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RF 송신부의 I/Q 변조기에서의 Imperfection 특성의 영향

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The Imperfection Feature Effects on the I/Q modulator in the RF transmitter

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Abstract – The modulation quality of the I/Q modulator in a wireless transmitter usually affects system performance and it mostly depends on both a nonlinearity and a distortion, from the third order intermodulation(IM3) signal and the imperfection features such as an input amplitude error and a local phase error, respectively. This paper focused on how much the Single Sideband Ratio(SSR), which indicates the signal distortion, changes according to the variation of the imperfection features. Since a desired signal, side band and IM3 signals at the I/Q modulator output are also represented with those power series coefficients and the imperfection features, the effects of the imperfection features on SSR can be clearly analyzed.

1. Introduction

Recently, the importance of a modulation quality at the I/Q modulator has been emphasized more than before [1] because the increased demand for a broadband requires the system to adopt a higher modulation over M-PSK. Since the modulation signal is usually degraded by IM3 signal and the imperfection features, it is very important to reduce IM3 signal and imperfection features. There are numerous analyses on signals and the SSR at the I/Q modulator [2]-[4], but they are not practical because none of them include both the system parameters and the imperfection features, and it can increase the difference between the simulated data and the measured data. In this reason, we propose a new expressions including both of them through the power series, they can make it clear to analyze the SSR according to the variation of the imperfection features error. In this paper, the nonlinear models for a mixer and the simulation results on the relations among OIP2, OIP3,. imperfection features and the SSR are presented in Section 2. Finally, the conclusion is represented in Section 3.

2. 본 론

2.1 A Nonlinear Mixer Model

The nonlinear mixer model to estimate the powers of a variety of output signals is shown in Fig. 1. For simplicity, input signal x(t) and output signal y(t) are assumed to be

$$x(t) = A\cos\omega_1 t + A\cos\omega_2 t \qquad (1)$$

$$y(t) \approx \alpha_1 x(t) + \alpha_2 x(t)^2 + \alpha_3 x(t)^3 \qquad (2)$$

In (2), the higher order terms are excluded because they are not a matter of concern in this analysis. From (1) and (2), the fundamental and intermodulation products are obtained as follows.

$$\omega_1, \omega_2 : \left(\alpha_1 A + \frac{9}{4}\alpha_3 A^3\right)\cos\omega_{1,2} t \qquad (3)$$

$$\omega_1 \pm \omega_2 : (\alpha_2 A^2)\cos((\omega_1 \pm \omega_2)t) \qquad (4)$$

$$2\omega_1 \pm \omega_2 : \left(\frac{3}{4}\alpha_3 A^3\right)\cos((2\omega_1 \pm \omega_2)t) \qquad (5)$$

In this paper, the key point is to derive the relations among the coefficients of α_1, α_2 and α_3. From a basic definition on IIP3 [5].

$$\alpha_1 A + \frac{9}{4}\alpha_3 A^3 = \frac{3}{4}\alpha_3 A^3 \qquad (6)$$

Solving the equation for variable A, and AIIP3 becomes

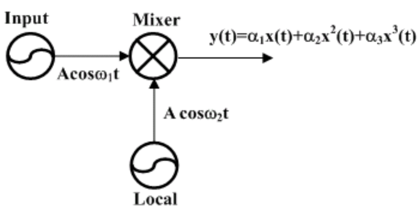

Fig.1 Nonlinear Mixer Model

$$A_{IIP3} = \sqrt{-\frac{2\alpha_1}{3\alpha_3}} \qquad (7)$$

Since OIP3 is equal to be IIP3 plus Gain, using (7), the relation between α_1 and α_3 series coefficient is obtained as follows.

$$\alpha_3 = -\frac{\alpha_1}{150\times 10^{\frac{OIP3-Gain-30}{10}}} \qquad (8)$$

From a basic definition on IIP2 [5],

$$\alpha_1 A + \frac{9}{4}\alpha_3 A^3 = \alpha_2 A^2 \qquad (9)$$

Since OIP2 is equal to be IIP2 plus Gain, inserting (8) into (9), the relation between α_1 and α_2 is obtained as well.

$$\alpha_1 = \frac{8c}{16-9mc^2}\alpha_2 \qquad (10)$$

$$\left(m = \frac{1}{150\times 10^{\frac{OIP3-Gain-30}{10}}}, c = \sqrt{400\times 10^{\frac{OIP2-Gain-30}{10}}}\right)$$

From the basic function of a mixer on conversion gain and (4), the equation about α_2 leads to.

$$\alpha_2 = \frac{1}{10^{\log_{10} A}} \times \sqrt{10^{\frac{Gain}{10}}} \qquad (11)$$

As listed from (3) to (11), α_2 is a function with only conversion gain, and both α_1 and α_3 are functions with OIP2, OIP3 and conversion gain, respectively.

In particular, since the practical I/Q modulator always has imperfection features such as the input amplitude error, ε_1 and local phase error, θ_2, a side band signal at $\omega_2 - \omega_1$ is also present at the I/Q modulator output [4]. From a similarity to the nonlinear mixer model, a desired signal, side band and IM3 products on different arms of the I/Q modulator are easily obtained. it is possible to represent the Single Sideband Ratio(SSR) as follows.

$$SSR[dBc] = 10\log\left[\frac{(\alpha_2 A^2 + \lambda\cos\theta_2)^2 + (\lambda\sin\theta_2)^2}{(\alpha_2 A^2 - \lambda\cos\theta_2)^2 + (\lambda\sin\theta_2)^2}\right] \quad (12)$$

2.2 Simulation Result

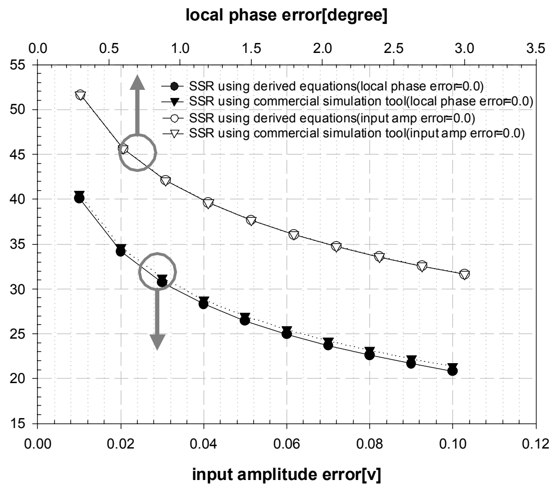

Fig.2 SSR vs input amplitude error with phase error=0˚
SSR vs local phase error with amplitude error=0v
(OIP2=60dBm, OIP3=30dBm, Gain=10dB)

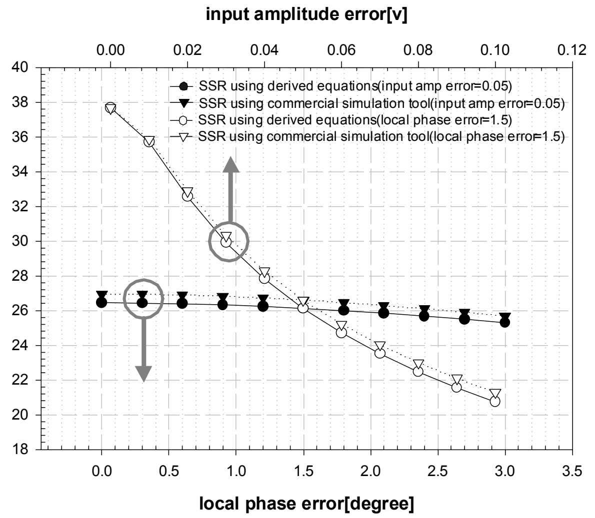

Fig.3 SSR vs variable input amplitude error with phase error=1.5˚
SSR vs variable local phase error with amplitude error = 0.05 v
(OIP2=60dBm, OIP3=30dBm, Gain=10dB)

First, all the simulations were performed and compared each other, using both derived equations and commercial circuit simulation tool [6]. The simulations for the effects of OIP2 and OIP3 on IM3 are performed under assumptions that input signals to the I/Q modulator have the peak values of ±0.5V, OIP2 from 50 to 75dBm, OIP3 from 30 to 55dBm and conversion gain of 10 dB, satisfying the condition that the P1dB is theoretically under 9.6 dB to IIP3 [5], for the I/Q modulator to operate below a saturation power.

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From (12), the SSR is shown to have relation with imperfection features such as the input amplitude error and local phase error. Assuming a maximum 10% error of an input amplitude and 3˚ error of a local phase, the curves relating those imperfection features to the SSR in Fig.2 represent that the SSR decreases as either an input amplitude or a local phase error increase, meaning the degradation of signal modulation. As expected in Fig.3, the SSR at the I/Q modulator having both the input amplitude error and local phase error decreases more than the cases of Fig.2, implying more degradation of signal modulation quality.

3. 결 론

In summary, it was key point to obtain the power series coefficients of α_1, α_2 and α_3 represented with the system parameters of OIP2, OIP3 and conversion gain for the nonlinear analysis of the I/Q modulator. As a result of that, the analytical expressions for a desired signal, side band and IM3 signal were derived. Moreover, it was definitely found that the SSR decreases according to the increase of the input amplitude error andlocal phase error. In the next work, it will be needed to analyze the effect of IM3 on the Error Vector Magnitude(EVM) and derive the relation between the SSR and the EVM.

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