Broadband HBT amplifiers

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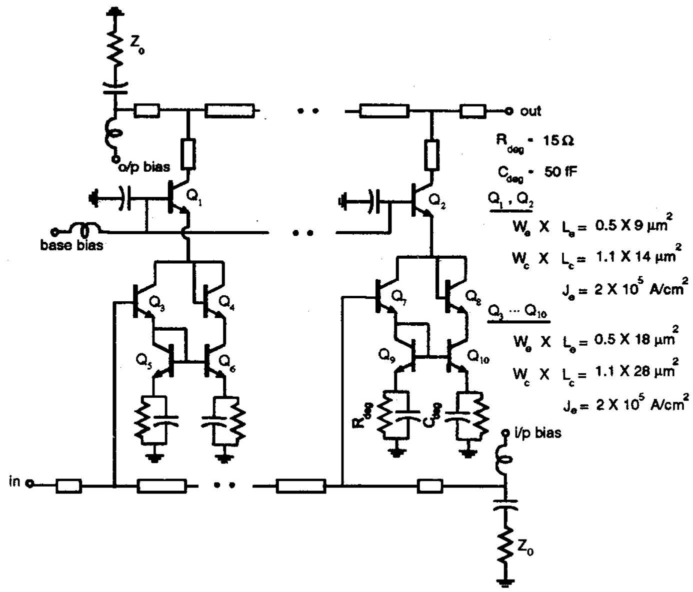
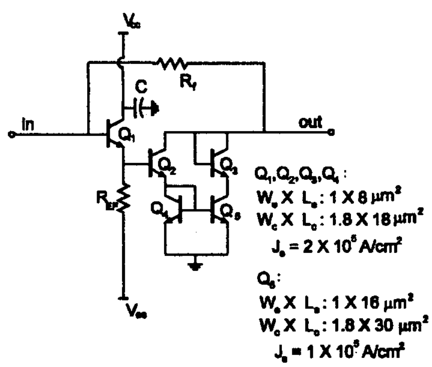
We report wide-band amplifiers using AlInAs/GaInAs transferred-substrate Heterojunction Bipolar Transistors (HBTs). A distributed amplifier exhibits 11.5 dB gain and 80 GHz bandwidth. Lumped amplifiers exhibit 8.2 dB gain with 80 GHz bandwidth and 18 dB gain with 50 GHz bandwidth and 400 GHz gain-bandwidth product, record for a single-stage amplifier.

In distributed amplifiers, gain-bandwidth products approaching the transistor f_{max} are achieved using capacitive division to reduce the device input RC time constant [1]. Here, this is instead implemented using RC emitter degeneration (fig. 1(a)). An emitter resistance, R, with a transistor of transconductance g_m reduces both the transistor input capacitance and transconductance in proportion to $(1+g_mR)^{-1}$. The capacitance reduction has two benefits: input capacitances smaller than that associated with a minimum geometry device can be obtained, as is required for very wideband designs. Secondly, the reduction in input capacitance allows HBTs of large junction areas to be used, with correspondingly reduced R_{bb} but increased C_{cb}. Transistor size can thus be varied to increase amplifier bandwidth. With such degeneration, the transistor input impedance has its resistive component increased by R, increasing the input losses and decreasing bandwidth. By bypassing R with $C=(2\pi Rf_\tau)^{-1}$, this degradation is eliminated. Cascode cells further improve the bandwidth.

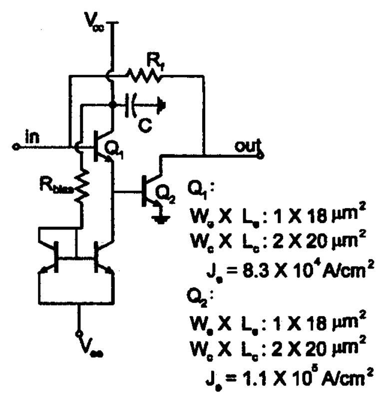
In the mirror doubler amplifier (fig. 1(b)), transistor Q_1 operates as an emitter follower while Q_2, Q_4 and Q_5 constitute an f_τ doubler [2]. In addition to providing the bias current for Q_1, R_{EF} provides the shunt loading of the emitter follower output to prevent gain peaking. For the Darlington amplifier (fig. 1(c)), transistor Q_1 operates as an emitter follower driving Q_2. IC photographs are shown in figure 2.



1(a)



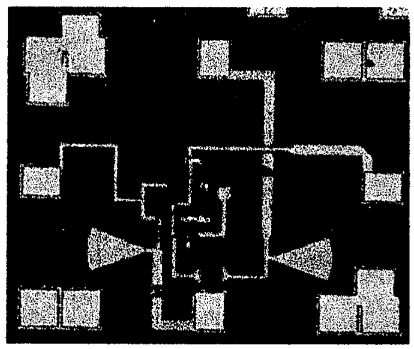
1(b)



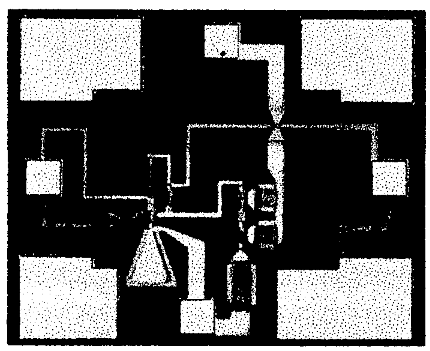
1(c)

Figure 1: **Circuit Schematics** of the distributed amplifier (a), the mirror doubler amplifier (b) and the high gain Darlington amplifier (c), W_c, L_c, W_e and L_e are the widths and lengths of the collector and emitter junctions; J_e is the emitter current density.

2(a)



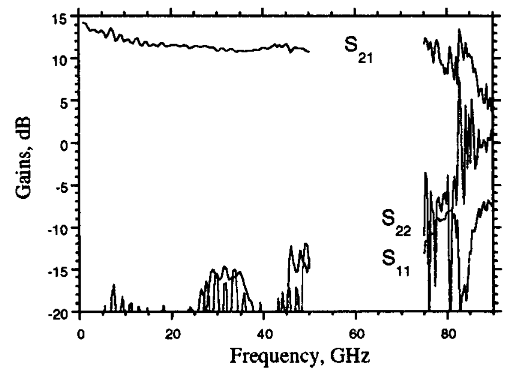
2(b)



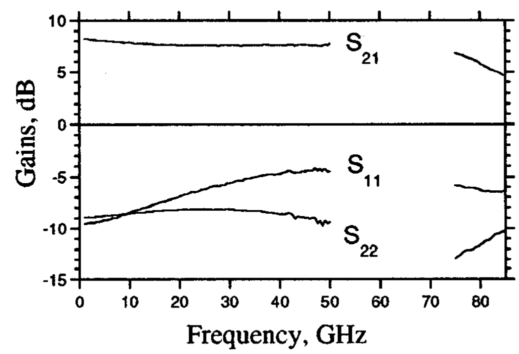
2(c)

Figure 2: IC chip photographs of the distributed amplifier (a), the mirror doubler amplifier (b) and the high gain Darlington amplifier (c)

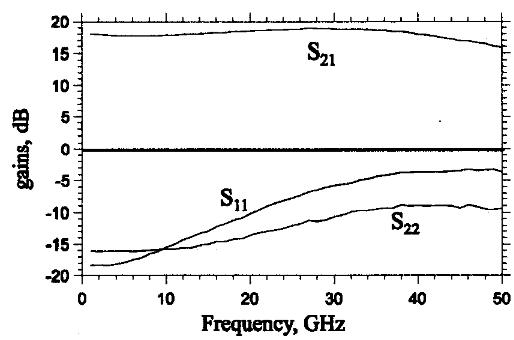
The amplifiers were measured using 0.5-50 GHz and 75-110 GHz network analyzers (figure 3). A low frequency gain of 11.5 dB and a bandwidth of 80 GHz was obtained for the distributed amplifier. For the mirror doubler, the low frequency gain is 8.2 dB and the 3dB bandwidth is 80 GHz. For the Darlington amplifier, the low frequency gain is 18dB and the 3dB bandwidth is 50 GHz. These amplifiers have applications in wideband microwave communication systems and mixed-signal ICs.



3(a)



3(b)



3(c)

Figure 3: S parameter measurements of the distributed amplifier (a), the mirror doubler amplifier (b) and the high gain Darlington amplifier (c)

References

1. B. Agarwal, Q. Lee, D. Mensa, R. Pullela, J. Guthrie, M.J.W. Rodwell: '80-GHz Distributed Amplifiers with Transferred-Substrate Heterojunction Bipolar Transistors', IEEE Transactions on Microwave Theory and Techniques, vol. 46, pp. 2302-7, Dec. 1998.
2. C. T, Armijo and R. G. Meyer : 'A new wideband Darlington amplifier', IEEE J. Solid State Circuits, vol. 24, pp. 1105-9, Aug. 1989