

A 60 GHz Medium Power Amplifier for Radio-over-Fiber System

Woojin Chang, Seung-Hyeub Oh, and Haecheon Kim

ABSTRACT—We present the design and fabrication of a 60 GHz medium power amplifier monolithic microwave integrated circuit with excellent gain-flatness for a 60 GHz radio-over-fiber system. The circuit has a 4-stage structure using microstrip coupled lines instead of metal-insulator-metal capacitors for unconditional stability of the amplifier and yield enhancement. The gains of each stage of the amplifier are modified to provide broadband characteristics of input/output matching for the first and fourth stages and to achieve higher gains for the second and third stages to improve the gain-flatness of the amplifier for wideband.

Keywords—60 GHz power amplifier; gain-flatness, millimeter-wave.

I. Introduction

In recent years, there has been major growth in millimeter-wave applications. Monolithic implementation is a key technology for small size and low cost, as well as high reliability, repeatability, and producibility, because conventional hybrid IC implementation is limited in the high-frequency range due to passive elements with unpredictable parasitics, an operational frequency limit, large size, and, therefore, low producibility. There is a growing demand for support for 60 GHz systems, including wireless personal area networks (WPANs) and automotive radar systems. We have designed a 60 GHz medium power amplifier monolithic microwave integrated circuit (MMIC) for 60 GHz radio-over-fiber (RoF) systems. The 60 GHz band is used for broadband wireless data transmission of up to 2 Gbps in WPAN application because of its spectrum

availability and because it has a high level of frequency reuse due to its severe attenuation in atmosphere.

II. 0.12 μm GaAs PHEMT Characteristics

The 60 GHz power amplifier MMIC was designed using a 0.12 μm GaAs pseudo-morphic high electron mobility transistor

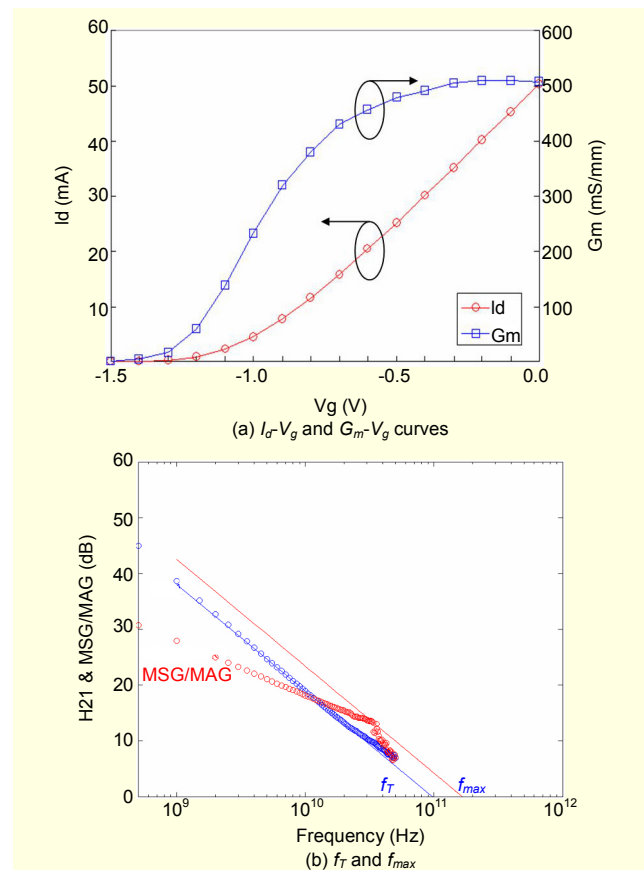


Fig. 1. Characteristics of the 0.12 μm GaAs PHEMT.

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Woojin Chang (phone: +82 42 860 1270, email: wjchang0@nate.com), and Seung-Hyeub Oh (email: ohseung@cnu.ac.kr) are with the Department of Electronics Engineering, Chungnam National University, Daejeon, Rep. of Korea.

Haecheon Kim (email: khc@etri.re.kr) is with the IT Components & Material Research Center, ETRI, Daejeon, Rep. of Korea.

(PHEMT) 4-inch process. The GaAs PHEMT has an effective gate length of 0.12 μm , a unit gate width of 50 μm , and two/four/eight gate fingers [1]. The T-shaped gate of the PHEMT has a wide gate head of 1 μm and a gate foot of 0.12 μm .

The PHEMT shows a peak transconductance ($G_{m,\text{peak}}$) of 500 mS/mm, a threshold voltage of -1.2 V, and a drain saturation current of 49 mA for 2 fingers and 100 μm total gate width (2f100) at $V_{ds}=2$ V. The RF characteristics of the PHEMT show a cutoff frequency, f_T , of 97 GHz, and a maximum oscillation frequency, f_{max} , of 166 GHz at $V_{ds}=2$ V and $V_{gs}=-0.2$ V. Figure 1 shows the PHEMT characteristics.

III. The 60 GHz Medium Power Amplifier MMIC

The 60 GHz medium power amplifier uses NiCr thin film resistors to provide high resistance on parts of the gate bias-lines to minimize RF signal leakage. Figure 2 shows a general concept for improving gain-flatness of the amplifier. The gains of each stage of the four-stage amplifier were modified to provide broadband characteristics of input/output matching for the first and fourth stages and to achieve higher gains in the edge regions of the operating frequency range for the second and third stages to improve the gain-flatness of the amplifier for wideband. The amplifier design was optimized as shown in Fig. 2. The amplifier was designed using microstrip-coupled lines (MCLs) instead of metal-insulator-metal (MIM) capacitors for unconditional stability and yield enhancement. The MCLs in all interstages perform DC blocking and RF matching. An MMIC is composed of active and passive devices, and the uniformity of each device in fabrication affects the yield. In the MMIC fabrication, MIM capacitors show about $\pm 10\%$ variation because of their dielectric constant and film thickness variations. However, MCLs have lower variations in their characteristics compared to MIM capacitors

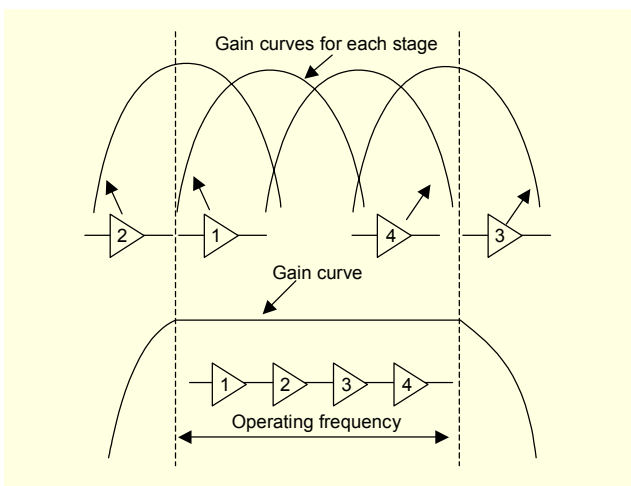


Fig. 2. General concept for improving gain-flatness.

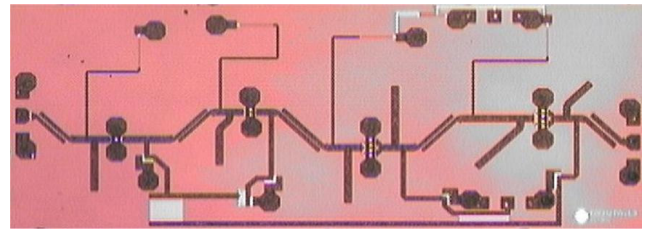


Fig. 3. Microscopic view of the fabricated 60 GHz medium power amplifier MMIC.

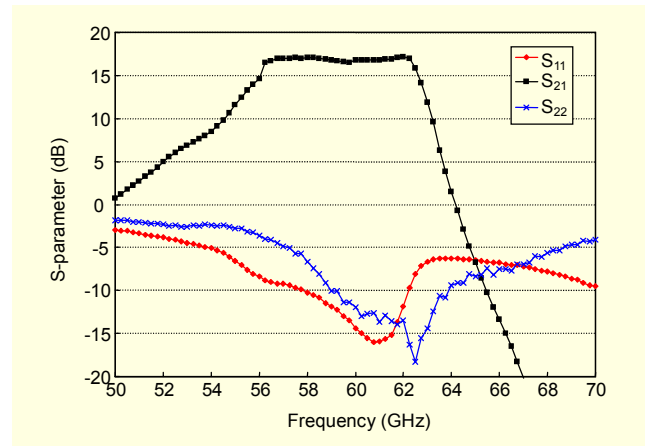


Fig. 4. S-parameter measurement of the fabricated 60 GHz medium power amplifier MMIC.

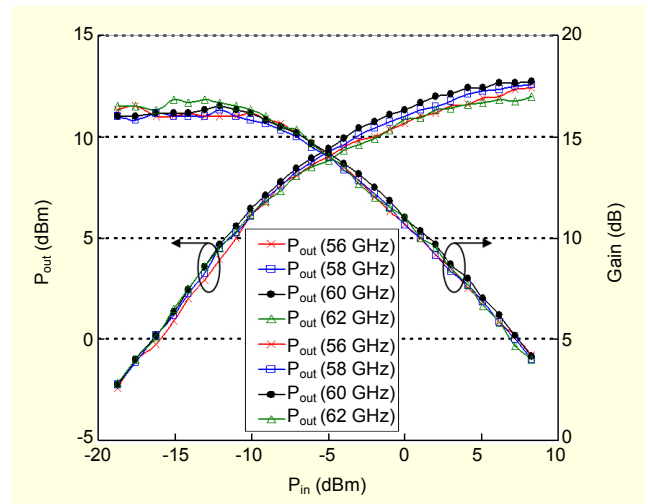


Fig. 5. Power measurement of the fabricated 60 GHz medium power amplifier MMIC.

because the effective metal thickness with 99% energy is very thin at millimeter-wave frequencies. Therefore, MCLs show very stable characteristics even if the metal thickness varies from a run-by-run fabrication process. The 60 GHz power amplifier is designed without any additional circuit (such as negative feedback, resistor, and so on) for unconditional

stability at the frequency range of 1 to 100 GHz.

A microscopic view of the fabricated 60 GHz power amplifier MMIC is shown in Fig. 3. The chip size of the amplifier MMIC is 3.7 mm × 1.4 mm. The fabricated 60 GHz amplifier MMIC has a measured small signal gain (S_{21}) of 16.5 to 17.2 dB, a gain-flatness of 0.7 dB, an input reflection coefficient (S_{11}) of -16 to -9 dB, and an output reflection coefficient (S_{22}) of -16 to -4 dB for 56 to 62 GHz as shown in Fig. 4. The amplifier has a maximum output power of 13 dBm as shown in Fig. 5.

Table 1 summarizes the performance of the 60 GHz power amplifier. The saturated output power of the 60 GHz power amplifier proposed in [3] achieved the best value; however, the gain and gain flatness of the proposed amplifier are better than those of the amplifiers presented in [2] to [4].

Table 1. Summary of the performance of this work and the previously reported 60 GHz power amplifiers.

| | This work | [2] (Korea) | [3] (Finland) | [4] (Japan) |
|----------------------------|-------------------------------------|-------------------------------------|------------------------------------|-------------------------------------|
| Technology | 0.12 μm GaAs PHEMT | 0.15 μm GaAs PHEMT | 0.1 μm GaAs PHEMT | 0.15 μm GaAs PHEMT |
| Freq. (GHz) | 56~62 | 58~62 | 57.5~63.5 | 55~64 |
| S_{21} (dB) | 16.5~17.2 | 12~13 | 12~13.5 | > 15 |
| Gain-flatness (dB) | 0.7 | 1 | 1.5 | N/A |
| S_{11} (dB) | < -9 | < -5 | < -3 | N/A |
| S_{22} (dB) | < -4 | < -5 | < -6 | N/A |
| $P_{\text{out,sat}}$ (dBm) | 13 | 10 | 17 | 14 |

IV. Conclusion

The gains of each stage of the proposed amplifier were modified to have broadband characteristics of input/output matching for the first and the fourth stages and to achieve higher gains at the edge regions of the operating frequency range for the second and third stages to improve the gain-flatness of the amplifier for wideband. The fabricated 60 GHz medium power amplifier MMIC outperformed previously proposed amplifiers in both gain and gain flatness. Therefore, the proposed amplifier MMIC is considered to be applicable to 60 GHz RoF system.

References

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