Design, Development and Testing of NASA's DART Radial Line Slot Array Antenna

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***Abstract*—The design, development and testing of NASA's DART Radial Line Slot Array Antenna (RLSA) High Gain Antenna (HGA) through the concept, prototypes, engineering, qualification and flight program is discussed. These antennas were designed for the X-band Deep Space Network (DSN) bands of 7.2 and 8.4 GHz.**

Keywords— Radial Line Slot Array, RLSA, NASA, DART, Double Asteroid Redirection Test

I. Introduction

DART is a planetary defense mission to test technologies for preventing an impact of Earth by a hazardous asteroid [1]. The primary science downlink on approach is a Radial Line Slot Array (RLSA) antenna. DART operates at the X-band DSN frequencies of 7.168 (Uplink) and 8.422 GHz (Downlink). There is approximately a 15% difference in frequency between uplink and downlink. An RLSA designed via the canonical methods have approximately a 3-5% bandwidth. Since deep space links typically have much higher downlink gain requirement than uplink gain requirement, we can design an RLSA with a much larger bandwidth, but reduced aperture efficiency at uplink to meet the requirements.

The basic design principles are presented in [2-4]. In summary a pareto optimizer is used to trade the total efficiency at uplink verse the total efficiency at downlink. The optimizer selects the slot geometry and layout for maximal efficiency along the pareto front from uplink to downlink.

II. DART Antenna Varients and Requirements

Multiple RLSA variants were fabricated and tested at APL. Figure 1 provides a pictorial summary of the DART RLSA antennas. The initial prototypes were based on a concentric array model with a waveguide feed. One prototype was designed for DART and the other for the Europa Lander program [2].

The concentric array phases the elements using a waveguide launcher with a circular polarizer as opposed to the spiral geometry with a coaxial launcher. It was initially believed that this design would yield a higher bandwidth since the phasing is no longer geometry dependent. Further prototypes would demonstrate that a spiral geometry can achieve very similar performance to the concentric array.

The RLSA antennas investigated in these prototypes were based on the requirements for NASA's Double Asteroid Redirection Test (DART) and Europa Lander mission concept studies. The Europa Lander concept was unique in that its telecom system is cross-linked so it can communicate with a relay spacecraft. Further studies of the Europa Lander concept without dielectrics were investigated in [3] and their designs were a step toward the development of the DART Engineering Model (EM).

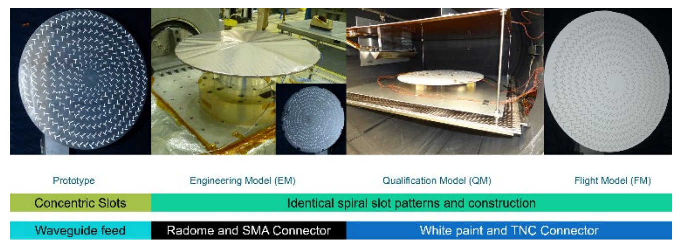

Fig. 1. RLSA Variant Fabricated under the DART Program

The DART EM, Qualification Model (QM), and Flight Model (FM) all used the same optimized slot pattern. The EM is different from the QM and FM models in that it used an SMA connector and radome for thermal control. The SMA connector was replaced with a TNC assembly for high power on the QM and FM units. These antennas also replaced the radome with white paint for thermal control as the radome introduced a few tenths of a dB of loss at downlink.

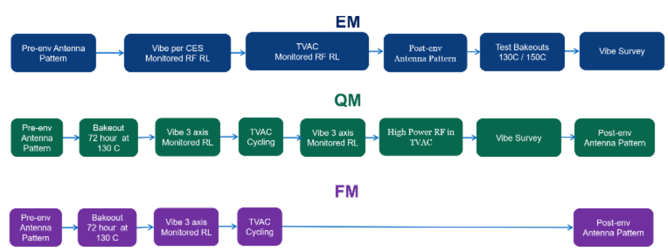

Fig. 2. DART Qualification and Acceptance Testing

Figure 2 summarizes the testing performed on the EM, QM, and FM units. The QM unit had a unique high power RF testing performed as a thermal balance test [5]. The QM RLSA was placed in a thermal vacuum chamber and excited with approximately 45 watts of RF power at 8.422 GHz. The unit was powered at a hot plateau and cold plateau. The data provided the delta temperature rise and was used to correlate thermal models for flight.

Table I summaries the electrical performance requirements for the DART Antenna. Table II summaries the electrical performance for the EM, QM, and FM antennas. All versions of the antenna had similar gain and return loss meeting the electrical requirements. The fabricated antennas also correlated well with simulations.

TABLE I. ELECTRICAL PERFORMANCE REQUIREMENTS

Technical Parameter:	Receive Band:	Transmit Band:
Frequency of Operation	7.168091821 GHz	8.421790124GHz
Polarization	LHCP	LHCP
Return Loss	≥ 12.5 dB, minimum	≥ 12.5 dB, minimum
Gain (Boresight ± 1 degree)	20.0 dBic	29.0 dBic
RF Power Handling	< 1 watt	65 Watts, typical

TABLE II. SUMMARY OF ELECTRICAL PERFORMANCE

Specification	**Simulation**	**EM Measurement**	**QM Measurement**	**FM Measurement**
Transmit Gain	29.7 dBic	29.8 dBic	29.8 dBic	29.9 dBic
Receive Gain	22.9 dBic	23.6 dBic	23.7 dBic	23.7 dBic
Transmit RL	-17.0 dB	-18.8 dB	-19.5 dB^2	-20.8 dB
Receive RL	-19.9 dB	-22.2 dB	-23.4 dB^2	-24.4 dB

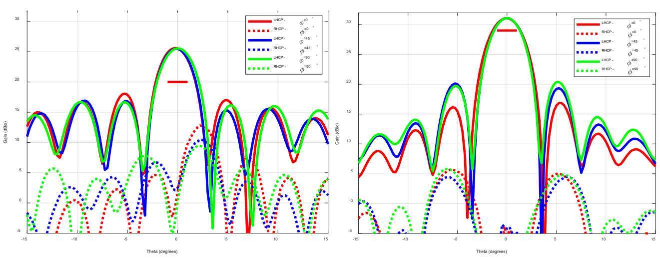

Fig 3. FM post-env radiation pattern. Left: 7.168 GHz, Right: 8.422 GHz

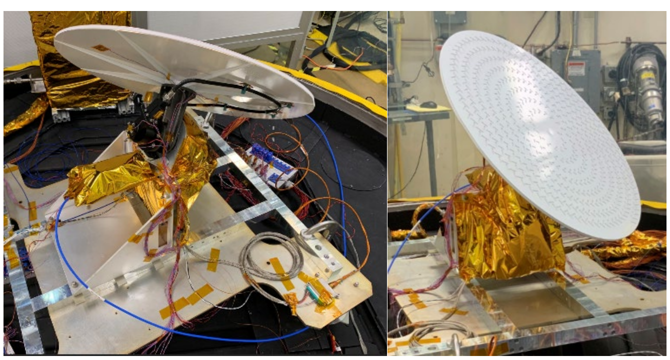

Fig. 4 Photograph of the HGAGA prior to TVAC door closure

Figure 3 shows the post-environmental radiation pattern of the FM antenna. The requirement line is shown in red in the figure. These results are nearly identical to the results reported for the QM in [4].

After the FM antenna completed acceptance testing it was incorporated into the High Gain Antenna Gimbal Assembly (HGAGA) shown in Figure 4. The HGAGA RF signal path is WR112 waveguide leading into a WR112 rotary joint, a waveguide to coax adapter, and a short section of TNC cabling. Testing consisted of various gimbal movements, a vibe test, and gimbal actuation during thermal vacuum testing. Figure 5 shows the HGAGA upink and downlink return loss over temperature during TVAC testing. The data was taken every 1 second during gimbal actuation and every 5 minutes otherwise. The HGAGA return loss is very stable over movements and temperature remaining less than -16 dB over all testing.

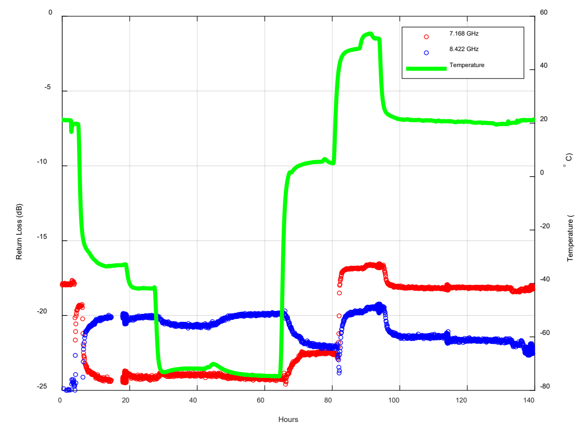

Fig. 5. HGAGA uplink and downlink return loss in TVAC

III. CONCLUSIONS

Multiple RLSA variants were fabricated and tested at APL. The EM, QM and FM variations of the DART antenna all met requirements and had very similar RF and mechanical performance. This RLSA is a light weight, low cost option for high gain antennas. Several RLSA DART copies were recently rebuilt for NASA's ESCAPADE mission. These copies followed a streamlined fabrication process and simplified test flow. RF performance of the antennas was nearly identical to the DART antennas.

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