Designing Test Targets for Verification of an Inverse Source Solver at Low Frequencies

Introduction

Understanding the electromagnetic near-field (NF) and far-field (FF) radiations of electrically powered devices is one of the areas of interest in engineering. Such radiations could be desired, for example, when the device is an antenna, and understanding electromagnetic radiations of which is a key to establishing reliable communication systems. Radiations can also be undesired, for example, for devices ranging from microelectronic circuits to large power electronic systems such as power converters or electric motor drives for industrial machinery, where electromagnetic interference can cause malfunctioning, and electromagnetic compatibility (EMC) becomes crucial.

Irrespective of the application, obtaining the radiation pattern of the device under test (DUT) in practice necessitates field measurements. Subsequently, NF to NF/FF transformation algorithms must be employed on the collected set of measured samples to approximate the radiation field.

Problem Statement

The precision of existing techniques for capturing the radiation field from a low-frequency operating DUT (when the electrical size of the DUT is much smaller than the wavelength), particularly when NF measurements are conducted within the intense reactive fields, faces certain limitations. The errors associated with known techniques are relatively higher compared to high-frequency measurement scenarios, for which efficient solutions such as inverse source solvers based on field integral equations exist.

Such high-frequency solvers can be stabilized to work at low frequencies as well (at least in theory and simulations). Therefore, there is a potential for the stabilized inverse source solvers to achieve higher levels of accuracy compared to existing techniques. Exploring this potential could pave the way for low-frequency measurements, particularly for accurate and efficient EMC analysis.

To ensure the reliability of an available low-frequency inverse source solver, we have to verify it in the real world. That is, we need to design, simulate, and fabricate practical test targets with diverse geometric structures, including capacitive and inductive elements operating at low frequencies, and conduct measurements.

Approach

The thesis involves designing a (series of) test board(s) to validate an existing inverse source solver and obtain measurement procedures. The test structures will include capacitive circuits for electric fields loop-like circuits for magnetic fields.

A good series of candidates are power converters (for example, DC-DC buck or boost converters due to their relatively simple design, which contain capacitors, inductors, and (active) switches - preferably, buck converters due to the control stability). Such converters usually have considerable radiations due to their switching nature (see for example [1]–[7]). The switching frequency of such power electronic devices can vary between a few KHz to hundreds of MHz that cover low and (relatively) high frequencies. This can be used as a preliminary validation tool since we expect high-frequency fields to be computed more accurately.

The circuit will be first designed and simulated in full-wave simulators such as CST STUDIO to evaluate the accurate radiated fields, serving as a reference. Different measurement setups need to be developed to verify the available solver in an ideal/noisy simulation environment. The next step would be fabricating the printed circuit board and conducting measurements.

Objectives

The objectives of this thesis are as follows:

1. Theoretical development of quasi-electro/magnetostatic radiations and their possible sources.

2. Designing and full-wave simulation of experimental circuit(s) (a switching DC-DC buck converter operating at low frequencies with pulse-width modulation (PWM)).

3. Identification of the dominant sources of the electric and magnetic field in the circuit.

4. Obtaining a measurement strategy for near-field measurements (using electric and magnetic probes).

5. Verify the existing inverse source solver.

6. Fabrication and measurement.

References

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