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Reducing the Third-Order Inter Modulation Distortion by Feed Forward Linearization of Power Amplifier

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Abstract: Power amplifier determines the performance of a wireless communication system but it tends to be highly non-linear and results in intermodulation distortion at its output, thereby degrading the signal quality and causing adjacent channel interference. In this paper, feedforward linearization technique is used to reduce power amplifier non-linearity. The simulations are carried out using two-tone harmonic balance input at the frequencies of 2120 MHz and 2130 MHz. It is seen that this technique reduces the third-order intermodulation distortion levels to -68 dBm and the distance between fundamental component and third-order distortion component is 106 dBm.

Keywords: Feedforward, Intermodulation distortion (IMD), Linearization, Power Amplifier (PA).

I. INTRODUCTION

In any wireless communication system power amplifier is one of the principal components whose performance affects the transmission quality [1]. Since, these power amplifiers have highly non-linear characteristics, so apart from the function of amplification; they also generate new spectral components which act as distortion in the output signal [2]. When multicarrier signal is input to the power amplifier then along with those two carriers, additional products are also generated in the vicinity of input signal carrier frequencies, both above and below the input carrier signals known as Intermodulation distortion (IMD) products. Since, the new products appear very close to the original carriers, they cannot be easily removed by filtering method [3]. This result in increase of adjacent channel power (ACP) [4] which means that an amount of usable energy has been leaked to the adjacent channel [5] which is infact a loss to the communication system. Thus, there is a need of some form of linearization technique to completely remove or reduce these distortion products.

The basic idea of linearization process is to either add a signal at the input of the power amplifier or at the output so as to make the signal look like it never went through any kind of degradation [6]. Out of all the techniques that have been developed like Feedforward, Cartesian feedback, Predistortion, Envelope Elimination and Restoration (EER) [7]; feedforward linearization has the capability of handling multi-carrier signals [1], offers wide bandwidth and provides good IMD reduction [8]. Ideally, feedforward amplifiers are capable of cancelling the undesired in-band intermodulation products completely [9]. Thus, to suppress in-band distortion, feedforward is an effective power amplifier linearization technique.

In this paper, feedforward linearization technique has been used to improve the linearity of a multicarrier power amplifier whose specifications are given in [10]; reduction in third-order IMD power levels, distance between fundamental component and distortion component and third-order intercept points are measured to show improvement in linearity. The paper is organised as follows: section II describes the basic operation of feedforward technique and mathematical equations depicting how feedforward cancels the distortion introduced by PA, section III describes the simulation and results and section IV gives the conclusion.

II. FEEDFORWARD TECHNIQUE

Fig. 1 shows a block diagram of feedforward system with spectrums at different nodes [8]. It has two cancellation loops- signal cancellation loop and error cancellation loop. The signal cancellation loop suppresses the signal from the output of main power amplifier in such a way that only distortion components are left thereby giving the error signal. The error cancellation loop takes this error signal; modify it so that distortion in main power amplifier output can be cancelled [11].

The first loop consists of main power amplifier, gain and phase adjusters and delay component. The second loop consists of error amplifier similar to main power amplifier along with gain and phase adjusters and delay component. The input signal is first split into two parts by using a splitter. The upper branch signal is amplified by main power amplifier and lower branch signal is delayed and is used as reference signal [2]. The main power amplifier output is then attenuated by a fixed attenuator to make its level equal to the level of the reference signal. Then this signal and the reference signal are combined to give error signal containing only distortion components. This error signal after necessary attenuation and phase adjustment is amplified by error power amplifier and combined with the main power amplifier output leaving only linearized signal at the output of the system. Variable attenuator is used to match the signal levels before combining and variable

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phase shifter is used to align the main power amplifier output in anti-phase with reference signal. Delay is basically used for wide-bandwidth operation and to time-align the power amplifier output and reference signal before combining [1][8].

In this technique, ideally the distortion components will be completely removed which is proved theoretically by the equations of feedforward as shown below:

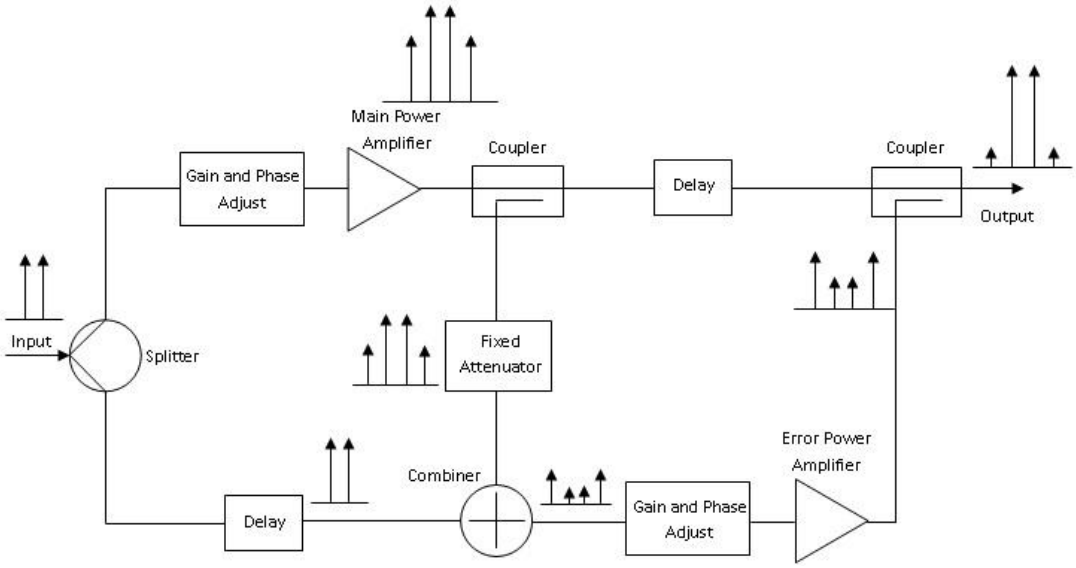

Fig. 1 Feedforward linearizer block diagram

Let V_i be the input signal applied to the circuit, A_v is the voltage gain of main power amplifier and V_D is the distortion signal. So, as a result of PA non-linearity, at the output we have,

$$V_{MA} = V_i A_v + V_D \quad (1)$$

In signal cancellation loop, the signal V_{MA} is attenuated by fixed attenuator with transfer function equal to $1/A_v$. So,

$$V_A = V_{MA}/A_v = V_i + V_D/A_v \quad (2)$$

Then, a subtraction of signal V_A from reference signal in lower branch takes place which gives error signal V_e.

$$V_e = V_A – V_i = V_i + V_D/A_v – V_i = V_D/A_v \quad (3)$$

This error signal is amplified by error amplifier giving,

$$V_{ea} = V_e A_v = (V_D/A_v).\ A_v = V_D \quad (4)$$

Then at the output coupler, both the signals i.e., V_{MA} and V_{ea} are subtracted to get the output $V_{O/P}$,

$$V_{O/P} = V_{MA} – V_{ea} = V_i A_v + V_D – V_D \quad (5)$$

$$V_{O/P} = V_i A_v \quad (6)$$

Therefore, ideally at the output of the feedforward circuit, distortion signal V_D is cancelled out and we are left with the amplified version of the input signal.

III.SIMULATION AND RESULTS

In our analysis, we used the system parameters as given in TABLE I. The simulation is carried out using two tone harmonic balance method [12]. The two tones are f1 = 2120 MHz and f2 = 2130 MHz. So, the third-order intermodulation signals are located at: 2f1-f2 = 2110 MHz and 2f2-f1 = 2140 MHz.

TABLE I SYSTEM PARAMETERS

Two Tones	f1 = 2120 MHz f2 = 2130 MHz
Power Amplifier	Operating Bandwidth – 2110 to 2170 MHz
	Gain = 50 dB
	Output Power = 16 W
Max. IMD order	3

The feedforward linearizer circuit is shown in Fig. 2. Harmonic balance simulation controller is used here and the values of phase shifters, attenuators and delays are adjusted and set to the optimum values so as to achieve minimum distortion levels and maximum distance between fundamental component and distortion component.

The simulation results for the feedforward circuit are given below. Fig. 3(a) shows the main power amplifier output spectrum before linearization and Fig. 3(b) shows the output spectrum after linearization. In the output, we observe that the intermodulation distortion levels after feedforward linearization at the frequencies of 2110 MHz and 2140 MHz are having power levels of -68.769 dBm and -67.673 dBm respectively. And the original carriers at the frequencies of 2120 MHz and 2130 MHz are at the power levels of 37.2 dBm each. In addition, the third-order intercept points are also measured. Fig. 3(c) shows the values of upper-toi and lower-toi. The values of upper and lower third-order intercept points are found to be 89.785 and 90.300 respectively.

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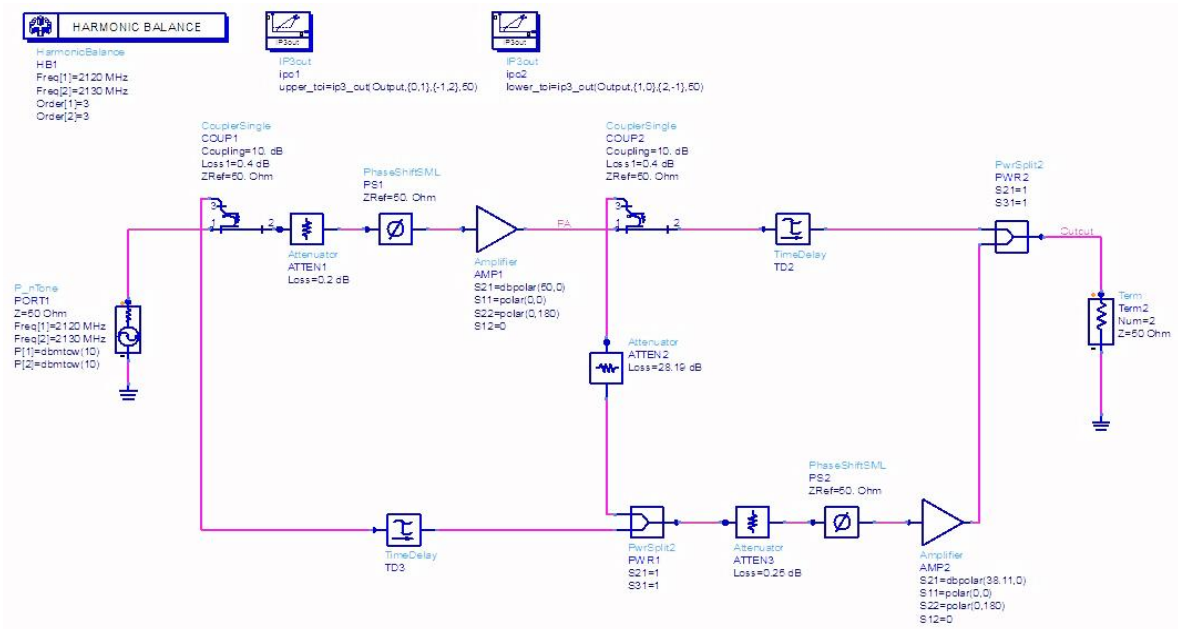

Fig. 2 Simulation circuit of Feedforward linearizer

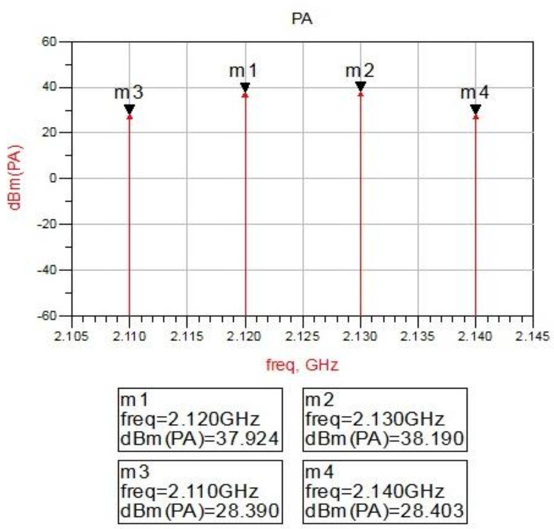

Fig. 3(a) Main PA Output before linearization

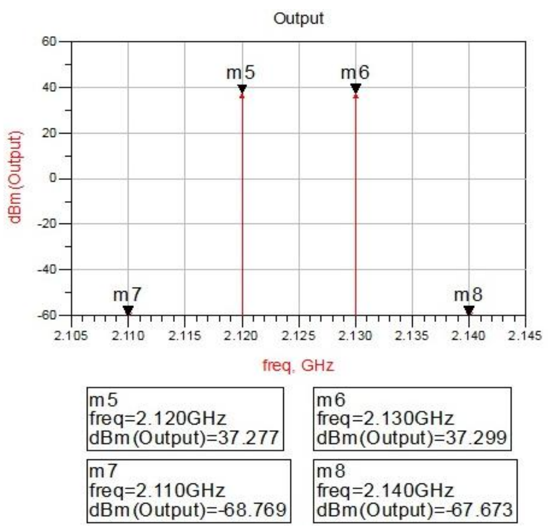

Fig. 3(b) Output Spectrum after linearization

Third-order Intercepts

upper_toi	lower_toi
89.785	90.300

Fig. 3(c) Third-order Intercept points

IV. CONCLUSION

Power amplifier linearity has been improved by using feedforward linearizer circuit. The circuit has been simulated to show greater reduction in third-order distortion components. The results presented show that for two tone harmonic balance input the intermodulation distortion has been reduced to -68 dBm. The maximum distance obtained between original carriers and the distortion component is 106 dBm. The values of upper and lower third-order intercept points are 89.785 and 90.300 respectively.

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