MICROWAVE TRAVELING WAVE TUBE AMPLIFIERS FOR SPACE COMMUNICATIONS SYSTEMS*

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INTRODUCTION

The need has become apparent for efficient and reliable high power microwave amplifiers for the Space Shuttle communications and tracking subsystems. Microwave output powers on the order of several tens of watts are required to reduce vehicle communications antenna size and achieve the most desirable subsystem configuration. Since microwave traveling wave tube amplifiers (TWTA's) have not only demonstrated high power capability for space application but also have the inherent characteristic of wide bandwidth, their selection to meet the need was in order. The wide bandwidth capability is most desirable for high data rate transmission of information. An additional factor, most important in the selection of a spacecraft amplifier, was that considerable improvement in the overall dc to rf conversion efficiency had been made under NASA sponsorship. The conversion efficiency is important to the spacecraft battery and/or solar panel requirements. The development of microwave traveling wave tube amplifiers specifically designed for Space Shuttle communications with Intelsat IV satellites could be accomplished utilizing presently available technology. Much of this technology is the result of several NASA-Langley sponsored programs to improve the conversion efficiency of space-type S-band traveling wave tubes and develop X-band traveling wave tubes for the international space research band as 8.4 GHz.

NASA studies on advanced data relay and tracking satellites have shown that improved communications performance can be obtained by extension of present microwave tube technology to K_u-band. Increasing the frequency of communications from C-band to K_u-band allows for an even wider bandwidth to permit the use of increased data rate transmission.

*This report was not presented at the conference.

BACKGROUND

The state-of-the-art traveling wave tubes which are presently available for spacecraft application have all evolved either directly or indirectly from NASA-Langley sponsored research programs and are summarized in table I. Initial improvement in the overall conversion efficiency of an S-band traveling wave tube (TWT) produced the WJ-274. This improvement was obtained by use of the overvoltage condition and by a tighter control on fabrication techniques and materials. The WJ-274, which achieved an efficiency generally in excess of 35 percent, represented quite an improvement at that time over other space-type TWT's whose efficiencies were in the 25-percent range. Its application to the Saturn program was achieved by NASA-Huntsville. Further improvement in the efficiency of the WJ-274 TWT was achieved under an additional research program resulting in efficiencies on the order of 42 percent using a positive tapered helix. Utilization of this improvement by Huntsville and JPL produced higher power versions of the WJ-274 with efficiencies greater than 40 percent at 50 watts (WJ-448) and greater than 45 percent at 100 watts (WJ-395). These tubes were developed as an advanced version of the Saturn TWT and the relay communications amplifier for Voyager, respectively. Designation of the space research band at 8.4 to 8.5 GHz prompted the development of a 20-watt X-band traveling wave tube amplifier for communications and telemetry use by NASA and other qualified users. The TWT (219-H) of the amplifier package has an efficiency of 35 percent. A list of the important characteristics of the complete TWTA (1153-H) unit is given in table II, and a photo of the amplifier package is shown in figure 1. The 1153-H X-band TWTA is presently on life test at NASA-Langley and has currently accumulated in excess of 9600 hours operation time with no change in output power.

DEVELOPMENT PROGRAM

Objectives

The objective of the Langley program is to develop microwave traveling wave tube amplifiers for the communications subsystem of the Space Shuttle vehicle utilizing presently available techniques and tube designs.

Approach

An engineering model (breadboard) of a C-band 100-watt traveling wave tube amplifier will be developed for the Space Shuttle communications subsystem and will be compatible with Intelsat IV. The main specifications of this tube are given in table III. This initial phase (phase I) will also produce firm specifications for amplifier design and assure compatible transmitter and antenna requirements. These specifications will also be used to generate the second phase of the development program (phase II), which will be the fabrication of

units for flight qualification and life testing. Upon completion of the C-band TWTA development phases, the same technology will be used to develop TWTA's at K_u-band for utilization of the Tracking Data Relay Satellite. This development will also involve subsequent qualification and life testing of flight units.

Current Status

Phase I of the C-band TWTA development program is presently being pursued. NASA-Langley contract number NAS1-10417 was awarded to the Hughes Electron Dynamics Division on November 10, 1970, to develop the engineering model of the 100-watt C-band TWTA. The TWT has been designated the 279 H, and the TWTA package is identified as the 1222 H. The unit will operate at approximately 100-watt rf output with less than 270-watt dc input and 42-percent efficiency over the band of 5.925 to 6.425 GHz. A hybrid cooling system consisting of heat pipes backed by a parallel conduction path for most efficient performance and maximum reliability will be used. Also the use of multi-stage depressed collectors is being investigated. At the present time, the electrical design of the first two tubes is complete, and the mechanical design is near completion. Their construction will be accomplished in the near future. The program schedule calls for all the experimental TWT's to have been built and tested by September 1971. Delivery of the complete TWTA package is expected near the end of 1971. However, final specification for the TWTA will be available before that time to allow the initiation of phase II of the development program for the fabrication of flight hardware for qualification and life testing.

TABLE I

STATE-OF-THE-ART SPACE TWT's*

TWT	FREQUENCY	POWER	EFFICIENCY	PROGRAM
WJ - 274	S-BAND	20 WATTS	35 PERCENT	SATURN
WJ - 448	S-BAND	50 WATTS	40 PERCENT	SATURN
WJ - 395	S-BAND	100 WATTS	45 PERCENT	VOYAGER
219 - H	X-BAND	20 WATTS	35 PERCENT	X-BAND TELEMETRY

* CONDUCTION COOLED

TABLE II

X-BAND 20W TWTA SPECIFICATIONS

20-WATT RF OUTPUT POWER

8400 - 8500 MHz

30-dB MIN. RF POWER GAIN

10-MHz B.W.

35-PERCENT MIN. EFF. (TWT)

85-PERCENT MIN. EFF. (PS)

TUBE WT.: 2-LB MAX.

TUBE SIZE: 80-IN^3 MAX.

PS WT: 5-LB MAX.

PS SIZE: 130-IN^3 MAX.

TABLE III

C-BAND TWT SPECIFICATIONS

FREQUENCY RANGE	- 5.925 TO 6.425 GHz
SATURATED OUTPUT POWER	- 100 ± 10 WATTS
RF GAIN	- > 33 dB AT SATURATION
EFFICIENCY	- TO BE MAXIMIZED
COOLING	- CONDUCTION
LIFE	- > 14,000 HOURS

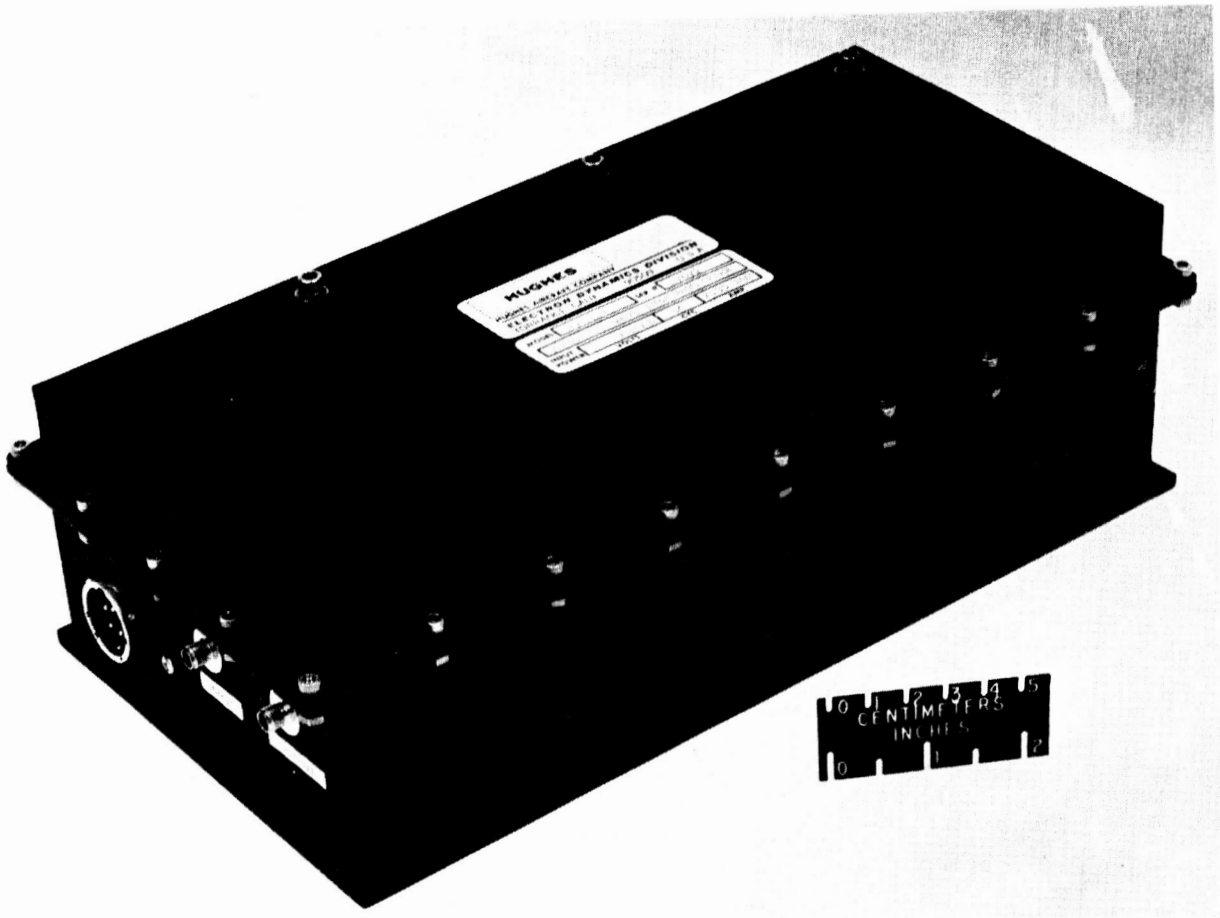

Figure 1. - The X-band 20-watt traveling wave tube amplifier.