Experimental and Theoretical Analysis of Digital Modulation Schemes and RF Power Amplifiers Subject to Electromagnetic Interference

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We will present experimental and theoretical evaluation of digital modulation schemes (incorporating a RF Power Amplifier) subject to intentional Electromagnetic Interference (EMI). We particularly consider constant and non-constant envelope modulation schemes to evaluate performance (Error Vector Magnitude, Upset or Failure) subject to in-band and out-of-band EMI. To observe device level EMI effects, we perform a detailed analysis of EMI effects on a RF-Power Amplifier with emphasis on non-linear effects on the device due to high power EMI illuminations. Measurements and simulations are carried out to observe EMI effects on both system and device level.

The performance of digital modulation schemes such as Quadrature Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (QAM) and binary modulation schemes such as Binary Phase Shift Keying (BPSK) is evaluated by computing the Error Vector Magnitude (EVM). Both in-band and out-of-band frequencies are injected into the system to study the vulnerability of the modulation schemes on intentional EMI. We are able to associate the overall effects with either direct deterioration of the modulated signals or an overall upset on the electronic modules that process the modulated signals. To do so, an RF-power amplifier was employed prior to the transmission stage and examined device effects on the modulated signal by measuring the EMV.

We observed that device level upset is predominantly seen when the power amplifier is forced into the nonlinear regime when high power EMI is injected to gate terminal. Based on the measurements and corresponding simulations, we demonstrate that intermodulation products lead to significant degradation of the power amplifier gain. The amplifier performance is further exacerbated due to thermal effects stemming from large DC power consumption.

In addition to direct EMI injection, we also exposed the power amplifier inside a metallic enclosure to high power plane wave illumination to examine external EMI effects in a more practical setting. For such a complex system, our analysis incorporates a hybrid S-parameter matrix for system modeling of the entire structure. Specifically, we integrate full wave EM models of the structure with a Harmonic Balance Circuit analysis for modeling the PCBs and RF (as well as digital) devices. Such analysis very general and allows for complete realistic evaluation of performance deterioration associated with active RF devices in realistic settings.