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Cryogenic Performance of DRP 1-14 GHz MMIC Amplifier

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1. Introduction

This report describes the cooled performance of a monolithic microwave integrated circuit (MMIC) distributed amplifier (AMP32) designed by the MMIC Design and Test (MMIC D&T) group and fabricated by the GaAs Prototyping Facility at the CSIRO Division of Radiophysics (DRP). This device was not designed for cryogenic operation. The cooled performance of the amplifier was measured over the range 8 - 13 GHz. The measurements above 12.5 GHz are less accurate as the gain of the noise figure measurement system was starting to roll off.

The amplifier unit supplied by the MMIC D&T group had SMA connectors for the RF input and output. The gates and drains of the three HEMTs in the distributed amplifier are connected in parallel. The amplifier was designed to operate in the range 1-14 GHz. Fig. 1 shows the room temperature performance of the packaged device supplied by the MMIC D&T group.

Initially the amplifier oscillated when installed in the dewar – at about 200 KHz at room temperature and 400 KHz at 15 Kelvin. The oscillation was stopped by decoupling the gate and drain feed throughs with 100 nF capacitors to ground. As the amplifier also had a problem with a short circuit in the input dc blocking capacitor, all testing was carried out with an HP33150A bias tee on the output of the noise source, so that the dc output impedance of the noise source would not affect the gate bias voltage. The insertion loss and noise figure of the bias tee is shown in Fig. 2.

2. Amplifier Performance

Fig. 3 shows the room temperature amplifier noise figure and gain measured at V_{DS}=4.5 V, I_D=30 mA and at V_{DS}=3.5 V, I_D=10 mA.

The amplifier was cooled with isolators on the input and output to minimise standing waves in the input and output coaxial lines. A block diagram of the cooled amplifier test set up is shown in Fig. 4.

Fig. 5 shows the amplifier noise figure and gain measured at 15 Kelvin at V_{DS}=4.5 V, I_D=30 mA and at V_{DS}=3.5 V, I_D=10 mA. The fine traces are the gain and noise figure of the complete test set up, including the bias tee, hermetic feed throughs, dewar input and output lines and isolators. The thick traces are the gain

and noise figure of the amplifier, after the measurements have been corrected for the losses in the bias tee, hermetic feed throughs, dewar input and output lines and isolators. The losses in these components are summarised in Table 1. It was assumed that the losses were independent of frequency, except for the loss of the bias tee.

3. Conclusion

These tests have shown that the distributed amplifier supplied by the MMIC D&T group can be successfully cooled. The minimum noise figure of the amplifier at 12 GHz was 1.24 dB at V_{DS}=3.5 V and I_D=10 mA and the corresponding gain was 7.28 dB.

Component	Loss (dB)	Temp of loss (K)
Bias tee	see Table 2	290
Hermetic feed through	0.50	290
Input line	0.23	155
Input isolator	0.40	15
Output isolator	0.40	15
Output line	0.54	155

Table 1

Frequency (GHz)	Insertion loss (dB)
8.0	0.40
8.5	0.40
9.0	0.44
9.5	0.80
10.0	1.20
10.5	0.54
11.0	0.40
11.5	0.50
12.0	0.50
12.5	0.58
13.0	0.08

Table 2. Insertion loss of HP33150A bias tee

Bias		T = 290 Kelvin		T = 15 Kelvin	
V_{DS} (V)	I_D (mA)	Gain (dB)	Noise figure (dB)	Gain (dB)	Noise figure (dB)
3.5	10	4.4	4.7	7.3	1.24
4.5	30	6.4	4.4	9.6	1.63

Table 3. Amplifier performance at 12 GHz.

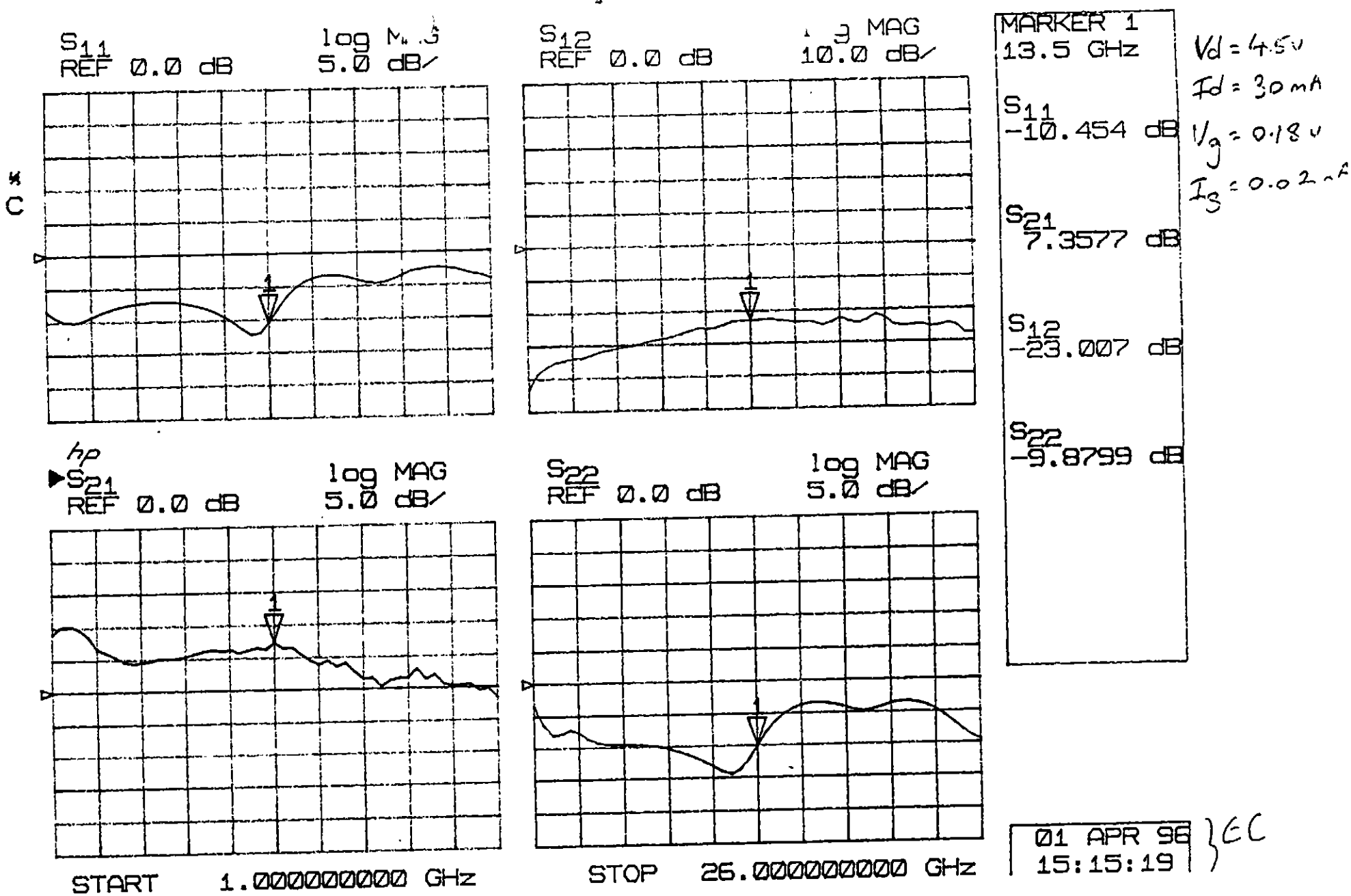


Fig. 1. Amplifier performance plots supplied by the MMIC D&T group (V_{DS} =4.5 V, I_D = 30 mA).

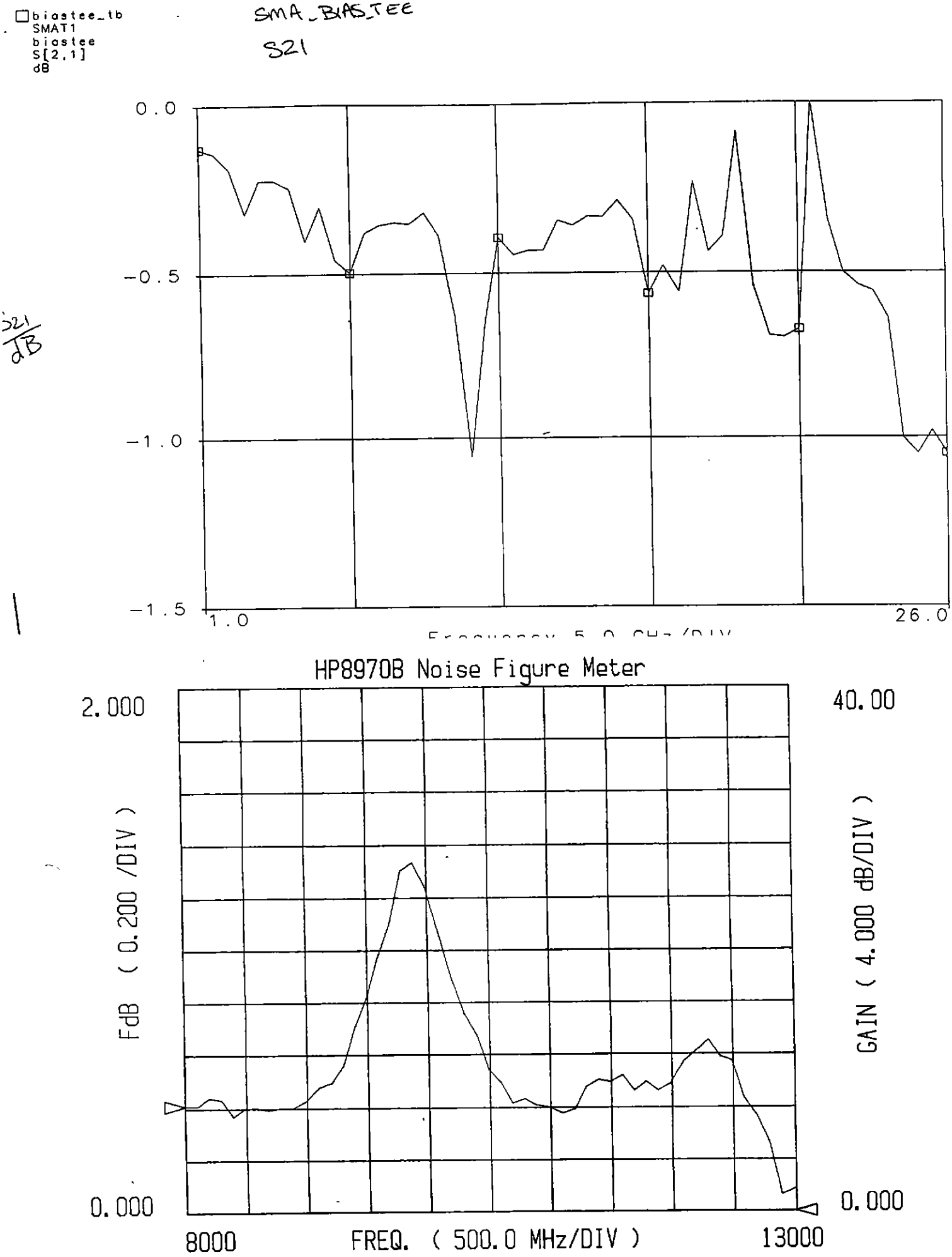
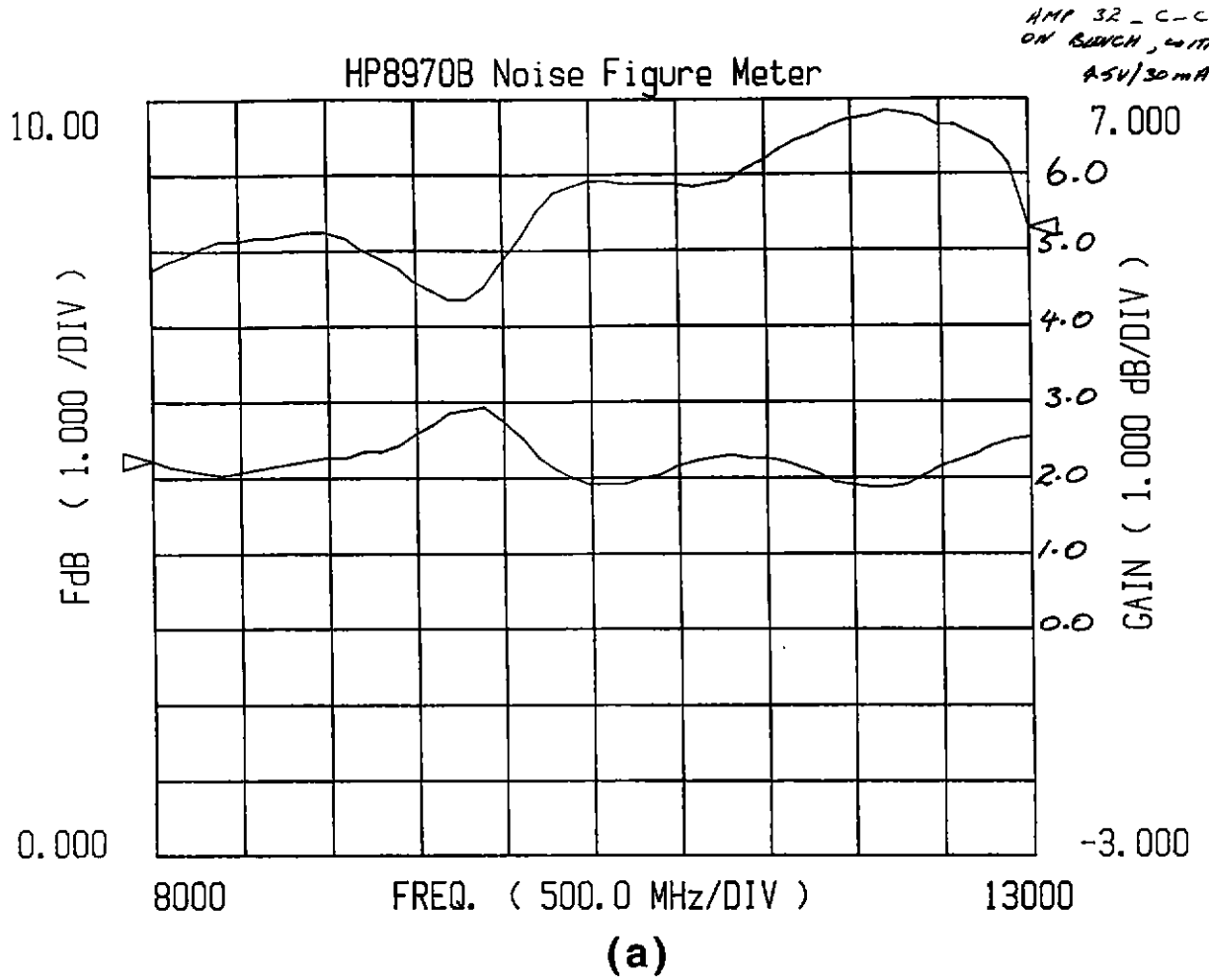


Fig. 2. Insertion loss and noise figure of the bias tee.



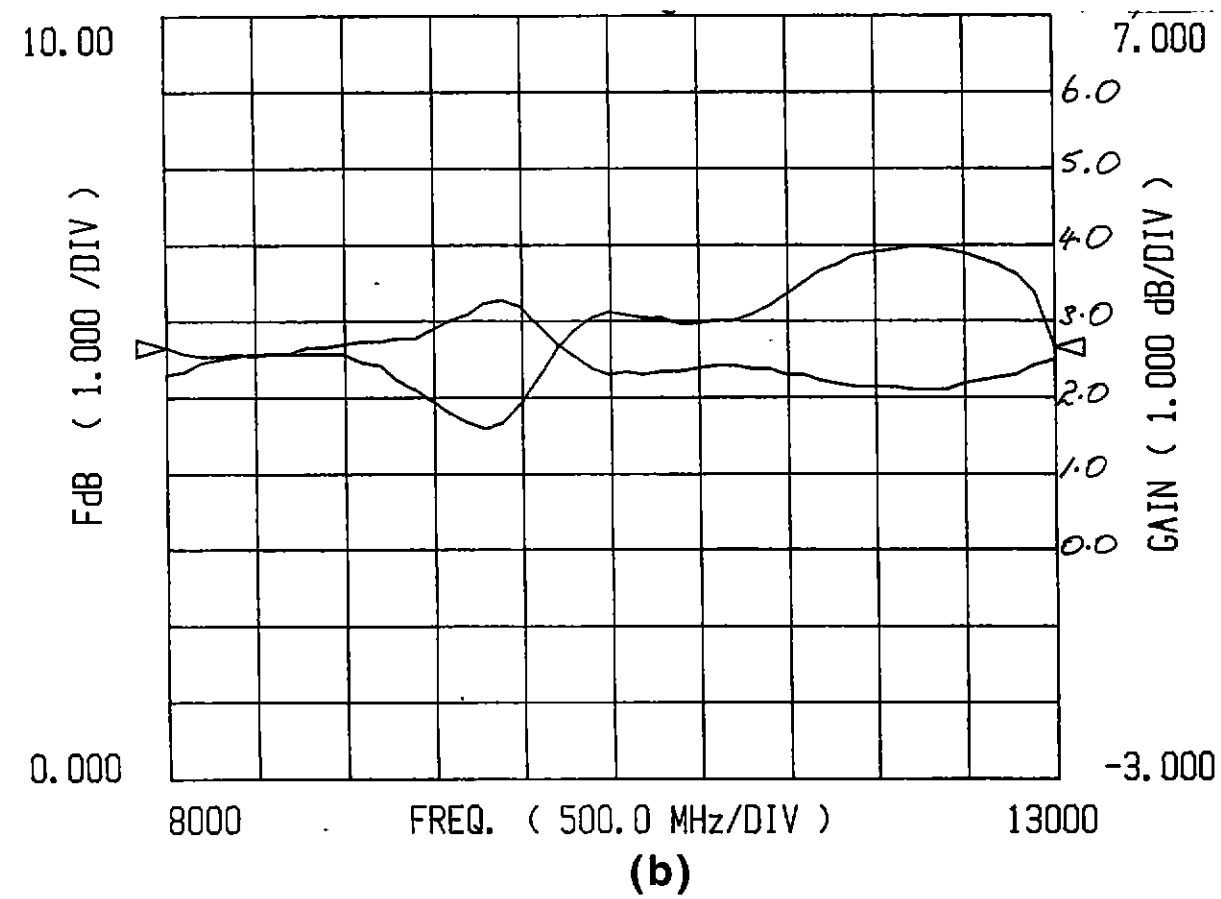


Fig. 3. Room temperature amplifier noise figure and gain
(a) V_{DS}=4.5 V, I_D=30 mA
(b) V_{DS}=3.5 V, I_D=10 mA.

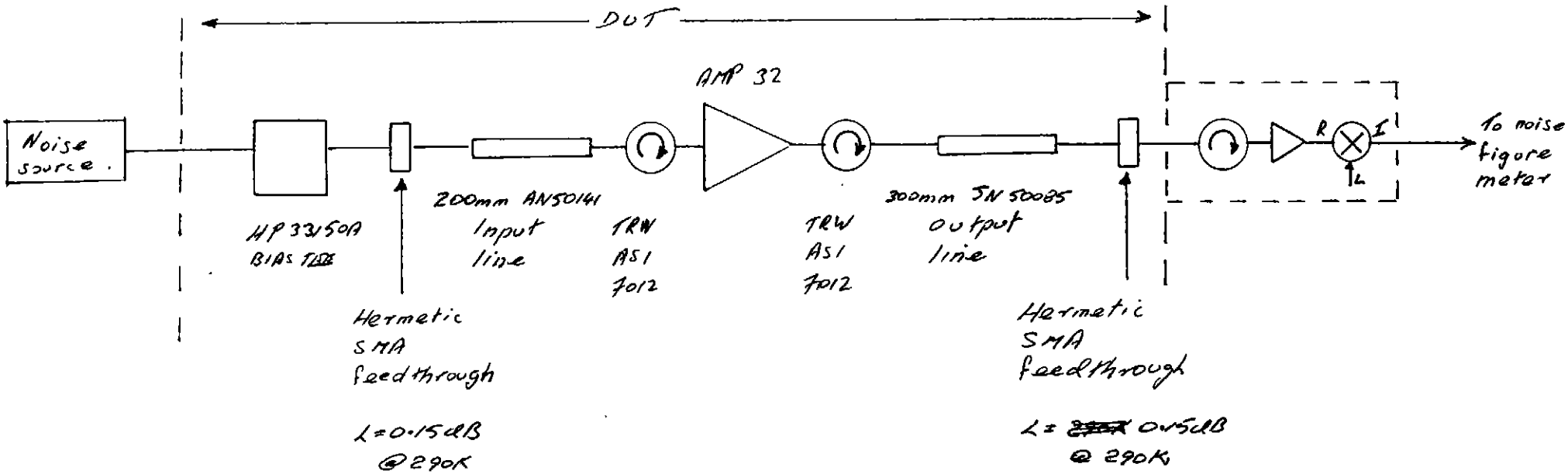
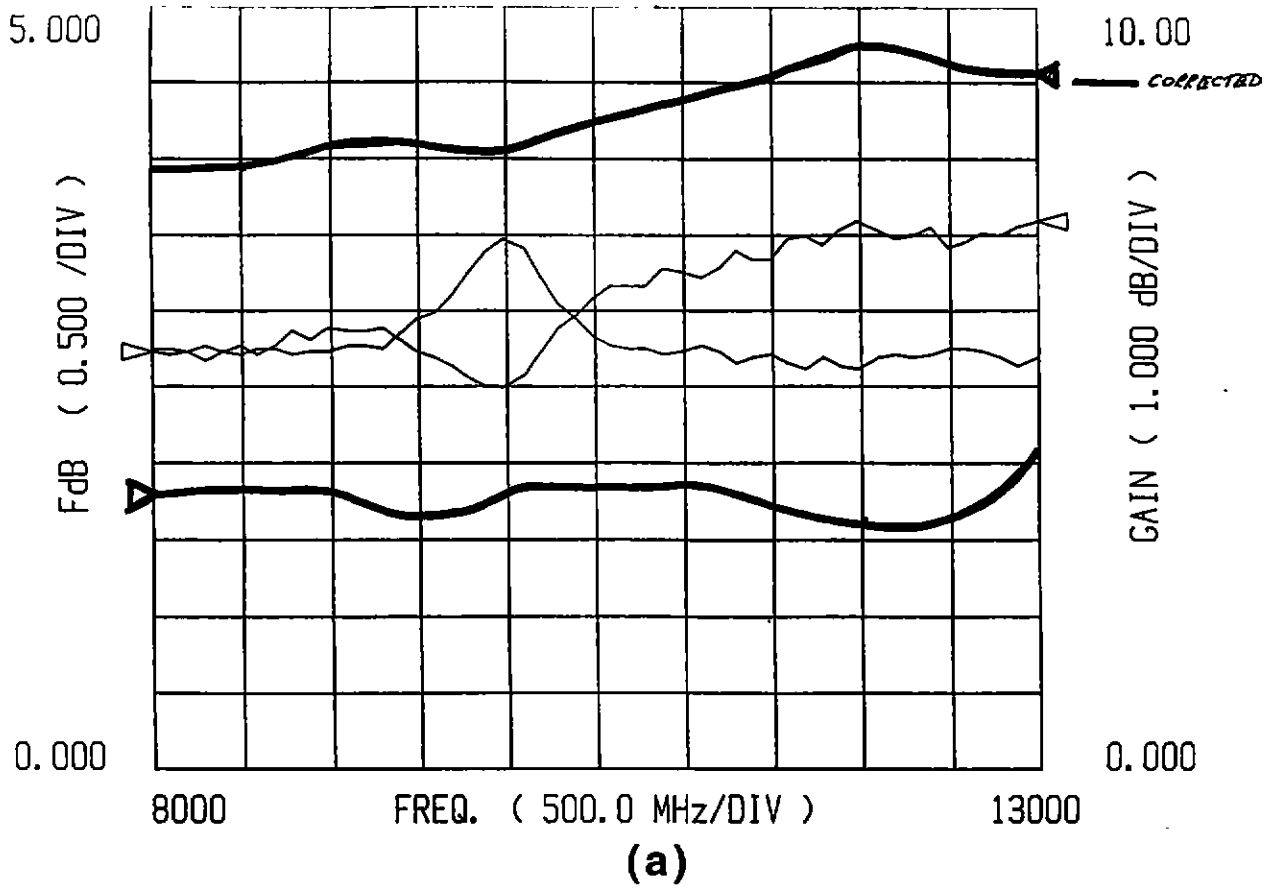
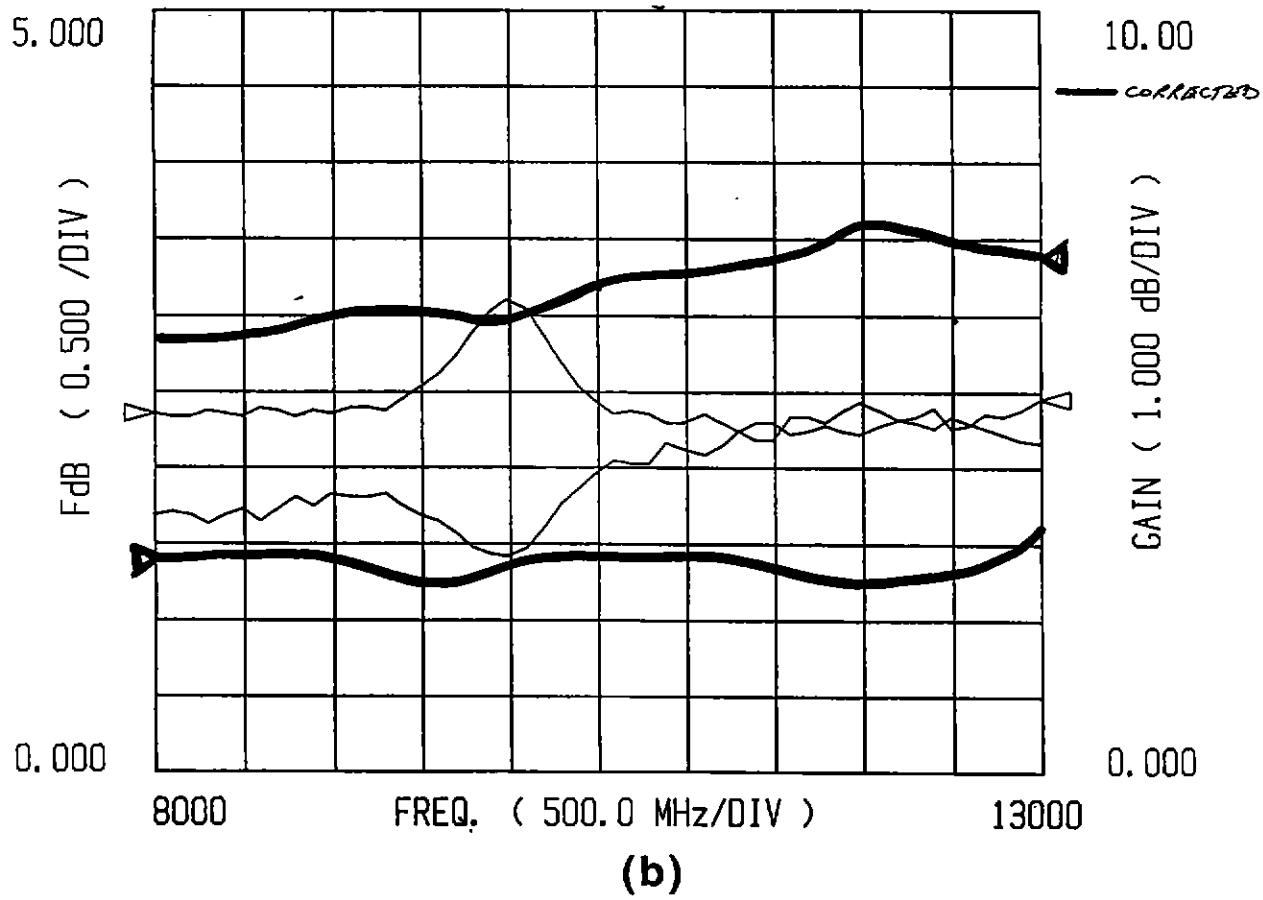


Fig. 4. Block diagram of the cooled amplifier test set up.



(a)



(b)

Fig. 5. Amplifier noise figure and gain measured at 15 Kelvin. The fine traces are the gain and noise figure of the complete test set up, including the bias tee, hermetic feed throughs, dewar input and output lines and isolators. The thick traces are the gain and noise figure of the amplifier, after the measurements have been corrected for the losses in the bias tee, hermetic feed throughs, dewar input and output lines and isolators.
(a) V_{DS}=4.5 V, I_D=30 mA
(b) V_{DS}=3.5 V, I_D=10 mA.