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LOW-NOISE GaInP/GaAs HBT WIDEBAND DUAL FEEDBACK AMPLIFIERS USING KUKIELKA AND MEYER TOPOLOGIES

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ABSTRACT: *GaInP/GaAs HBT inductorless wideband amplifiers using shunt-series shunt-shunt dual-feedback topology (Kukielka topology) and shunt-series series-shunt dual-feedback topology (Meyer topology) are demonstrated in this article. Three amounts of feedback are applied on each topology. At the high-gain mode, the Kukielka/Meyer wideband amplifier achieves the small-signal power gain of 30/27 dB with the 3-dB bandwidth of 6 GHz at a 5 V supply. The noise figure of both amplifiers is lower than 3 dB within 6 GHz. To increase the amount of feedback widens the bandwidth at the cost of power gain and noise figure degradation.* © 2010 Wiley Periodicals, Inc. Microwave Opt Technol Lett 52: 1486–1489, 2010; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.25280

Key words: *GaInP/GaAs HBT; kukielka; meyer; wideband amplifier; feedback amplifier*

1. INTRODUCTION

A wideband amplifier is a general-purpose building block. The gain bandwidth, matching bandwidth, 1-dB gain compression point (P_{1dB}), linearity performance, and noise performance are important criteria to judge whether a wideband amplifier is qualified. Upon so many topologies of wideband amplifiers, there are basically two most popular inductorless two-stage wideband amplifier configurations: (1) the Kukielka amplifier [Fig. 1(a)] with shunt-series and shunt- shunt feedback loops [1–4] and (2) the Meyer amplifier [Fig. 1(b)] with shunt-series and series-shunt feedback loops [5–7]. Because of the high-speed and matching properties, these two wideband amplifiers are appropriate for wireless applications and optical systems.

A Kukielka amplifier [1–4] preserves the broadband characteristics of the Cherry-Hooper amplifier, and the global shunt-series feedback loop can further increase the bandwidth. The input/output matching is achieved simultaneously by the global shunt-series feedback loop and the local shunt-shunt feedback loop. The input impedance is lowered by the shunt-series feedback loop, whereas the output counterpart is reduced by the shunt-shunt feedback loop.

However, a Meyer wideband amplifier is a two-stage amplifier with two global feedback loops, including the shunt-series and series-shunt topologies, and the schematic of the Meyer configuration is totally different from that of the Kukielka topology. However, the gain-bandwidth and input/output matching bandwidth can be simultaneously achieved by two feedback loops as shown in Figure 1(b). Because the Meyer amplifier does not consist of a Cheery-Hooper amplifier, the frequency response of the Meyer amplifier is slightly worse than that of the Kukielka amplifier. However, the performance of the Meyer topology is much uniform than that of the Kukielka configuration. Because there are two global feedback loops in the Meyer topology, the input and output common-mode levels and the bias currents are well-defined. As a result, the Meyer amplifier has more advantages for mass production when compared with the Kukielka amplifier.

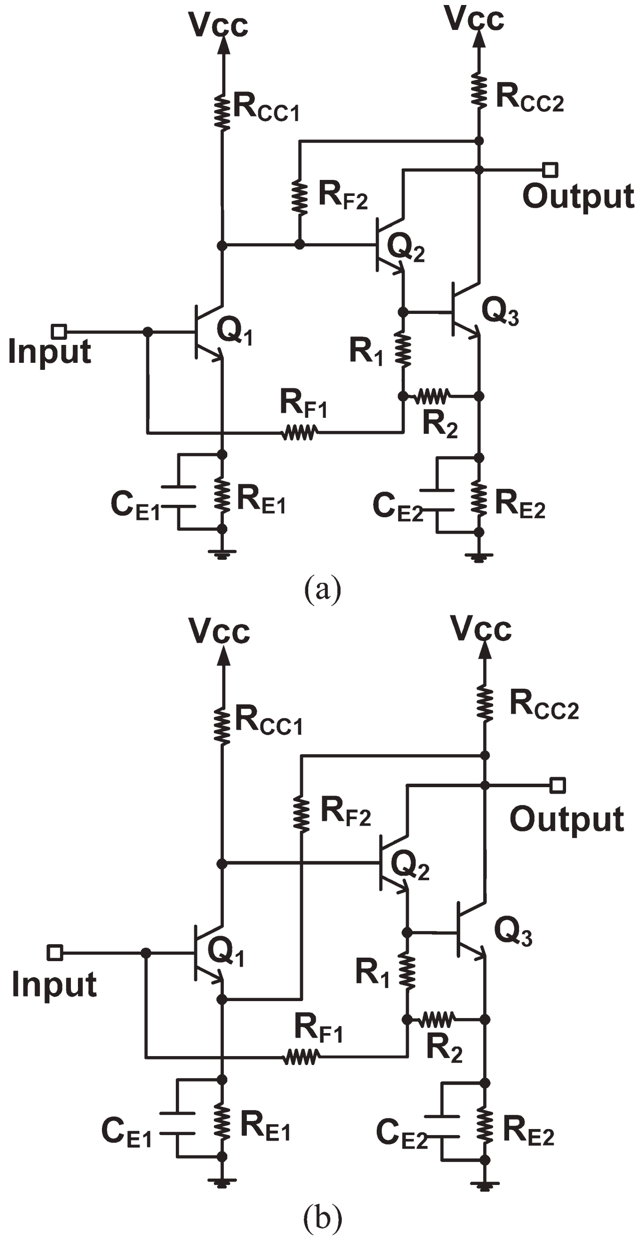
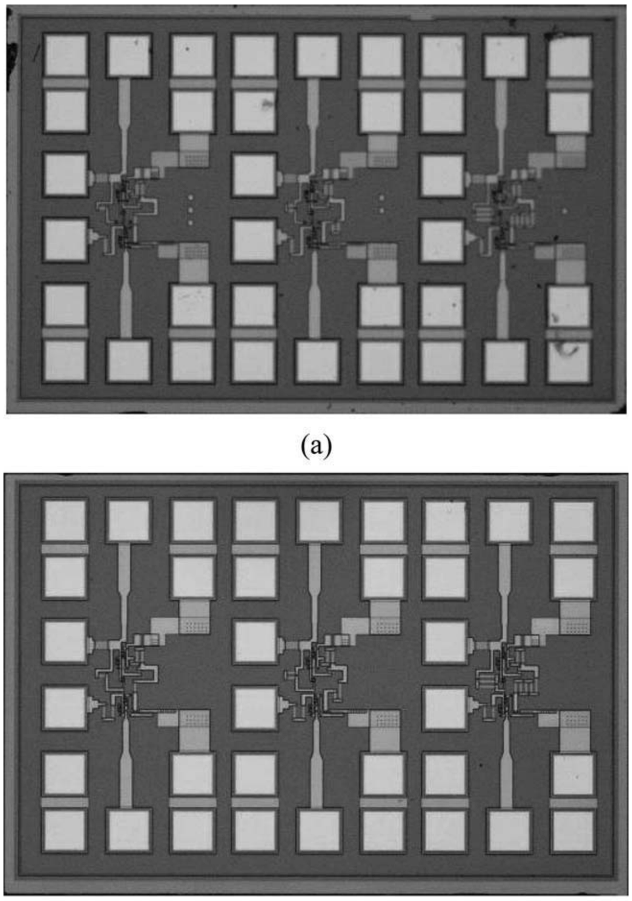


Figure 1 Schematic of (a) shunt-series shunt-shunt dual feedback amplifier (Kukielka topology) and (b) shunt-series series-shunt dual feedback amplifier (Meyer topology) using GaInP/GaAs HBT technology

2. CIRCUIT DESIGN

The first stage of the Kukielka/Meyer amplifier is a common-emitter amplifier (transistor Q_1), whereas the second stage is a



(a)

(b)

Figure 2 Dye photo of (a) Kukielka wideband amplifier and (b) Meyer wideband amplifier using GaInP/GaAs HBT technology

Darlington pair (transistors Q_2 and Q_3). Intrinsically, the Darlington pair has a better frequency response when compared with the common-emitter amplifier. In addition, the feedback loops increase the gain-bandwidth and the matching bandwidth, simultaneously. Local series-series feedback loops (resistor R_{E1} and R_{E2}) are also used to increase the speed of the transistors Q_1 and Q_3. Besides, both amplifiers employ the capacitive peaking technique to widen the bandwidth.

The input matching is achieved by the shunt-series feedback loop of the Kukielka wideband amplifier. However, the input impedance-matching is achieved by the global shunt-series and series-shunt feedback loops for the Meyer amplifier. The shunt-series global feedback loop lowers the input impedance whereas the series-shunt global feedback loop increases the input impedance. As a result, the designer has two parameters to design the input impedance. Moreover, the output return loss is only defined by one feedback loop, that is, shunt-shunt feedback for Kukielka amplifier and series-shunt feedback for Meyer amplifier.

The noise figure of this wideband amplifier is very small if the feedback resistors of the amplifier are properly designed [8]. In addition to the circuit design, the GaInP/GaAs HBT has a very small base resistance (R_B). As a result, the thermal noise of the wideband amplifier can be minimized.

Figure 2(a) and 2(b) show the dye photos of the wideband Kukielka and Meyer amplifiers, respectively. The total chip area of each topology is 1.4×0.8 mm^2, which includes three circuits with different amounts of feedback. As shown in the photos, the RF on-wafer probing pads limit most of the chip area.

3. MEASUREMENT RESULTS

The supply voltages of both the Kukielka and Meyer wideband amplifiers are both 5 V and the former amplifier draws 25 mA, whereas the latter one draws 40 mA. Figure 3 shows the measured *S* parameters of the Kukielka amplifier. With different amounts of feedback, the S_{21} of each amplifier is 30/24/15 dB. The stronger feedback results in a wider bandwidth but a lower gain performance. Further, the amount of the global feedback is inversely proportional to the feedback resistance. The shunt-type feedback lowers the input/output impedance. In this work, the 10-dB return loss criterion is still achievable within the 3-dB bandwidth for these three amounts of feedback, as shown in Figure 3(b). Similarly, for a Meyer topology, different amounts of feedback result in different gain and bandwidth performance. The achieved gain is 27/22/15 dB but the output return loss is relatively worse than the Kukielka Amplifier as shown in Figure 4(b). However, the noise figure of all amplifiers with respect to frequency is plotted in Figure 5. The noise figure of Kukielka/Meyer amplifiers is <3 dB at the high gain mode with the 3-dB bandwidth is 6 GHz. But the lower feedback resistance (larger

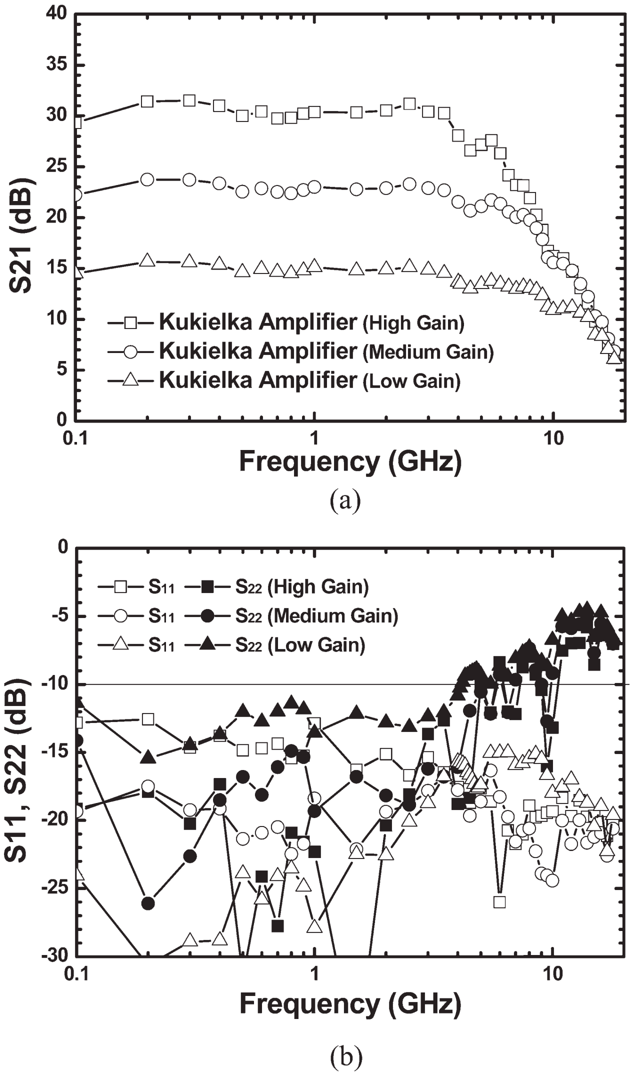
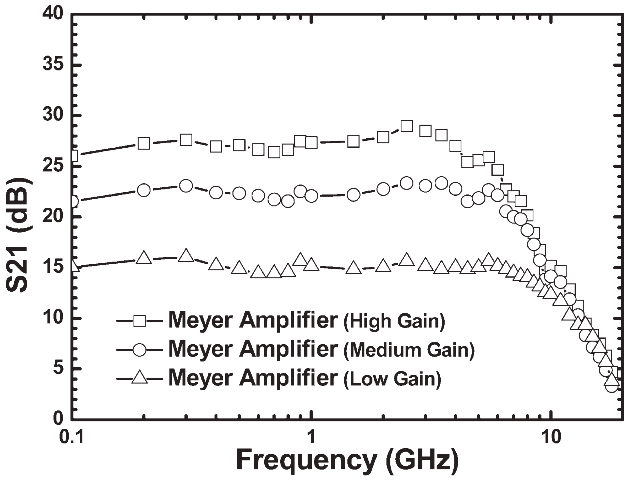
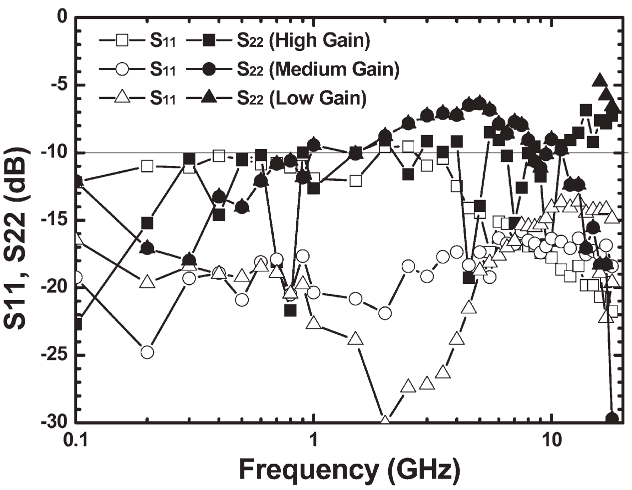


Figure 3 (a) S_{21} and (b) S_{11} and S_{22} of the Kukielka wideband amplifier using GaInP/GaAs HBT technology

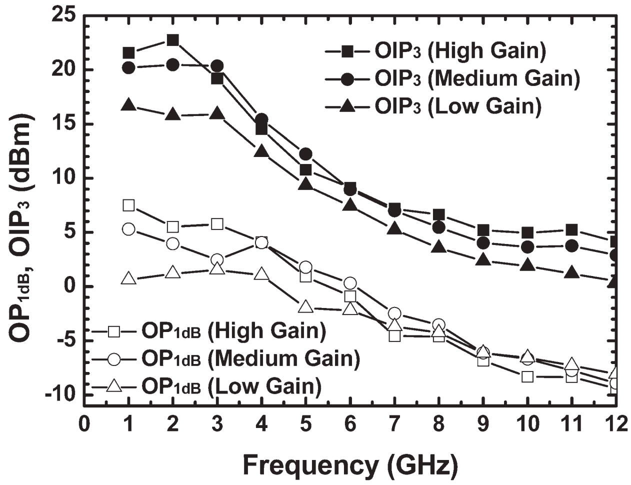


(a)

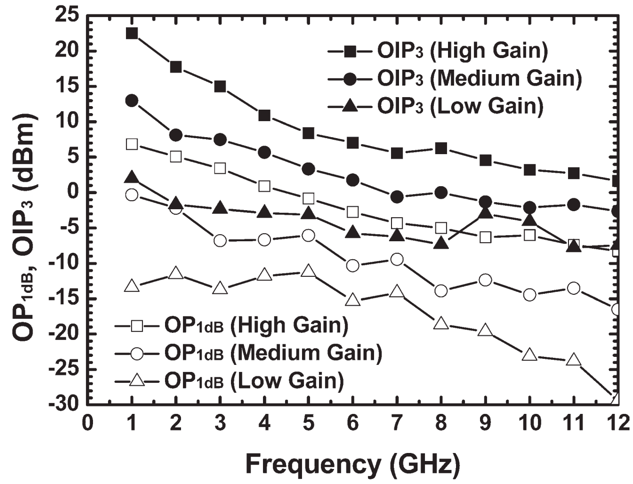


(b)

Figure 4 (a) S_{21} and (b) S_{11} and S_{22} of the Meyer wideband amplifier using GaInP/GaAs HBT technology



(a)



(b)

Figure 6 OP_{1dB} and OIP_3 of (a) Kukielka wideband amplifier and (b) Meyer wide band amplifier using GaInP/GaAs HBT technology

amount of feedback) generates larger input referred noise current; thus, the noise figure increases [8]. The power performances, including OP_{1dB} and OIP_3, of the Kukielka and Meyer amplifiers as a function of frequency is shown in Figure 6(a) and 6(b), respectively. The overall performances of these six circuits are summarized in Table 1.

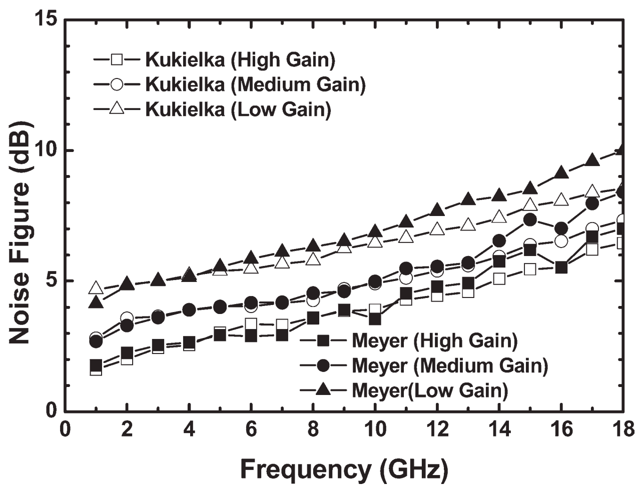


Figure 5 Noise figure of the Kukielka wideband amplifier and the Meyer wideband amplifier using GaInP/GaAs HBT technology

4. CONCLUSION

In this article, GaInP/GaAs HBT Kukielka and Meyer inductorless wideband amplifiers are demonstrated using different amounts of feedback. These feedback wideband amplifiers have trade-offs between gain, bandwidth, and noise performance. A wider bandwidth can be achieved by applying larger amount of feedback (lower feedback resistance) with the power gain and noise figure degradation.

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TABLE 1 Performance Summary

	V_{DD} (V)	I_{DD} (mA)	Gain (max) (dB)	3dB Bandwidth (GHz)	OP_{1dB} [at 1 GHz] (dBm)	OIP_3 [at 1 GHz] (dBm)	Noise Figure (dB) [Within 3dB Bandwidth]
Kukielka Amplifier	5	25	30	5.8	8	22	3
			24	8.4	5	20	4.3
			15	9.6	1	17	6.5
Meyer Amplifier	5	40	27	6	7	23	3
			22	8.3	0	13	4.5
			15	10	−12	2	6.8

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A HIGH-POWER SOLID-STATE RF SOURCE DRIVEN BY A DOUBLY-DIFFERENTIAL SIGNAL

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ABSTRACT: *This letter presents a new solid-state RF source generating kW-level output power at HF band. Four power transistors are driven in a doubly-differential way, operated in a switching mode, and combined together to produce high output power. A multilayered input feed network is carefully designed, such that an accurate doubly-differential signal is provided to the transistors. The output matching and combining circuitry is optimized toward a high efficiency. The implemented RF source produces a CW signal of 1.5 kW at 29 MHz with a drain efficiency of 85%. The measured high efficiency is attributed to the well-balanced and symmetric switching-mode operation of each transistor, which is verified experimentally by a thermal image.*

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Key words: *kW-level RF source; switching mode; doubly-differential drive; high efficiency; HF band*

1. INTRODUCTION

HF-band high-power RF sources are widely used in industrial, medical applications as well as broadcasting transmitters. As the output power level required for these applications is over a kW, a high efficiency is an important factor to maintain reliable operation of the RF source system. Even small degradation of the efficiency may pose a critical thermal stress, finally leading to system failure. Traditionally, HF-band RF sources have been implemented in vacuum tubes, which, unfortunately, is vulnerable to the low efficiency and the resulting overheat [1].

Recently, solid-state devices are replacing vacuum-tubes in the RF sources. The solid-state devices present a smaller size, longer lifetime, more reliability, and cheaper price than the vacuum-tube equivalents. Moreover, if transistors are tuned to operate in a switching mode, the RF source may generate high power with a high efficiency, up to 100% in principle [2, 3]. For example, a 2.7-kW power amplifier operating in a class-E/F mode was implemented at 29 MHz by combining eight vertically double diffused MOS transistors [4].

In this letter, we present a new solid-state RF power source, generating 1.5-kW CW output power at 29 MHz. Two push-pull amplifiers are driven by a doubly-differential signal and combined by a magnetically-coupled technique. Compared with the amplifier in [4], this RF source introduces several differences and improvements. First, four transistors are combined rather than eight, presenting higher output impedance to each drain terminal. This high impedance leads to a low current level at the same bias voltage, thereby reducing ohmic loss at the transistors and matching components. Therefore, the efficiency is improved by 5% at an identical power level of 1.5 kW. Second, a differential input feed network is implemented on a multilayered board that is designed by EM simulation. This enables all transistors to be driven by accurate doubly-differential input signals, leading to the high efficiency. Third, due to the improved efficiency and balanced operation of transistors, the operating temperature of transistor packages is suppressed well below its rating, which is experimentally confirmed.

2. HF-BAND RF POWER SOURCE

The schematic of the RF power source is shown in Figure 1. Four transistors (M_1, M_2, M_3, and M_4) are driven in a doubly-differential way, such that any two adjacent transistors (M_1-M_2,