Introduction to Waveguides, Antennas, and Electromagnetic Compatibilty

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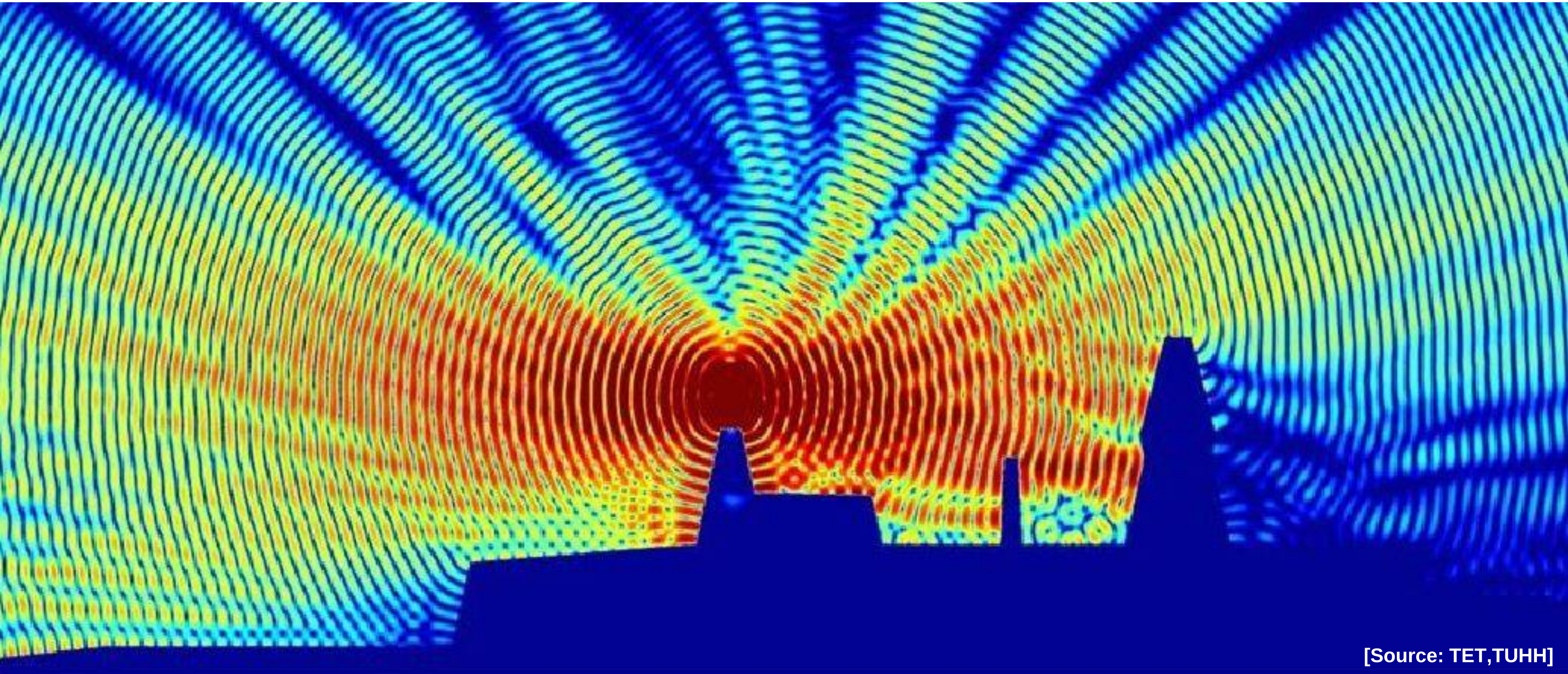
Course Overview, Summer Term 2021



[Source: TET,TUHH]

What this is About

This course is intended as an introduction to:

Electromagnetic Wave Propagation,
Guiding, Sending, and Receiving
as well as
Electromagnetic Compatibility (EMC)

that does not require to have a background in electrical engineering. It will be useful for engineers that face the technical challenge of transmitting high frequency / high bandwidth data and / or EMC problems in e.g. medical, automotive, or avionic applications. Both circuit and field concepts of electromagnetic wave propagation will be introduced. Relevant physics will be reviewed.

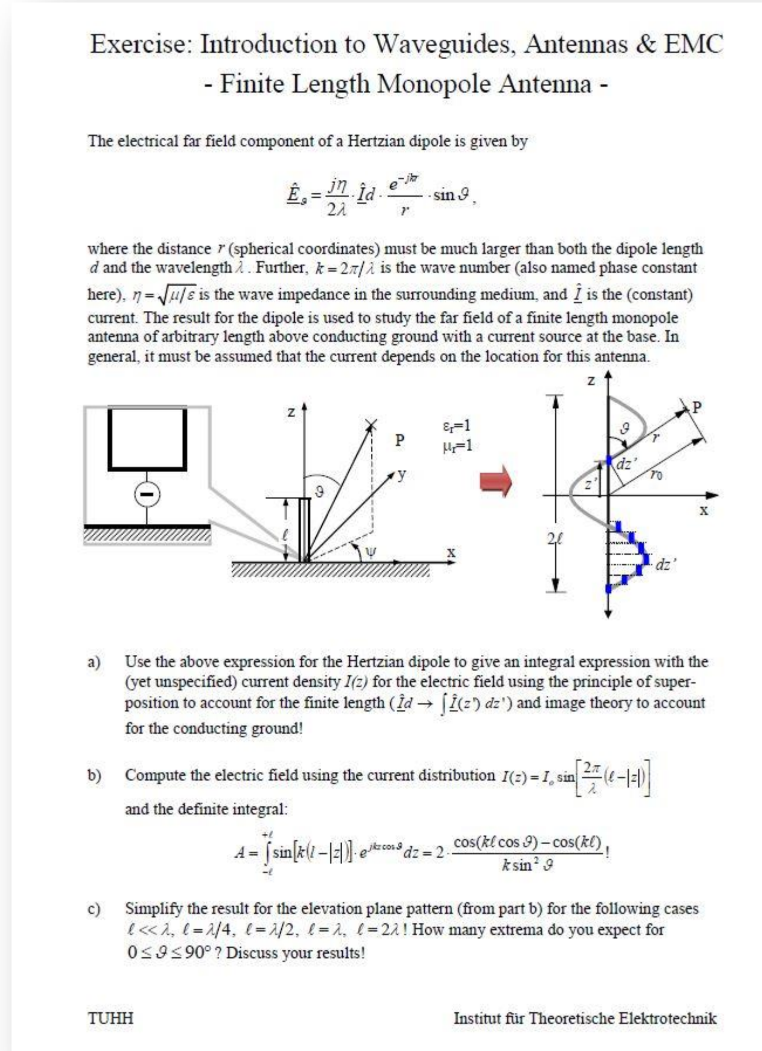
Curriculum

Week	Topics	Lecture Notes
1	Course Overview, Introduction to Waveguides & Antennas, Introduction to EMC	[00] – [02]
2	Basic Time-Harmonic Circuit Analysis, Power and Power Transfer	[03] – [04]
3	Quality Factors, Resonant Circuits, Matching Circuits	[05] – [07]
4	Two-Port Network Parameters, Transmission Line Basics, Telegrapher‘s Equations and Solutions	[08] – [10]
5	Transmission Lines with Terminations, Impedance Transformation of Loads	[11] – [12]
6	Transmission Lines with Junctions, Transmission Lines in Time Domain	[13] – [14]
7	Time Domain Reflectometry, Basics of Waveguide Theory, Electrical Waveguide Design	[15] – [17]
8	Plane Electromagnetic Waves, Radiation and Radiation Fields	[18] – [19]
9	Wire Antennas & Antenna Parameters, Wireless Communication	[20] – [21]
10	Further Antenna Types & Antenna Arrays, Modeling for EMC, Noise Sources	[22] – [24]
11	EMC Standards & Organizations, Galvanic, Inductive, Capacitive Coupling,	[25] – [26]
12	Radiative Coupling, Transmission Line Coupling	[27] – [38]
13	Overview of EMI Control Techniques, Signal Balancing and Filtering, Grounding and Decoupling	[29] – [31]
14	Shielding, Wrapping Up	[32] – [33]

Exercises

All exercises are „just in time“, i.e. students shall actively work on the task during the exercise under the guidance of the teaching assistant. Working and discussing in groups is highly desired.

Solution to the tasks will be provided on Stud.IP after the exercise has taken place.



Exercise: Introduction to Waveguides, Antennas & EMC

- Finite Length Monopole Antenna -

The electrical far field component of a Hertzian dipole is given by

$$\underline{\hat{E}}_\vartheta = \frac{j\eta}{2\lambda} \cdot \underline{\hat{I}} d \cdot \frac{e^{-jkr}}{r} \cdot \sin\vartheta ,$$

where the distance r (spherical coordinates) must be much larger than both the dipole length d and the wavelength λ. Further, $k = 2\pi/\lambda$ is the wave number (also named phase constant here), $\eta = \sqrt{\mu/\varepsilon}$ is the wave impedance in the surrounding medium, and $\underline{\hat{I}}$ is the (constant) current. The result for the dipole is used to study the far field of a finite length monopole antenna of arbitrary length above conducting ground with a current source at the base. In general, it must be assumed that the current depends on the location for this antenna.

a) Use the above expression for the Hertzian dipole to give an integral expression with the (yet unspecified) current density $I(z)$ for the electric field using the principle of super-position to account for the finite length ($\underline{\hat{I}} d \rightarrow \int \underline{\hat{I}}(z')\, dz'$) and image theory to account for the conducting ground!

b) Compute the electric field using the current distribution $I(z) = I_o \sin\left[\frac{2\pi}{\lambda}(\ell - |z|)\right]$ and the definite integral:

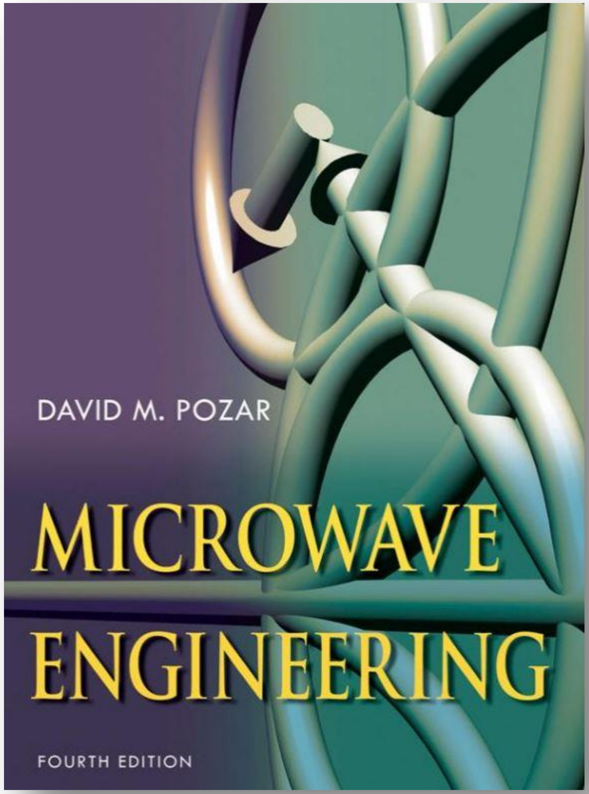
$$A = \int_{-\ell}^{+\ell} \sin\left[k(l - |z|)\right] \cdot e^{jkz\cos\vartheta} dz = 2 \cdot \frac{\cos(k\ell\cos\vartheta) - \cos(k\ell)}{k \sin^2\vartheta} !$$

c) Simplify the result for the elevation plane pattern (from part b) for the following cases $\ell << \lambda,\ \ell = \lambda/4,\ \ell = \lambda/2,\ \ell = \lambda,\ \ell = 2\lambda$! How many extrema do you expect for $0 \le \vartheta \le 90°$? Discuss your results!

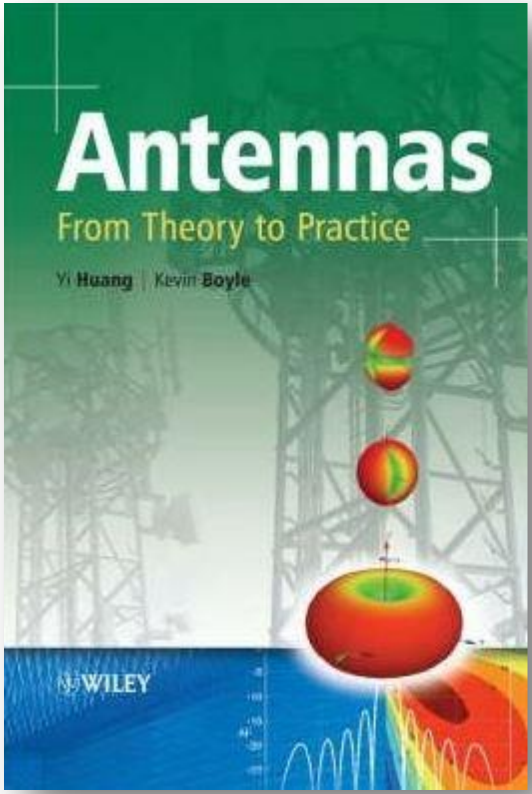
TUHH Institut für Theoretische Elektrotechnik

English Literature

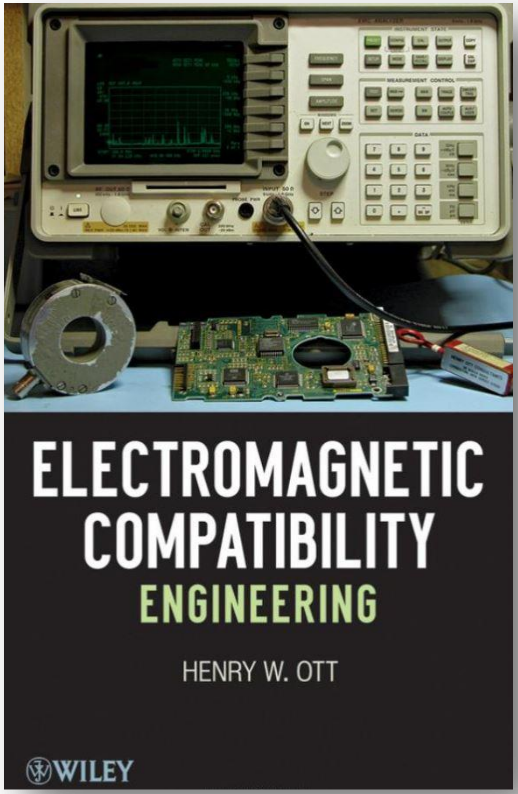
Useful references in English (available at TUHH):



[Source: www.amazon.com]



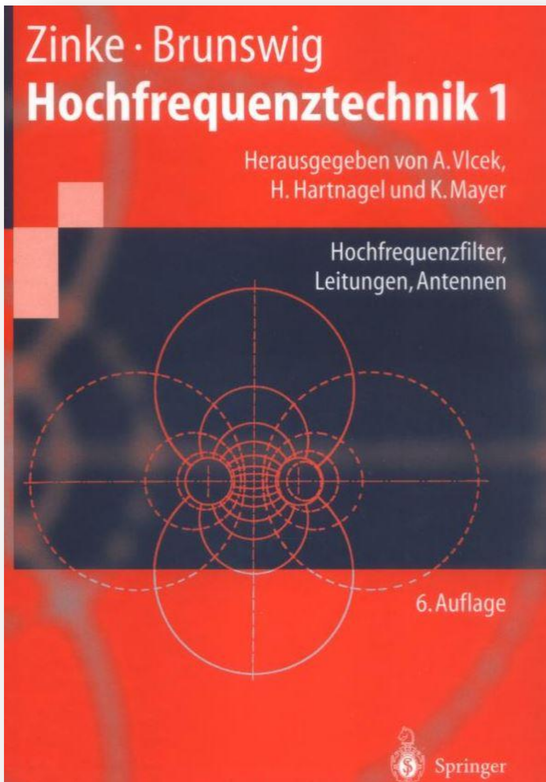
[Source: www.amazon.com]



[Source: www.amazon.com]

German Literature

Useful references in German (available at TUHH):



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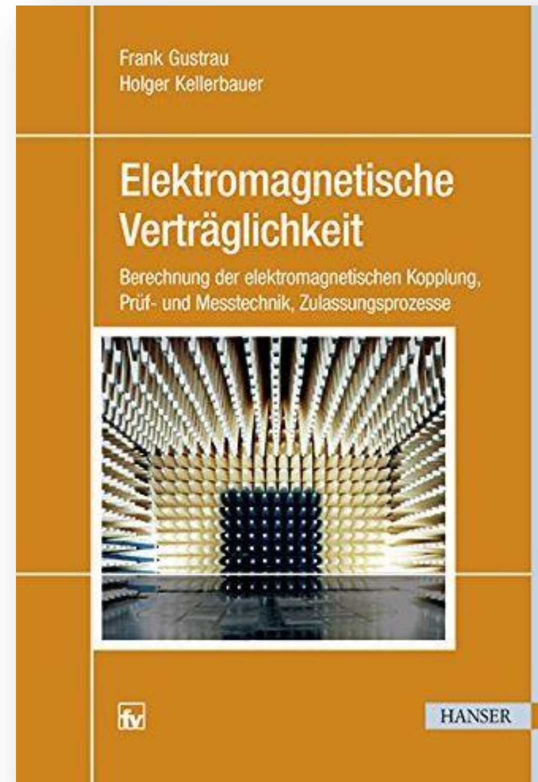

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