Lecture 1

Part 1: Radiation Processes

Key ref: Rybicki & Lightman (1979)

Brief review of classical E&M. Work in Gaussian/cgs units to be compatible w/ most books. Thus, in vacuum $\epsilon_0 = \mu_0 = 1$ & $\vec{E}$ & $\vec{B}$ have same units (Gauss)

M.E. in vacuum

$$\vec{\nabla} \cdot \vec{E} = 0 \qquad \vec{\nabla} \cdot \vec{B} = 0$$

$$\vec{\nabla} \times \vec{E} = -\frac{1}{c}\frac{\partial \vec{B}}{\partial t} \qquad \vec{\nabla} \times \vec{B} = \frac{1}{c}\frac{\partial \vec{E}}{\partial t}$$

From these we get the wave equations:

$$\nabla^2 \vec{E} - \frac{1}{c^2}\frac{\partial^2 \vec{E}}{\partial t^2} = 0 \quad \& \quad \nabla^2 \vec{B} - \frac{1}{c^2}\frac{\partial^2 \vec{B}}{\partial t^2} = 0$$

With plane wave solutions:

$$\vec{E}(\vec{r},t) = \vec{E}_0 e^{i(\omega t - \vec{k}\cdot\vec{r})}$$

$$\& \quad \vec{B}(\vec{r},t) = \vec{B}_0 e^{i(\omega t - \vec{k}\cdot\vec{r})}$$

$\vec{k}$ is the wave vector: $|\vec{k}| = \frac{2\pi}{\lambda}$ & $\omega = 2\pi\nu$

and points in the direction of

and $\lambda\nu = c$

propogation...

M.E. tells us that $\vec{E}_0$; $\vec{B}_0$; $\vec{K}$ are all mutually perpendicular and $|\vec{E}_0| = |\vec{B}_0|$

The electric ; magnetic fields contain energy w/ densities $U_E = \dfrac{E^2}{8\pi}$; $U_B = \dfrac{B^2}{8\pi}$. Thus propogating $\vec{E}$; $\vec{B}$ fields in radiation carry energy with a flux [energy/area/time] given by the Poynting vector

$$\vec{S} = \frac{c}{4\pi}\left(\vec{E}\times\vec{B}\right).$$

For plane waves, $\langle S\rangle = \dfrac{c}{4\pi}\langle|\vec{E}\times\vec{B}|\rangle = \dfrac{c}{4\pi}\langle E^2\rangle$

$$= 2c\langle U_E\rangle = c\left(\langle U_E\rangle + \langle U_B\rangle\right)$$

$$= c\,U_{rad}$$

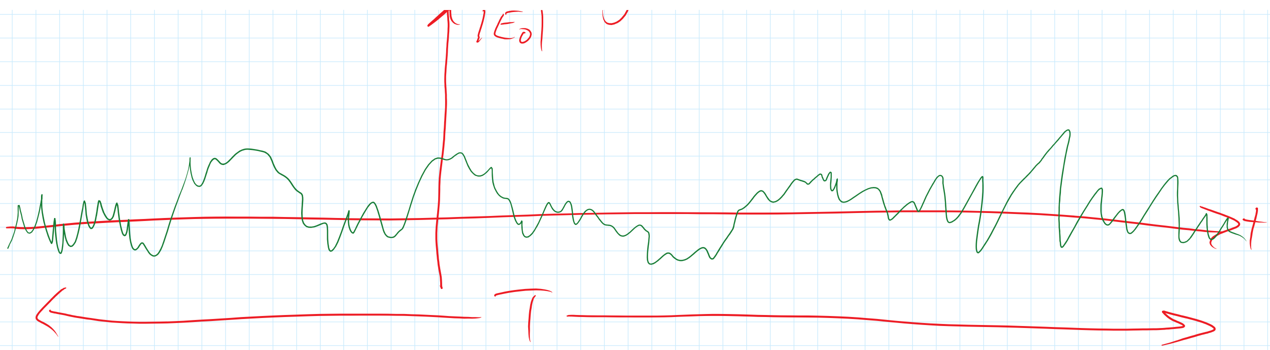
where U_{rad} is the energy density the rad'n field.

(Note that this is flux = (speed of object)(density of object))

Power Spectra

The detected/emitted radiation will be a function of time, which, in general, can take any shape

$\uparrow |\vec{E}_0|$



One cannot charactize this radiation w/ a wave equation at a precise instant of time, Knowing only $\vec{E}_0$ at one point. If we measure $|\vec{E}_0|(t)$ for Δt, we still can only define the wave train to within a freq. resolution $\Delta\omega$ where

$$\Delta\omega\Delta t > 1$$

Back to our pulse, how much energy does it contain

At one point in time: $\langle S \rangle = \frac{dW}{dt\,dA} = \frac{c^2}{4\pi} E^2(t)$ energy

So, the total energy per unit area in the pulse is

$$\frac{dW}{dA} = \frac{c}{4\pi}\int_{-\infty}^{+\infty} E^2(t)\,dt$$