ELECTRICALLY SMALL MAGNETO-ELECTRIC ANTENNAS FOR SHILDING EFFICIENCY QUANTIFICATION IN IC-STRIPLINE EMISSION TESTS

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Abstract

Shielding of unwanted electromagnetic emissions of ICs is vital for a proper electromagnetic compatibility (EMC) of the IC with other electronic based devices in close proximity. Due to high integration densities large metallic shielding caps are impractical. Hence, other shielding measures have to be developed. In order to quantify the shielding efficiency (SE) of the developed methods specific test configurations are needed. In the present work, finite element method-based investigations on electrically small magneto-electric antennas are conducted which should be used for shielding-efficiency tests.

1 Introduction

Optical sensors with internal light sources are fundamental components in modern mobile devices. Such sensors are e.g. used for face recognition purposes. Quite often so-called Vertical Cavity Surface Emitting Lasers (VCSEL) are utilized as light source in such sensors [1]. This VCSELs are driven by pulsed currents with very short signal rise-times (hundreds of pico-seconds) and rather high currents (up to 10 A). Due to the working principle of such VCSELs the driving current flows vertically through the device which requires a bonding wire from the driver IC to the VCSEL as shown in Fig. 1. Naturally, the current path formed by the bond wire and the VCSEL forms a current loop resulting in a magnetic dipole moment [2]. Thus, this dipole moment can cause unwanted electromagnetic radiation and consequently lead to compatibility issues. To ensure a proper light pulse, typically buffering capacitances are placed in close proximity to the VCSEL device which can result in an unwanted electric dipole moment leading also to unwanted electromagnetic radiation. In order to overcome the unwanted effect of this parasitic dipole moments, metallic shielding caps can be used to reduce the unwanted electromagnetic radiation [3]. On the other hand, there is still the need for an aperture in the shielding cap such that the light pulse can be emitted. Hence, the requirements on such shielding counter-measures are rather elaborate. The aim of this work is to develop a simulation-based test bench which allows the

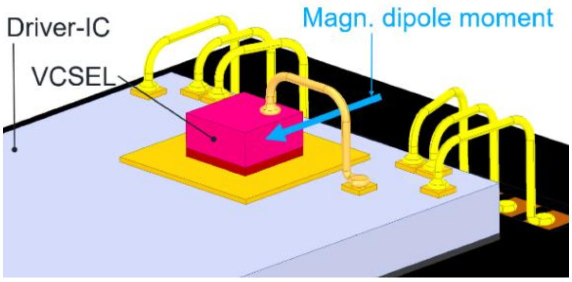

Figure 1: Principle sketch of a VCSEL device with bonding wire. The current path of the VCSEL forms a magnetic dipole moment.

quantification of the SE of shielding measures for such VCSEL devices. Furthermore, the test bench shall be in accordance to the so-called IC stripline test method [4] used for standardized radiated emission test for ICs. Due to the small geometry of the device under test and the corresponding frequency range in the GHz domain electrically small antennas with distinct magnetic and electric dipole moments are needed in order to model the VCSEL behaviour.

2 IC stripline-based emission measure-ments

The IC stripline test methodology, based on the TEM cell method [5], is an EMC/EMI (electromagnetic immunity) test method specifically for packaged integrated circuits. The general working principle of the IC stripline is based on a transversal electromagnetic wave being present in a coaxial cable like device as shown in the cross-sectional view in Fig. 2. The device under test (DUT) is places upside down on a grounded test PCB between the septum and the grounded housing of the IC stripline. The septum itself is the extension of the inner conductor of the coaxial cable connected to the EMI receiver or vector network analyser (VNA) used as measurement device. The needed powerlines or other signalling lines are guided through ducts in the test PCB. By means of a 2-port VNA measurement the transmission coefficient (i.e. the scattering parameter S12) between the electrically short test antenna and the IC stripline can be determined (see principle sketch in Fig. 2). When comparing the transmissions coefficients between the unshielded and shielded case the SE of the specific shielding method can be quantified. Note, that this procedure can be conducted in terms of measurements with prototype devices or a digital twin of the whole test set up.

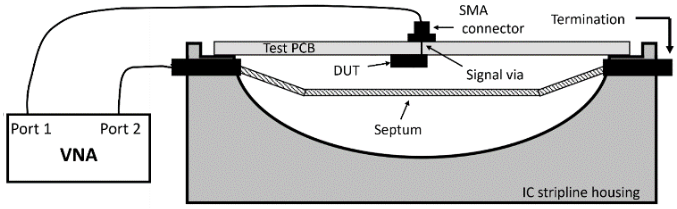

Figure 2: Two-port VNA measurement set-up for measuring the transmission coefficient between the DUT and the IC stripline.

With the help of the measured terminal voltages at the IC stripline also a quantification possibility for the dipole moments of the magneto-electric test antenna is given. The electric dipole m_e and the magnetic dipole moment m_m are given by [6]:

$$|m_e| = \frac{|U_1+U_2|h}{Z_W}, \quad (1)$$

$$|m_m| = \frac{|U_1-U_2|hZ_0}{Z_W}. \quad (2)$$

Where U_1 and U_2 are the terminal voltages of the IC stripline, h is the distance between the septum of the IC stripline and the test PCB, and Z_0 and Z_W are the intrinsic free-space wave impedance and the characteristic impedance of the stripline, respectively.

This makes it easy to distinguish whether the shielding materials can shield electric or magnetic fields.

3 FEM-based modelling and simulation of the test bench and preliminary results

In order to find proper radiating structures mimicking the unwanted radiating dipole moments of such VCSEL devices, a FEM-based model of the whole test bench has been developed. Due to the fact that the outer dimensions of such VCSEL devices are in the range of max. 1-2 mm, test antennas (see Fig. 3), which shall be placed inside the shielding caps, are electrically small in the frequency domain of interest. Hence, matching to the 50 Ω VNA test system is challenging. Since the quantification of the SE is based on a relative measurement between two cases (with and without shielding), a matching of the antenna impedance to the wave impedance of the VNA measurement system is not needed. As already discussed in [2] the thickness of the shielding plays an important role for the SE. This circumstance is naturally related to the skin depth of the specific material in the operating frequency range. Fig. 4 shows the SE for coupling and non-coupling magnetic dipole moments. The steadily increasing SE in case of the coupling magnetic moment is a consequence of the relationship between skin depth and shield thickness. The explanation of the behaviour for the non-coupling magnetic moment is the subject of ongoing research. A detailed discussion of the results obtained will be presented at the conference and in the extended paper.

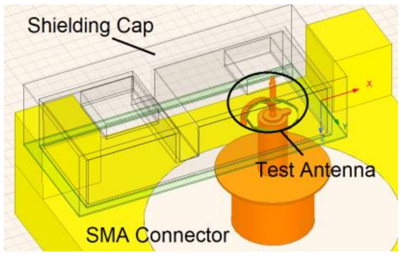

Figure 3: Proposed magneto-electric test antenna

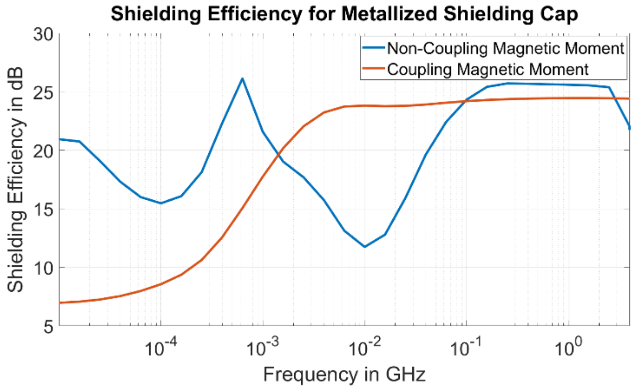

Figure 4: SE as function of the frequency for coupling and non-coupling magnetic moment

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