Bendix Aerospace Systems Division

ALSEP/LCRU EMC Test Results	NO. ATM 1050	REV. NO.
	PAGE 1 OF 10	
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The results of the ALSEP/LCRU EMC test are reported in this ATM.

Prepared by: C. Jensen

C. Jensen

Approved by: D. Fithian

D. Fithian

INTRODUCTION

The Lunar Communications Relay Unit (LCRU) is used to relay Astronaut voice and biomed and transmit TV signals to the earth. It is mounted to the LRV and operates in the vicinity of ALSEP. Therefore, because of its relatively high effective radiated power the LCRU represents a potential RFI problem to ALSEP. For this reason, an EMC test was conducted, using the MSFN model ALSEP Central Station, a high power signal generator, representing the LCRU transmitter, and an 18 inch parabola to represent the LCRU high gain antenna. This ATM reports the results of this test.

LCRU BACKGROUND INFORMATION

The LCRU operates in either a high power mode or a low power mode.

Low Power Mode

The low power mode is used to relay the astronaut voice and biomed signal to earth when TV is not transmitted. It is used primarily when the LRV is moving. There are two low power transmitting modes, PM-1 and PM-2. In PM-1 the astronaut voice is modulated directly on the downlink carrier (2265.5 MHz). This is an emergency mode of transmission. In PM-2, voice and biomed are first modulated on a 1.25 MHz subcarrier and then this signal is phase modulated onto the downlink carrier. The low power mode is transmitted via a helical low gain antenna built by BRLD. The gain of this antenna is 10.8 dB on boresight and at least 6.5 dB at an angle 30^{o} from antenna boresight. The minimum transmitter power, referred to the antenna terminals is 5.5 dBW but is actually about 1 dB better or 6.5 dBW. The maximum effective radiated power for the low power mode is 17.3 dBW.

High Power Mode

The high power mode is used when TV from the camera mounted on the LRV is transmitted to earth. Note that TV is transmitted only when the LRV is stopped. Three high power transmission modes are available, PM-2, FM-TV, and Remote TV. PM-2 is the same as described for the low power mode. In FM-TV, the voice and biomed signal is phase modulated on a 1.25 MHz subcarrier and then added to the TV-video signal. This composite signal is frequency modulated onto the down-link carrier. In the Remote TV mode, only the TV signal is frequency modulated onto the downlink carrier. When this mode is used, voice and biomed are transmitted to earth via the LM. The high power mode is transmitted via a 38 inch parabolic antenna. This antenna is pointed to earth by the astronaut using an optical sighting device. The specified effective radiated power transmitted when operating in the high power mode is 30 dBW minimum within 2.5^{o} of antenna boresight. The antenna gain at 2.5^{o} from boresight is 23 dB thus the transmitter power is a minimum of 7 dBW. Actually the high power transmitter output is a minimum of 8 dBW. Thus on boresight, where the calculated antenna gain is 24.5 dB, the effective radiated power is 32.5 dBW.

The two transmitters operate through a diplexer that has a 3 dB bandwidth of 15 MHz. The diplexer should provide a minimum of 60 dB attenuation at the ALSEP uplink frequency (2119 MHz).

Figure 1 is a plot of the power density at the ALSEP Central Station as as function of range, antenna pointing, and transmission mode. The levels at which radiated susceptibility measurements are made in accordance with AL770000 along with the maximum levels used in these tests are also plotted for comparison.

It should be noted that under normal operation neither the high gain antenna or the low gain antenna will be pointed directly at ALSEP. These situations could occur only if either antenna is inadvertently pointed at ALSEP. However, the fact that these antennas are mechanically adjustable, and are adjusted with the transmitters operating requires that these worst case conditions be considered.

The minimum distance between ALSEP and the LCRU has not been established for Apollo 16 and 17. Therefore the mission guidelines for Apollo 15, which permitted a minimum operating distance of 20 feet, has been assumed for all flights.

Test Set Up

The equipment used in the test included the ALSEP MSFN model C/S, a 60 foot length of 20 conductor flat cable, an 18 inch parabolic antenna, an AIL Power Oscillator - type 1246, the System Test Set (STS), various directional couplers, and an H-P power bridge. The tests were conducted in the ALSEP experiments lab, the location of the STS, to permit monitoring of the C/S telemetry. Figures 2 and 3 are photographs of the layout of the C/S and flat cable.

Throughout the tests the location of the antenna was varied from a position directly over the flat cable to positions at angles of up to 90° with the flat cable and at distances ranging from 6 feet to 10 feet. In addition, the antenna feed was rotated for both vertical and horizontal polarization at each location.

One end of the 60 foot - 20 conductor flat cable was connected to the first 20 pins of J80, the SIDE input connector. With this arrangement two flat cable conductors were connected to the C/S multiplexer. The multiplexer input is the circuit most vulnerable to damage due to LCRU radiation because of its high impedance and because many of its input signals are via the experiment flat cable.

The distant end of the flat cable was open circuited except for the case where an analog voltage was applied to the conductors connected to pins 11 and 19 of J80. Pin 11 is the SIDE signal return input and pin -19 is the SIDE high energy count rate analog input. Note that analysis shows that the conductor and dielectric losses for the flat cable at S-Band are great enough that the RFI voltages at C/S end of the cable are independent of the terminations at the distant end.

As can be seen in the photographs, both the C/S and the flat cable were deployed on a foam base to reduce the short circuit effect of the laboratory floor. The C/S was raised approximately 3 inches while the flat cable was raised a distance 1 1/4 inches from the floor. The electric field at the flat cable was calculated for this condition assuming that the floor was a perfect reflector, the worst case. These calculations showed that the electric field at the flat cable for the test conditions is greater than that which will occur for the flat cable lying on the lunar surface for antenna angles of interest.

Tests were run with the AIL oscillator operating CW which approximates the FM signal of the LCRU and also amplitude modulated at 30 Hz, 1KHz, 1.06 KHz and 2 KHz.

In addition to the radiated interference tests an antenna conducted test was run with the oscillator output coupled to C/S RF input through a directional coupler. During these tests the AIL oscillator was run CW and amplitude modulated at 1 and 2 KHz. The maximum level coupled to the RF input was +18 dBM. Based on the assumption that the ALSEP antenna is pointed toward earth from a lunar location no more than 60° from the sub earth point and that the minimum LCRU-ALSEP distance is 20 feet, the LCRU signals will be received at the ALSEP antenna at sidelobe levels. Then the maximum level at the ALSEP antenna terminals is approximately +13 dBM or 5 dB below the test level.

TEST RESULTS

The specific test set up for each test run and the results are listed below.

1. With a CW output signal, the oscillator output level was set at -1.6 dBW referred to the antenna terminals and the radiating antenna was located approximately 10 feet from the C/S. The housekeeping data was monitored through several data cycles and compared to that printed when the transmitter was off. No differences were noted.

2. With a CW output signal, the level referred to the antenna terminals was increased to +6 dBW. The radiating antenna was located at various positions ranging from 6 feet to 10 feet. The antenna polarization was aligned both vertically and horizontally at each position. Again housekeeping data printed out with and without an interfering signal was compared. No differences were noted. In addition the downlink signal was monitored on the STS oscilloscope. No effects from the interfering signal could be detected.

3. Step 2 was repeated with 2 volts DC applied to the SIDE high energy detector count rate analog line at the distant end of the flat cable. No differences in the HK printout with and without the interfering signal present was noted.

4. The interfering signal was coupled directly to C/S RF input at levels from 11 dBM to 18dBM. Tests were run with a CW signal and with an AM signal, modulated at 1 and 2 KHz. No differences in the HK printout were noted for the interfering signal present or not present.

   In addition, commands were transmitted to ALSEP at uplink levels down to -101 dBM and the command error rate with and without the interfering signal present monitored. No differences were noted.

5. This test was run with the Experiment Data Simulation Program in which simulated experiment data generated by the STS is delivered to the C/S Data Processor and then transmitted via the ALSEP transmitter back to the STS where it is compared with the generated data. For this test the C/S was inverted with the cover removed, as shown in Figure 3, so that the C/S harness was exposed to the radiated interfering signal. The interfering signal was amplitude modulated at 30 Hz. All the simulated data was correctly received at the STS.

6. The induced voltages on the 2 conductors flat cable were measured at both ends of the cable with an NF 112 receiver. The voltages measured at the cable ends did not exceed the ambient values detected when the receiver was not connected to the cable. The ambient level was 100 dBμV. The receiver itself loads down the cable due to its 50 ohm input impedance, and thus could act to reduce the induced voltages. However, at S-Band, the flat cables are lossy enough that they appear as a resistor with a value equal to the transmission line characteristic impedance for lengths greater than about 20 feet.

The characteristic impedance for adjacent conductors and for conductors separated by six intermediate conductors was measured previously and found to be 160 ohms and 280 ohms respectively. Thus in the worst case the loading of the NF 112 would reduce the measured voltage by a factor of six. Thus the maximum RF voltage on the flat cable cannot exceed 0.6 volts, well below the levels which would result in damage.

Based on the results of these tests, operation of the LCRU at a distance of 20 feet from the ALSEP C/S does not adversely effect the operation of the ALSEP C/S even if the LCRU antenna is pointed directly at the ALSEP C/S.

Nevertheless it is recommended that the warning on the astronaut cuff list stating that the LCRU antenna is not to be pointed directly at the ALSEP C/S be retained for future missions.

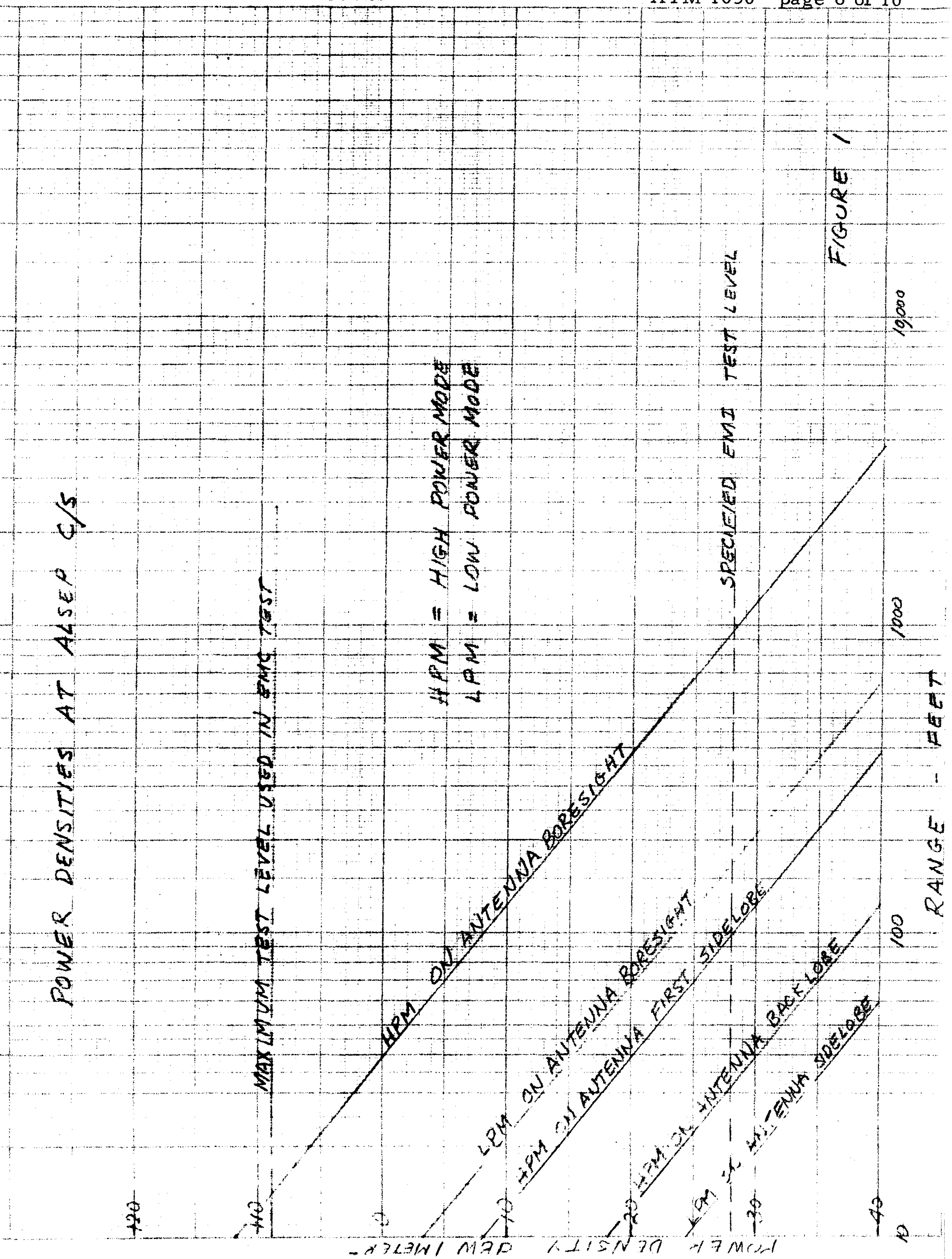
POWER DENSITIES AT ALSEP C/S
MAXIMUM TEST LEVEL USED IN EMC TEST
HPM = HIGH POWER MODE
LPM = LOW POWER MODE
SPECIFIED EMI TEST LEVEL
HPM ON ANTENNA BORESIGHT
LPM ON ANTENNA BORESIGHT
HPM ON ANTENNA FIRST SIDELOBE
HPM ON ANTENNA BACK LOBE
LPM ON ANTENNA SIDELOBE
10,000
1000
100
RANGE - FEET

FIGURE 1

7.1 HARDWARE DISCREPANCY SHEET

DR NUMBER	STATUS OPEN	CLOSED	Q A STAMP	DCASR STAMP

Figure 2 - Test Set Up for ALSEP/LCRU Radiated Interference Test

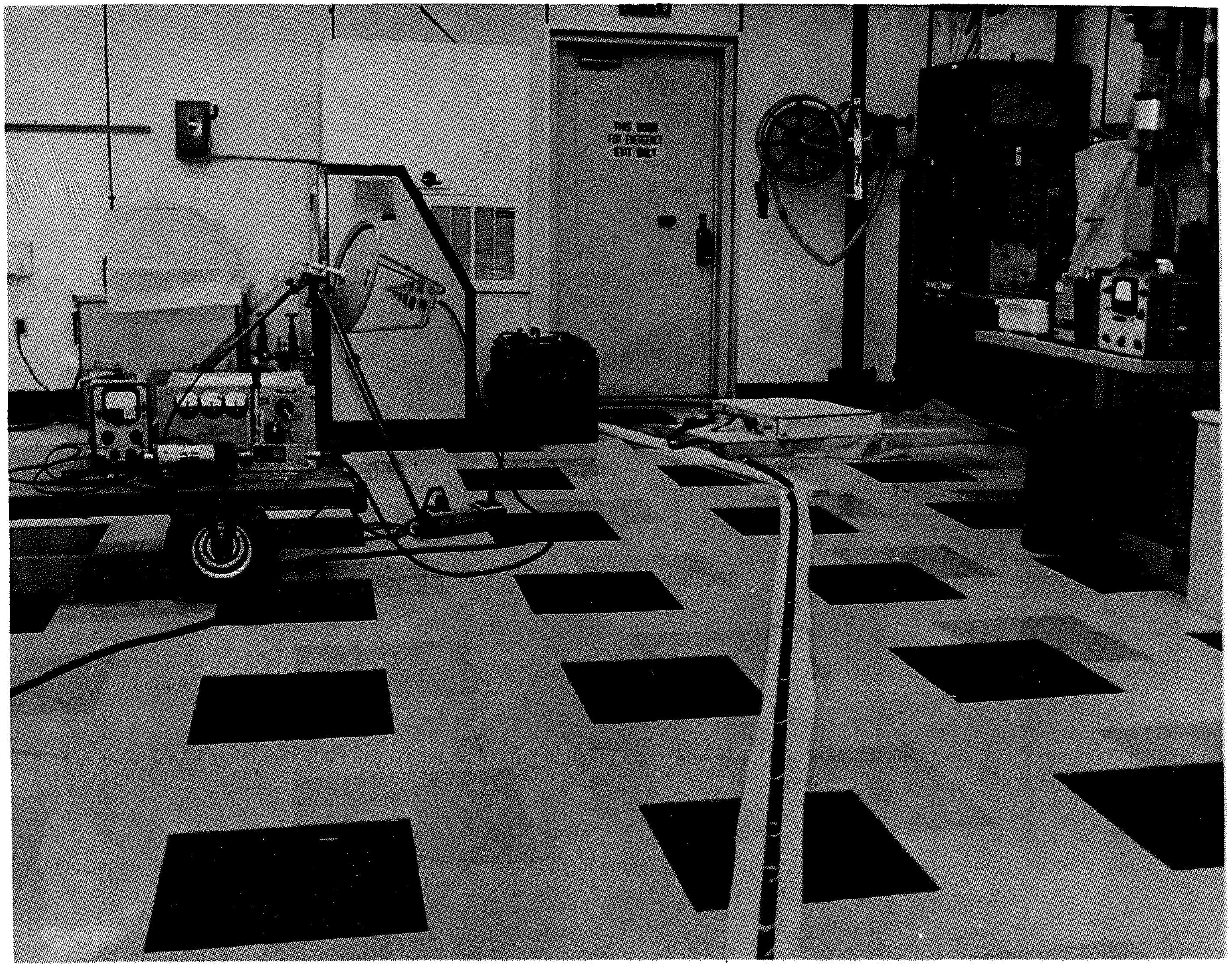

Figure 3 - Test Set Up Used for Experiment Data Simulation Program Test