Contact-Free Estimation of the Critical Frequencies for Back- and Frontdoor Coupling into Electronic Devices

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Abstract—In this paper, a novel procedure that enables the determination of frequencies at which electromagnetic signals can couple into electronic devices is presented. The proposed procedure determines the power absorbed by the device under test (DUT) as a function of the frequency, based on the measured values of the power fed into an electromagnetic reverberation chamber and the power losses both empty and loaded chamber. The maxima of the spectral power absorption function indicate critical frequencies for the electromagnetic coupling into the device under test.

Keywords—Power absorbed by DUT, Reverberation chamber, frontdoor coupling, backdoor coupling

I. INTRODUCTION

Knowledge of the coupling paths of interfering signals into electronic devices is vital information when hardening a system against external threats becomes important. Traditionally, a lot of estimations have to be made, e.g. investigating the dimensions of existing apertures and estimating the corresponding wavelengths. Alas, the final result usually depends heavily on the experience of the designer.

II. MEASUREMENT

We propose a novel method for measuring the critical frequencies. To this end, we set up a mode stirred chamber with a test volume which is big enough for the largest DUT to be analyzed, an oscillator for the excitation of a harmonic electromagnetic field (by a transmitting antenna inside the mode stirred chamber) and a receiving antenna.

In a first step, we measure the average power $P_{in}$ of the exciting field generated by the oscillator, averaged for one full turn of the mode stirrer. At the same time, we measure the average power $P_{out}$ at the footpoint of the receiving antenna inside the mode stirred chamber. By calculating the power difference

$$ P_{loss,empty} = P_{in} - P_{out,empty} \quad (1) $$

we can determine the losses in the empty mode stirred chamber. The biggest part of the losses are caused by the power dissipated in the metallic (non-PEC) walls of the mode stirred chamber. Additionally, the losses in the antennas and the losses stemming from mismatches or nonlinear amplifiers are also included. As a second step, we load the reverberation chamber with the DUT and measure $P_{in}$ and $P_{out}$, again. As a result we get the total power loss in the loaded reverberation chamber. The difference of the losses in the loaded and unloaded chamber is the power coupling into the DUT at a given frequency:

$$ P_{DUT} = P_{loss} - P_{loss,empty} \quad (2) $$

Repeating this procedure for a range of frequencies gives the spectral power coupling into a DUT from an external EM field, $P_{DUT}(f)$. The peaks of the resulting function are the critical frequencies for coupling, and can be used to optimize the hardening process.

III. PROOF OF CONCEPT

To proof the concept, various generic DUTs with resonances at single pre-determined frequencies were

Figure 1. Generic DUT with $f_0=1.25$ GHz
We selected monopole antennas with a conductive “plane” and a termination of 50 Ω, displayed in Fig. 1. Fig. 2 shows the sketch of one generic DUT.

Their resonant frequencies were calculated with the use of an commercial available simulation software. These were validated by placing the generic DUT between two antennas, measuring the transmission coefficients and determining the minima of these coefficients.

The power absorption of the generic DUTs were measured afterwards, but were suffering from statistical artifacts and noise. Therefore, we modelled their absorption characteristics by a Lorentz curve

\[ P(\omega) = \frac{A}{1 + (\frac{\omega - \omega_0}{\delta})^2} \]  

with the amplitude A, the attenuation factor δ and the circular frequency ω. and used linear multiparameter fitting to determine the unknown parameters.

Results for one generic DUT are displayed in Fig. 3, where the blue dots represent single measurement and the red curve is the plot of the fitted function. For multiple DUTs we were able to estimate the coupling frequencies with an error below 5%.

Additional measurements were performed with different DUTs and additional casing (which implies shielding and additional resonances).

![Figure 2: Cross section of generic targets.](image)

![Figure 3: Power absorption for DUT with f0=1.25 GHz, plus result of fitting.](image)