Electromagnetics:

Introduction

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Course book: Field and Wave Electromagnetics

(D. K. Cheng, 2nd ed., Addison-Wesley, 1989)

- What you have learnt (I presume):
  - *Chap. 1. The Electromagnetic Model*
  - *Chap. 2. Vector Analysis*
  - *Chap. 3. Static Electric Fields*
  - *Chap. 4. Solution of Electrostatic Problems*
  - *Chap. 5. Steady Electric Currents*
  - *Chap. 6. Static Magnetic Fields*

This is all you need to learn!

- *What you will be learning:*
  - *Chap. 7. Time-Varying Fields and Maxwell's Equations*
  - *Chap. 8. Plane Electromagnetic Waves*
  - *Chap. 10. Waveguides and Cavity Resonators (incl. Optical Fibers)*
  - *Chap. 9. Theory and Applications of Transmission Lines*
  - *Chap. 11. Antennas and Radiating Systems*

Maxwell's Equations

$$\nabla \times \mathbf{E} + \frac{\partial \mathbf{B}}{\partial t} = 0$$

Faraday's law

"Displacement current"

$$\nabla \times \mathbf{H} - \boxed{\frac{\partial \mathbf{D}}{\partial t}} = \mathbf{J}$$

Ampère's law

$$\nabla \cdot \mathbf{D} = \rho$$

Gauss's law

$$\nabla \cdot \mathbf{B} = 0$$

No free magnetic monopole (?)

$$\mathbf{D} = \varepsilon \mathbf{E} = \varepsilon_0 \mathbf{E} + \mathbf{P}$$

$$\mathbf{H} = \frac{1}{\mu} \mathbf{B} = \frac{1}{\mu_0} \mathbf{B} - \mathbf{M}$$

Constitutive relations

Findings of 19th century!!

Electromagnetic Waves

Wave equations:

$$\nabla^2\mathbf{E}-\mu\varepsilon\frac{\partial^2\mathbf{E}}{\partial t^2}=0,\ \nabla^2\mathbf{H}-\mu\varepsilon\frac{\partial^2\mathbf{H}}{\partial t^2}=0$$

(Homogeneous and no source)

$$e.g.\ \ f(x,t)=f(x-\delta x,t-\delta t)$$

Plane wave:

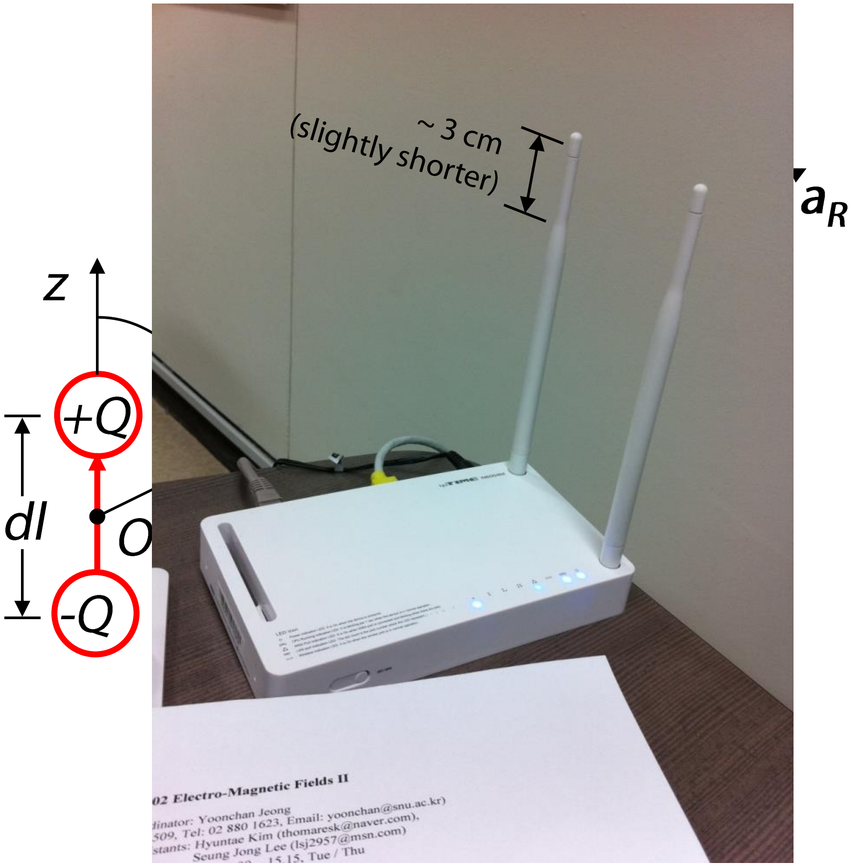
$$\psi=e^{i(\omega t-\mathbf{k}\cdot\mathbf{r})},\quad |\mathbf{k}|=\omega\sqrt{\mu\varepsilon}$$

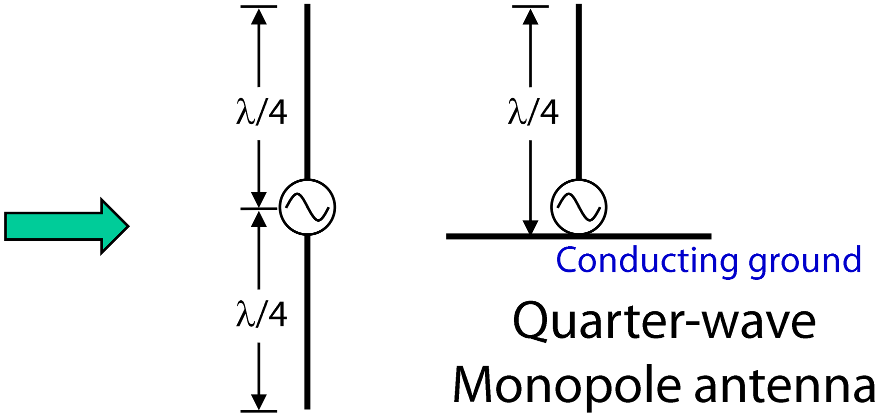
Phase velocity:

$$\omega t-\mathbf{k}\cdot\mathbf{r}=\text{constant},\quad \mathrm{u}_{\mathrm{p}}=\frac{\omega}{k}=\frac{1}{\sqrt{\mu\varepsilon}},$$

$$c=\frac{1}{\sqrt{\mu_o\varepsilon_o}}=2.997930\ \times10^8\,m/s$$

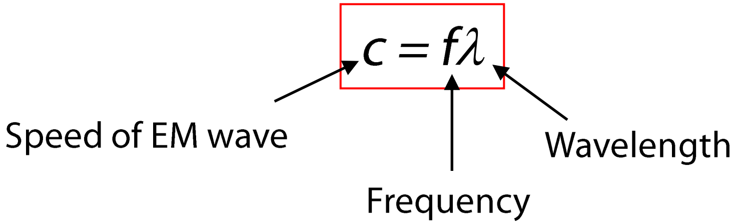
Time-Varying (Oscillating) Fields: Electromagnetic Waves (RF/MW)





Half-wave
dipole antenna

Quarter-wave
Monopole antenna



$c = f\lambda$

Speed of EM wave

Frequency

Wavelength

WiFi router (f = 2.4 GHz)

$\lambda/4 = 3\times10^8 / 2.4\times10^9 / 4 \approx 0.031$ m

Conclusions

- Electromagnetics, simple or complicated?
  - Only 4 independent equations!
  - *Maybe, even easier than "Introduction to electromagnetism with practice"!*
- A lot of exciting things to do if you've made it through!
  - Electronics (Wired/Wireless communications, high-speed circuits, etc.)
  - Photonics (Optical communications, lasers, sensors, displays, bio-medicine, energy, nano/meta materials, etc.)
  - Quantum Electrodynamics (Bose-Einstein condensation, superradiance, etc.)