High-Gain Frequency-Tunable Low-Noise Amplifiers for 38–42.5-GHz Band Applications

A. Miras and E. Legros

***Abstract*— High-performance tunable low-noise amplifiers for 38–42.5-GHz applications are presented based on a fully stabilized GaAs pseudomorphic high electron mobility transistor (PHEMT) 0.2-μm technology. A single 1.5 $\times$ 3 mm^2 chip, incorporating six amplifying stages, shows a measured gain of 36–42 dB depending on the center frequency. Both maximum gain frequency and input impedance of the amplifier are accurately tunable on the chip. This means that the amplifier provides a narrow-band filtering function and can be matched to a fast p-i-n photodiode as well as to a 50-Ω load. This is the first time such performances are reported for single chip narrow-band tunable amplifiers using a GaAs PHEMT technology.**

***Index Terms*—GaAs PHEMT, high-gain, low-noise, millimeter-wave amplifier, narrow-band.**

I. Introduction

HIGH-PERFORMANCE photoreceivers in the 38–42.5-GHz frequency range are key elements for both high-bit-rate optical transmissions and radio over the fiber distribution networks. Narrow-band amplifiers realize both functions of amplification and filtering. Providing very high gain at the working frequency on a single chip allows low-power consumption, better compactness, and lower cost by simplifying the packaging (avoiding to cascade chips [1]–[3]). Frequency-tunable circuits allow reuse of the same circuit for all applications in the same frequency range. In Europe, the 38–42.5-GHz frequency range is considered for civil wireless communications including radio on-the-fiber. In addition, for clock recovery in optical time domain multiplexing (OTDM) transmissions at 40 Gbit/s, the center frequency is 39.813 GHz. Moreover, as the impedance of the first stage of our amplifier is adjustable, the amplifier can be matched to the impedance of a fast side-illuminated AlGaInAs/InP p-i-n photodiode [8], as well as to a 50-Ω load, depending on the application.

The GaAs pseudomorphic high electron mobility transistor (PHEMT) technology available in foundry is now mature and shows excellent repeatability [3], [4] which is a major point when designing narrow-band amplifiers. We used the fully stabilized D02AH process with 0.2-μm gate length, developed by Philips Microwave Limeil. The transistor has a Ft of 61 GHz, with a transconductance of 470 mS/mm. In this letter, we report on the gain characteristics of monolithic six-stage tunable amplifiers. The maximum gain is as high as 7 dB per stage, which is an excellent performance [3], [5], [6], with low input and output return losses.

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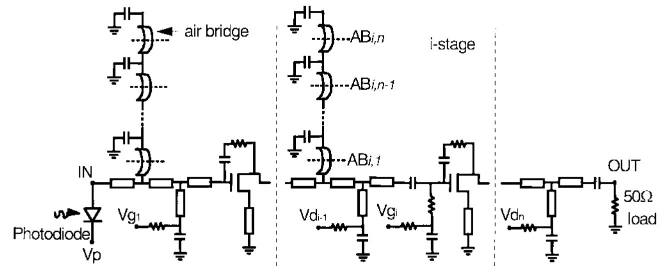

Fig. 1. Schematic of the amplifier. The air bridges $AB_{i,k}$ are cut from $k = n$ to 1, to increase the center frequency.

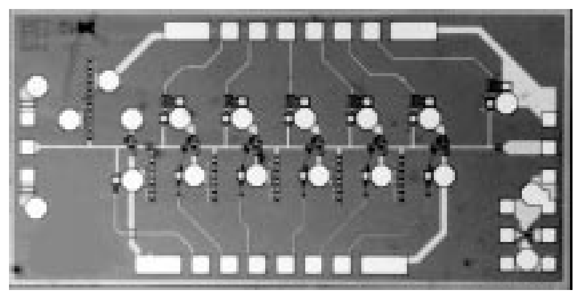

Fig. 2. Chip photograph (a-version).

II. Circuits Design

The amplifiers designed on a single chip include six stages; each stage uses a 60-μm GaAs PHEMT. The schematic of the amplifiers is given on Fig. 1. A photograph of the amplifier chip is shown on Fig. 2. Chip size is 1.5 $\times$ 3 mm^2.

The input and interstage matching networks are designed to get low noise in the gain-peak frequency range. MIM capacitors and microstrip lines are used for the matching stages [7]. In order to improve the gain, to reduce the noise, and to get the filtering function, the amplifier stages are matched on the aimed narrow-band frequency. The major difficulty is to accurately tune the center frequency. A tuning procedure has been developed and validated. It consists in adjusting the length of an open stub for each stage. The open stubs are made with repeated sections which can be disconnected, starting from the end and moving toward the PHEMT. Each section includes an air bridge, removable by a pin, followed by a MIM capacitor (several femtoFarads), whose size is chosen to obtain 2-GHz frequency steps for each section disconnection.

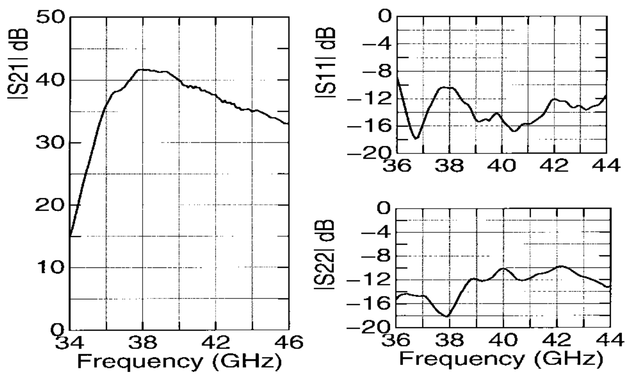

Fig. 3. Measured S-parameters for tuning at 38 GHz (a-version).

The output impedance of the chip is 50 Ω. Adjusting the length of the open stub in the first stage allows to match the amplifier to the impedance of a fast side-illuminated AlGaInAs/InP p-i-n photodiode (characterized by a capacitance of typically 60 fF), but also to a 50-Ω load. Except for the first stage, the matching tee junction at the input of each transistor [7] is replaced by a high value resistance. A negative drain-gate feedback on the PHEMT's improves the gain on a larger tuning frequency range. This gain value is limited by the feedback resistance and the length of the stabilizing lines between the PHEMT sources and the via-holes, designed to avoid circuit oscillation at the peak frequency. These elements are designed for an amplifier bandwidth of about 3 GHz.

III. Measured Circuit Performances

Two versions of the amplifiers have been designed following the same schematic. The difference between them is essentially a frequency shift of 2 GHz. The power consumption of each circuit is 126 mW ($V_d = 2V - I_{d\text{total}} = 63$ mA). The measured S-parameters of the first amplifier (a-version) tuned at 38 GHz is shown on Fig. 3. The measured gain is 42 dB over a 3-GHz bandwidth, which means 7 dB per stage without any oscillation. The measured gain of the second amplifier (b-version) is shown on Fig. 4, for different tuning frequencies; the number of remaining cascaded sections on the tunable open stubs is respectively six sections on the first stage and five sections on the other stages at 34 GHz, five/four at 36 GHz, five/three at 38 GHz, five/two at 40 GHz, four/one at 40–42.5 GHz. With a single chip, different narrow-band amplifiers can be realized in the 34–42.5-GHz frequency range with more than 36 dB of gain above 38 GHz. Input and output return losses are better than −10 dB over the whole tuning range. The equivalent input noise current density of previous versions of this type of amplifiers [3] has been measured on an assembled photoreceiver. Less than 35 pA/$\sqrt{}$Hz is obtained over a 3-GHz bandwidth, with a minimum of 23 pA/$\sqrt{}$Hz, which corresponds to a noise figure of 3.5 dB.

The tuning procedure may be advantageously used to quickly and accurately characterize this type of narrow-band amplifier. When the demonstrator-circuit characteristics are achieved, application-specific narrow-band amplifiers can be put into production with the same layout except the removed air bridges (only the interconnection mask has to be modified).

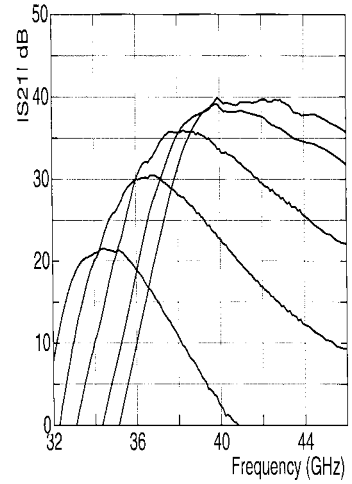

Fig. 4. Measured gain for different center frequency tunings (b-version).

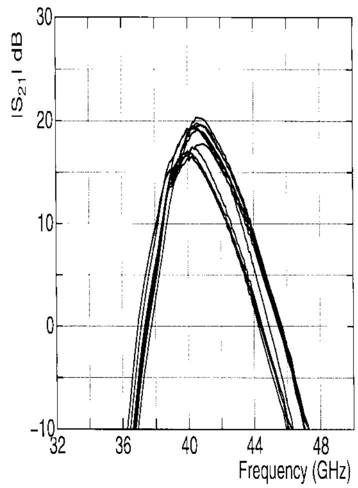

Fig. 5. Repeatability test on two wafers.

We have already validated this approach and demonstrated its excellent repeatability. Fig. 5 presents the gain measured for eleven circuits coming from two different wafers tuned using this tuning concept to get a maximum gain near 40 GHz. For the different circuits of a same wafer, the center frequency and the maximum gain are very close.

IV. Conclusion

We have demonstrated two versions of a six-stage tunable narrow-band amplifier for two main applications: clock recovery in high-bit-rate transmissions and radio over the fiber distribution networks. One amplifier version shows a measured gain of 36–39 dB over the 38–42.5-GHz frequency range, while another version of the same amplifier shows a measured gain of 42 dB at 38 GHz. This is believed to be the highest amplifier gain ever reported on a single chip at millimeter-wave, and with a very low power consumption (126 mW).

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