X-Band Monolithic Variable Gain Series Feedback LNA

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ABSTRACT

An X-band monolithic four-stage low-noise amplifier (LNA) employing series feedback has demonstrated a 1.8-dB noise figure with 33.8-dB gain and greater than 40-dB gain control capability. This design features single- and dual-gate FETs (DGFETs) on the same chip. Gain control is achieved without degradation of input or output VSWR. The two input stages use single-gate FETs to achieve minimum noise figure, while the output stages employ DGFETs for gain control capability.

INTRODUCTION

IN CONVENTIONAL DGFET amplifiers, up to 30 dB of gain control can be achieved by varying the gate-2 bias. However, the noise figure of a DGFET is a strong function of gate-2 voltage and the noise figure typically degrades significantly as the device approaches pinchoff.[1] Many applications require variable gain capability in an amplifier with minimum noise figure degradation. This paper describes the design and performance of a variable gain LNA using both single- and DGFETs to achieve superior noise figure performance over a 40-dB gain control range.

CIRCUIT DESIGN

The first two stages of the LNA, designated the EG–8316 (see Fig. 1), are composed of 0.5- by 300-μm single-gate FETs and serve as a low-noise preamplifier for the variable gain output stages. Minimum noise figure and low input VSWR are achieved simultaneously using inductive series feedback. Implementation of series feedback provides several advantages for low-noise amplifier design. Inductive reactance in the source lead of a common-source FET increases the real part of the input impedance. With proper impedance loading at the output of the FET, the conjugate of the FET input impedance and the optimum noise match impedance become coincident. Fig. 2 illustrates the effect of the series feedback on S_{11}* and Z_{opt} at 10 GHz. Series feedback decreases the equivalent noise resistance, r_n, of the two-port (device plus feedback), as well as decreasing the sensitivity to changes in the intrinsic device properties. Because inductive series feedback increases the real part of the input impedance, the stability of the device is enhanced.[2]

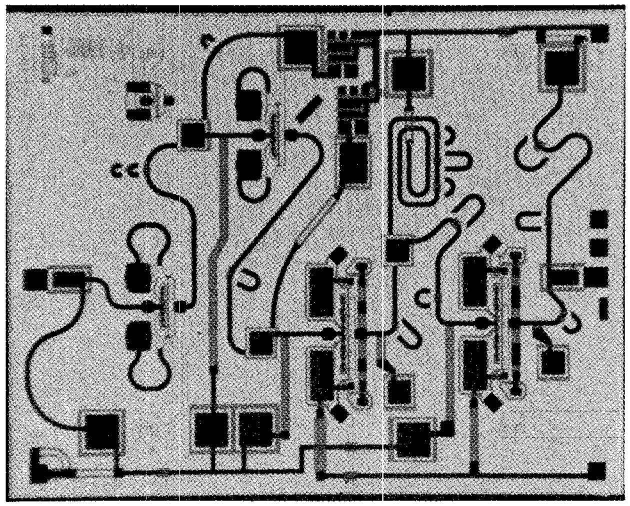

Fig. 1. Variable gain low-noise amplifier photograph

The last two stages are designed to provide flat gain and to minimize variations in gain shape as the second gate voltage is varied. Although gate-2 terminations have been investigated by various researchers for improved phase performance [3], in the interest of stability, 20-pF capacitors were selected for gate-2 terminations of the DGFETs. Gain flatness over the gain control range is maintained by using shunt resistive feedback between gate 1 and drain of each of the DGFETs. The output impedance of a DGFET varies with gate-2 voltage. To maintain good output VSWR over the gain control, the output of the DGFET is loaded with a shunt 200-ohm resistor. Fig. 3 shows a circuit schematic of the four-stage LNA.

RF PERFORMANCE

The monolithic four-stage variable gain LNA with series feedback has demonstrated a 1.8-dB noise figure with 33.8-dB gain and greater than 40-dB gain control capability. At 10 GHz, input return loss of 12 dB and output return loss of 19 dB have been achieved. The X-band gain control response is shown in Fig. 4. Table I shows the noise figure, gain, and input and output return loss as a function of gate-2 voltage. Input return loss improves to 14 dB as the gain is reduced and the

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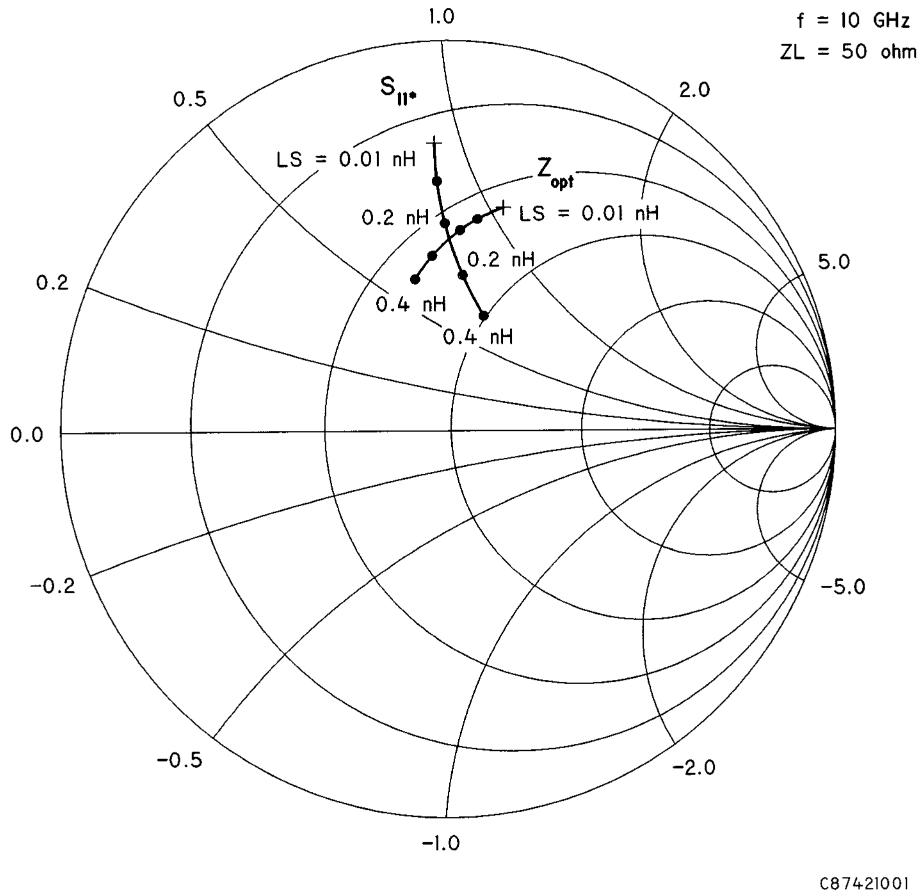

Fig. 2. Mapping of series feedback on z_{opt} and s_{11*}

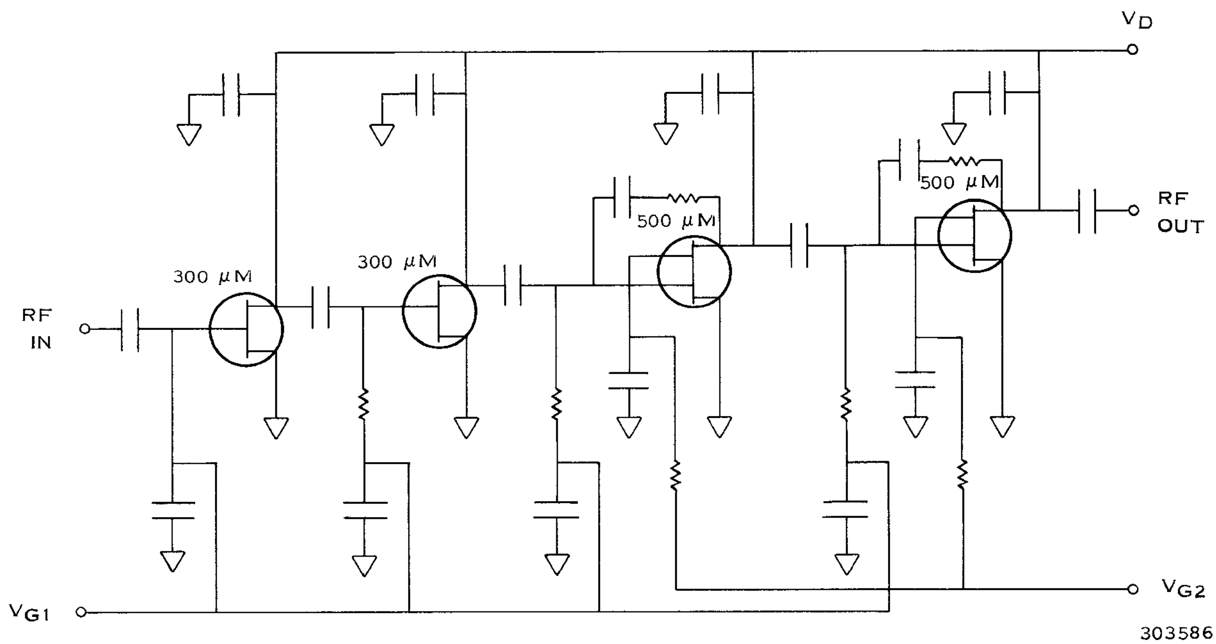

Fig. 3. Variable gain LNA schematic

output return loss improves to 20 dB. Also included in Table I is the third-order intercept point of the LNA referenced to the input. Nominal bias conditions for maximum gain are V_{ds} = 5 V, I_{ds} = 100 mA, V_{g1} = −0.5 V, V_{g2} = 1.5 V.

CONCLUSIONS

Variable gain amplification has been achieved in an X-band monolithic amplifier with minimal degradation of noise figure through the use of single- and dual-gate FETs on the same chip. The LNA maintains good input VSWR and noise figure through the use of series feedback. This paper highlights LNA performance over gain control.

REFERENCES

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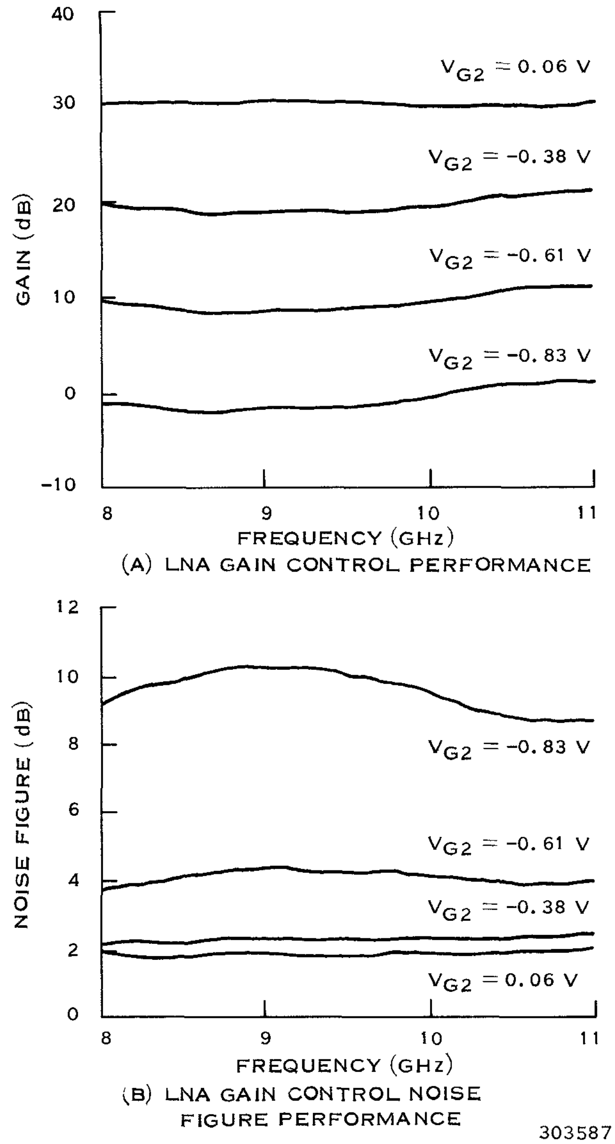

Fig. 4. 8216 LNA performance

TABLE I. 10-GHz PERFORMANCE SUMMARY OF VARIABLE GAIN LNA

Gate 2 (Volts)	Drain Current (mA)	Gain (dB)	Noise Figure (dB)	Input Return Loss (dB)	Output Return Loss (dB)	Third-Order Intercept (dBm)
1.50	101	33.8	1.8	12.2	19.1	−10.0
0.06	85	28.2	1.9	13.0	18.9	−10.6
−0.10	80	23.4	2.2	13.7	18.7	−11.3
−0.23	75	18.6	2.5	14.0	19.5	−12.7
−0.35	70	13.6	3.3	14.1	19.2	−11.2
−0.44	64	8.8	4.6	14.0	19.5	−8.2
−0.55	58	3.5	7.0	13.9	19.8	−5.3
−0.65	52	−1.6	10.3	13.8	20.0	−3.9
−0.78	45	−7.1	14.6	13.7	20.1	−3.5