N81-14141

R. F. TESTING OF THE THIRD GENERATION DEFENSE COMMUNICATION SATELLITE

John Sargent *
Dr. Michael Massaro **

Abstract

This paper will describe the approach taken to test, on a system level, a completed DSCS Communications Satellite. Areas to be described are measuring RF isolation of separate communications subsystems and a test method which insures that one RF subsystem does not interfere with another. In addition, the method of complying with MIL-STD-1541 in the area of demonstrating safety of electroexplosive devices in an RF field will be discussed.

INTRODUCTION

In January of 1977 a contract for the third generation Defense Satellite Communication System was awarded to the General Electric Space Division. This newer generation satellite is unique compared to earlier generations in that it has a six channel transponder designed for both frequency and time domain access operation and real-time commandable uplink and downlink multibeam antennas. On the satellite the six SHF channels can be received via one of two earth coverage horns, or a 61 element, switchable multibeam antenna (MBA) and transmitted via one of two earth coverage horns, a gimballed high-gain reflector antenna (GDA), or one of two 19 element switchable multibeam antennas. In addition, there are two omnidirectional S-Band antennas for TT&C operation, and a Single Channel Transponder operating at UHF and SHF. Thus, there are a total of twelve antennas, two SHF earth coverage Transmit horns, two earth coverage Receive horns, one 61 MBA Receive antenna, a GDA Transmit antenna, a UHF Transmit and Receive Antenna, and finally, two S-Band omni antennas.

The RF testing of the DSCS III satellite represents a unique challenge from a technical standpoint, as well as from an implementation standpoint regarding needed facilities and test equipment.

This paper presents the test philosophy, test approach and test acceptance criteria and expected test results of the DSCS III satellite RF tests. In particular, the following tests will be discussed:

- Antenna Isolation
- RF Self Compatibility Performance
- Radiated Electro Magnetic Susceptibility
- Intermodulation Product Generation

All of the above satellite tests will be performed in a large anechoic room which was designed to absorb most of the RF energy radiated from the spacecraft in order to closely duplicate free space. The above tests are being conducted to verify basic program design performance parameters or to determine compliance

* System Test Engineer ** EMC Engineer
General Electric Space Division
Valley Forge, Pa.

with the design and test requirements of MIL-STD-1541, which has been applied to the program. The antenna isolation test and the RF self compatibility performance test are performed to satisfy both requirements; whereas, the Radiated EMISM test satisfies only the latter, and the IMP test the former.

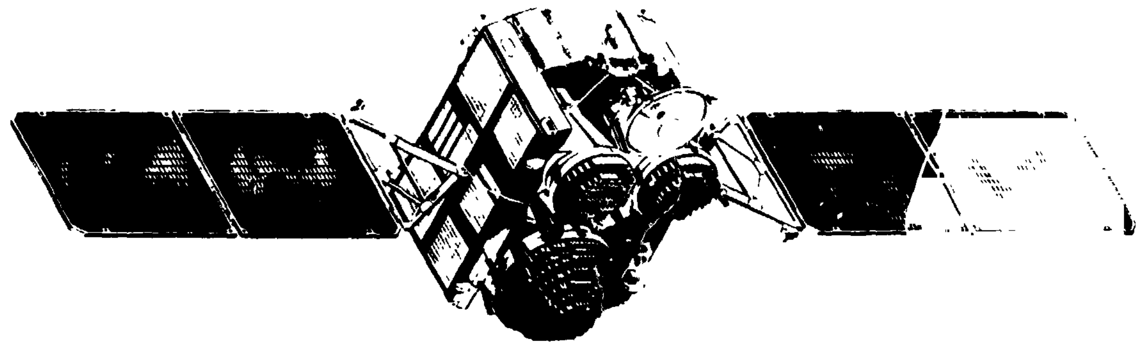

Figure 1 - DSCS Satellite

DSCS III Satellite Description

The Defense Communications Satellite, due for launch early in 1981, is a third generation communication satellite which, during its 10 year design life, will act as a repeater in space for our defense forces. The satellite, which is presented in Figure 1, is a three-axis stabilized synchronous orbit satellite whose body size measures 6 1/2 feet wide (38 feet including solar array), 6.75 feet long and 6.5 feet high, weighing 2200 pounds. Ten communication antennas are mounted on its earth viewing face. Antennas operating at X-band consist of two receive earth coverage horns, two transmit earth coverage horns, two 19 beam transmitter antennas, one 61 beam receive antenna and one gimball dish. At UHF there are separate receive and transmit antennas. At S-band there are two antennas, one on earth viewing and one on space facing side used for telemetry and command functions. The north face of the satellite contains the communications and the south panel, which contains the power controller and regulation unit, attitude control, command decoder, telemetry unit, data encrypters, decrypters and batteries. All subsystems are fully redundant and may be cross strapped. Frequency spectrum covered by the communications payload is 7900 to 8400 MHz for X-band receive, 7250 to 7750 MHz for X-band transmit. This transmit band is divided into 6 bands or channels whose downlink transmit power is provided by two 40 watt and four 10 watt TWT's. There are two standard SGLS channels number 12 and 16 for S-band TT&C control.

In addition, there is a single channel transponder whose UHF downlink communicates to all AFSATCOM equipped force elements. Access to AFSATCOM transponder is via UHF; X-band direct, X or S-band TT&C. DSCS III has two beacons operating with identical simultaneous modulation. Telemetry is impressed on the beacon modulation using an interplex modulation of two telemetry streams modulated on two subcarriers. One telemetry stream is time shared between a PN code and SCT telemetry data. Main telemetry is 61 K bits in length with a 1 K BPS rate. The Transmit and Receive frequencies are indicated in Figure 2.

Designation of Tests

Early in the program ground rules were agreed to which determine which tests were to be automated and which were to be manual. These ground rules were:

a) Are the measurements of a repetitive nature, such as transponder power output across the band?

b) Will the automation reduce overall test time?

c) Will the test be used repetitively on each satellite, or is it just for qualification of one satellite?

d) Will the additional complexity of the test which includes computer operators and software programmers be recoverable in shortened test time? Thus, a five-hour manual test shortened to one hour through automation may not be cost effective if it takes 4 times the number of people to run the test.

SATELLITE SYSTEM RF TESTS

Antenna Isolation

Ant	Ch	MHz	BW
MBA1	1	7280	60
	3	7467	75
MBA2	2	7365	60
	4	7560	60
ECX2	4	7560	60
	6	7725	50
BEACON		7605	
ECX1	3	7457	75
	5	7645	60
BEACON		7600	
DISH	1	7580	60
	2	7365	60
	4	7560	60

Ant	Ch	MHz	BW
ECR1	3	8172	75
	4	8285	60
	5	8370	60
ECR2	1	8005	60
	2	8010	30
	6	7925	50
MBR	1	8005	60
	2	8090	60
	3	8172	75
	4	8285	60
UHF	R	360	90
	T	247	20
S	R	1807	1823
	T	2237	2277

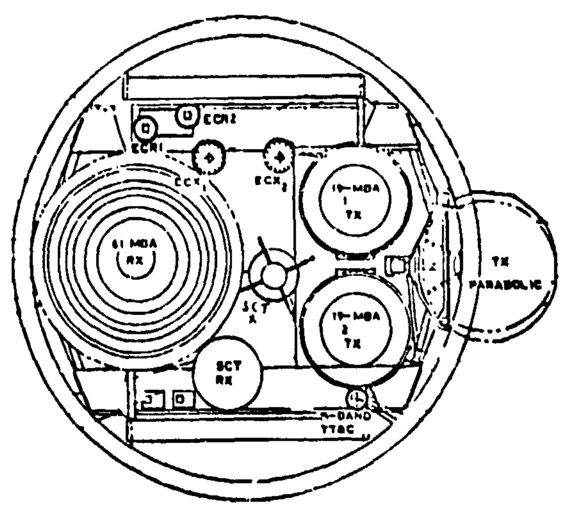

Figure 2

Since the spectrum of frequencies of the satellite is so broad band, there exist many possibilities for one subsystem to interfere with another by means of spurious responses, intermodulation products, or adjacent channel noise. To prevent this from happening, the harmonic content of each transmitter is minimized by careful design. By measuring the satellite's receiver thresholds - that is - the minimum signal necessary to operate the system and a transmitter's fundamental and harmonic output at a specific frequency, the magnitude of isolation which must exist between the two on-board RF subsystems to prevent intrasystem interference can be determined.

On the DSCS satellite there exist high field strengths from all transmit antennas, and therefore large isolation values were required of the antenna systems. It was decided to measure isolation across the antenna's entire operating band to insure that any peaks in the antenna's coupling from one antenna to another would not be overlooked.

There are many ways to make isolation measurements - phase lock receivers, network analyzers, and tracking generators. Each system was evaluated for ease of use and minimization of set up time. It was decided that because of the wide band of frequencies to be covered, the sweep generator and spectrum analyzer approach would be employed. There are over 50 combinations of pairs of antenna measurements to be made. Since the sweep generator power source had to be coupled to many antenna ports, and since there would be frequent connection changes, the use of waveguide as the test signal path was impractical. Therefore, all antenna ports using waveguide are transitioned to coax for connection to the test equipment. To prevent the sensitive spectrum analyzer from measuring the leakage from coax used for the tests and mistaking it for antenna leakage, solid shield short length heliax cable will be used for interconnection. Reflected energy from the walls of the facility are expected to be low and in the order of -70 dBc, as shown in Table I. Being so low in amplitude, they will not interfere with the isolation measurement.

BAND	PATH	ANT. SIDE LOBE	ABSORBER	TOTAL ATT.
UHF	30	32	10	70
S	42	6	25	73
X	45	50	30	125

TABLE I - RF ISOLATION FROM FACILITY

Although the test is repetitive in nature and thereby qualifies for automation, it will be performed manually because the test will only be done on the Qual vehicle. Antenna isolation is affected by antenna position, type of antenna geometric layout, operating frequencies and load matching networks.

These relationships should not change from satellite to satellite. Preliminary design data indicates that isolation is 10 dB better than acceptance levels, and therefore there is little chance of risk in performing this test on only one satellite.

RF SELF COMPATIBILITY PERFORMANCE

Up to the point in time where this test is performed, the satellite has been tested in a hard wire configuration where antennas were not connected to operating subsystems. During this test the satellite will radiate through its antennas and system performance tests via air link for the first time. The purpose of the test is a) to insure there is no mutual RF interference between two subsystems - that is - satellite receivers listening to their own on-board transmitters, and b) the RF field around the satellite does not leak into a performing subsystem and effect its operation. The first is detected by spectrum analysis of the transmitted signal. The second is measured by offsets in telemetry from those values recorded in a baseline measurement.

An optimistic test plan would exercise the spacecraft in every possible configuration in all modes and insure proper operation, but considering the fact that the 6-channel comm transponder alone has 155,000 possible operating modes, this is impractical. Therefore, we must scope our tests to only those configurations which can realistically be affected. A study was performed and ground rules made to simplify the tasks necessary for an uncompromising compatibility test. A summary of this study was as follows:

a) Attitude control system is affected by RF because the sensitive sun and earth sensors measuring satellite attitude are within the radiation field of the antennas.

b) The Single Channel Transponder's receiver may incorrectly AGC due to RF leakage entering the X or UHF receivers.

c) The X-band communications channels may be affected by RF leakage into their mixer stages and cause spurious outputs within their channels.

d) Power subsystem may incorrectly regulate due to RF leakage onto power controller sense lines.

To test for these effects and others, the satellite is configured by air link to a minimum power configuration and each subsystem is powered up by itself, and baseline measurements recorded. As an example, the attitude control system is initialized to a stable null condition and all sensor outputs recorded. The single channel transponder is configured by UHF and is placed in a bypass mode where it operates as a true transponder. In this configuration the uplink power is varied and a bit error rate curve is generated. Comm transponder outputs in each channel are monitored by spectrum analyzer under no uplink and noise power measurements made. Command threshold measurements are made on the command system and minimum uplink power points are established for S-band and X-band commanding. Beacon modulation spectrum measurements are made and center frequency is accurately established.

These tests are then repeated on each subsystem while all other systems are fully on. If there is any interference, it will show up on that subsystem by a delta in performance as measured either directly on a spectrum analyzer or on telemetry by changes from baseline values previously recorded.

Radiated EMISM Spray Test - Figure 3

The RF Radiated Spray Test must demonstrate that the various subsystems of the vehicle could operate within their specified performance limits if the environmental field-strengths were increased 6 dB above their nominal levels. That is, electromagnetic radiated interference safety margins, (EMISM) must be established for the various subsystems of the spacecraft. An EMISM must be demonstrated for the following coupling modes:

(1) Transmit antenna-to-component case radiated field coupling.

(2) Transmit antenna-to-wire bundle and cable radiated field coupling.

(3) Transmit antenna-to-electroexplosive device case and wire harness radiated field coupling.

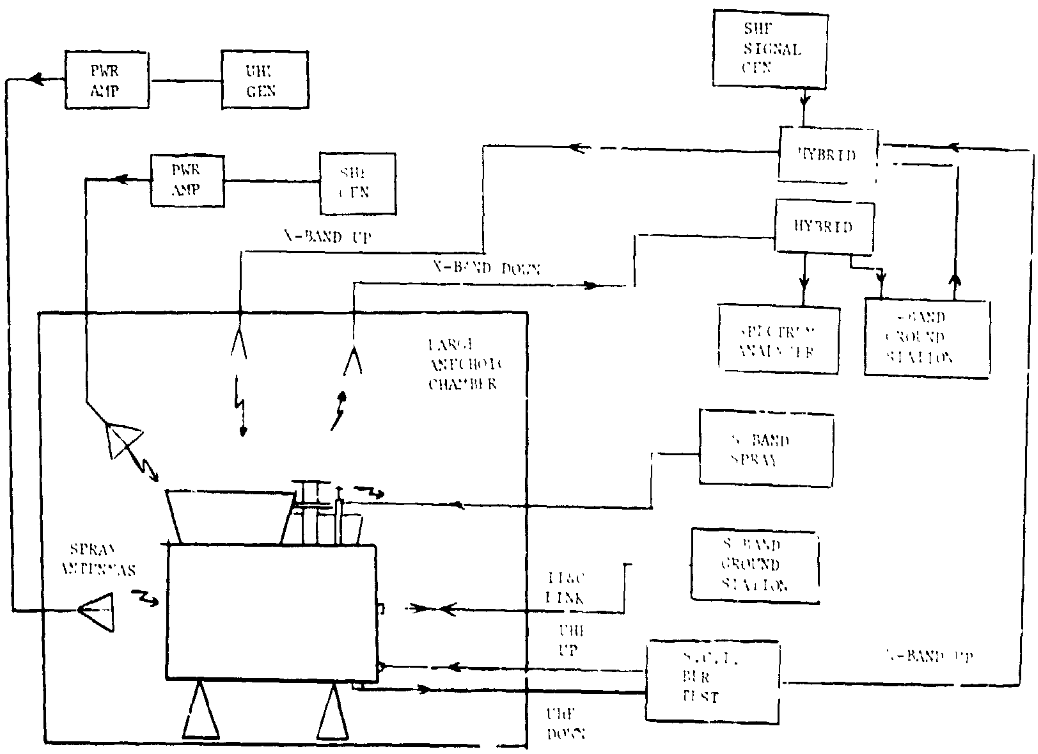

Figure 3

This test is accomplished by first measuring the ambient fields around the vehicle at the transmitter fundamental frequencies and large harmonics. It was decided to use a Radiation Hazard probe (RADHAZ) type instrument to measure the ambient fields. RADHAZ probes are typically broadband, omnidirectional and polarization independent, and are thus ideal for probing unknown field distributions. However, RADHAZ probes have low sensitivity with minimum discernible fields on the order of about 2.0 V/m. Consequently, this limit was used to establish the lower limit of the intensity of the spray field at a level of 5 V/m.

After establishing the ambient field levels, the S/C is then sprayed a level that is 6 dB greater in intensity at each of the measured frequencies. During the spray test at each frequency, selected critical performance parameters are monitored to determine if acceptance limits have been exceeded. For example, for the SHF transponders, spurious sideband levels are measured. For the TT&C system X-Band and S-Band downlink telemetry is monitored for upsets and changes. For the Single Channel Transponder system, a Bit error rate test is performed.

The test is performed for the Electro-explosive device system (EED) by first determining the largest environmental field strength that the EED system, EED device, case and control cable will experience. The environment in this case refers to the fields that exist at the launch pad, the fields produced by pre-launch tests, or the fields produced by the launch vehicle. The test is performed to ensure that the RF environment does not cause a false firing of the EED. A 20 dB safety margin must be established, i.e., the EED must be sprayed with an effective field that is a numerical factor of 10 higher than the maximum ambient environmental field. For DSCS III the maximum overage environmental field strength was a level of 60 V/m produced by the launch vehicle. Since the test field strength for this case (600 V/m) was enormous, an effective field strength of 600 V/m can be produced by removing the shield from the EED harnesses and spraying at a field strength of 6 V/m. This reduction in the spray intensity is based on the fact that the shields can produce 40 dB of attenuation to external fields. The harness is sprayed at this level for 2 months and a non firing of the EED is the pass criteria.

Internal Product (IMP Testing)

When a non linear electrical device on the satellite is simultaneously sprayed with RF at two different frequencies, doubling and mixing actions take place which can produce and self generate a third frequency. If this self generated signal lies within a satellite's receive pass band, and is strong enough to be "seen" by the satellite's receive antenna, the satellite will amplify this signal and rebroadcast it on the downlink. This extra signal is capable of saturating the transponder's power and rendering - in extreme cases - the channel useless. Examples of elements which cause IMP generation are loose waveguide points, dissimilar metals in waveguide switches, and antenna elements poorly joined. They are usually parts which are exposed to high power.

Recognizing the importance of this test, it is planned to be performed three times in the satellite test cycle. First, after initial satellite assembly in order to prove workmanship quality. Second, after acoustic noise exposure to prove structural integrity, and a third time after pyro shock exposure. Since this test is so discretely repetitive and must be performed on every satellite, it is a prime candidate for automation.

To perform this test a "full up" satellite is required. The test must be air linked in order to allow the IMP to ring around into a receive antenna port.

The test philosophy is as follows. An intermod measurement pair is selected, such as those shown in Figure 4.

Xmit Ant.	Xmit Freq.	Rec Ant.	Rec. Freq.
Dish	7335	Earth Horn	8060
Earth Horn	7750	Earth Horn	7950
IMP Rec. Ant.	IMP/R Freq.	IMP/Xmit Freq.	Imp Ant
M Beam	8165	7440	Earth Horn 1

Figure 4

Two uplink signal generators are programmed to 8060 and 7950 GHz and the signals sent to the satellite are received on earth horn #1. The signals are translated 750 MHz down in frequency, amplified and transmitted from the satellite dish and earth horn #1 antennas. If there is a non linear IMP generator, it will mix the two transmit frequencies and the resultant third order internal product will fall at 8165 MHz. This is a receive frequency IMP which will be translated down 750 MHz, amplified and rebroadcast on 7440 GHz. It is to this frequency the spectrum analyzer is tuned. Baseline noise power measurements out of the satellite are made at this frequency at a bandwidth of 10 KHz to determine amplitude of pure noise with no uplink established. Once this noise power is quantized, the two uplink signals are sent and power again measured at the IMP frequency. If power increases 8 dB with uplink signals present, there is an indication of an intermod product signal.

Considerable care in the selection of test equipment has been exercised to insure that the uplink signal path does not in itself generate IMP products. Two separate uplink antennas will be used to keep the two uplink test signals separate until they ultimately mix within the satellite. Low power from the uplink signal generators - in the order of -30 dBM - will be used for the test signals to prevent IM products from being generated on the uplink and close coupling to the receive antennas will achieve immunity to generating IM products on the uplink.

By testing all possible pairs of transmit and receive ports across all possible IMP frequencies, we will eliminate any "surprise" signals from being self generated by the satellite after launch.

CONCLUSIONS

As in every satellite test program there exists a myriad of component and subsystem tests which prove proper subsystem design. However, it is only at the system level test where proper satellite operation is proven. This is accomplished by verifying test parameters under true orbit simulation.

In this DSCS program, with regard to RF system test parameters, we have attempted to assume nothing. We have replaced "test by analysis" with analysis then test. By completely testing a satellite in a mode which duplicates its operation in orbit, then linking this with testing for a proper margin of proper system operation, a high level of confidence for correct system operation is achieved.