Extended Abstracts of the 2006 International Conference on Solid State Devices and Materials, Yokohama, 2006, pp. 614-615

P-6-2

Broadband 60 GHz Power Amplifier MMIC with Excellent Gain-Flatness

Woo Jin Chang, Hong-Gu Ji, Jong-Won Lim, Ho-Kyun Ahn, Haechoen Kim and Seung-Hyub Oh*

Microwave Devices Team, ETRI

161 Gajeong-dong, Yuseong-gu, Daejeon, Korea

E-mail: wjchang@etri.re.kr, Tel.: +82-42-860-1270, Fax: +82-860-6183

*Electronics Engineering Department, Chungnam National Univ.

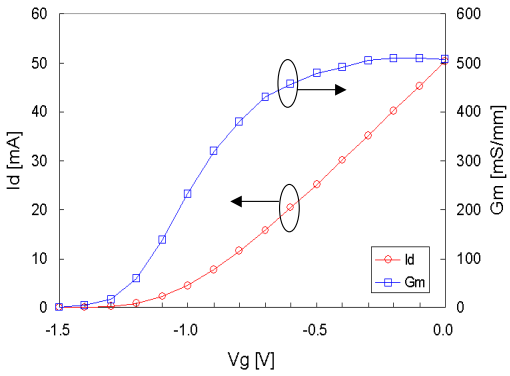
220 Gung-dong, Yuseong-gu, Daejeon, Korea

Abstract

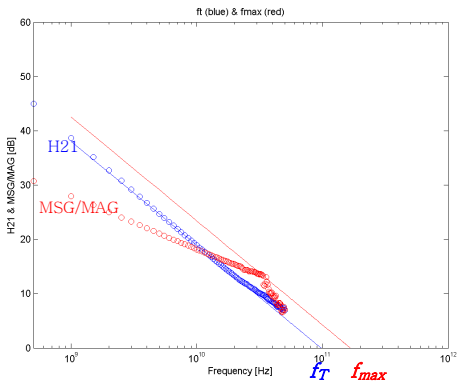
This paper introduces the design and fabrication of broadband 60 GHz power amplifier MMIC with superior gain-flatness for IEEE802.15.3c WPAN (Wireless Personal Area Network) system. The 60 GHz power amplifier MMIC was designed using ETRI's 0.12 ㎛ GaAs pseudomorphic high electron mobility transistor (PHEMT) 4-inch process. The power amplifier was a designed 4-stage structure using the MCLFs instead of the MIM capacitors for unconditional stability of the amplifier and yield enhancement. It was used NiCr thin film resistors to have high resistance on parts of gate bias-lines so that may minimize RF signal leakage. The gains of the each stages of the amplifier were modified to have broadband characteristics of input/output matching for first and fourth stages and get more gains for second and third stages in order to make the gain-flatness of the amplifier excellently for wide band. The performances of the fabricated 60 GHz power amplifier MMIC are operating frequency of 56.25 ~ 62.25 GHz, bandwidth of 6 GHz, small signal gain (S_{21}) of 16.5 ~ 17.2 dB, gain flatness of 0.7 dB, an input reflection coefficient (S_{11}) of -16 ~ -9 dB, output reflection coefficient (S_{22}) of -16 ~ -4 dB and output power (P_{out}) of 13 dBm.

I. 0.12 um GaAs PHEMT characteristics

The 60 GHz power amplifier MMIC was designed using ETRI's 0.12 ㎛ GaAs PHEMT 4-inch process. The GaAs PHEMT has an effective gate length of 0.12 ㎛, a unit gate width of 50 ㎛, and 2-/4-/8- gate fingers. The T-shaped gate of PHEMT has a wide gate head of 1 um and a gate foot of 0.12 ㎛. The PHEMT shows a peak transconductance ($G_{m,peak}$) of 500 mS/mm, a threshold voltage of -1.2 V, and a drain saturation current of 49 mA for 2 fingers and 100 ㎛ 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. Figure 1 shows the PHEMT characteristics.



(a) I_d-V_g and G_m-V_g curves



(b) f_T and f_{max}

Fig. 1. 0.12 ㎛ GaAs PHEMT characteristics

II. 60 GHz power amplifier MMIC

The 60 GHz power amplifier was used NiCr thin film resistors to have high resistance on parts of gate bias-lines so that may minimize RF signal leakage. The gains of the each stages of the amplifier were modified to have broadband characteristics of input/output matching for first and fourth stages and get more gains of edge regions of operating frequency range for second and third stages in order to make the gain-flatness of the amplifier excellently for wide band as shown in Fig. 2. The 60 GHz power amplifier was designed

using the MCLFs (Microstrip Coupled Line Filters) instead of the MIM (Metal-Insulator-Metal) capacitors acting like DC blocking for the unconditional stability and the yield enhancement. And the MCLFs in all interstages act on DC blocking and RF matching. MMICs are composed of active and passive devices and the uniformity of each device in fabrication is very important to MMIC yield. In MMIC fabrication, MIM capacitors show about ±10 % variation because of their dielectric constant and film thickness variations. But the MCLFs compared with the MIM capacitors have lower variations in their characteristics because the effective metal thickness with the 99 % energy is very thin at millimeter wave frequency. Therefore, the MCLFs show very stable characteristics even if the metal thickness varies from a run-by-run fabrication process. The 60 GHz amplifier is designed without any additional circuit (e.g. negative feedback, resistor, etc) for the unconditional stability at the frequency range of 1 to 100 GHz.

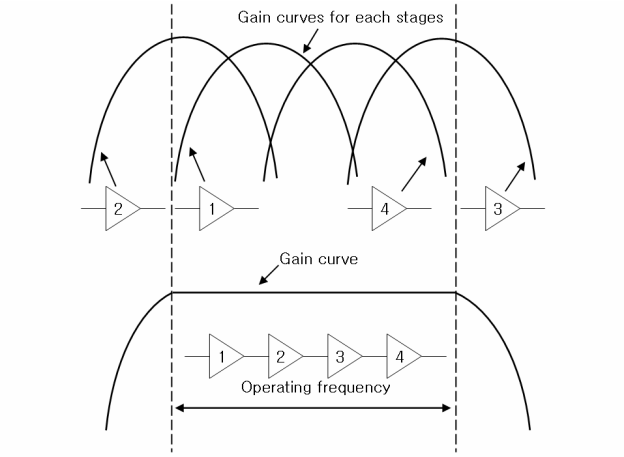


Fig. 2. Scheme for excellent gain-flatness

A microscopic view of the fabricated 60 GHz power amplifier MMIC is shown in Fig. 3. The chip size of the amplifier MMIC was 3.7 × 1.4 mm^2. The fabricated 60 GHz power amplifier MMIC was measured small signal gain (S_{21}) of 16.5 ~ 17.2 dB, gain flatness of 0.7 dB, input reflection coefficient (S_{11}) of -16 ~ -9 dB and output reflection coefficient (S_{22}) of -16 ~ -4 dB for 56.25 ~ 62.25 GHz as shown in Fig. 4. The power amplifier has maximum output power of 13 dBm as shown in Fig. 5.

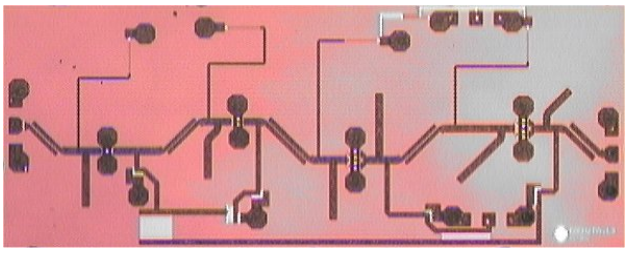


Fig. 3. Microscopic view of the fabricated 60 GHz power amplifier MMIC.

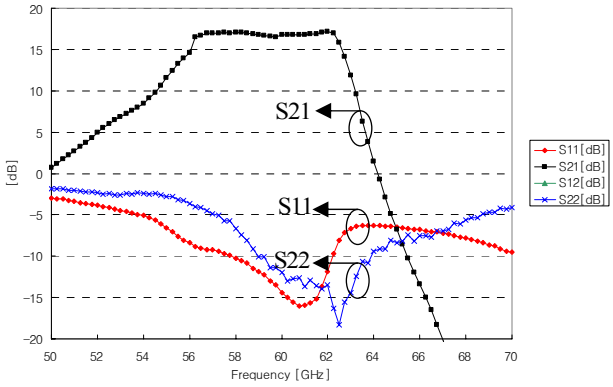


Fig. 4. S-parameter measurement of the fabricated 60 GHz power amplifier MMIC.

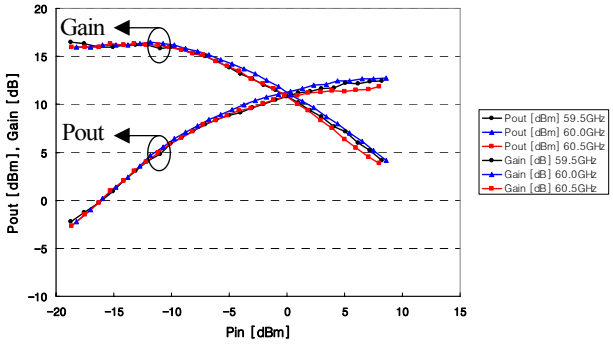


Fig. 5. Power measurement of the fabricated 60 GHz power amplifier MMIC

III. Conclusion

The gains of the each stages of the amplifier were modified to have broadband characteristics of input/output matching for first and fourth stages and get more gains of edge regions of operating frequency range for second and third stages in order to make the gain-flatness of the amplifier excellently for wide band. The fabricated broadband 60 GHz power amplifier MMIC was measured small signal gain (S_{21}) of 16.5 ~ 17.2 dB, gain flatness of 0.7 dB, input reflection coefficient (S_{11}) of -16 ~ -9 dB, output reflection coefficient (S_{22}) of -16 ~ -4 dB and maximum output power of 13 dBm for 56.25 ~ 62.25 GHz. The fabricated 60 GHz power amplifier MMIC is considered to be applicable to IEEE802.15.3c WPAN system.

IV. References

[1] S.M. Sze: *Physics of Semiconductor Devices* (John Wiley and Sons, Inc., New York, 1981).

[2] David M. Pozar: *Microwave Engineering* (John Wiley and Sons, Inc., 1998) 2nd ed., Chap. 11, p.614.

[3] Jong-Won Lim, Ho-Kyun Ahn, Hong-Gu Ji, Woo-Jin Chang, Jae-Kyoung Mun and Haecheon Kim: Jpn. J. Appl. Phys., 43 (2004) No. 12, 7934.