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Olukoya, O. and Budimir, D.

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Rectifier Nonlinearity Effects on 4G and 5G Wireless Systems

Oludotun Olukoya[1], Guido Unich[2], Djuradj Budimir[3,4]
[1,2,3]*Wireless Communications Research Group, University of Westminster,*
115 New Cavendish Street, London, WI W 6UW, UK.
[3]d.budimir@wmin.ac.uk
[4]*School of Electrical Engineering, University of Belgrade, Belgrade, Serbia*

***Abstract*—In this paper, a waveform comparison and rectifier nonlinearity effects on 4G and 5G wireless systems are presented. The 3 MHz CP-OFDM and 5G FBMC signals are used in Matlab simulations. It is noted that 3 MHz CP-OFDM signals have larger side-lobes in comparison with 5G FBMC signals. The 5G FBMC signals have stepper slope at the edges and very low out-of-band leakage. The simulated output spectra densities of the rectifier for 3 MHz LTE and 5G FBMC signals at 1.5 GHz are illustrated.**

***Index Terms*—Rectifiers, 4G signals, 5G signals, Peak-to-average-power ratio (PAPR), Filter Bank Multicarrier (FBMC) Power spectra densities (PSD), Nonlinear distortion.**

I. INTRODUCTION

The emergence of microwave power transmission (MPT) plays a vital role in wirelessly powered circuits such as RF identification (RFID) and other low power wireless sensors [1]. The total efficiency of the microwave wireless system depends mainly on the RF-dc conversion efficiency of the rectifier circuits which has made high efficiency rectifier design very important.

Recent researches have focused on different topologies to improve RF-dc conversion efficiency performance [2]. Some of such topologies and models have been proposed in [3] – [6]. It was found that the electromagnetic energy is generally not constant due to the varying input power and operating frequency which leads to input impedance variation. The impedance variation degrades the rectifier performance due to the nonlinearity of the rectifying device. Another drawback from some of these improvements was due to load variation at the output of the rectifier which also leads to input impedance modification that can cause efficiency to deteriorate. To overcome the drawbacks and boosts robustness against the input power and output load variations, some further techniques were developed. Some of those solutions included resistance compression networks [7] which helped to improve the input impedance variation issue but still had bandwidth efficiency issues.

Recent works have now focused on the performance of rectifiers under different signal types rather than just considering the matching network and device selection. Previous work had considered single and two tone modes of operation. It has been observed when investigating multi tone signals that high peak-to-average power ratio (PAPR) may lead to a higher RF-dc conversion efficiency than its equivalent signal with the same input power [8]. This work investigates the waveform comparison and rectifier nonlinearity effects on CP-OFDM and 5G FBMC Wireless systems. In this paper, a rectifier will be tested using 3 MHz LTE and 5G FBMC signals for nonlinear distortion verification.

II. RECTIFIER DESIGN

The design of the rectifier circuit is essential to achieve the best RF-dc conversion efficiency, for this purpose a single stage, full-wave; peak to peak rectifier has been used [8]. A single stage rectifier is designed. Full wave rectifiers can achieve higher RF to DC efficiency than the half-wave. In this design the zero-bias Schottky diodes (Skyworks SMS7630) have been selected as the rectifying components. A comparison between three commercially available Schottky diodes are shown in Table I. The selection has been made considering the lowest zero-bias capacitance C_{j0} and the highest saturation current I_s , since these are the two parameters directly responsible for the RF-dc conversion efficiency.

TABLE I. SCHOTTKY DIODES COMPARISON

	Skyworks SMS7630	***MACOM MA4E2054***	***Avago HSMS2852***
I_S	$5\ \mu A$	$0.03\ \mu A$	$3\ \mu A$
C_{j0}	$0.14\ pF$	$0.13\ pF$	$0.18\ pF$
V_j	$0.34\ V$	$0.4\ V$	$0.35\ V$
N	1.05	1.05	1.05
R_S	$20\ \Omega$	$11\ \Omega$	$25\ \Omega$
I_{bv}	$100\ \mu A$	$10\ \mu A$	$300\ \mu A$
V_{bv}	$2\ V$	$5\ V$	$3.8\ V$

Fig. 1 shows the schematic of the designed rectifier. At the input of the rectifier a T-type matching network was used to assure the highest power transfer between input power and output power through converting the 50 Ω input impedance of the antenna to match the conjugate input impedance of the rectifier. In section III are combined. The results are obtained and analysed in the next section for efficiency performance.

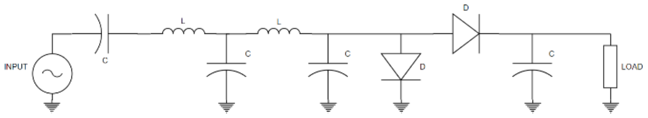

Fig. 1. Schematic of the rectifying circuit

III. RESULTS

Digitally modulated 4G LTE and 5G FBMC signals are used to evaluate the performance of the rectifier design. Its effects are observed, analysed and compared. The CP-OFDM and FBMC signals were generated using matlab simulations. Simulation results were obtained using the model of the signal generator in Keysight's Agilent ADS software with multitone signal generation capability (using matlab files) and a vector signal analyser.

To evaluate the nonlinear properties at the rectifier's output, 3 MHz LTE and FBMC signals are used. The simulated output power spectra densities of the rectifier with 3 MHz LTE for input power of 0 and 10 dBm are shown in Fig. 2 and Fig. 3 respectively.

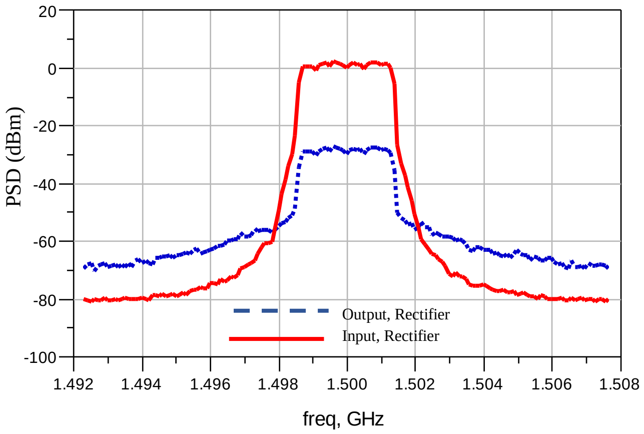

Fig. 2. Simulated power spectra densities of the rectifier with 3 MHz LTE signal at input power of 0 dBm

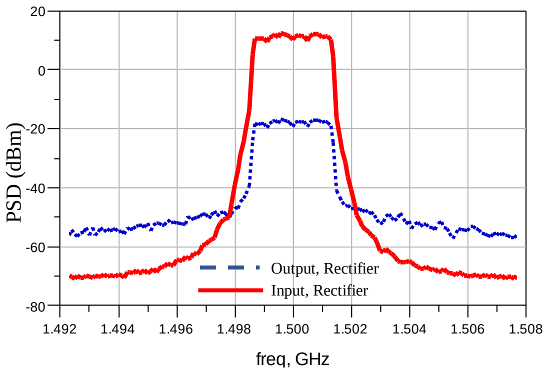

Fig. 3. Simulated power spectra densities of the rectifier with 3 MHz LTE signal at input power of 10 dBm

The simulated output power spectra densities of the rectifier with 3 MHz FBMC for input power of 0 and 10 dBm are shown in Fig. 4 and Fig. 5 respectively.

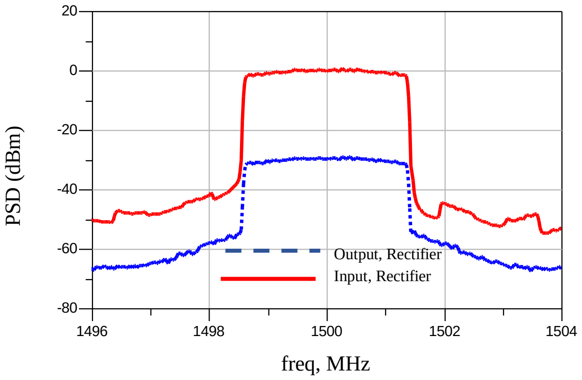

Fig. 4. Simulated power spectra densities of the rectifier with 3 MHz FBMC signal at input power of 0 dBm

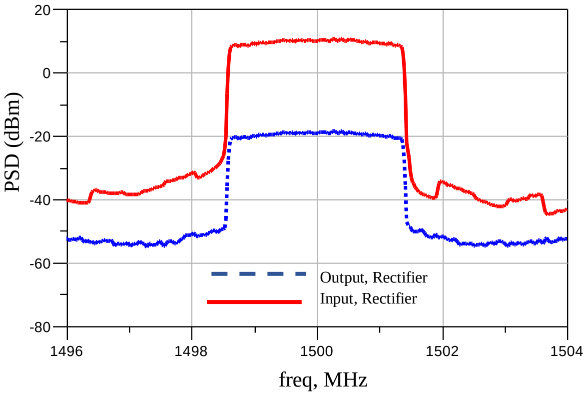

Fig. 5. Simulated power spectra densities of the rectifier with 3 MHz FBMC signal at input power of 10 dBm

To further evaluate its nonlinear effects, the output power spectral densities for a different range of input power levels using 3 MHz FBMC signals are compared and shown in Fig. 6.

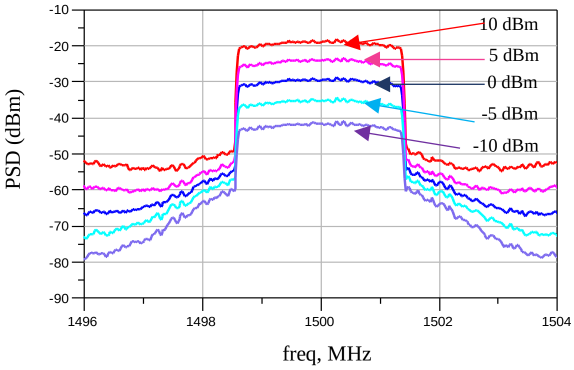

Fig. 6. Simulated power spectra densities of the rectifier with 3 MHz FBMC signal at input power of -10, -5, 0, 5 and 10 dBm.

CONCLUSION

A waveform comparison and rectifier nonlinearity effects on 4G and 5G wireless systems have been presented in this paper. The 3 MHz 4G/CP-OFDM and 5G FBMC signals at 1.5 GHz have been used in Matlab simulations. The simulated output spectra densities of the rectifier for 3 MHz LTE and 5G FBMC signals at 1.5 GHz have been presented. The proposed rectifier configuration will be very effective for the next generation low power sensor networks, IoT (Internet of Things) and 5G applications.

ACKNOWLEDGMENT

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