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K-Band TWTA for the NASA Lunar Reconnaissance Orbiter

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Abstract

This paper presents the K-Band traveling wave tube amplifier (TWTA) developed for the Lunar Reconnaissance Orbiter and discusses the new capabilities it provides.

Introduction

The Lunar Reconnaissance Orbiter (LRO) is the first mission in NASA's Vision for Space Exploration, a plan to return to the moon and then to travel to Mars and beyond. LRO will launch in late 2008 with the objective to finding safe landing sites, locate potential resources, characterize the radiation environment, and demonstrate new technology.

The spacecraft will be placed in low polar orbit (50 km) for a 1-yr mission under NASA's Exploration Systems Mission Directorate. LRO will return global data, such as day-night temperature maps, a global geodetic grid, high-resolution color imaging and the moon's UV albedo. However, there is particular emphasis on the polar regions of the moon where continuous access to solar illumination may be possible and the prospect of water in the permanently shadowed regions at the poles may exist. After one year, the Orbiter will transition to a science phase under NASA's Science Mission Directorate (ref. 1). The Orbiter Program Office is located at NASA Goddard Spaceflight Center.

The K-Band data link transmits at 25.65 GHz with left-handed circular polarization, with rate 1/2, K = 7 convolutional and RS coding. The transmission rate is 228.7 Msps for normal operations (100 Mbps before coding) with contingency rates of 114.3 Msps (50 Mbps) and 57.2 Msps (25 Mbps). LRO uses a 75 cm combined S-band/K-Band high-gain antenna for the K-Band link, transmitting to an 18 m antenna at White Sands, New Mexico. Since the orbiter needs 40 W of RF power to provide adequate margin on the link, a TWTA was needed.

The LRO TWTA contract (ref. 2) is managed by the NASA Glenn Research Center as a continuation of the 32 GHz high power TWT program with L-3 Communications, Electron Technologies, Inc. (ETI), which produced a 180 W TWT (ref. 3). Two TWTAs were produced under the contract, a Flight Model and a Protoflight Model, which also functions as a spare.

TWTA Design

By basing the design of the LRO TWT on the 180 W TWT, we were able to provide a very robust TWT for the LRO mission very rapidly. The chief changes needed were to redesign the input and output couplers to connect to WR–34 instead of WR–28 waveguide, and to modify the helix design for the lower power and frequency. The TWTs are shown in figure 1.

The LRO TWT is a helix TWT with a four stage depressed collector, samarium cobalt periodic permanent magnetic focusing, and a tungsten/osmium cathode.

The Electronic Power Conditioner (EPC) design is based on the L-3 Communications, ETI standard 2300Hx series, with the necessary modifications to meet the LRO specifications. The most significant change was to the input filter and magnetics to reduce the conducted emissions of the EPC. The modifications reduced the conducted emissions by more that 20 dB, although the EPC is still short of the stringent MIL–STD–461C. The L-3 Communications ETI designation of the TWTA is Model 9835H.

The following tables compare the NASA specifications for the TWTA (table I) with the actual performance of the Flight TWTA (table II) and Protoflight TWTA (table III).

Except for the conducted emission, the Flight TWTA meets the NASA specifications. The Flight TWTA was delivered for integration into the Lunar Reconnaissance Orbiter communications subsystem in January 2008. The Protoflight TWTA meets the NASA specifications except for the conducted emissions and for the worst case DC power consumption. The Protoflight TWTA was delivered in April 2008.

Future Missions

A third TWT was built under this program (SN 203). The third TWT is being considered for the Communication Navigation and Networking Reconfigurable Testbed (CoNNeCT). The LRO TWTA design also serves as the baseline for the Lunar Communications Terminal (LCT).

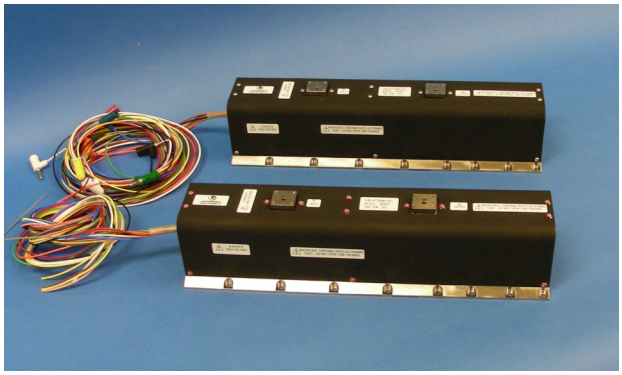

Figure 1.—Flight and protoflight TWTs.

TABLE I.—TWTA K-BAND TWTA SPECIFICATIONS

Parameter	NASA Specifications
Frequency band	25.5 to 25.8 GHz
Output power (CW)	40 W min.
Saturated gain	46 dB min.
Saturated gain flatness	0.5 dB max.
AM-to-PM	4.5°/dB max.
VSWR	2.0:1 max.
TWT efficiency	44 percent min.
Mass	3.5 kg max.
DC power	104 W max.
Overall efficiency	38.5 percent min.
Operating/mission life	14/26 mos.
Environment	Lunar orbit
Input/output ports	WR–34
EMI/EMC specification	MIL–STD–461C

References

1. http://lunar.gsfc.nasa.gov/mission.html
2. NASA Glenn Research Center Contract Number NNC04CB13C.
3. W. Menninger, N. Robbins, D. Dibb, and D. Lewis, "Power Flexible Ka-band Traveling Wave Tube Amplifiers of Up to 250-W RF for Space Communications," *IEEE Trans. Electron Devices*, vol. 54, no. 2, pp. 181–187, Feb. 2007.

TABLE II.—TWTA K-BAND TWTA SN 201 (FLIGHT MODEL) PERFORMANCE

Parameter	Performance
Frequency band	25.5 to 25.8 GHz
Output power (CW)	41.6 W min.
Saturated gain	48.93 dB min.
Saturated gain flatness	0.3 dB
AM-to-PM	3.3°/dB max.
VSWR	1.7:1 max.
TWT efficiency	49.5 percent min.
Mass	2.95 kg
DC power	94.6 W max.
Overall efficiency	44.0 percent min.

TABLE III.—TWTA K-BAND TWTA SN 202 (PROTOFLIGHT MODEL) PERFORMANCE

Parameter	Performance
Frequency band	25.5 to 25.8 GHz
Output power (CW)	41.0 W min.
Saturated gain	47.93 dB min.
Saturated gain flatness	0.1 dB
AM-to-PM	2.6°/dB max.
VSWR	1.81:1 max.
TWT efficiency	44.6 percent min.
Mass	2.95 kg
DC power	107.8 W max.
Overall efficiency	38.0 percent min.

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14. ABSTRACT
This paper presents the K-Band traveling wave tube amplifier (TWTA) developed for the Lunar Reconnaissance Orbiter and discusses the new capabilities it provides.

15. SUBJECT TERMS
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