Influence of Some Imperfect System Performances on Linearizers

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Abstract

In this paper the effect of demodulator errors on predistortion techniques and the effect of output return losses of power amplifiers as well as the return loss of load and power combiner on LINC linearization technique are studied. The simulations show that for Cavers' predistorter only a DC offset will affect the ACI (Adjacent Channel Interference). Gain imbalance and phase imbalance of the demodulator have little effect on the ACI. For Nagata's predistortion system, although the predistorter is also misadjusted because of errors, the ACI will not deteriorate. But due to these errors, BER of both systems will deteriorate. The output return losses of amplifiers and the return loss of load can also deteriorate the performance of LINC linearizer while the isolation resistor can improve it.

Introduction

Many techniques to linearize nonlinearities of power amplifiers have been investigated in the past [1],[2],[3],[4],[5]. Predistortion techniques [1],[2],[7],[8] and LINC [5] (LInear amplification using Nonlinear Components) are the two most frequently used linearization techniques. The past studies showed that complex gain predistorters are very sensitive to modulator errors [6],[8] while mapping predistorters can correct these errors [2],[8]. But few efforts [6] have been described to investigate the effect of demodulator errors on the linearization. On the other hand the effect of some imperfect system performances on LINC lineariser is also not clear. In this paper the effect of all demodulator errors on the Cavers' and Nagata's predistortion linearizations is separately studied. Therefore the effect of each error on linearization can be clearly detected. LINC linearizer is also analyzed in detail. A guideline for designing LINC lineariser is given in the paper.

Effect of Demodulator Errors on Predistortion Linearization

Figure 1 gives an adaptive predistorter system. According to different definitions of predistorters, Cavers' complex gain predistorter $s_p = G_{pc}s_i$ with an one-dimensional look-up-table and Nagata's mapping predistorter $s_p = G_{pm} + s_i$ with a two-dimensional look-up-table can be defined.

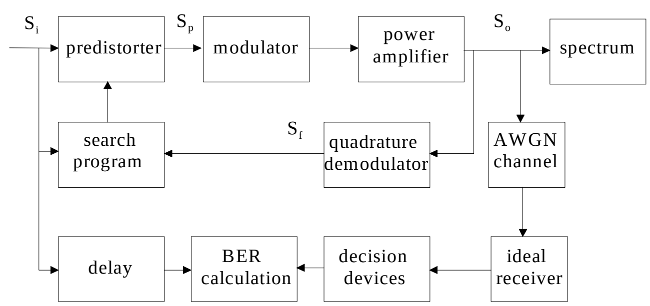

Figure 1: Configuration of an adaptive predistorter system and systems for BER calculation

Due to demodulator errors, $s_f \neq s_o$. s_f is often expressed as $s_f = As_o + Bs_o^* + C$. A and B are constants derived from gain imbalance and phase imbalance of the demodulator. C is the DC offset of demodulator [6].

Convergence of the search program is usual no problem. Then at the sample points $s_f = s_i$. From spectrum theory it is known that a linear signal transformation (rescale, rotation and signal shift) can not change its spectrum. Therefore the input, output and feedback signals have the same spectrums, as long as the transformation between s_o and s_f is linear and the predistorter can compensate nonlinearities of the power amplifier at all interpolated points. From here we can derive the gain of Cavers' predistorter:

$$G_{pc} = \frac{s_i - C}{G_A(|A|^2 - |B|^2)s_i}\left\{A^* - B\frac{(s_i - C)^*}{(s_i - C)}\right\}, \qquad (1)$$

where G_A is the complex gain of the power amplifier. From (1) it is easily seen that if $C \neq 0$, G_{pc} changes with s_i. At the same address $|s_i|$, different complex gains with unequal amplitudes and phasors can be reached, as long as the phasors of the signals are different. This is contrary to the definition of the complex gain predistorter. It must introduce errors into linearization and leads to deterioration of ACI. But if $C = 0$, on the basis of complex conformal transformation, formula (1) is changed into a circle with constant radius when the phase of signal s_i changes with the same amplitude. The complex gains have the same amplitude and unequal phase. There exist only linear distortions. The predistorter can compensate nonlinearities of the amplifier at all interpolated points. Therefore it will not deteriorate ACI. And for a mapping predistorter, G_{pm} is a function of s_i. At all interpolated points the predistorter can also compensate nonlinearities of the channel and the transformation between s_o and s_f is linear. But due to these errors, linear distortions will emerge in both system and BER of both systems will deteriorate. A similar analysis can be carried out for the predistorters proposed in the paper [8]. The same conclusions as given above for a mapping predistorter can be derived for a self-tuning mapping predistorter [8]. But all demodulator errors in a predistorter as it has been proposed in [7] will affect ACI.

Influence of Some Imperfect System Performance on LINC Linearizer

In Fig. 2 a LINC linearizer is given. The central part of the LINC linearizer is a signal component separator. Through this component the input nonconstant envelope signal s_i is divided into two constant envelope signals s_1 and s_2. These signals are amplified by nonlinear high efficient power amplifiers. These amplified signals are then combined again. The distorted out of band signals can be canceled because of the outphasing effect in the subpaths. The three signals have the following relationship: $s_1(t) = s_i(t) + e(t)$, $s_2(t) = s_i(t) - e(t)$ and $e(t)$ is a modified signal as given in [5]. $2s_i = s_1 + s_2$, $s_o = G_1 s_1 + G_2 s_2$. As long as $G_1 = G_2$, the distorted signals can be removed. G_1 and G_2 are the complex gains of the amplifier 1 and 2, respectively.

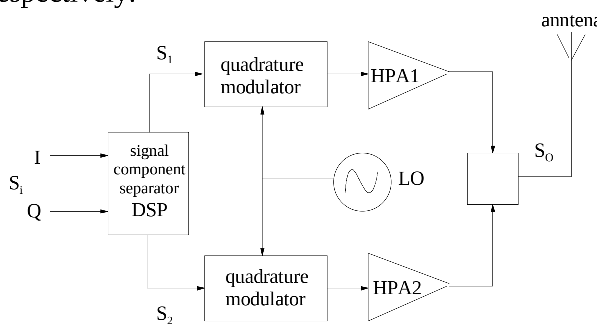

Figure 2: Configuration of LINC lineariser

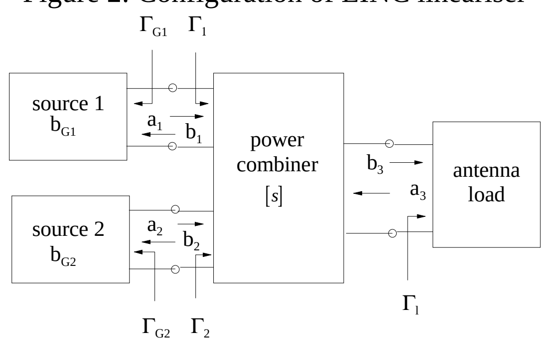

Figure 3: The network connected with power combiner

Fig. 3 shows the combiner network. From network theory s_o can be deduced which is a function of the power amplifier output signals b_{G1} and b_{G2}, the output return losses of power amplifiers Γ_{G1} and Γ_{G2}, the return loss of the antenna Γ_l and the scattering parameter $[s]$ of the power combiner. a_i and $b_i, i = 1, 2, 3$ are the incident waves and reflected waves at ports 1, 2 and 3, respectively. Z_o is the characteristic impedance of the transmission lines at the ports.

$$\bar{s}_o = (a_3 + b_3)Z_o^{1/2}, \qquad (2)$$

where $\bar{s}_o$ is a function that is dependent on $b_{G1}, b_{G2}, \Gamma_{G1}, \Gamma_{G2}, \Gamma_l$ and s parameters. This means that these parameters will affect the linearization results.

Simulation Results

In this section a class AB power amplifier will be used in the simulations. A 16-QAM digital modulated signal which is pulse shaped by a square root raise cosine filter with a roll-off factor 0.35 is assumed. A low pass equivalent method is adopted to simplify the simulation process.

Firstly the effect of demodulator errors on the linearization in complex gain predistorters is examined. Effects of DC offset 1%, 2.5% and 5% are simulated. From figure 4 it is easily recognized that DC offset has a large effect on the linearization. The results are in good agreement with results given in [6]. The errors are jitter-induced errors.

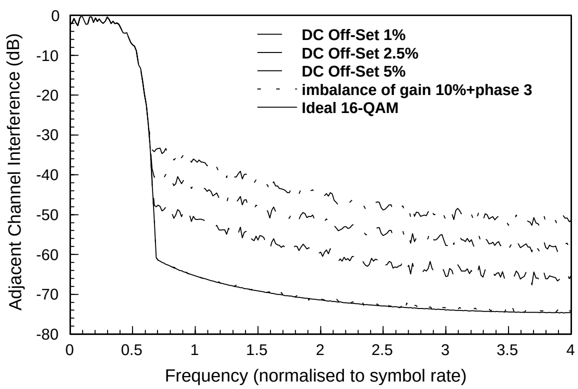

Figure 4: Changes of ACI with the DC off-set of demodulator

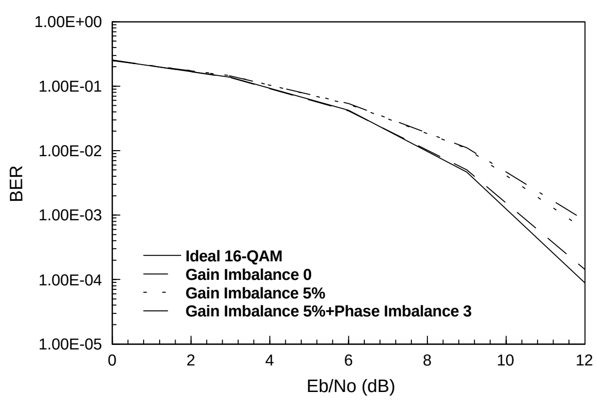

Figure 5: Changes of BER with the demodulator errors for Carvers' predistorter

A more interesting phenomenon is observed if a gain imbalance of 10% and a phase imbalance of 3^o are given. It is found that ACI is not increased although there exist errors of the demodulator. But BER simulations according to the system given in figure 1 show that BER is deteriorated as shown in figure 5. Compared with ideally linearized power amplifier, BER has increased from 1.43×10^{-4} to 5.91×10^{-4} if there is a gain imbalance of 5% at $E_b / N_o = 12\ dB$.

Next, the effect of demodulator errors on linearization in mapping predistorters is analyzed. According to the analysis given above, all errors of the demodulator have no effect on ACI. But they will increase BER of the system. Figure 6 shows the comparison of BER due to these errors. It is not difficult to observe that BER is raised with the increase of errors. From these curves it is clear that a DC offset has great effect on BER. But the spectrums continue to have the shape of the input signal.

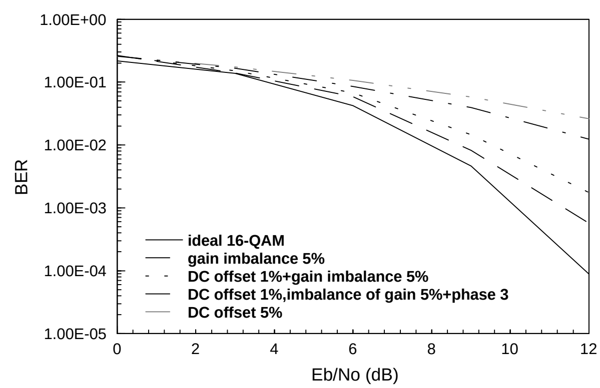

Figure 6: Changes of BER with DC off-set, imbalance of gain and phase of the demodulator for Nagata's predistorter

Now, the effect of load return loss, output return losses of amplifiers and power combiner on LINC linearisation are simulated. In order to clearly observe the effect of other factors on the linearization, the complex gains of the power amplifiers in the two subpaths are assumed to be identical, that is $G_1 = G_2$. An out of band point f =0.68 (normalized to symbol rate) is chosen to observe and to compare the effect of $\Gamma_{G1}, \Gamma_{G2}, \Gamma_l$ and the s parameters on ACI.

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Firstly, let $\Gamma_l = -10\ dB$. Under this condition it is clearly seen from Fig. 7 that the return loss of the load and output return losses of amplifiers have a big effect on the linearization. ACI increases very rapidly if the difference between output return losses of amplifiers is increased only a little.

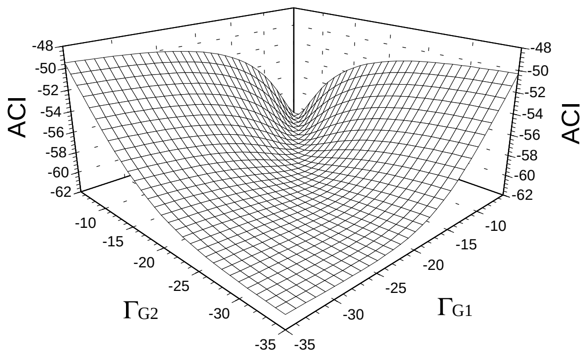

Figure 7: ACI changes with Γ_{G1} and Γ_{G2} if $\Gamma_l = -10\ dB$

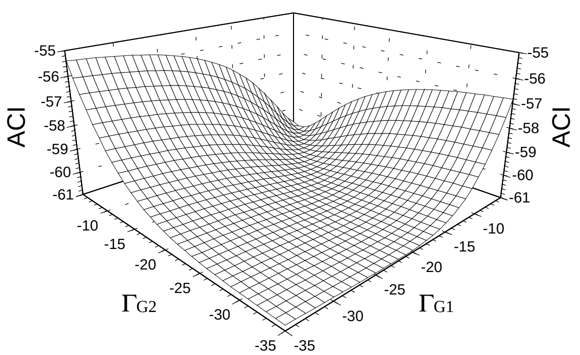

Figure 8: ACI changes with Γ_{G1} and Γ_{G2} if $\Gamma_l = -10\ dB$ and $s_{21} = -25\ dB$

Secondly, we add an isolation resistor to the power combiner. Now $s_{12} = s_{21} \neq 0$ and it is usually in the order of $-35\ dB$ to $-25\ dB$. We also assume $\Gamma_l = -10\ dB$ and $s_{12} = s_{21} = -25\ dB$. Compared with Fig. 7, ACI is highly improved due to the isolation resistor to absorb the reflected waves as shown in Fig. 8. From this figure we can also see that the isolation resistor does not absorb all reflected waves completely. This means that other methods must be taken into account. But if $\Gamma_l \leq -20\ dB$, these factors have little effect on linearization. Therefore in practice all Γ_{G1}, Γ_{G2} and Γ_l should be small enough in order to get satisfactory ACI. Γ_{G1}, Γ_{G2} and Γ_l should be less than $-20\ dB$.

Conclusion

A theoretical fundament is presented to examine the effect of demodulator errors on linearization. It shows that only a DC offset error in Cavers' predistorter affects ACI. Other errors have little effect on ACI. These errors have also no effect on ACI in Nagata's mapping predistorter. But all errors will deteriorate BER of both systems. To reduce the effect of Γ_{G1}, Γ_{G2} and Γ_l on ACI of LINC linearisation, Γ_{G1}, Γ_{G2} and Γ_l should be less than $-20\ dB$.

Acknowlegement

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Reference

[1] J.K. Cavers, "Amplifier linearization using a digital predistorter with fast adaptation and low memory requirements," *IEEE Trans. on Vehicular Technology*, vol. 39, no. 4, pp. 374-382, November 1990.

[2] Y. Nagata, "Linear amplification technique for digital mobile communications," In: *Proceedings of the 39th IEEE Vehicular Technology Conference*, pp. 159-164, May 1989.

[3] H. Seidel, "A microwave feed-forward experiment," *The Bell System Technical Journal*, vol. 50, no. 9, pp. 2879-2916, Nov. 1971.

[4] M. Johansson and T. Mattsson, "Transmitter linearization using cartesian feedback for linear TDMA modulation," in: *Proceedings of the 41st IEEE Vehicular Technology Conference*, pp. 439-444, May, 1991.

[5] S.A. Hetzel, A. Bateman and J.P. McGeehan, "LINC transmitter," *Electronics Letters*, vol. 27, no. 10, pp. 844-845, 1989.

[6] J. K. Cavers, "The effect of quadrature modulator and demodulator errors on adaptive digital predistorters for amplifier linearization," *IEEE Trans. Vehicular Technology*, vol. 46, no. 2, pp. 456-466, May 1997.

[7] E.G. Jeckeln, F.M. Ghannouchi and M. Sawan, "Adaptive digital predistorter for power amplifiers with real time modeling of memoryless complex gains," In: *1996 IEEE MTT-S Int.* Microwave Symp. Dig., pp. 835-838, 1996.

[8] Q. Ren and I. Wolff, "Improvement of digital mapping predistorters for linearising transmitters," In: *1997 IEEE MTT-S Int.* Microwave Symp. Dig., pp. 1691-1694, 1997.