Student Paper

W-band Power Amplifier in 0.15µm InGaAs pHEMT Technology with Microstrip Transmission Lines

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In this paper, the existing feasibility of microstrip transmission lines (MTL) in RF applications has been asserted with the design of a novel 2 stage common source power amplifier (PA). The novel inductorless MTL based PA is designed in 0.15µm InGaAs pHEMT. The PA achieves a gain of 10 dB, operating 3-dB bandwidth of 3 GHz, in the W band at 82 GHz center frequency. The PAE and P_{1dB} are 9.1 % and 9.2 dBm respectively. The power consumed by the PA is 38 mW for a source voltage of 2.5 V.

At microwave frequencies, the conventional lumped components cannot work as their desired performance as an inductor or capacitor is significantly dwarfed by the undesired device parasitics. In today's wireless communication we need to operate at those very high frequencies and therefore the need of MTL is very much essential. The simulation of the PA is conducted with 0.15µm InGaAs pHEMT process technology. As we know, at microwave frequencies III-V semiconductors such as the InGaAs pHEMT are used in spite of their high power consumption because they have significantly higher f_T and breakdown voltage and importantly very high electron mobility when compared to CMOS.

The MTL is transmission line geometry with a single conductor trace on one side of a dielectric substrate and a single ground plane on the opposite side. The MTL achieves inductance with the flow of current in the conductor, whereas the capacitance is associated with the conducting strip separated from the ground plane by the dielectric substrate [1]. In Fig. 1 Inset, a typical MTL device is illustrated. The dielectric substrate considered in this paper is GaAs. The microstrip characteristic impedance, Z, and the inductance, L, are computed as follows:

$$Z = \frac{1}{2\pi}\sqrt{\frac{\mu_0}{\varepsilon_0\varepsilon_e}}\, log[F\frac{h}{w} + \sqrt{\left\{1+\left(2\frac{h}{w}\right)^2\right\}}]\ ;\ \mathrm{L} = \frac{Zl}{\lambda f}$$

where, F & ε_e are obtained from expressions in [2]. In Fig. 1 we illustrate the inductance dependence on the aspect ratio (w/h) of the MTL at 82 GHz for a strip of length (l) 1.5 mm.

The DC characteristic of the transistor is initially obtained to determine the Q point of the transistor. The power amplifier is biased for Class A operation to achieve the best linearity.

The novel PA circuit introduced here (Fig. 3) is an inductorless microstrip based common source 2 stage amplifier circuit. The microstrips are considered shorted at one end at microwave frequencies and act as inductors. The two stages of the amplifier aids in improving the gain characteristics of the circuit. The number of fingers in the both the transistors are 2 with the device width fixed at 25 µm. The power consumed by the PA is 38 mW for a source voltage of 2.5 V. The impedance matching with the antenna is obtained at 50 Ω. The EM and circuit co-simulation is achieved using Agilent ADS, in which the passive elements are initially simulated by ADS Momentum. The PA achieves a peak gain of 10 dB (Fig. 4), 3 dB bandwidth of 6 GHz and operates in the W band at ~ 80 GHz center frequency. The input and output return losses, indicated in Fig. 5, imply efficient impedance matching and power transfer. The input & ouput return losses indicate only one-tenth and one-fifth of the power are lost respectively. The rollet stability factor (Fig. 6) is observed to be greater than 1 in the operating frequency range. The PAE and P_{1dB} of the amplifier is found to be 9.1 %. and 9.2 dBm. The PA circuit can be compared to a similar coplanar waveguide transmission line based V-band PA structure designed in 90 nm CMOS [3].

The performance of a novel PA operating at the W band is presented. The PA does not use any inductors and therefore evolves as an area efficient alternative to analog IC design at microwave frequencies. The MTLs completely replace the inductors in this design.

References

[1] Fred Gardiol, "Microstrip Circuits", Wiley series in Microwave and Optical Engineering, 1994.

[2] E. Hammerstad and O. Jensen, "Accurate models for microstrip computer aided design", " *IEEE MTT-S International Microwave Symposium"*, 1980, pp. 407-409

[3] Babak Heydari et al., “A 60 GHz Power Amplifier in 90 nm CMOS Technology”, *in IEEE Custom Integrated Circuits Conference (CICC)*, 2007, pp. 769-772

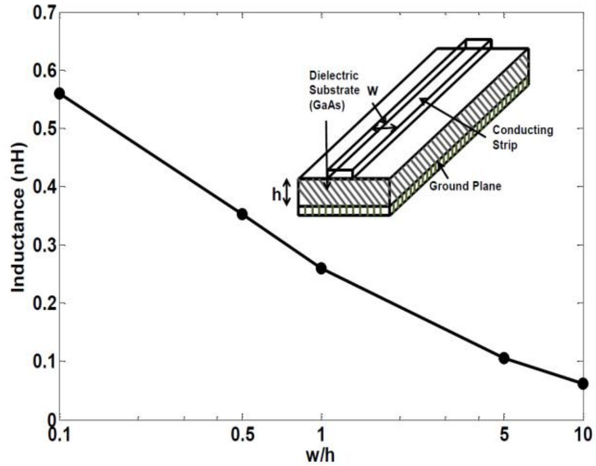

Fig. 1 The inductance versus microstrip aspect ratio (w/h) at 82 GHz. Inset: The dimension of the Microstrip Transmission Line.

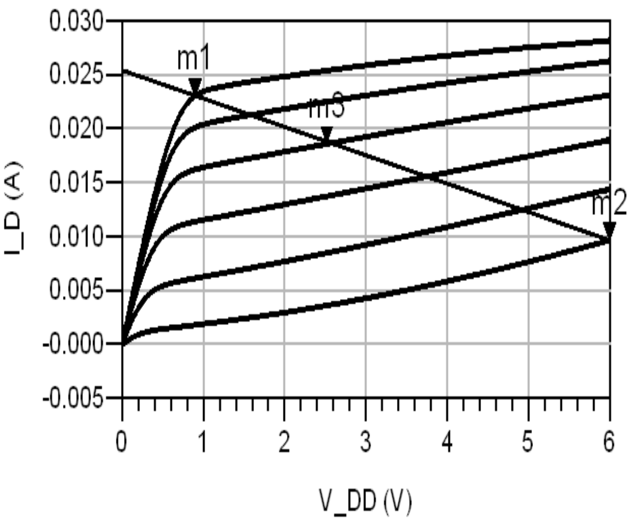

Fig. 2 The I-V characteristics of the pHEMT. The marker ‘m3’ determines the biasing point for Class A operation.

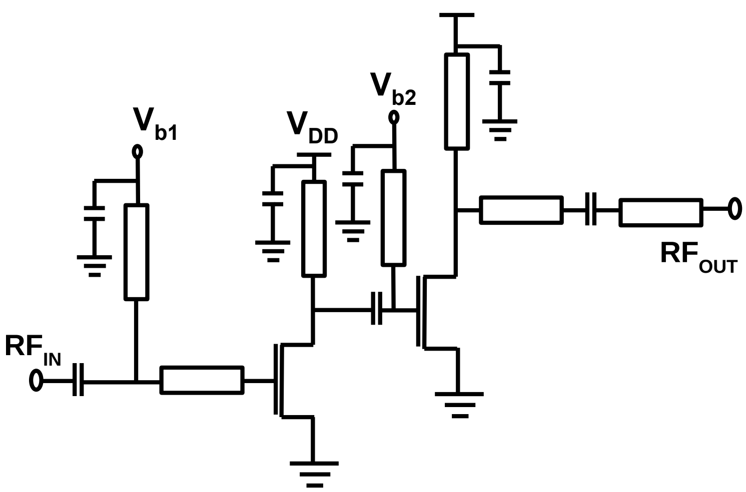

Fig. 3 The schematic of the proposed 2 stage CS Power Amplifier.

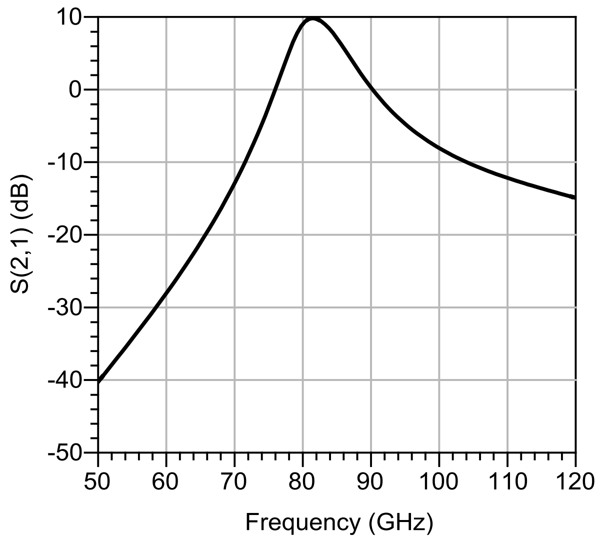

Fig. 4 The Gain (S_{21}) of the PA circuit in dB.

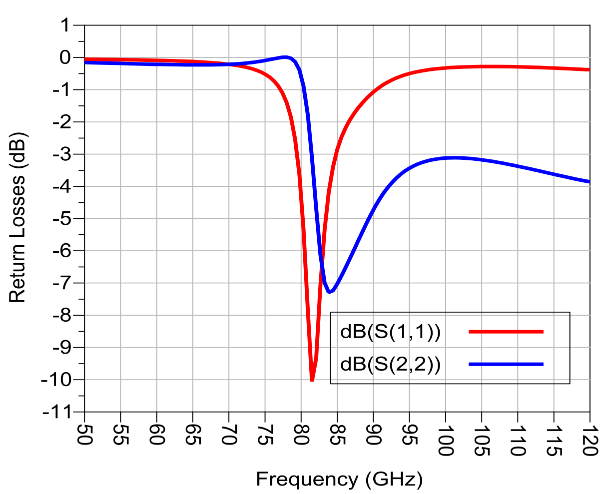

Fig. 5. The input and output reflection losses.

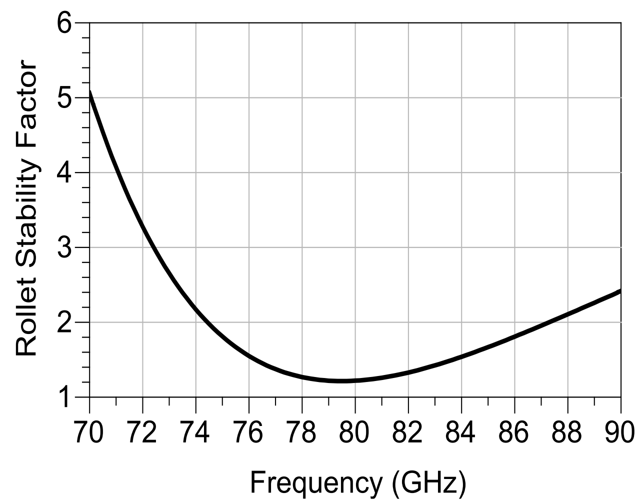

Fig. 6 The stability factor of the Power Amplifier.