A Design of Predistortion HPA using Frequency Up-Conversion Mixing Operation

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Abstract — **In this paper, a predistortion linearizing method using frequency up-conversion operation. This method doesn't require any additional signal sources even though using mixing operation. This method uses the 2nd low frequency intermodulation distortion signal of driver amplifier as mixing signal. With the proposed predistortion method, the $(C/I)_{3rd}$ of amplifier is improved 26dB (@Po=22dBm/tone), where two tones are 1.8544GHz and 1.8556GHz.**

I. Introduction

In the third generation (3G) of mobile radio standards, very high linear transmitter that can support high crest factor signal is demanded than ever. So to power amplifier designer, high linearity and high efficiency is critical issue. In fact, as the power amplifier operates close to saturation region where both high efficiency and high output power emission are achieved, the degradation of linearity becomes significant. Compromise between power efficiency and linearity must be considered. Or linearization technique to recuperate nonlinearity of power amplifier is only solution. Various linearization methods which are named feedforward, feedback, predistortion, LINC(LInear amplification with Nonlinear Components), CALLUM(Combined Analog Locked Loop Universal Modulator), EER(Envelope Elimination and Restoration), and so forth are reported [1][2][3][4].

Predistortion is conceptually the simplest form of linearisation method for an RF power amplifier, but reducing effect is not as better as feedforward method. Predistortor can correct for both AM/AM and AM/PM distortion and is not restricted in bandwidth and can implemented in compact size. This method is proper to use for medium power HPA or relatively loose requirement of reducing distortion. In general, a predistortion method is difficult to generate predistortion signals and control magnitude and phase of predistortion signals to reducing distortion signals of HPA.

In the paper, we proposed a predistortion method using frequency up-conversion mixing operation. The proposed predisotrtion method doesn't require any additional signal sources even though using mixing operation. And this method is simple to generate predistortion signals and control them[5][6].

II. Theory

A. Frequency up-conversion mixing operation

Mixer performs frequency up- or down-conversion operation by using nonlinearity of the mixer with LO (Local Oscillator) signal. For up-conversion case, RF port frequency components are sum and difference between LO and IF signal frequency component. If LO signals consist of two, equal-amplitude, signals which frequencies are f_1, f_2 ($f_1 < f_2$) and IF signal frequency is $\Delta f = f_2 - f_1$, then frequency components of RF port signals are f_1, f_2, $f_1 - \Delta f$, and $f_2 + \Delta f$. These $f_1 - \Delta f$, and $f_2 + \Delta f$ frequency components are the 3rd order intermodulation distortion components that can be made in amplifier. Figure 1 shows the frequency spectrum of up-conversion mixing operation[5].

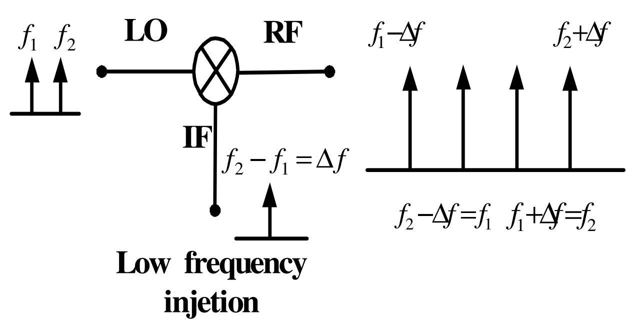

Fig. 1 The frequency spectrum of frequency up-conversionmixing operation

B. The 2nd order low frequency intermodulation signal generation

The transfer function of weakly nonlinear amplifier can be expressed as a Taylor series form below.

$$V_{out} = G_1 \cdot V_{in} + G_2 \cdot V_{in}^2 + G_3 \cdot V_{in}^3 + \cdots \quad (1)$$

The coefficients G_i (i=1,⋯n) are determined by the exact shape of the input/output characteristics. If input signal is consist of two, equal-amplitude, signals as;

$$V_{in} = A[\cos(\omega_1 t) + \cos(\omega_2 t)] \quad (2)$$

Then we take DC, intermodulation distortion components ($\omega_1 \pm \omega_2$, $2\omega_1 - \omega_2$, $2\omega_2 - \omega_1$, ⋯) and harmonic components ($2\omega_1$, $2\omega_2$, $3\omega_1$, $3\omega_2$, ⋯) besides amplified input signals at the output. Figure 2 shows output signal spectrum of nonlinear amplifier. For frequency up-conversion mixing operation, the 2[nd] order low frequency intermodulation signal ($\omega_1 - \omega_2$) is required.

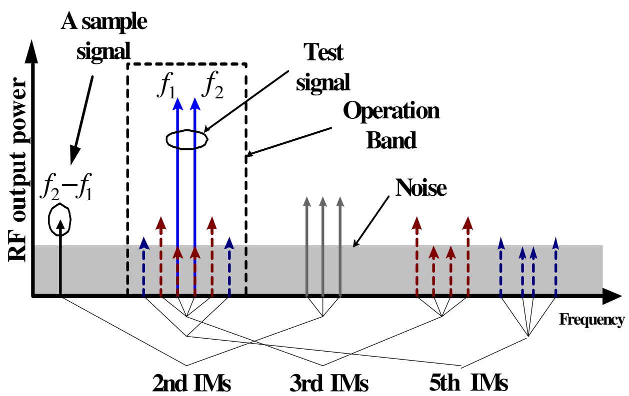

Fig. 2. Output signal spectrum of amplifier

In this paper, the 2[nd] order low frequency intermodulation signal(LIM$_2$) generator is proposed as like Fig.3.

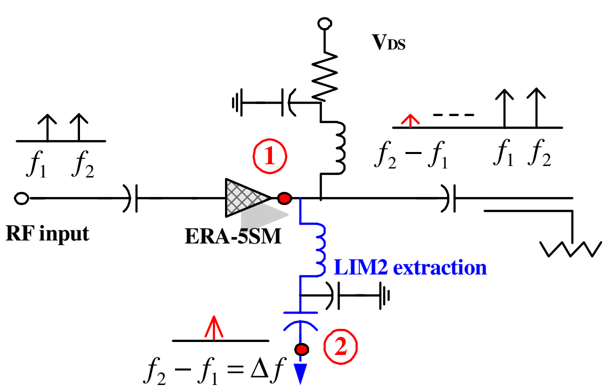

Fig.3. The block diagram of the 2[nd] order low frequency intermodulation signal generator

The generation circuit consists of an amplifier, a coupler, inductors (Ls), and capacitors (Cs). The used amplifier is the ERA-5SM of Mini-circuits. The coupler operates as band-pass filter to terminate operating band signals. And the series LC resonator are used to extracts LIM$_2$ signal.

C. Design of predistortion HPA using frequency up-conversion mixing operation

We designed predistortion HPA using frequency up-conversion mixing operation as like Fig. 4. It consists of a power divider, Automatic Level Controller(ALC), the LIM$_2$, mixer, variable attenuator, and variable phase shifter. Applied two-tone signals are divided, through the power divider, into the power amplifier path and ALC path.

ALC generates constant signal level for dynamic input power range. And then these signals are divided into to LO port and the LIM$_2$ generator. The voltage gain amplifier (VGA) controls magnitude of LIM$_2$. Finally LO port signal are mixed with the amplified LIM$_2$ and predistortion signals are generated. The gain and phase of these predistortion signals are controlled through both the variable attenuator and variable phase shifter to match those of intermodulation distortion signals of HPA.

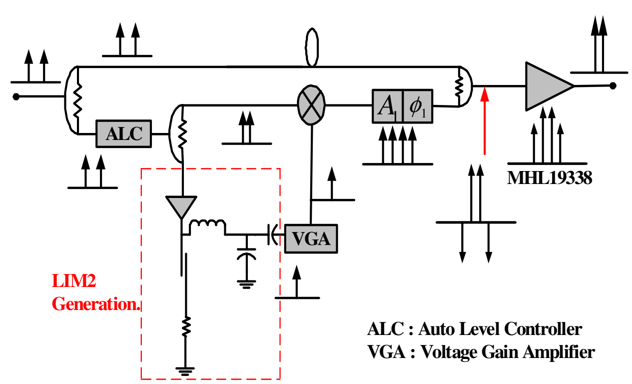

Fig.4. Block diagram of predistortion HPA using frequency up-conversion mixing operation

III. EXPERIMENTAL RESULT

To show the validation of the proposed linearizing method, the proposed predistortior and HPA are fabricated. MHL19338 of Motorola is used as HPA, the gain is 30dB and P_{1dB} is 35dBm. For LIM_2 generation, ERA-4SM of Mini-Circuits is used. The used VGA and mixer are AD602 of Analog device and LRMS-30J of Mini-circuit, respectively. Variable attenuator and variable phase shifter all use reflection-type in order to obtain good reflection coefficients. Varactor diode 1T362 of Sony is used for the variable phase shifter and PIN diode HSMP-4810 of HP for the variable attenuator.

Figure 5 shows transfer characteristics of the fabricated LIM_2 generator. Figure 6 shows output spectrum of LIM_2 generator, where input frequencies are 1.8544GHz and 1.8556GHz, respectively. Figure 7 shows output spectrum of frequency up-conversion mixing operation. In mixing operation, the signal level of LO and RF port are controlled not to make intermodulation signals of LO signals themselves.

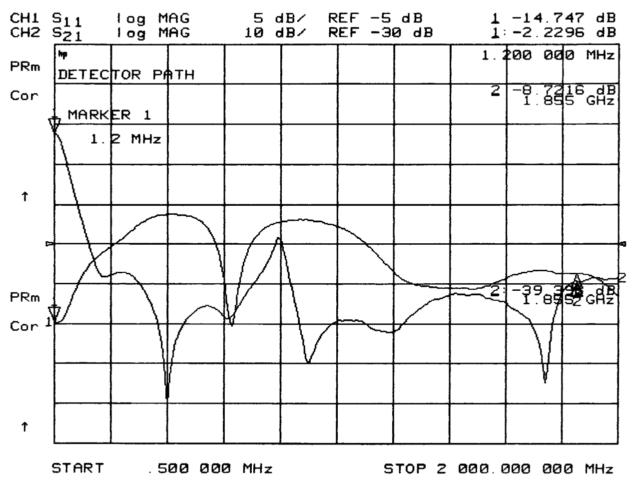

Fig. 5. The transfer characteristic of the fabricated 2nd order low frequency intermodulation signal generator

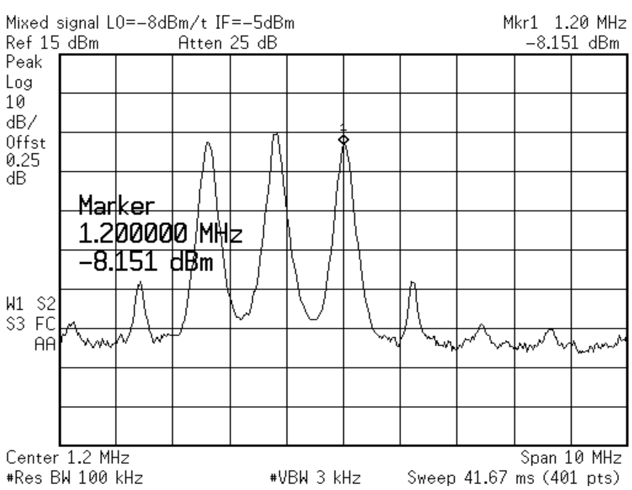

Fig. 6. Output spectrum of the fabricated 2nd order low frequency intermodulation signal generator

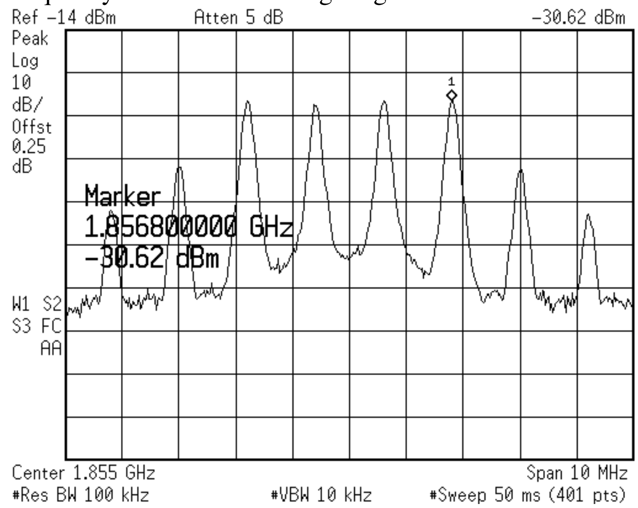

Fig. 7. Output spectrum of frequency up-conversion mixing operation

Fig.8 shows the comparison results of HPA nonlinear characteristic with and without predistorter using frequency up-conversion mixing operation. At the output power Po=22.09dBm/tone, $(C/I)_{3rd}$ is 39.97dBc in case of without the predistorter and is 65.97dBc with the predistorter. Hence $(C/I)_{3rd}$ is improved about 26dB. And Fig. 8 shows improvement characteristics of IM_3 for output power range 11~28 dBm/tone. We could improve at least by 20dBc on the whole range.

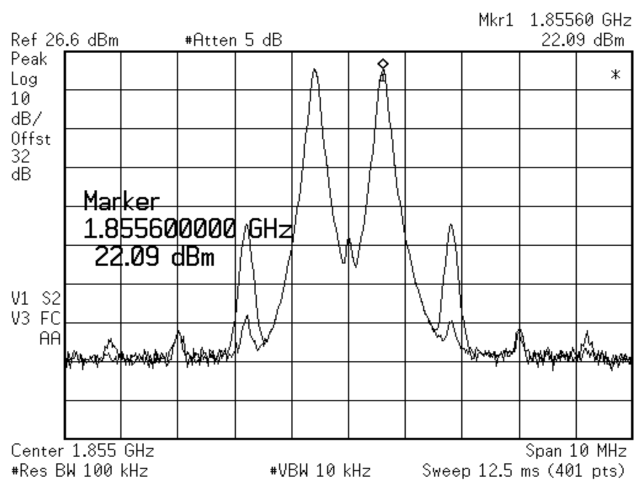

Fig. 8 Comparison between 3rd order IMD without predistorter & with predistortor(@Po=22.09dBm/tone)

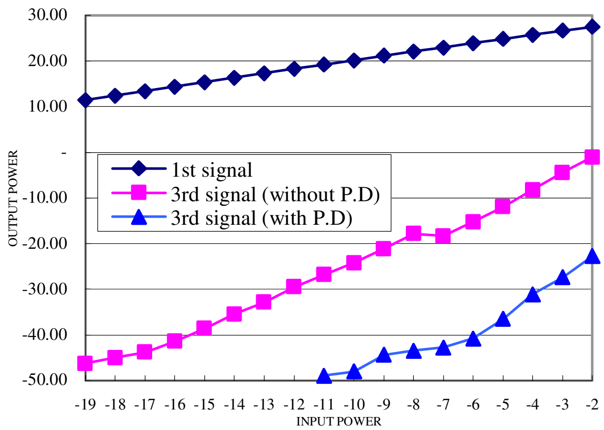

Fig 9. Comparison between 3rd order IMD without predistorter & with predistortor

IV. Conclusion

In this paper, we proposed predisotrion HPA scheme using frequency up-conversion operation. The proposed predisotrtion method doesn't require any additional signals source even though using mixing operation. And this method is very easy to generate predistortion signals and control them. Also we showed the 2nd oreder low frequency signal generation scheme. With the proposed method, $(C/I)_{3rd}$ can be improved more than 20dB over 10dB dynamic range.

Acknowledgement

This work was supported by grant No. R01-2000-00257 from the Basic Research Program of the Korea Science & Engineering Foundation. We sincerely appreciate Ansoft Koreas's & Agilent Technology's cooperation in our research with the donation simulation software(HFSS, ADS).

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