OPTIMIZATION OF AN ANALOG CUBIC PREDISTORTER FOR MULTICARRIER COMMUNICATION SYSTEMS

Cebrail ÇİFLİKLİ[1]   A. Çağrı YAPICI[2]   A. Tuncay ÖZŞAHİN[3]
e-mail: cebrailc@erciyes.edu.tr   e-mail: cyapici@erciyes.edu.tr   e-mail: atozsahin@erciyes.edu.tr
[1,3]Erciyes University, Kayseri Vocational College, 38039, Melikgazi, Kayseri, Turkey
[2] Erciyes University, Faculty of Engineering, Department of Electrical & Electronics Engineering, 38039, Melikgazi, Kayseri, Turkey

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ABSTRACT

This study presents an optimization of an analog cubic predistorter to reduce the intermodulation distortion caused by radio frequency power amplifiers in multicarrier communication systems. The analog cubic predistorter is mostly preffered for reducing the third order intermodulation products and requires an excellent match between nonlinear properties of power amplifier. In order to achieve this matching optimization of the cubic predistorer is presented and evaluation of the performance of the predistorter is carried out for communication systems using 16-QAM and CDMA systems.

I. INTRODUCTION

Increasing demand for wireless communication systems requiring higher data rates has introduced new technologies using multicarrier modulation techniques. However, these multicarrier modulation schemes introduce high envelope fluctuations. High envelope fluctuations of the modulated signal make the communication system more sensitive to nonlinear properties of the system components. One of the important nonlinear device in communication system is radio frequency (RF) power amplifier (PA). While input signal having envelope fluctuations, nonlinear properties of RF-PA , introduce intermodulation distortion (IMD) in communication system [1-3]. These IMD products give rise spectral regrowth which increases adjacent channel interference and inband distortion. In order to preserve IMD in acceptable levels and obtaining desired adjacent channel power ratio (ACPR) level, linear conventional RF PA with appropriate back-off power should be used. However this results with low power efficiency. A better solution could be using a power efficient amplifier, therefore highly nonlinear, together with a linearization method.

Several techniques have been proposed for linearization of RF PAs such as feedback [4,5], feed-forward [6-9] and predistortion techniques [10-17]. Conventional feedback method suffers from the disadvantages such as instability and bandwidth limitation [2,3]. In addition to this feed-forward method requires auxiliary amplifiers and complicated control circuits. These disadvantages make feed-forward method bulky in size and expensive [10]. On the other hand, predistortion method has advantages such as low complexity, stable operation and small sizes.

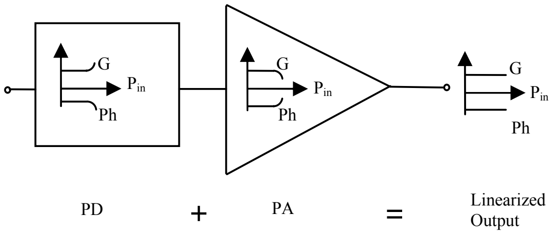

Figure1. Block diagram of predistortion linearization method

The block diagram of the predistortion linearization is shown in Figure 1. In order to obtain a linear characteristic both in gain and phase, predistorter has an inverse characteristic of the PA. Gain compression by the increasing input power of the amplifier is compensated by the expansion characteristic of the predistorter. In a same manner for the phase, expansion characteristic of the amplifier by increasing input power, compensated by the compression characteristic of the predistorter. Therefore, by utilizing predistorter with RF PA desired linear characteristic is achieved.

Several predistortion techniques such as analog, digital and hybrid have been proposed before. Digital predistorters are more accurate to implement the nonlinearities of the RF PA. However they have a disadvantage as computational time which introduces bandwidth limitation. Beside these, analog predistorters are small in size and operating in RF/IF frequencies without requiring baseband digital signal. However, analog predsitorters are generally focused on reducing the third order IMD products. Most of the applications in communication systems concern on third order distortion. Therefore an analog cubic predistorter is suitable for reducing the third order intermodulation distortion.

II. CUBIC PREDISTORTER LINEARIZATION

The general block diagram of cubic predistorter is shown in Figure 2. There are two branches created by power splitter and combined before power amplifier.

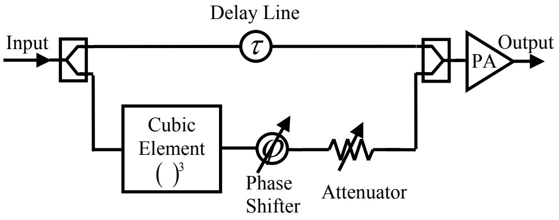

Figure 2. Cubic predistortion amplifier

Delay line in the upper branch compensates the time delay of the lower branch process. Cubic element in the lower branch produces the third order nonlinearity and generally chosen as an anti-parallel diode circuit. Phase and amplitude control is important for matching the phase and gain characteristic of the nonlinearity [17]. These phase and amplitude control elements can be voltage control devices. They can be optimized to achieve optimum cancellation of IMD products.

Cubic predistortion amplifier linearization has no feedback, so it is an open loop system. This method can be applied both RF and intermediate frequency (IF) systems.

Since the most concern IMD product is third order one, cubic predistortion can be utilized for reducing the third order IMD.

III. ANALYSIS OF CUBIC PREDISTORTER

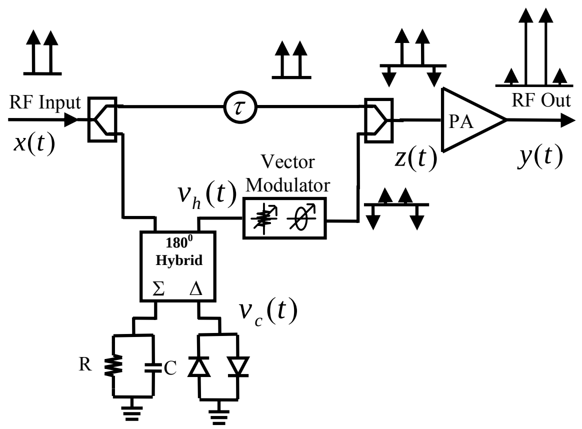

Figure 3. Block diagram of proposed cubic predistorter

The proposed cubic predistorter applied to the RF PA is shown in Figure 3. Analysis of the cubic predistorter is carried out by two tone test signal. The input two tone test signal composed by equal power can be defined as,

$$x(t) = \mathrm{Re}\left\{Ae^{j\omega_1 t} + Ae^{j\omega_2 t}\right\} \tag{1}$$

where *A* is the amplitude of the signals, ω_1 and ω_2 are the carrier frequencies. Also input signal can be written as,

$$x(t) = A\{\cos\omega_1 t + \cos\omega_2 t\} \tag{2}$$

The input signal is split in two equal power and branches by the power splitter and utilized into anti parallel diode circuit which is the cubic predistorter device of the circuit. The signal after the anti parallel diode circuit can be written as,

$$v_c(t) = a_1 x(t) + a_3 x^3(t) \tag{3}$$

here a_3 is the coefficient which describes the cubic predistortion and a_1 is the coefficient controlling the main signal. In order to eliminate the main signal form the predistorted signal, the parallel *RC* circuit has been utilized. The anti parallel diode circuit and the *RC* circuit are combined by using the 180^0 hybrid component. The output of the hybrid can be defined as,

$$v_h(t) = a_3\left(\frac{A}{2}\right)^3 \{\cos\omega_1 t + \cos\omega_2 t\}^3 \tag{4}$$

In order to achieve the inverse characteristic of the third order intermodulation distortion, the predistorted signal is controlled by the vector modulator and then combined by the original signal comes from the upper branch. At the end, before the RF PA the predistoted signal can be written as,

$$\begin{aligned} z(t) &= \beta_0 \cdot \{\cos(\omega_1 t) + \cos(\omega_2 t)\} \\ &\quad - \beta_1 \cdot \{\cos[(2\omega_1 - \omega_2)t] + \cos[(2\omega_2 - \omega_1)t]\} \end{aligned} \tag{5}$$

here the coefficients β_0 and β_1 affects the original signal and the third order intermodulation distortion respectively. Both of them come from the cubic predistorter and the vector modulator. As a result, reducing the intermodulation distortion can be possible by optimizing the cubic preditorter circuit parameters *R, C* and the gain, phase parameters of the vector modulator.

IV. RESULTS AND DISCUSSION

In this study optimization of an analog cubic predistorter has been used for reducing the intermodulation distortion in communication systems using modulation schemes having high envelope fluctuations. The performance of the cubic predistorter has been evaluated by using two different modulation schemes such as 16-QAM and CDMA. Optimization and evaluation of the proposed cubic predistorter has been carried out by Agilent-ADS2005A. While evaluating the performance of the predistorter for both modulation schemes, the same PA circuit containing Motorola MOSFET MRF9742 has been used. Gain and 1 dB compression points of PA are 9.5 dB and 25 dBm respectively.

The modulation scheme, 16-QAM has a centre frequency of 850 MHz and symbol rate as 24.3 kHz. Figure 4 depicts the power spectrum of the PA with and without utilizing cubic predistorter for 16-QAM modulation scheme. As it is expected, by using RF PA together with the predistorter, the spectral regrowth is suppressed and third order intermodulation distortion is reduced. ACPR levels are -26.83 dBc and -53.85 dBc in the cases of the system utilized PA alone and together with predistorter respectively for the frequency offset 30 kHz. This shows that almost 27 dB ACPR improvement has been established by utilizing analog cubic predistorter together with RF PA.

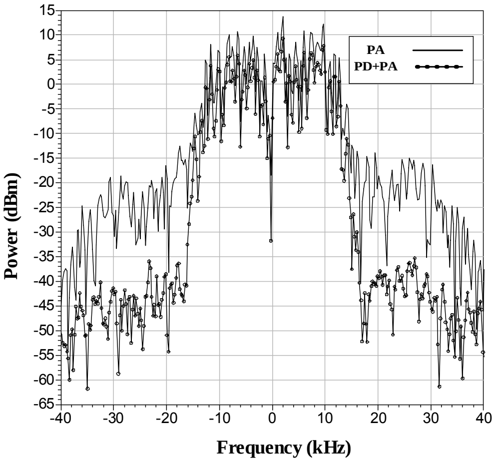

Figure 4. Power spectrum of PA with and without predistorter (PD) for 16-QAM modulation scheme.

The second modulation scheme for the evaluation of the performance is CDMA and has a centre frequency as 850 MHz and symbol rate as 1.2888 MHz. Figure 5 depicts the power spectrum of the PA with and without utilizing cubic predistorter in the case of CDMA modulation scheme.

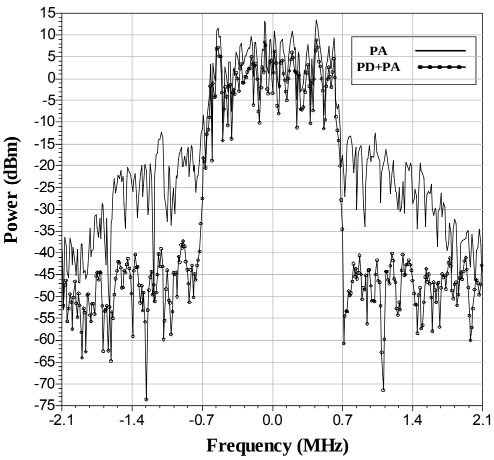

Figure 5. Power spectrum of PA with and without predistorter (PD) for CDMA modulation scheme.

Utilizing cubic predistorter with RF PA suppress the spectral regrowth of the power spectrum. ACPR levels are -30.33 dBc and -52.57 dBc in the cases of the system utilized PA alone and together with predistorter respectively for the frequency offset 1.4 MHz. Also there is ACPR improvement in the second case and it is nearly 22.24 dB.

V. CONCLUSION

Optimization of an analog cubic predistorter is proposed for reducing the intermodulation distortion in multicarrier communication systems. Mathematical analysis of the proposed cubic predistorter has been carried out by two tone test signal. Simulation of the cubic predistorter has been carried out for two different modulation schemes as 16-QAM and CDMA. Results of the simulations show that proposed analog cubic predistorter is suitable for reducing the third order IMD products.

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