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Technical Memorandum 33-503

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CALIFORNIA INSTITUTE OF TECHNOLOGY
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PREFACE

The work described in this report was performed by the technical divisions of the Jet Propulsion Laboratory, under the cognizance of the Mariner Mars 1971 Project.

ACKNOWLEDGMENT

The information documented in this report was compiled by Albert G. Brejcha of the Telecommunications Division of the Jet Propulsion Laboratory.

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ABSTRACT

The Mariner Mars 1971 S-band antenna subsystem is used to transmit and receive S-band signals to and from the Deep Space Instrumentation Facility ground stations. The antenna subsystem consists of a low-gain antenna, a medium-gain antenna, a directional coupler, a high-gain antenna, and all transmission lines required to interconnect the antennas to the spacecraft radio frequency subsystem. The low-gain antenna is used to transmit signals during cruise and receive signals throughout the mission. The medium-gain antenna is coupled to the low-gain antenna via the directional coupler and is used to transmit and receive signals during Mars orbit insertion. The high-gain antenna is used to transmit high data rate signals primarily during Mars orbit.

I. INTRODUCTION

The Mariner Mars 1971 (MM'71) S-band antenna (SBA) subsystem baseline design was simply to incorporate the Mariner Mars 1969 (MM'69) design with the exception of two provisions, i. e., two shorter low-gain antennas (LGA) and a two-position high-gain antenna (HGA). However, about midway through the program, it was felt that the complexity of switching to a second LGA for real-time telemetry during Mars orbit insertion (MOI) was not within the limitations of the program. Because of this, the second LGA was deleted and a medium-gain antenna (MGA) and a directional coupler (DC) were added to the baseline design.

II. BASELINE DESIGN

The baseline design philosophy was to use the MM'69 design approach for the LGA and HGA (details of the MM'69 detail design can be found in Ref. 1). However, since the MM'71 HGA required a two-position pointing capability, instead of a fixed position like the MM'69, it was necessary to develop a flexible cable joint across the deployment hinge.

The polarizing section and radiating aperture of the MM'71 LGA are the same as those of the MM'69 LGA. The length of the circular waveguide between the feed subassembly and the polarizing section was reduced from 241.94 to 146.05cm (95.25 to 57.50 in.) in order to keep the antenna aperture out of the plum region of the propulsion engine. Because of the shorter waveguide, the septum pin spacing had to be redesigned. During the redesign, performance problems were encountered, i.e., the gain was somewhat lower and the ellipticity somewhat higher than that of the MM'69 LGAs. Because of cost limitations and schedule impact, the design was not optimized any further. A summary of the MM'71 performance is shown in Table 1 and Fig. 1.

The MM'71 HGA was identical to the MM'69 HGA. No new hardware was built since the left-over MM'69 HGAs were readily adaptable to the MM'71 spacecraft. The performance of the HGAs along with the MM'69 and MM'71 usage is summarized in Table 2. A typical pattern is shown in Fig. 2.

Because the HGA had a two-position pointing capability, it was necessary to develop a flexible RF transition across the deployment hinge. Keeping simplicity in mind, it was established that a small section of RG 142/B flexible cable would adequately serve the purpose (a similar technique was used on the Mariner Venus 67 HGA). However, a 4CT connector, which is used on the HGA and semi-rigid cables, did not exist for flexible cable. The design of the 4CT connector-flexible cable attachment was modeled after the Gremar connector (part number 6003), utilizing a center conductor encapsulation. Venting was provided to all regions within the connector which could possibly contain entrapped air. Extensive assembly-level qualification testing (vibration, ionization breakdown, flexing under temperature, and axial pull strength) was performed early in the program. The typical VSWR and insertion of the cable was 1.06 and 0.15 dB and 1.05 and 0.15 dB at 2115 and 2295 MHz, respectively.

III. CHANGES TO ORIGINAL BASELINE

Almost midway through the program, it was established that incorporating additional switching in the radio to switch to a second LGA for telemetry during MOI was too costly and complex. Therefore, a new design approach that had no impact on the radio was considered. The look angles back to Earth during MOI were constrained to a small angular area (a circle projected on a sphere, the diameter of which subtends an angle of 40 deg). This meant that an antenna with medium gain (≈14 dB) could be passively coupled into the LGA circuit via a 6-dB directional coupler which would yield an effective gain of 5 dB (which is a little more than required at Mars encounter) or greater over the angular area. (The 3-dB beamwidth of a 14-dB antenna is 40 deg.)

Several MGA design approaches were analyzed as follows:

(1) Turnstile over a ground plane.

(2) Conical spirals.

(3) Paraboloidal reflectors.

(4) Helices.

(5) Planner array (Surveyor HGA type).

(6) Conical horns.

The location of the MGA was to be between one of the solar panel outriggers; therefore, it was desirable to have an antenna with low sidelobe levels to minimize any spacecraft effect on performance. Also, packaging limitations were such that a high-efficiency antenna would be required since lack of gain efficiency could not be made up by increasing the aperture size. Because of these two major facts and the fact that the LGA design technology could be utilized to its maximum extent, it was decided that a conical horn would be the best approach to the MGA design. The resultant configuration is shown in Fig. 3. The throat section consists of a feed and polarizer that are identical to the LGA feed and polarizer. The horn has a diameter of 23.50 cm (9.25 in.) and flare angle of 34 deg. The total length of the antenna is 53.34 cm (21 in.). Table 3 summarizes the performance of the MGA, and Fig. 4 shows a typical radiation pattern.

Figure 5 shows the directional coupler that was designed to couple the MGA to the LGA. The principal design problem areas that were encountered were mechanical interfacing and mechanical tolerances. Mechanical considerations dictated the design for embedding the coupling bars in the dielectric. The connectors were threaded into bosses which were an integral part of the housing which in turn controlled the ground plane spacing. The dielectric was bonded to the aluminum ground planes. Only one of the dielectric sheets was machined to accept the coupling bars. All void areas were vented and tolerances were kept extremely tight in order to prevent an air gap between the two dielectric sheets. Assembly was difficult from the point of view of soldering. Solder joints existed at each of the rectangular to coaxial junctions which occurred at the transition from the parallel plate to coaxial configuration. A somewhat better technique would have been to extend the circular cross section of the connector line slightly into the parallel-plate region. This was considered too late to incorporate. A design improvement (also too late to realize) was to solder spring finger contacts to the rectangular bars similar in all respects to the bullet design which connects the center conductors of mating assemblies of the antenna subsystem. The connector center conductors would then simply slide onto and make contact with the coupler strip conductors. Soldering and assembly efforts would have been made significantly easier. However, incorporating these design improvements would have jeopardized SAF deliveries.

The connectors were exactly equivalent to the semirigid cable assembly connector (4CT). The external thread which joins the connector to the body was 5/16 - 24 UNEF-2A and was bonded to the body in the same manner that a connector shell was bonded to a threaded cable end.

The termination was a 50-Ω coaxial metal film resistor coated with a thin layer of quartz. The resistor was supplied by Filmohm Corporation (Part Number 5098) and, in fact, is also used in the radio frequency subsystem. The load housing cap has two vent holes in the end and was spot-bonded to prevent it from coming loose under dynamic loads.

The dielectric material was supplied by Rogers Corporation (Part Number RT/Duroid 5870). By a unique manufacturing process that coats glass microfibers with Teflon and then forms them into sheets by the building up of extremely thin laminations, a homogeneous blend of resin-encapsulated glass fibers and Teflon was formed. Greater stiffness and resistance to cold flow was thereby provided. The dielectric constant and loss tangent was 2.37 and 0.001, respectively, at 2.3 GHz, somewhat greater in both cases than Teflon.

The specification values of the losses, including coupling losses, was 1.2 ±0.2 dB for the LGA port and 6 ±0.2 dB for the MGA port. However, when the flight couplers were tested, it was found that the MGA port exceeded the specification value by about 1.0 dB. Upon investigation it was found that a design error had been made. The coupling arm spacing was 0.09 cm (0.035 in.) greater than it should have been. Since there was still adequate margin over the MGA with the additional 1-dB loss, a waiver was issued for accepting the couplers "as is." The performance of the directional coupler is summarized in Table 4.

IV. SPACECRAFT-CENTAUR RFI PROBLEM

Late in the program, during flight hardware fabrication, it was felt that a potential radio frequency interference (RFI) problem could exist between the spacecraft and Centaur. The reason for concern was that when the spacecraft was mounted to the Centaur, the MGA would be pointing directly at the Centaur guidance and destruct electronics. To resolve this problem several possibilities were considered:

(1) Keep the spacecraft radio off. This was discarded since this meant that the radio could not be turned on during launch checkout.

(2) Incorporate a switch into the MGA circuit.

(3) Incorporate an RF attenuation plug into the MGA horn to reduce the radiation to an acceptable level. The plug would then be ejected by means of a lanyard coupled to the solar panel deployment.

The third alternate was adopted for reasons of preserving cost and schedule impact.

The design of the RF attenuation plug was completed within three weeks from its conception. The plug is shown in Fig. 6. It was made up of two orthogonal fins which were 180-Ω carbon-impregnated fiberglass-resistance cards. The two springs served as the force to eject the plug. Figure 3 shows the plug in place. A release ring, which holds the two spring fingers, is kept from rotating by a lanyard coupled in tension to a solar panel. When the panel is deployed after spacecraft/Centaur separation, the lanyard tension is released and the release ring rotates; hence, the plug ejects. RF radiation intensity tests were performed at General Dynamics during the match-mate tests. The radiation levels measured were found to be acceptable. The plug attenuation and VSWR were 20 dB and 3.0 and 21 dB and 1.7 at 2115 and 2295 MHz, respectively.

REFERENCE

1. "Mariner Mars 1969 Project: Antenna Assembly," in Flight Projects, Space Programs Summary 37-54, Vol. I, pp. 31-40. Jet Propulsion Laboratory, Pasadena, Calif., Nov. 30, 1968.

Table 1. Performance data of Mariner Mars 1971 LGAs

Unit	Gain, dB		VSWR		On-axis ellipticity, dB	
	2115 MHz	2295 MHz	2115 MHz	2295 MHz	2115 MHz	2295 MHz
PTM	7.3	7.9	1.1	1.1	0.8	1.8
Flight 1	7.1	7.7	1.2	1.1	1.8	2.3
Flight 2	6.9	7.7	1.2	1.1	1.5	2.2

Table 2. Performance data of Mariner Mars 1971 HGAs[a]

MM'69 use	MM'71 use	Gain, dB	VSWR	On-axis ellipticity, dB
PTM	PTM	25.7	1.2	0.8
ATM	Flight 1	25.7	1.1	1.3
Flight spare	Flight 2	25.7	1.1	1.3

[a]Frequency = 2295 MHz.

Table 3. Performance data of Mariner Mars 1971 MGAs

Unit	Gain, dB		VSWR		On-axis ellipticity, dB	
	2115 MHz	2295 MHz	2115 MHz	2295 MHz	2115 MHz	2295 MHz
PTM	13.6	13.9	1.1	1.1	1.8	2.4
Flight 1	13.8	14.1	1.1	1.1	1.8	2.0
Flight 2	13.6	14.1	1.2	1.1	1.8	1.9

Table 4. Performance data of Mariner Mars 1971 directional couplers

Measured arms	Measured											
	PTM				Flight 1				Flight 2			
	VSWR		Loss, dB		VSWR		Loss, dB		VSWR		Loss, dB	
	2115	2297	2115	2297	2115	2297	2115	2297	2115	2297	2115	2297
Input	1.09	1.09			1.18	1.09			1.03	1.08		
Output	1.03	1.08			1.10	1.03			1.09	1.08		
Coupled	1.23	1.14			1.23	1.15			1.23	1.13		
Direct			0.997	0.997			1.05	1.02			1.17	1.09
Coupling			7.171	7.062			7.32	7.15			7.55	7.33
Directivity			20.9	19.9			19.1	19.7			19.8	20.8

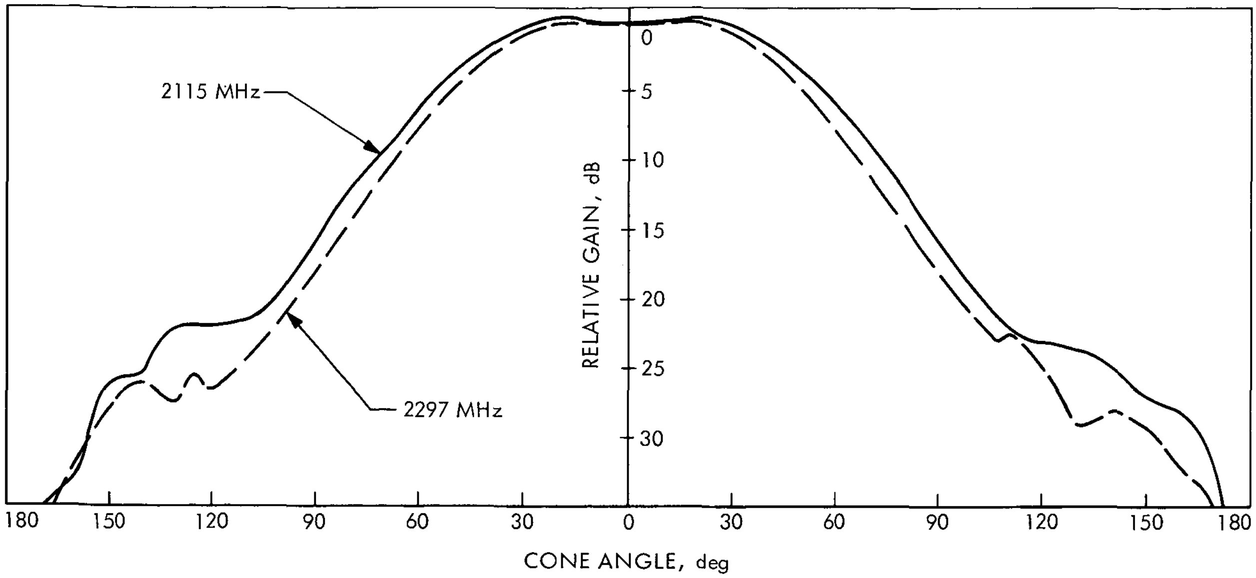

Fig. 1. Mariner Mars 1971 low-gain antenna radiation pattern

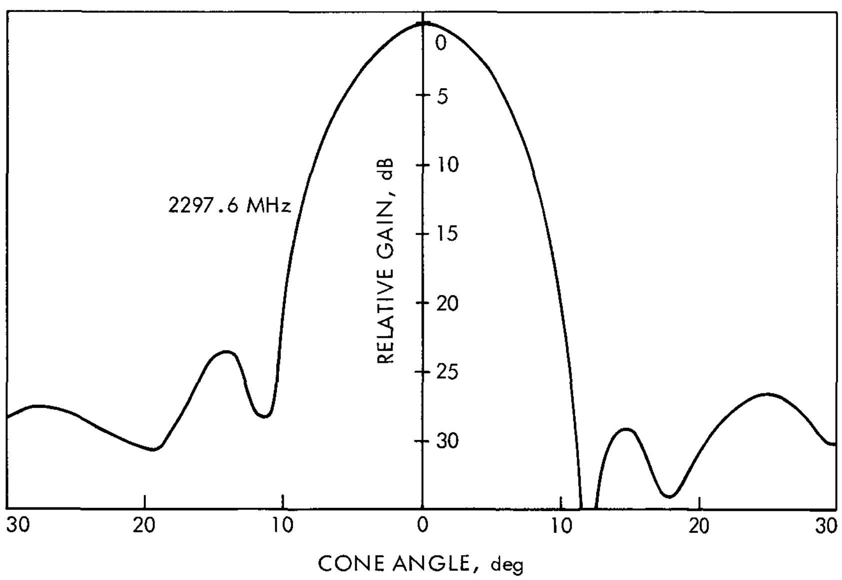

Fig. 2. Mariner Mars 1971 high-gain antenna radiation pattern

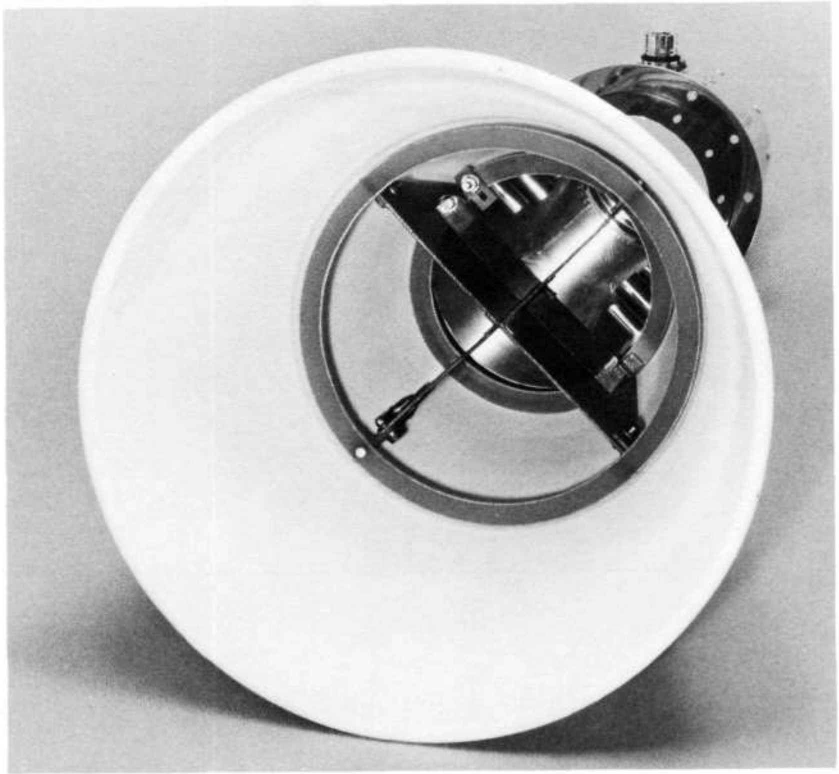

Fig. 3. Medium-gain antenna configuration

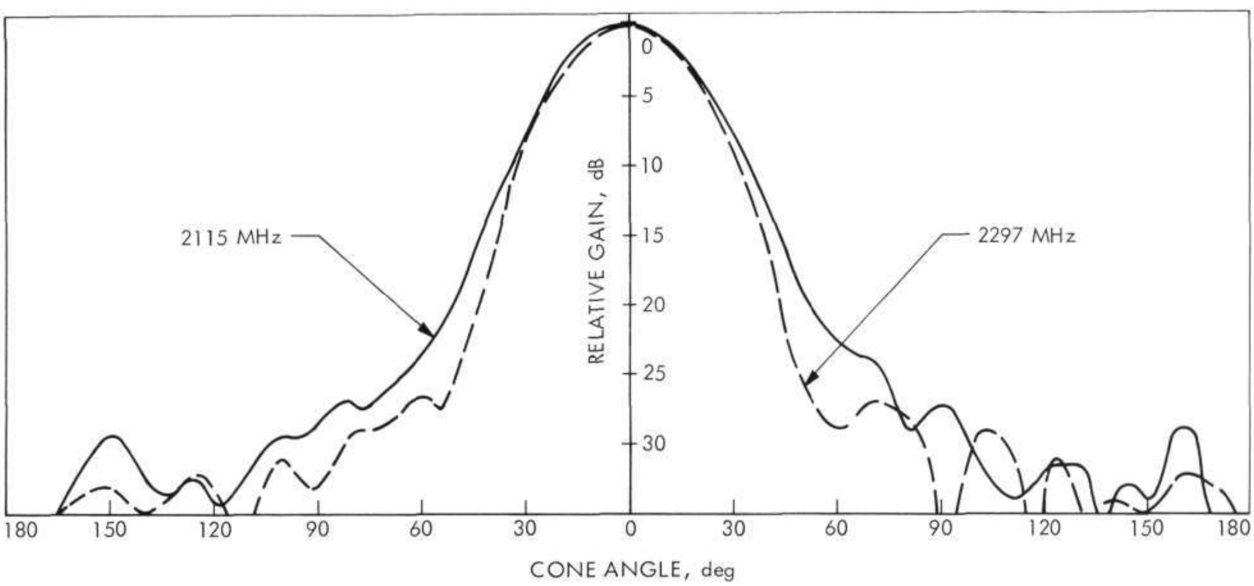

Fig. 4. Mariner Mars 1971 medium-gain antenna radiation pattern

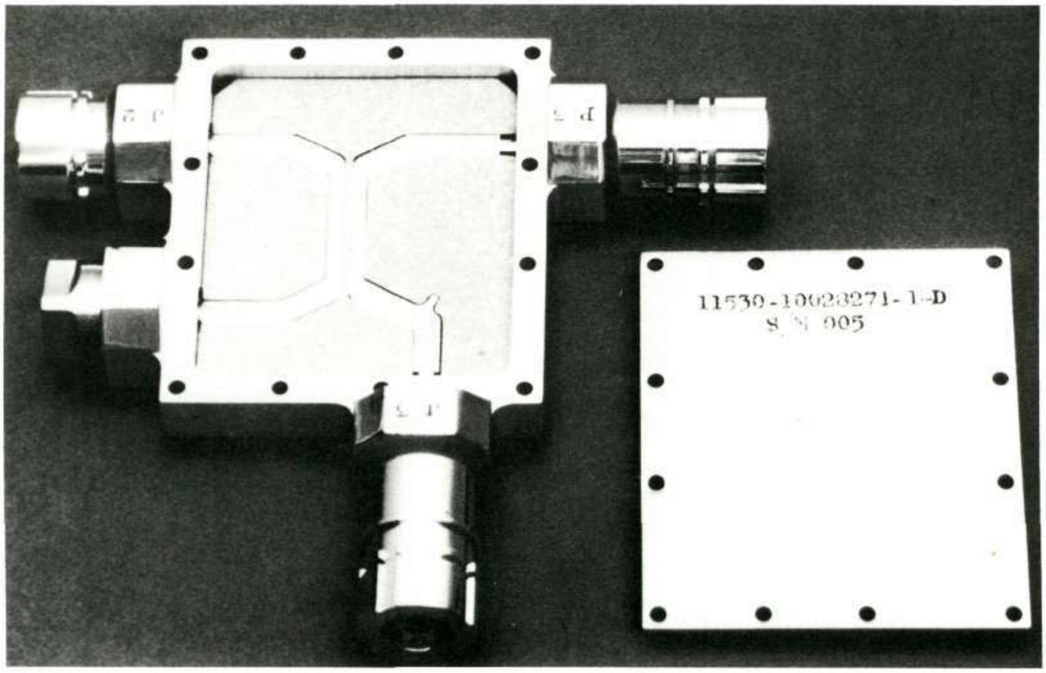

Fig. 5. Directional coupler

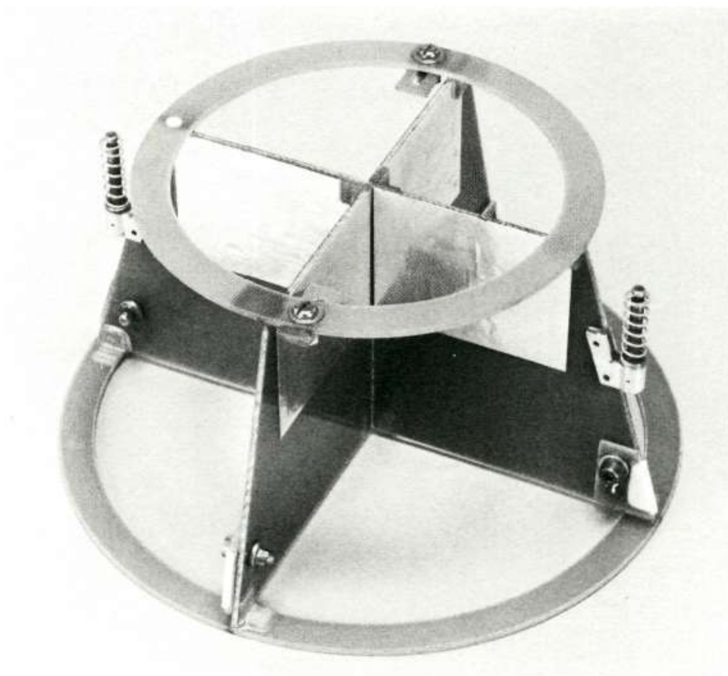

Fig. 6. Medium-gain antenna RF plug assembly