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Cryogenic Performance of DRP 12 GHz MMIC Amplifier

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1. Introduction

This report describes the cooled performance of a two stage monolithic microwave integrated circuit (MMIC) amplifier designed and fabricated by the Solid State Devices group at the CSIRO Division of Radiophysics (DRP). This device was not designed for cryogenic operation: it was designed as the gain element of a room temperature balanced amplifier.

The amplifier unit supplied by the Solid State Devices group has SMA connectors for the RF input and output, and four feed throughs to bias the HEMTs in the MMIC. The amplifier has 50Ω resistors in series with the HEMT drains. In this report I have used V_{DS} and I_D to denote *terminal* voltages and currents measured at the feedthroughs.

Figs 1. and 2. show the amplifier performance plots supplied by the Solid State Devices group. The amplifier operates best at around 12 GHz with the HEMTs biassed at $V_{DS} = 5$ V and $I_D = 17$ mA.

2. Amplifier Performance

Fig. 3 shows the room temperature gain and return loss of the amplifier at $V_{DS_1} = V_{DS_2} = 4.5$ V and $I_{D_1} = I_{D_2} = 11$-17 mA. To maximize the gain, the amplifier was biassed with $I_{D_1} = I_{D_2} = 13$ mA. At this bias the amplifier had a gain greater than 8 dB in the range 12 - 14.5 GHz, an input return loss greater than 4 dB in the range 11.5 - 13.5 GHz and an output return loss greater than 10 dB in the range 12.5 - 16 GHz.

The amplifier was placed in a test dewar to measure the performance at cryogenic temperatures. Fig. 4 shows the variation in amplifier gain, at 13 GHz, as the amplifier was cooled. The amplifier was measured with $V_{DS_1} = V_{DS_2} = 4.5$ V and $I_{D_1} = I_{D_2} = 13$ mA. The measurements have been corrected for the estimated loss in the input isolator and input and output coaxial lines and hermetic SMA feed-throughs. The room temperature isolator loss at 13 GHz is 0.25 dB, and is assumed to be independent of frequency. The coaxial line losses decrease from 1.1 dB at 300 K to an estimated 0.8 dB when the amplifier is operating at 20 K.

Varying the HEMT drain-source voltages and drain currents (with $V_{DS_1} = V_{DS_2}$ and $I_{D_1} = I_{D_2}$) showed that the minumum noise, at 12 GHz, for the amplifier operating at 19 K, occurred at $V_{DS_1} = V_{DS_2} = 4.2$ V and $I_{D_1} = I_{D_2} = 17$ mA. Note that with $I_{D_1} = I_{D_2} = 17$ mA, there is a voltage drop of 0.85 V across the 50Ω resistors in series with the HEMT drains, so the HEMTs have only 3.35 volts on their drains.

Figs. 5 and 6 show the variation in amplifier gain and noise temperature with drain-source voltage and drain current. The measurements were made with the amplifier operating at 19 K and have been corrected for the estimated loss in the input and output coaxial lines and hermetic SMA feedthroughs as shown in Table 1. The amplifier noise temperatures have also been corrected for loss in the input isolator, which contributes about 9 K at the noise minimum.

Fig. 7 shows the amplifier gain and noise temperature, at 19 K, with $V_{DS_1} = V_{DS_2} = 4.2$ V and $I_{D_1} = I_{D_2} = 17$ mA. The measurements have been corrected for the estimated input and output losses (assumed independent of frequency) at 12 GHz.

Fig. 8 shows the variation in amplifier gain and noise temperature, at 12 GHz, as the amplifier was warmed up with $V_{DS_1} = V_{DS_2} = 4.2$ V and $I_{D_1} = I_{D_2} = 17$ mA. The measurements have been corrected for the estimated input and output losses. No room temperature noise measurements were made as the amplifier did not survive the site power outage which occurred on the morning of November 21, 1995.

3. Conclusion

These tests have shown that the device technology used by the Solid State group can be successfully cooled. Although this MMIC amplifier was designed for use in a room temperature balanced amplifier, it can be cooled and has surprisingly good gain and noise performance when operated at cryogenic temperatures.

Lossy RF component	Loss for amplifier operating at 290 K (dB)	Loss for amplifier operating at 19 K (dB)
Input hermetic SMA feed through	0.16	0.16
Input coaxial line	0.39	0.25
Input isolator	0.35	0.35 (est.)
Output coaxial line	0.69	0.55 (est.)
Output hermetic SMA feed through	0.16	0.16
Total	1.75	1.47

Table 1. Losses, at 12 GHz, associated with the connection of the MMIC amplifier to the input and output flanges of the test dewar.

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Packaged re-designed Michael Goonan amp file

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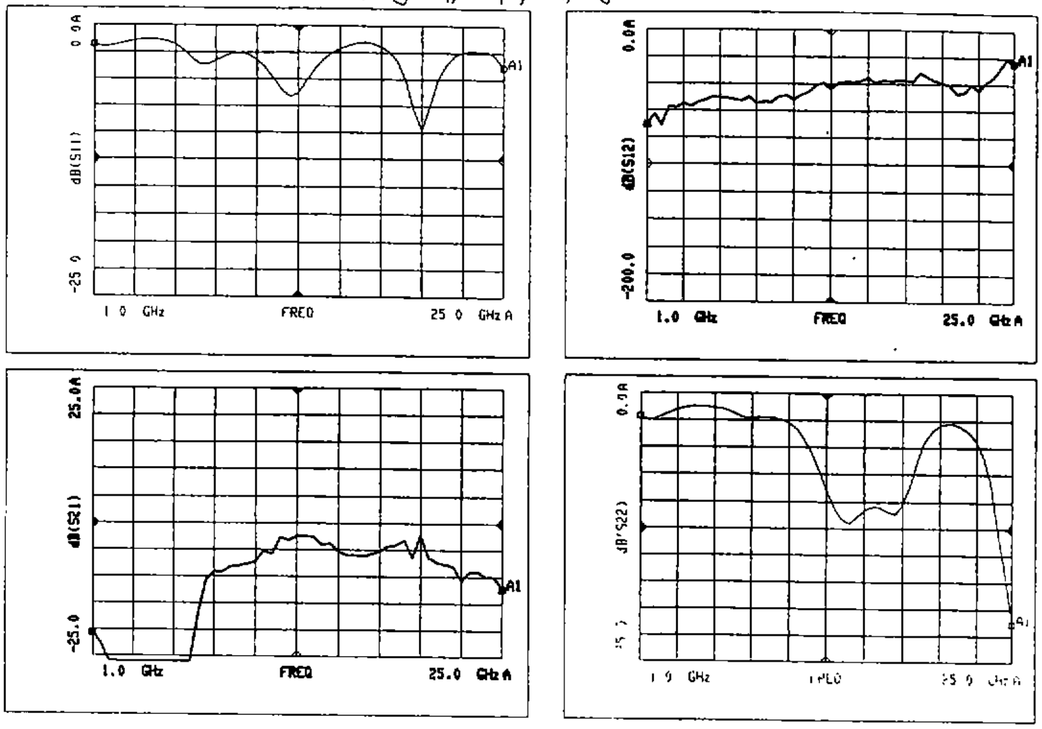

RF power = -5.0dB

Bias Conditions:

V_{d_1} = 3.5V
I_{d_1} = 10.3mA
V_{g_1} = -0.805V
I_{g_1} = -13.1μA

V_{d_2} = 3.5V
I_{d_2} = 10.3mA
V_{g_2} = -0.56V
I_{g_2} = -0.65μA

Fig. 1. Amplifier performance plots supplied by the Solid State Devices group ($V_{DS_1} = V_{DS_2} = 5.0$ V, $I_{D_1} = I_{D_2} = 10$ mA).

Dataset=amps Qualifier=▨

Packaged re-designed Michael Goonan amp file

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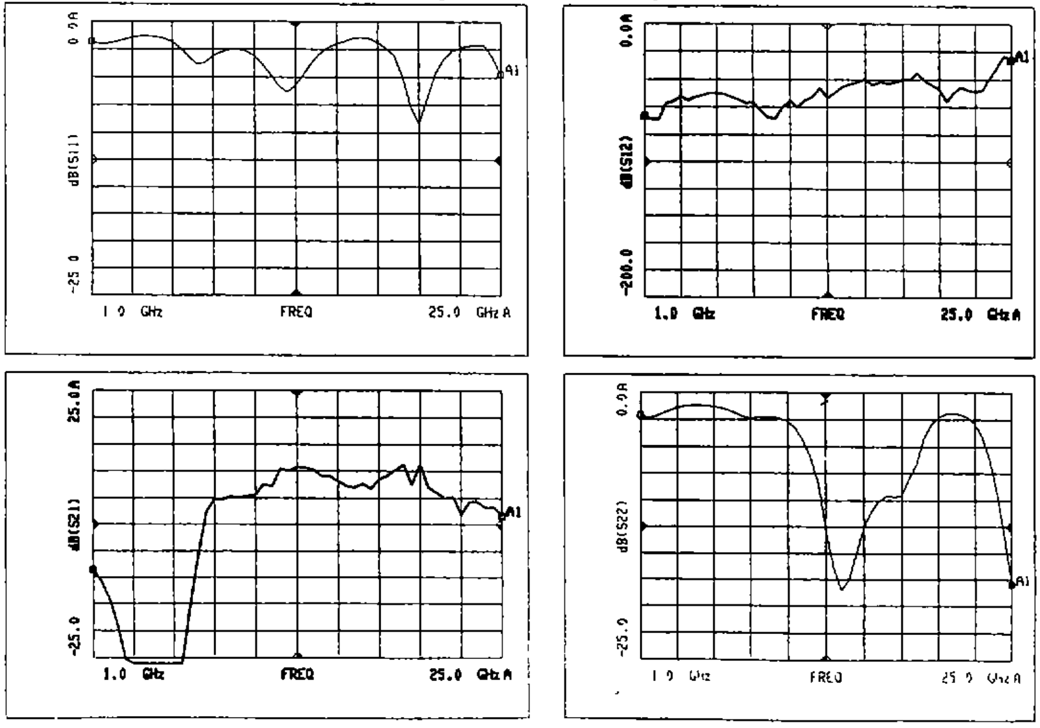

RF power = -5.0dB

Bias Conditions:

V_{d_1} = 5.0V
I_{d_1} = 16.92mA
V_{g_1} = -0.976V
I_{g_1} = -19.95

V_{d_2} = 5.0V
I_{d_2} = 16.6mA
V_{g_2} = -0.865V
I_{g_2} = -15.38μA

Fig. 2. Amplifier performance plots supplied by the Solid State Devices group ($V_{DS_1} = V_{DS_2} = 5.0$ V, $I_{D_1} = I_{D_2} = 17$ mA).

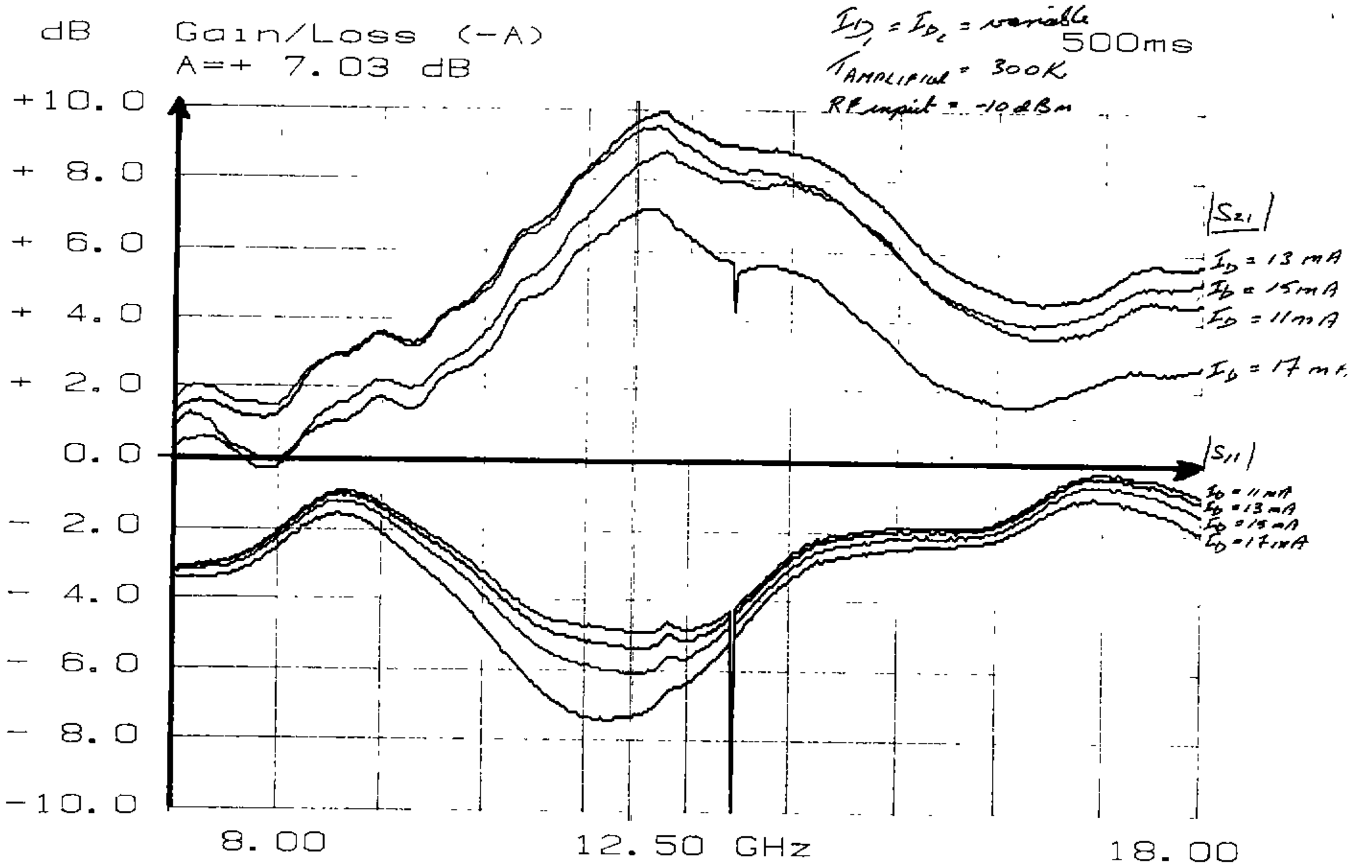

Fig. 3 Room temperature gain and return loss of amplifier ($V_{DS_1} = V_{DS_2} = 4.5$ V, $I_{D_1} = I_{D_2} = 11\text{-}17$ mA).

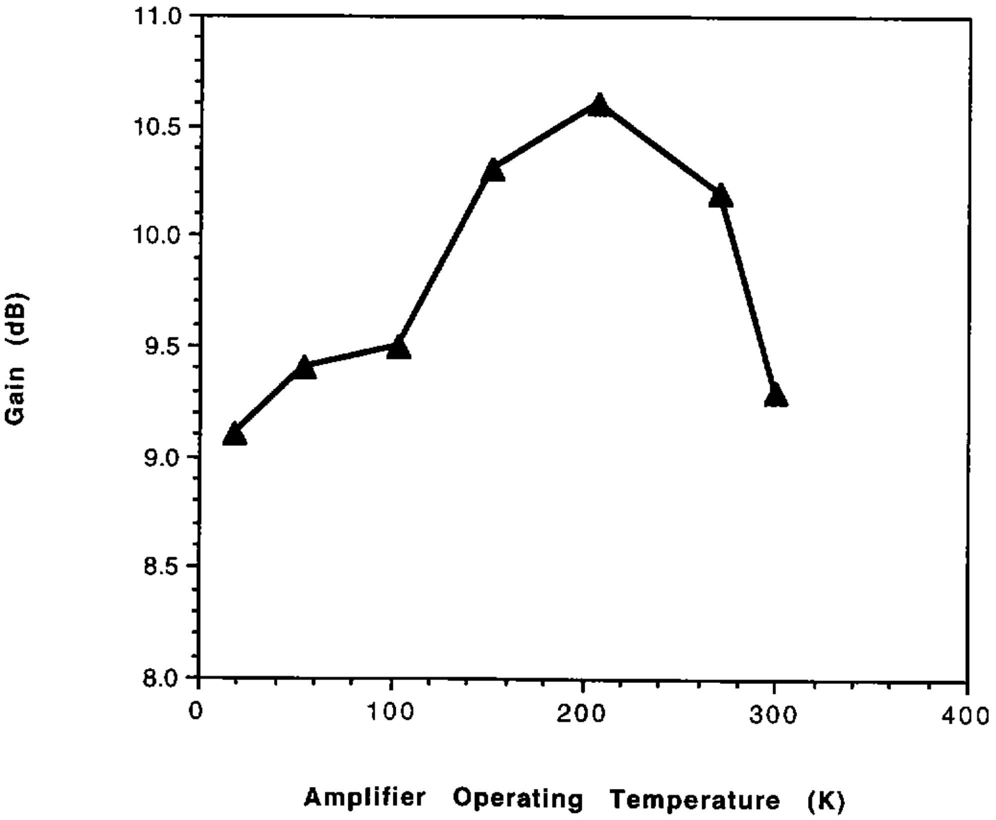

Fig. 4 Variation of amplifier gain at 13 GHz as the amplifier was cooled ($V_{DS_1} = V_{DS_2} = 4.5$ V, $I_{D_1} = I_{D_2} = 13$ mA).

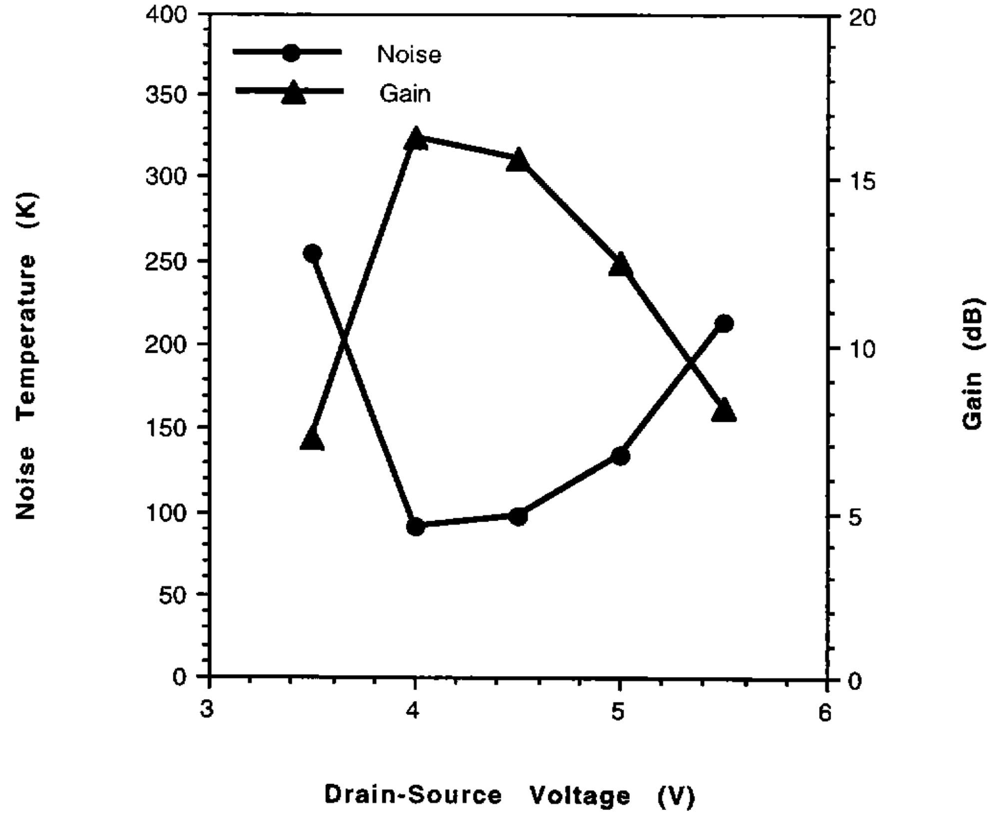

Fig. 5 Variation of amplifier gain and noise temperature with drain-source voltage ($V_{DS1} = V_{DS2}$, $I_{D1} = I_{D2} = 17$ mA, Frequency = 12 GHz, $T_{amplifier} = 19$ K)

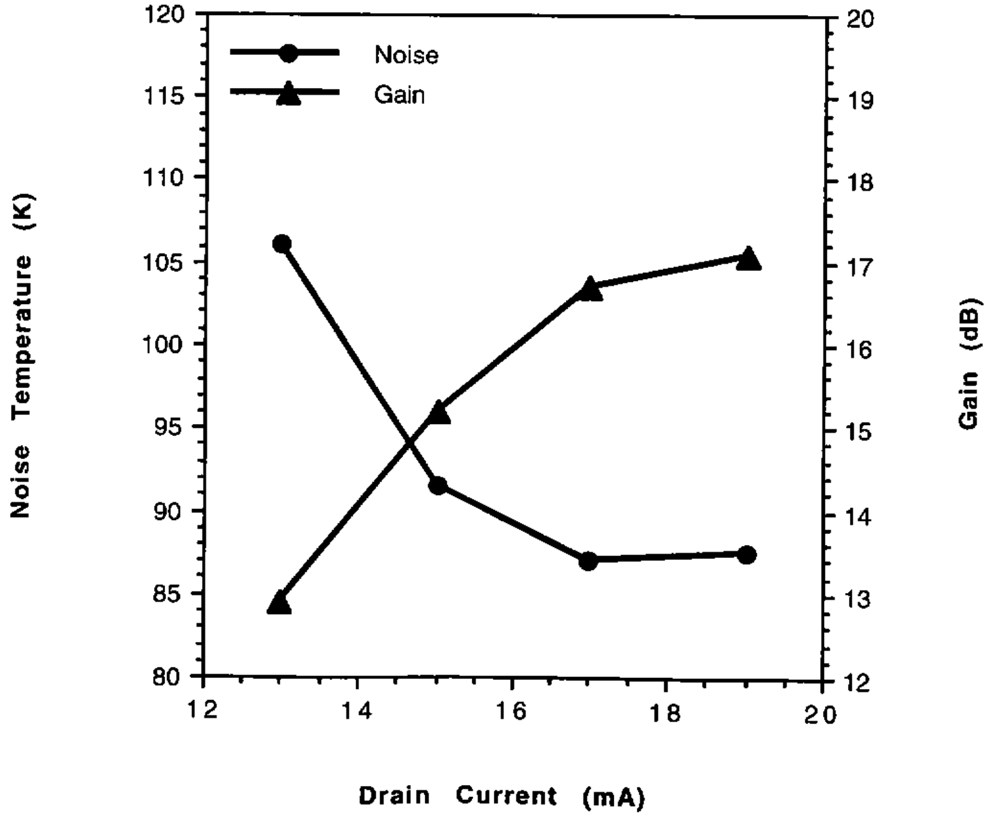

Fig. 6 Variation of amplifier gain and noise temperature with drain current ($I_{D1} = I_{D2}$, $V_{DS1} = V_{DS2} = 4.2$ V, Frequency = 12 GHz, $T_{amplifier} = 19$ K)

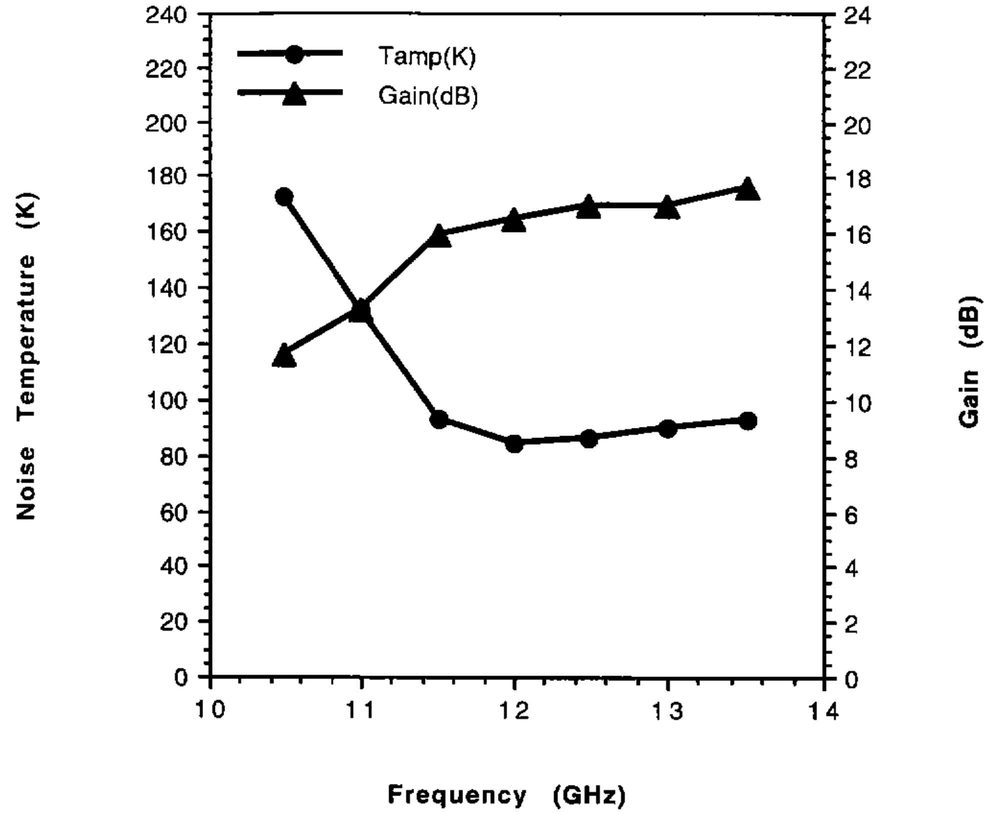

Fig. 7 Amplifier gain and noise temperature, at $T_{amplifier} = 19$ K ($V_{DS1} = V_{DS2} = 4.2$ V, $I_{D1} = I_{D2} = 17$ mA). The measurements have been corrected for the estimated input and output losses (assumed independent of frequency) at 12 GHz.

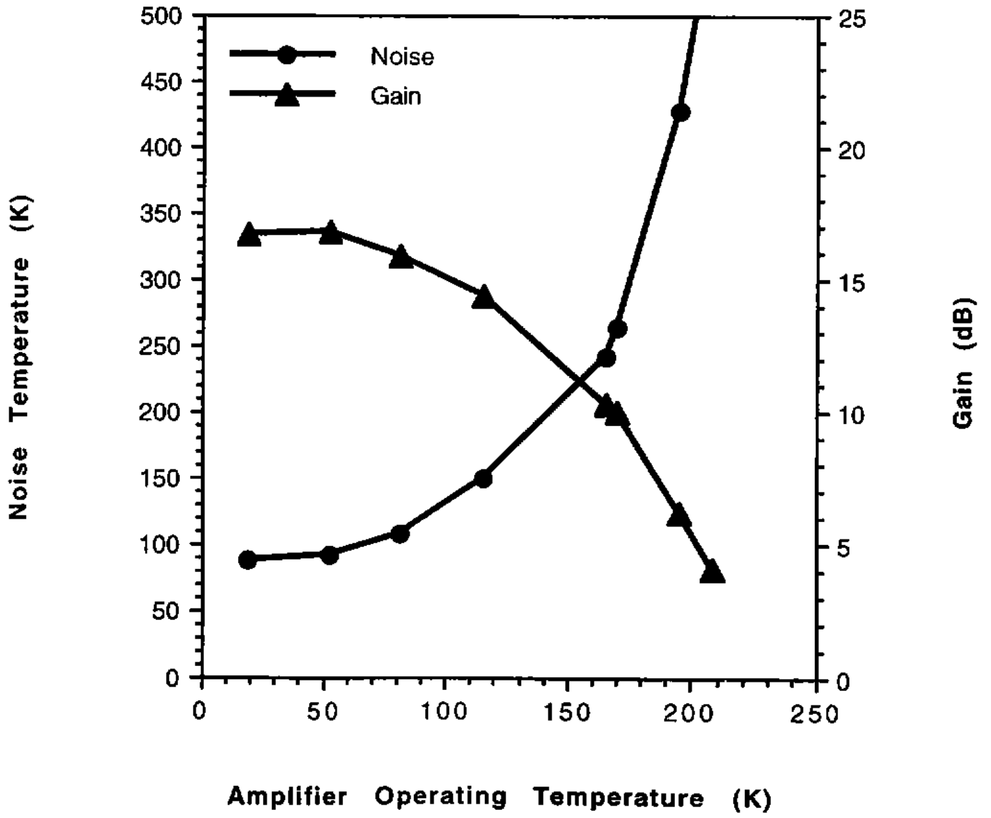

Fig. 8 Variation of amplifier gain and noise temperature at 12 GHz as the amplifier was warmed up ($V_{DS1} = V_{DS2} = 4.2$ V, $I_{D1} = I_{D2} = 17$ mA).