A 4–9 GHz 10 W wideband power amplifier

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Abstract: A 4–9 GHz wideband high power amplifier is designed and fabricated, which has demonstrated saturated output power of 10 W covering 6–8 GHz band, and above 6 W over the other band. This PA module uses a balance configuration, and presents power gain of 7.3 ± 0.9 dB over the whole 4–9 GHz band and 39% power-added efficiency (PAE) at 8 GHz. Both the input and output VSWR are also excellent, which are bellow –10 dB.

Key words: wideband PA; balance amplifier; Lange couple; microwave integrate
DOI: 10.1088/1674-4926/30/2/025002 **EEACC:** 1220; 1150F

1. Introduction

High power amplifiers (HPAs) have played a most important role in the transceivers of wireless communication, such as telecommunications, phase-array radars, and aerospace systems. As the progress in these fields, HPAs with higher power and wider band are greatly needed.

Microwave integrate circuits (MICs) have played a key role in the growth of microwave applications during the past 30 years. It has been demonstrated to be a useful way to realize power amplifier circuits, which takes lower cost, less time, easier to manufacture and more convenient to debug[1]. In this paper we design and fabricate a wideband MIC power amplifier which shows excellent power performance.

2. Circuit design and fabrication

Balance configuration is used in this circuit for wideband design, since it has a lot of advantages such as improvement of output power by 3 dB, inherent 50 Ω input/output impedance, and most importantly cancellation of input (output) reflection[2]. Our team has recently reported a 4–12 GHz balance power amplifier which has a 1 dB output power of 29.5 dBm at 8 GHz[3]. A configuration of balanced amplifier is shown in Fig.1. Two identical single-matched amplifiers are fed from an input Lange coupler, which produces two signals in phase quadrature, the outputs being recombined using the same coupler connected in reverse. Any mismatch reflections from the amplifiers pass back through the couplers and appear in antiphase and therefore cancel at the RF input (or output) port.

We make use of a four-finger Lange coupler to realize the balance amplifier. A schematic of Lange coupler is shown in Fig.2.

Many reports have shown the design procedure of this coupler[4]. We first calculate the finger width W and the conductor spacing S to get a –3 dB coupling coefficient for the 50 Ω characteristic impedance on the Al_2O_3 substrate, the relative permittivity (ε_r) of which is 9.8. The result is $W = 38$ μm, $S = 26$ μm. The length of the coupler is set to $\lambda/4$ at 8 GHz, which is calculated to be 4 mm by Eq.(1).

$$\lambda/4 = \lambda_0/4\sqrt{\varepsilon_{\rm eff}} = \lambda_0/4\sqrt{(\varepsilon_r+1)/2} = c/(4f\sqrt{(\varepsilon_r+1)/2}). \quad (1)$$

These data are imported to ADS momentum simulation and be optimized. Figure 3 shows the simulation result of the designed Lange coupler.

The power device of this amplifier circuit is Excelics Semiconductor Inc's EPA680AV, which has 36.5 dBm typical output power and 8 dB typical power gain at 12 GHz. This device is matched to achieve good power performance

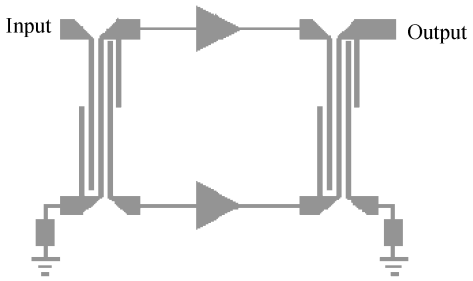

Fig.1. Configuration of balanced amplifier.

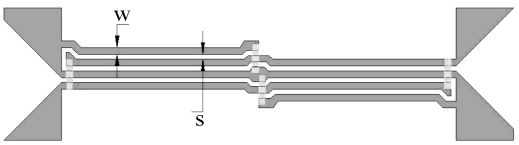

Fig.2. Schematic of the four-finger Lange coupler.

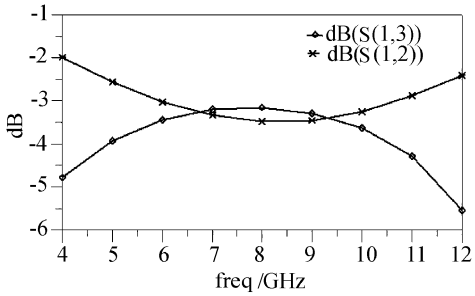

Fig.3. Simulation result of the designed Lange coupler.

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Received 24 June 2008, revised manuscript received 13 October 2008

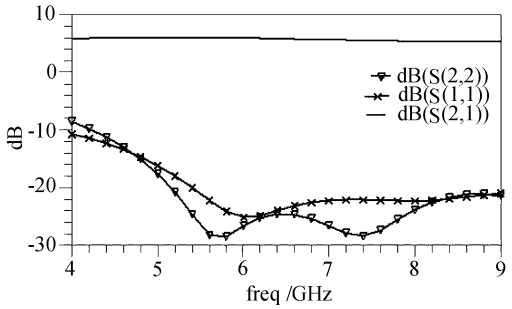

Fig.4. Simulation result of the whole amplifier.

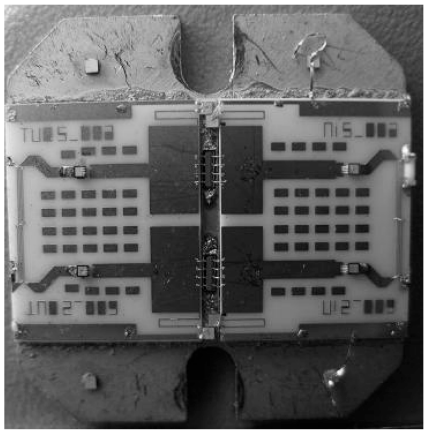

Fig.5. The fabricated 4–9 GHz wide band power amplifier.

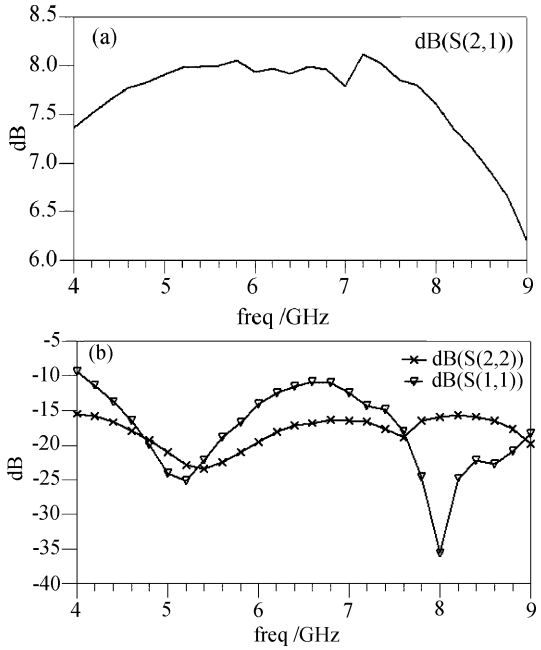

Fig.6. The small signal performance of the fabricated PA: (a) The measured power gain of the fabricated PA (biased by V_{ds} = 9 V, I_d = 2 A); (b) The measured VSWR of the fabricated PA (biased by V_{ds} = 9 V, I_d = 2 A).

and flat power gain over the band with a single matching network. The output matching network is considered first, which is particularly designed to present relatively optimum load impedance to the output of the device over the whole band, using distributed elements. The input matching network consists of several microstrip lines with different widths to get a

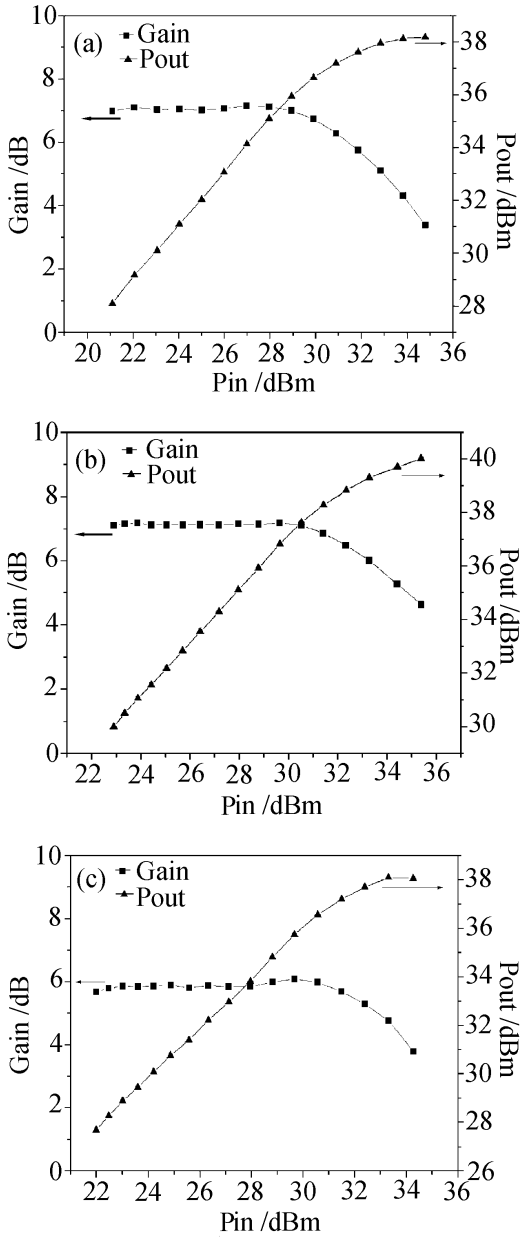

Fig.7. Power gain and output power at (a) 4 GHz, (b) 8 GHz, and (c) 9 GHz, biased by V_{ds} = 9 V, I_d = 2 A.

wide band match, and a $\lambda/4$ line as bias-line is also added to both the input and output matching networks. The simulation is executed in Agent ADS with the S parameters of the device. The VSWR of this single matching circuit is not taken into account as the Lange coupler would greatly improve it.

When the design of Lange coupler and single matching circuit are finished, we combine them to make up of the whole balance amplifier circuit. After optimizing it, the simulation result is shown in Fig.4.

The whole circuit is fabricated on Al_2O_3 ceramic substrate, including Lange coupler, matching circuit and bias-lines. The ceramic and power devices are then welded to kovar using eutectic technology to achieve better heat dissipation. After capacitors are wire bonded to the circuit, the whole balance power amplifier is realized. Figure 5 shows the fabricated power amplifier.

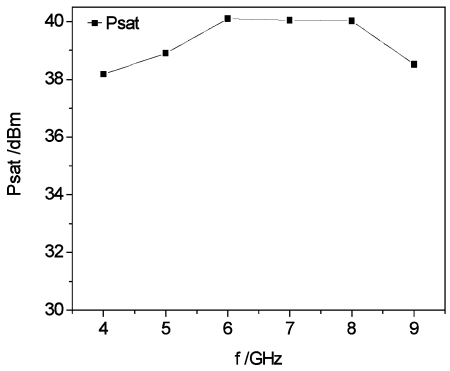

Fig.8. Saturated output power at various frequency points, biased by V_{ds} = 9 V, I_d = 2 A.

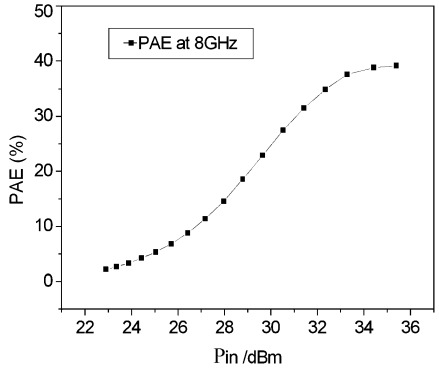

Fig.9. The measured PAE of the fabricated PA at 8 GHz, biased by V_{ds} = 9 V, I_d = 2 A.

3. Amplifier performance

The amplifier is measured both the small signal performance and the power characters at bias point of V_{ds} = 9 V, I_d = 2 A. The small signal power gain is 7.3 ± 0.9 dB, and the VSWR is well bellow –10 dB covering the whole 4–9 GHz frequency band, as shown in Fig.6.

The amplifier also achieves a saturated output power level of 10 W covering 6–8 GHz band, and above 6 W over the other bands. The power performance at 4, 8, and 9 GHz can be seen in Fig.7, and the saturated output power at various frequency points can be seen in Fig.8. The amplifier also exhibits a high power-added efficiency (PAE) of 39% with output power of 10 W at 8 GHz, as shown in Fig.9.

4. Conclusion

A 4–9 GHz wideband high power amplifier was designed and fabricated, which has demonstrated a saturated output power of 10 W covering 6–8 GHz band, and above 6 W over the other bands. This PA module uses a balance configuration, and presents power gain of 7.3 ± 0.9 dB over the whole 4–9 GHz band and 39% power-added efficiency (PAE) at 8 GHz. Both the input and output VSWR are also excellent, which are bellow –10 dB.

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