Title

A NEW ABSOLUTE NOISE THERMOMETER AT LOW TEMPERATURES

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Varactor Diode Amplifier at Liquid Helium Temperature*

Previous experiments with parametric amplifiers[1,2] have indicated that the effective input noise temperature of the amplifier can be substantially reduced by refrigerating the amplifier down to liquid nitrogen temperature. It was also found that the noise temperature of the amplifier with a gallium-arsenide diode decreased almost linearly as the amplifier temperature was lowered from room temperature to 40°K.[3] Our recent investigations of the junction capacitance of gallium-arsenide diodes have shown that the change in junction capacitance from liquid nitrogen temperature to liquid helium temperature is much smaller than that from room temperature to liquid nitrogen temperature; similar results have also been obtained with some epitaxial silicon diodes. It has also been found that the dynamic quality factor $\tilde{Q}$ of gallium-arsenide diodes improves continuously down to liquid helium temperature. Blake and others at the MIT Lincoln Laboratory have recently measured 10°K excess noise temperature for an *L*-band parametric amplifier operated at liquid helium temperature.[4] This correspondence presents the experimental results of a 4-Gc parametric amplifier at liquid helium temperature.

The input impedance loci of the 4-Gc amplifier with a gallium-arsenide diode measured at three different temperatures, *i.e.*, 298°K, 77°K and 4.2°K, as a function of bias voltage are shown in Fig. 1. All three impedance loci were measured at 4.17 Gc with all circuit conditions maintained constant for the entire experiment. Notice that the resonant bias voltage shifted from −1.25 v at 298°K to −0.94 v at 77°K and to −0.85 v at 4.2°K. From the capacitance measured at room temperature and the data in Fig. 1, one can determine the effective diode capacitance at each temperature. The series resistance R_s also decreased as the temperature was lowered to liquid helium temperature, as is shown by the increase in the VSWR at the resonant point as the temperature is reduced.

The 4-Gc nondegenerate parametric amplifier was operated successfully at liquid helium temperature. The effective input noise temperature of the amplifier, including the insertion loss of the room-temperature circulator and a 17-inch-long input coaxial line, was less than 24°K; of this, only 2°K is believed to be due to the amplifier itself. Fig. 2 shows a photograph of the amplifier. The amplifier mount is identical to that of the amplifier for the Telstar ground station receiver.[2] The external idler load is removed, however, to accommodate the amplifier to an available helium dewar. The input frequency is 4.17 Gc and the pump frequency is 23 Gc. The varactor diode used in this amplifier is the gallium-arsenide point-contact diode originally developed by W. M. Sharpless and further developed by N. C. Vanderwal.[5,6] The experimental results are tabulated in Table I.

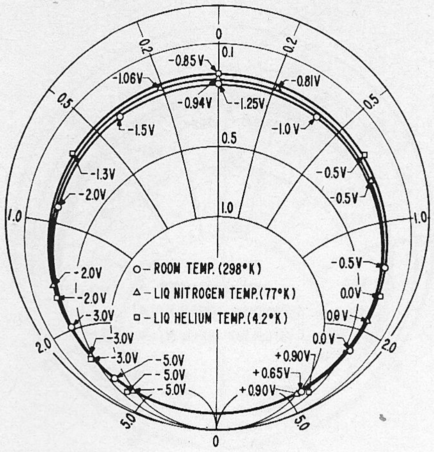

Fig. 1—Input impedance loci of 4-Gc parametric amplifier as a function of bias voltage.

The accuracy of noise-temperature measurement is believed to be ±3°K. The noise figure of the mixer and IF amplifier was 8.3 db and the theoretical noise temperature was calculated based on the measured R_g/R_s.[7] The pump power required for 20-db gain was 30 mw at the input of the dewar. The pump circuit was tuned from outside the dewar and only a few milliwatts were dissipated in the amplifier.

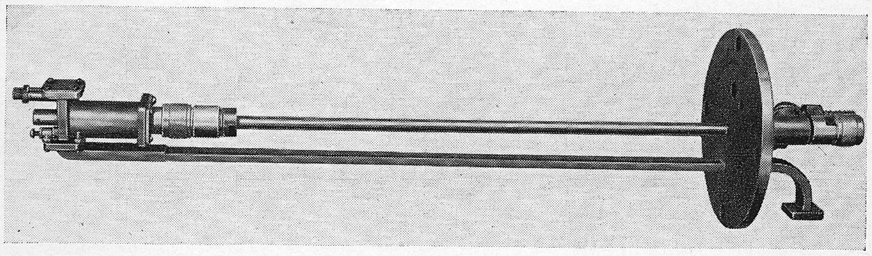

Fig. 2—Photograph of 4-Gc parametric amplifier.

TABLE I

Amplifier temperature (°K)	298	77	4.2
Dynamic quality factor $\tilde{Q}_1$ at 4.17 Gc	9.4	11.6	12.0
Normalized generator impedance R_g/R_s	5.0	5.4	5.9
Measured over-all noise temperature (°K)			
at 20 db gain	192	79	42
30 db gain			24.5
35 db gain			23.5
Noise temperature, paramp only (with 17″ line) (°K)	154	46	9.0
Calculated noise temperature at 20-db gain (without 17″ line) (°K)	154	38	2.0

In a future experiment, the amplifier together with a circulator will be refrigerated down to liquid helium temperature. We believe that the over-all noise temperature of the parametric amplifier will be as good as that of the maser. The parametric amplifier has definite advantages over the maser, *i.e.*, broader bandwidth, higher saturation power level, lower pump frequency and power, and a simpler cryogenic system because the operating temperature is not critical.

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* Received October 26, 1962.

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