IMPROVEMENT OF DIGITAL MAPPING PREDISTORTERS FOR LINEARISING TRANSMITTERS

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ABSTRACT

In this paper we present a new kind of 2-dimensional mapping predistorter for linearising transmitters. This method applies self-tuning adaptive control to eliminate iteration processes and therefore to reduce adaptation time. All errors due to modulator imperfections (e.g. RF carrier leakage from local oscillator, differential gain and phase imbalance between I and Q paths) can be corrected by this method. The simulation shows that adaptation time and memory size of look-up-tables are reduced.

INTRODUCTION

Power and spectral efficiency are two most important factors to be considered in the design of a communication system, especially in the case of mobile communication systems where many users have to be handled at the same time and high power efficiency is very critical due to a short life time of battery. Power amplifiers in transmitters dissipate most of the power in a communication system. Therefore it is demanded to use high efficient power amplifiers to raise the power efficiency of the system and spectral efficient modulation techniques are used to increase the capacity of communication. Today it is widely accepted that in a mobile communication system high efficient power amplifiers(e.g. class AB,B,C and F power amplifiers) and linear modulation techniques(e.g. M-QAM and $\pi/4$-DQPSK) which are spectral efficient are applied. But linear modulation techniques are very sensitive to system nonlinearities. They are especially sensitive to nonlinearities of the power amplifiers and imperfections of the modulators in the transmitter. Many techniques to compensate the nonlinearities of amplifiers, e.g. predistortion techniques [1],[2], feedforward [3], cartesian feedback [4], LINC [5] and CALLUM [6] have been proposed. Among them, predistortion techniques which can be realized by analogue and digital techniques are oftenly used. Analogue implementation has less accuracy but digital implementation has good accuracy. Compared to other digital implementation techniques (complex gain predistorter [2] and LINC [5]) only the 2-dimensional mapping predistorter [1] has good properties to correct errors due to imperfections of modulators which can damage the system characteristics seriously as shown in Fig 2. But using this method the convergence time is quite long (10 seconds) and the memory of the 2-dimensional look-up-table is huge (2M words)[1]. These drawbacks have limited its use in practice.

In this paper we demonstrate a new kind of mapping predistorter by self-tuning adaptive control [2],[7] to eliminate the iteration process and to reduce adaptation time. In reference [2] the authors have applied the method to complex gain predistorter to eliminate the iteration process. But using this method the imperfections of modulators can not be corrected. As shown in references [8], [9] the imperfections of modulators seriously affect the system performance. We therefore applied the self-tuning adaptive control techniques in this paper to a 2-dimensional mapping predistorter. By this method the adaptation time for mapping pre-

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distorters is reduced (in this simulation 6.6 times faster than before [1]). To speed up look-up-table processes and to reduce the memory size of the look-up-table we have used a domain decomposition method to interpolate the 2-dimensional look-up-table values. The simulation shows that the process is very fast, the memory size is reduced and all errors due to imperfections of modulators can be corrected .

NEW MAPPING PREDISTORTER

Fig. 1 shows a 2-dimensional look-up-table self-tuning adaptive predistorter. s_i is the input source signal that is filtered by a square-root raised consine filter and is expressed by its quadratic form s_{iI} and s_{iQ}. s_p is the predistorted signal. Behind the quadrature modulator the predistorted signal is changed to s_p' due to imperfections of the modulator. s_o is the output signal of the power amplifier. Firstly the adaptive algorithm detects the input signal s_i and the output signal s_o. If the error is large, identification of modulator and amplifier imperfections is carried out. This process can be realized directly and needs no iteration steps. The sensor detects the output and the predistorted signals. Then we have

$$s_o = G_A s_p', \tag{1}$$

$$s_p' = f_m(s_p, k_i, k_q, \theta, s_{RF}). \tag{2}$$

In the above k_i,k_q,θ and s_{RF} are differential gains, differential phase and local oscillator RF leakage, respectively. G_A is the complex gain of the amplifier which represents the power gain and the phase shift of the amplifier. Secondly a 2-dimensional look-up-table is built up. If the output signal is normalized to the linear gain of the amplifier and there is no distortion between input and output signal $s_i = s_o$. We have

$$s_p = G_p + s_i, \tag{3}$$

$$s_i = s_o. \tag{4}$$

At the address s_i we have $(s_{iI}, s_{iQ}) \rightarrow (G_{pI}, G_{pQ})$. G_p is the modified signal of the input signal.

SIMULATION

According to the principle given above we have simulated a linearized class AB amplifier. To simplify the simulation we have adopted the low pass equivalent method. We adopted 16-QAM modulation which is filtered by a square-root raised consine filter with a roll off factor 0.35. Fig. 2 shows ACI of the input signal and ACI due to nonlinearities of the amplifier without predistorter and ACI due to nonlinearities of the amplifier and imperfections of the modulator without predistorter (in this example differential gain between I and Q subpaths is 0.5 dB). Fig. 3 shows the results of a simulation with a complex gain predistorter and the new self-tuning 2 dimensional mapping predistorter if there are errors in the modulator. It can clearly be seen that errors in modulator can not be corrected by the complex gain predistorter but the new method corrects all imperfections of the modulator. Additionally ACI is improved by more than 30 dB. At the same time the adaptation time is reduced. The simulations show that this method is 6.6 times faster than the method given in [1] for the linearized class AB amplifier because at least 5 to 10 iterations are eliminated in each adaptation process and the table size is reduced from 2M words to 0.22M words. For a strong nonlinear amplifier we expect that the time can be further reduced because using the method given in [1] it needs more iterations to reach convergence. Fig. 4 gives a comparison of the different table sizes. In order to speed up the look-up-table process we have divided the table into 576 subdomains. We adopted a scatter data interpolation method as given in [10] to interpolate the look-up-table values. The simulation shows that this process depends on the numbers of subdomains. How many subdomains are needed depends on the practical problem.

CONCLUSION

A new 2-dimensional mapping predistorter was described in the paper. Compared with 2-dimensional mapping predistorter given in [1], the iteration process is eliminated by the method. The developed predistorter has fast adaptation and a small size look-up-table. It can not only compensate nonlinearities of the power amplifiers but also correct imperfections raised by the modulators.

ACKNOWLEDGMENT

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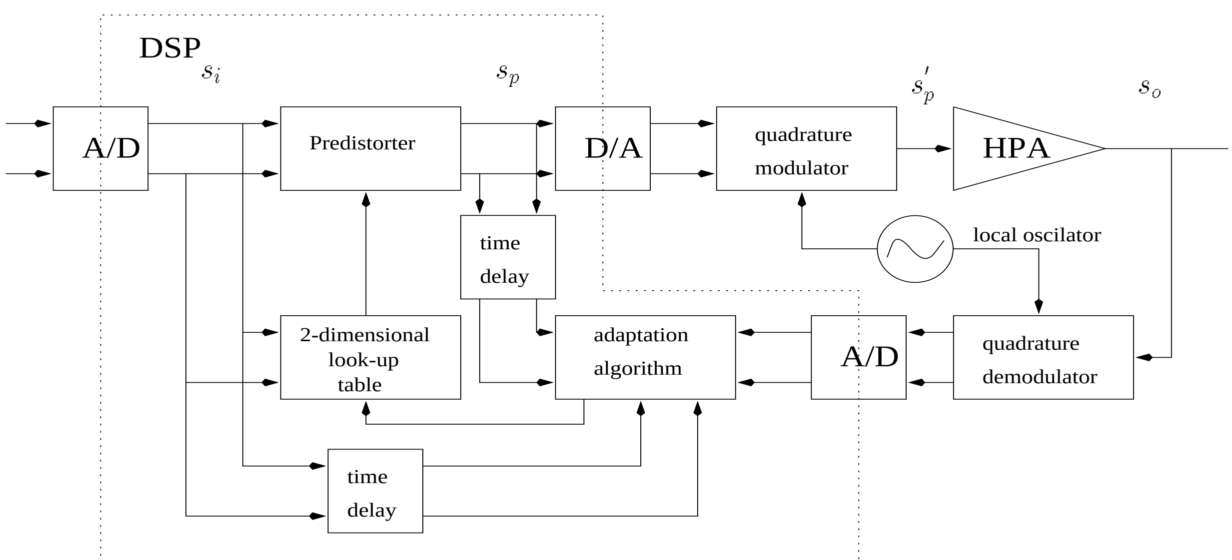

Fig. 1 Principle of self-tuning 2-dimensional mapping predistorter

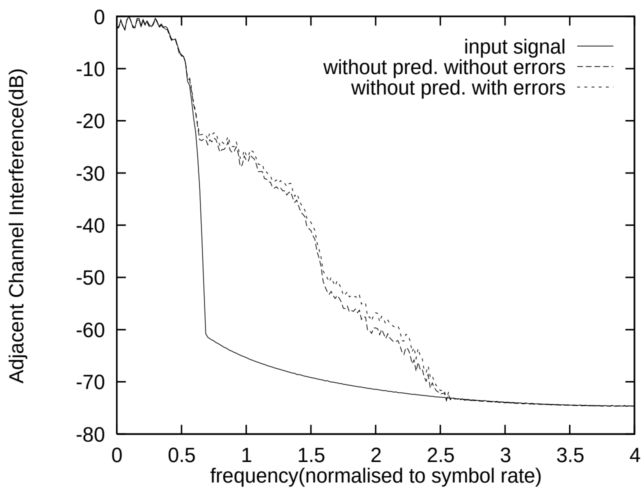

Fig. 2 ACI of input signal, ACI due to nonlineaties of HPA and ACI due to nonlinearities of HPA and imperfections of modulator.

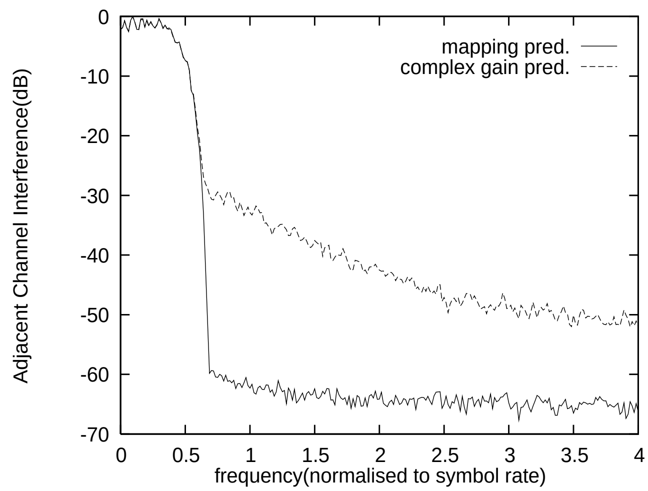

Fig. 3 ACI comparison of complex gain predistorter and new self-tuning 2-dimensional mapping predistorter with modulator imperfections

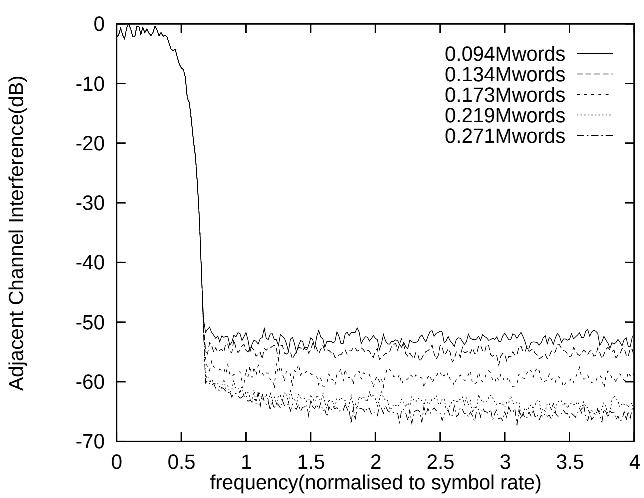

Fig. 4 Comparison of ACI of different table sizes