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HIGH-LINEAR-POWER MESFET DEVICES USING SOURCE-DEGENERATION INDUCTANCE AND INPUT-IMPEDANCE MISMATCH

C. C. Meng[1] and W. Wang[2]
[1] Department of Communications Engineering
National Chiao Tung University
Hsinchu, Taiwan, R.O.C.
[2] Department of Electrical Engineering
National Chung-Hsing University
Taichung, R.O.C.

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ABSTRACT: *Linearity can be improved drastically by sacrificing power gain with the same output power. GaAs MESFET devices with via-hole ground and with bond-wire ground are used to investigate the effect of source-inductive feedback and input-impedance mismatch on the effect of linearity. At 2.4 GHz, the device without bond-wire ground and mismatched input impedance has the highest linearity $OIP_3 = 50$ dBm, gain = 13.5 dB gain, and $P_{1dB} = 29$ dBm, while the device with via-hole ground and matched input impedance has the lowest linearity $OIP_3 = 40$ dBm, 18.3 dB gain, and $P_{1dB} = 29$ dBm.* © 2006 Wiley Periodicals, Inc. Microwave Opt Technol Lett 48: 953–954, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21530

Key words: *power amplifier; MESFET; linearity; GaAs; intermodulation*

INTRODUCTION

All the modern high-data-rate wireless communication systems have strong linearity requirement, and the linearity of a wireless transmitter relies on the linearity of the power amplifier. Linearity optimization involves many factors such as device-structure design, bias-point selection, input impedance, output impedance, feedback, and harmonic termination [1–4]. This paper describes the effects of source grounding and input-impedance matching on the linearity of a GaAs MESFET power device. The formula for the input impedance Z_{in} of a MESFET device with source inductive degeneration is expressed as follows:

$$Z_{in} = Z_1(1 + g_m Z_2) + Z_2, \tag{1}$$

$$Z_{in} = j\omega L + \frac{1}{j\omega C_{gs}} + \frac{g_m}{C_{gs}} L_s, \tag{2}$$

where $Z_1 = (1/j\omega C_{gs})$, $Z_2 = j\omega L_s$, C_{gs} is the gate-to-source capacitance, L_s is the source degeneration inductance, g_m is the transconductance, and ω is the angular frequency. The input impedance Z_1 is increased by a factor of $1 + g_m Z_2$, as expected from the feedback point of view. Feedback can reduce the nonlinear at the cost of lower gain. Because Z_1 is capacitive, an inductive feedback caused by Z_2 creates a real input resistance. The source-degeneration inductance behaves as a series resistor when looking into the gate and thus lowers the overall power gain. In addition, input matching also shows the strong influence on the linearity from our experimental data. In this paper, our results clearly demonstrate that the linearity of a power MESFET device can be improved from the source bond-wire inductive degeneration and input-impedance mismatch.

POWER AND LINEARITY PERFORMANCE

A narrow-recessed MESFET device with doping density of $1 \times 10^{17}/\text{cm}^3$ is used in this study. The gate length is 0.7 μm and total gate width is 2 mm. The device has g_m of 200 mS, I_{dss} of 440 mA, pinch-off voltage of −2.5 V, and gate-to-drain breakdown voltage of 20 V. Both via-hole and bond-wire-ground devices are packaged by the same ceramic packages, and mechanical tuners are used to characterize the power performance of the device. The gain, output power, and power-added efficiency (PAE) as a function of the input available power are measured at the given bias point. The output-matching values for all the devices are tuned for the maximum power condition and all the measurements are performed at 2.4 GHz. It turns out that the device biased at $I_{ds} =$ 200 mA and $V_{ds} = 10$ V has the best linear power performance. The bias point of $I_{ds} = 200$ mA and $V_{ds} = 10$ V corresponds to the bias point equally away from all waveform-clipping gain-compression mechanisms such as knee voltage, pinch-off voltage, breakdown voltage, and maximum rf drain current [5].

The one-tone power performance for the via-hole-ground and bond-wire-ground devices when the output impedance is tuned for maximum output power is shown in Figure 1. The results for input impedances tuned for the maximum small-signal gain and deliberately mismatched are also shown in Figure 1. The via-hole-ground device with matched input impedance has 18.3-dB gain, 29-dBm P_{1dB}, and 40% PAE at P_{1dB} while the via-hole-ground device with mismatched input impedance has 15.4-dB gain, 29-dBm P_{1dB}, and 40% PAE at P_{1dB}. The bond-wire-ground device with matched input impedance has 16.2-dB gain, 29-dBm P_{1dB}, and 40% PAE at P_{1dB}. The source bond-wire causes 2-dB gain reduction. The bond-wire-ground device with mismatched impedance input has 13.5-dB gain, 29-dBm P_{1dB}, and 40% PAE at P_{1dB}.

The linearity of a power amplifier, which can be evaluated by two-tone intermodulation measurements, can be described in two ways as follows. One way is 3rd-order intermodulation IM_3, the difference between fundamental tone P_{f1} (or P_{f2}) and intermodulation components P_{2f1-f2} (or P_{2f2-f1}). Normally, IM_3 is specified at a certain P_{f1}. The other way is OIP_3, which is determined from the intercept point where the extrapolated P_{f1} equals to the

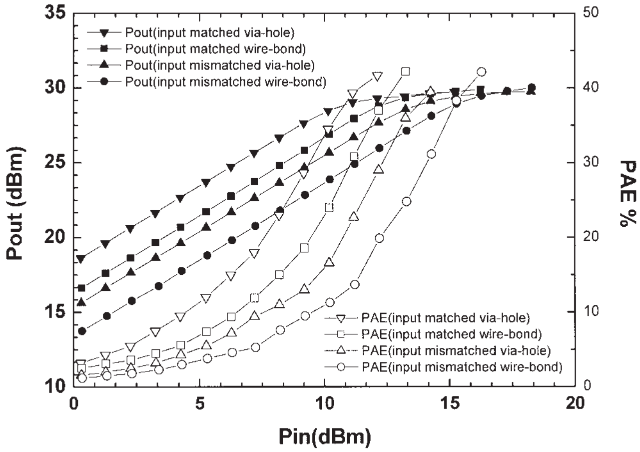

Figure 1 One-tone power performance for via-hole-ground and bond-wire-ground GaAs MESFET devices

extrapolated P_{2f1-f2}. The two-tone power performance for the via-hole-ground device when the output impedance is tuned for maximum output power is shown in Figure 2 (P_{f1} is already shown in Fig. 1 and is not repeated in Fig. 2 for simplicity). OIP_3 is unique for a given bias point and is calculated as the summation of P_{f1} and $IM_3/2$. This formula for OIP_3 is only true in the small-signal region. Thus, only OIP_3 calculated in the small-signal region is shown in Figure 2. The via-hole-ground device with matched input impedance has 40-dBm OIP_3 and the via-hole-ground device with mismatched input impedance has 45-dBm OIP_3. The 2.9-dB gain reduction by mismatch increases the OIP_3 by 5 dB. The two-tone power performance for the bond-wire-ground device is also shown in Figure 2. The bond-wire-ground device with matched input impedance has 45-dBm OIP_3 and the bond-wire-ground device with mismatched input impedance has 50-dBm OIP_3. The 2.7-dB gain reduction by mismatch increases the OIP_3 by 5 dB. All four cases have almost the same PAE at P_{1dB} because all of them have enough power gain. IM_3 at a given output power is also an important figure of merit for linearity. Thus, IM_3 versus power output per tone for all the four cases are shown in Figure 3. The results clearly indicate that the improvement for linearity occurs for 6-dB back-off from P_{1dB}.

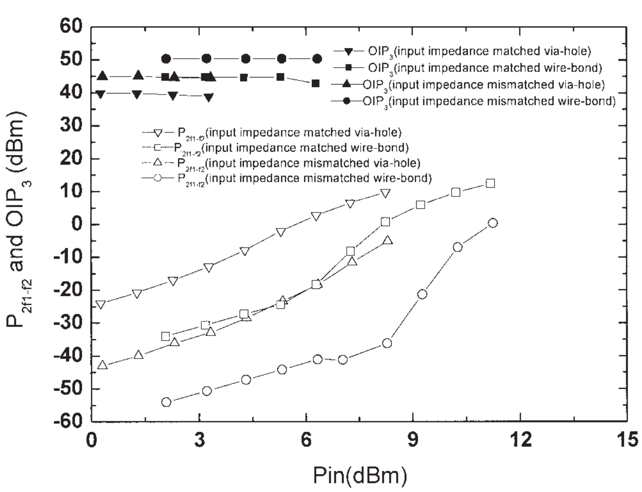

Figure 2 Two-tone power performance for via-hole-ground and bond-wire-ground GaAs MESFET devices

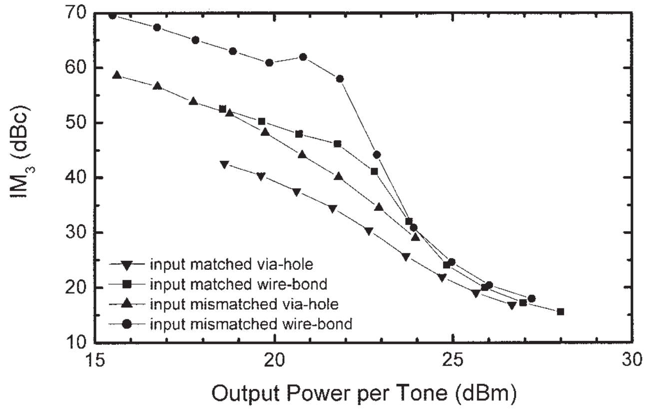

Figure 3 Two-tone IM_3 power performance for via-hole-ground and bond-wire-ground GaAs MESFET devices

DISCUSSION AND CONCLUSION

Power gain can be reduced to improve linearity with the same output power for GaAs MESFET devices. At 2.4 GHz, the device without bond-wire ground and mismatched input impedance has the highest linearity $OIP_3 = 50$ dBm and $P_{1dB} = 29$ dBm. The difference between OIP_3 and P_{1dB} is 21 dB. On the other hand, the device with via-hole ground and matched input impedance has the lowest linearity $OIP_3 = 40$ dBm and $P_{1dB} = 29$ dBm. The difference between OIP_3 and P_{1dB} is 11 dB. The effect of source-inductive feedback and input-impedance mismatch can improve the linearity by 10 dB with the same output power and PAE. The input-impedance mismatch of a power device will not cause any problem because most of the power amplifiers are two-stage (driver stage and power stage) power amplifiers. Thus, a power amplifier can have mismatch in the interstage matching for linearity but still keep input-impedance matching for the driver stage.

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