A 1-157 GHz InP HEMT TRAVELING-WAVE AMPLIFIER

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ABSTRACT

We report traveling wave amplifiers with 1-157 GHz 3-dB bandwidth, 5 dB gain. These amplifiers were fabricated in a 0.1 μm gate length InGaAs/InAlAs HEMT MMIC technology. The use of gate-line capacitive-division and low-loss elevated coplanar waveguide lines have yielded record bandwidth broadband amplifiers.

INTRODUCTION

Broadband amplifiers are key components in multi-gigabit fiber-optic communication systems and as premaplifiers in broadband instrumentation. Future 100 and 160 Gbit/s optical transmission systems will require gain blocks with very high bandwidths. HEMT traveling wave amplifiers (TWAs) with $\simeq$100 GHz bandwidths have been demonstrated [1, 2, 3]. Pusl et al. [1] used capacitive voltage division [4] on the gate synthetic line to obtain very wideband TWAs. Capacitive division decreases the frequency-dependent losses on the gate synthetic transmission line. With these losses reduced, the number of TWA cells can be increased to increase TWA gain. In this manner, the feasible gain for a given design bandwidth is increased. With very small capacitive division ratios, losses associated with the HEMT input resistance are reduced to the point where other loss mechanisms are significant. If the dominant loss mechanisms are the HEMT series input resistance and the shunt output conductance, the capacitive division TWAs can obtain gain-bandwidth products close to the transistor f_{max}. For design bandwidths above 100 GHz, TWA design is also strongly impacted by both the losses and physical dimensions of the gate synthetic transmission line. With small capacitive division ratios and design bandwidths above 100 GHz, transmission-line skin-effect losses become the dominant factor limiting the amplifier bandwidth, and the required transmission-line lengths become shorter than the physical dimensions of the HEMTs. By using a coplanar waveguide with a raised center conductor for the gate and drain lines, the line skin-effect losses are reduced [5, 6], and the wave velocity is increased due to reduced effective permittivity of the coplanar waveguide. A increased wave velocity implies longer transmission lines for a given electrical delay. The amplifier can then be laid out. With this technique, we have fabricated TWAs with a record 157 GHz bandwidth, 5 dB gain.

CIRCUIT DESIGN AND FABRICATION

Figure 1 shows a circuit diagram of the capacitive division TWA. Cascode connected HEMTs are used to reduce drain line losses. C_{div} is the division capacitor at the input of the common-source transistor. R_g is a small damping resistor in the gate of the common-gate transistor to prevent oscillations. R_{gterm} is the 50 Ω gate termination resistor. R_{dterm}, the drain termination

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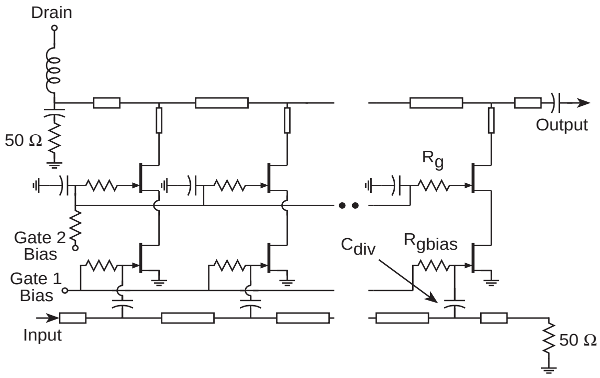

Figure 1: Schematic circuit diagram of the capacitive-division traveling-wave amplifier.

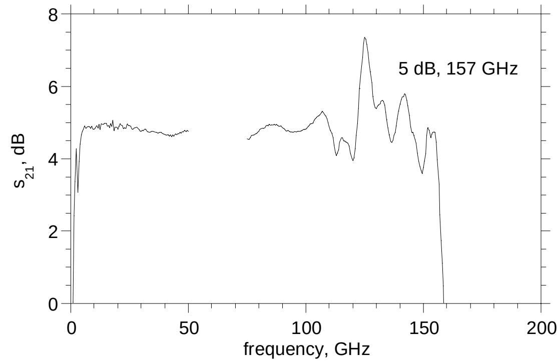

Figure 3: Measured forward gain s_{21} of the amplifier.

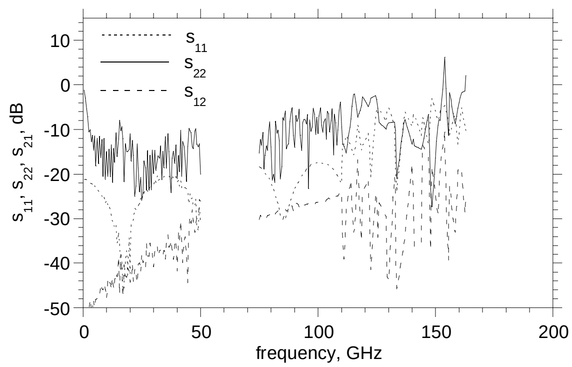

Figure 4: Measured return losses and reverse isolation of the amplifier.

resistor and the drain bias are connected through an off-chip bias tee. The two gate biases are also shown. The amplifier had 11 cascode cells with a capacitive division ratio of 0.33 : 1. The simulated gain and bandwidth are 6 dB and 200 GHz respectively.

The designs were implemented in a 0.1 μm gate length InGaAs/InAlAs HEMT MMIC technology [7]. Typically, these HEMTs have f_{max} = 300 GHz and f_τ = 160 GHz. Figure 2 shows a photomicrograph of the fabricated chip. The die size is about 2.2 mm × 1 mm.

RESULTS

The amplifier were tested on-wafer using commercial network analyzers from 45 MHz - 50 GHz and 75-110 GHz. Beyond 110 GHz, we used inhouse on-wafer network analysis based upon active probes [9]. Figure 3 shows the measured forward gain s_{21} of the amplifier. The 3-dB bandwidth is 157 GHz and the gain is $\simeq$ 5 dB. To our knowledge, this is the highest reported bandwidth for a broadband amplifier in any technology. Both the gain and the bandwidth are lower than the design values because of low values of f_τ ($\simeq$110 GHz) on this wafer. The low frequency cut-off is about 1 GHz and is determined by the gate bias networks and the output capacitor and HEMT output conductance. Figure 4 shows the input return loss s_{11}, the output return loss s_{22} and the reverse isolation s_{12} of the amplifier. The amplifier output return loss s_{22} shows many resonances because of the off-chip drain line termination.

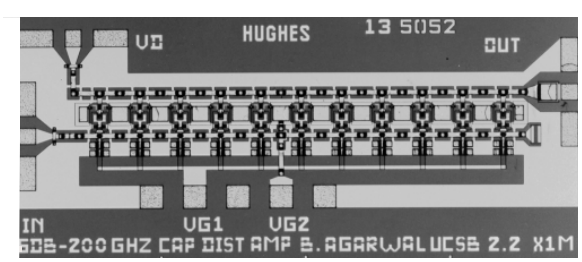

Figure 2: Photomicrograph of the fabricated amplifier IC.

CONCLUSIONS

In summary, we have designed and fabricated TWAs with 1-157 GHz bandwidth and 5 dB gain.

Off-wafer bias circuits can be used to reduce the lower cut-off frequency to the KHz range. These amplifiers can be used in very high bit-rate fiber-optic systems.

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