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Characterisation of electromagnetic susceptibility of integrated circuits using near-field scan

A. Boyer, S. Bendhia and E. Sicard

A susceptibility characterisation test for integrated circuits using a miniature magnetic near-field probe is described. The method is efficient up to a frequency of 6 GHz and maps immunity to radiated fields.

Introduction: In recent years there has been an exciting evolution in integrated circuits (ICs), with reductions in the supply voltages of IC cores but, unfortunately, with increase in susceptibility to electromagnetic disturbances. Modern ICs suffer from high susceptibility to radio frequency interference up to 5 GHz [1, 2]. Both IC vendors and customers use normalised measurement methods to characterise components [3]. Most susceptibility test methods are limited in frequency to 1 GHz, which means that important sensitive bands are not considered. The GTEM and anechoic chamber methods may determine overall aggression of up to 18 GHz, which is not adequate for failure diagnostics. The recent development of the near-field scan method for measuring IC radiated emissions [4] has motivated this study, the objective of which is to develop an immunity test method [5] to obtain localised results at high frequencies. As this method uses also a magnetic coupling, it is proposed as an extension to the existing bulk current injection (BCI) test method for frequencies above 400 MHz. This Letter describer the method and its main advantages, namely improvement in the frequency limit and the ability to detect susceptible areas.

Method description: The near-field scan immunity (NFSI) method is based on use of a miniature near-field probe placed above a device under test (DUT), thus producing a strong localised field in the vicinity of the DUT. A loop is built at the end of a semi-rigid coaxial cable but it could also be put on a printed circuit board (PCB). The loop diameter should not exceed 5 mm, since its resonant frequencies are about several tens of GHz. The loop can be ended by a known load to reduce the standing-wave ratio, but adding the resistive load will decrease the current flowing in the loop and thus the radiated magnetic field. Fig. 1 shows the setup for a near-field scan immunity test. A harmonic disturbance produced by a combination of the signal generator and the power amplifier feeds the near-field probe. A bidirectional coupler is used to measure the amount of forward and reflected power. Even if susceptibility thresholds are typically given in terms of forward power, information about reflected power is helpful in simulation to check the validity of the model of the coupling path. The probe is moved above the DUT by means of a high-precision mechanical positioning system (to within 100 μm minimum). At the chip aggression level the widest conductor is the package, which means that disturbances from the probe couple mainly to the package leads and bondings. During the entire test the functional behaviour of the DUT is checked and is considered to have failed if a predefined susceptibility criterion is no longer achieved.

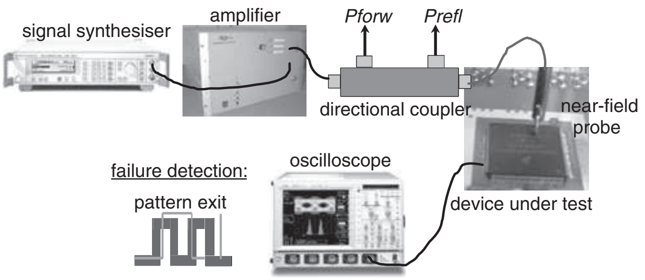

Fig. 1 *Measurement setup*

Characteristics of method: Miniature magnetic probes mainly radiate a magnetic field of up to several tens of GHz, which means that the coupling between the probe and the DUT remains inductive. The coupling can be modelled primarily as a mutual inductance between the probe and the package lead or bonding. A method such as the partial equivalent element circuit model (PEEC) [6] is adapted to characterise the coupling factor from known geometrical data of conductors. The coupling depends on the distance and orientation between the probe and each conductor.

Fig. 2 shows measurement and simulation results of the transmission coefficient between a magnetic probe and a 50 Ω adapted strip line situated 1 mm below. Correlation of measurement and simulation data shows that the transmission coefficient obeys a simple inductive coupling law up to 6 GHz. Between 1 and 4 GHz the measured coefficient remains almost constant at ±3 dB, and then begins to decrease slightly until 6 GHz. At more than 6 GHz, resonances occur which are linked with the non-ideal behaviour of the DUT. The coupling value reaches 4%, which seems weak but is equivalent or better than the performances of other standardised IC susceptibility methods such as the TEM/GTEM cell or BCI methods. Consequently, as this method exhibits regular frequency characteristics up to 6 GHz and coupling is significant above 100 MHz, the best frequency range is 100 MHz–6 GHz.

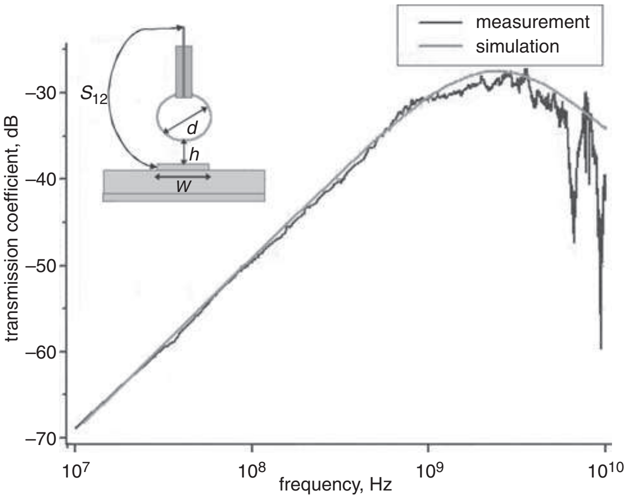

Fig. 2 *Measurement and simulation of transmission coefficient between probe and 50 Ω adapted strip-line (probe height = 500 μm)*

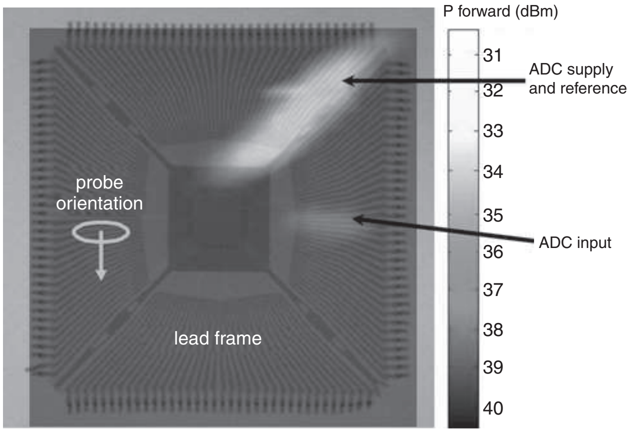

Fig. 3 *Susceptibility mapping highlights a weakness of ADC at 500 MHz (probe height = 500 μm)*

Case study: We investigated the ability of the NFSI to detect locations of weaknesses inside an IC which were responsible for failures. For this purpose, the near-field scan immunity method was used to study susceptibility of a 16-bit microcontroller. Several circuit blocks were tested, such as the PLL, the internal regulator, analogue-to-digital converters (ADCs) and the output port. For each test, a localised near-field disturbance was applied at each point 500 μm above the top of the package at varying frequencies from 1 MHz to 2 GHz, to detect weak zones. Fig. 3 highlights a weakness area located close to the ADC inputs and supply of around 500 MHz. In this test, susceptibility criterion is a modification of one bit of the converted value by the ADC. Orientation of the probe is indicated in the Figure. Radiated disturbances couple mostly with the PCB and the IC package. Another example is the characterisation of the immunity of the bus clock. In this test, susceptibility criterion is a variation of 5% of the frequency of the bus clock. NFSI shows that two leads are responsible for failures. The normal of the probe is oriented perpendicularly to these leads to optimise the coupling. These leads are connected either to the internal PLL or the external quartz. This implies that two different mechanisms are responsible for the detected failure. Each of these blocks has different susceptibility thresholds as shown in Fig. 4. A 10 W (40 dBm) amplifier would highlight the 450 MHz weak zone, while a 100 W amplifier (50 dBm) clearly exhibits a wide bandwidth susceptibility centred around 1250 MHz.

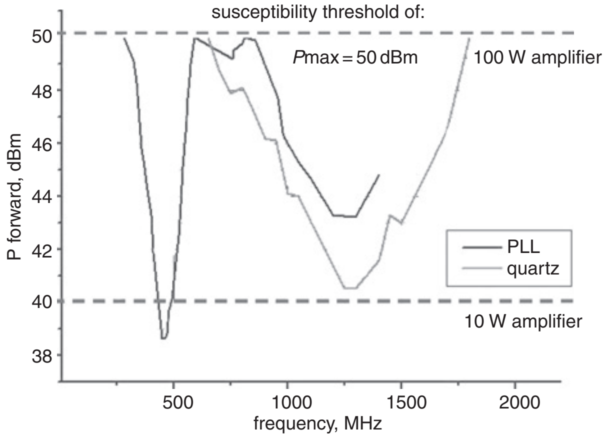

Fig. 4 *Susceptibility threshold of internal PLL and quartz of micro-controller (probe height = 500 µm)*

Conclusion: A method has been developed for determining IC susceptibility based on near-field aggression. This method is able to localise disturbances, which is helpful for identifying the causes of susceptibility. NFSI can be applied in the frequency range 100 MHz–6 GHz. The lower bound can be extended for a range of 10–100 MHz despite the low coupling. Finally, NFSI injection can easily be modelled with an inductive model. Consequently the method is well suited for localised immunity testing, as a high frequency extension of the BCI method.

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