Extended Abstracts of the 2007 International Conference on Solid State Devices and Materials, Tsukuba, 2007, pp. 302-303

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Low Power Consumption and Low Noise InGaP/GaAs HBT MMIC Amplifier for Full-Band UWB Receiver

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1. Introduction

Ultra-wideband (UWB) radio system is one of the most promising candidates for short-range wireless ultra-fast data links. A frequency bandwidth prepared for the full-band UWB covers from 3.1 GHz to 10.6 GHz. In Japan, the bandwidth is divided into the lower (3.4 GHz~4.8 GHz) and upper (7.25 GHz~10.25 GHz) bands as the standard. To realize the fastest data transfer or miniaturization of the composite system for the Japanese UWB in the next generation, development of components for the full-band UWB system are strongly required. We already proposed some full-band UWB components such as an antenna [1], a filter [2], an MMIC amplifier for the antenna drive [3], and a group delay compensator [4].

In this paper, a developed broadband InGaP/GaAs HBT MMIC amplifier as the full-band UWB receiver is described. The amplifier is configured to the same circuit scheme developed previously [3] and was designed by adjusting the circuit parameters based on scaling law with some modifications to obtain a low power consumption and a low noise characteristics. The fabricated amplifier exhibited a low power consumption of smaller than 16 mW and a low noise figure of less than 3.7 dB with the maximum gain of 14.1 dB in the full-band of the UWB. The sate of the art performance for full-band UWB system was obtained using a 2-micron low-cost InGaP/GaAs HBT MMIC structure.

2. Design of Broadband MMIC Amplifier

The circuit configuration of the broadband amplifier is shown in Fig. 1. A resistive feedback scheme was used to the broadband amplifier to reduce the chip size. A peaking inductor, L_p, was employed to compensate the gain at high-frequency region. In order to decrease the power consumption to 1/10 of that for the driver amplifier developed previously, scaling law for the driver amplifier was applied. However, signal source and load impedances, i. e. 50 ohms, cannot be scaled up. Additionally, the minimum size for HBT's is led to the HBT process/layout rules. For input/output impedance matching, inductors, L_{m1}, and L_{m2}, were additionally inserted so that a source/load impedance value of 50 ohms is retained, under an allowable sacrifice of deteriorating broadband characteristics. For the limitation of the HBT layout dimension reduction, R_1, R_2, and R_3, were increased to the values larger than those obtained from the scaling law to reduce the bias currents, considering noise figure. The noise figure for broadband amplifiers depends

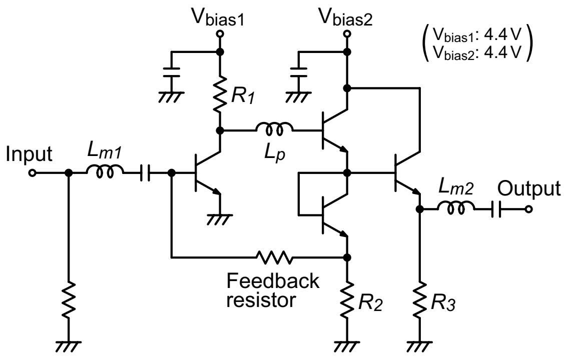
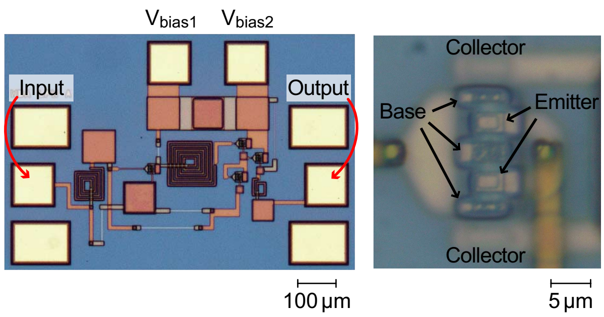


Fig. 1 Circuit configuration of the broadband amplifier.

mainly on an equivalent noise resistance, source impedance, and on feedback resistance for the first stage HBT. Equivalent base resistance was also reduced to improve noise figure by adopting a triple-base double-emitter structure.

3. Fabrication of MMIC Amplifier

Figure 2 shows photographs of the fabricated MMIC amplifier and the used InGaP/GaAs HBT. The MMIC was fabricated by using the WIN foundry service. The layout rules and the layer structures were the same as the previous fabrication [3]. The input and output ports were contacted by GSG on-wafer probes with the pitch of 150 μm in the experiment. In Fig. 2 (b), the emitter length was shortened from 12 μm to 3.6 μm to decrease the power consumption. Additionally, triple-base structure was employed for the double-emitter HBT to reduce the base resistance of the HBT.



(a) MMIC amplifier (920 μm × 620 μm)

(b) InGap/GaAs HBT

Fig. 2 Photographs of the fabricated MMIC amplifier and the used InGaP/GaAs HBT

4. Measured Performances of Fabricated Amplifier

Figure 3 shows the measured gain and input return loss bandwidth characteristics for the fabricated InGaP/GaAs MMIC amplifier. The amplifier provided a 3-dB gain roll off bandwidth from 1.1 GHz to 10.6 GHz with a 14.1-dB peak power gain. Better than 7 dB input return loss was also obtained. Figure 4 shows the measured input and output power response at 3.0, 7.0, and 10.5 GHz for the amplifier. A 1-dB output power compression points were between –19.7 dBm and –22.6 dBm in the gain bandwidth. A total power consumption of the amplifier was 15.9 mW. Figure 5 shows the measured noise figure as a function of the frequency for the amplifier. The measured noise figure of the amplifier was from 2.9 dB to 3.7 dB in the gain bandwidth. A little vibration was observed in the measured characteristic owing to a little mismatching at an input of an external preamplifier used to an NF analyzer. Table I shows a comparison between full-band UWB amplifiers reported in this work and in the others [5-8]. A favorable performance was obtained as the full-band UWB receiver amplifier in comparison with other reported amplifiers.

5. Conclusions

An InGaP/GaAs HBT MMIC amplifier was developed for full-band UWB receiver. The amplifier was configured to a resistive feedback scheme, which was the same circuit configuration developed as the driver amplifier previously.

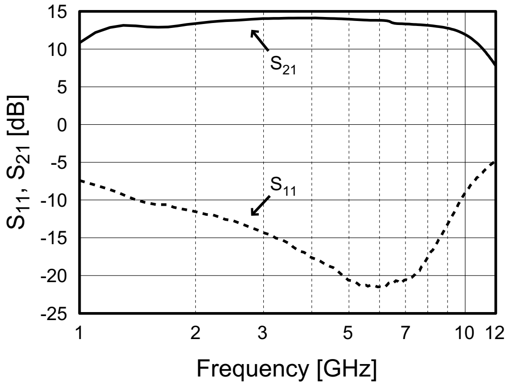


Fig. 3 Measured gain (S_{21}) and input return loss (S_{11}) bandwidth characteristics for the fabricated InGaP/GaAs HBT MMIC amplifier.

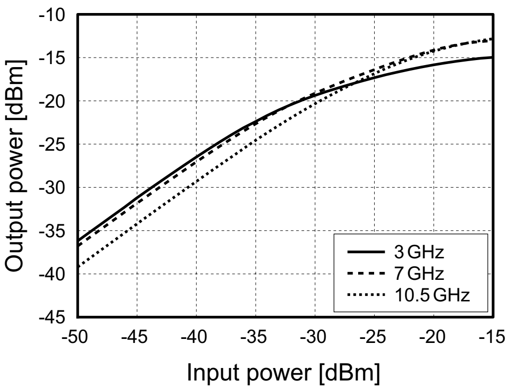


Fig. 4 Measured input and output power response for the fabricated InGaP/GaAs HBT MMIC amplifier.

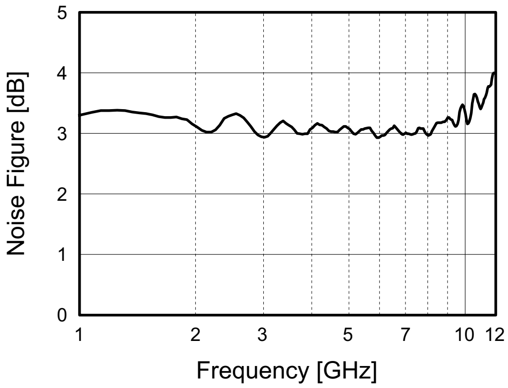


Fig. 5 Measured noise figure as a function of the frequency for the fabricated InGaP/GaAs HBT MMIC amplifier.

Table I Comparison with reported UWB amplifiers.

Ref.	$BW_{3\text{-dB}}$ [GHz]	$Gain_{max}$ [dB]	S_{11} [dB]	NF [dB]	Power* [mW]	Transistor
[3]	2.4~10.8	14.1	< –10.2	–	295	InGaP/GaAs HBT
[5]	0.5~14	11.5	< –11	3.4~5.4	52	Si nMOSFET
[6]	3.1~10.6	10	< –7	4.5~5.5	5.4	SiGe HBT
[7]	3.1~14.5	22	< –1	2.7~3.9	13.2	SiGe HBT
[8]	0.1~13.6	20.3	< –7.2	1.8~3.1	26	SiGe HBT
This work	1.1~10.6	14.1	< –7	2.9~3.7	15.9	InGaP/GaAs HBT

*Power consumption

It was designed by adjusting the circuit parameters based on scaling law. The matching inductors were added for the 50-ohm input and output connections. The bias resistors were adjusted to decrease the power consumption. The triple base structure for the double-emitter HBT was employed to decrease the base resistance and to suppress the noise generation. The fabricated amplifier provided a 3-dB gain roll off bandwidth from 1.1 GHz to 10.6 GHz with a 14.1-dB peak power gain. It exhibited a low power consumption of 15.9 mW and a low noise figure of less than 3.7 dB with the maximum gain of 14.1 dB in the full-band of the UWB. More details of the scaling design including gain bandwidth, power consumption, and noise figure will be presented at the conference.

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