

Evaluation of Nonlinear Distortion of RF Amplifiers for Full Duplex Networks

Moses Kasule
Wireless Communications Research
Group, School of Computer Science
and Engineering, University of
Westminster
London, UK

Moses Kasule
Qualcomm Technology Inc., Tempe,
USA.

Djuradj Budimir
Wireless Communications Research
Group
School of Computer Science and Eng.,
University of Westminster
London, UK
d.budimir@wmin.ac.uk

Djuradj Budimir
School of Electrical Engineering
University of Belgrade
Belgrade, Serbia
d.budimir@etf.rs

Abstract—This paper presents an evaluation of the nonlinear distortion of power amplifiers for full duplex transmitter applications. Simulation-based spectra of a 3 MHz QPSK and 16QAM waveforms at the input and output of the amplifier (Mini-Circuits ZX60-4016E-S+) at 3.5 GHz with an input power of -10 dBm and 0 dBm, respectively, are investigated. Experimental spectra of 5 MHz QPSK waveforms at the same amplifier output frequency of 3.5 GHz, with input powers of 0 dBm and 10 dBm, respectively, are also presented. The presented evaluation of power amplifiers' nonlinearities is important for the impact of power amplifiers on self-interference in full-duplex transmitter applications.

Keywords— Full Duplex, RF Amplifiers, Power Spectrum Density (PSD), Self-Interference (SI).

I. INTRODUCTION

Advancements in wireless communications, such as a full duplex system which is driven by its significant potential benefits for future wireless generations, including 5G and 6G. If successfully implemented, full duplex could double the effective capacity of a given slice of radio spectrum and significantly reduce communication latency because data wouldn't need to wait for alternating transmit/receive slots [1]. However, these systems come with drawbacks, such as strong self-interference and high peak-to-average power ratios (PAPR) [2]. Deployment of such systems poses several design challenges for RF transmitters, including power consumption, efficiency, and nonlinear distortion. These challenges primarily manifest in power amplifiers, degrading the overall performance of the transmitter. At low input powers, power amplifiers are mostly linear at the expense of efficiency [3]. During the deployment of multiband wideband waveforms, power amplifiers will exhibit memory effects at high input power, resulting in degradation of spectral regrowth and error vector magnitude. Spectral regrowth will produce interference in the adjacent channel and violate regulatory requirements.

This paper, evaluates the nonlinearities of the power amplifiers for full-duplex transmitters. Evaluation is performed using a 3 MHz QPSK and 16 QAM waveform at 3.5 GHz with input power of -10 dBm and 0 dBm, respectively. The paper is organised as follows. Section II presents the simulation setup, which serves as the basis for this paper. In Section III, simulation and experimental results for performance analysis of amplifiers and transmitters are presented. The conclusion is described in Section IV

II. SIMULATION SETUP

A. Simulation Setup

As shown in Fig. 1, we set up the PA (Mini-Circuits ZX60-4016E-S+) with the following features:

- Wide bandwidth, 20 MHz to 4 GHz
- Gain = 15.68 dB at 3.5 GHz
- Low noise figure, 3.9 dB typ.
- Input Power (no Damage) 13 dBm
- P1dB = 15.45 dBm
- Output power up to 17.4 dBm typ.
- DC Voltage 12.5 V

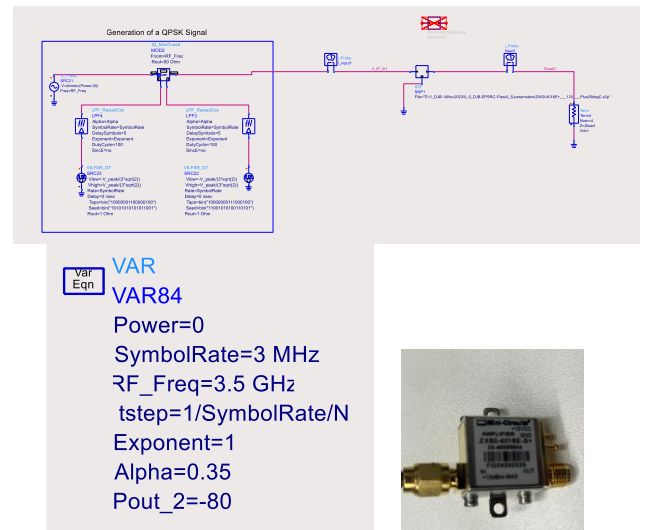


Fig. 1. Keysight ADS experimental setup

The test bench in ADS used a PA (ZX60-4016E-S+) from Mini-Circuits and swept the input power from min to max, using a CW tone to generate the power amplifier AM/AM and AM/PM curves, which were then imported into the Simulink block test bench. Complex baseband QPSK and 16QAM waveforms are generated and sent through the transmitter model, where they are converted to the analogue domain, modulated, and upconverted to RF.

III. SIMULATION AND EXPERIMENTAL RESULTS

In this paper, a performance analysis of power amplifiers for full-duplex applications is presented, along with several experimental and simulation results. The Power Spectral Density (PSD) of a 3 MHz QPSK and 16QAM waveforms, at the input (a) and output (b) of the amplifier Mini-Circuits (ZX60-4016E-S+) at 3.5 GHz with input power of -10 dBm and 0 dBm, respectively, are plotted and shown in Fig. 2, Fig. 3, Fig. 4 and Fig. 5, respectively.

The experimental evaluation of 5 MHz QPSK waveforms at the amplifier output (ZX60-4016E-S+) at 3.5 GHz with an input power of 0 dBm (a) and 10 dBm (b) is shown in Fig. 6. As can be noted, the nonlinear distortion for the input power of 10 dBm is significant and needs some linearisation, such as DPD.

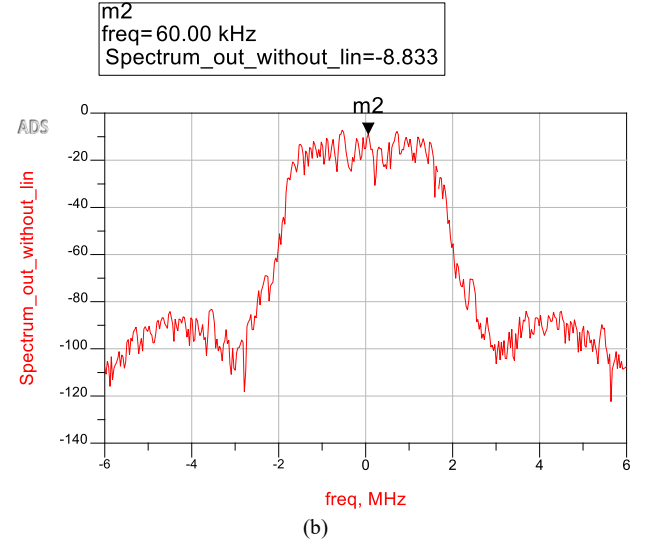
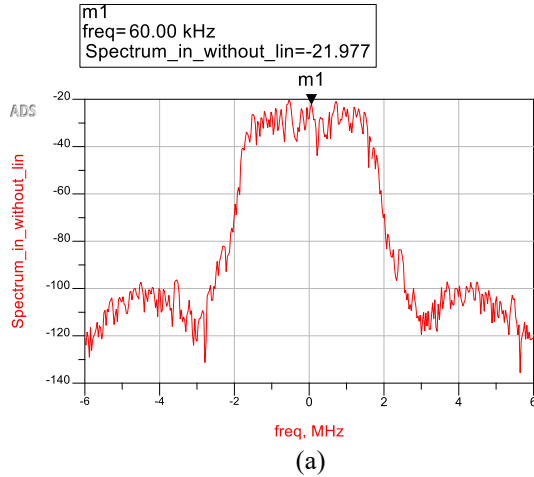


Fig. 2. Spectra of a 3 MHz QPSK signal at the input (a) and output (b) of the amplifier (ZX60-4016E-S+) at 3.5 GHz with an input power of -10 dBm.

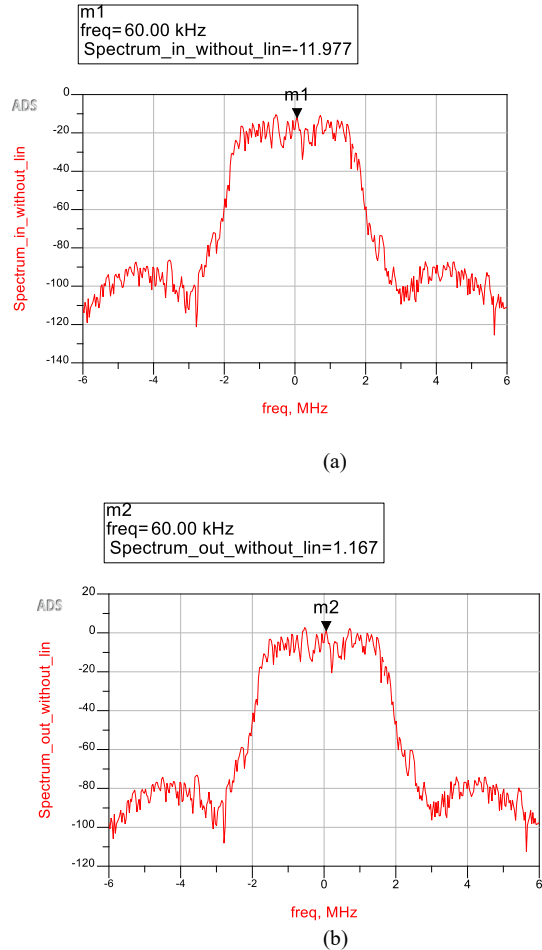


Fig. 3. Spectra of a 3 MHz QPSK signal at the input (a) and output (b) of the amplifier (ZX60-4016E-S+) at 3.5 GHz with input power of 0 dBm.

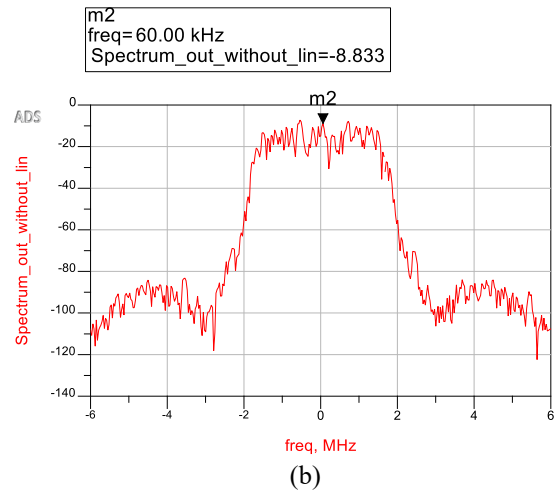
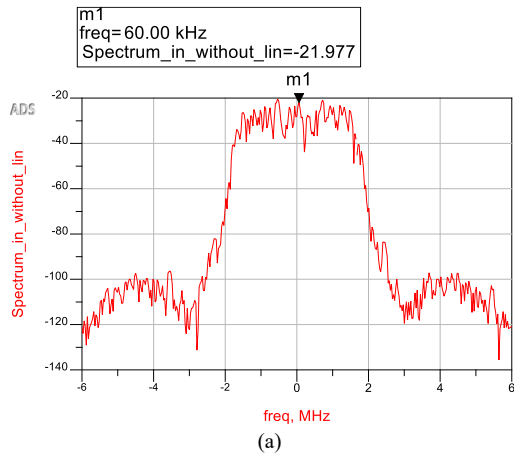


Fig. 5. Spectra of a 3 MHz 16QAM signal at the input (a) and output (b) of the amplifier (ZX60-4016E-S+) at 3.5 GHz with an input power of 0 dBm.

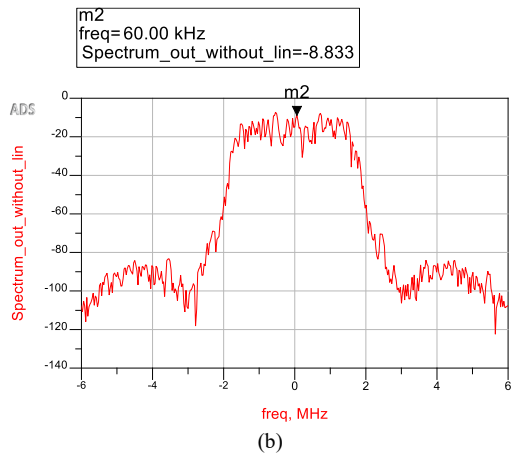
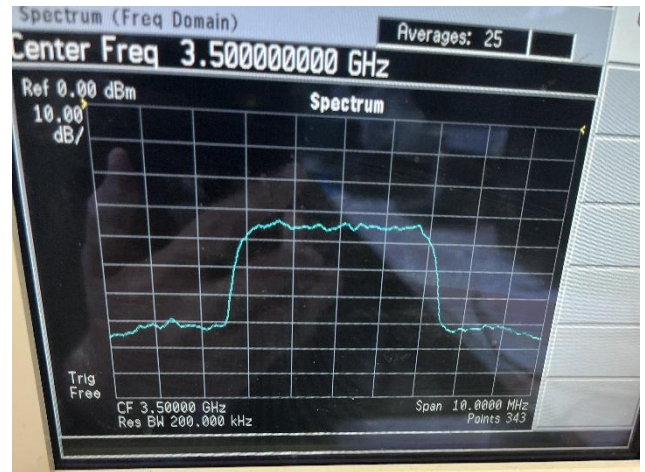
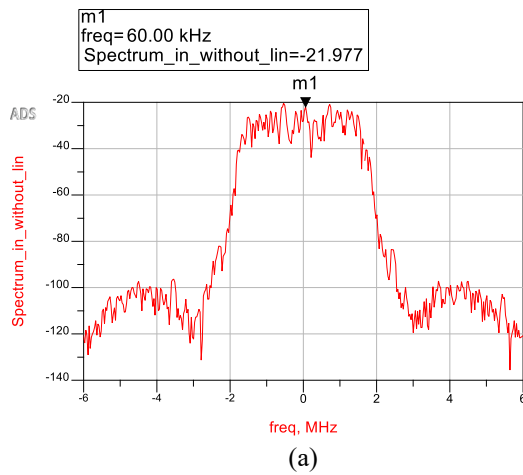
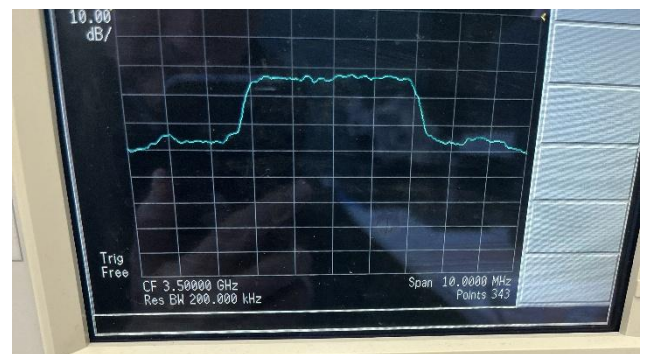


Fig. 4. Spectra of a 3 MHz 16QAM signal at the input (a) and output (b) of the amplifier (ZX60-4016E-S+) at 3.5 GHz with an input power of -10 dBm.



(a)



(b)

Fig. 6. Spectra of a 3 MHz QPSK signal at the output of the amplifier (ZX60-4016E-S+) at 3.5 GHz with input power of 0 dBm (a) and 10 dBm (b).

IV. CONCLUSION

The evaluation of nonlinear distortion in power amplifiers for full duplex transmitter applications, which demands low latency, high data rates and network capacity over an increasingly saturated radio spectrum, is presented. Simulation-based spectra of a 3 MHz QPSK and 16QAM waveforms at the input and output of the amplifier (Mini-Circuits ZX60-83LN-S+) at 3.5 GHz with an input power of -10 dBm and 0 dBm, respectively, are presented. Experimental spectra of a 3 MHz QPSK and waveforms at the amplifier output (Mini-Circuits ZX60-4016E-S+) at 3.5 GHz with input powers of 0 dBm and 10 dBm, respectively, are also presented.

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REFERENCES

- [1] A. Sabharwal, P. Schniter, D. Guo, D. Bliss, S. Rangarajan, and R. Wichman, "In-band full-duplex wireless: Challenges and opportunities,"
- [2] Y. Akaiwa, Introduction to digital mobile communication. John Wiley & Sons, 2015.
- [3] J. L. Dawson, *Feedback linearization of RF power amplifiers*. Stanford University, 2003.
- [4] A. A. Saleh, "Frequency-independent and frequency-dependent nonlinear models of twt amplifiers," *IEEE Transactions on communications*, vol. 29, no. 11, pp. 1715–1720, 1981.
- [5] H. W. Kang, Y. S. Cho, and D. H. Youn, "Adaptive precompensation of wiener systems," *IEEE Transactions on Signal Processing*, vol. 46, no. 10, pp. 2825–2829, 1998.
- [6] M. Faulkner, T. Mattsson, and W. Yates, "Adaptive linearisation using pre-distortion," in *40th IEEE Conference on Vehicular Technology*, IEEE, 1990, pp. 35–40.
- [7] D. R. Morgan, Z. Ma, J. Kim, M. G. Zierdt, and J. Pastalan, "A generalized memory polynomial model for digital predistortion of rf power amplifiers," *IEEE Transactions on signal processing*, vol. 54, no. 10, pp. 3852–3860, 2006.