A Measurement Setup for Radiated EMI of Un-buffered DRAM Modules

Mojtaba Joodaki and Amir Attar

Abstract. As clock frequency and switching current of DRAM (dynamic random access memory) modules are ever increasing, electromagnetic interference (EMI) of such modules is gaining a very high degree of importance. Normally EMI measurements of memory modules are performed implementing complete motherboards or PCs. This makes it very difficult to only separate the radiated EMI of the memory module with a single EMI measurement. This is the first attempt to construct a shielded measurement setup for radiated EMI for DRAM PCBs. The measurement setup is fabricated and tested for un-buffered double data rate (DDR) modules and gives excellent results. This is very helpful in EMI and electromagnetic compatibility (EMC) investigation of memory modules. Although the measurement setup is just implemented for memory modules, the approach can be used for other types of PCBs too.

Keywords: EMC/EMI measurement, DRAM PCBs radiation.

1. Introduction

The compulsory test and evaluation of electromagnetic interference (EMI) and electromagnetic compatibility (EMC) for each electrical and electronics circuit and system include radiated emission test [1], [2]. DRAM (dynamic random access memory) modules, like any other electrical and electronic equipment and systems, are capable of emitting electromagnetic energy which can constitute electromagnetic interference (EMI). In the new memory technologies, designers are implementing effective clock frequencies as high as 3.2 GHz (DDR4-3200) and switching currents above 10 A. This generates a very high di/dt, which results in much higher radiated emissions. Furthermore, to increase the lifetime and reliability, metallic heat-sink is generally used to remove the heat from the surface of DRAM module and decrease the operating temperature of the DRAM chips on board [3], [4]. Improper implementation of such a large area of metallic component in the presence of above gigahertz signals can cause efficient antenna which degrade the EMI/EMC performance of the module drastically [5], [6]. Therefore, EMI/EMC is a major challenge for future DRAM products.

Manuscript received September 9, 2014; revised December 12, 2014; accepted December 25, 2014.
The authors are with the Department of Electrical Engineering, Faculty of Engineering, Ferdowsi University of Mashhad, Iran.
The corresponding author's e-mail is: joodaki@um.ac.ir.

A very important point in EMI investigation of memory modules is to measure only the radiated EMI from the module itself. In this paper we shield the whole PC from outside and provide a proper slot for DRAM module by using a designed riser card. The idea is to shield the rest of the system and to measure only the fields radiated from the modules under test. This provides us with a deeper sight into the EMI/EMC performance of our memory modules. The details of the measurement setup are given in Section 3. The measurement setup is tested and the successful results are presented in Section 4.

2. Radiated EMI Regulation and Importance of EMC Consideration in Modern Electronics

A. EMC Radiated Emission Regulations

Among the radiated emissions standards available for commercial electronic products, the US standard of FCC part 15 (subpart B) and the European standard of EN 55022 (the same as CISPER 22), are the most used standards. Since digital electronic devices are prone to radiate electromagnetic waves unintentionally, every digital circuit that has a clock greater than 9 KHz, is covered by the FCC part 15 (subpart B). The two above- mentioned standards have similar test arrangements but somewhat different limits. Their limits are compared in Fig. 1.

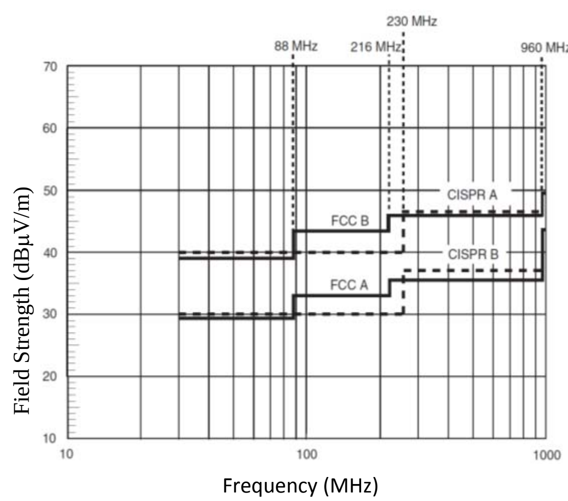

Fig. 1. Radiated emission limits for FCC and CISPR measurement distance equal to 10 m). Solid line: FCC, dashed line: CISPER [7].

The radiated emission standards cover two classes: class B for the products used in domestic environments (where the use of broadcast radio and television receivers may be expected within 10m of the apparatus concerned) while class A covers the rest of other products [8]. Since class B devices are more prone to interfere with radio and television receivers, they are more restricted (10 dB lower than class A).

B. Importance of EMC/EMI Consideration in Modern Electronics

For an electronic product to comply with an EMC standard it is needed to function properly in its intended electromagnetic environment and it should not be a source of radiation to that electromagnetic environment. Always the trend in electronic industry is toward more packed and miniaturized systems with much higher speed and more functionality but at lower cost, weight and operating voltage. Therefore the future electronic devices not only will suffer more from the EMI issues due to the small distance to the neighboring devices and much higher switching speeds, but they will be more susceptible to the external noises due to the lower operating voltage.

Table 1 shows the roadmap for the semiconductor technology development [9]. According to the roadmap as technology develops, the gate length (LG) decreases, which results in increase of the current density and the switching speed, hence, higher d*i*/d*t* and higher radiated EMI. On the other hand, operating voltage (V_{DD}) reduction worsens the immunity of the devices against the EMI. This is well explained in Fig. 2.

Table 1. Overall roadmap technology characteristics for logic products based on the international technology roadmap for semiconductors (ITRS), 2007.

Year	Gate Length L_G (nm)	V_{DD} (V)	Intrinsic switching speed (GHz)
2010	18	1	2439
2011	16	1	2778
2012	14	0.9	3226
2013	13	0.9	3571
2014	11	0.9	4348
2015	10	0.8	4762

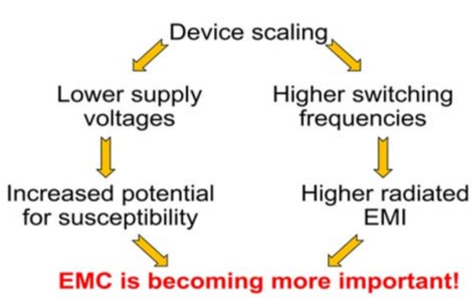

Fig. 2. Impact of device scaling on EMC problems.

3. The Measurement Setup [10]

Far-field measurements of the radiated EMI of a complete electronic system on a PCB or motherboard is usually performed in an anechoic chamber according to the well known EMI measurement standards of FCC part 15 (subpart B) or the European standard of EN 55022 (or CISPER 22) [8]. On the other hand, far-field radiated EMI of memory integrated circuits (ICs) and packages are usually measured using transverse electromagnetic (TEM) cells under IC-EMI measurement standards such as IEC 61967-2 [11]. According to our best knowledge there is no reliable measurement method available to measure the radiated EMI of an electronic PCB or module that vertically stands on a motherboard. Therefore, this work aimed at developing such a measurement method. The required measurement setup must fulfill the following criteria:

- Though it should effectively shield the radiated EMI from the rest of the system under test, it should have minimum influence on the DRAM module emission.
- To prevent difficulties in measurements regarding transportation of the measurement setup to the EMI/EMC labs and in order to be easily handled in the semi-anechoic chamber, it should be small and light.
- Improper grounding of the motherboard and power-supply cable will results in radiation of the main shielding case which hinders proper measurements.
- It should provide a proper thermal path similar to the PC with its normal case. A shielding case with an improper thermal path will damage the system under test or influence the measured results.
- Similar to any other product, it would be in our interest to make it be as cheap as possible.

A scheme of the suggested measurement setup is illustrated in Fig. 3.

In order to provide an excellent shielding and a good electrical ground for the system, the main aluminum case has a thickness of 1 mm to 3 mm. Different parts such as motherboard, power supply and ac cable are fixed and electrically connected to the main case through very low impedance paths. In order to minimize the electromagnetic interference between the power supply and the motherboard, they are separated by some aluminum partitioning walls. On the left side of the measurement setup a window is used for periphery interfaces such as monitor and keyboard cables. During the measurements, after running the memory test program, this window must be screwed up. Since the memory modules under test must be outside the main aluminum shielding case, different riser-cards and exchangeable metal cover plates are implemented for different memory module types (DDR1, DDR2, So-DIMM DDR1, and So-DIMM DDR2). There is a 3 mm wide slot in each metal cover plate for the riser-cards connector. To prevent electromagnetic emissions from these slots, 1 cm thick absorber foams and rubbers are used around the slots on the inner sides of the metal cover plates. The grilled air vents are used to transfer the dissipated heat to the outside of the setup. Openings in the air vents have a diameter of 3 mm. This provides the system with good air ventilation paths and a proper electromagnetic shielding at few GHz frequency ranges.

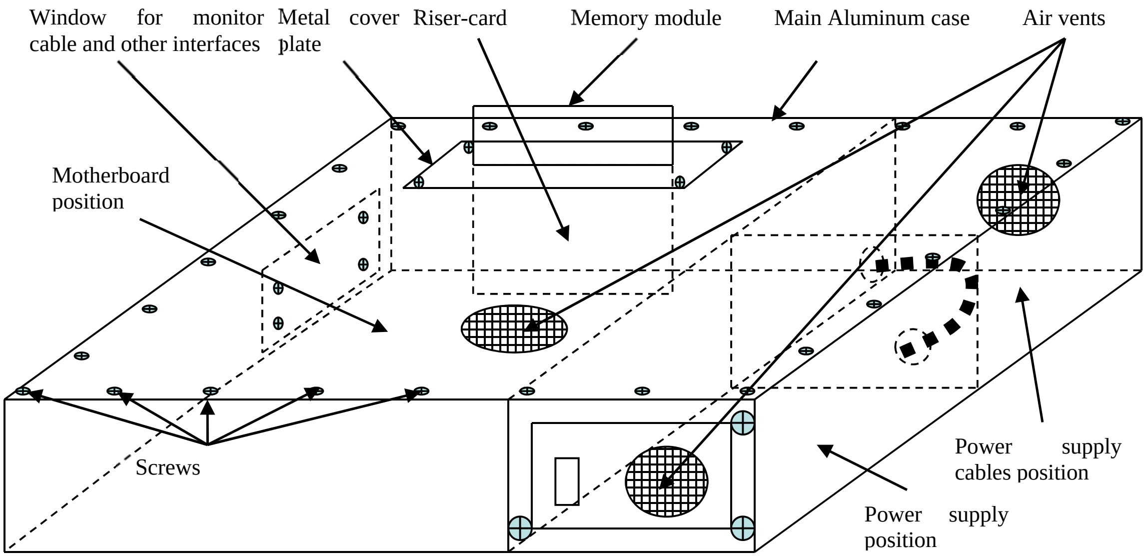

Fig. 3. A scheme of the proposed EMI/EMC measurement setup for DDR1, DDR2, So-DIMM DDR1, and So-DIMM DDR2 un-buffered memory modules.

Fig. 4. The constructed measurement setup ready for measurement.

Fig. 5. Top view of the inside of the constructed measurement setup.

To minimize any common mode radiation on the ac cable during the measurement, a shielded cable which is earthed to the main case is used. Fig. 4 shows the realized measurement setup prepared for radiated EMI. In Fig. 5 the top cover plate of the main case is removed to give a better view of the setup.

4. The EMI Test Results

The radiated EMI tests in this work are done according to the European standard for emission limits of EN 55022 at a certified measurement lab. The details regarding the measurement equipments and conditions are given in the reference [8]. Although this section covers only the results of unbuffered DDR modules, as mentioned above, the setup is capable of performing unbuffered So-DIMM test as well. The clock frequency for the DDR1 and DDR2 modules were 133 MHz and 266 MHz, respectively. In order to investigate the measurement setup systematically different tests are done and presented in this section. The frequency range of interest in this evaluation is limited to 1 GHZ.

Before performing any test, to have a fair evaluation, the background EMI noise in the blank semianechoic chamber should be known. The second step is to confirm that the setup generate no considerable radiated emission from the common mode current on the surface of the main aluminium shielding case. For this purpose a metal cover plate with no slot is used to fully close the setup and during the test the system is running using an unbuffered DDR2 module inside the EMI test setup. The results of these two tests are presented in Fig. 6 and confirm no considerable self radiated emission from the test setup.

Another question raised is related to the radiated emissions of the 3 mm wide slot in the metal cover plate and the riser-card connector. At this stage, in addition to the DDR2 module inside the test setup, a metal cover plate with a slot for DDR2 modules and a DDR2 riser-card are used for the interference radiation tests. Fig. 7 shows the results and compared them with that of the fully closed test setup in Fig. 6. Regarding the results it can be easily understood that shielding at the slot which used for DDR2 riser-card is properly done.

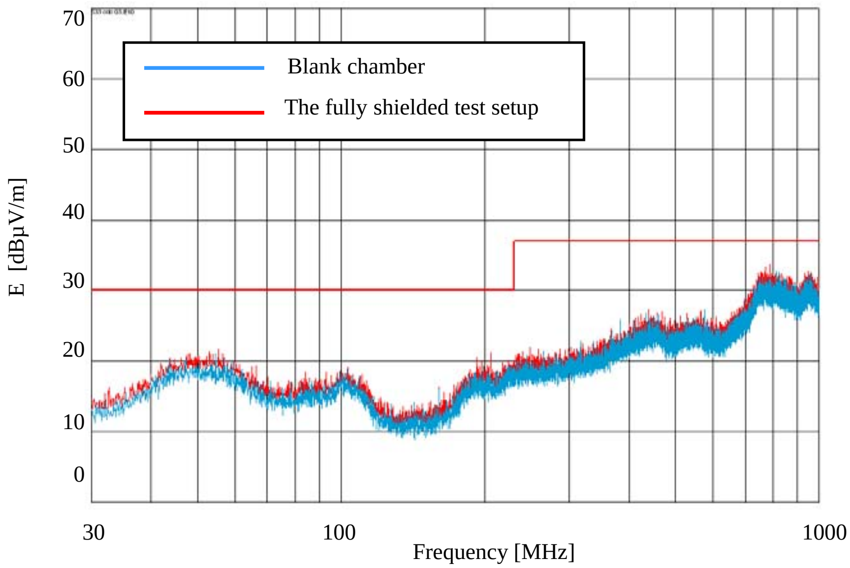

Fig. 6. Measured radiated emissions; (a) blank semi-anechoic chamber, (b) the fully shielded EMI test setup.

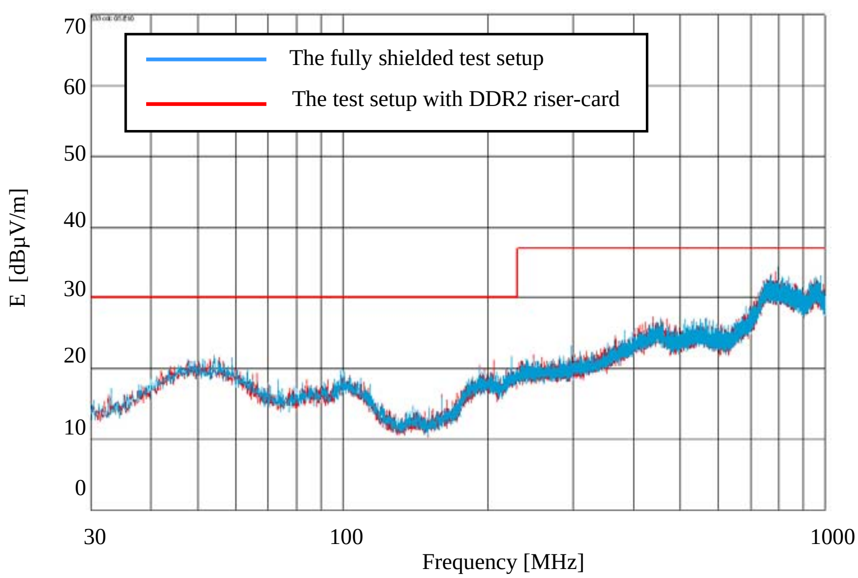

Fig. 7. Measured radiated emissions, (a) the fully shielded EMI test setup, (b) the EMI test setup with only DDR2 riser-card placed in the slot.

Fig. 8 illustrates the interference radiation test for the un-buffered DDR2 using the new EMI measurement setup. The measured EMI is just emitted from DRAM module and the first, the second and the third harmonies of the clock frequency (266 MHz) are easily recognized. It should be noted that some EMI/EMC failed modules are intentionally prepared for this investigation to present a better understanding of the test setup. In order to present the advantages of using such a test setup and its robustness in cancelling the undesired measured emissions from the rest of the system, the same measurement with an open motherboard (with no shielding case) is performed and the result is compared with that of DDR2 with the new shielded measurement setup, see Fig. 9. The emission of the open test system at frequencies between 60 MHz to 130 MHz are mostly related to the dc power-supply system and cables and can be suppressed by using several EMI ferrite filters on the cables. In this measurement even by implementing three EMI ferrite filters still the EMI at these frequency ranges is higher than the EMI standard limit of 30 dBµV/m.

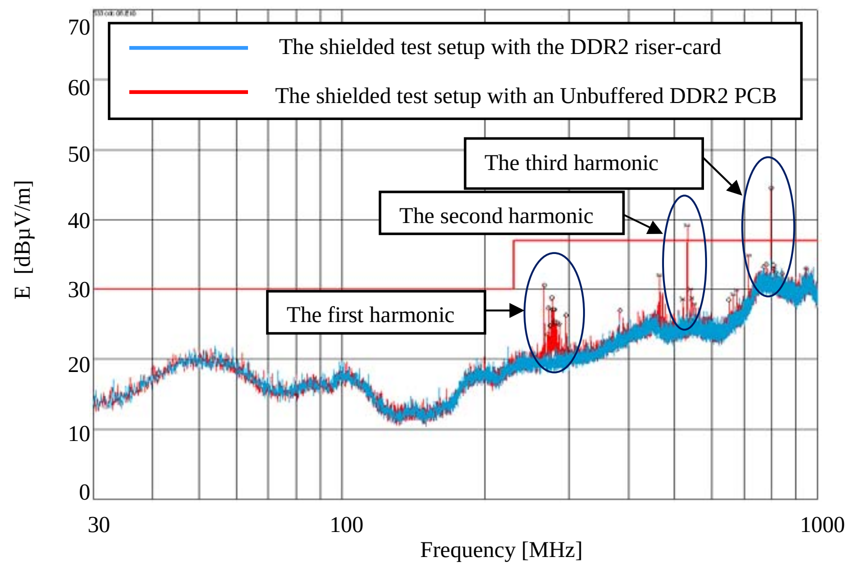

Fig. 8. Measured radiated emissions, (a) the shielded EMI test setup only with the DDR2 riser-card, (b) the shielded EMI test setup with the DDR2 riser-card and an un-buffered DRR2 PCB.

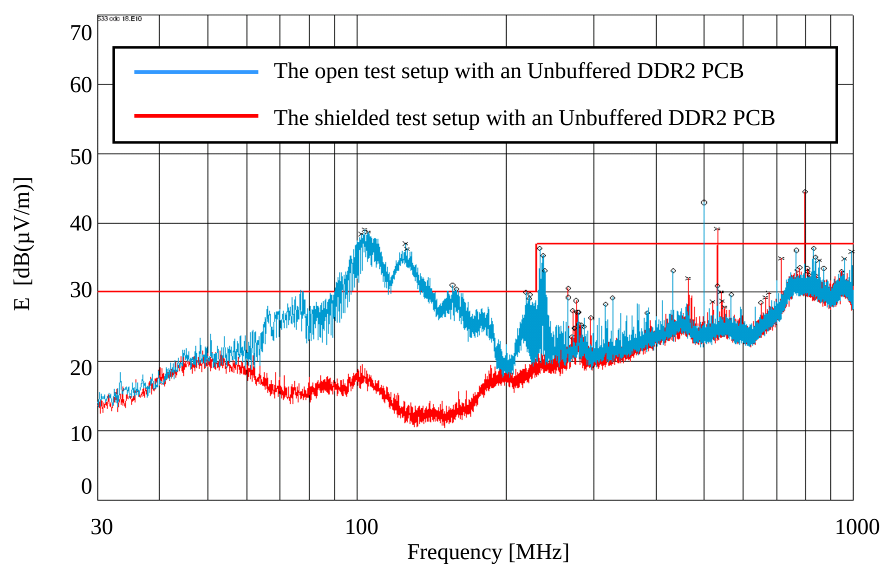

Fig. 9. Measured radiated emissions, (a) the shielded EMI test setup with DDR2 riser-card and an un-buffered DDR2 PCB, (b) the Open EMI test setup with an un-buffered DDR2 PCB.

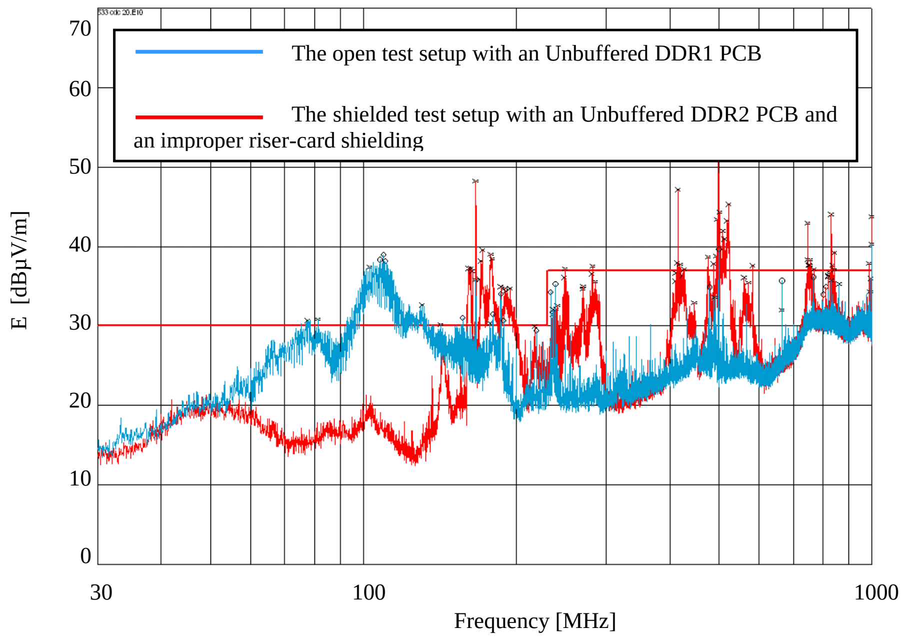

Fig. 10. Measured radiated emissions, (a) the open EMI test setup with an un-buffered DDR1 PCB, (b) the shielded EMI test setup with the DDR1 riser

Another important point is that the EMI information of the memory PCB under test is lost in the measurement with the open board system. This happens because of two reasons: the first is that there are stronger radiated emissions from the rest of the system and they easily cover the radiation peaks from the memory module (see the measured EMI of the DDR2 module with the open system at frequencies around 230 MHz). The second is that the radiations from the memory module are influenced by the nonlinear environment of the open system or they are easily modulated by other parts radiation and are transferred to other frequencies. This can be also seen in the measured results in Fig. 9. The EMI peak at the second harmony of the DRAM clock frequency (533 MHz) is easily distinguishable from the measured data of the DDR2 module with the shielded system; but it seems this EMI peak for the open setup is influenced by the system and transferred to a lower frequency of 500 MHz.

It is of outmost importance to prevent any improper grounding and shielding in the test setup construction. Such mistakes may cause very high radiated emissions which make proper EMI tests impossible. To have a feeling about such problems, the DDR1 memory module is measured with both open and shielded systems. In the open setup measurement no riser-card is used but in the shielded setup test a riser-card is used which is 1 cm taller than the main shielding case and is out of the case by 1 cm. Both measured results are presented in Fig. 10. The closed setup has suppressed the radiated emissions from the power-supply system and cables, however much higher unwanted emissions have been induced by imperfect shielding at the slot provided for the riser-card.

5. Conclusion

A new measurement setup for radiated emission test of un-buffered memory module was introduced and validated by systematic numbers of tests in a semi-anechoic chamber at a certified test lab. The measurements testify that the new shielded setup is very useful in EMI/EMC investigation of the memory modules and separate the radiated EMI of the memory PCB from that of the rest of the system, thus providing useful information about the EMI of the memory modules under test. Further, improper setup construction aspects are discussed and investigated experimentally. The proposed test setup can be constructed and implemented for other types of memory modules.

Acknowledgment

The author would like to thank Mr. S. Muff, Mr. U. Brandt, Mr. A. Motamedi, and Dr. M. Gospodinova from Qimonda AG for their support and useful discussions.

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Mojtaba Joodaki was born in Khorram Abad, Iran in 1970. He received his B.S. and M.Sc. in electrical and electronic engineering from Iran Science and Technology University in 1994 and Tarbiat Modarres University, Tehran, Iran, in 1997 and his Ph.D. degree in electrical engineering from Kassel University, Kassel, Germany, in 2002, respectively. He joined ATMEL Germany GmbH, Heilbronn, Germany as a device engineer in 2002. There, he was working on technology development, modeling and characterization of Si and SiGe-based devices for RF applications. In April 2005, he joined Infineon Technologies AG in Munich, Germany as a development engineer, where he was responsible for EMI/EMC of memory modules. In his last industrial position, from Oct. 2006 till July 2009, he was a device engineer at Qimonda GmbH, Dresden, Germany, involved in developing nano-transistor for DRAM products. Then, he started working as a visiting scientist and lecturer at the Institute of Nanostructure Technologies and Analytics (INA) at Kassel University, where he defended his Habilitation dissertation in April 2011. Since Sept. 2010, he has been with the Department of Electrical Engineering, Ferdowsi University of Mashhad, Mashhad, Iran, where he was an Assistant Professor and became an Associate Professor in Nov. 2011.

Amir Attar received the B.Eng. degree in robotics and automation engineering from Shahrood University of Technology in 2012 and the M.Sc. in electronics engineering from Ferdowsi University of Mashhad. He has joined the EMC lab. of Electrical Engineering Department of Ferdowsi University of Mashhad since 2013. His main area of interests is Electromagnetic compatibility, high frequency electronic, and metamaterial structures engineering.