A Novel Linearizing Technique Using Dual Diode Based Linearizers for Lightweight Power Amplifiers

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***Abstract* — A novel way to compensate the distortion of Power Amplifier(PA) modules is presented in this paper. A diode linearizer with an inductor is used to compensate the distortion of the PA using LDMOS FET and has a characteristic of a positive phase and a gain expansion. Two diode-based linearizers are employed to compensate the distortions. One linearizer compensates the distortion of the phase, mainly. The other compensates the ones of the gain and the phase. It is possible to compensate the distortion of the PA module using this linearizing technique even though the driver stage of the PA module has the distortion. This implies that the PA modules can operate with high efficiencies. In addition, it is possible to achieve lightweight PA modules. A modulated spectrum power of 8 dB and an EVM of 1.4 % can be improved using the proposed techniques in the PA module when a 16-QAM modulated signal is used at a 42 dBm output power and a 3 dB back-off condition.**

I. INTRODUCTION

Linearizing techniques are very important to achieve high bit-data rate digital communications. There are many reports to achieve improvements of amplifier's linearity such as gain, phase, intermodulation, Adjacent Channel leakage Power(ACP), Error of Vector Magnitude, etc. There are also many ways to improve the linearity of the amplifiers and appropriate methods are applied based on system requirements[1]-[4]. A linearizer using diodes is one of them and has characteristics of lightweight and relatively larger bandwidth. For satellite communications of the maritime applications, antennas should track to the satellites to ensure qualities of communications against ship's agitation. In addition, it is preferred that microwave circuits are attached at the reverse of the antenna in order to reduce the unwanted losses. Consequently, lightweight PA modules are necessary for the antenna to swivel smoothly and diode linearizers are attractive for such applications.

Several papers show excellent performances using diode linearizer[5]-[7]. There are, however, few reports of the diode linearizers which have positive phase deviation and gain expansion when the input power is increased[8], [9].

In this paper, a novel way of the linearization using diode linearizer with the positive phase deviation and the gain expansion characteristics is presented for LDMOS FET PAs. This technique can also improve the linearity of the PA module whose driver stage shows non-linearity.

II. DIODE LINEARIZER WITH POSITIVE PHASE DEVIATION AND GAIN EXPANSION

Power amplifiers using Si-based LDMOS FET usually have characteristics of negative phase deviation and gain compression as an input power is increased. In order to compensate this distortion, the linearizers are required to have characteristics of positive phase deviations and gain expansions. Figure 1 shows a circuit configuration and a microphotograph of a diode linearizer with an inductor which is connected parallel. The diode in the linearizer acts as a variable resistor along with increase of the input power.

When the resistance of the diode becomes small, the linearizer shows an inductive impedance so the phase of the transmission is positive. Figure 2 and figure 3 show measured AM-AM and AM-PM characteristics of the proposed diode linearizer. Toshiba 1SS271 Si-based diodes are used in both linearizers. An inductor of 5.6 nH and a resistor of 100 Ω are used for the linearizer in the case of Fig. 2. A positive phase deviation of more than 15 degree is achieved with a gain expansion of 2.8 dB at 1.64 GHz. This dependence of the deviations on the input

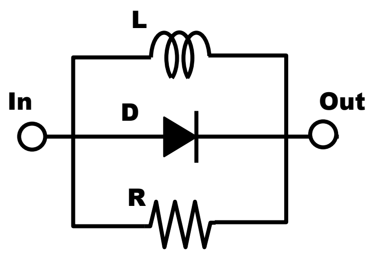


Fig. 1. Schematic circuit diagram and a microphotograph of diode linearizer with an inductor.

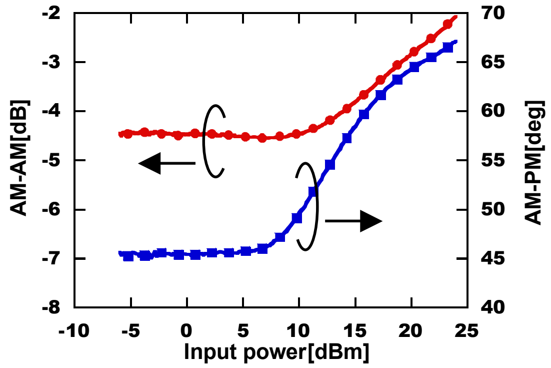


Fig. 2. Measured AM-AM and AM-PM characteristics of the diode linearizer. The inductance is 5.6 nH and the resistance is 100 Ω.

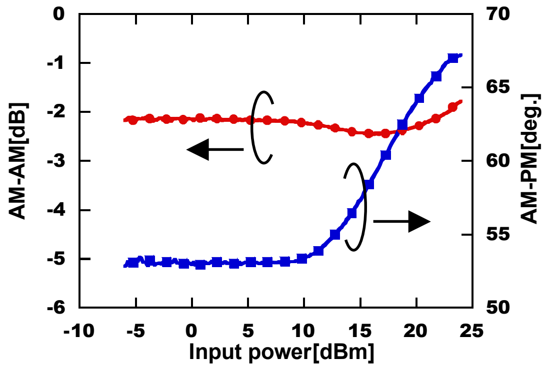
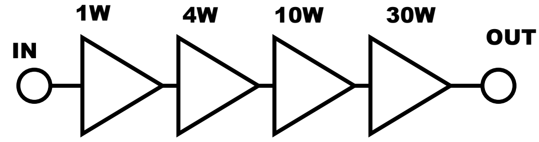


Fig. 3. Measured AM-AM and AM-PM characteristics of the diode linearizer. The phase is changed while the gain is kept to a constant. The inductance is 3.6 nH and the resistance is 82 Ω.

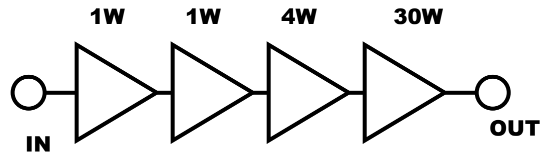
power can be controlled by selecting appropriate parameters of the inductor, diode, and the resistor in the linearizer. Measured AM-AM and AM-PM characteristics are shown in Fig. 3 when the inductor of 3.6 nH and the resistance of 82 Ω are used in the linearizer. A positive phase deviation of more than 10 degree is obtained while a gain deviation is within 0.4 dB over the input power level from –6 dBm to 24 dBm at 1.64 GHz.

III. Compensation of Linearity When Using Non-Linear Driver Amplifier

Power amplifier modules consist of several stages to ensure a required output power. Fig. 4 shows two block diagrams of the PA modules. Each PA module consists of the 4 stage amplifier. Usually, the phase(AM-PM) of the amplifier is changed at the lower input power level



(a) PA module with very high linearity.



(b) PA module with a driver amplifier having phase distortion.

Fig. 4. Block diagrams of the PA module.

compared with the change of the gain along with increase of the input power. The driver amplifiers are required very linear characteristics in order to ensure the linearity of whole amplifier modules shown in Fig. 4(a). In Fig. 4 (b), the PAs with 1 W output power capability are used for the 1st stage and the 2nd stage instead of the 4 W output power amplifier. In addition, the amplifier having the output power capability of 4 W are adopted to drive the final stage amplifier instead of the 10 W output power amplifier. In this case, the 3rd-stage amplifier shows non-linearity characteristics, especially, of phase. The PA using smaller size FETs is attractive for the cost reduction and high efficiency operation. Figure 5 shows the gain(AM-AM) and the phase(AM-PM) characteristics of both modules. The module depicted in Fig. 4(b) has

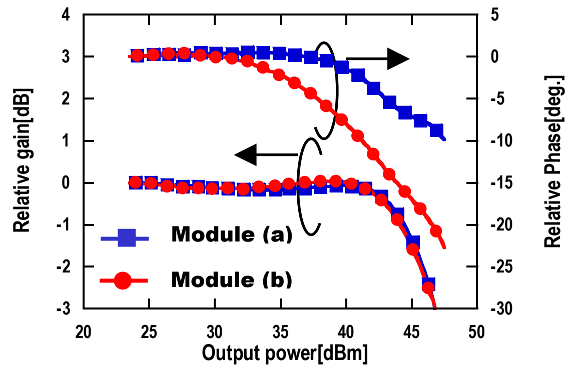


Fig. 5. Measured AM-AM and AM-PM characteristics of the PA modules. Module (b) has a larger phase distortion than (a).

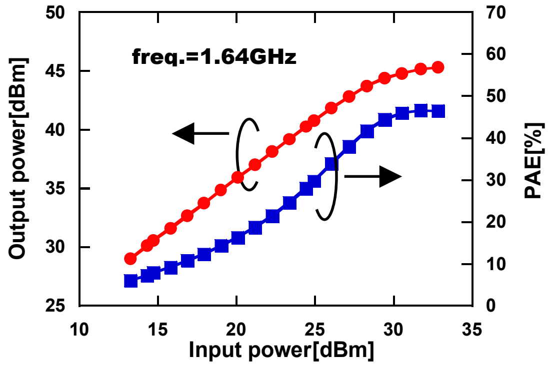


Fig. 6. Measured output power and PAE of the Power Amplifier at 1.64 GHz.

the large phase distortion compared with one of the module(a). Both PA modules use Motorola MRF18030A fabricated using Si LDMOS at the final stage. Measured output power and power added efficiency characteristics are shown in Figure 6. A 1 dB compression output power of 45 dBm is achieved at 1.64 GHz.

Figure 7 shows a proposed diode linearizer module in order to compensate the non-linearity of the PA module included the driver amplifier with the phase distortion. The linearizer A compensates the distortion of the phase and the gain. On the other hand, the linearizer B compensates the distortion of the phase while the gain is kept a constant value. The linearizer B compensates the phase distortion at the lower input power level than the one of the linearizer A due to the gain of the driver amplifier. Total gain and phase characteristics of the PA module(b) are shown in Figure 8. A 10 degree of the phase distortion is improved using the proposed diode linearizer at the output power of 45 dBm which the PA module delivers the 1 dB compressed output power. Measured modulated spectrums are shown in Figure 9 when 16-QAM modulated signal with the symbol rate of 33.6 k/sym and α of 0.25 is inputed. An improvement of 8 dB for the modulated spectrum is achieved at 29.8 kHz offset and 3 dB back-off condition(42 dBm output). An EVM of 1.4 % is also improved using the linearizer.

IV. Conclusion

A novel way to compensate the distortion of PA modules using LDMOSFET is presented using diode linearizers with inductors. The diode linearizer has a characteristic of a positive phase and a gain expansion. Two diode-based linearizers are employed to compensate the distortions. One linearizer compensates the distortion of the phase, mainly. The other compensates the ones of the gain and the phase. It is possible to compensate the distortion of the PA module using this linearizing technique even though the driver stage of the PA module has the distortion. The modulated spectrum power of 8 dB and the EVM of 1.4 % can be improved using the proposed techniques in the PA module when a 16-QAM scheme is used at 3 dB back-off condition(42 dBm output power). This linearizing technique promises to achieve lightweight PA modules and appropriate linearity for the satellite communications in the maritime applications.

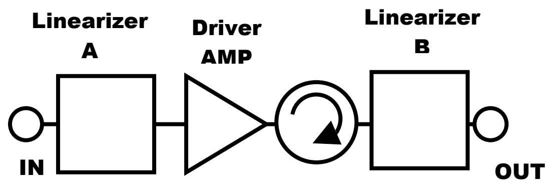


Fig. 7. Block diagram of the proposed linearizer.

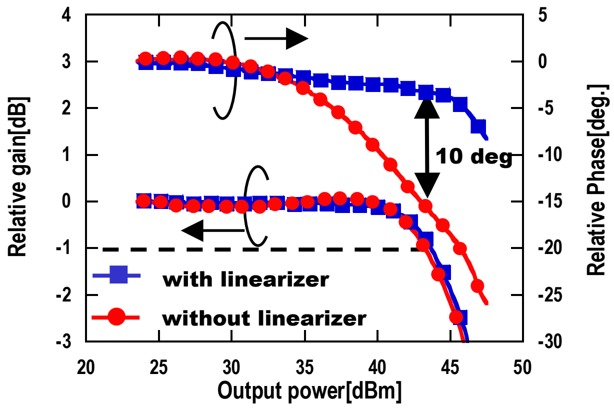


Fig. 8. Measured the gain and phase deviations of the linearized PA module. The data is compared with one of PA module without the linearizer.

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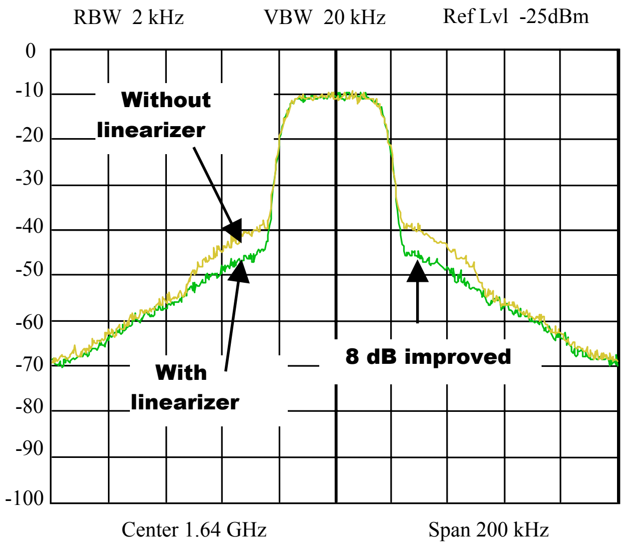

Fig. 9 Measured modulated spectrum at 16 QAM condition. Frequency is 1.64 GHz.

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