A High Efficiency, Miniaturized Ka Band Traveling Wave Tube
Based on a Novel Finned Ladder RF Circuit Design

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Space communications architectures are being planned to meet the high rate data
distribution requirements of future NASA Enterprise missions. These will require the use
of traveling wave tube amplifiers (TWTAs) to provide the high frequency, RF power and
efficiency needed for many of the communications links. Future missions will also
employ smaller spacecraft with corresponding requirements of reduced size and weight
of the onboard communications systems. A program addressing these requirements is
currently underway at NASA Glenn Research Center (GRC)* for the development of a
high efficiency, 20 watt, 32 GHz TWT of reduced size and weight that is based on a
novel high gain slow-wave circuit design, termed the “finned ladder”. The goal is 60%
overall efficiency with efficiency enhancement resulting from computational
optimization of the RF circuit and multistage depressed collector designs and the use of
an electrically efficient cathode. Although a frequency of 32 GHz and a moderate RF
power of 20 W have been selected for development, the TWT can be readily scaled for
operation over a broad range of frequencies and power levels.

The finned ladder slow-wave circuit, designed using the computer programs MAFIA,
Microwave Studio (MWS) and GRC developed advanced optimization software, has an
exceptionally high gain per unit length. For operation at 6.8 kV and 32 GHz, the period
is on the order of 0.5 mm. A section of the RF circuit is shown in Figure 1. The very
high RF/electron beam interaction impedance (>100 ohms) enables more than 40 dB of
gain over a 5 cm length and an RF efficiency greater than 20%, which offers a significant
reduction in RF circuit length and the potential for TWT miniaturization. As shown in
the computer simulated (MAFIA) mode diagram in Figure 2, only the fundamental
forward wave mode is excited, indicating the absence of instability due to the backward
wave present in helical circuits. Cold test results show excellent agreement with the
computer simulated (MWS) dispersion curve (Figure 3).

One of the approaches being pursued for RF circuit fabrication is the stacking and
bonding of the period disk elements (alternating the active circuit elements containing the
beam tunnel with spacer elements). The unusual geometry, small dimensions (as small as
0.1 mm) and close tolerances (as small as 2.5 microns) of the RF circuit, require the use of microfabrication methods. Among the methods under investigation are photochemical machining, high precision laser machining and high precision Electric Discharge Machining (EDM).

Details on the finned ladder TWT design will be presented, as well as progress on the fabrication of the RF circuit.

Figure 1. 3D view of section of "finned ladder" periodic RF circuit

Figure 2. Computer simulated mode diagram (MAFIA)

Figure 3. Simulated (MWS) and experimental dispersion curves

*This work is supported by the NASA Computation, Information and Communications Technology (CICT) program (Code R)