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Scope of the Conference

3. High-power Devices and Techniques

Abstract

In this paper, a new behavioral model of power amplifier is proposed. This model has a expanded inphase – quadrature structure that is composed of main and intermodulation signals of wideband power amplifier . Also, we are proposed a new measurement setup to find transfer function of power amplifier based on CW 2-tone signals. The simulation results using the proposed behavioral model of power amplifier are agreed well with the measurement value for Korean PCS base-station transmitting band.

The Study of Behavioral Model of Power Amplifier

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In this paper, a new behavioral model of power amplifier is proposed. This model has a expanded inphase – quadrature structure that is composed of main and intermodulation signals of wideband power amplifier . Also, we are proposed a new measurement setup to find transfer function of power amplifier based on CW 2-tone signals. The simulation results using the proposed behavioral model of power amplifier are agreed well with the measurement value for Korean PCS base-station transmitting band.

1. Introduction

In the evaluation of an arbitrary system with simulator, the results are applicable in case that the equivalent model of system is correct. Oversimplified models don't predict correct simulation results of the system and extremely complex models may be impractical for simulation. In this research, the amplifier model that is one of the most critical elements in transmitter is proposed to adequately characterize any aspect of the amplifier in case of wide band modulated signal.

Some models are derived primarily from CW or narrow band measurement methods and assumed under the category of memoryless models. Memoryless models can only predict the nonlinear behavior within the narrow band environment quite well. Since these AM/AM, AM/PM curves are measured with a single tone, it is a just narrow band characterization of the power amplifier. Also, these characterizations are dependent of frequency and memory effects[1]-[2]. In this paper, we propose the nonlinear behavior model of wideband power amplifier and a new measurement setup of transfer function of power amplifier by measurements of amplitude and relative phase of input carrier and intermodulation distortion signals.

2. Measurement Method

For most high power amplifiers, the behavioral model based on single tone transfer characteristics cannot even accurately predict the third order intermodulation distortion (IM_3) and the fifth order intermodulation distortion(IM_5) in the CW 2-tone test, because of narrow band characteristic. Therefore, a more accurate behavioral model based on CW 2-tone characterization including phase information would be a better choice for modeling of power amplifier.

Fig. 1 shows the proposed measurement setup of transfer function of power amplifier based on CW 2-tone signals. Three signal generators must be synchronized reference signal source, 10MHz. This setup consists of three signal generators, a vector network analyzer, a spectrum analyzer, a variable attenuator, a variable phase shifter and a RF switches. The measurement procedure of amplitude and relative phase of arbitrary frequency component is followed. First, after setup as like as Fig. 1, we decide frequencies and power levels of signal gen.1 and signal gen.2. Because transistor makes nonlinear components besides of amplified signals, the role of signal gen.3 is represented an arbitrary frequency component that request to obtain transfer function and can be changed. In order to cancel out specified frequency component, a variable attenuator and a variable phase shifter is controlled. If two signals are equal amplitude and 180^{o} out of phase, these are cancelled. By controlling of the variable attenuator and the variable phase shifter, we can measure attenuation and phase quantity according to input signal level variation. These are represented measurement value of amplitude and relative phase of arbitrary frequency component, which can be measured with network analyzer by switching RF path of switches.

Fig. 2 shows signal cancellation characteristics according to amplitude and phase imbalances of two input signals. To measure correct phase information, cancellation more than 30dB must be guaranteed. But the cancellation cannot reach as high as 30dB in a low input power level range due to noise floor level of the spectrum analyzer. Generally, the relative phase error must be reduced to obtain the same cancellation characteristic when the amplitude mismatch is increased between two signals. By the prearranged amplitude mismatching, we can obtain correct phase values of fundamental, IM_3 and IM_5 components even though small signal cancellation condition[3]-[4].

In order to show validity of the proposed measurement method, the power amplifier (STA1800-37 of Sewon Teletch Inc.,) for base station or a repeater of Korean Personal Communication Service (KPCS) is used. The gain and the 1dB compression point are 50dB and 37dBm, respectively. When the input level varied, the amplitude and the relative phase of output components are displayed Fig. 3 and Fig. 4 in condition of tone spacing 1MHz and 10MHz.

3. Behavioral Model of Power Amplifier

We assume that the nonlinearity of the amplifier can be expressed in terms of a power series as like equation (1).

$$y = k_1 x + k_2 x^2 + k_3 x^3 + k_4 x^4 + \cdots\cdots \qquad (1)$$

where x is input and y is output signal. If input signals consist of two, equal-amplitude, signals as below;

$$x = A[\cos(\omega_1 t)+\cos(\omega_2 t)] \qquad (2)$$

then the output was chosen odd order terms because operating frequency bandwidth is narrow. We are assumed two conditions. First, because we are measured only main carrier, IM_3, and IM_5, we ignored above seventh IM terms. Secondly, the phase variation of each order is independent parameter. Fig. 5 shows transfer function of power amplifier with individual order transfer characteristics.

At Fig. 5, we are observed that the first order term is only main carrier component, the third order term is mixed main carrier and IM_3 components and the fifth order term is compounded main carrier, IM_3, and IM_5 components. That is, each terms can be expressed inphase-quadrature equation with phase relation[5]. The coefficients of each tone are compounded measurement value of amplitude and relative phase. We are arranged Eq. (3) as the extended inphase-quadrature power amplifier model, where is represented Fig. 6.

$$\begin{aligned} y = {} & i_{a1}[P_a]\cdot\cos(\omega_1 t) - q_{a1}[P_a]\cdot\sin(\omega_1 t) \\ & + i_{a2}[P_a]\cdot\cos(\omega_2 t) - q_{a2}[P_a]\cdot\sin(\omega_2 t) \\ & + i_{b1}[P_a]\cdot\cos\{(2\omega_1 t - \omega_2)t\} - q_{a1}[P_a]\cdot\sin\{(2\omega_1 t - \omega_2)t\} \\ & + i_{b2}[P_a]\cdot\cos\{(2\omega_2 t - \omega_1)t\} - q_{a2}[P_a]\cdot\sin\{(2\omega_2 t - \omega_1)t\} \\ & + i_{c1}[P_a]\cdot\cos\{(3\omega_1 t - 2\omega_2)t\} - q_{c1}[P_a]\cdot\sin\{(3\omega_1 t - 2\omega_2)t\} \\ & + i_{c2}[P_a]\cdot\cos\{(3\omega_2 t - 2\omega_1)t\} - q_{c2}[P_a]\cdot\sin\{(3\omega_2 t - 2\omega_1)t\} \end{aligned} \qquad (3)$$

We are simulated above polynomial with curve fitting. And we compared simulation and measurement of magnitude and phase characteristic of IM_3, and IM_5 with different 2-tone spacing. So, we are confirmed that the simulation results are agreed well with the measurement value. Fig. 7 shows the simulation result with frequency spacing is 4MHz.

4. Conclusion

In this paper, a new behavioral model of power amplifier using extended inphase–quadrature structure is proposed. Also, we proposed a new measurement setup to find transfer function of power amplifier based on CW 2-tone signals. The simulation results using the proposed behavioral model are agreed well with the measurement value for Korean PCS base-station power amplifier transmitting band. This behavioral modeling method will be used effectively simulation of wideband signal system and digital predistortion system.

5. Reference

[1] Kathleen J. Muhonen, *Amplifier Linearization for Broadband Wireless Applications*, The Thesis in the Pennsylvania State University , 1999

[2] Wolfgang Bosch, and Giuliano Gatti, "Mesurement and Simulation of Memory Effects in Predistortion Linearizers," *IEEE Trans. on Microwave Theory and Techniques*, pp. 1885-1890, 1989

[3] Younggoo Yang, Jeahyok Yi, Joongji Nam, Bumman Kim, and Myungkyu Park, "Measurement of Two-Tone Transfer Characteristics of High Power Amplifiers," *IEEE Trans. on Microwave Theory and Techniques*, pp. 568-571, 2001

[4] Peter B. Kenington, *High-Linearity RF Amplifier Design*, Artech House, 2000

[5] A.R. Kaye, D.A. George, and M. J. Eric, "Analysis and Compensation of Bandpass Nonlinearities for Communications," *IEEE Trans. on Comm.*, Vol.21, pp.965-972, Oct. 1972

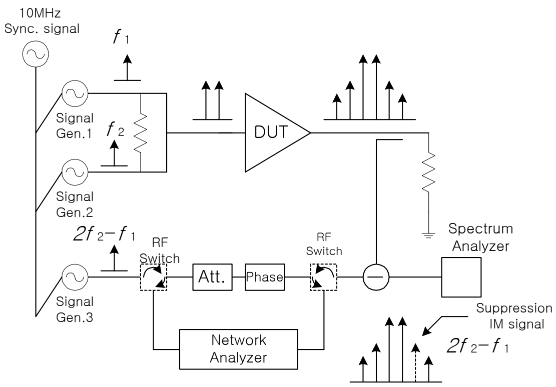


Fig. 1. The proposed measurement setup of transfer function of power amplifier based on CW 2-tone signals

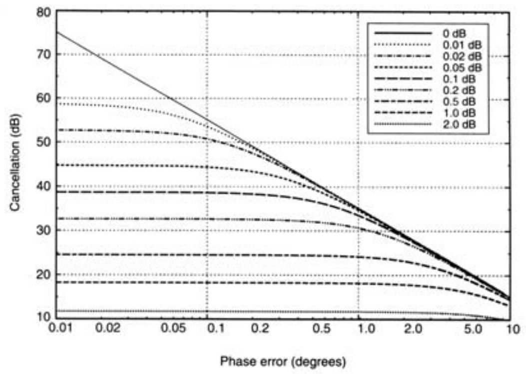
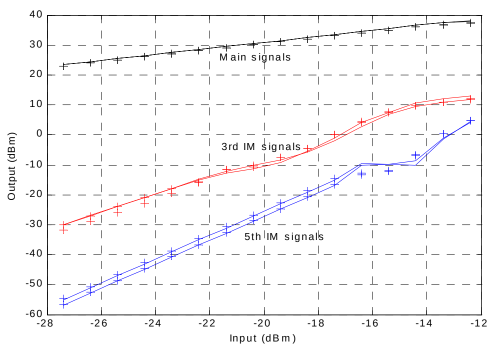
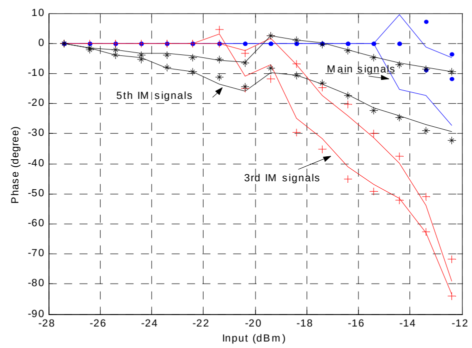


Fig. 2. Signal cancellation characteristics according to amplitude and phase imbalances of two input signals

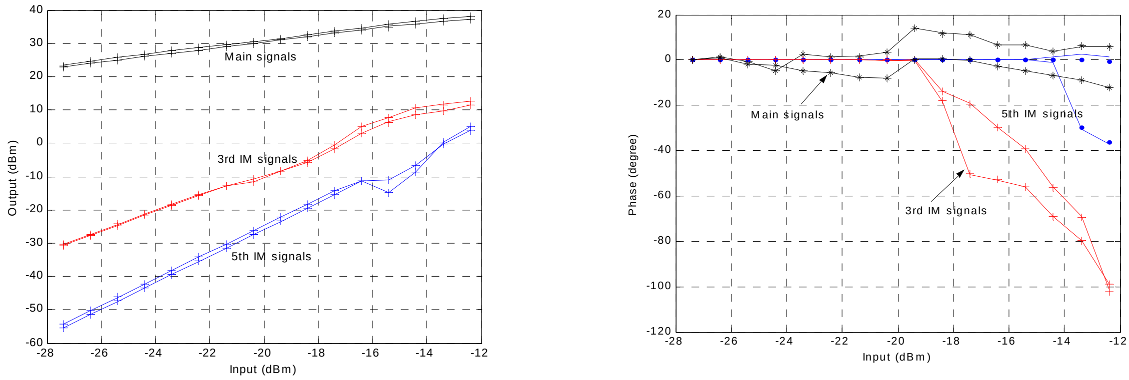


(a)



(b)

Fig. 3. The measured amplitude and relative phase variation of amplifier (a) Magnitude (b) Relative phase (@Δf=1MHz).



(a) (b)

Fig. 4. The measured amplitude and relative phase variation of amplifier (a) Magnitude (b) Relative phase (@Δ*f*=10MHz).

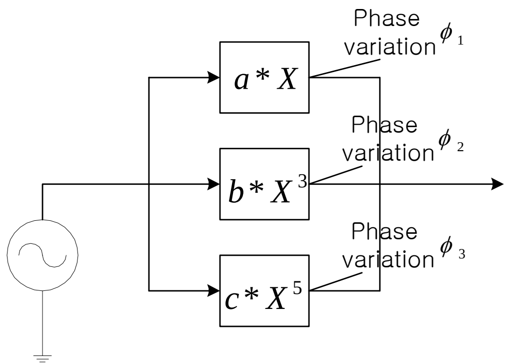


Fig. 5. Transfer function of power amplifier with individual order transfer characteristics.

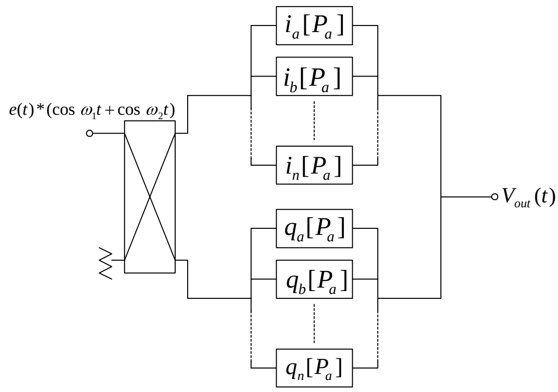
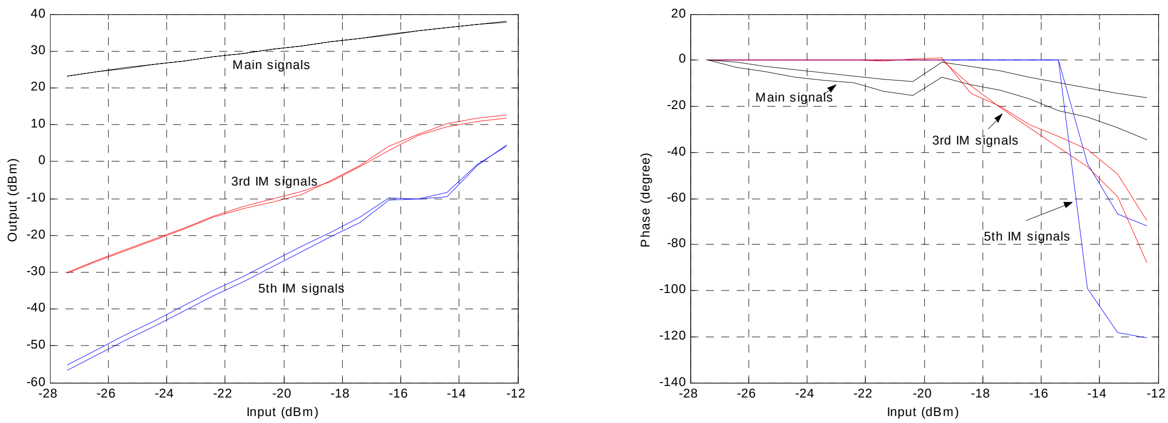


Fig. 6. The extended configuration of inphase and quadrature power amplifier model.



(a) (b)

Fig. 7. Simulation result of magnitude and relative phase (a) Magnitude (b) Relative phase (@Δ*f* =4MHz).