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Modified Linearization Technique For Intermodulation Cancellation Within Wireless Receiver

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ABSTRACT

This paper proposes a modified model of RF receiver which enhance its linearity characteristics by using a mirror amplifier (MA). This MA has the same properties of the RF receiver such as third-order intercept point (IIP3), noise figure (NF) and gain (G). By using this model, we study the effect of receiver's nonlinearity on the performance of telecommunication systems and we could achieve about 30 dB cancellation of third-order intermodulation products. We but the scenario of interference caused by intermodulation products generated by unwanted interference signals inside the RF receivers. Specifically, third-order intermodulation distortion (IMD3) that could be at frequencies within working band for the desire system. Using ADS software and nonlinear amplifier model which equivalent to the RF receiver, we achieve a practical calculations for the cancellation of third-order products.

Key words : RF receiver, nonlinearity, intermodulation, ADS, cancellation, linearization.

1. INTRODUCTION

At the end of 2014, half of the world's population had at least one mobile subscription, totaling over 3.6 billion unique mobile subscribers. By 2020, around three-fifths of the global population will have a mobile subscription, with close to one billion new subscribers added over the period [1]. This increment in the number of mobile subscribers around the world is lead to achieve more operators and base stations and frequencies reuse. Which lead to a diverse range of challenges in frequency planning and new interference issues in both mobile and base stations at the same time.

As a result of what mentioned above, intermodulation distortions are arise as a major cause for interferences in wireless communication systems nowadays due to nonlinearity of these systems. As an example two CDMA-PAMR carriers operating in the adjacent frequency range between 917-921 MHz could be received by GSM receiver and block an operating GSM carrier by mixing inside the nonlinear receiver [2].
In [3], they used an adaptive cancellation technique as a solution for interference caused by intermodulation products which generated due to nonlinearity of wireless receivers at base stations. By using this technique, they achieve a cancellation of 46 dB for jamming signals and this drives intermodulation products below the noise floor without any effect on wanted signal. Although the interference cancellation levels are accepted, it couldn't be used to cancel intermodulation interference in mobile station because it requires to use a reference antenna to drive an adaptive cancellation loop that cancels the interfering signals. This reference antenna should receive just the jamming signals which are unachievable in mobile station.

In [4] and [5], they suggest to use duplexing filters and couplers to cancel the interference which caused by collocate of other system as GPS and Bluetooth with receiver inside mobile station. These techniques are useless in the case of intermodulation product interference in receiver, as long as it caused by jamming signals received from transmitters belong to another unit.

In this paper, we will describe intermodulation interference issue for nonlinear receiver, its causes and effects. We will describe a linearization model for nonlinear receiver at mobile station by modifying linearization techniques used for nonlinear LNA, our model will be used to cancel intermodulation products interference generated by jamming signals so it could be consider as a solution for intermodulation product generated within receiver but on the other side, frequency allocation and planning techniques should be modified in order to mitigate this issue. In this paper, we will describe the cancelation theory for our model and ADS software (Advanced Design System) will be used for simulation and show the cancelations levels achieved by using this model.

2. INTERMODULATION INTERFERENCE ISSUES IN WIRELESS RECEIVERS

The coexistence of different wireless communication systems which operate at various bandwidths in the same geographical area could cause intermodulation interference issues inside wireless receiver due to nonlinearity of its components.

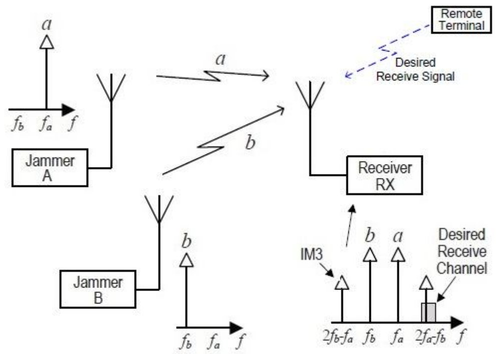

Figure 1: Intermodulation interference scenario.

Intermodulation interference may be generated in the receiver as a result of the receiver being driven into nonlinearity by broadcasting signals outside the aeronautical band. This interference is occurring, when at least two broadcasting signals are received and they have a frequency relationship which, in a nonlinear process, can produce an intermodulation product within the wanted RF channel in use by the aeronautical receiver. One of the broadcasting signals must be of sufficient amplitude to drive the receiver into regions of nonlinearity but interference may then be produced even though the other signal(s) may be of significantly lower amplitude [6]. Because of third order intermodulation products, GSM signals could cause IM interference that can damage the performance of UMTS receivers [7].

Our studied scenario of intermodulation interference in nonlinear wireless receiver is shown in Figure 1, where there are two base stations transmit high power signals a(t), b(t) at frequencies F_a, F_b respectilly. These signals combine at the low noise amplifier (LNA) and mixer of the receiver Rx, and form IM distortions that has frequencies may fall in its receive channel and cause interference [8].

3. THEORY OF IM DISTORTIONS CANCELLATION WITHIN NONLINEAR RECEIVER

Our model to cancel IM distortions is based on power amplifier's linearization techniques with some modification because of the main difference between receiver and PA. Where in the PA the input and output will be at same frequency, but in the receiver the input and output of nonlinear part (from antenna to input of demodulator as shown in Figure 2) will be at different frequencies due to mixing stages. Different linearization techniques are used to operate the PA at higher power in output for higher efficiency without sacrificing Linearity and they could be used to improve linearity of PA with different efficiency, cost, reliability and complexity. These techniques are classified into three main categories: feedback, feedforward and predistortion [9] [10].

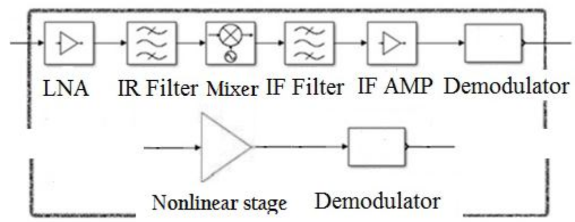

Figure 2: Wireless receiver's nonlinear stage.

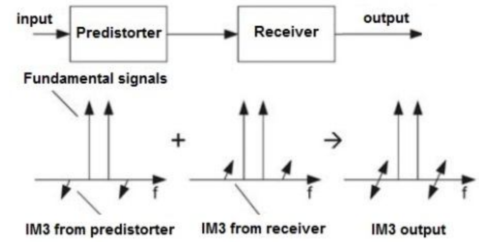

Figure 3: IM cancellation using a predistorter technique.

To cancel the IM distortions within receiver, we merge both the predistortion and the feedforward techniques by compromising between the advantages and disadvantages of both techniques. In our model, we use a low power amplifier "mirror PA" which has the same nonlinear characteristics as the receiver's nonlinear characteristics. Therefore, it generates the same distortion characteristics then the nonlinearities generated by the mirror PA are properly fed to the input of the receiver, so that they appear at the output in the same magnitude but out of phase with the generated receiver nonlinearities, resulting in IM cancellation as shown in Figure 3.

Our IM3 cancellation block diagram is shown in Figure 4, where the intermodulation products generated within receiver are canceled at its output by feeding the intermodulation products generated by the mirror amplifier to the input of the receiver. To achieve the cancellation, paths ABCDEHK and AIJK must be at equal magnitudes, but with 180^o difference in the phases. Moreover it is required to cancel the carrier coming out from the mirror PA. This is done by adding path CD to path FG with the same magnitude and 180^o out of phase.

Both the magnitude and the phase for paths ABCDEHK and FG are controlled by Vector Modulator 1,2,whereas Delay 1,2 are used to equalize the time delay of the two paths.

By feeding the third intermodulation products at the input of the receiver in the proper magnitude and phase, they will be amplified and appear at the output with the same magnitude but with difference in phase equal to 180^o with the already generated intermodulation products resulting in cancelling it.

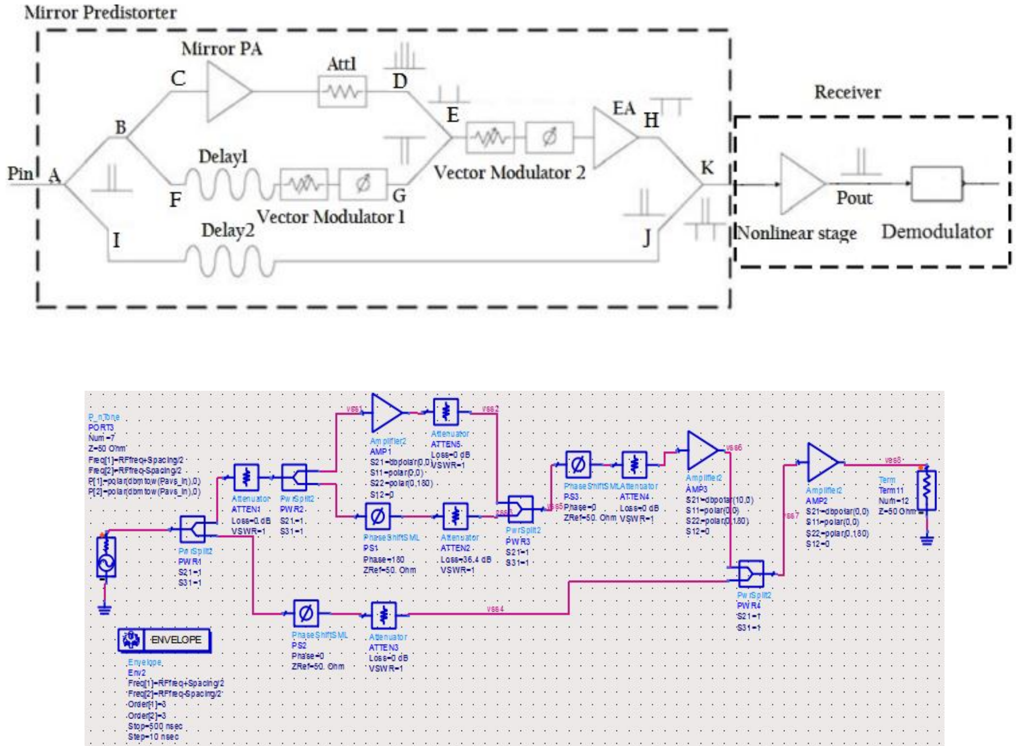

Figure 5: Our IM3 cancellation model by ADS.

4. SIMULINK AND RESULTS

We use ADS 2014.01 software with our model to calculate the IM3 cancellation. The RF receiver is equivalent a nonlinear amplifier “AMP2” with IIP=-18 dBm and the mirror AP is “AMP1” which has the same characteristics as “AMP2” which represents the RF receiver. The fundamental signals are at frequencies 849.5, 850.5 MHz. To turn off cancellation system, attenuator “ATTEN4” value should be changed to 100 dB. The Simulink model is shown in Figure 5.

4.1 Without cancellation system

By increasing attenuation of “ATTEN4”, the effect of mirror amplifier will be canceled and the Simulink results show nonlinearity of RF receiver. Without cancellation system, the IM3 components are at frequencies 848.5, 851.5 MHz and their power is about -39 dBm, as shown in Figure 6b.Whereas the input signals are shown in Figure 6a.

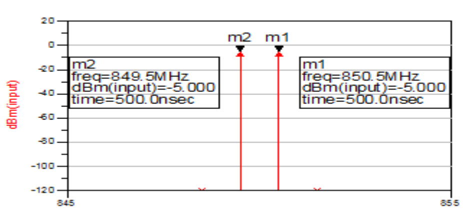

Figure 6a: Signals at input.

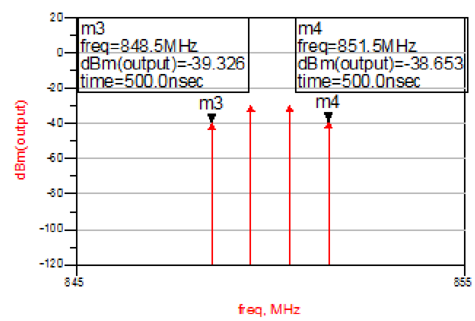

Figure 6b: Signals at output.

Figure 6: Without cancellation system.

4.2 With cancellation system

To turn on cancellation system, “ATTEN4” value should be changed to 0 dB. The result is shown in Figure 7, where we could notice that the gain of error amplifier (EA) will determine level of IM3 cancellation so it should be chosen carefully. For error amplifier with gain 18 dB, as shown in Figure 7c, we achieve 10 dB cancellation of left IM3 product and 22 dB for the right one. Although this levels of cancellation are accepted, we could achieve higher level of cancellation for the left IM3 product equal to 36 dB by change error amplifier’s gain into 19 dB, as shown in Figure 7d. Figure 7a and Figure 7b show the input signals and the output of the mirror amplifier respectively.

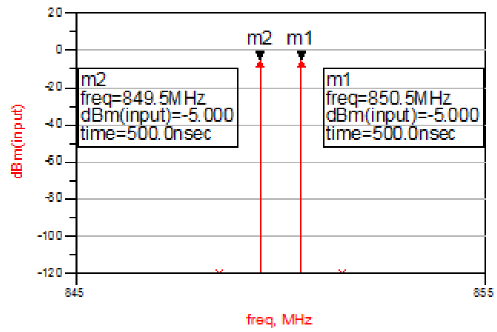

Figure 7a: Signals at input.

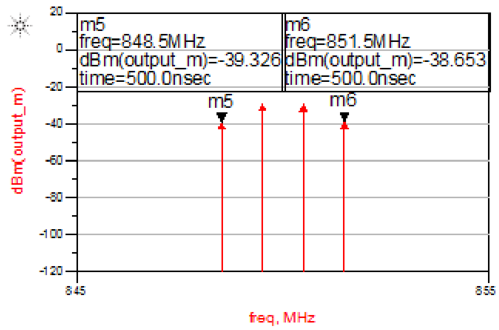

Figure 7b: Signals at output of mirror AP..

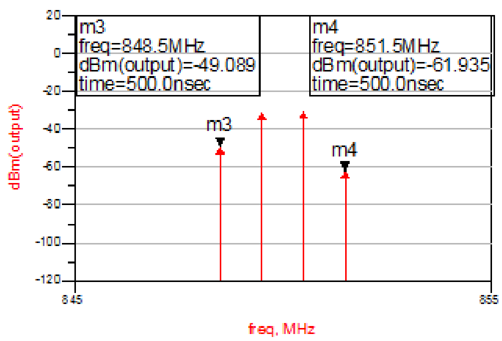

Figure 7c: Signals at output for 18 dB EA's gain.

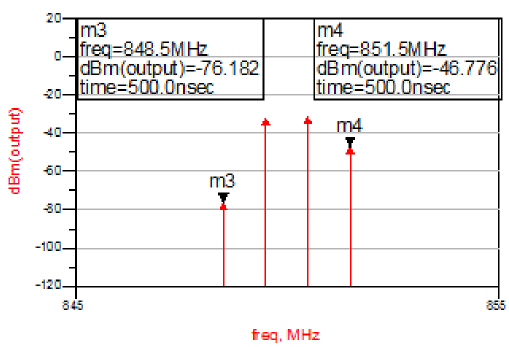

Figure 7d: Signals at output for 19 dB EA's gain.

Figure 7: With cancellation system.

5. CONCLUSION

As a result of growth in the need of wireless systems applications and its services, more systems should be achieved in the same geographical area which leads to the appearance of intermodulation products issue as a result of nonlinearity of wireless receivers. Intermodulation products are considered as one of the biggest problem which face wireless telecommunication engineers nowadays. This issue can be solved by two steps: the first one is by modify mobile networks planning technique and frequency allocation algorithms to avoid generating these unwanted interference signals beside of receiver nonlinearity, and the second level is to modify RF receiver diagram to improve linearity characteristics of it. In this paper, we give a proposal to cancel the intermodulation products generated within the RF receiver and improve its properties by using nonlinear amplifier's linearization techniques to minimize the impact of the existence of many wireless systems at same area due to nonlinearity of the receiver.

REFERENCES

1. GSMA Intelligence. ***The mobile economy 2005***, London, UK, 2015,ch. 1, pp. 6-9.
2. Electronic Communications Committee (ECC). ***Adjacent band compatibility between GSM and CDMA-PAMR at 915 MHz***, Granada, February 2004, pp. 20-21.
3. S. Ahmed and M. Faulkner. **An adaptive cancellation system for a colocated receiver and its dynamic range**, in *Proc. IEEE Radio and Wireless Symposium*, January 2011, pp. 271-274.
4. S. Kannangara and M. Faulkner. **Adaptive duplexer for multiband transreceiver**, in *Proc. Radio and Wireless Conference, 2003. RAWCON '03. Proceedings* , August 2003. pp. 381-384.
5. R. J. McConnell and R. Tso. **Method and apparatus for reducing GPS receiver jamming during transmission in a wireless receiver**, in *United States Patent*, Novemper 2005.
6. ITU-R. ***Compatibility between the sound broadcasting service in the band of about 87-108 MHz and the aeronautical services in the band 108-137 MHz***. Geneva, 2010, pp. 3-4.
7. G. Paschos, S. A. Kotsopoulos, D. A. Zogas, , and G. K. Karagiannidis. **The impact of intermodulation interference in superimposed 2G and 3G wireless networks and optimization issues of the provided QoS**, in *International conference on computer, communication and control technologies CCCT'03*, January 2003, pp. 276-282.
8. Y. Abd Alrahman and I. Iliev. **Effect of RF receiver nonlinearity on mobile telecommunication systems**, in *51st International Scientific Conference on Information, Communication and Energy Systems and Technologies ICEST*, June 2016.

9. M. K. Nezami. **Fundamentals of power amplifier linearization using digital pre-distortion**, in *High Frequency Electronics*, Vol.3 No.8, pp.54-60, September 2004.
10. R. Kaur and M.S. Patterh. **Overview of the linearization techniques to mitigate the nonlinear effects of power amplifier**, in *An International Journal of Engineering Sciences*, Vol. 17, pp. 479-485, January 2016.