V-2. An X-Band Parametric Amplifier with Closed-Cycle Cooling

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The objective of the work described here was to develop a system-oriented closed-cycle cooled parametric amplifier using a commercially available cooler. The desired characteristics were: tuning range, 7.0 to 8.0 Gc; instantaneous bandwidth, 20 to 30 megacycles; effective noise temperature, about 70° Kelvin including the uncooled X-Band four port circulator. The compatibility for use, at a later date, of more complex multistage coolers to allow cooling of the circulator and parametric amplifier combination, was also an important consideration.

This paper describes the means employed to achieve the foregoing objectives and includes a discussion of the amplifier design, its noise figure, cooling approach, and characteristics obtained.

The amplifier was designed using a commercially available gallium arsenide diode having a spreading resistance R_s of approximately 2.0 ohms and a dynamic quality factor γQ of about 7.5 at room temperature. The generator impedance was adjusted to approximately 15.0 ohms for optimum noise performance consistent with high gain in the manner prescribed by Blackwell and Kotzebue.[1] A pump frequency of 23.8 Gc was chosen. This choice is well below the optimum predicted by Blackwell and Kotzebue for optimum noise performance. Several reasons dictated this choice. First, at reduced temperatures, the choice of the optimum pump frequency becomes less important; second, excessive power dissipation and resultant diode junction heating at too high pump frequencies has been observed; finally, stable two-cavity klystrons, operating at 23.8 Gc with adequate power, are readily available.

The amplifier body was constructed of tellurium copper because of its very good thermal and electrical conductivity. Cool-down time and resistive losses were both minimized by this choice. The amplifier was thermally isolated from its surroundings by using thin-walled stainless steel waveguides and coaxial lines for pump and signal connections, respectively.

In order to minimize heat flow into the amplifier, a novel method of mounting the amplifier within the evacuated container was devised. Several thin stainless steel wires were attached radially to the amplifier body and then to the wall of the container. The amplifier is held rigidly in place by these wires and the stainless steel rf transmission lines.

A cross-section drawing of the amplifier is shown in Fig. 1. Figure 2 shows the amplifier inserted into the vacuum insulated container for cooling purposes.

As shown in Fig. 1, the amplifier design consists of a short coaxial line terminated in the varactor, and a signal tuning circuit consisting of a shorted section of coaxial line which is adjusted to resonate the diode at the signal frequency. A low-pass filter is incorporated in the signal line to prevent

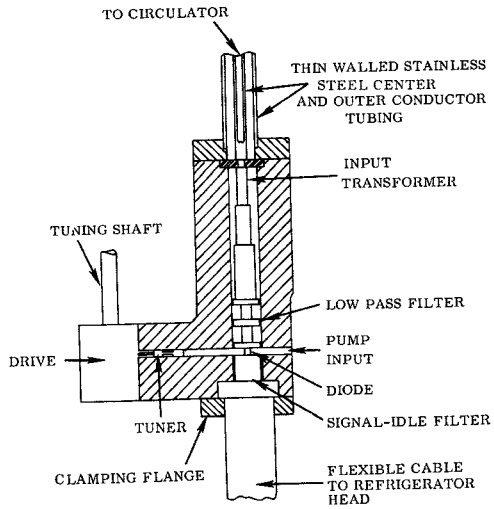

Fig. 1. Amplifier cross-section.

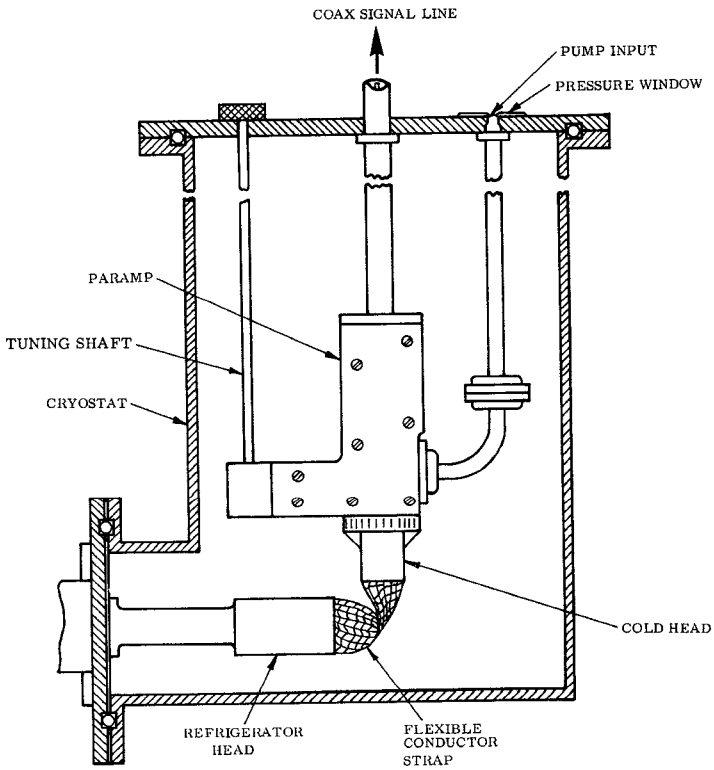

Fig. 2. Amplifier mounted in vacuum insulated container.

pump leakage and to restrict the idler circuit primarily to the diode. The amplifier idle circuit is tuned by an adjustable short circuit. A right angle drive is used to allow the idle tuning shaft to enter the container at one end. This shaft is made of thin-walled stainless steel tubing for thermal isolation purposes.

The cold head of the closed-cycle cooler protrudes into the container near the "diode" end of the parametric amplifier, and thermal contact between the refrigerator and the amplifier body is achieved by use of a flexible copper strap similar to a battery strap. Typical characteristics achieved with the amplifier are given in Table I.

TABLE I.

Amplifier Characteristics

Tuning Range	7.0 to 8.0 Gc
Amplifier Structure Temperature	$\approx 40^{\circ}$ Kelvin
Effective Noise Temperature (including uncooled circulator losses)	70° Kelvin
Instantaneous Bandwidth	$\approx$ 25 megacycles
Gain	20 db

REFERENCE

1. L. A. Blackwell and K. L. Kotzebue, *Semiconductor Diode Parametric Amplifiers*, (New York: Prentice Hall, 1961) pp. 60-66.

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