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

E.G. Wintucky, J.D. Wilson, K.R. Vaden, D.A. Force, J.C. Freeman, G.G. Lesny
NASA Glenn Research Center, 21000 Brookpark Rd., Cleveland, OH 44135
Email: Edwin.G.Wintucky@grc.nasa.gov), Tel: 216-433-3510

C.L. Kory, C.T. Chevalier
Analex Corporation, 3001 Aerospace Parkway, Brook Park, OH 44142
Email: Carol.L.Kory@grc.nasa.gov, Tel: 216-433-3512

B. Ebihara
Consultant
Email: benebi@apk.net

J.A. Dayton
Consultant
Email: jd10423@aol.com, Tel: 216-961-1696

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 and technology demonstration, the TWT can be readily scaled for operation over a broad range of frequencies and power levels. For example, circuits designed for 10 W at 26.5 GHz and up to 35 W at 32 GHz are also being investigated.

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, ultra precision laser micromachining and ultra 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.

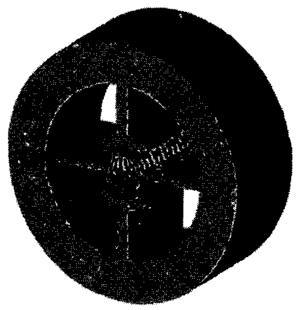

Figure 1. 3D view of section of "finned ladder " circuit

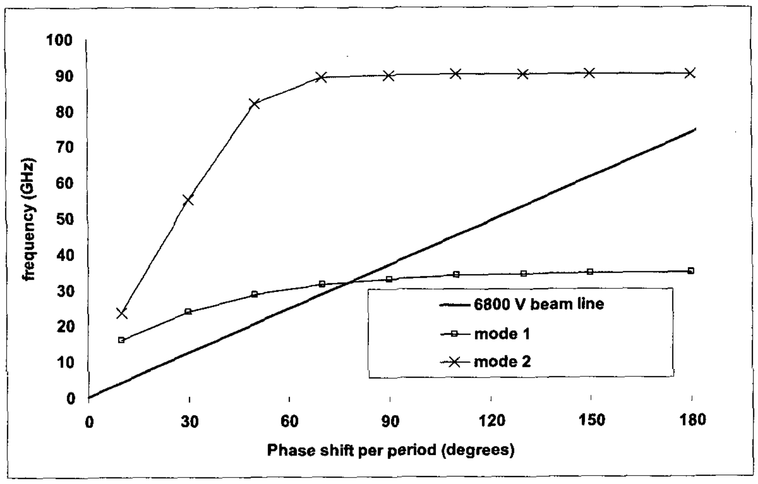

Figure 2. Computer simulated mode diagram (MAFIA)

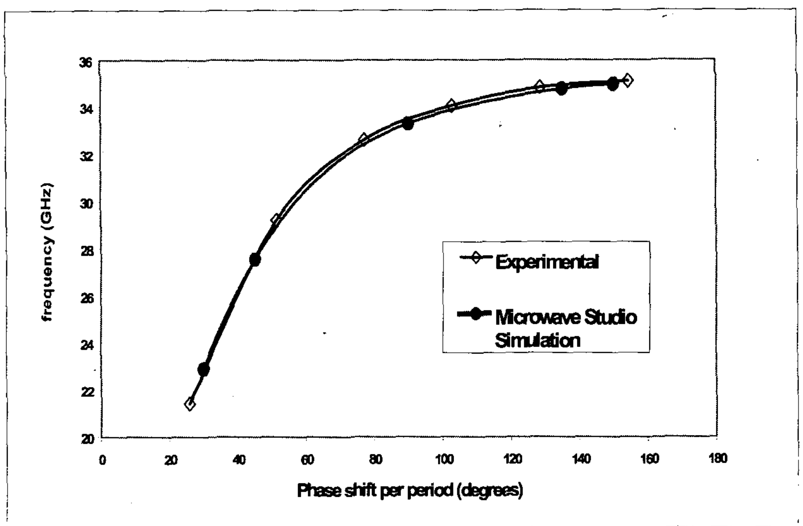

Figure 3. Simulated (MWS) and experimental dispersion curves

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