Amplifiers for RF and microwave multichannel wireless systems.

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Abstract:

An amplifier for RF and microwave multichannel wireless systems where the third order IM distortion has been reduced is presented. The injection of the difference frequency of the two input signals in the amplifier together with the *n* fundamental signals will produce additional IM products at the output. By proper selection of phase and amplitude of the injected difference frequency signal, it is possible to make the third order IM products produced by the second harmonics and the original third order IM products out of phase and equal in amplitude. As a result third order IM products will be eliminated, in principle. The experimental results on a commercially available amplifier are presented.

Introduction

The IM products, especially the third order are regarded as the most troublesome in multichannel wireless communication systems and they cause some undesired effects. In many communication systems the ratio of carrier to the third order IM products of the transmitter output is a system figure of merit. The desirability of reducing the IM distortion has led to the devising of a number of techniques. Applying these techniques may prevent the designer from using the full capability of the active device or alternatively the required circuitry may be complex, expensive and large in size. Reducing the third order IM products at the output ideally should not affect the fundamental output power levels. Reducing the fundamental power levels means that the amplifier power efficiency has been reduced which is not a desired result. This paper presents the experimental results obtained at 880 MHz in which the level of the third order IM products is reduced without affecting the fundamental power levels.

Theory

The proposed technique uses the amplifier non-linear characteristic to generate a second order IM signal which is used to cancel the original IM product at the output. In this technique the low frequency signal is injected into the amplifier as well as fundamental signals. Non-linearity of the amplifier causes interaction between the source signals and their injected low frequency signal. This interaction results in additional signals at the output of the amplifier at the IM frequencies. On the other hand there are components of the IM product due to the interaction between the fundamental signals. By proper selection

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of phase and amplitude of the injected low frequency signal, it is possible to make the IM product produced by the low frequency signal and the original IM product out of phase and equal in amplitude. As a result the IM will be eliminated, in theory. In order to analyse the technique mathematically an approximate general expression for non-linear transfer function is used with its first three terms:

$$V_o = A_1 V_{in} + A_2 V^2{}_{in} + A_3 V^3{}_{in} \tag{1}$$

Where *Vin* is the input and *Vo* is the output of the non-linear device. This model can be applied to a non-linear amplifier by modifying the output as the drain current and the transconductance as the non-linear parameter of the amplifier which gives:

$$I_d = g_{m1} V_{in} + g_{m2} V^2{}_{in} + g_{m3} V^3{}_{in} \tag{2}$$

Where *Id* is the drain current and *Vin* is the input signals at the gate of the transistor. Without injecting the low frequency signal, the three input signals which are equal in amplitude and slightly different in frequency are:

$$Vin = A\cos \omega_1 t + A\cos \omega_2 t \tag{3}$$

In order to obtain simple equations the amplitudes of the fundamental signals are assumed to be unity. When (3) is substituded in (2) we obtain the output drain current *Id* as:

$$I_d = A\, g_{m1}[\cos(\omega 1t)+\cos(\omega 2t)]+A^2 g_{m2}[\cos(\omega 1t)+\cos(\omega 2t)]^2+ A^3 g_{m3}[\cos(\omega 1t)+\cos(\omega 2t)]^3 \tag{4}$$

Expanding the third term in (4) and using trigonometric identities we obtain :

$$A^3 g_{m3}\{3/2\cos(\omega 1t) + 3/4\,[\cos(2\omega 1+\omega 2)t + \cos(2\omega 1-\omega 2)t + \cos(2\omega 2+\omega 1)t + \cos(2\omega 2-\omega 1)t] + 3/2\cos(\omega 2t)\} \tag{5}$$

The terms in the form of $\cos(2\omega 1 \pm \omega 2)t$ and $\cos(2\omega 2 \pm \omega 1)t$ are the third order IM products which are located adjacent to the carriers. When we inject the low frequency signal together with the fundamental signals the input signal is:

$$Vin = A\cos(\omega 1t) + A\cos(\omega 2t) + A_1\cos((\omega_1-\omega_2)\,t+\Phi_1) \tag{6}$$

where $\Phi 1$ is the phase and A_1 is the normalised amplitude of the injected low frequency signal. Substituding (6) in (2) gives all the components at the output of the amplifier. For simplicity, only the third order IM products in the form of $(2\omega 1-\omega 2)t$ are shown as (7) :

$$3/4A^3 g_{m3}\cos(2\omega_2 t-\omega_1 t) + (3/4\,A\,A_1 A_1)\,g_{m3}\cos(2\omega_2 t-\omega_1 t-2\Phi_1) \tag{7}$$

By the proper selection of the phases and the amplitudes of the injected low frequency signal, the original third order IM products and the ones which has been produced by the low frequency signal harmonics can cancel each other and the result will be the elimination of the third order IM products.

Experimental Results

Functional block diagram of the experimental setup.is shown in Figure 1. In order to illustrate the new approach, the three main input fundamental signals at 0.875 GHz, 0.877GHz and 0.879 GHz and low frequency signal at 0.002 GHz injected and their input power levels of -10 dBm has been considered as example. Figure 2a shows the spectrum at the output of an amplifier without injecting the low frequency signal . The corresponding spectrum with the low frequency signal injected at the optimum amplitude and phase is shown in Figure 2b. As can be seen the IM product levels have been reduced by 10 dB and the fundamental levels are unchanged.The corresponding spectrum with the difference frequency signal injected at 1 MHz with the optimum amplitude and phase is shown in Figure 3. In this figure, the fundamental signals are at 880, 881, 882, 883, 884, and 885 MHz.

Conclusion

A high efficiency low distortion amplifier for RF and microwave multichannel wireless communication systems applications is presented. Experiment shows that the third order IM level at the output of a non-linear amplifier can be reduced by the injection of the low frequency signal in the amplifier together with the fundamental signals. The reduction in the third order IM products can be considered as a huge improvement in the amplifier distortion performance.

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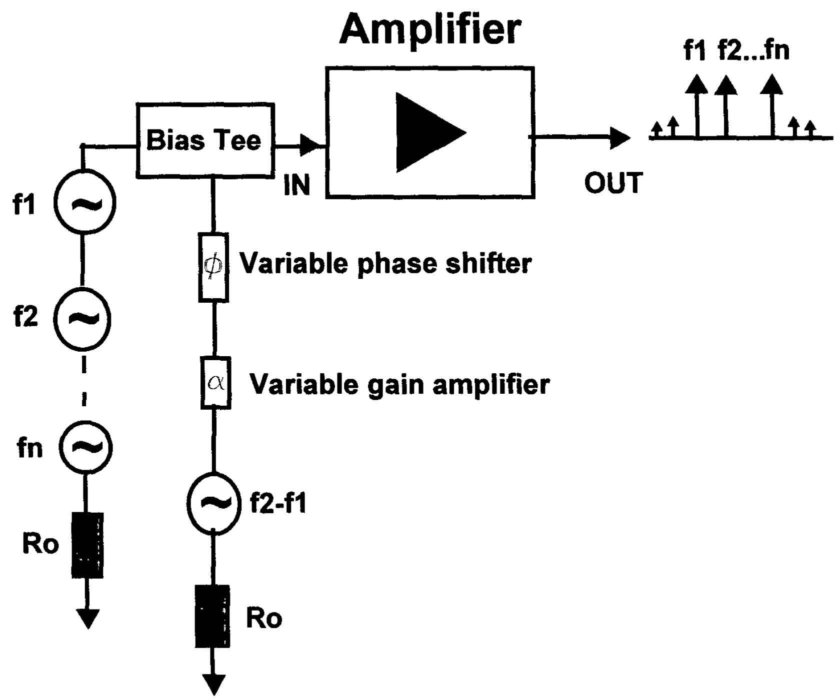
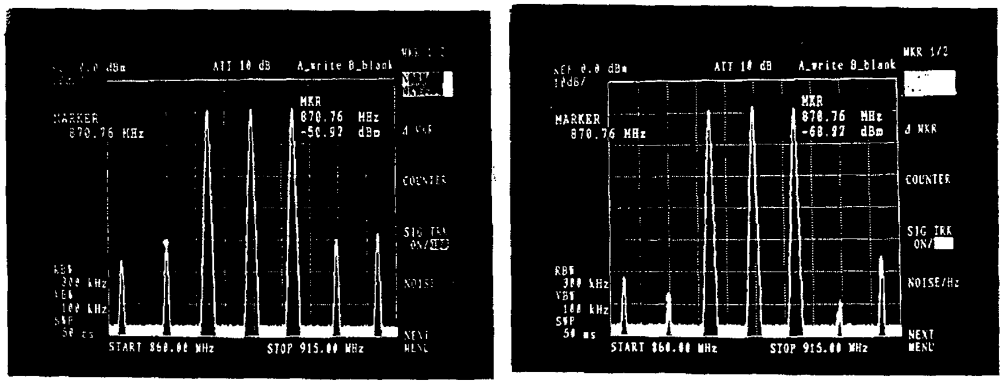


Figure 1. The Amplifier Schematic Circuit Diagram with a low-frequency injection at *f2-f1*.



(a) (b)

Figure 2. The measured fundamental powers (n=3) and the higher order IM powers for Pin=-10dBm. (a) without technique (b) with technique

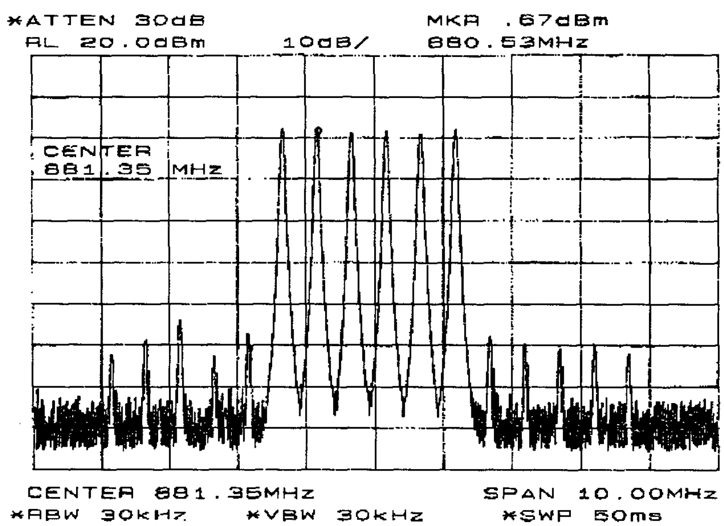


Figure 3. The measured fundamental powers (n=6) and the higher order IM powers after employing the technique.