Complex Gain Predistortion in WCDMA Power Amplifiers with Memory Effects

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Abstract: *Power amplifiers are essential components in communication systems and are inherently nonlinear. The nonlinearity creates spectral growth beyond the signal bandwidth, which interferes with adjacent channels. It also causes distortions within the signal bandwidth, which decreases the bit error rate at the receiver. In digital predistortion system, an inverse characteristic of power amplifier is generated and its amplitude and phase are combined to the signal input. So the input signal is predistorted and the power amplifier response is corrected. This process has to be controlled at high accuracy to achieve a satisfactory compensation effect. The inverse characteristics are stored in a memory (look-up table) and this data are updated using an error that is produced by comparing the outputs of power amplifier with the input signals. In this paper a novel technique for compensating such effects is proposed. It is a combination of two techniques, memory polynomial predistortion and the gain based predistorter method. This method is compared with the other technique, memory polynomial method and validated using a 1.9 GHz 60W LDMOS power amplifier and various signals such as 2-carrier WCDMA with 10 MHz carrier spacing and 15 MHz bandwidth. Simulations and results show improvement in ACLR reduction and EVM with applying this method.*

Keywords: *Digital predistortion, memory effects, ACLR, power amplifier, WCDMA.*

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1. Introduction

Although Spectrally efficient linear modulation techniques are used in the third generation systems and their performance is strongly dependent on the linearity of the transmission system, Also, the efficiency of the amplifier has to be maximized, which means that it must work near saturation. Newer transmission formats, with wide bandwidths, such as multi carrier Wideband Code Division Multiple Access (WCDMA), Wireless Local Area Network (WLAN), Worldwide interoperability for Microwave Access (WiMAX), are especially vulnerable to Power Amplifier (PA) nonlinearities, due to their high peak-to-average power ratio, corresponding to large fluctuations in their signal envelopes. In order to comply with spectral masks imposed by regulatory bodies and to reduce BER, PA linearization is necessary. A number of linearization techniques have been reported in recent years [1, 2, 3, 5, 6, 7, 8, 10, 13, 16]. One technique that can potentially compensate for PA nonlinearities in such an environment is the adaptive digital predistortion technique. The concept is based on inserting a non-linear function (the inverse function of the amplifier) between the input signal and the amplifier to produce a linear output. The Digital PreDistortion (DPD) requires to be adaptive because of variation in power amplifier nonlinearity with time, temperature and different operating channels and so on. Another limitation of predistortion is the dependence of amplifier's transfer characteristic's on the frequency content of the signal or defined as changes of the amplitude and phase in distortion components due to past signal values, that is called memory effects. The memory effects compensation is an important issue of the DPD algorithm in addition to correction of PA nonlinearity especially when the signal bandwidth increases. Many studies are involved in this technique but many of them suffer from limitations in bandwidth, precision or stability [2, 10, 16].

In this paper, a new technique of adaptive digital predistortion that is a combination of two techniques, the gain based predistorter [2] and memory polynomial model [4] is presented. Both previous techniques have demonstrated acceptable results but both have disadvantages. In memory polynomial predistortion the complexity of extracting the coefficients of predistortion function decrease the capability of linearization and so it needs to apply other method like [11] for implementing it. In complex gain predistortion method the memory effects that cause dynamic AM-AM and AM-PM are not considered. So here the main objective is not only to demonstrate the capability of this new method to overcome for such disadvantages, but also to show that with applying this technique all the memory contents of power amplifier that is modeled with memory polynomial is compensated. For validating this technique several simulations are applied. The adaptation is based on linear convergence method in the simulations. For simplicity, the effects of the quadrature modulator and demodulator and A/D and D/A is not considered.

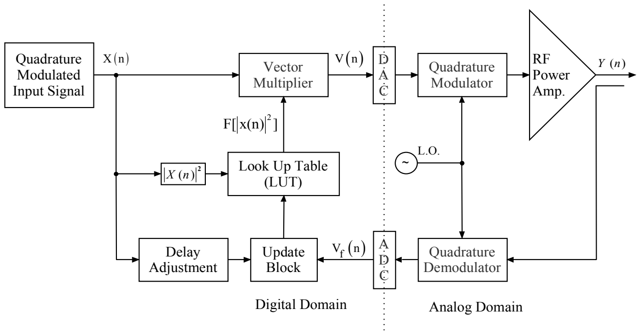


Figure 1. Adaptive digital predistortion block.

The LUT size is 10 bit and addressing the LUT is based on the input amplitude. Simulations are compared with the memory polynomial technique and two power amplifiers. It will be shown that with applying this method all the memory contents of the power amplifier especially the one that cause dynamic AM-AM and AM-PM are compensated. Simulations and results are examined based on Motorola's MRF1806 1.9 GHz LDMOS PA with 13 dB gain and 60W output power. To demonstrating the results several tests are shown with 2-carrier WCDMA signal..

2. Predistortion Technique

Figure 1 shows a block diagram of the adaptive digital predistortion [5]. A fully adaptive digital predistortion system requires the addition of a predistortion circuit consisting of a digital predistorter and Look Up Table (LUT) to the transmission path in addition to a feedback path consisting of a demodulator, Analog to Digital Converter (ADC) and adaptation circuit for updating the LUT.

The block diagram assumes that all components of the system except the predistorter and High Power Amplifier (HPA) have a linear response and hence can be ignored in the analysis. In this paper also these effects are ignored. The predistorter is equivalent to a nonlinear circuit with gain expansion response that is inverse of the power amplifier gain compression AM-AM (Amplitude dependent gain) and a phase rotation that is the negative of the Power Amplifier phase rotation AM-PM (Amplitude Dependent Phase Shift). In this figure x(n)=I+jQ is the quadrature modulated input signal and $v_f(n)$ is the quadrature demodulated feedback signal. These signals are sampled synchronously, and their values are used to generate a predistortion vector function $F[|x(n)|^2]$ which is stored in polar or rectangular form in LUT. The input signal $x(n)$ is predistorted according to $F[|x(n)|^2]$, so that the predistorted signal $v(n)$ produced the linearized output from the RF amplifier. Here the LUT is 10bit and the absolute of input signal is used for addressing it.

The main objective of this paper is to study the electrical memory effects that cause dynamic AM-AM and AM-PM [4]. The previous studies [4, 9, 11, 14, 15] were all restricted to calculation of the coefficients of the power amplifier. This way needs a lot of computation and therefore takes a lot of processor time and also never can be implemented when the number of coefficients increases. The technique that is proposed here doesn't have that drawback. It even claims that can compensate the dynamic memory effects in wideband applications. This method will be discussed in details in next section. One of the other important things in studying the predistortion method is that the predistortion attempts to add 3rd and 5th order intermodulation products to the input signals that cancels out the 3rd and 5th order intermodulation products added by the PA, thus the bandwidth of the predistorted signal must be three times greater than the bandwidth of the input signals to be able to represent up to 5th order intermodulation products. In the real world the predistorted signals are fed into a DAC and then low pass filtered at the Nyquist rate (half the input sample rate), the predistorted signal must have a sample rate of at least six times that of the original input signals. Thus in simulations the input signals are interpolated by a factor of six before being fed into the predistorter. In the next section the new technique of predistortion is discussed.

3. Complex Gain Predistortion

Figure 2 shows the predistortion function $F[|x(n)|^2]$ that cascades with power amplifier that has shown with $G[|v(n)|^2]$ function. $F[|x(n)|^2]$ and $G[|v(n)|^2]$ are complex gain functions of predistortion and power amplifier. As proposed in [4] the equivalent discrete baseband PA model considering memory effects and bandpass nonlinearity can be represented with a memory polynomial model which is a special case of Volterra series.

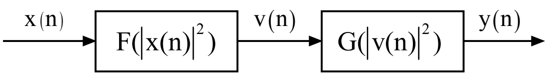


Figure 2. Cascade of predistortion and power amplifier.

This model can be presented as:

$$y(n) = \sum_{\substack{k=1 \\ \text{Odd}}}^{K} \sum_{q=0}^{Q} a_{kq} v(n-q) \left| v(n-q) \right|^{2(k-1)} \qquad (1)$$

where $v(n)$ is the discrete input complex signal of power amplifier after predistortion block and $y(n)$ is the discrete output complex envelope signal. *K* is the order of nonlinearity and *Q* is the memory length. This model considers only odd-order nonlinear terms due to bandpass nonlinear characteristics that cause intermodulation distortion. In equation 1, *v(n)* also can be represented as

$$v(n) = x(n)\,F[|x(n)|^2] \tag{2}$$

where *x(n)* is the discrete input complex and $F[|x(n)|^2]$ is the complex gain of the predistortion block. Equation 1 can be simplified as

$$y(n) = \sum_{q=0}^{Q} v(n-q) \sum_{\substack{k=1\\ \text{Odd}}}^{K} a_{kq}\,|v(n-q)|^{2(k-1)} \tag{3}$$

where the function $G_q(|v(n-q)|^2)$ can be represented as

$$G_q[|v(n-q)|^2] = \sum_{\substack{k=1\\ \text{Odd}}}^{K} a_{kq}\,|v(n-q)|^{2(k-1)} \tag{4}$$

Then equation 3 is

$$\begin{aligned} y(n) &= \sum_{q=0}^{Q} v(n-q)\,G_q[|v(n-q)|^2] \\ &= v(n)\,G_0[|v(n)|^2] + v(n-1)\,G_1[|v(n-1)|^2] + .. \end{aligned} \tag{5}$$

This equation demonstrates that the memory contents of the power amplifier are not only appeared in the coefficients a_{kq} of equation 1, but it also can be shown as the complex function, which means that the memory effects are appeared in the function $G_q[|v(n)|^2]$. Previous efforts only tried to extract the a_{kq} to compensate for such memory effects but here it will be shown that without having the coefficients also the memory effects can be compensated and even the compensation is better and includes all the memory [12]. From equation 2 for finding the function $F[|x(n)|^2]$, first it is assumed that Q=0 or the power amplifier is memoryless thus from equation 5 it can be conculded

$$y(n) = v(n)\,G_0[|v(n)|^2] \tag{6}$$

Ideally the power amplifier should satisfy the below condition for having the linear output

$$y(n) = Gx(n) \tag{7}$$

where G is the linear gain of power amplifier. Replacing equation 5 in equation 7 then

$$y(n) = \sum_{q=0}^{Q} v(n-q)\,G_q[|v(n)|^2] = Gx(n) \tag{8}$$

with assuming Q=0 and replacing the *v(n)* in equation 6 and with considering that the quadrature modulator is a perfect unity gain device the optimum predistorter characteristic, denoted by $F[|x(n)|^2]$, would satisfy

$$x(n)\,F[|x(n)|^2]\,G_0[|x(n)\,F[|x(n)|^2]|^2] = Gx(n) \tag{9}$$

then the optimum value of the predistortion complex gain is calculated from below iterative equation

$$F_{i+1}[|x(n)|^2] = F_i[|x(n)|^2] - \frac{F_i[|x(n)|^2]}{v(n)\,G_0[|v(n)|^2]} V_{error}(n) \tag{10}$$

where

$$V_{error}(n) = y(n) - Gx(n) \tag{11}$$

Now assume that the power amplifier includes one memory or Q=1 then after some simplification, equation below will be generated

$$F(|x(n)|^2) = \frac{G}{G_0[|v(n)|^2]} - \frac{v(n-1)\,G_1[|v(n-1)|^2]}{x(n)\,G_0[|v(n)|^2]} \tag{12}$$

the second fraction of equation 12 indicates the memory effects of the power amplifier. If Q increases then the elements in equation 12 also will increase. The iterative solution for equation 12 is

$$\begin{aligned} F_{i+1}(|x(n)|^2) &= F_i[|x(n)|^2] - \frac{F_i[|x(n)|^2]}{v(n)\,G_0[|v(n)|^2]} V_{error}(n) \\ &+ \frac{F_i[|x(n)|^2]\,v(n-1)\,G_1[|v(n-1)|^2]}{v(n)\,G_0(|v(n)|^2)} - \frac{v(n-1)\,G_1[|v(n-1)|^2]}{x(n)\,G_0[|v(n)|^2]} \end{aligned} \tag{13}$$

This equation can be simplified as

$$\begin{aligned} F_{i+1}(|x(n)|^2) &= F_i[|x(n)|^2] - \frac{F_i[|x(n)|^2]}{v(n)\,G_0[|v(n)|^2]} V_{error}(n) \\ &+ \frac{v(n-1)\,G_1[|v(n-1)|^2]}{G_0[|v(n)|^2]}\left(\frac{F_i[|x(n)|^2]}{v(n)} - \frac{1}{x(n)}\right) = \\ F_{i+1}(|x(n)|^2) &= F_i[|x(n)|^2] - \frac{F_i[|x(n)|^2]}{v(n)\,G_0[|v(n)|^2]} V_{error}(n) \end{aligned} \tag{14}$$

The function $F[|x(n)|^2]$ in equation 14 is similar to equation 10 when the power amplifier has no memory. This formula can be extended to more memory and is still valid. Simulations and results will prove the validity of this equation later. Memory polynomial method was very complicated and it couldn't calculate all the coefficients in the volterra series and only could compensate for 2 or 3 memory length but this method proves that it can compensate all the memory contents of the power amplifier.

The important parameter in equation 14 is the gain factor which is the only difference between equation 10 and equation 13 and it is the $F[|x(n)|^2]$ over $v(n)\,G_0(|v(n)|^2)$. In the case of having memory, $G_0[|v(n)|^2]$ can not be found and also equation 6 can not be assumed except the case of memoryless power amplifier. As it is shown in [1, 5] the gain factor can be a constant number between zero and one and it indicates the stability and convergence rate. If the gain factor sets to the larger value then the convergence is faster but the probability of convergence is low. For controlling and making the convergence slower and reach to the highest linearity especially at saturation point, equation 13 can be written as

$$F_{i+1}(|x(n)|^2) = F_i[|x(n)|^2] - \alpha \frac{F_i[|x(n)|^2]}{v(n)\,G_0[|v(n)|^2]} V_{error}(n) \qquad (15)$$

In [2], α is a constant between 0 and 1. This parameter indicates the convergence rate and stability and its value should be allocated with considering the linearity requirements. In [2] the condition for convergence of equation 15 is shown. For calculating the function $F[|x(n)|^2]$ in equation 15 first the error vector should be calculated and then the gain factor which involves the division and then these values multiply together. $F[|x(n)|^2]$ is initially one then after some iteration the optimum value will be found. Finding the appropriate gain factor is possible as described below. The parameter $v(n)G_0[v(n)]$ in the gain factor is the power amplifier output without memory and it can be modeled with the block diagram in Figure 3. For finding the $v(n)G_0[v(n)]$ parameter, it is possible to initially calculate the coefficients of the power amplifier without memory and save it in LUT and then calculate the gain factor.

With doing this, a lot of processor time and hardware resources will be compensated. It is important that if the feedback in Figure 3 comes from the output of the amplifier with memory which is *y(n)* rather than that the one which is shown in this figure this method will not linearized the power amplifier and equation 15 will not convergence. The value of α in equation 15 should be considered accurately to have a convergence in the loop. The only drawback that is still remained, is calculating the inverse of $v(n)G_0[v(n)]$ which after finding it and multiplied with error vector and predistortion function $F[|x(n)|^2]$ the LUT contents could be updated. So in implementation the main concern is the division part. One solution for this is to convert the division to multiply and this could be done with newton raphson method but it leaves for future work.

In equation 15 with two or three iterations convergence is achieved and it will be shown that as compared with memory polynomial method the efficiency improves more and it is less complex. The only time consuming part for implementing this method is the calculation of the gain factor which requires the division of the complex gain of predistortion block to the $G_0[|v(n)|^2]$. The predistorter is assumed to be implemented as a LUT of complex gain values [2] that here the size is 10bit, and is indexed by the squared magnitude, as shown in Figure 3.

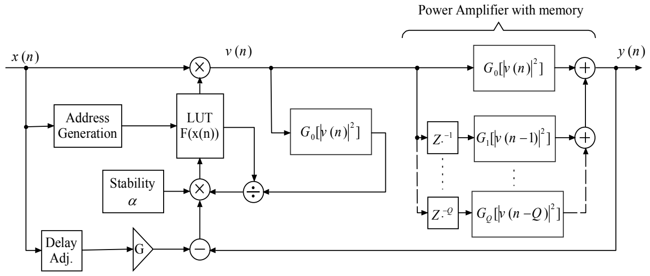


Figure 3. Predistortion block with memory compensation.

It is also possible to index by magnitude, or any other monotonic function of magnitude, depending on the regions of amplifier characteristic that need the greatest accuracy of representation. However, these considerations do not enter the analysis of the present paper. Also to help evaluate the performance of the DPD a figure for in-band distortion as well as out of band distortion which is measured with Adjacent-Channel-Leakage-Ratio (ACLR) is calculated. This involves calculating the Error Vector Magnitude (EVM) in transmitter, which is given by the following equation

$$EVM = \frac{rms(|V_{error}(n)|)}{rms(|(x(n)|)} \qquad (16)$$

where $V_{error}(n)$ is from (11) and $x(n)$ is the input signal.

4. Simulations and Results

In order to validate the proposed method several simulations are done. MATLAB is applied for simulations. The power amplifier is Motorola MRF1806 1.9GHz 60W LDMOS class AB power amplifier suitable for CDMA applications. First the power amplifier is designed in Microwave Office 2007. The input and output matching are designed accurately. The results of input and output matching are shown in Figure 4. The power amplifier is designed to cover the 60 MHz bandwidth from 1.93 GHz to 1.99 GHz. the gain parameter S21 which is 13.5 dB should be flat in all the bandwidth. It is always a trade off between the gain parameter S21 and input and output matching that represent with S11 and S22. For having the flat gain in all the bandwidth one of the parameter S11 or S22 should be scarified. Here as it is shown in Figure 4 the S22 is around -4 dB to -10 dB and it is higher than S11 which is at less than -20 dB range. After the matching results are confirmed, then the AM-AM and AM-PM characteristics of this power amplifier are generated and then the 4096 input and output data samples are imported to MTLAB for further analysis. These samples are used to model the power amplifier based on equation 1 which is the memory polynomial method. The extracted coefficients that include the memory effects are shown in Table 1. it is assumed that Q=2 and K=3. In Figure 5, the AM-AM and AM-PM characteristics of this power amplifier are shown.

Table 1. Comparison of the two predistortion techniques for different power amplifeirs with 2 carrier wcdma signal.

Predistortion Technique	**Power Amplifier Coefficients**	**MEMR**	**ACLR(dBc)**		**EVM (%)**
			Left	**Right**	
Memory Polynomial	a_{10}=0.9800-0.300i; a_{11}=0.06+0.03i; a_{12}=0.02+0.08i; a_{13}=-0.01+0.02i; a_{30}=-0.3+0.42i; a_{31}=-0.02+0.05i; a_{32}=-0.01-0.08i; a_{33}=0.02-0.01i;	1	-39.1	-40.2	0.89
	a_{10}=1.4513+0.132i; a_{11}=-0.123-0.023i; a_{12}=0.012-0.0043i; a_{30}=-0.132-0.430i; a_{31}=0.322+0.243i; a_{32}=-0.0123-0.12i; a_{50}=-0.755-0.654i; a_{51}=-0.213-0.411i; a_{52}=0.233+0.233i;	0.45	-45.2	-46.5	0.78
Complex Gain	a_{10}=0.9800-0.300i; a_{11}=0.06+0.03i; a_{12}=0.02+0.08i; a_{13}=-0.01+0.02i; a_{30}=-0.3+0.42i; a_{31}=-0.02+0.05i; a_{32}=-0.01-0.08i; a_{33}=0.02-0.01i;	1	-56.1	-50.6	0.71
	a_{10}=1.4513+0.132i; a_{11}=-0.123-0.023i; a_{12}=0.012-0.0043i; a_{30}=-0.132-0.430i; a_{31}=0.322+0.243i; a_{32}=-0.0123-0.12i; a_{50}=-0.755-0.654i; a_{51}=-0.213-0.411i; a_{52}=0.233+0.233i;	0.45	-57.1	-53.3	0.71

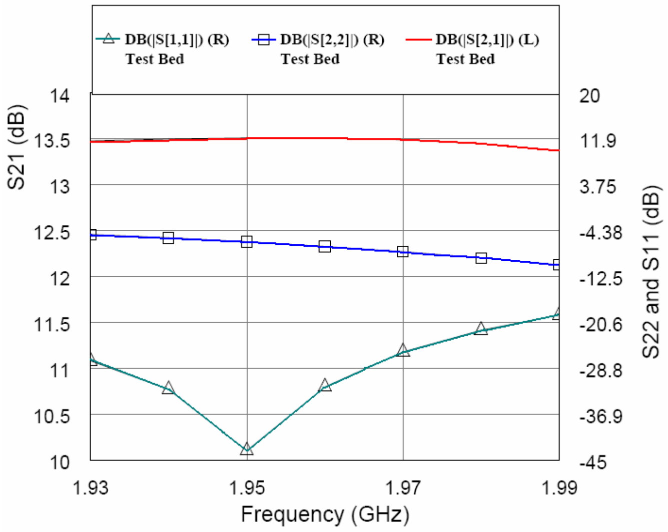
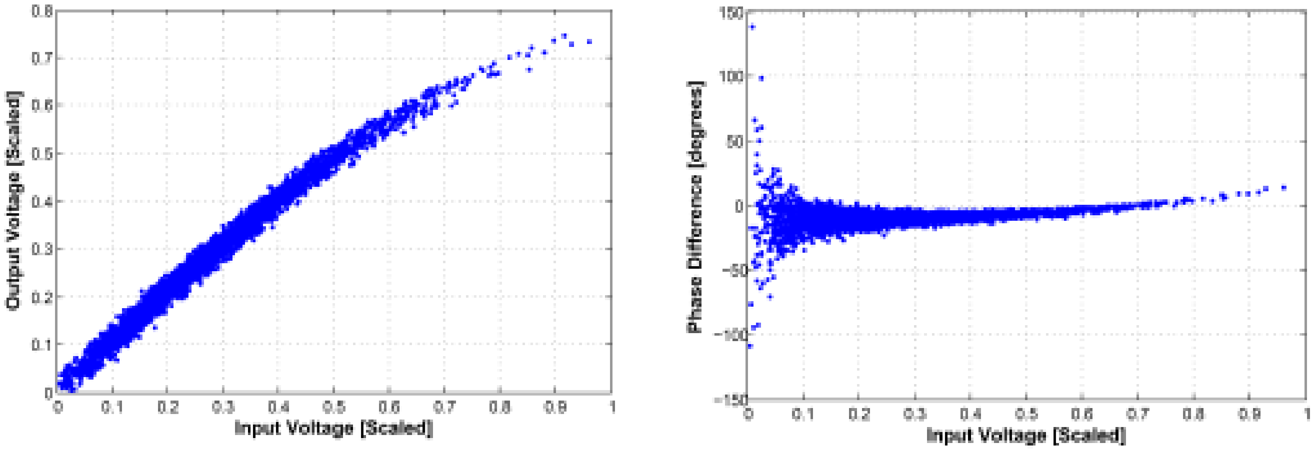


Figure 4. The S parameter of the amplifier MRF1806.



(a) Input power versus output power.

(b) Input power versus phase difference.

Figure 5. AM-AM and AM-PM characteristics of the 1.9 GHz LDMOS PA when a 2-carrier WCDMA signal is applied.

These characteristics are extracted with two carrier WCDMA signal with 10 MHz carrier spacing that is generated from Microwave Office 2007. It is shown the scattering of samples that is because of the memory effects. It can be shown that when the memory effects are more, these samples will be scattered more, then the digital predistortion technique should have more iterations in adaptation algorithm to compensate for such effects. It is clear in Figure 5(a) that the AM-AM characteristic is not linear when the input amplitude is increased. And also on Figure 5(b) the curve bends too. This is because of the nonlinear characteristics of power amplifier which here it is assumed that the order of nonlinearity K=3. It should be noticed that all the input and output samples in the simulations are normalized. In Table 1 the proposed method is compared with the memory polynomial method for two different power amplifiers with different memory contents for 2 carrier WCDMA signal. The comparison is with ACLR and EVM.

For modeling the memory effects of the power amplifiers authors in [7] proposed a method for modeling the power amplifiers with memory. This method that is based on the spars delay taps is actually able to take into account all the memory effects of power amplifier. The Memory Effect Modeling Ratio (MEMR) was used to show the amount of memory that this method can model. The power amplifier that is designed here has MEMR=0.45 and the one in [7] has MEMR=1 and these coefficients are shown in Table 1. previous researches could present the comparison of the power amplifier with MEMR that is less than one. Here the presented method is successfully tested with these two types of PA models. In all the simulations the input back off is 3 dB from saturation point. More efficiency is possible to reach with applying some additional circuits [2]. Here also the effects of analogue imperfections are not considered. Fig. 6 shows the measured Power Spectral Density (PSD) of the two different power amplifiers with memory when 2 carrier WCDMA signal is applied. The PSD that is used in all the simulations is based on Welch spectral estimator and Hann window with 1024 segment length. Figure 6(a) is for the PA having MEMR=1 and Figure 6(b) is the PA with MEMR=0.45. It can be seen that the out of band distortion specially (third intermodulation distortion) IM3 and IM5 is more in the power amplifier with MEMR=1 because of more memory effects that is modelled in this PA. The other effect that can be seen in this figure is the asymmetric of the distortion in which the left side and the right side have different ACPR, authors in [7] proposed the method for reducing such effects. The other interesting thing that it is shown in this figure is the power amplifier with MEMR=1 with the order of nonlinearity (K) that is 2 has only IM3 and for the power amplifier with MEMR=0.45 this value is 3 then it includes the IM3 and IM5.

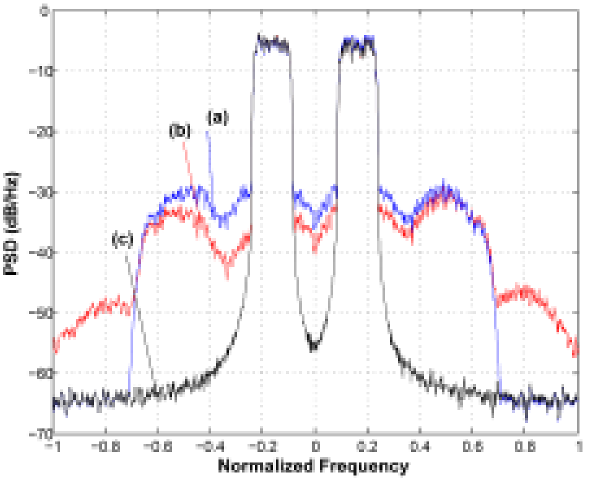


Figure 6. Power spectral density for two different power amplifiers with 2 carrier WCDMA signal applied, (a) power amplifier with k=2 and Q=3 and MEMR=1, (b) power amplifier with k=3 and Q=2 and MEMR=0.45, (c) input signal.

Figure 7 shows the results of applying the predistortion techniques. In this figure when applying the memory polynomial technique the amount of deduction in out of band distortion is averagely -39.5 dB and EVM is 0.89 %, but when applying the new predistortion technique after 9 iterations it is almost like the input signal and these values are -53 dB and 0.71 % respectively. It means around 13.5 dB improvement in ACLR. Here as it is shown with increasing the iteration the amount of ACLR reduction is also increased, but it has the drawback in practical implementation to reduce the bandwidth because in there is an inverse relation between the convergence time and required bandwidth.

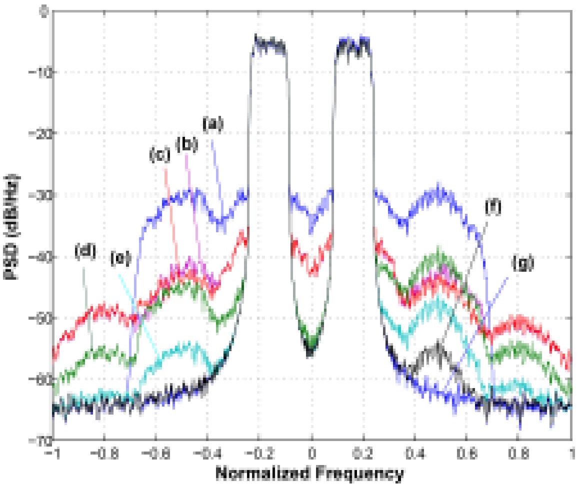


Figure 7. Comparison of the power spectral density (PSD) between memory polynomial predistorter and gain predistortion for 2 carrier WCDMA signal, (a) Output without predistortion, (b) Output with memory polynomial predistortion (Q=3, K=2), (c) Output with memory polynomial predistortion (Q=20, K=2), (d) Output with gain predistortion (iteration=5), (e) Output with gain predistortion (iteration=7), (f) Output with gain predistortion (iteration=9), (g) Input data.

In Table 1 the coefficients that are used in the simulation for both power amplifiers are shown. Also the comparison of ACLR and EVM for each technique is presented. According to this table the ACLR for Figure 7 is -56.1 dB at the left side and EVM is 0.71 % with applying the complex gain predistortion.

Figure 8 shows the power spectral density when the power amplifier is with MEMR=0.45. According to the table I the ACLR for memory polynomial technique is averagely -45.8 dB and EVM is 0.78 % and when applying the complex gain technique these values are -55 dB and 0.71 %. In this case the improvement of around 10 dB in ACLR is achieved. According to Figure 7 memory polynomial technique couldn't suppress the out of band distortion even when the memory length increases to 20, but the complex gain technique completely reduce that effects. It should be note that the number of iteration in complex gain technique should be more when the amount of memory is more. It should be noted that the value of alpha in adaptation equation should be between zero and one and depends on how much the back off we apply this value should be adjusted, the higher value of alpha the convergence is faster but it has the drawback that we will lose the efficiency and the lower the value the convergence is slower but it has the advantages to reach to the higher output power. It is always a trade off in choosing alpha.

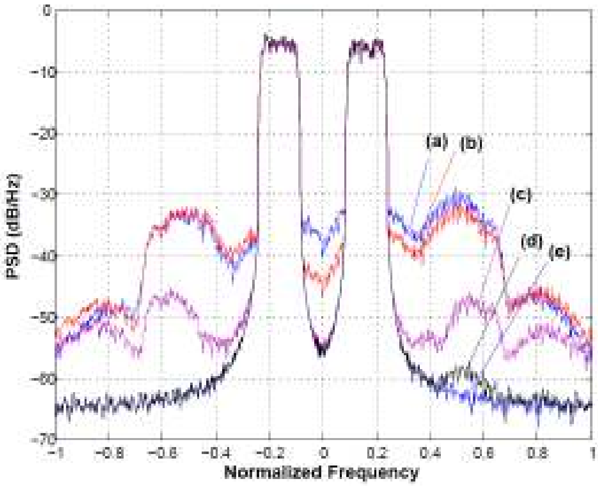


Figure 8. Comparison of the power spectral density (PSD) between memory polynomial predistorter and gain predistortion for 2 carrier WCDMA signal, (a) Output without predistortion, (b) Output with memory polynomial predistortion (Q=0, K=3), (c) Output with memory polynomial predistortion (Q=2, K=3), (d) Output with gain predistortion (iteration=5), (e) Input data.

Figure 9 shows the Error Vector Magnitude (EVM) of the PA with predistortion for two power amplifiers for different iterations. The red line is the EVM of the PA with MEMR=0.45 and the blue line is for the PA with MEMR=1.

This result shows that initially the power amplifier with more memory effects has the EVM which is more than the power amplifier with less memory effects after applying the complex gain predistortion and after 2 iterations the EVM drops to less than 1 % and after more iteration the EVM will reach to 0.71 %. This is equal for both PA.

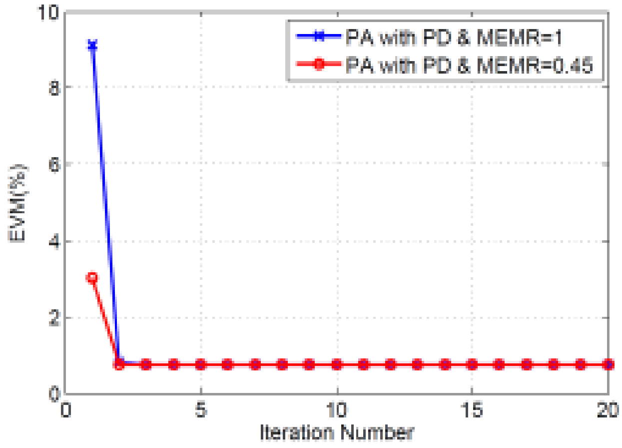


Figure 9. Error vector magnitude of the power amplifiers with different memory effects for the complex gain predistortion technique.

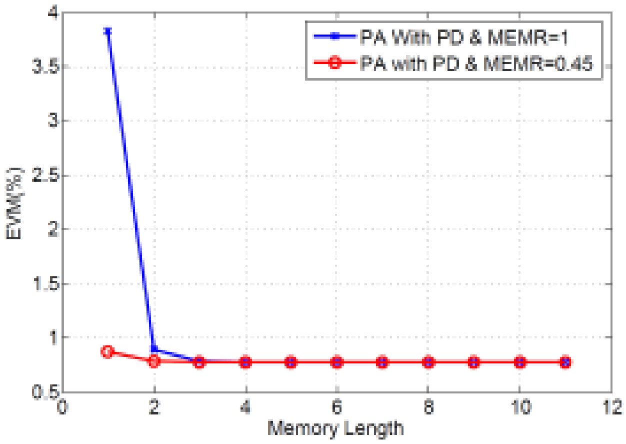


Figure 10. Error vector magnitude of the power amplifiers with different memory effects for the memory polynomial method.

In Figure 10 the EVM is shown for the PAs but with applying memory polynomial technique. This result is based on the memory length which indicates the amount of memory in this technique. After increasing memory length to 10 the final EVM is reached to 0.77 % which is close to the complex gain predistortion.

5. Conclusions

The new digital predistortion technique is introduced. This technique is the combination of two techniques, complex gain predistortion and memory polynomial predistortion. This technique claims to reach the higher efficiency in power amplifiers and also can compensate the more amounts of memory effects. The novelty in this method is based on the idea that the complex gain of the predistortion function that is stored in LUT could also model the memory effects that cause dynamic AM-AM and AM-PM. According to the proven formula these effects appears in the output values where the values are not only depends on the current time but also are related to the past values too. Simulations and results are examined for power amplifiers with different amount of memory. The 2 carrier WCDMA signal is used for validation of the results. The results show the improvement of 13 dB in ACLR and improvement in EVM. The future research should be on the implementation of this technique using FPGA and DSP.

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