Interference Cancellation: New Configuration Technique for Cancellation of Strong Interferences from Adjacent Frequency Bands.

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Abstract- **This paper presents a study on existing techniques on cancellation of strong interference in frequency bands adjacent to the radio receivers. It also proposed a new configuration for cancellation of this strong interference, merging techniques known with a new model developed. The idea is to build an end cancellation/attenuation interference of affordable sub-system, that is universal and adjustable to the technology of radio frequency used by the receiver (compensating the intermodulation distortion created in LNA).**

Index Terms— **Interference cancellation, interference problems, IMD, microwave limiters.**

I. INTRODUCCIÓN

The co-existence of various technologies in the radio frequency spectrum has always led to problems of interference between systems. The regulatory authorities (whether national or international) try to avoid those interferences with rules and restrictions to radio frequency systems that coexist in the same band frequency or adjacent bands. However, even following all these standards and specifications, the presence of interference in a particular system is unavoidable, usually leading to degradation (or loss) of its quality and functionality.

Associated to the problem of loss of service quality, developing new technologies with high power densities, lower costs, able to "jamming" communications, "blind" locations and destroy the LNAs of receivers, lead to a constant concern of shielding of communications systems by preventing the failure of service or their destruction[1].

There are many scenarios where such interference is highly prejudicial and penalty in the performance of major systems.. The most critical example is the military applications, where the role of communications is vital. The masking of an RF signal may have severe consequences and cause serious actions no less harmful. Other typical scenarios are RFID systems (particularly the systems that use passive TAGs) and RF systems that are installed near big broadband systems as TV or Radio. Despite come to different frequencies, the harmonics generated by broadband systems can cause severe damage in systems with high sensitivity.

For these reasons, the development of techniques and subsystems able to cancel (or at least mitigate strongly) the adverse effects they have on of radio receivers. These techniques become even more important when the interferences have high power densities such in military scenarios or near transmitters of broadband systems.

Another scenario where the study of the cancellation of interference is extremely important is the Software Defined Radio (SDR) [2]. The main objective of the SDR is the construction of a radio frequency terminal capable of receiving and decoding all radio signals that are in the spectrum captured by it. Although the selection and decoding is done by software, coexistence of several signals with different levels of power, raises serious problems in the ADC, where high intermodulation distortion products emerge, preventing the correct conversion of the signal from analog to digital.

This paper begins with a brief theoretical study on the effects of intermodulation products in presence of strong radio frequency interference. It will be used an example with 2 tons of entry. In Section III are presented and discussed (briefly) the techniques currently used and the new configuration propose. In Section IV some CAD/CAE simulation results are given. Finally some conclusions and future work will be drawn.

II. NONLINEAR DISTORTION PROBLEMS FOR HUGE INTERFERENCES

In the receptor the Low Noise Amplifier component is always nonlinear, since for a certain input the output signal is no longer proportional, neither follows the super-position principle [3][4].

The easiest way to understand this nonlinear mechanism is by approximating the nonlinear response of the RF system, by a Taylor or Volterra series expansion if the system presents memory [3], represented by expression (1).

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$$\delta_{NL}[y(x)] = K_0 + \underbrace{\frac{1}{1!}\frac{d\delta_{NL}[y(x)]}{dx}\bigg|_{x(t)=x_0}}_{c_1}(x-x_0) + \underbrace{\frac{1}{2!}\frac{d\delta_{NL}^{2}[y(x)]}{d^2x}\bigg|_{x(t)=x_0}}_{c_2}(x-x_0)^2 + \underbrace{\frac{1}{3!}\frac{d\delta_{NL}^{3}[y(x)]}{d^3x}\bigg|_{x(t)=x_0}}_{c_3}(x-x_0)^3 + \ldots$$

For better comprehension let assume that *x(t)* is a two tone signal, where at ω_1 is the interference and ω_2 the desire signal.

$$x(t) = A_1 \cos(\omega_1 t) + A_2 \cos(\omega_2 t) \qquad (2)$$

Then *y(t)* will be:

$$y(t) = y_0 + y_1(t) + y_2(t) + y_3(t) + \ldots$$
$$y_1(t) = c_1 x(t) = c_1.[A_1 \cos(\omega_1 t) + A_2 \cos(\omega_2 t)]$$
$$y_2(t) = c_2 x^2(t) = c_2.[A_1 \cos(\omega_1 t) + A_2 \cos(\omega_2 t)]^2 \qquad (3)$$
$$y_3(t) = c_3 x^3(t) = c_3.[A_1 \cos(\omega_1 t) + A_2 \cos(\omega_2 t)]^3$$
...

If we look carefully to the third order component, we see that it will have a mixing product that falls exactly in the same frequency of the desire signal.

$$y_3(t) = c_3 x^3(t) = c_3.[A_1 \cos(\omega_1 t) + A_2 \cos(\omega_2 t)]^3 =$$
$$= \ldots \frac{3}{4} c_3 A_1^2 A_2 \cos(\omega_1 t - \omega_1 t + \omega_2 t) + \frac{3}{8} c_3 A_2^3 \cos(\omega_2 t - \omega_2 t + \omega_2 t) + \ldots$$

Because we are assuming a very strong interference, A_1 is much higher than A_2. As such, even if the LNA has of very small intermodulation products (very low c3), the first tranche will continue to strongly affect the signal reception (fig. 1)..

So, if we to use the previously cited example (a interference signal with a power about 40dBm when the signal desired have -50dBm), easily concludes that the intermodulation product will completely corrupt the desired signal.

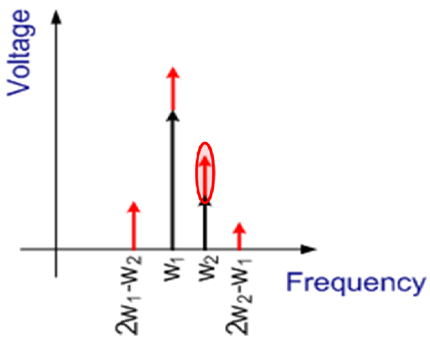

Fig.1. Spectrum components from a non-linear third order system with two tones entry signal. In black are the fundamentals and in red the intermodulation products. In the red circle is shown the major interference in the desire signal

III - Implementation of Interference Cancellation System

As related in the previous chapter, the main goal will be the development of a new configuration that, associated to the LNA can result in the cancellation of the intermodulation products (fig.2). Although this problematic is very present and with sufficiently extensive use, there isn´t many scientific studies, what it becomes it a more tempting and challenging work. From the cancellation configurations known, we can distinguish the configurations from Nightingale [5] or Raghavan [6].

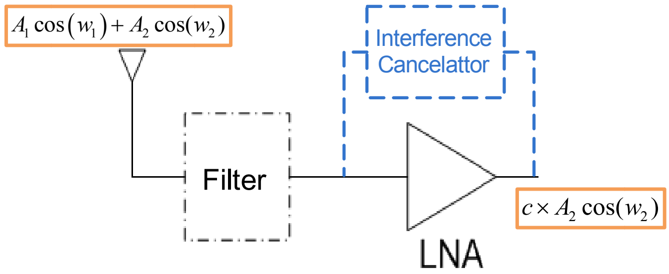

Fig. 2. Main goal diagram.

They use a small reference signal from the interferer signal to cancel its effect on the desired signals. However these techniques have a failure: they imply the knowledge and previous access to the interference signal. The configuration that we will be presented will assume that the interferer signal is unknown.

One of the techniques used in this work is a frequency limiter[7]. The frequency limiter limits the power of the entrance signals in frequency (the limit differs in frequency). This different treatment in frequency allows a much lower offensive limiting technique and a reduction in amplitude of the intermodulation products in this output when compare with conventional limiters.

Besides the use of a frequency limiter, configurations of frequency cancellation image (as Hartley or Weaver) are also used as starting point for the drawing of the new configuration present in figure 3.

The operational principle is as follows:

1. The frequency limiter has the function of limiting the interference signal of entrance (in w1). The limit threshold must be defined in form that the intermodulation products are reduced and with the guarantees that the LNA does not enter in saturation mode. It is also important not reduce too much into this threshold in order to prevent the significant intermodulation products introduce by the frequency limit itself.
2. When the signal arrives Direct Coupler a small reference signal will be push to feedback way.
3. The Power Divider is used to create a second reference signal for future interference cancellation.
4. This Shift Phase is use to delay the reference phase signal by 180º, that will be use in cancellation of the two original tones.
5. A Stopband filter is used to cut de desire signal (maintaining the interference signals). This is important, because is this feedback we will be able to cancel also the interferer. If the desire signal don’t be cut at this moment it will appear at the final stage and degrade the desire signal.
6. In this point is taken a replica from the LNA output signal and reduce (with the attenuator) to the level of the two tones from 2.

7. The combination of the two signals of 4 and 6, will result in a replica of the intermodulation products originated in the LNA.
8. From the sum of the two components results a signal that have a replica from the interference signal and the intermodulation products. A Power Amplifier is use to raise this reference signal to the output power from the LNA and from the sum of this two signals result the cancellation of interference.

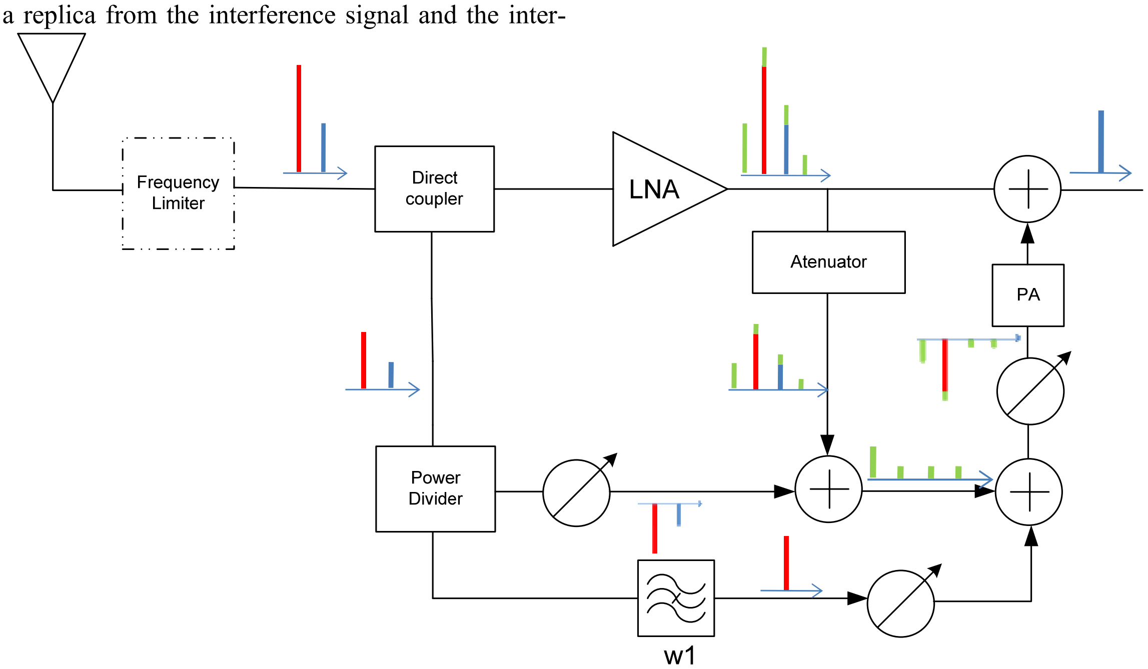

Fig. 3 - Interference cancelation schematic propose

The sub-system proposes has the advantage of being fully included in all types of operating systems and for any type of interference (unless the interference in-band).

IV - CAD/CAE SIMULATION OF THE SYSTEM

In order to understand the behavior of the proposed system, it was simulated in a CAD/CAE Simulator from ADS [8].
In the first simulations with all circuit calibrated we consider placing at the entrance two tones with 40dBm (the interference signal) and -50dBm (the desired signal) at 990Mhz and 1GHz respectively (fig.4). A Monte Carlo (with 250 iterations) technique was used in simulation (Harmonic Balance), with a variation of the 2% in all electronic components. It's also consider that the Frequency Limiter has very good behavior. The results are presented in figure 5.

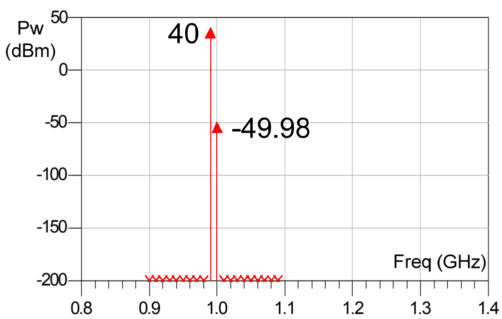

Fig. 4 – Input signal: The interference signal with a RF power of 40 dBm and the desire signal with -50 dBm.

As we can observe in fig. 5, in the worse scenario the interference signal will be at the same the level of the desired signal, that is, represents a reduction greater than 80dB. These results take-in believing that the presented topology can authorize good results in real scenarios.

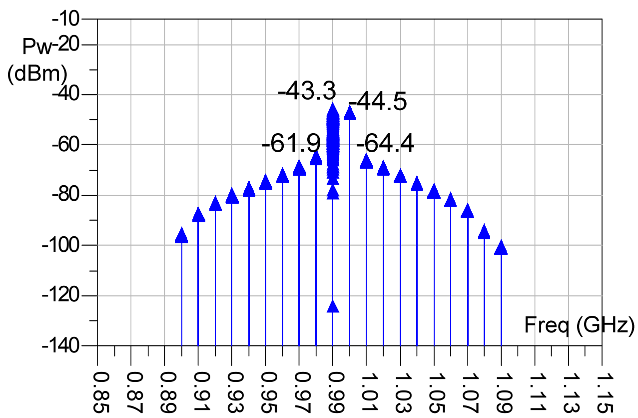

Fig. 5 – Output signal in first simulation: The interference level is at the same then the desire signal in the worst case.

In the second case we assume a lower interferer but with a more realistic frequency limiter (attenuation of 30 dB). Thus the input signal would now consist of two tones with 20dBm (the interference signal) and -50dBm (the desired signal) at the same frequency. A normal Harmonic Balance was made at this point and the achieve results are present in figure 6.

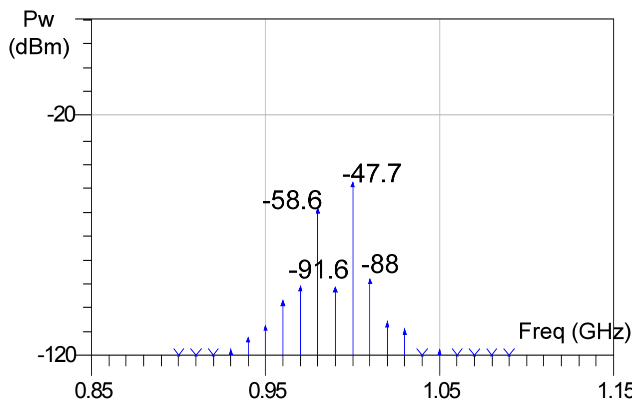

Fig. 6 – Output signal in second simulation.

As we can see the two figures the results show a significant reduction in the intermodulation products and in the interference signal. The main difficulties and disadvantages of this sub-system lie in the large number of components used and the high sensitivity of the system in the face of variation in the phase shifts. The way to ensure satisfactory results requires the use of components with lower tolerances and a rigorous calibration of the system canceller.

V – INTERFERENCE CANCELLATION SYSTEM(2): INTRODUTION

In continuation of the study and development of the proposed system and to ensure better results using fewer elements, it was developed a new topology presented in next picture.

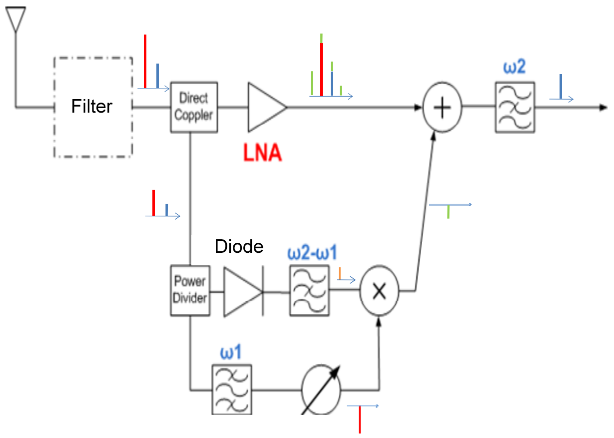

Fig. 7 - Second interference cancelation schematic propose

In this system, the goal is the cancelation of the intermodulation product in band with the desire signal only. The operational principle is as follows:

1. As shown in the first system, after the filtering the received signal, a replica is taken in the Directinal Coppler.
2. In this system, the diode will work as a generator of nonlinearities. With a replica from the two entry tones, the diode will generate replicas from of the intermodulation products created by LNA.
3. A Stopband filter is used to cut de desire signal (maintaining the interference signals), and a Shift Phase is use to delay the interference phase signal by 180º.
4. The modulation of the non-linear product of 2nd order (w2-w1) with the interference sign will create a replica from the intermodulation product (LNA) that falls in the frequency of the desired signal (w2).
5. The result signal is combining with the output LNA signal. Using another Bandstop filter, it´s possible to achieve only the desire signal. The use of the Bandstp filter after the LNA it´s not as detrimental to the system since the LNA significantly reduces the contribution of the filter for Noise Figure.

This second system is still under study at the moment. For that reason it's not possible to present any simulated or experimental results yet. Hopes that its performance can best results so far.

VI - CONCLUSIONS AND FUTURE WORK

This paper showed a possible two new configuration for interference cancelation. This first configuration obtains reasonable results in the two simulation tests (more than 80dB reduction in the interference signal), that opening good expectations for the experimental tests that will be made in the near future.

This system could be applied in locations with a huge density of interferences or in systems with very high sensitive that could be corrupted in the presence of a strong interference. The disadvantage is the number of components needed that could be a major obstacle to implementing this topology in some RF systems.

At this moment the first topology is tested with real signals (ex: WLAN) and will start the simulated tests with the second proposed system.

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