

# Chapter 1

## Introduction



*I have not failed. I've just found 10'000 ways that won't work.*

—Thomas A. Edison

### 1.1 What Is EMC?

*Electromagnetic compatibility (EMC)* is an established discipline within the field of electrical and electronics engineering. EMC is the ability of equipment or a system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment [1]. In other words, each device must have a certain immunity against electromagnetic disturbances, and on the other hand, each device must keep its own electromagnetic emissions low enough to not disturb other devices in its environment (Fig. 1.1).

### 1.2 EMC vs. EMI

*EMI* stands for *electromagnetic interference* and is often mixed up with EMC. EMI means that one electronic device A is causing disturbance to another electronic device B, which is in the surrounding of device A.

What is the difference between EMC and EMI? Now, an EMC-compliant product has to be tested on EMI during its development. For an EMC-compliant product, EMI should not happen anymore. This is because EMC-compliant products proved their electromagnetic immunity to be high enough and their electromagnetic emission to be low enough to work seamlessly in its predefined environment.

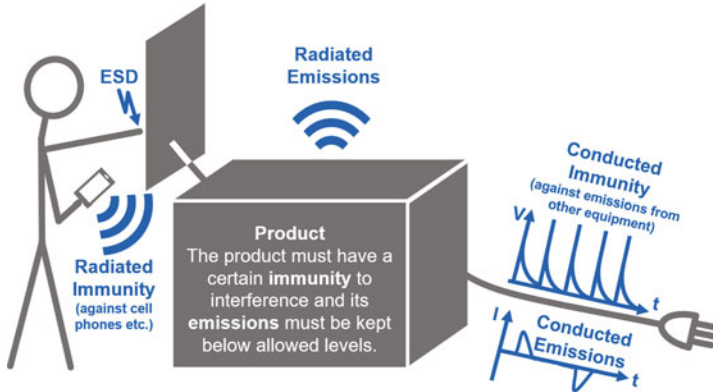


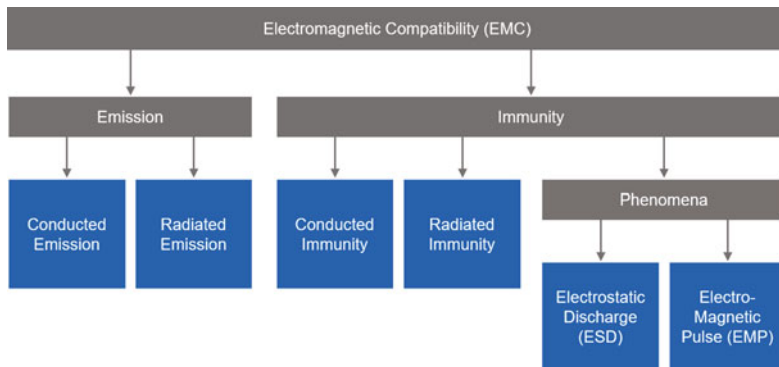
Fig. 1.1 How an EMC design engineer sees a product

### 1.3 Why Is EMC Important?

EMC-compliant products reduce the risk of undesired interference and disturbances. However, why is that so important? EMC is important because interference and disturbances of electrical equipment can seriously harm people, infrastructure, and the environment. For example, in 1992, a woman died because the heart machine of the ambulance shut down every time the technicians turned on their radio transmitter to ask for advice [12]. Another example is the explosion of the Texaco refinery in Milford Haven UK, on the 24th of July 1994, which was caused by an electrical storm giving rise to power surges which tripped out a number of pump motors while leaving others running. The explosion led to 26 people being sustainably injured and damage of £48 million [12]. These are just two of numerous examples and show us that taking care of EMC-compliant design is not just a necessity for selling products; it means a safer world with reliable products and satisfied customers.

### 1.4 EMC Terms and Definitions

The discipline of EMC can primarily be divided into the subjects of *emission* and *immunity* (or *susceptibility*). Figure 1.2 shows the most important terms and definitions in EMC. Other EMC abbreviations and acronyms can be found in chapter “Acronyms” in the front matter of this book on page xxiii.



**Fig. 1.2** EMC terms and definitions

### 1.4.1 Emission

It is distinguished between *conducted emissions* (CE) and *radiated emissions* (RE).

- **Conducted emissions.** Conducted emissions are measured at cables that are connected to the equipment under test (EUT). For commercial and industrial electrical/electronic equipment, it is distinguished between different emission aspects:
  - **RF conducted emissions.** Goal: prevent connected cables from radiating and avoid the interference of connected equipment. The frequency range of the RF emission measurements for commercial and industrial products goes from 150 kHz to 30 MHz (CISPR 32 [2], FCC 47 CFR Part 15 [3]). However, the frequency range depends on the industry and may be as wide as from 30 Hz to 40 GHz for defense and military products (MIL-STD-461G [13]).
  - **Harmonics.** Goal: limitation of harmonic currents injected into the public mains supply system. The mains supply input current of many devices and machines is often not a harmonic sine wave.
  - **Flicker.** Goal: limitation of voltage changes, voltage fluctuations, and flicker in public low-voltage supply systems. *Flicker* is the impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time [1].
- **RF radiated emissions.** Goal: prevent disturbance of nearby electrical and electromechanical equipment. Radiated emissions are measured in an anechoic or semi-anechoic chamber or at an open area test site (OATS). For commercial and industrial products, the frequency range of radiated emission measurements goes from 30 MHz to 6 GHz (CISPR 32 [2]) or 30 MHz up to 40 GHz (FCC 47 CFR Part 15 [3]). However, the frequency range depends on the industry and may be as wide as from 10 kHz to 40 GHz for defense and military products (MIL-STD-461G [13]).

## 1.4.2 Immunity

It is distinguished between conducted immunity/susceptibility (CI, CS), radiated immunity/susceptibility (RI, RS), and immunity against phenomena like electrostatic discharge (ESD) or electromagnetic pulses (EMP).

- **Conducted immunity.** Conducted immunity tests are performed at cables that are connected to the EUT. For commercial and industrial electrical/electronic equipment, it is distinguished between different immunity aspects:
  - **RF conducted immunity.** Goal: functional immunity to conducted disturbances induced by RF fields. The frequency range of the conducted RF immunity tests for commercial and industrial products goes from 150 kHz to 80 MHz (IEC 61000-4-6 [9]).
  - **EFT.** Goal: functional immunity to repetitive electrical fast transients (EFT, bursts), such as those originating from switching transients (interruption of inductive loads, relay contact bounce, etc.). Test voltages vary from 0.5 kV to 4 kV (IEC 61000-4-4 [8]).
  - **Surge.** Goal: functional immunity to unidirectional surges caused by overvoltages from switching and lightning transients. Test voltages vary from 0.5 kV to 4 kV (IEC 61000-4-5 [11]).
  - **Dips.** Goal: functional immunity to voltage dips, short interruptions, and voltage variations at the power supply ports.
- **Radiated RF field immunity.** Goal: functional immunity to radiated radio-frequency electromagnetic radiation in the far-field (80 MHz to 6 GHz: IEC 61000-4-3 [6]) or in the near-field (26 MHz to 6 GHz: IEC 61000-4-39 [7]).
- **Radiated magnetic field immunity.** Goal: functional immunity to magnetic disturbances at mains power frequencies 50 Hz and 60 Hz (IEC 61000-4-8 [10]) or at wireless charging/inductive power transfer frequencies 9 kHz and 26 MHz (IEC 61000-4-39 [7]).
- **ESD.** Goal: immunity to static electricity discharges, from operators directly and from personnel to adjacent objects. Test voltages vary from 1 kV to 15 kV (IEC 61000-4-2 [5]).
- **EMP.** Goal: protection against electromagnetic pulses (EMP). An EMP is an instantaneous, intense energy field, which can be caused by a nuclear explosion or other pulse-generating devices. If this explosion happens at a high altitude, it is called a HEMP. EMPs are a topic for defense and military applications and not for commercial and industrial products.

## 1.5 Design for EMC

Design for EMC means considering EMC early during product development, not just at the end of the project. If you test your product for EMC just shortly before the product is to be launched, project delays and budget overruns result. Figure 1.3 shows that the later a defect in the product life cycle is fixed, the more expensive it is. Here are some essential points regarding EMC and product development:

- **EMC concept.** You need to define an EMC concept at the very beginning of the development project (before the first hardware is designed). This EMC concept should especially define the following points:
  - **Grounding.** Define a grounding concept for the product (system grounding), the subsystems of the product (intrasystem grounding), and PCBAs (board-level grounding).
  - **Shielding.** Define if and how to shield sensitive circuits and cables (intrasystem and external cables). Define the bonding of the shields.
  - **Filtering.** Define if and how cables and wires (intrasystem and external cables) have to be filtered. Especially consider ESD, EFT, and surge for cables that leave your product. RF-filtering should be considered for every cable.
- **Iterative testing.** It is recommended to test the EMC performance (emission, immunity) at different product development iterations. There are typically four iterations in hardware development projects: breadboard, prototype, pilot, and series. It is good practice to do pre-compliance testing (testing in-house or at a not fully accredited compliance lab) at the prototype stage and fully compliant EMC testing at the later project stages (pilot, series). Pre-compliance EMC testing is an excellent choice to save time and money. Another advantage of in-house EMC testing is the constant improvement of the EMC knowledge of the development team.

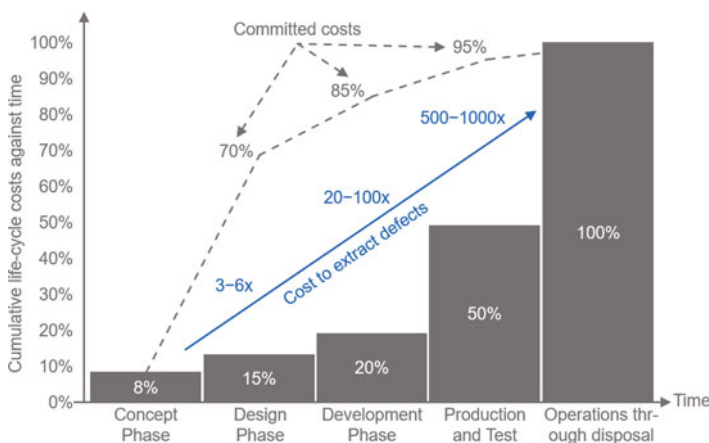


Fig. 1.3 Life cycle costs [4] and the costs of fixing defects at different life cycle stages

## 1.6 Summary

- **EMC.** EMC is the ability of equipment or a system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.
- **EMC tests.** EMC tests can be divided into two categories: emission tests and immunity tests.
- **Coupling paths.** EMI occurs via conduction (connected cables), via radiation (directly from and to a product), or a combination of both.
- **Design for EMC.** Considering EMC design in the early product development stages helps to prevent budget overrun and product launch delays.

## References

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