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Investigation of Nonlinear Distortion of RF Amplifiers for 5G FR1 Full Duplex Networks

Moses Kasule

Wireless Communications
Research Group
University of Westminster
London W1W 6UW
Qualcomm Technology Inc.
Temple, USA

Djuradj Budimir

Wireless Communications
Research Group
University of Westminster
London W1W 6UW
d.budimir@wmin.ac.uk

Abstract—This paper presents an investigation of the nonlinear distortion of RF amplifiers for 5G FR1 full duplex applications. Simulation-based spectra of 10 MHz, 50 MHz and 100 MHz 16QAM waveforms at the input and output of the amplifier (Mini-Circuits ZHL-4240W+) 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 output of the amplifier (Mini-Circuit ZX60-4016E-S+) at 3.5 GHz, with input power of 0 dBm, are also presented. The presented evaluation of RF amplifiers' nonlinearities is important for the impact of RF amplifiers on self-interference in full-duplex applications

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

I. INTRODUCTION

Advancements in mobile wireless communications, such as 5G FR1 full-duplex network systems that demand high data rates and network capacity, require the development of wideband wireless systems [1]-[3]. These systems achieve high spectral efficiency but come with drawbacks, such as strong self-interference and high peak-to-average power ratios (PAPR) [4]. Deployment of such systems poses several design challenges for RF power amplifiers and 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, PAs are mostly linear at the expense of efficiency [5]. During the deployment of wideband and multiband signals, PAs will exhibit memory effects at high input power, resulting in degradation of error vector magnitude (EVM) and spectral regrowth. Spectral regrowth will produce interference in the adjacent channel and violate regulatory requirements.

In this paper, we investigate the nonlinearities of the RF amplifiers for 5G FR1 full-duplex applications. Evaluation is performed using 10 MHz, 50 MHz and 100 MHz 16QAM waveforms at 3.5 GHz with input power levels 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. ALGORITHM AND SIMULATION SETUP

A. Simulation Setup

As shown in Fig. 1, a Keysight ADS set-up of the Medium High Power Amplifier PA (Mini-Circuits ZHL-4240W) with the following features:

- Wide bandwidth: 10 MHz to 4200 MHz
- High Gain: 39 dB (Min.), 42 dB (Typ.) and 47 dB (Max.)
- Output Power at 1dB compression: 28 dBm (Min.) 30 dBm (Typ.)
- High IP3: +38 dBm typ.
- Low noise figure: 6 dB typ.
- Input Power (no damage): -5 dBm
- P1dB: 15.45 dBm
- Output power up to 17.4 dBm typ.

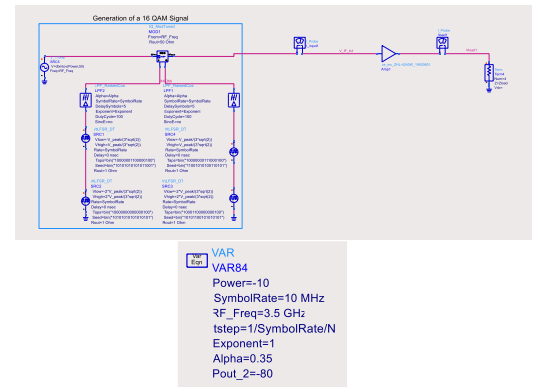


Fig. 1. Keysight ADS setup

The test bench in ADS used a PA (ZHL-4240W+) from Mini-Circuits and swept the input power from min to max, using a CW tone to generate the PA 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. RESULTS

Here, a performance analysis of RF amplifiers for full-duplex applications is presented, along with several experimental and simulation results. The Power Spectral Density (PSD) of 10 MHz, 50 MHz and 100 MHz 16QAM waveforms, at the input (a) and output (b) of the Mini-Circuits amplifier (ZHL-4240W+) 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, Fig. 5, Fig. 6 and Fig. 7, respectively.

The experimental evaluation of a 5 MHz QPSK waveform at the output of the Mini-Circuits amplifier (ZX60-4016E-S+) at 3.5 GHz with an input power of 0 dBm is shown in Fig. 8. As can be noted, the nonlinear distortion for the input power level of 0 dBm is significant and needs some linearisation techniques, such as DPD.

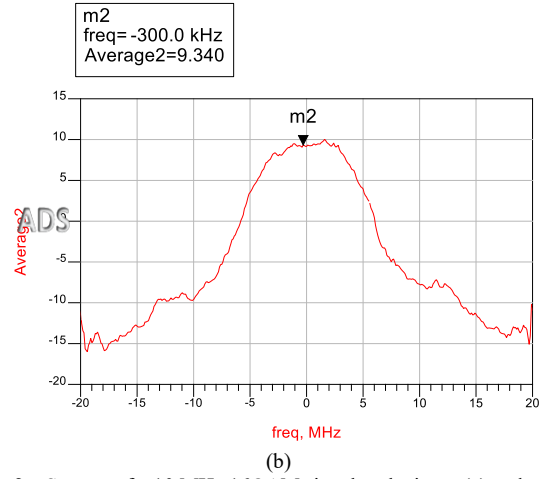
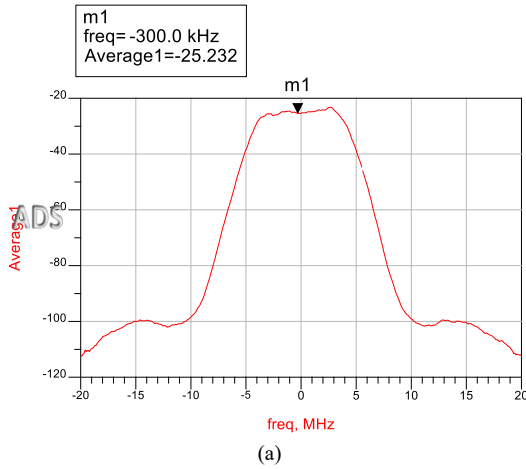


Fig. 2. Spectra of a 10 MHz 16QAM signal at the input (a) and output (b) of the amplifier (ZHL-4240W+) at 3.5 GHz with an input power of -10 dBm.

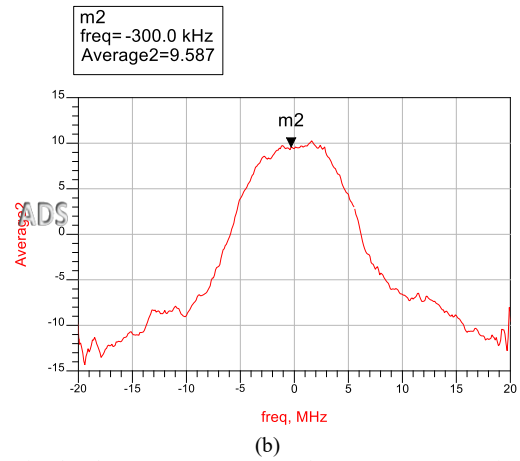
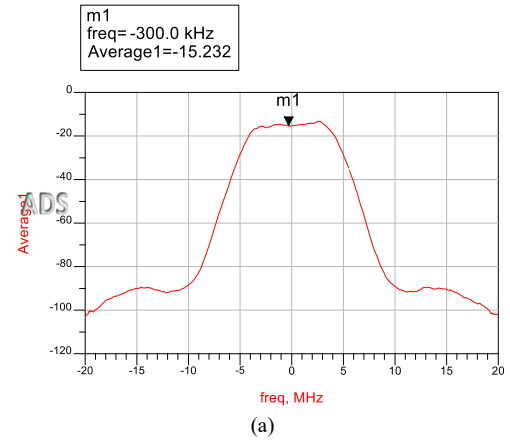


Fig. 3. Simulated output power spectra of a 10 MHz 16QAM signal at the input (a) and output (b) of the amplifier (ZHL-4240W+) at 3.5 GHz with input power of 0 dBm.

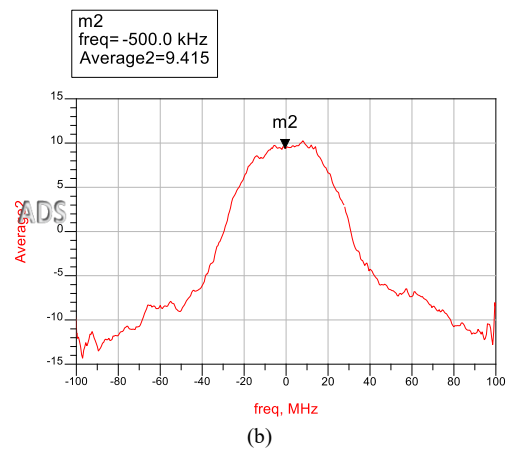
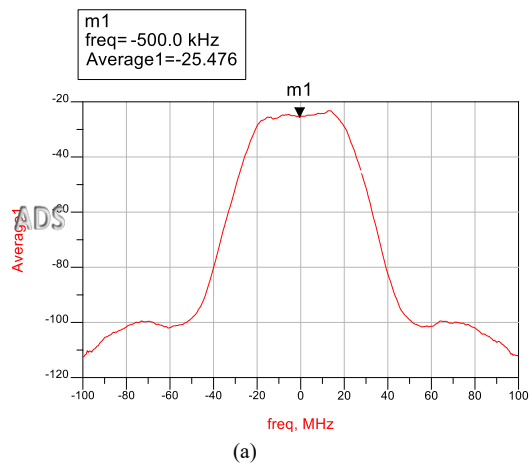


Fig. 5. Spectra of a 50 MHz 16QAM signal at the input (a) and output (b) of the amplifier (ZHL-4240W+) at 3.5 GHz with an input power of 0 dBm.

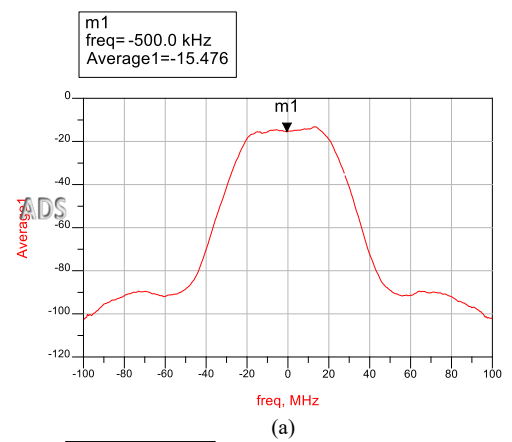
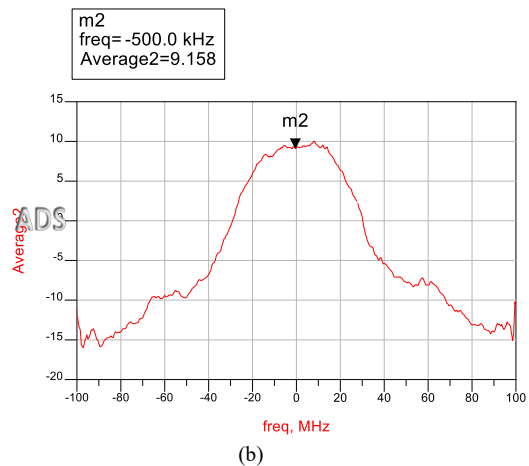


Fig. 4. Spectra of a 50 MHz 16QAM signal at the input (a) and output (b) of the amplifier (ZHL-4240W+) at 3.5 GHz with an input power of -10 dBm.

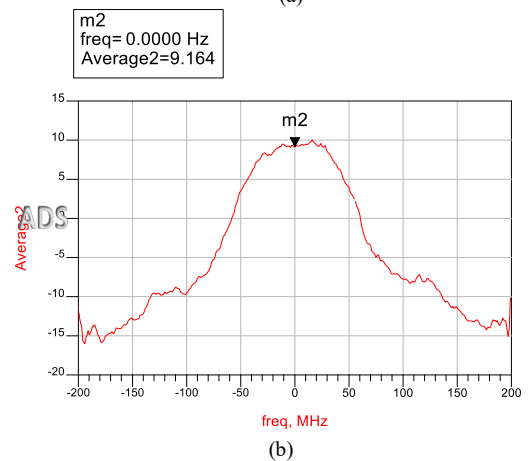
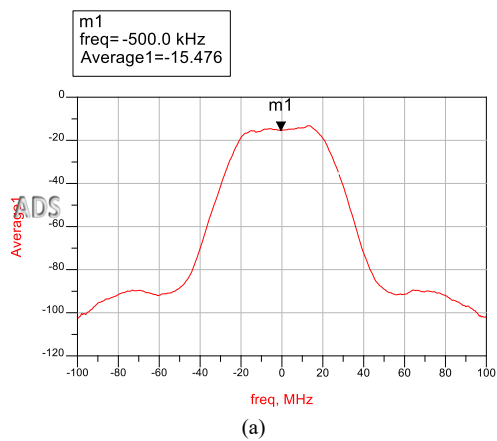


Fig. 6. Spectra of a 100 MHz 16QAM signal at the input (a) and output (b) of the amplifier (ZHL-4240W+) at 3.5 GHz with an input power of -10 dBm.

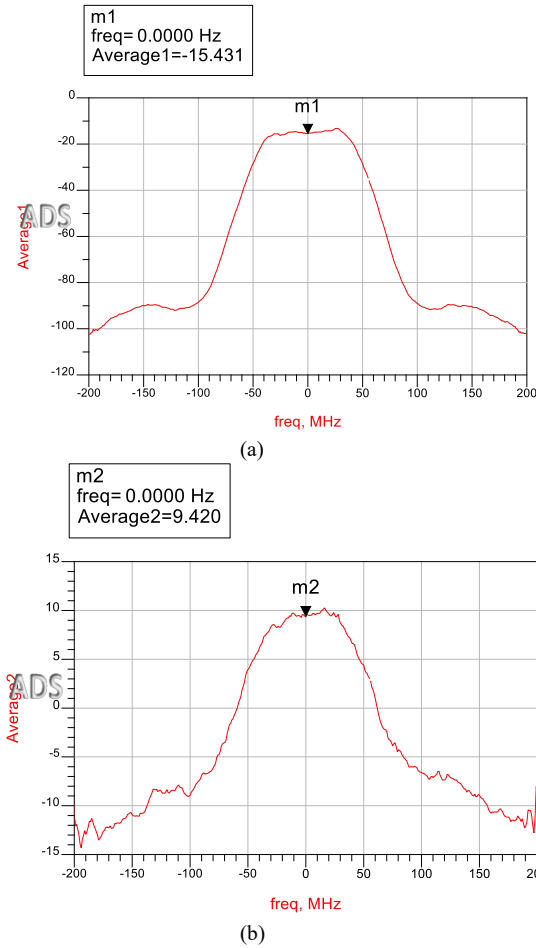


Fig. 7. Spectra of a 100 MHz 16QAM signal at the input (a) and output (b) of the amplifier (ZHL-4240W+) at 3.5 GHz with an input power of 0 dBm.

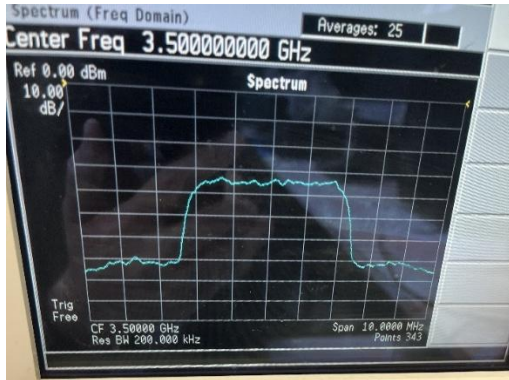


Fig. 8. Spectra of a 5 MHz QPSK signal at the output of the amplifier (ZX60-4016E-S+) at 3.5 GHz with input power of 0 dBm

IV. CONCLUSION

In this paper, the investigation of nonlinear distortion in RF amplifiers for 5G FR1 full-duplex technology, which demands high data rates and network capacity over an increasingly saturated radio spectrum, is presented. Simulation-based spectra of 10 MHz, 50 MHz and 100 MHz 16QAM waveforms at the input and output of the amplifier (Mini-Circuits ZHL-4240W+) at 3.5 GHz with an input power of -10 dBm and 0 dBm, respectively, are presented. The measured power spectrum of a 5 MHz QPSK waveform at the output of the amplifier (Mini-Circuits ZX60-4016E-S+) at 3.5 GHz, with an input power of 0 dBm, has also been presented. The presented evaluation of amplifiers' nonlinearities is important for the impact of power amplifiers and transmitters on self-interference in full-duplex applications.

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