

## EMC-Education

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### Abstract

The industry needs good EMC engineers, not only for efficient solving the problems, but also for organising EMC management and EMC related products (and systems) development.

For the education of engineers in the EMC domain, we present the following possibilities: University activities, in-house courses for industry and co-ordination between University and Industry.

This paper illustrates an education program for engineers.

*Main program of the EMC-Education must include:* Theory and numerical experiments; Experiments in EMC Labs *and* case studies

### 1. Introduction

#### What is EMC?

- *The ability of a device, equipment or system to function satisfactorily (the equipment is not susceptible to electromagnetic signals that other equipment puts into the environment) in its electromagnetic environment without introducing intolerable electromagnetic disturbances (the emission of electromagnetic signals by the equipment does not cause electromagnetic interference problems*

*in equipment also present) to anything in that environment.*

### 2. EMC Education at University Level

At the University of Applied Sciences Zurich, EMC courses for undergraduate and graduate degrees have been established. Additional to that some research activities exist. The outline of the courses is:

- ***Introduction to EMC***  
Basic EMC definitions, EMC Regulations
- ***Electromagnetic Theory***  
Maxwell's Equation in time and frequency domain. Electromagnetic Waves. Analytical solution methods, numerical solution methods (Finite Difference Method, Finite Element Method, Method of Moments, Monte Carlo Methods) and symbolic methods, Antennas, Wave Guides.
- ***Modelling of Coupling***  
Capacitive Coupling, Inductive Coupling, Resistive Coupling, Radiation

- **Transmission Line and Multiconductor Transmission Line (MTL)**

Modelling of two-wire transmission line. Transmission line parameter. Theory of MTL. Reflection coefficients. Transients. Crosstalk. Field-to-Wire Coupling. Emission of Wires and Cables. Cable Shield Transfer Impedance and Admittance.

- **Grounding and Bonding**

- **Filtering**

- **Shielding**

Shielding Effectiveness, Modelling, Multilayer, Apertures

- **Radiated Emission and Susceptibility**

- **Conducted Emission and Susceptibility**

- **EMC Standards**

- **EMC Tests**

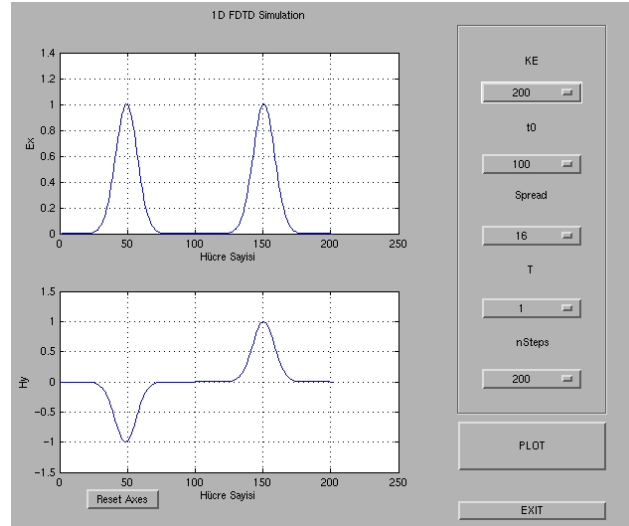
EMC Test Plan, Instrumentation, Test-Set-Up, Anechoic Chamber, Shielded Room, Open Site Measurements

- **EMC Equipment Design**

System, Subsystem and Components

The lecture courses offered as standalone options. Some courses include the use of proprietary software packages to illustrate EMC effects. The use of such software can enable a greater variety of problems to be tackled and more “what if” experiments to be performed than either analysis or conventional measurements allow. The following example illustrates electromagnetic wave propagation using FDTD for 1D.

**Example: Electromagnetic wave propagation using FDTD for 1D MATLAB & GUI**



**3. Research Activities**

The following subjects are actual research activities:

- Symbolic Computation Techniques for Electromagnetics **MAPLE, MACSYMA, MATLAB .....**
- Wavelets for Electromagnetics
- Antennas

The main activities are due to co-operation with the University of SAKARYA – TURKEY and TÜBİTAK.

The following example shows a result of **Symbolic Computation of an aperture Antenna.**

**Example: Symbolic Computation of an aperture Antenna**

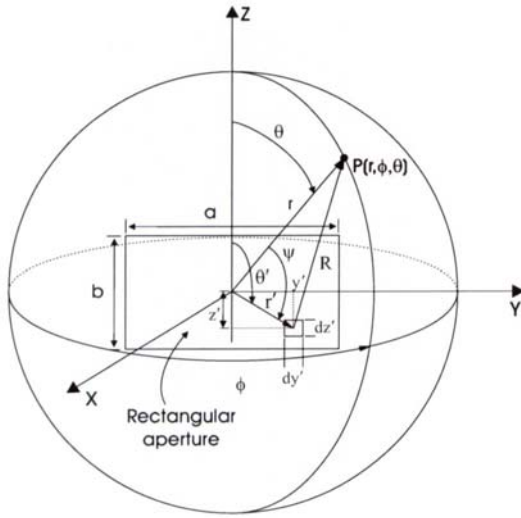


Figure 3.1 Rectangular aperture

A rectangular aperture of finite dimensions can be analyzed in terms of the elemental area of the preceding section. Consider an aperture in the  $x=0$  plane with sides of lengths  $a$  and  $b$  in the  $y$  and  $z$  directions, respectively, as shown in Fig. 3.1. Let the electric field be aligned with the  $y$  axis and the magnetic field be aligned with the  $z$  axis to give a plane wave traveling in the  $x$  direction.

**3.1 Uniformly Illuminated Aperture**

If the aperture is uniformly illuminated, the electric field is constant in amplitude and phase over the aperture. For this case, the electric ( $\mathbf{J} = \mathbf{n} \times \mathbf{H}$ ) and the magnetic ( $\mathbf{M} = -\mathbf{n} \times \mathbf{E}$ ) surface current densities are

C:\Macysma\Macysma2\system\init.lsp being loaded.

Batching the file C:\Macysma\Macysma2\user\mac-init.mac  
Batchload done.

```
(c1) declare([n,le,vh,y,vm,vn,Var,rp,lp,ymax],nonscalar)$
(c2) n:[1,0,0];
(d2) [1, 0, 0]
```

```
(c3) ve:[0,le0,0]; [V/m]
(d3) [0, E0, 0]
(c4) vh:[0,0,le0/20]; [A/m]
(d4) [0, 0, E0/20]
```

The far magnetic field  $\mathbf{H}$  can be obtained as

```
(c15) vh:[0,-%i*k*exp(-%i*k*r)*(V[2]/z0+ln[3]/(4*%pi*r),
        %i*k*exp(-%i*k*r)*(V[2]-V[3]/z0)/(4*%pi*r)]$
(c16) (vh:expand(vh),vh:trigexpand(vh),vh:expand(vh),vh:undistrib(vh)); [A/m]
```

$$0, \frac{i e^{-i k r} \sin\left(\frac{b k \cos(\theta)}{2}\right) \sin\left(\frac{a k \sin(\phi) \sin(\theta)}{2}\right) E_0}{\pi k r \sin(\theta) Z_0}$$

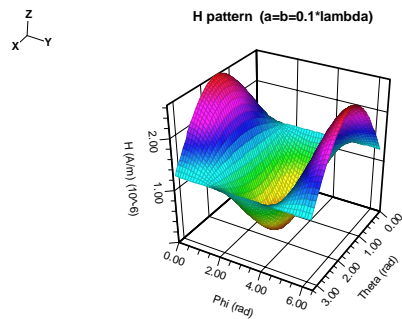
$$\left[ \begin{array}{l} i e^{-i k r} \left( \frac{\cos(\phi)}{\sin(\theta)} + 1 \right) \\ * \sin\left(\frac{b k \cos(\theta)}{2}\right) \\ * \sin\left(\frac{a k \sin(\phi) \sin(\theta)}{2}\right) E_0 \end{array} \right] \frac{1}{\pi k \sin(\phi) r \cos(\theta) Z_0}$$

The magnetic field pattern is

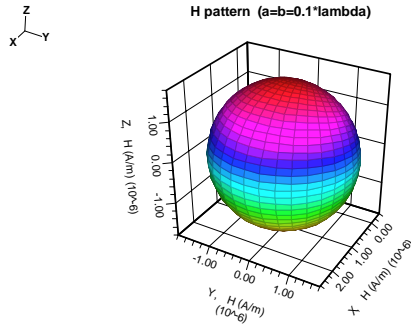
```
(c17) assume(a>0,b>0,lambda>0,le0>0,z0>0,r>0,k>0)$
(c18) (h:sqrt(abs(part(vh,2))^2+abs(part(vh,3))^2),h:trigsimp(h))$
C:\Macysma\Macysma2\share\trigsimp.fas being loaded.
(c19) define(vh(phi,theta),subst(part(h,1,1,1)=(1+cos(phi))*sin(theta))^2,h));
```

$$H(\phi, \theta) := \frac{\left| \cos(\phi) \sin(\theta) + 1 \right| + \left| \sin\left(\frac{b k \cos(\theta)}{2}\right) \right| + \left| \sin\left(\frac{a k \sin(\phi) \sin(\theta)}{2}\right) \right| E_0}{\pi k |\sin(\phi)| r |\cos(\theta)| |\sin(\theta)| Z_0}$$

```
(c20) (lambda:1, le0:1, z0:120*%pi, r:10*lambda, k:2*%pi/lambda)$
(c21) (a:.1*lambda, b:.1*lambda)$
plot3d(vh(phi,theta),theta,.0001,%pi-.0001,phi,.0001,2*%pi-.0001,
"Theta (rad)","Phi (rad)","H pattern (a=b=0.1*lambda)",
zlabel:"H (A/m)",plotnum0=50,plotnum1=50,plot_style=scientific3d$
```



```
block([equalscale:true,plotnum0:50,plotnum1:50,plot_tessellation:4],
plotsurf([vh(phi,th)*sin(th)*cos(phi),vh(phi,th)*sin(th)*sin(phi),
vh(phi,th)*cos(th)],th,.0001,%pi-.0001,ph,0.0001,2*%pi-.0001),
xlabel:"X, H (A/m)",ylabel:"Y, H (A/m)",zlabel:"Z, H (A/m)",
title:"H pattern (a=b=0.1*lambda)",plot_style=scientific3d$
```



#### 4. Experimental Activities

A new EMC laboratory has been established at the Technopark Zurich. The EMC laboratory is used for teaching and research and development. It is an anechoic chamber, with hybrid shielding. It can be used for 3 m standards measurements. The frequency range is 30 MHz – 18 GHz. The laboratory has all necessary EMC equipments and accessories, sources, antennas and PC based Software.

Many include laboratory experiments illustrate isolated EMC phenomena and effects.

The EMC course provides for EMC laboratory work involving the following measurements:

- Conducted emission and susceptibility
- Radiated emission and susceptibility
- Crosstalk
- Transfer impedance of shielded cables
- Electrostatic discharge
- S-Parameters
- VSWR Measurements
- Antenna Characteristics

The IEEE EMC Society Education Committee has published a handbook of EMC experiments to use only common laboratory equipment. This materials are very useful for EMC experiments for students.

#### 5. Co-ordination between University and Industry

*(University of Applied Sciences and EURO EMC SERVICE)*

The University of Applied Sciences Zurich makes common EMC-course organisations with the EURO EMC SERVICE also common R&D-Projects.

This course has four modules:

##### **Modul A: EMC Standards, EMC Specifications**

- overview of national, international and European EMC standards
- European council (EMC) directives
- national EMC laws, transitional norms
- import, export considerations, CE mark and international competition
- product liability and quality assurance
- metrology, accreditation, certification, timing, budgets, marketing and sales
- optimum EMC management and personnel

##### **Modul B: Digital Techniques (Theory and Experiments)**

- practical problems and solutions
- EMI emissions from digital electronics
- conducted and radiated effects - coupling path
- predicting print emissions
- prudent selection of logic families
- real world components
- case studies for optimal circuit design
- print layout and design rules
- protection of power supply, input and output
- case studies: microprocessors, multilayer and emission control by ferrite filters
- topology of zoning, filter design
- precompliance tests
- project management and costs

## Modul C: Analog Techniques (Theory and Experiments)

- actual problems, trends and solutions
- sources of EM-Interference
- RF characteristics of electronic components not stated by manufacturers , e.g. OP-amps
- conducted EMI protection - design
- input/output protection
- power supply DC/AC
- layout of prints, case studies, check lists and costs
- precompliance testing
- sudden malfunctions in modern sensitive electronic systems and equipment, EMI accidents, symptomatic of EMI phenomena
- effective mitigation techniques

## Modul D : EMC Equipment and Systems ( Case Study)

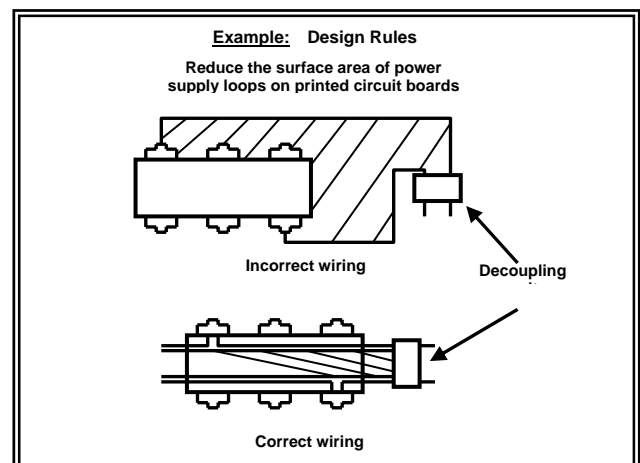
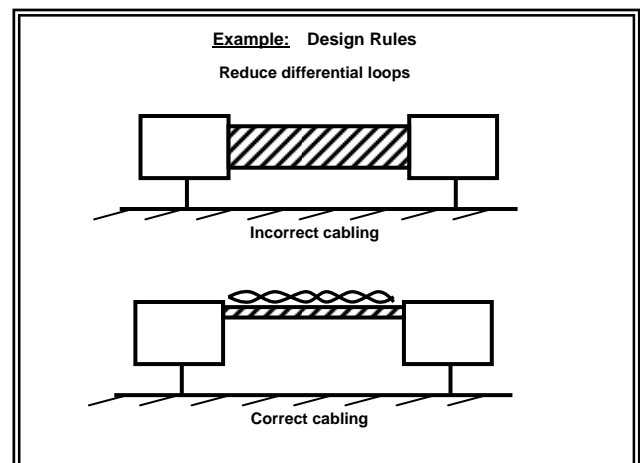
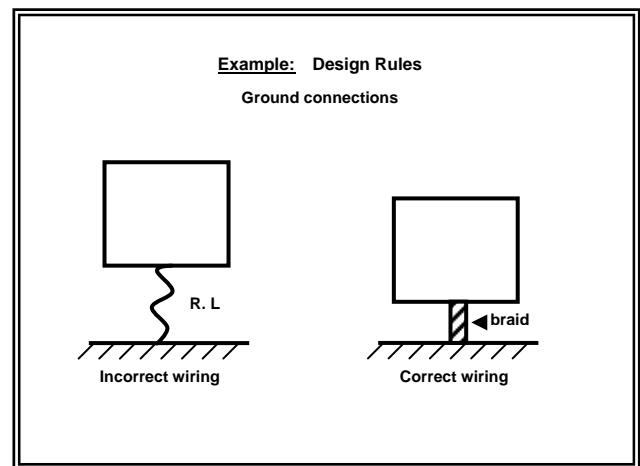
- M threat level impact on electronic equipment and systems, environment
- zoning concept for global protection, cabling grounding, bonding, filtering and shielding
- coupling effects between EM sources and victims
- protection principles and mitigation for conducted and radiated EMI
- proven design concepts, system integration (boxes, system, OEM etc.) and design rules
- optimized test methods for development and acceptance testing
- awareness 'Think EMC' from the beginning of the project, case studies and check lists
- hints for successful EMC project management
- technical and organizational help for all aspects of electromagnetic effect engineering

*For those engineers working in industry who do not have time for or access to university course provide a solution. They can learn all basics at the in-house courses. The above program will*

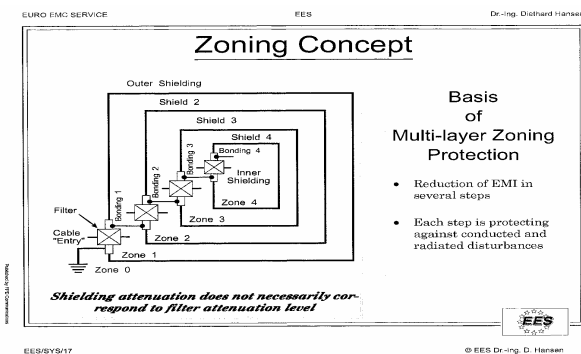
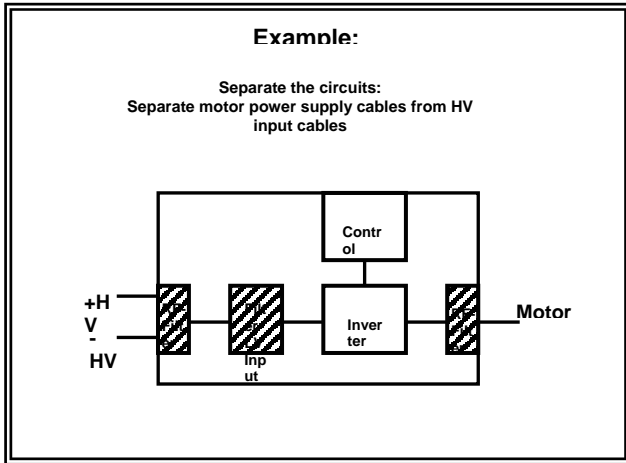
*be implemented but experiments are limited due to the equipment facilities.*

## Examples

In the following, some design rules for circuits, equipment and systems are illustrated.



[7] Mardiguan M. Electrostatic Discharge, Inc. Gainesville 1986



## 6. Conclusions

An EMC-Education must include both Theory and Experiments. It is very important to realize in-house courses for industry. It is necessary to care a continuous co-ordination between University and Industry.

## References

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