Electromagnetic Irradiation Effects based on Chaos and Nonlinearities

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These distortion and interference of electronic systems during HPM irradiation are often based on a rectification process of the irradiated signal at nonlinear circuit elements like diodes or transistors. They are either found as discrete elements on the board or as parasitic elements at the pn-junction of complex integrated circuits. Rectification is associated with a generation of a signal envelope which transforms the radio frequency components of the incident electromagnetic wave to low frequency components and adds them to the nominal signal. When the signal/interference ratio exceeds a system specific threshold, the system will loose its functionality. Due to the sharp bend in the current/voltage characteristic of the parasitic diodes, the interference process shows a material-specific knee voltage (Si 0.7V; Ge 0.6V; GaAs 1.4V; Schottky 0.4V), which is responsible for the observable staircase like interference-threshold. Pure sinusoidal waveforms produce a direct-current-offset in the circuit, AM-modulated carriers create a replication of their modulation-signal.

Nonlinearities without memory are described by a look-up-table or power series. When additional memory elements like inductors, capacitors or cables are active, the Volterra-series analysis dominates at low amplitudes up to the convergence radius. The piece-wise linearization or signal specific describing functions describe effectively high amplitude effects.

A huge number of real life systems with memory are represented by non linear differential equations which however can not be solved analytically in most cases. Especially feedback systems which are able to oscillate might change into the chaotic state during irradiation. In chaotic systems smallest changes in the initial state lead to completely different results. Very good known representatives are the chaotic weather equations which do not allow long term prediction. Chaotic systems cannot be solved numerically. Due to the quantization error at the beginning of the iterative solution, each calculation-run shows different results.

Chaotic effects during electromagnetic irradiation with low field strength are observed in praxis especially at PLL structures like RF-receivers, IR- and radar-detectors. An interference signal drives the oscillating state of voltage-controlled-oscillators (VCO) in the chaotic state. Then, the resulting oscillator signal with accidental zero crossings cannot be further used as a mixer signal in synchronous detector circuits. Hence, smallest interference signal amplitudes enable the suppression of communication links and the functionality of detectors.