XV. Spacecraft Radio

TELECOMMUNICATIONS DIVISION

A. Spacecraft Power Amplifier, *L. J. Derr*

1. Introduction

The electrostatically focused amplifier (ESFA) project is a portion of JPL's advanced development program for S-band (2295 MHz) spaceborne transmitter tubes. The work is being performed by the Klystron Department of EIMAC, Division of Varian Associates, under JPL Contract 951105 (SPS 37-37, Vol. IV, pp. 258–259; SPS 37-48, Vol. III, pp. 278–280).

2. Mechanical and Electrical Design

A fifth developmental tube has been fabricated and tested. This was the first of the experimental ESFAs to use a radiation-cooled collector system. The electrical design of tube 5 was similar in most respects to its water-cooled predecessor, tube 4, which had reached nearly all of the electrical design goals. The mechanical design, however, was changed significantly to accept the radiating cooling system and to conform to the intended final packaging design.

a. Radiating cooling system. The kinetic energy remaining in the spent beam of a klystron is converted to thermal energy in the collector element of the tube. Normally, this unwanted heat is conducted away by an external cooling system that may be either active or passive. The ESFA project supported the development of a collector-cooling system that efficiently radiates this heat directly through the vacuum envelope of the tube into its outside environment, whether atmospheric or vacuum, thus relieving the spacecraft cooling system of this significant thermal load.

The basic design is a collector element that is a thin tungsten egg-shell shape. One end is opened to admit the electron beam that, in turn, heats the tungsten shell to extremely high temperatures. The shell radiates this heat through a sapphire, infrared transparent window with the aid of a tantalum reflector. Prototypes of this collector system were tested earlier in the program and demonstrated radiating efficiencies of 80%.

Tube 5 was the first operating ESFA to employ the radiating collector and successfully demonstrated that this technique is usable. Figure 1 shows tube 5 under undriven conditions where its collector is operating at 1600°C. At this temperature, the collector is directly radiating 214 W of heat. Vendor measurements show that simultaneously 32 W is conducted back to the tube body. Also heating the body is the beam interception current, amounting to 18 W, and the heater power which is 4.3 W.

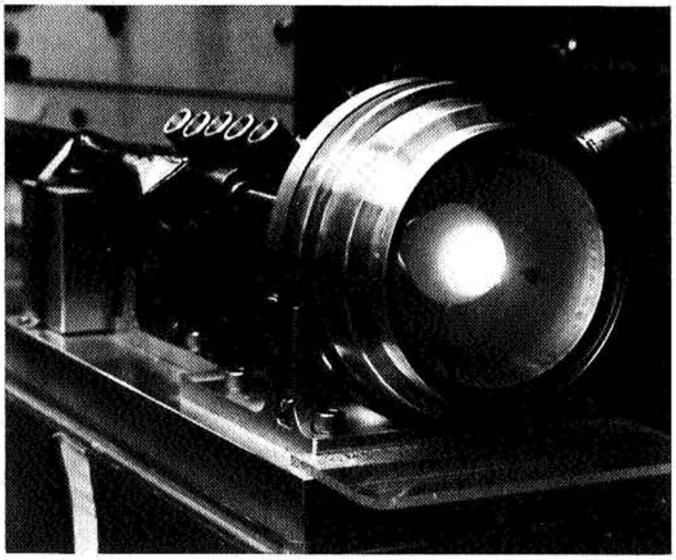

Fig. 1. Tube 5 operating in an RF undriven condition

This brings the total body heat to 54.3 W. Thus, the total tube, in this condition of operation, radiates its own generated heat with an efficiency of 75%.

Under RF driven conditions (100-W RF output), the beam is spread by RF fields and heats the collector more uniformly. The RF power output of the tube subtracts energy from the beam, and the collector temperature lowers to 1300°C. The intercepted body currents increase with the beam spreading, and the radiation efficiency of the collector decreases because of the lower collector temperature. Accurate thermal measurements have not yet been made in this condition of operation.

b. Electrostatic lenses. It is intended that all of the focusing lenses be connected to the cathode potential. In prior experimental tubes, each lens was brought out separately to evaluate its influence on confining the beam. The sizes of the lenses were refined in tube 5 so that it was possible to connect the first 5 (total of 8) directly to the cathode and yet obtain proper focusing fields. No RF feedback through the lens system was observed.

c. Helical resonators. The loaded Q of resonators 2, 3, and 4 was lowered from 270 to 150 to produce a smoother bandpass characteristic of the tube. This was accomplished by plating a thin coating of iron on a portion of each of the helical circuits. This successfully removed the high-Q ripples in the output bandpass of tube 5.

d. Electron gun. Dispenser cathodes have been used in all prior experimental models of the ESFA because of their ability to be reactivated after a tube has temporarily lost its vacuum. These cathodes require 12 W of heater power and do not possess the life capability for the specified 20,000 h. A long-life oxide cathode was designed for the final units, and the first one was installed in tube 5. It provided full beam power and required only 4.3 W of heater power.

3. General Tube Performance

The electron gun in tube 5 was misaligned during its assembly. The beam was thereby directed out of the focusing axis, which resulted in heavy interception on the helical circuits of resonators 5, 6, and 7. The resulting heat that was created evaporated the helix brazing material which redeposited on the surrounding insulator rods. After locating the beam by thermal profile measurements, it was centered in the tube by external magnets. Subsequent RF tests made at the 100-W output level indicated the gain to be 40 dB and the bandwidth at 30 MHz. The damaged resonators, however, lowered the electronic efficiency to 34%, whereas prior tubes had produced 45% at the same operating point.

4. Future Tasks

Tube 5 will be rebuilt, using new helical resonators and a new electron gun. Its output cavity and radiating collector will be used again, since no damage occurred in these elements. Heliarc seals will be used in place of brazed joints in several areas to ensure better alignment of the component parts. Tube 5 is scheduled to finish its refurbishing cycle late in November 1968.