A Novel Amplitude and Phase Linearizing Technique for Microwave Power Amplifiers

Masatoshi Nakayama, Kazutomi Mori, Kazuhisa Yamauchi, Yasushi Itoh, and Tadashi Takagi

Mitsubishi Electric Corporation
Electro-Optics & Microwave Systems Laboratory
5-1-1 Ofuna, Kamakura, Kanagawa, 247 Japan

ABSTRACT

A novel amplitude and phase linearizing technique for microwave power amplifiers has been developed. It employs a series feedback amplifier with a large source inductance as a predistortion linearizer, which provides positive amplitude and negative phase deviations for input power and can compensate for AM-AM and AM-PM distortions of power amplifiers. Applying this technique to a 1.9 GHz MMIC power amplifier for use in the Japanese Personal Handy-Phone System (PHS), an improvement of adjacent channel leakage power (ACP) up to 7 dB has been achieved when it is used for $\pi/4$-shift QPSK signal.

INTRODUCTION

Highly efficient, linear power amplifiers with low adjacent leakage power are a key component for digital mobile telephones and personal handy-phone systems. To reduce power consumption, the power amplifier has to be operated near saturation region for high efficiency where amplitude and phase distortions significantly increase, resulting in increased adjacent channel interference. To achieve low distortion and high efficiency simultaneously, several types of linearizers have been reported [1],[2],[3]. They have a drawback in that the power amplifier becomes large in size and consumes large DC power. To overcome this problem, we have developed a novel amplitude and phase linearizing technique, which employs a series feedback amplifier having a miniaturized size and low DC power consumption. Applying this technique to a 1.9 GHz power amplifier for the Japanese PHS, an improvement of ACP up to 7 dB has been achieved when it is used for $\pi/4$-shift QPSK signal.

AMPLITUDE AND PHASE LINEARIZING TECHNIQUE

Fig. 1 shows a block diagram of the predistortion linearizer comprised of a series feedback amplifier with a large source inductance. The series feedback amplifier employs a common-source FET with a large source inductance and input/output matching networks. To achieve positive amplitude and negative phase deviation for input power, we utilize a nonlinearity of gm, Gd, and Cgs of GaAs FETs in conjunction with a feedback effect. Fig.2 shows the calculated amplitude (gain) and phase deviations for input power as a

TH 3F

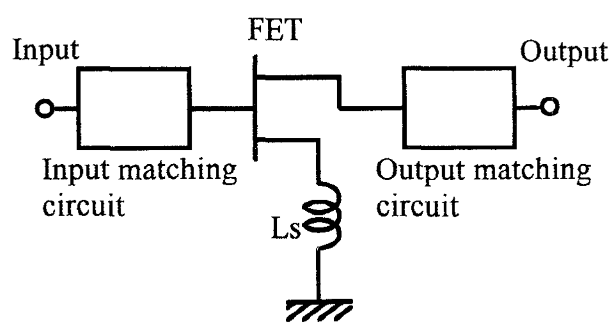

Fig.1 Block diagram of the predistortion linearizer

CH3577-4/95/0000-1451$01.00 © 1995 IEEE

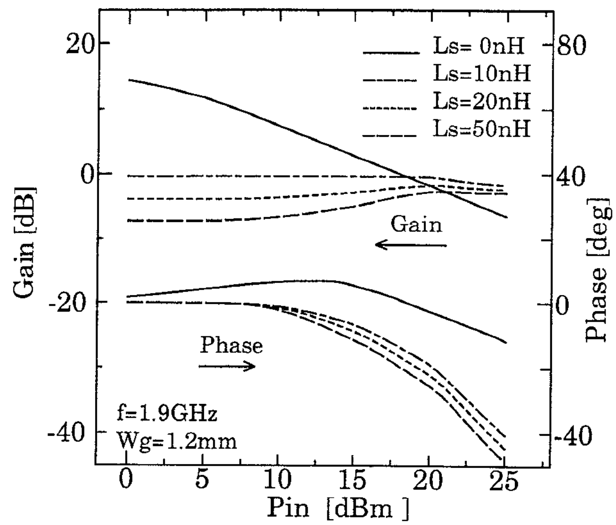

Fig. 2 Calculated amplitude and phase deviation for input power as a function of a source inductance (Ls) of the predistortion linearizer.

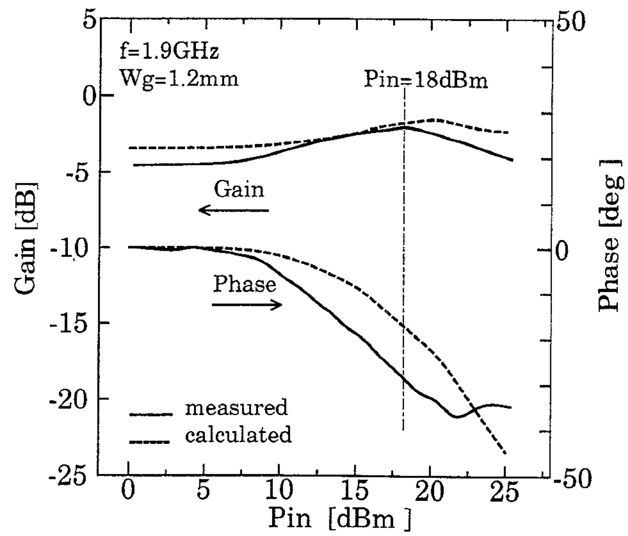

Fig. 4 Measured and calculated gain and phase deviation for the predistortion linearizer of Ls=16nH

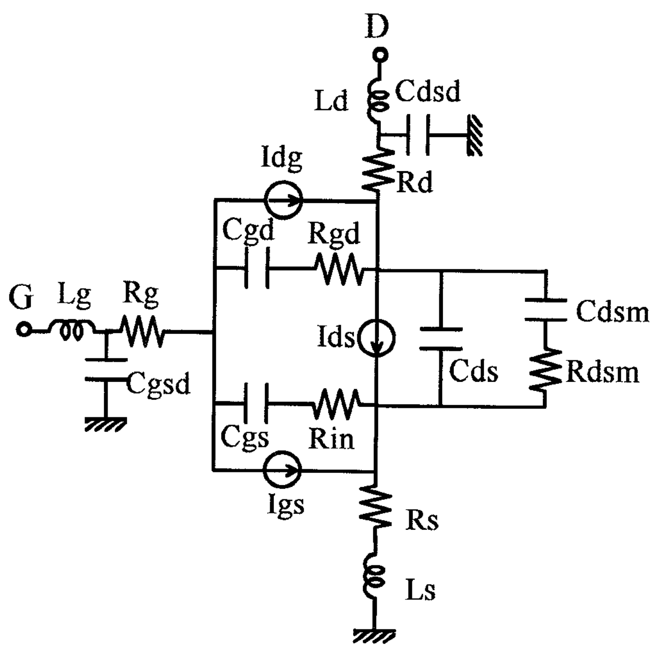

Fig. 3 Large signal FET model

function of a source inductance (Ls). The calculation was done at 1.9 GHz for the series feedback amplifier employing GaAs MESFETs with a gate periphery of 1.2 mm. The large signal model and model parameters of the 1.2 mm GaAs MESFET are shown in Fig. 3 and Table 1. The FET is operated under class-AB operation with Vds = 2 V and Ids = 78mA/mm (idle current). It is clear in Fig. 2 that positive amplitude and negative phase deviations have been obtained for Ls > 10 nH. The measured and calculated gain and phase deviations are plotted in Fig. 4 for Ls = 16 nH. It is clear in Fig. 4 that positive amplitude and negative phase deviations have been obtained for an input power from 5 to 18 dBm. A gain deviation of 2.5dB and phase deviation of -30degrees have been obtained for Pin=18dBm. A good agreement between the measured and calculated results has been achieved for gain and phase.

Table 1 Model parameters (Wg=1.2mm)

Ld (nH)	0.32
Lg (nH)	0.36
Ls (nH)	0.11
Cgd (pF)	0.10
Cgs (pF)	2.82
Cds (pF)	0.42
Cdsm (pF)	1000
Cgsd (pF)	0.001
Cdsd (pF)	0.001
Rd (ohm)	0.94
Rg (ohm)	2.00
Rs (ohm)	0.48
Rin (ohm)	2.7
Rdsm (ohm)	44.0
Rgd (ohm)	33.0

LINEARIZED POWER AMPLIFIER PERFORMANCE

A block diagram of the linearized power amplifier is shown in Fig. 5. It is comprised of a 1.9 GHz power amplifier, a predistortion linearizer, isolators and an attenuator for adjusting input power level. The 1.9 GHz power amplifier has a linear gain of 36.5 dB, a P1dB of 17 dBm, a maximum phase deviation of 40 degrees. Fig. 6 demonstrates the measured gain compression from linear gain and phase deviation of the 1.9 GHz power amplifier with and without the use of the predistortion linearizer. The gain compression and phase deviation have been improved by 2.3dB and 30degrees at Pout=23dBm, respectively. The results are consistent with the data at Pin=18dBm shown in Fig. 4. To confirm effects of the linearizer for digital modulation signal, the adjacent channel leakage power (ACP) has been measured for 384kbps $\pi/4$-shift QPSK signal utilized in Japanese PHS. Fig. 7 shows the measured result of ACP at 600kHz offset with bandwidth of 192kHz. A significant improvement of around 7 dB has been achieved for ACP.

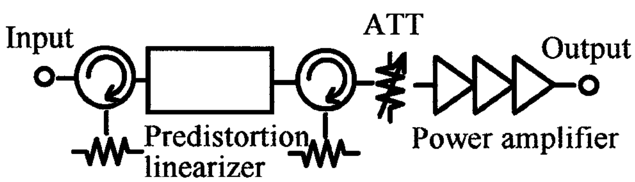

Fig. 5 Block diagram of the linearized amplifier

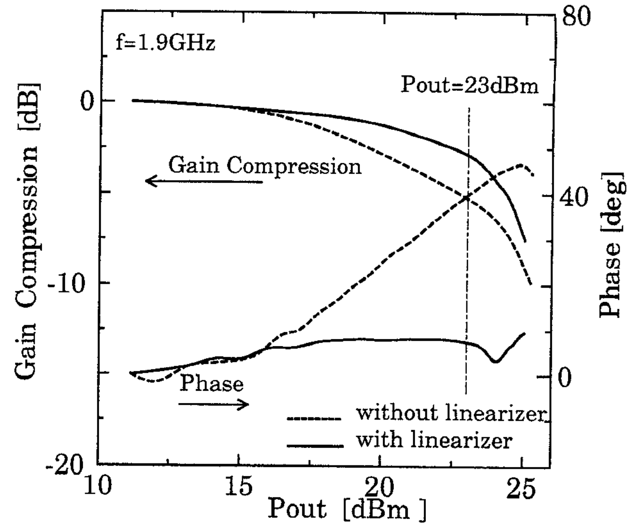

Fig. 6 Measured gain compression and phase of the power amplifier with and without the use of the predistortion linearizer.

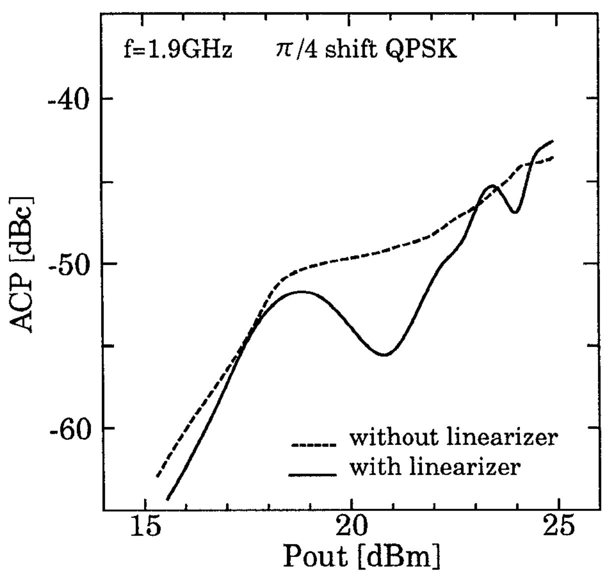

Fig. 7 Adjacent channel leakage power

CONCLUSION

A novel amplitude and phase linearizing technique for linear power amplifiers has been demonstrated. It employs a series feedback amplifier with a large source inductance as a predistortion linearizer, which provides positive amplitude and negative phase deviations for input power and can compensate for AM-AM and AM-PM distortions of power amplifiers. This predistortion linearizer, which is suitable for MMIC design, would be a good candidate for achieving low AM-AM and AM-PM distortions along with high efficiency for use in the digital mobile telephones and personal handy-phone systems.

REFERENCES

[1] N. Suematsu, T. Takagi, A. Iida and S.Urasaki, "A Predistortion Type Equi-Path Linearizer in Ku-Band", The 3rd Asia-Pacific Microwave Conference Proceedings, pp. 1077-1080, Sept. 1990.

[2] A.S. Wright, W.G. Durtler, "Experimental Performance of an Adaptive Digital Linearized Power Amplifier", IEEE Transaction on Vehicular Technology, Vol.41, No.4, pp.395-400, Nov. 1992.

[3] J-S. Cardinal and F.M.Ghannouchi, "A New Adaptive Double Envelop Feedback Linearizer for Mobile Radio Power Amplifiers", IEEE MTT-S International Micro- wave Symposium Digest, pp. 573-576, 1994.