Broadband MMIC Power Amplifier for Multiple Wireless Systems

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ABSTRACT — **We report the successful development of a broadband, high-linearity MMIC PA. This single PA is useful for multiple wireless systems including satellite mobile ground terminal, GPS transmitter, WiFi repeater, and WiMAX repeater applications. Using GaAs MESFET technology, we connect two 12mm FET unit cells both RF and DC in series (HIFET) to achieve a total gate width of 24mm. This way, the DC bias voltage is doubled from 7V to 14V. Because the 12mm FET's optimum output impedance is about 6 ohms, a single conventional 24mm FET's optimum output impedance will be about 3 ohms. The 2HIFET output optimum impedance is twice that of a 12mm FET, which is about 12 ohms. This high output impedance leads to broadband capability. This is the key reason that a single MMIC PA can serve multiple wireless system applications. This 2-stage MMIC PA is housed in a commercial ceramic package. It achieves 27dB small-signal gain, 39dBm P1dB, 30% power added efficiency over the 1.5GHz to 2.5GHz band. It has good linearity of 51dBm IP3, which is 12dB above P1dB. We believe the combination of bandwidth, output power, efficiency, and linearity is the best reported for MESFET MMIC PA to date.**

INDEX TERM: WIRELESS COMMUNICATION, MMIC POWER AMPLIFIER, HIFET, BROADBAND POWER AMPLIFIER. HIGH LINEARITY POWER AMPLIFIER

1. INTRODUCTION

Power amplifier usually consumes the highest DC power and is one of the most expensive parts in the wireless communication system. It is highly desirable to develop a PA having high efficiency and low cost at the same time. One approach to reduce the cost is to develop a broadband MMIC, which can be used for multiple wireless systems. In this case, the total production volume of this broadband MMIC PA is relatively high, leading to low production cost. But this approach has a technical challenge that high power, broad bandwidth, and high efficiency are usually difficult to achieve simultaneously. In this paper, we report an innovative approach to mitigate this technical problem.

2. Technical Approach.

We connect two FET unit cells both DC and RF in series. We call this configuration HIFET (High-voltage, High-Impedance FET) [1,2,3,4,5,6,7] as shown in Figure 1. The drain (D1) of the bottom FET1 is connected to the source (S2) of the top FET2. If the drain bias voltage of the unit cell FET is Vds, the bias voltage of the 2HIFET is 2 Vds. Notice that the RF input connects only to the gate of FET1, while the RF output is from the drain of FET2, which has 2x

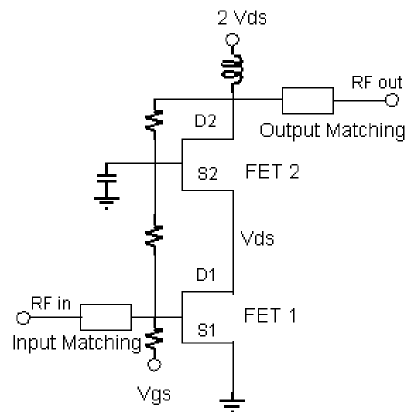

Figure 1. Two FETs connected both DC and RF in series (2HIFET)

of the unit cell FET output power. Therefore, the 2-cell HIFET (2HIFET) has 3dB higher gain than that of the unit cell FET. While the input impedance of 2HIFET is the same as the input impedance of the unit cell FET, the output impedance of the 2HIFET is twice that of the output impedance of the unit cell FET. This high output impedance (Closer to 50 ohms than that of the unit cell FET) enables HIFET to achieve broad bandwidth.

3. MMIC design.

We have designed a 2-stage MMIC power amplifier based on the 2HIFET concept. The first stage (driver stage) is two 2mm FETs (0.5um gate length) in series. The input matching is designed to be 50 ohms from 1.3 to 2.7GHz. The inter-stage matching is also on-chip from 1.3 to 2.7GHz. The output matching however, is deliberately left off chip. There are several reasons to adapt the off-chip output matching configuration: 1). Matching circuit on GaAs has higher loss than on PC board because GaAs chip is only 4-mil thick and it has relatively high dielectric constant of 12.8. This results in very narrow transmission line, which has high ohmic loss. 2). We can optimize the performance for a particular frequency band. And, 3).

Because the output matching circuit usually is quite large, leaving output matching circuit off chip leads to small GaAs chip size, which reduces the chip cost. Figure 2a is a photograph of this 2HIFET MMIC PA. The chip size is very small at 1.79mm x 2.22mm because there is no on-chip output matching circuit. The input is at the left hand side of the chip, and the output is at the right hand side, which does not have an on-chip matching circuit. It can be seen that the output-stage 2HIFET consists of FET1 (left side of the output FET) and FET2 (right side of the output FET). Notice that FET1 and FET2 are electrically connected in series, yet they are physically side-by-side. Therefore, the two unit cells are thermally in parallel. This is another advantage of HIFET, Which is especially important for high power density device such as GaN HEMT - HIFET configuration actually reduces the thermal resistance of an equivalent high voltage device using field plate technology. The MMIC is housed in a ceramic package on a copper carrier as shown in Figure 2b.

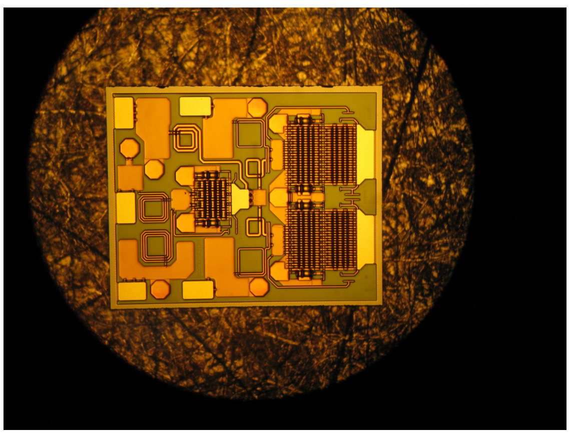

Figure 2a. Photo of a 2-stage, 2HIFET MMIC PA.

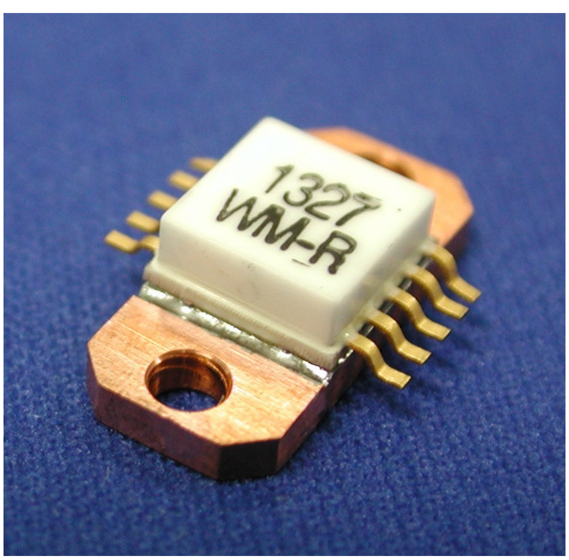

Figure 2b. MMIC in a ceramic package with a copper flange.

Figure 3 shows the off-chip matching circuit on PC board (10-mil thick FR4 PCB) for 1.5 to 2.5GHz band.

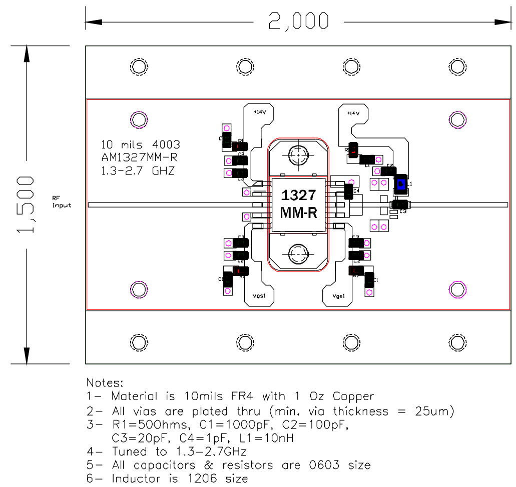

Figure 3: Off-chip output matching circuit on PCB (10-mil thick, FR4 PCB)

3. Measurement Results

Figure 4 shows the measured small signal gain and return loss versus frequency. The small signal gain is 27dB +/- 3dB from 1.5GHz to 2.5GHz.

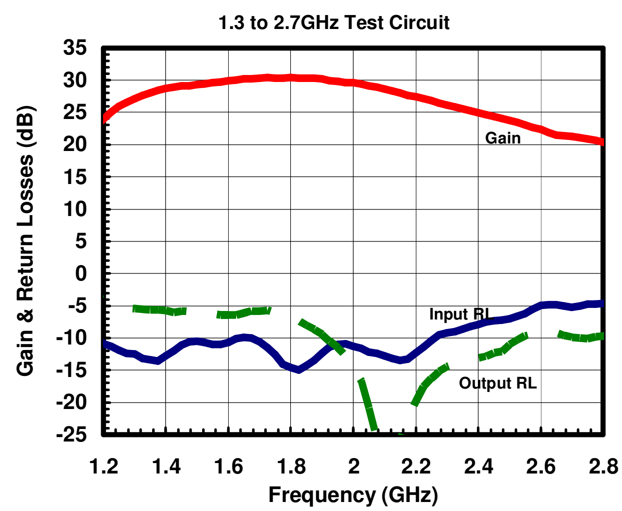

Figure 4. Measured small signal gain versus frequency.

Figures 5a shows P_{1dB} and Eff_{1dB} at 1dB gain compression point versus frequency. Figure 5b shows P_{3dB} (3dB gain compression) and Eff_{3dB} versus frequency. P_{1dB} is 39dBm from 1.5-2.5GHz with more than 30% power added efficiency. P_{3dB} is 39.5dBm with 31% power added efficiency. Notice that P_{3dB} is only 0.5dB above P_{1dB}, indicating good linearity. Not shown in Figure 5 is IP3, which is 51dBm. The IP3 is 12dB above P_{1dB}, another indication of high linearity. The high linearity is a result of HIFET design, which has built-in resistive feed back (Fig. 1).

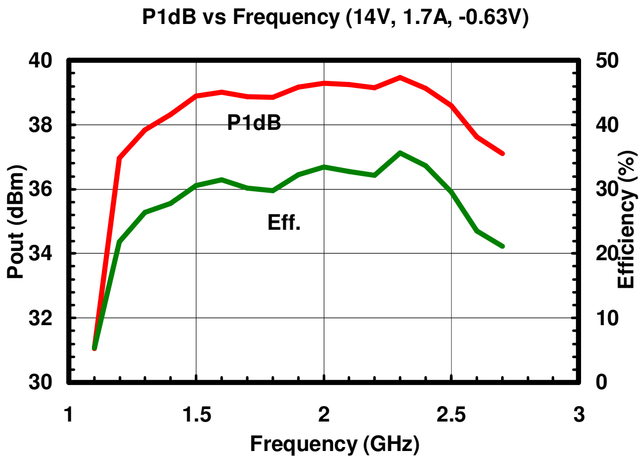

Figure 5a: P_{1dB} and Eff_{1dB} versus frequency

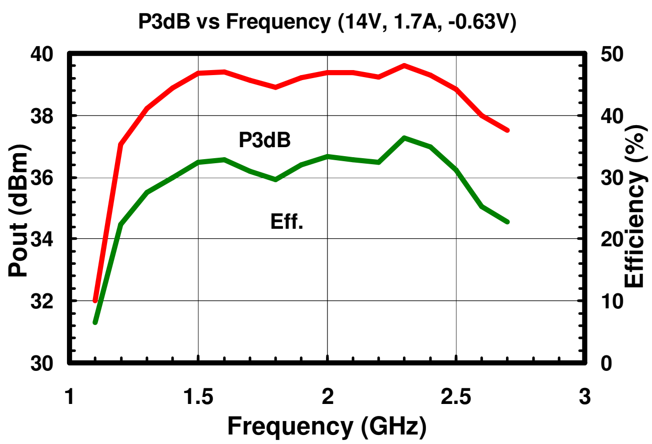

Figure 5b. P_{3dB} and Eff_{3dB} versus frequency

4. Conclusions

We report here a broadband, low-cost MMIC PA for multiple wireless communication applications. We applied the HIFET technique to achieve broad bandwidth, which enables the same MMIC PA to be applicable to multiple wireless systems. This way will lead to large quantity production, resulting in low cost. We also use an off-chip output circuit matching configuration to control the MMIC chip size, further reducing the chip cost. The MMIC PA achieves 27dB small-signal gain, 39dBm P1dB, 30% power added efficiency over the 1.5GHz to 2.5GHz band. It has good linearity of 51dBm IP3, which is 12dB above P_{1dB}. We believe the combination of bandwidth, output power, efficiency, and linearity is the best reported for MESFET MMIC PA to date.

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