Abstract — This paper presents a new approach to mixer linearization using the post-distortion technique. A practical prototype was designed implemented and characterized with a two-tone test. The validity of this approach was verified experimentally and the results state this technique as a simple and viable solution for mixer linearization ready for chip integration.

Index Terms — Nonlinear systems, microwave mixers, mixers.

I. INTRODUCTION

A wireless receiver generally uses a mixer to perform the translation from RF to the IF band. Since it is inherently nonlinear in order to achieve mixing, its distortion behaviour is a matter of concern. This point is especially acute when dealing with active mixers and multistage receivers [1]-[2]. In the design process, there are some techniques that can be used in order to achieve a favourable behaviour concerning linearity. Nevertheless, when operating near the compression point, spectral regrowth is always present.

In wide band communication systems scenario, every carrier, in the presence of system nonlinearity, behaves like a jammer to the adjacent channels. The global multi-carrier signal’s behaviour could only be predicted statistically and the peak power may be much higher than the average signal level.

Then, operating a mixer at lower input power values is not a solution due to the extended dynamic range of the signal. One way out is to decrease the noise’s device and, as a consequence, improve the SNR (Signal to noise ratio). But, higher ears could be achieved by expanding the operating area towards the compression zone.

A lot of research has been done until now and mixers became a well understood and performing device, fulfilling the demands of the underlying applications. However, the new advent of the wireless world is reformulating the telecommunications standards, and the way people conceive solutions is no longer the same. In this sense, the scientific community has been challenged in the way of improving electronic device’s behaviour where mixers are included, so that the final solutions have a higher performance and a competitive cost.

To overcome this constraint, linearization schemes are regularly used.

There are some standard topologies to perform the mixer’s linearization at the system level [3]-[6].

In [3]-[4] a feed-forward topology is presented. In practical circuits this configuration is not so promising due to the precision required in the amplitude and phase of the signals to be added. The critical points in this approach are the amplifier’s distortion which is not cancelled and passes directly to the output, and the low dynamic range caused by the sensitivity to the IMD’s amplitude changes.

Pre-distortion techniques [5] are the most spread linearizing methods in the industry because of their simplicity and fair results. Despite of that, this set-up has the disadvantage of suffering deviations from the tuning point induced by the aging process and changes in devices’ temperature. This is a critical point since this configuration works in open loop.

Finally a set-up using a feed-back topology is presented in [6]. This set-up has the best IMD cancellation performance reported, although at the high cost of circuit complexity.

Further, all these techniques are based on the use one auxiliary extra mixer or are implemented in the RF part of circuit, which imposes additional design complexity.

To overcome some of these constraints, this paper deals with a post-distortion technique, which has not been investigated until now in mixer linearization.

This technique is conceptually similar to the predistortion but has some advantages, especially in the down-conversion mixer configuration. The main point is that, being implemented at IF frequency, it becomes less demanding in terms of technology and less sensitive to the aging process. Another advantage is that the post-distorter circuit could be conceived as a stand alone subsystem leading to a systematic design.
II. THEORY AND CIRCUIT DESIGN

The idea beyond the post-distortion is to cascade two nonlinear blocks so that the IMD generated within the two sub-systems cancels mutually. In this approach the main block is followed by the canceling block.

\[ H_C^3(\omega_1, \omega_2, \omega_3) = H_A^3(\omega_1 + \omega_2 + \omega_3)H_B^4(\omega_1, \omega_2, \omega_3) + H_B^3(\omega_1, \omega_2, \omega_3)H_A^4(\omega_1)H_B^4(\omega_2)H_A^4(\omega_3) \]

\[ \frac{H_B^3(\omega_1, \omega_2, \omega_3)}{H_A^3(\omega_1 + \omega_2 + \omega_3)} = \frac{H_B^4(\omega_1, \omega_2, \omega_3)}{H_A^4(\omega_1)H_B^4(\omega_2)H_A^4(\omega_3)} \]

For a perfect linearization, \( H_C^3(\omega_1, \omega_2, \omega_3) \) should be zero. So:

\[ H_B^3(\omega_1, \omega_2, \omega_3) = H_A^3(\omega_1 + \omega_2 + \omega_3)H_B^4(\omega_1, \omega_2, \omega_3) \]

\[ H_B^3(\omega_1, \omega_2, \omega_3) = H_A^3(\omega_1 + \omega_2 + \omega_3)H_B^4(\omega_1, \omega_2, \omega_3) \]

This means that the second block has to generate nonlinear distortion with the same amplitude relation of that generated by block A, but in opposite phase.

One possible approach to the post-distorter is presented in the Fig 2.

\[ \text{Gain} \quad \text{Distortion} \]

This setup presents two branches. To accomplish the condition (4) it is needed to control two independent variables in order to achieve a proper cancellation. Those variables are the phase and the gain of the IMD. The upper branch allows the control of the gain and delay of the signal, while the lower branch is responsible for the generation and adjust of the phase of the distortion.

\[ \text{Fig 3- Full circuit showing the mixer and the post-distorter} \]
The implemented post-distorter configuration, along with the mixer it was supposed to linearize, is presented in Fig 3. The mixer implemented has a singly-balanced configuration based on a Schottky diode. As the post-distorter is required to add an IMD in opposite phase of that generated by the mixer, we used another Schottky diode as the auxiliary distortion source. Actually, Fig. 4 and 5 obtained by harmonic-balance simulations showed that by varying the bias point, this simple device can still present a wide range of IMD values, either in phase or in opposite phase to the fundamentals (below and above 200µA quiescent current, respectively). The parallel inductive reactance, the series variable attenuator and the diode quiescent current, determine the amplitude and phase of the auxiliary IMD. In conjunction with the linear upper branch of the post-distorter, they provide the flexibility necessary to build the appropriate ratio $H^B_3(/)/H^B_1(/)$ of (4).

Being in parallel with the nonlinear arm, the post-distorter upper branch also reduces the overall attenuation of the linearizer since it is a free path for the signal of mixer.

Two-tone harmonic-balance simulations of the mixer showed that its IMD was in opposite phase to its fundamental IF components. Therefore, the post-distorter quiescent current was less than 200µA, the point where auxiliary IMD presents the phase inversion.

III. EXPERIMENT AND RESULTS

For an input power of -10 dBm the resulting mixer IMD optimization, is presented on Fig. 7. There, a 12dB cancellation was obtained. Figure 8 presents a sweep of input power where that performance is achieved. The linearizing system was tested with a CDMA signal and an improvement of 5 dB in ACPR was verified. The accomplished results are presented in figure 9.

As seen from these figures, good linearization performance is achieved with both two-tone and real CDMA excitations.
IV. CONCLUSIONS

A new post-distorter linearizer configuration for mixers was proposed and experimentally validated. The experimental results are fair good and state this technique as an alternative to solve the mixer’s linearity issue. The main advantages of the post-distortion circuit presented are its very simple circuit design at low frequencies, which allows a viable and efficient integration.

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