Radio Frequency Fields Generated by the S-Band Communication Link on OV102

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Abstract

THE Plasma Diagnostics Package (PDP) flew as part of the Office of Space Science (OSS-1) mission aboard the Columbia on STS-3 in March 1982. The PDP had as part of its instrumentation an S-band antenna and detector. By utilizing the remote manipulator system (RMS) arm, the PDP was maneuvered through a predetermined computer-controlled sequence in the Orbiter X-Z plane above the upper quad and hemi S-band communications antennas. Measurements of the field strength of these antennas during high-power modes of the transmitters were made and compared to ground full-scale measurements and predictions. Results indicated a field strength approximately 4.8 ± 3 dB higher than measurements predicted. This rf field is due primarily to the quad PM transmitter which had a power output of approximately 115 W compared to 15 W for the hemi.

Contents

Instrumentation

A description of the detailed instrumentation of the PDP can be found in Ref. 1, and a detailed block diagram of the S-band field measurement system is available in Ref. 2. The system employs a broadband folded dipole antenna developed at the National Bureau of Standards for hf and uhf frequencies and parallel linear and log detector systems. Due to an rf relay failure, only data obtained from the linear detector are used in this analysis. The dynamic range of this linear detector configuration at the quad pm frequency of 2287.5 MHz is approximately 35 dB. The minimum detectable field along boresight is 1 V/m. The sensitivity at 2250 MHz (hemi transmitter frequency) is 4 dB greater.

Operation

Since the PDP was designed as an RMS probe for this flight, a special automated sequence was created to measure the S-band field strength above the cabin and Orbiter bay. This sequence is illustrated in Fig. 1. The PDP is shown on the end of the arm with the structure pointing downward being the S-band antenna. At each of the locations shown, the PDP was rotated about an axis parallel to the Orbiter Y axis (see Fig. 1). The rotation enabled the data taken to reproduce the PDP receiver antenna pattern, which had been measured in the lab, and thus to sort out that part of the data that was not reliable. This technique was useful since the Columbia's quad transmitter power was intermittent at times on this flight. The RMS sequence in Fig. 1 was run several times under different transmitter configurations. However, the data taken when the upper starboard quad and upper hemi antennas were selected at high power provided the highest field strength and thus are used in this report.

Data Analysis

Data reduction involved first sorting out those data which, by reproduction of the antenna pattern, appeared reliable. Next, an average electric field at the RMS position was calculated by correcting for the receiver antenna gain $G(\theta,\phi)$ to an equivalent field measured at boresight with gain $G(0,0)$.

Although the hemi and quad antennas were both active, the reduced power of the transmitter at 2250 MHz (15.5 W at 2250 MHz vs 114 W at 2287.5 MHz), plus the position of the PDP with respect to the hemi resulted in the primary response of the detector being due to the 2287.5 MHz quad signal in the first two cases listed in Table 1. However, for positions 2 and 3 some correction to received power was made due to received hemi power. Table 1 lists the four measurement positions that were illustrated in Fig. 1 relative to the starboard quad antenna.

Both sources of predicted field strengths, 49 V/m/R (Ref. 3) and 75 V/m/R (Ref. 2), assumed a measurement boresight with the transmitting quad antenna. Since none of the PDP data was at boresight, a correction for pattern of the trans-

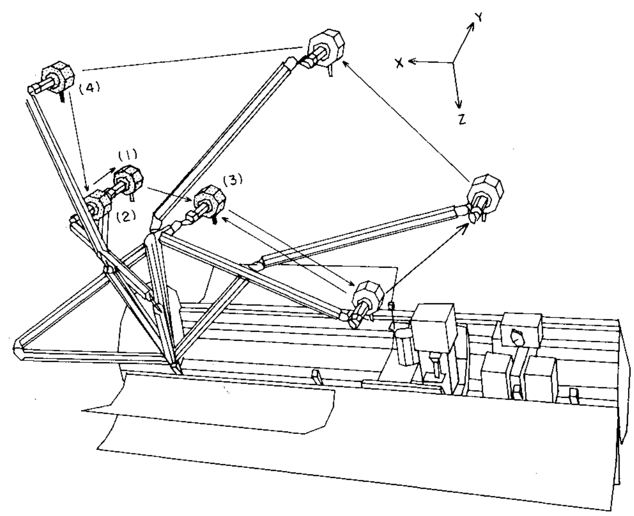

Fig. 1 Automode sequence 4: measurement points highlighted.

Table 1 PDP locations for starboard quad measurements

Position no.[a]	RMS position[b] X	Y	Z	ψ,[c] deg	R, m
1	−550	110	−650	52	4.3
2	−550	10	−650	83	4.4
3	−750	10	−650	86	6.5
4	−550	10	−850	74	9.3

[a] Position number corresponds to Fig. 1. [b] RMS position (in inches) in Orbiter body axis system (origin at nose of external tank). [c] ψ is angle from boresight of transmitting quad antenna.

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Table 2 Measured field intensity compared to predictions

Position no.	Measured field,[a] V/m	Predicted field[c] 75/*R*	50/*R*	Prediction error[d]
1	22.8 ± 2.4 dB[b]	13.8	9.2	± 1 dB
2	19.2 ± 3.5 dB	8.5	5.8	± 2 dB
3	8.5 ± 3.4 dB	5.1	3.4	± 2 dB
4	7.8 ± 2.6 dB	5.4	3.6	± 1 dB

[a]Corrected for receiving antenna gain and response to the lower power hemi transmitter. [b]Error includes measurement uncertainty plus calibration uncertainty. [c]Corrected for $G_t(\theta,\phi)$. [d]Only the error in correcting for $G_t(\theta,\phi)$ is included.

mitting antenna must be made. Utilizing measurements of the antenna pattern made on a full-scale half-model of the starboard quads[2] a normalization to boresight can be made. The angle of the PDP from boresight of the upper starboard quad is shown in Table 1 and the required correction in Table 2. By dividing by the distance of the PDP measurements (Table 1), an electromagnetic field normalized to the same units of these two models is obtained for comparison.

Table 2 summarizes the results of the four measurements along with their associated errors and compares the measured values with the predicted field at that distance and angle from the antenna.

Assumptions and Sources of Error

Calibration errors are most easily accountable and are estimated to total ± 2 dB.[2] Other sources of error involve uncertainty in correction of data for G_r (θ,ϕ) the receiving antenna gain, and $G_t(\theta,\phi)$ the transmitting antenna gain. The PDP receiving antenna gain function is not smooth and errors can be as great as ± 2 dB. Since detailed patterns of the transmitting quad given in Ref. 2 were a superposition of all quad antennas, correction factors for $G_t(\theta,\phi)$ at large θ and ϕ can be in error. The actual angle between transmitter boresight and the PDP is large in all cases (see Table 1), therefore, the correction for $G_t(\theta,\phi)$ could result in an error of ± 2 dB.

Summary

The average measured electric field at a given point (Table 2) is 4.8 dB higher than the Ref. 2 prediction corrected for distance and measurement position. Considering the calibration accuracy of the PDP receiver, assumptions about antenna gain, and the resulting magnitude of uncertainty in this measurement, the guideline driving design criteria for payloads manipulated by the RMS should be on the high side of prediction with a several decibel safety margin. It must also be noted that at no time during measurements made in the cargo bay did the S-band electric fields exceed 1 V/m.[4] More information about other sources of electromagnetic interference is available in Ref. 4.

Acknowledgments

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References

[1]Shawhan, S.D., Murphy, G.B., and Pickett, J.S., "Plasma Diagnostics Package Initial Assessment of the Shuttle Orbiter Plasma Environment," *Journal of Spacecraft and Rockets,* Vol. 21, July-Aug. 1984, pp. 387-391.

[2]Murphy, G.B. and Shawhan, S.D., "Report on S-Band Field Strength Due to Transmitters of the Columbia as Measured on STS-3," Department of Physics and Astronomy, University of Iowa, Iowa City, Iowa, Rept. 82-10, Rev. 1, May 1983.

[3]Reubens, A., "'Orbiter's Intentionally Generated RF Environment," NASA Johnson Space Flight Center, Houston, Tex., Internal Rept. Oct. 1980.

[4]Shawhan, S.D., Murphy, G.B., and Fortna, D.L., "Measurements of Electromagnetic Interference on OV102 Columbia Using the Plasma Diagnostics Packge," *Journal of Spacecraft and Rockets,* Vol. 21, July-Aug. 1984, pp. 392-397.