A 3.3V, 1.4W GaAs Power Amplifier for CDMA/AMPS Dual-mode Cellular Phone

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ABSTRACT

For CDMA/AMPS dual-mode cellular phones, a power amplifier operating at 3.3V has been developed for the first time. The amplifier shows an output power of 31.5 dBm and a power-added efficiency of 61% for AMPS mode. The third order intermodulation and the fifth order one are measured to be -32 dBc and -45 dBc at an output power of 26 dBm for CDMA mode. These are good enough for dual-mode requirements.

INTRODUCTION

A mobile communication system changes from the analog system to the digital system as a communication capability increases. The supply voltage of the cellular phone has been decreased to 3.3V in order to reduce the volume and weight of the phone. There are several reports regarding power amplifiers with a low supply voltage. However, they are related to either the analog[1,2] or the digital phones[3]. To our knowledge, there is no report on a power amplifier for dual-mode cellular phones. Therefore, it is necessary to develop a dual-mode power amplifier in realizing the dual-mode cellular phones.

The AMPS mode requires an output power of 31 dBm and a power-added efficiency(PAE) more than 55%. The CDMA mode using offset QPSK modulation requires both the third order intermodulation (IM3) less than -30 dBc and the fifth order intermodulation (IM5) less than -40 dBc at an output power of 26 dBm. In this work, we developed a power amplifier with a supply voltage of 3.3 V for the CDMA/AMPS dual-mode cellular phone, which simultaneously satisfied the linearity for CDMA mode, and the output power and the PAE for AMPS mode.

DESIGN AND FABRICATION

In order to obtain the linearity for CDMA together with the output power and PAE for AMPS mode in the 3.3 V operation power amplifier, it is important to develop a highly efficient and linear power MESFET with a supply voltage of 3.3 V. Figure 1 shows a low-high doped channel structure that used in the fabrication of power MESFETs. GaAs/AlGaAs superlattices were used as a buffer layer to improve RF performances by reducing output conductance[4,5,6]. Figure 2 shows uniform transconductance of 18mm-width power MESFET for the gate voltage, ranged from -2.0V to +0.5V. The third order intercept point of the MESFET is 49.5 dBm. Details on the performance of the MESFETs were described in elsewhere[6].

The optimum impedances for the output power and PAE of the first and second MESFETs were measured by the load/source-pull method using input and output tuners.

The circuit diagram of the power amplifier for the dual-mode cellular phone is shown in Figure 3. It consists of two stages to obtain a small signal gain more than 31dB. The bias circuits for the first and second stages were designed by near class A and class AB operation, respectively. The gate bias of -3V is supplied through divider resistors with a predetermined voltage. Resistive matching circuits are employed in input and gate bias circuits for more stable operation. The matching networks have high pass characteristics which provide DC bias isolation from the RF input and output. The matching networks were optimized using a linear simulator. In the second stage amplifier, an output matching circuit was designed to have low impedances for the second and third harmonic frequencies to reduce the harmonics. Figure 4 shows the simulated impedance contour of an output matching circuit at the drain terminal of the MESFET as a function of frequency. The matching and bias circuits were composed of microstrip transmission lines, chip capacitors and resistors (1005-type). In order to reduce the RF and DC loss, the microstrip lines of 300 um-width were employed in the output matching circuit.

Figure 5 shows a top view photograph of the dual-mode power amplifier with 11.9 x 21.0 mm^2. Glass-based epoxy(FR-4) was used as a substrate, and total cost of the power amplifier will be reduced. Although the low cost substrate with a loss tangent of 0.018 was used, high RF performance was achieved for both AMPS and CDMA modes, simultaneously.

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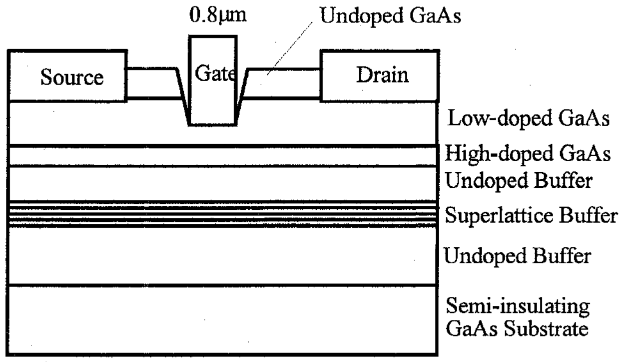

Fig.1 Structure of a low-high GaAs power MESFET.

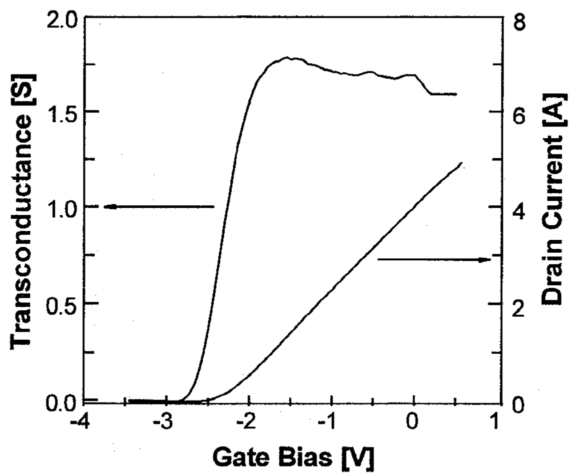

Fig.2 Transconductance and drain current of 2nd FET versus gate bias voltage

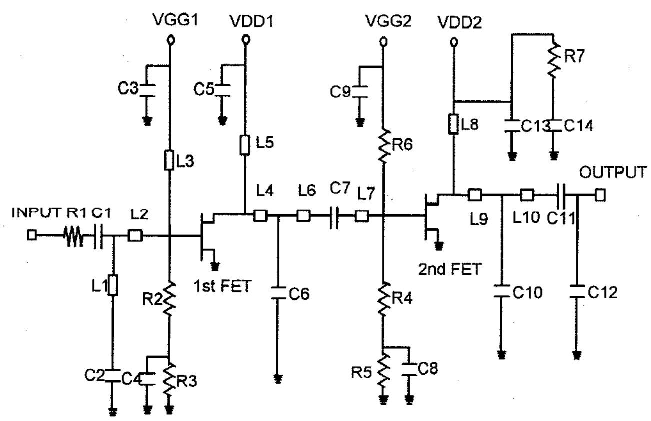

Fig.3 Circuit diagram of dual-mode power amplifier

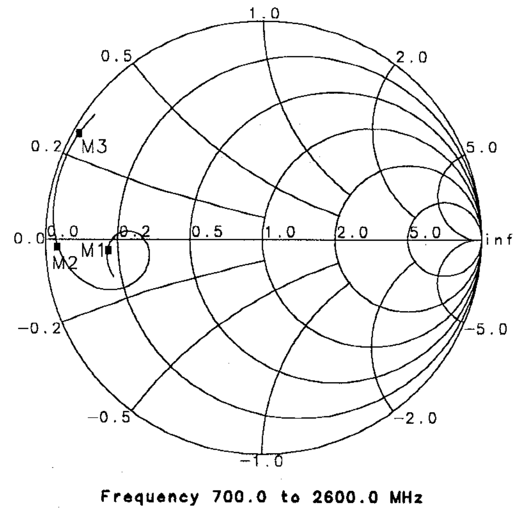

Fig.4 Simulated impedance contour of an output matching circuit as a function of frequency(M1 : 836.5 MHz, M2: 1673 MHz, M3 : 2510MHz)

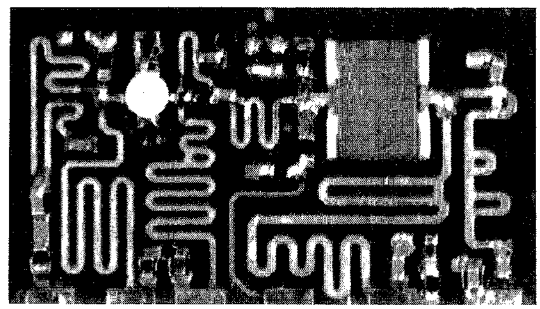

Fig.5 Top view photograph of dual-mode power amplifier module

RESULTS

Figure 6 shows the output power and PAE of the power amplifier. It was measured at a 3.3V supply voltage and a 7 dBm input power as a function of frequency. At the frequency range between 824 MHz and 849 MHz, the output power of 31.5 dBm was maintained within ± 0.2 dBm, and the minimum PAE of 60% was obtained. These are higher than the requirements for AMPS mode. Figure 7 shows the gain and PAE of the power amplifier as a function of output power at 836.5 MHz. At the output power lower than 26 dBm, the power gain of 31.5 dB was maintained within ± 0.4 dB deviation. The PAE for AMPS at the output power of 31.5dBm and that for CDMA at 26dBm were measured to be 61% and 30%, respectively. The output power and the harmonics with the input power at 836.5 MHz are shown in Figure 8. The 2nd and 3rd harmonics of the amplifier at an output power of 31.5 dBm were measured to be -50 dBc and -51 dBc, respectively, which are much lower than those previously reported [1].

The intermodulation of the amplifier with the input power was measured using two-tone frequencies, 836.5000 and 836.9425 MHz. The IM3 and the IM5 at an output power of 26 dBm, as shown in Figure 9, were measured to be -32 dBc and -45 dBc, respectively, which are good enough for CDMA mode applications.

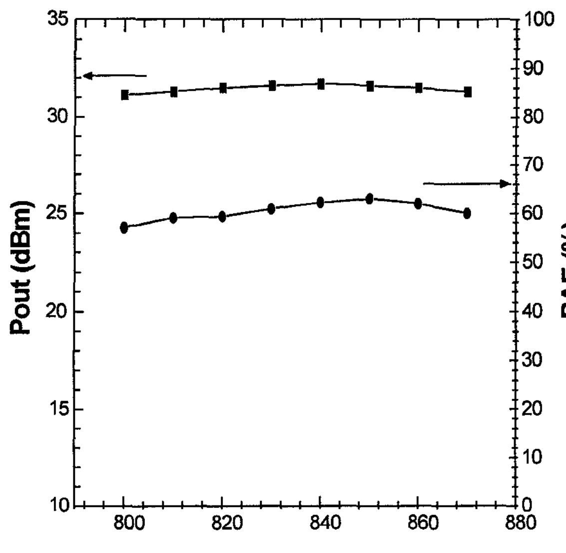

Fig.6 Pout and PAE as a function of frequency

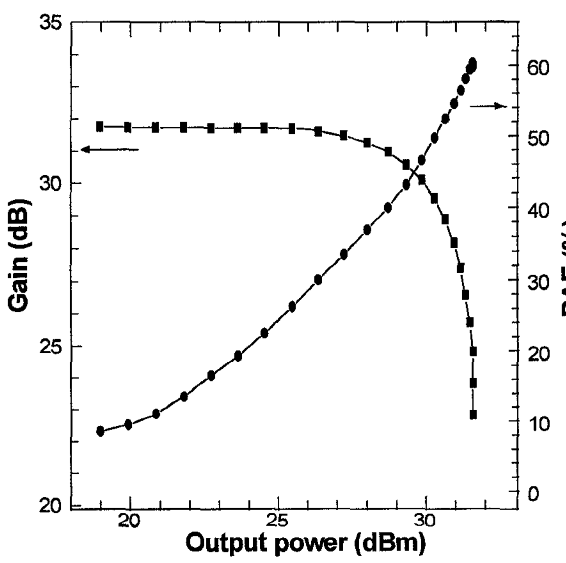

Fig.7 Variation of gain and PAE vs output power

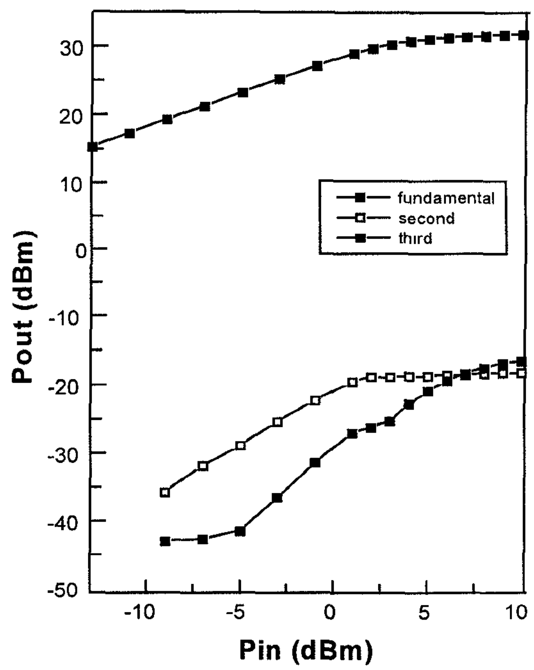

Fig.8 Fundamental, 2nd and 3rd harmonics vs input power

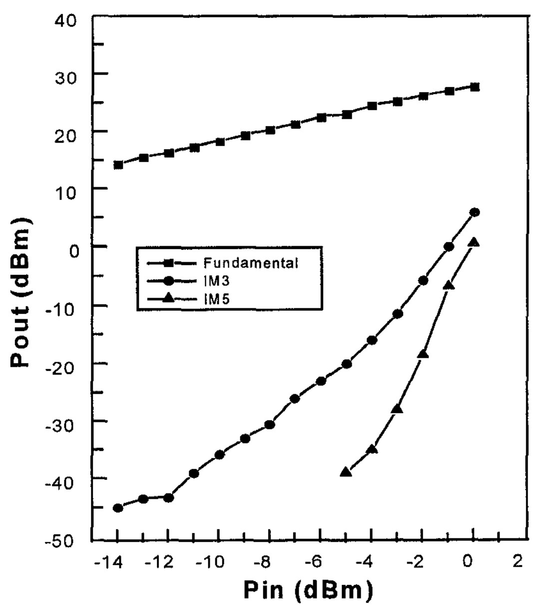

Fig.9 Fundamental, IM3 and IM5 power vs input power

CONCLUSIONS

A power amplifier operating at 3.3V has been developed for Korean CDMA/AMPS dual-mode cellular phones. It consists of linear GaAs power MESFETs and an output matching circuit which reduce 2nd and 3rd harmonics. The measured characteristics of the dual-mode power amplifier are summarized in Table 1. For AMPS mode, the amplifier shows an output power of 31.5 dBm and a PAE of 61%. For CDMA mode, the IM3 of -32 dBc and the IM5 of -45 dBc are obtained at an output power of 26 dBm. These are evaluated to be good enough for dual-mode requirements.

Table 1 Measured Results of the Power Amplifier

Common Specifications	
Frequency Range	824~849MHz
Amplifier Size (PCB)	11.9 x 21.0 mm^2
Small Signal Gain	31.5 dB
Supply Voltage	3.3V
AMPS Mode @ 836.5 MHz, Pin=7dBm	
Output Power	31.5 dBm
Power-Added Efficiency	61%
Harmonics (2fo)	-50 dBc
Harmonics (3fo)	-51 dBc
CDMA Mode @ 836.5 MHz, Pout=26 dBm	
Gain Linearity (≤26dBm)	< ± 0.4 dB
Power Added Efficiency	30%
Intermodulation (3rd)	-32 dBc
(5th)	-45 dBc

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REFERENCES

[1] M.Maeda, M.Nishijima, H.Takehara, C.Adachi, H. Fujimoto, Y.Ota, and O.Ishikawa,"A 3.5V, 1.3W GaAs power multi chip IC for cellular phone," ***IEEE GaAs IC Symp. Tech. Dig.*** pp.53-56, 1993.

[2] K.Yamamoto, K.Maemura, M.Komaru, N.Kasai, T.Oku, Y.Sasaki, and N.Tanino," A 3.3V, 1W GaAs one-chip power amplifier MMIC for cellular phones," ***Proc. 24th European Microwave Conference***, pp.1066-1071, 1994.

[3] K.Tateoka, A.Sugimura, H.Furukawa, M.Yuri, N.Yoshikawa, and K.Kanazawa,"A GaAs MCM power amplifier of 3.6V operation with high efficiency of 49% for 0.9GHz digital cellular phone systems," ***IEEE MTT-S Digest***, pp.569-572,1994.

[4] J.L.Lee, H.Kim, J.K.Mun, O.Kwon, J.J.Lee, H.M.Park, and S.C.Park," 3.3V operation GaAs power MESFET with 65% power-added efficiency for hand-held telephone," ***IEE Electronics Letters***. vol.30, No.9, pp.739-740, April 1994.

[5] J.L.Lee, H.Kim, J.K.Mun, H.G.Lee, H.M.Park," 2.9V operation GaAs power MESFET with 31.5-dBm output power," ***IEEE Electron Device Letters***. vol.15, No.9, pp.324-326, September 1994.

[6] J.L.Lee, J.K.Mun, H.Kim, J.J.Lee, H.M.Park, and S.C.Park," 2.3V operation GaAs power MESFET with 68% power-added efficiency," ***IEEE GaAs IC Symp. Tech. Dig.*** pp.133-136, 1994.