptance. The developmental approach uses many data samples (1000 nominal, but operator controlled) to determine the statistical mean, variance and three-sigma values of the data. These computer-calculated statistical reprots are then compared to the system specification values. The acceptance approach uses a single data sample which is compared to the combined random and bias specification values. Twenty-three range rate accuracy tests make up this test module. The tests are configured to verify the radar subsystem's measuring capability through the specified regime of operation.

3.1.2.11 <u>Radar target acquisition test</u>

The radar target acquisition test module contains three test segments: nonscanning acquisition, the sidelobe test and the mainscan acquisition. This test module verifies that the radar subsystem will properly transition from acquisition to target track. A brief description of the three test segments in this module is as follows:

(1) Nonscanning acquisition. This test verifies that the radar system will detect and angle track a target placed within the 3 dB beamwidth. The operator selects the antenna pointing direction, the location of the target relative to the antenna, the mode (active or passive), and whether the target is at short or long range.

The range will determine the settling time of the acquisition loop. The antenna is not scanned during this test.

(2) Sidelobe test. The sidelobe logic of the radar operation is verified. The operator designates the location of the target relative to the antenna boresight. A default position for the target is available and is set to 2.5°.

The test is conducted in the GPC DESIGNATE mode rather than an angle-tracking mode. The nonangle-tracking mode will permit target track (i.e., range and range rate track) but would preclude the antenna servos from nulling out the target position. This enables the radar subsystem to determine that the target is in the sidelobe and provide a steady indication of this status.

(3) Mainscan acquisition. The mainscan acquisition tests the system for target lock-on when the scanning antenna encounters a target within the scan trajectory. The operator designates the scan center location, the target location relative to the scan center, and the scan volume.

There are only 10 scan volumes, and not all scan volumes need be employed; this choice is left to the operator.

Verification of target acquisition leading to track with all related Ku-band system designators (e.g., track, detect status bits) correctly responding will determine test acceptance.

3.1.2.12 Radar moving-target acquisition test

This test consists of a target moving inward toward the scan center as the antenna is scanning. Successful acquisition results in stopping the antenna scan and ending in target track. There are five test profiles that can be selected on the basis of test number, as listed below:

Test No.	Scan Volume (°)	Target Velocity (°/sec)
1	30	0.1
2	25	0.2
3	11	0.3
4	8	0.6
5	6	1.1

In each test, two signal levels maximum or minimum must be designated corresponding to a 1 square meter or 10,000 square meter target. A third quantity must also be given and allows for fine correction of the test signal conditioner panel RF output level. The value is specified in decibels of attenuation. A positive value decreases the signal level whereas a negative value increases it. Specifying 0 dB does not change the programmed levels.

3.1.2.13 Radar recovery time test

The test consists of the Ku-band system locking on to a moving target. Target eclipse takes place for a predetermined time interval; the target then reappears. The test observes whether or not reacquisition occurs.

The four selectable tests are listed below:

Test No.	Loss Time
1	0.1 sec
2	0.2 sec
3	0.3 sec
4	Operator designated

The target is at 12 nm with 1 square meter cross-section and moves normal to the line of sight. In addition to selecting the test number, the operator must specify the following parameters:

CF Correction factor for the RF signal level, given in decibels of attenuation

RB Range bias correction for test equipment, given in feet

V Target loss rate in °/sec; 2 °/sec maximum.

3.1.2.14 Radar gimbal pointing control

The tests involve the Ku-band servo system capability to accurately point the antenna, hold the designated position and verify part of its dynamic response. In all tests, selected test locations are given. The operator has, in most of the tests, the option of designating the test location. The tests are partitioned into three sections and are described as follows:

(1) Gimbal pointing and stabilization test. There are four selectable positions to which the gimbals are designated, with an option for the operator to designate a fifth location. After reaching the designate, the position holding test can be selected in either the body stabilized or inertial stabilized mode. The test positions in the alpha-beta coordinates are:

1. 0, 0
2. 0, 30
3. 0, 60
4. -45, 45
5. Operator designated.

(2) Gimbal slew test. The test consists of measuring gimbal slew rates as the antenna moves between designates. Two types of designates are used. The difference is whether or not the wraparound logic is exercised. Straight slew has operator option of selecting the pointing designates.

(a) Gimbal straight slew test. Test position for alpha and beta (°) are:

Test	Initial Alpha	Initial Beta	Final Alpha	Final Beta
1	0	65	0	0
2	0	-85	0	0
3	Operator supplied			

(b) Gimbal slew test with wraparound logic involved. Wraparound primarily exercises the alpha gimbal with the beta gimbal held constant. Alpha moves from 145° to -205°.

Test No.	Beta (°)
1	0
2	60
3	75
4	-60
5	-85
6	Operator supplied

3.1.2.15 Radar angle track--servo convergence test

The servo convergence test will verify the radar servo loop bandwidth. Several parameters are supplied to define the test.

Test No.	Mode	Bandwidth (Hz)
1	Passive	0.12
2	Passive	0.075
3	Passive	0.027
4	Active	0.075
5	Active	0.027

The test numbers are selected in addition to the following:

CF Correction factor for the RF signal level, given in decibels of attenuation

RB Range bias correction for test equipment, given in feet

V Target LOS rate in °/sec

A,B Antenna location expressed in degrees

AR,BR Target location relative to the antenna, expressed in degrees.

The angle error signals are recorded on a strip chart recorder or equivalent equipment.

3.1.2.16 Radar angle track--dynamic tracking test

There are two major tests. The first measures the Ku-band systems's capability to angle-track a target into the antenna pole locations. The second test verifies the capability of tracking a target accelerating normal to the line-of-sight (LOS). In the second test, the operator has the option of specifying the test parameters in addition to a preselected case.

3.1.2.17 Radar angle track--angle track statistics test

The angle-track statistics test derives statistical angle parameters when the Ku-band system is in radar angle-track. There are two tests, as follows:

(1) Static angle-track. Antenna is positioned at coordinates designated by operator. Angle-track is established. MDM and SAE angle data are collected (500 samples). Mean and 3-sigma values are derived.

(2) Dynamic angle-track. 500 samples of angle rate data from MDM are collected with the Ku-band system tracking a target moving with constant velocity. A baseline velocity of 0.06°/second can be selected. Other rates up to 0.5°/second can be designated by the operator.

3.2 Rockwell Specification versus the DSTE Test Module Matrix

After reviewing the 14 communications and 17 radar test modules, the next task was to compare the module capabilities to the Rockwell specification. Even though this task initially appeared to be straightforward, some problems developed.

The first problem is that TP32090-001 gives very general test descriptions. In the radar tests, for example, the system is initialized to the GPC DESIGNATE mode, but it is not clear whether or not the test module automatically switches to the GPC ACQUISITION mode in the course of the test. In order to determine the answer to this question, it would be necessary to review each software step for every test module. There is no convenient intermediate Hughes document between the software and TP3209-001.

The second problem is that the test modules were generated approximately two years ago, primarily for developmental testing. The modules were not intended to be used to verify system performance.

Because reviewing the software in great detail would be too costly and time-consuming and because the modules are for developmental testing, some interpretation and judgments were used in generating the matrix. While Hughes may take exceptions to the matrix in some areas, Axiomatix feels that the matrix is fairly representative of the test module capabilities.

The matrix is shown in Appendix A but, before discussing it, some explanations are required. The Rockwell specification paragraphs are listed along the left-hand side and the communications or radar tests are listed across the top. Listed along the right-hand side are the verification methods required per the Rockwell specification. Of special interest is the column just to the left of the test module columns which indicates whether or not the test module completely tests a particular Rockwell paragraph.

The reader must be cautioned that, because numerous asterisks appear in the "not completely tested by the development test module" column, this does not mean that requirement never gets tested. It simply means that the test module itself does not completely test the paragraph.

In reviewing the matrix, it is evident that the test modules do not completely verify system performance with respect to the Rockwell specification. It must be noted, however, that the DSTE may be placed in a manual mode.

This manual mode is accomplished by loading the Manual Control Program (MCP) into the computer; now the test operator is allowed to manually key-in test parameters and commands. In conversations with various personnel, it has been stated that, with this manual mode, the DSTE can simulate almost any Ku-band function or operating situation.

Since the test modules were never really intended to be used to verify the entire system performance, the manual mode or, perhaps, additional test modules should be explored in more detail. Unfortunately, at this time, there appears to be no document which fully describes the DSTE capabilities. While the present test modules seem inadequate to fully verify system performance as required per the Rockwell specification, generating new modules or utilizing the MCP so that parameters and commands may be input manually would increase the present DSTE performance capabilities.

3.3 DSTE Sell-Off Procedures

The previously mentioned Hughes document TP32012-074 describes the test modules to be used for DSTE sell-off. There are a number of DSTE check-out tests but, essentially, Hughes is taking the ADL Ku-band system after the LRU's have passed their respective ATP's and connecting the ADL LRU's to the ESTL DSTE. Also, the ESTL LRU's will be connected to the ADL DSTE. The assumption is that, since the LRU's have passed their acceptance tests, if the same results are achieved using the ADL LRU's with the ESTL DSTE and vice-versa, the DSTE's must be functioning properly.

Hughes will be using two of the 14 communications test modules and four of the 17 radar test modules to conduct the DSTE sell-off. The sell-off modules are listed as follows:

1. COMMUNICATIONS MODE

   Forward Link Acquisition Time Test
   Communications Mode Target Acquisition and Track Test

2. RADAR MODE

   Radar Power Up/Down Consumption Test
   Antenna Obscuration Zone Test
   Antenna Stabilization Test
   Radar Target Track Test.

By examining the Rockwell specification versus the DSTE test module matrix, the two communications tests and the four radar tests simply do not exercise the Ku-band system or, for that matter, the DSTE to any great extent. Granted that many of the DSTE components had been used for the LRU ATP's, it is the opinion of Axiomatix that a more extensive sell-off procedure is required.

4.0 CONCLUSIONS/RECOMMENDATIONS

The 31 test modules provide a good cross-section of tests with which to exercise the Ku-band system. However, based on the test modules currently available, the DSTE is very limited when being used to verify the Ku-band system performance as per the Rockwell specification. Additional test modules or utilizing the MCP mode would greatly increase the present capabilities.

It is recommended that a DSTE capabilities document be generated by Hughes which discusses in detail the DSTE performance characteristics. With this document, the DSTE end users, NASA and Rockwell, could more easily generate new tests to meet specific needs.

It is further recommended that TP32090-001, "Subsystem Development Test Procedure for the Ku-Band Integrated Radar/Communications Equipment," be expanded to include a more detailed test description. The reader and test module user will now have a better understanding as to exactly which Ku-band modes are really tested by the module.

A major area of concern is the DSTE sell-off procedure. In Axiomatix's opinion, the present procedure is inadequate, and it is recommended that a more detailed sell-off procedure be used.

APPENDIX A

KU-BAND RADAR SUBSYSTEM TESTS CROSS-REFERENCE MATRIX

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Rockwell Specification Paragraph MC409-0025 Rev B	RADAR Specification Title/Test Criteria	Not Completely Tested by Dev. Test Modules	Radar Power Up/Down Consumption Test	Radar Self-Test	Antenna Stow/ Unstow Test	Antenna Obscurat'n Zone Test	Antenna Stabiliza-tion Test	Radar Target Track Test	Radar Antenna Scan Volume Test	Radar Waveform Test	Radar Range Accuracy Test	Radar Range Rate Accuracy Test	Radar Target Acquisition Test	Radar Moving Target Acquisition Test	Radar Recovery Time Test	Radar Gimbal Pointing Test	Radar Angle Track-Servo Converg. Test	Radar Angle Track-Dynam. Track'g Test	Radar Angle Track-Angle Track Statistics Test	N/A	To Be Verified By Analysis	To Be Verified By Assessment	To Be Verified By Test
3.2.1.3	Rendezvous Radar Requirements	*						X			X	X	X	X		X					X	X	X
3.2.1.3.1	Pass. Targ. Sig. Decorrelation Enhancement	*																			X	X	X
3.2.1.3.2	Antenna Angle Servo Requirements	*															X	X	X		X	X	X
3.2.1.3.2.1	Target Inertial Angle Rate for Detection																				X	X	X
3.2.1.3.2.1.1	Target Motion Direction Constrained	*																			X	X	X
3.2.1.3.2.1.2	Target Motion Direction Unconstrained	*																			X	X	X
3.2.1.3.2.2	Target Inertial Angle Rate for Tracking																			X			
	• 0 to 0.5°/second																		X		X	X	X
	• 0.5 to 1.1°/second																	X			X	X	X
3.2.1.3.3	Radar Operating Modes	*					X				X	X	X			X			X		X	X	X
3.2.1.3.3.1	GPC Acquisition Mode																			X			
	• GPC Designates used for Antenna Position'g													X		X			X		X	X	X
	• Automatic Angle Track							X					X								X	X	X
	• Variable Search Volume								X				X								X	X	X
	• Output Range and Range Rate Data	*																			X	X	X
	• Output Range & Range Rate Data-Good Flag													X	X						X	X	X
	• Output Angle Data (Gimbal) Roll; Pitch							X													X	X	X
	• Output Angle Rate Data, Roll; Pitch							X													X	X	X
	• Output Angle & Angle Rate Data-Good Flag												X	X	X				X		X	X	X
	• Inertial Stabilization	*																			X	X	X
	• Sidelobe Lock Test	*																			X	X	X
3.2.1.3.3.2	GPC Designate Mode																			X			
	• GPC Designates used for Antenna Position'g															X					X	X	X
	• Output Range and Range Rate Data										X	X									X	X	X
	• Output Range & Range Rate Data-Good Flag										X	X									X	X	X
	• Output Angle Data (Gimbal) Roll; Pitch															X			X		X	X	X
	• Inertial Stabilization						X									X					X	X	X
	• Body Axis Stabilization															X					X	X	X
3.2.1.3.3.3	Manual Mode																			X			
	• Respond-to-Slew Switches						X														X	X	X
	• Output Range and Range Rate Data	*																			X	X	X
	• Output Range & Range Rate Data-Good Flag	*																			X	X	X
	• Output Angle Data (Gimbal) Roll; Pitch	*																			X	X	X
	• Body Axis Stabilization						X														X	X	X

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3.2.1.3.3.4	Auto Mode																			X			
	• Automatic Angle Tracking	*																			X	X	X
	• Programmed Search	*																			X	X	X
	• Respond-to-Slew Switches	*																			X	X	X
	• Output Range and Range Rate Data	*																			X	X	X
	• Output Range & Range Rate Data-Good Flag	*																			X	X	X
	• Output Angle Data (Gimbal) Roll; Pitch	*																			X	X	X
	• Output Angle Rate Data, Roll; Pitch	*																			X	X	X
	• Output Angle Data-Good Flag	*																			X	X	X
	• Output Angle Rate Data-Good Flag	*																			X	X	X
	• Inertial Stabilization	*																			X	X	X
	• Sidelobe Lock Test	*																			X	X	X
3.2.1.3.4	Vectored Search	*							X				X								X	X	X
3.2.1.3.4.1	Target Coordinate Designation																			X			
3.2.1.3.4.2	Search Volume																			X			
	• GPC Acquisition Mode	*							X														
	• GPC Designate Mode (Scan Inhibited)								X												X	X	X
	• Manual Mode	*																			X	X	X
	• Auto Mode	*																			X	X	X
3.2.1.3.4.3	Search Time																				X	X	X
3.2.1.3.4.4	Angle Rates During Search	*																			X	X	X
3.2.1.3.4.5	Search Angle Scan Mechanization	*							X					X							X	X	X
3.2.1.3.4.5.1	Search Angle Scan Pattern	*							X												X	X	X
3.2.1.3.4.5.2	Search Scan Angular Velocity Limit	*																			X	X	X
3.2.1.3.4.6	Manual Target Coordinate Designation	*																				X	X
3.2.1.3.4.6.1	Auto Mode																			X			
	• Search Initiation by Manual Control	*																			X	X	X
	• Auto. Target Detect. & Acq. following Manual Designate or Search Initiate	*																			X	X	X
	• Auto. Target Track'g Following Detect.	*																			X	X	X
	• Inertial Space Angular Drift Rate 4°/Min. for Specified Conditions	*						X													X	X	X

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Rockwell Specification Paragraph MC409-0025 Rev B	RADAR Specification Title/Test Criteria	Not Completely Tested by Dev. Test Modules	Radar Power Up/Down Consumption Test	Radar Self-Test	Antenna Stow/ Unstow Test	Antenna Obscurat'n Zone Test	Antenna Stabiliza-tion Test	Radar Target Track Test	Radar Antenna Scan Volume Test	Radar Waveform Test	Radar Range Accuracy Test	Radar Range Rate Accuracy Test	Radar Target Acquisition Test	Radar Moving Target Acquisition Test	Radar Recovery Time Test	Radar Gimbal Pointing Test	Radar Angle Track-Servo Converg. Test	Radar Angle Track-Dynam. Track'g Test	Radar Angle Track-Angle Track Statistics Test	N/A	To Be Verified By Analysis	To Be Verified By Assessment	To Be Verified By Test
3.2.1.3.4.6.2	Manual Mode																			X			
	• Auto Angle Track'g Servos Disabled								X												X	X	X
	• After Target Detection, Auto Target Tracking in Range and Range Rate	*																			X	X	X
	• Antenna Position in Orbiter Coordinates	*																			X	X	X
	• ±0.3° when Orbiter coordinates selected						X																
	• Angle Data Output to GPC and D&C	*																			X	X	X
3.2.1.3.5	Prob. of Detection & False Alarm Rate	*																			X	X	X
3.2.1.3.5.1	Ground Clutter	*																			X	X	X
3.2.1.3.6	Acquisition																			X			
	• GPC Acquisition/Auto. Modes	*											X	X							X	X	X
	• GPC Designate/Manual Modes	*											X								X	X	X
3.2.1.3.6.1	Auxiliary Search								X													X	X
3.2.1.3.6.2	Automatic Track							X					X									X	X
3.2.1.3.7	Radar Operation Interruption	*																			X	X	X
3.2.1.3.8	Radar Parameter Measurement Limits										X	X									X	X	X
3.2.1.3.9	Radar Parameter Measurement Accuracies										X	X									X	X	X
3.2.1.3.9.1	Radar Param. Meas. Accur. Convergence Time												X		X						X	X	X
3.2.1.3.9.2	Meas. Accuracies & Output Data Update Rate	*																			X	X	X
3.2.1.3.10	Break-Track Condition							X					X		X							X	X
3.2.1.3.11	Radar System Power-Up/Down Procedure		X																			X	X
3.2.1.3.12	Radar System Operation Sequence	*							X				X									X	X
3.2.1.3.13	Received Signal Strength Indication							X														X	X
3.2.1.3.14	Radar System Design Requirements																			X			
3.2.1.3.14.1	Transmitter	*								X											X	X	X
3.2.1.3.14.2	Microwave Losses	*																			X	X	X

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Rockwell Specification Paragraph MC409-0025 Rev B	RADAR Specification Title/Test Criteria	Not Completely Tested by Dev. Test Modules	Radar Power Up/Down Consumption Test	Radar Self-Test	Antenna Stow/ Unstow Test	Antenna Obscurat'n Zone Test	Antenna Stabiliza-tion Test	Radar Target Track Test	Radar Antenna Scan Volume Test	Radar Waveform Test	Radar Range Accuracy Test	Radar Range Rate Accuracy Test	Radar Target Acquisition Test	Radar Moving Target Acquisition Test	Radar Recovery Time Test	Radar Gimbal Pointing Test	Radar Angle Track-Servo Converg. Test	Radar Angle Track-Dynam. Track'g Test	Radar Angle Track-Angle Track Statistics Test	N/A	To Be Verified By Analysis	To Be Verified By Assessment	To Be Verified By Test
3.2.1.3.14.3	Antenna	*																				X	X
3.2.1.3.14.3.1	Antenna Error Detection																					X	
3.2.1.3.14.3.2	Antenna Beam Sidelobe Lock-On																					X	
3.2.1.3.14.3.3	Stabilization						X														X	X	X
3.2.1.3.14.3.4	Polarization									X											X	X	X
3.2.1.3.14.3.5	Gimbal Arrangements																					X	
3.2.1.3.14.3.6	Antenna Control Servos																					X	
3.2.1.3.14.4	Receiver																					X	
3.2.1.3.14.4.1	Receive Signal Dynamic Range	*																			X	X	X
3.2.1.3.14.4.2	IF Preamplifiers	*																			X	X	X
3.2.1.3.14.4.3	Operating Modes Compatibility	*																			X	X	X
3.2.1.3.15	Radar Self-Test			X																	X	X	X
3.2.1.3.16	Radar System Power Consumption		X																		X	X	X
3.2.1.3.16.1	Power Consumption in Operating Modes and Conditions		X																		X	X	X
3.2.1.3.16.2	LRU Heater Power		X																		X	X	X

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Rockwell Specification Paragraph MC409-0025 Rev B	COMMUNICATIONS Specification Title/Test Criteria	Not Completely Tested by Dev. Test Modules	Comm. Power Up/Down Consumption	Comm. Subsystem Slant Range	Forward Link Signal Strength Test	Forward Link Tracking Threshold Test	Forward Link Acquisition Time Test	Forward Link BER Test	Functional Test (Return Link)	BER Test (Return Link)	Comm. Mode Antenna Stow Unstow Test	Comm. Mode Obscuration Zone Test	Comm. Mode Antenna Stability Test	Comm. Mode Antenna Slew Test	Comm. Mode Target Acq. Track Test	Comm. Antenna Scan Volume Test	N/A	To Be Verified by Analysis	To Be Verified By Assessment	To Be Verified By Test
3.2.1.2	Communication Subsystem Performance	*		X											X	X			X	X
3.2.1.2.1	Ang. Search, Signal Detection and Track Requirements	*		X											X				X	X
3.2.1.2.1.1	TDRS Forward Link Signal						X												X	X
3.2.1.2.1.2	Antenna Angle Coverage for Communications																X			
3.2.1.2.1.2.1	Acquisition Coverage											X						X	X	X
3.2.1.2.1.2.2	Tracking Coverage											X						X	X	X
3.2.1.2.1.3	Orbiter-TDRS Link Acquisition & Handover																X			
3.2.1.2.1.3.1	Link Acquisition Mode Definition	*																X	X	X
3.2.1.2.1.3.1.1	Primary Acquisition Mode	*																X	X	X
3.2.1.2.1.3.1.2	Alternate Acquisition	*																X	X	X
3.2.1.2.1.3.2	Handover Requirements	*																X	X	X
3.2.1.2.1.3.2.1	Return Link Data																X			
3.2.1.2.1.3.2.2	Data Transfer Sequencing	*																X	X	X
3.2.1.2.1.3.3	Detection IF Bandwidth	*																X	X	X
3.2.1.2.1.3.4	Detection Requirements	*	X												X	X		X	X	X
3.2.1.2.1.3.4.1	Signal Uncertainties for Detection																	X	X	
3.2.1.2.1.3.4	Link Acquisition Time																X			
3.2.1.2.1.3.5.1	TDRS Signal Acquisition	*					X									X			X	X
3.2.1.2.1.3.5.2	Signal Processing Time						X												X	X
3.2.1.2.1.4	Antenna Control Servos	*													X	X		X	X	X
3.2.1.2.1.4.1	Open-Loop Operation	*																X	X	X
3.2.1.2.1.4.1.1	Angle Search															X			X	X
3.2.1.2.1.4.1.2	Search Scan Mechanization															X		X	X	X
3.2.1.2.1.4.1.3	GPC Designate Tracking	*				X									X				X	X
3.2.1.2.1.4.1.4	Wide-Angle Antenna Characteristics	*																X	X	X
3.2.1.2.1.4.2	Closed-Loop Operation																X			

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3.2.1.2.1.4.2.1	Angle Tracking Accuracy												X		X			X	X	X
3.2.1.2.1.4.2.2	Angle Tracking Limitations												X	X	X			X	X	X
3.2.1.2.1.4.2.3	Break Track Condition	*																X	X	X
3.2.1.2.2	Forward Link Data Subsystem	*					X												X	X
3.2.1.2.2.1	Forward Link Data Subsystem Characteristics	*					X												X	X
3.2.1.2.2.1.1	Forward Link Subsystem Characteristics	*						X											X	X
3.2.1.2.2.2	Data Characteristics																X			
3.2.1.2.2.2.1	Information Signal Characteristics																X			
3.2.1.2.2.2.1.1	Mode 1 Forward Link Data	*																X	X	X
3.2.1.2.2.2.1.2	Mode 2 Forward Link Data	*																X	X	X
3.2.1.2.2.2.2	Spread Spectrum						X											X	X	X
3.2.1.2.2.2.3	Unspread Spectrum						X											X	X	X
3.2.1.2.2.3	Data Output	*				X	X												X	X
3.2.1.2.2.4	Data Quality Estimation	*			X	X	X											X	X	X
3.2.1.2.2.4.1	Data Quality Estimate Duration	*			X	X	X											X	X	X
3.2.1.2.2.5	Forward Link Performance	*			X	X	X	X										X	X	X
3.2.1.2.3	Ku-Band Comm. Transmit Subsystem																X			
3.2.1.2.3.1	Transmit Subsystem Description	*							X										X	X
3.2.1.2.3.2	Return Link Data Requirements	*							X									X	X	X
3.2.1.2.3.2.1	Mode 1 Data Requirements	*																X	X	X
3.2.1.2.3.2.2	Mode 2 Data Requirements	*																X	X	X
3.2.1.2.3.2.3	Data Source Selection	*							X										X	X
3.2.1.2.3.3	Return Link Characteristics																X			
3.2.1.2.3.3.1	Modulation Type																		X	
3.2.1.2.3.3.2	Data Channelization	*																X	X	X
3.2.1.2.3.3.3	Return Link Operational Characteristics	*							X									X	X	X
3.2.1.2.3.3.4	Return Link Data Throughput	*																X	X	X

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3.2.1.2.3.3.4.1	Digital Data Throughput	*																X	X	X
3.2.1.2.3.3.4.1.1	Bit Transition Density	*																X	X	
3.2.1.2.3.3.4.1.2	Data Asymmetry	*							X									X	X	X
3.2.1.2.3.3.4.2	Analog Data Throughput	*																X	X	X
3.2.1.2.3.4	Modulation																		X	
3.2.1.2.3.4.1	Mode 1 Modulation	*																	X	X
3.2.1.2.3.4.2	Mode 2 Modulation	*																	X	X
3.2.1.2.3.4.3	Analog Data via Channel 2	*																	X	X
3.2.1.2.3.4.4	Unmodulated Carrier																		X	X
3.2.1.2.3.5	Data Degradation ~~Deleted~~																			
3.2.1.2.3.5.1	Mode 1 Degradation																			
3.2.1.2.3.5.2	Mode 2 Degradation																			
3.2.1.2.4	Communications B Subsystem																		X	
3.2.1.2.5	Comm. System Self-Test ~~Deleted~~																			
3.2.1.2.6	Comm. System Power Consumption		X																	

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