Monolithic AlGaAs-GaAs HBT Single- and Dual-Stage Ultra-Broadband Amplifiers

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Abstract—**The circuit design and performance of single- and dual-stage ultra-wideband MMIC amplifiers utilizing AlGaAs-GaAs Heterojunction Bipolar Transistors (HBT's) are presented. The single-stage feedback amplifier has 10 dB gain and a 3-dB bandwidth of DC to 18 GHz. The two-stage ac coupled version achieves over 20 dB of gain and a 3-dB bandwidth of 0.1 to 18 GHz. Both of these amplifiers are extremely small in size (single-stage—24 mils × 24 mils, two-stage—24 mils × 40 mils) since there are no reactive matching elements. This results in high chip yield and low cost.**

Circuit Description

BROADBAND MMIC amplifiers have been developed using GaAs MESFET and HEMT's, advanced Si Bipolar transistors and more recently GaAs HBT's [1]. The HBT MMIC amplifiers presented in this letter, utilize the Darlington configuration with resistive feedback (Fig. 1) to achieve flat gain over a broad bandwidth. The Darlington configuration consists of a 40 μm HBT ($Q1$) driving an 80-μm ($Q2$) HBT. Series feedback is provided by resistor RE2 in the emitter of $Q2$, while shunt feedback is provided by resistor RFB1 between the base of the input device $Q1$ and collector of output device $Q2$. The use of series as well as shunt feedback helps desensitize the design to variations in active device parameters. In addition, an MIM capacitor (CE2) has also been used across the emitter resistor of the 80-μm device to reduce the series feedback at high frequency and further extend the bandwidth. The bleeder resistor RE1 was used to achieve proper bias for device $Q2$. In order to provide maximum flexibility in biasing, an RF choke (realized with a multiturn spiral inductor) was put on chip in addition to resistor RC. This on-chip RF choke can be used when the frequency of operation is above 500 MHz. Circuit operation down to DC can be achieved using collector resistor RC for biasing.

These amplifiers were fabricated at Rockwell Science Center on an MBE grown AlGaAs-GaAs HBT process with f_{max} of 80 GHz and an f_t of 40 GHz. The AlGaAs-GaAs HBT employs a dual lift-off self-aligned process to minimize the base resistance and the collector-base capacitance and uses 2-μm emitter fingers. The emitters of the Darlington devices were grounded using via-holes.

Circuit Performance

The single-stage Darlington feedback amplifier (Fig. 2) achieves a 3-dB bandwidth from DC to 18 GHz and has 10

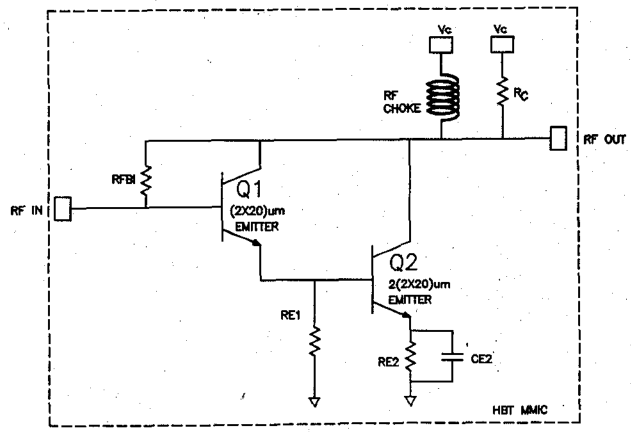

Fig. 1. Schematic of a Darlington feedback HBT amplifier.

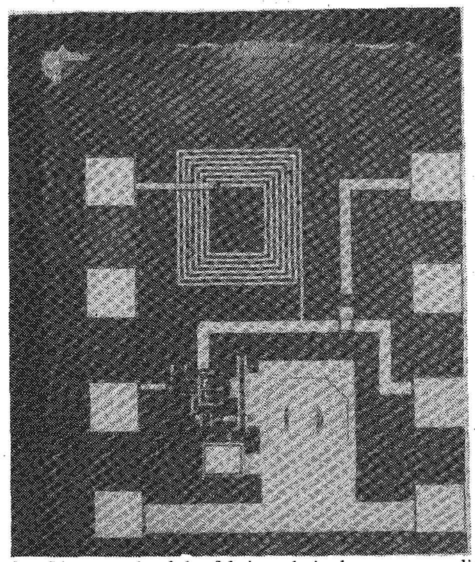

Fig. 2. Photograph of the fabricated single-stage monolithic HBT amplifier.

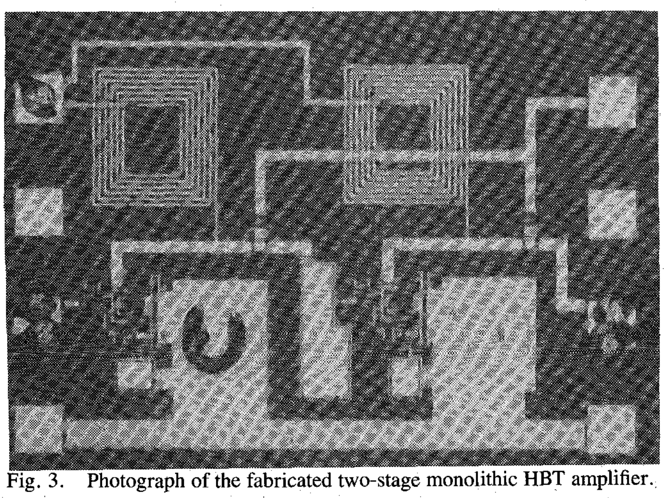

Fig. 3. Photograph of the fabricated two-stage monolithic HBT amplifier.

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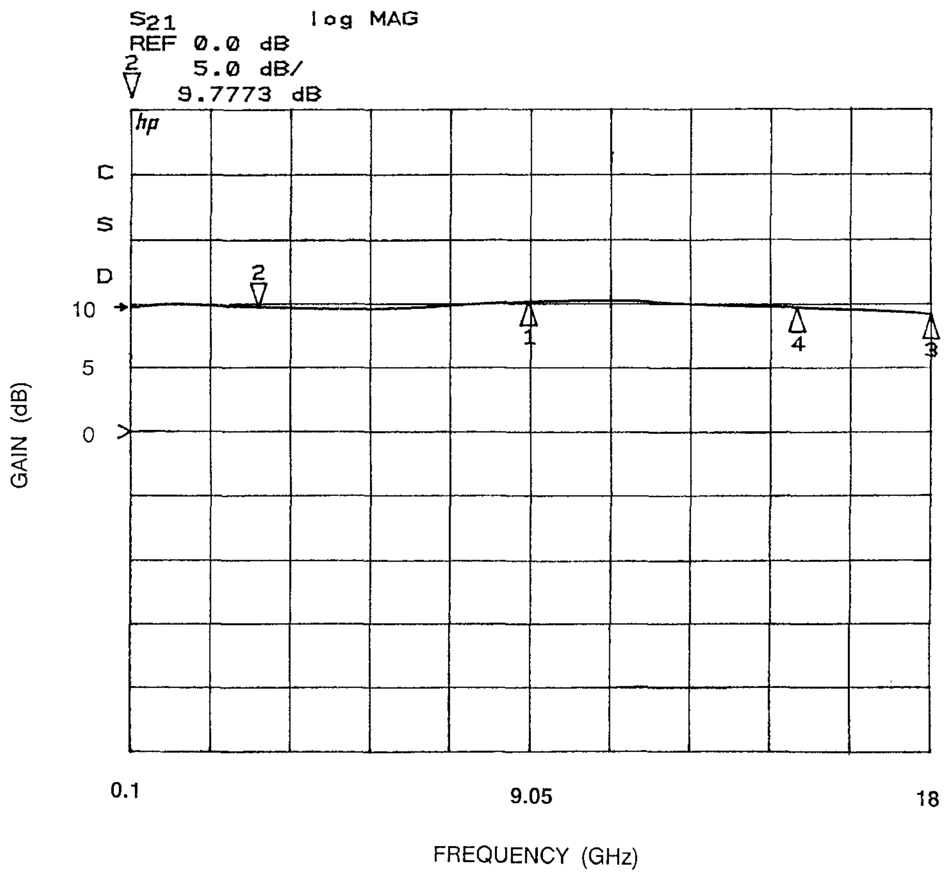

Fig. 4. Small signal gain performance of the single-stage HBT amplifier.

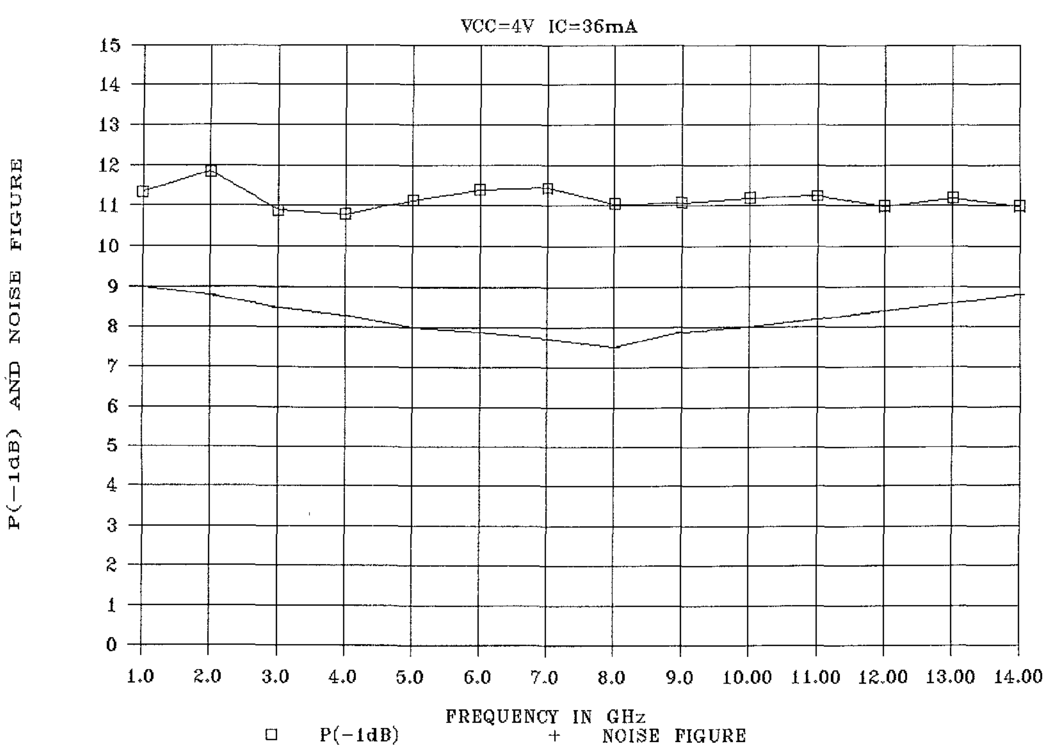

Fig. 5. Power and noise figure performance of the single-stage HBT amplifier.

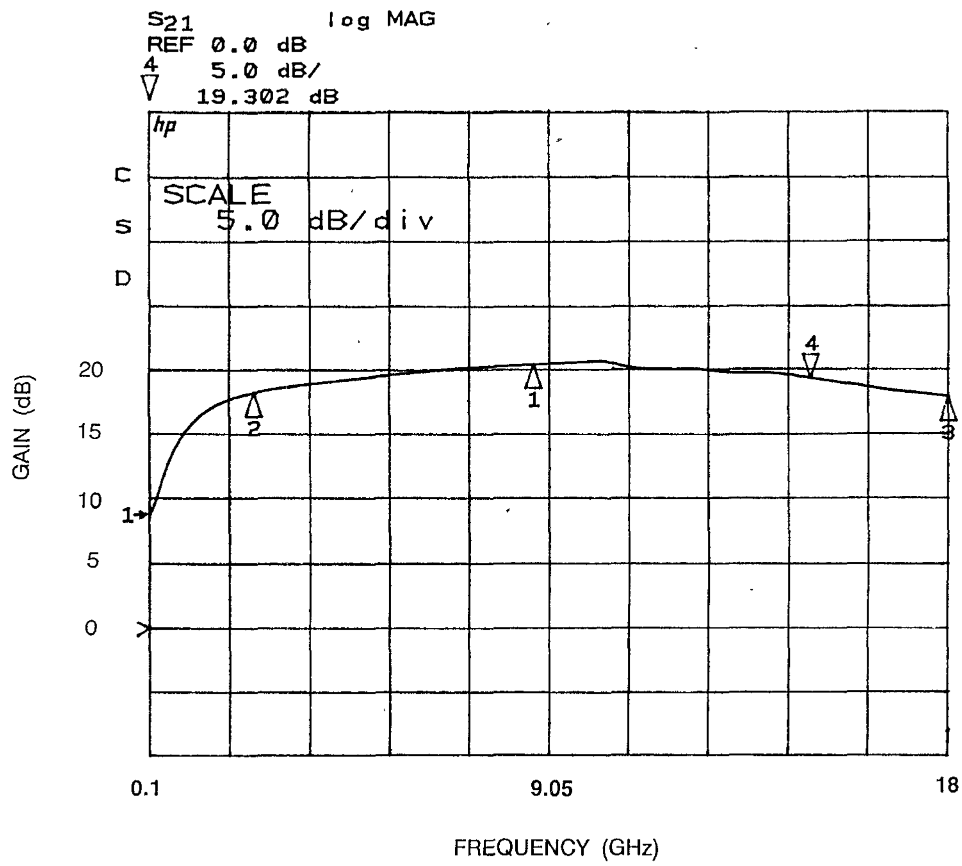

Fig. 6. Small signal gain performance of the two-stage HBT amplifier.

dB of gain (Fig. 4). The 1-dB gain compression power is 11 dBm and the noise figure is between 7.5–8.5 dB as shown in Fig. 5. The DC power dissipation is 144 mW at a bias voltage of 4V. The two-stage version consists of two single-stage amplifiers coupled by a series capacitor (Fig. 3, chip size—40 mils × 24 mils). The lower frequency performance of this circuit is limited by the coupling capacitor value. This two stage version exhibits 20 dB of gain (Fig. 6), 10.5 dBm of P-1db and 8.5–9.5-dB noise figure. Both of these amplifiers have better than 14 dB input and output return loss so that they can be easily cascaded for higher gain with minimum ripple. These results have been obtained at the carrier level without any de-embedding of the fixture loss. The gain-bandwidth limitation of such flat gain feedback amplifiers constraints the ultimate performance well below f_t of the device.

Compared to similar 0.5-μm gate GaAs MESFET distributed amplifiers, these HBT amplifier's third-order intercept point (IP3) to DC power ratio is two times greater, chip size is seven times smaller and gain is 2 dB higher. Compared to similar advanced silicon bipolar Darlington amplifiers [2], these amplifiers have more than twice the bandwidth and compared to previously reported HBT amplifiers [3], these have 5 dB more gain and are smaller in size. The noise figure performance of these broadband HBT amplifiers are comparable to similar broadband GaAs MESFET distributed amplifiers.

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