A FEED-FORWARD AMPLIFIER APPLICATION FOR 802.11A WLAN TRANSCEIVER ARCHITECTURE

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ABSTRACT

In this study, a feedforward amplifier is designed as the high-linear power amplifier block of the 802.11a WLAN transceiver layer [1]. Intermodulation distortion products investigated in detail at the output of the main amplifier and at the feedforward output with the application of The Two-tone Test.

I. INTRODUCTION

Due to their non-linear natures almost all the amplifiers possess the property of distorting the signals, which they are required to amplify. The existence of distortion and hence nonlinearity in the amplifiers is very displeasing phenomena because it restricts the output power capabilities of those circuits. For example, high fidelity amplifiers have been designed and refined over the years to reduce it to levels considered to be inaudible by the human ear.

When considering radio frequency amplifier, the fidelity of the transmitted signal is still of importance, but is no longer the only consideration. Some other important aspects such as spectral efficiency and the requirement of low interference products at their outputs are also needs to be considered.

It is well known for years that the linearity requirement reduces efficiency very much, increases the cost and causes low reliability. The linearization techniques like feedback, pre-correction and feed-forward cannot be easily applied to the high-power amplifiers as it can be to the low power systems. Numerous studies made on the subject have revealed that the effort consumed on these studies justified by economical benefits.

In this study, the feed-forward circuit structure that operates as a part of 802.11a WLAN transceiver, which operates on 5.725 – 5.775 GHz with 50 MHz band-with has been built and two-tone test signals is applied to the input of the system to investigate their linearity performance. The suppression levels of the intermodulation distortion products of the main amplifier and the suppression levels of the intermodulation distortion products at the output of feed-forward system are taken into consideration. The main and error amplifiers have chosen to supply the gain of 30 dB with the main output power of 30 dBm (1 Watt).

II. ARCHITECTURE AND OPERATING PRINCIPLES

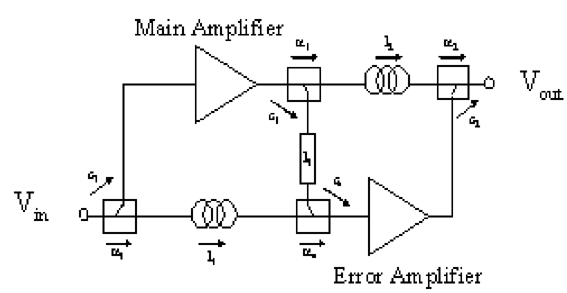

Fig.- 1. Feedforward Amplifier Architecture

Fig.-1 shows a simplified representation of a feed-forward amplifier. The input is first splitted into two paths by a power splitter (usually a directional coupler) with one path going to the non-linear main amplifier and the other going to a delay element. A portion of the distorted main amplifier output is separated from the main amplifier path using a second coupler as a power divider and after appropriate scaling subtracted from the delayed input signal. An error amplifier then amplifies the resulting error signal, ideally containing only distortion components, before being subtracted from a delayed version of the main amplifier output, thus cancelling the distortion components in the main path. [2]

FEED-FORWARD ANALYSIS

The system at Fig.- 1 consists of two amplifiers (main and error), couplers, attenuators and delay elements. There are two loops in the system; to obtain required amplification and linearity these two loops must be perfectly balanced [3]. Thus, the gain calculations of the feedforward system, main amplifier and error amplifier in decibels become:

$$G_{ff} = A_1 + A_2 + A_3 + A_4 + L_1 + L_2 - C_1 - C_4 - L_3 \quad (1)$$

$$G_m = G_{ff} - C_3 - A_1 - L_2 - A_2 \quad (2)$$

$$G_e = G_{ff} - A_3 - L_1 - A_4 - C_2 \quad (3)$$

Where G_{ff}, G_m and G_e are feedforward, main amplifier and error amplifier gains (dB) respectively; C_i represents coupling coefficients; A_i represents coupler losses; L_i represents delay elements losses and attenuator value.
$i = 1,2,3,4$.

IV. EXPERIMENTS AND RESULTS

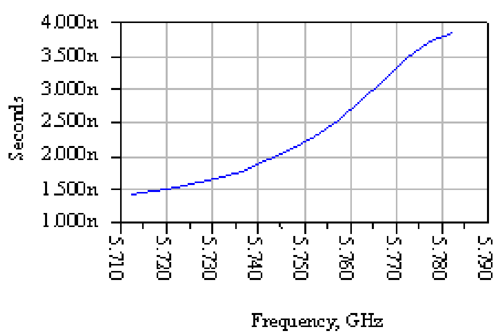

Figure 2. Delay Characteristic of Main and Error Amplifiers

To achieve the required signal cancellation level at the carrier cancellation loop (1st loop) the delay of the delay element must be equal to the total delay of the path, which includes main amplifier [4]. Also, the delay of the delay element at the distortion cancellation loop (2nd loop) must be equal to the delay of the path, which includes error amplifier. The delay characteristic of the amplifiers that are used in the design (HMC408LP3 GaAs InGaP HBT MMIC 1 Watt Power Amplifier, 5.1 - 5.9 GHz. Hittite Microwave Corporation – Same amplifier model is used for main and error amplifier blocks) has found to exhibit the delay characteristic as shown in Fig.- 2.

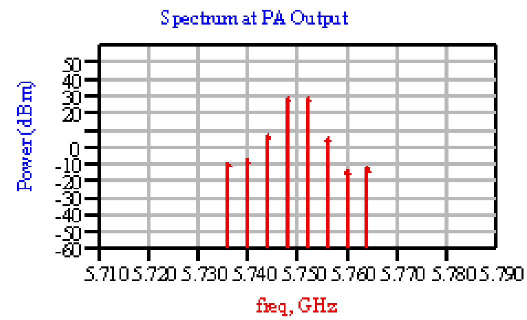

Figure 3. Signal Spectrum at The Main Amplifier Output

HMC408LP3 supplies minimum 17 dB, typically 20 dB of gain at the desired frequency range (5.7-5.9 GHz). The amplifier offers +30 dBm P1dB and provides, +32.5 dBm of saturated power, 27% PAE from a +5.0V supply voltage. Output Third Order Intercept (IP3) is typically 43 dBm and amplifier has typical noise figure of 6 dB.

As it is also shown in Fig.- 3, the values of the 3rd level harmonics intermodulation distortion products at the output of the main amplifier are at about 10 dBm and the levels of 5th and 7th order inter-modulation products levels are around –10 dBm.

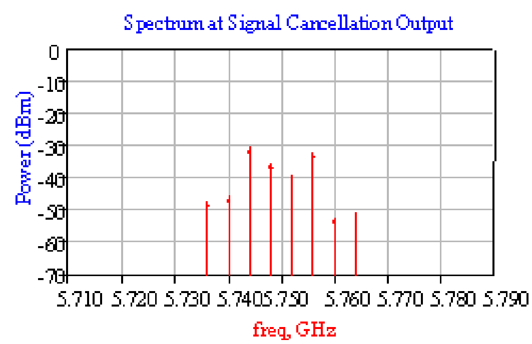

Fig.- 4. Signal Spectrum at The Input of The Error Amplifier

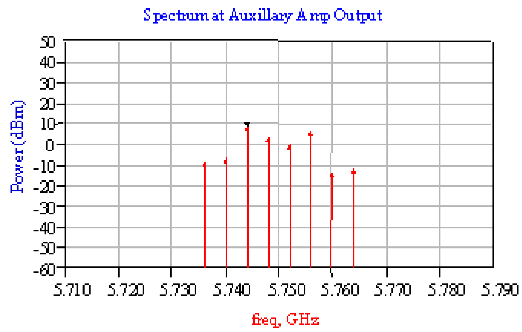

Fig.- 5. Signal Spectrum at The Output of The Error Amplifier

The two-tone test signals is suppressed at the carrier cancellation loop and intermodulation distortion products caused by the main amplifier is now dominant (Fig. 4). At the output of the error amplifier, the level of the two tone dragged down to 0 dBm so that the level of these tones will not effect the two-tone components of the amplified signal at the distortion cancellation loop output or feed-forward output (Fig.- 5).

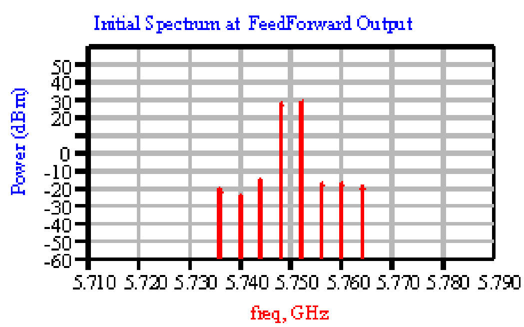

Fig.- 6. Signal Spectrum at Feedforward Output

The amplified signal including the intermodulation distortion products from main amplifier and the signal consist of suppressed signal and intermodulation distortion products from error amplifier cancelled from each other at the output of distortion cancellation loop (2nd loop). The resultant signal spectrum is shown at the Fig. 6, which clearly shows the effectiveness of the inter-modulation level cancellation. The 3rd order inter-modulation terms are suppressed more than 25 dB than those originally appeared at the output of the main amplifier.

V. CONCLUSION

Feed-forward amplifier design method introduced as the linearization technique, which is effective on the inter-modulation distortion products that cannot be removed by filtering. While the level of intermodulation distortion products were between 10 and –10 dBm at the output of the main power amplifier, these products suppressed to the level of –20 dBm at the output of the feedforward system. By considering the chosen application for the 802.11a WLAN system output transmitter amplifier, which requires an extreme linearity due to the modulation method, amplifier system seems to be exceedingly effective from the linearity point of view. As the conclusion, the required level of linearity that cannot be observed at the output of the power amplifier can be obtained by using feedforward linearization technique. Although the feed-forward technique brings more complexity to the design of a power amplifier its performance pays its cost by providing the required linearization, which cannot be provided by using any other linearization techniques.

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