Analysis of SWIPT System Behaviour with Modulated Waveforms

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Abstract: Simultaneous wireless information and power transfer (SWIPT) has gained increasing interest since it enables receiver nodes with smaller or no batteries. To optimise wireless power transfer (WPT), both rectifier hardware and signal waveform have been optimised to increase RF-to-DC conversion efficiency (PCE). These power optimised waveforms (POWs) typically have a large peak to average power ratio (PAPR). However, these waveforms have to be modulated for information transfer, impacting PCE. On the other hand, using high PAPR waveforms increases distortion from hardware, impacting wireless information transfer (WIT). Our work studies the mutual impact of information transfer and power transfer, including rectifier behaviour when excited by, and transmitter imperfections when generating modulated POWs.

WPT-researchers typically focus on the rectifier hardware and excitation to increase PCE. Such excitations are signals with high PAPR like multisines and chaotic waveforms [1], [2]. WIT research on the other hand generally focuses on energy management and channel impact [3]. Our work analyses the mutual impact of both subsystems. The system setup is shown in Figure 1. The corresponding measurement setup is shown in Figure 2. The transceiver generates QAM and PSK modulated POWs which are upconverted to 2.45GHz. The transceiver's RF output is connected to either the transceiver's RF input to analyse the generated distortion, or the rectifier's input to analyse the impact on PCE and the transient behaviour of the rectifier's output. In the latter case, the rectifier's output is connected to a scope or the VST' baseband input ports. The rectifier was designed by the author's colleagues and is described in [4].

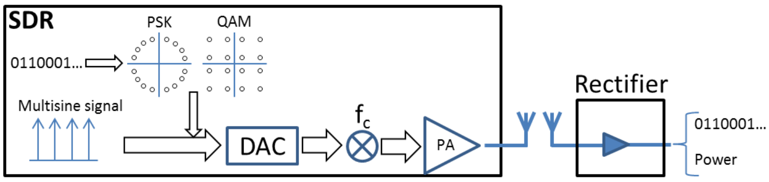

Figure 1: System setup

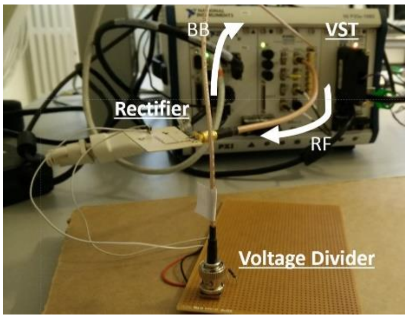

Figure 2: Measurement setup

POWs have a large PAPR, which will cause non-linear distortion from the transmitter, decreasing the information link quality. Error vector magnitude (EVM) is used as figure of merit to quantify this impact. To demonstrate transmitter impact, two different software defined radios (SDRs) are used as transceiver and compared: a VST (NI PXIe-5645R) and USRP (NI-2952R). Our measurements show that the transmitter's distortion measured in terms of EVM is highly dependent on the excitation's modulation. This impact is larger for the USRP which is less complex compared to the VST.

On the other hand, modulating POWs for WIT will impact the power transfer subsystem since not all symbols are guaranteed to have equal power, causing power level ripples at the rectifier's output. Our measurements show that the output voltage ripple is highly dependent on the excitation's modulation. For example, our measurements show an output voltage spread of 500mV at an average output level of 300mV when using 256-QAM.

Our work shows that the rectifier hardware behaves similar to an envelope detector for excitations with low symbol rate and similar to a perfect rectifier with only DC output for excitations with very high symbol rate. This analysis of the rectifier's output's transient behaviour revealed the fact that the rectifier can be used to downconvert the RF signal without using a local oscillator, which greatly reduces power consumption.

We conclude that multiple trade-offs between power transfer and information transfer exist in a SWIPT system. Firstly, generating high PAPR tones for WPT will increase transmitter distortion from which the WIT link will suffer. Secondly, modulation will impact the rectifier output, from which the WPT link will suffer. Thirdly the dual purpose behaviour of the rectifier results in a trade-off between information transfer and power transfer, depending on the symbol rate in the excitation.

References:

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