



### K-Band Traveling-Wave Tube Amplifier

**This amplifier can be used for high-data-rate transmission from communications satellites.**

*John H. Glenn Research Center, Cleveland, Ohio*

A new space-qualified, high-power, high-efficiency, K-band traveling-wave tube amplifier (TWTA), shown in the figure, will provide high-rate, high-capacity, direct-to-Earth communications for science data and video gathered by the Lunar Reconnaissance Orbiter (LRO) during its mission. The TWTA is designed for 20 years of operational life, well in excess of the expected 7 years of mission life. It is a vacuum electronics device that is used to amplify microwave communications signals. TWTs are needed for high-frequency and high-power applications, such as communications from the Moon, because they have significantly higher power capability and efficiency than solid-state devices. Amplification in a TWT is by a factor of about 100,000. The RF power and data rate values for the LRO TWTA, when compared with other space based K-band transmitters, are an order of magnitude higher and represent a new state of the art.

Several technological advances were responsible for the successful demonstration of the K-band TWTA. A numerical model enabled manufacturing a wide-band TWT with high power output and efficiency leading to a first-pass design success. A dual-anode isolated-focus electrode electron gun enabled excellent focusing, which kept the power loss due to beam interception minimal over a wide range of voltage and current values. A WR-34 waveguide was used for the input/output couplers and larger,



A K-Band 40-W TWTA is shown here for the Lunar Reconnaissance Orbiter Mission.

thicker RF quartz windows, allowing operation not only at LRO frequencies but also at future near-Earth mission frequencies. Furthermore, it is more robust against mechanical shock and vibrations, and lowers the total attenuation of the signal in the waveguide run between the TWT output and the antenna. An external filter was developed to suppress the unwanted conducted emissions from the EPC (electronic power conditioner) to the spacecraft bus by greater than 20 dB.

The TWTA has successfully completed a vigorous spaceflight qualification effort, including random vibration testing and cycling between temperature extremes

that the hardware is expected to experience during mission operation. Other possible applications include high-data-rate transmission from geosynchronous communications satellites to Earth.

*This work was done by Dale A. Force, Rainee N. Simons, and Todd T. Peterson of Glenn Research Center, and Paul C. Spitsen of L-3 Communications Electron Technologies, Inc. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18443-1.*

### Simplified Load-Following Control for a Fuel Cell System

**A load-dependent voltage would be used to control a parasitic device.**

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A simplified load-following control scheme has been proposed for a fuel cell power system. The scheme could be used to control devices that are important parts of a fuel cell system but are sometimes characterized as parasitic because they consume some of the power

generated by the fuel cells.

The parasitic devices can include the following: a pump for circulating coolant to remove waste heat, pumps for circulating reactant gases and humidifying inlet gases, an electric heater for keeping the fuel cell stack

above a minimum operating temperature when the production of waste heat is insufficient for this purpose, and a centrifugal water separator. Operating these parasitic devices steadily at their full power levels would waste power, reducing the overall efficiency