Practicalities: Transmission Lines

- Impedence &Transmission Lines
  - using coax cables:
    reflection, termination, impedance matching

- Presentations:

  Marc L'Heureux "Guitar - Pickups"

  Alex Shyr "Guitar - Amplifiers"

(I must stop at 9:50 - 0:14 - 0:14 = 9:22)

Cables and Conductors

Consider a coax cable.

If we put a potential difference across the inner and outer conductors, a current will flow.

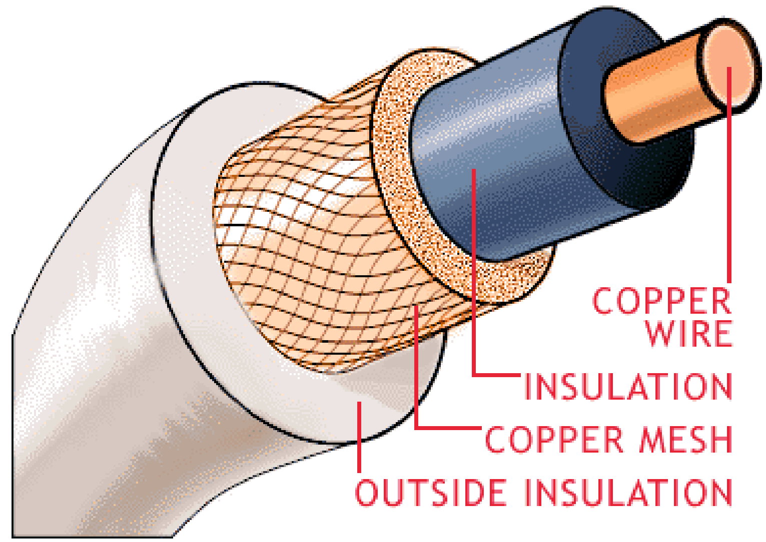
RG58 50 Ohm coax cable with 7/0.3mm centre conductor, 64 strand braided screen and a solid polyethylene insulator.

Just how much current flows will depend on what's at the other end of the coax cable:

- If there's just a resistor down there, then V=IR determines how much current I will flow.
- If it's an open circuit down there, nothing happens
- If we just connect the inner and outer ends of the coax cable down there, the current will be infinite.. Or just huge if there is a tiny resistivity associated with the cable.

Lines and Conductors

When we turn on a potential difference between the conductors, we set up an electric field in the dielectric between the conductors, a current will run as well, which gives rise to a magnetic field.



So we have an electric field and a magnetic field: we just made an electromagnetic wave, which now runs down this waveguide.

But Maxwell's eqns and the BC's which result from these eqns must be satisfied. We already deduced that E=cB, so we can deduce the E field resulting from the potential difference, and now the B field is set, so we may use it to calculate the current.

The impedance of this coax cable is Z=V/I   It depends only on geometry, materials.

Reflections

When we turn on a potential difference between the conductors, we send a pulse down the cable. If the cable has vacuum between the conductors, the pulse will travel at the speed off light.
For a dielectric, the pulse's speed will be $v=\omega/k$.

If there is a metal wall at the end of the cable, the EM wave will reflect and pick up a phase shift of π (i.e it will be inverted)
- we know this: we already investigated what happens to an EM wave incident upon a conducting surface.

If there is nothing at the end, I.e. an open circuit, The current has no place to go- it comes back, but right-side-up. (work thru BC's)

Termination of lines

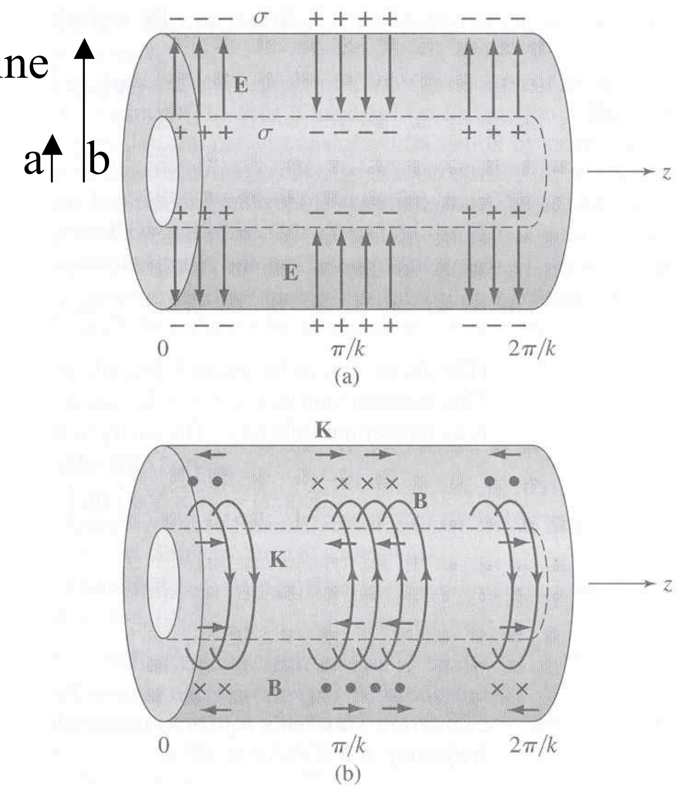
If there is some resistor at the end of the cable (some load), a reflected wave will come back: Z=V/I

BUT if we put at the end a resistor with Z= the characteristic impedance at the end, then we'd get no reflection! Any other R and we'd just get some reflected.

If we put another coax cable at the end, we'd get a reflection UNLESS the impedances are matched, enabling the entire EM signal to be transmitted into the 2nd cable. On both sides of the junction of the 2 cables, the E, B would have to be the same.

Coaxial Transmission Line

We saw a few classes ago: Coax transmission line
(here TEM_{00} mode shown)
(inner radius a, outer radius b)



Solution:

$$\vec{E}(\vec{x},t) = \frac{V_0 \hat{r}}{r \ln(b/a)} e^{i(kz-\omega t)}$$

$$\vec{B}(\vec{x},t) = \frac{V_0 \hat{\phi}}{v r \ln(b/a)} e^{i(kz-\omega t)}$$

$$I = Qv = 2\pi\varepsilon r E v = 2\pi\varepsilon v \frac{V_0}{\ln(b/a)} e^{i(kz-\omega t)}$$

$$V = -\int_a^b E \cdot dl = V_0 e^{i(kz-\omega t)}$$

$$Z = \frac{V}{I} = \frac{\ln(b/a)}{2\pi\varepsilon v} \qquad v = \frac{1}{\sqrt{\varepsilon\mu}}$$

$$\Rightarrow Z = \frac{V}{I} = \frac{\ln(b/a)}{2\pi}\sqrt{\frac{\mu}{\varepsilon}} = 60\Omega \cdot \ln(b/a)$$

for $\varepsilon \approx \varepsilon_0$
$\mu \approx \mu_0$

Characteristic Impedance

When a potential difference is first connected to a length of transmission line, there will be a time delay until the signal travels to the other end of the line.
During this time, the signal, of course, doesn't "know" long the line might be.
Energy is supplied to the line, to establish the electromagnetic fields around the conductors. Energy is stored in the capacitance between the conductors, and in the magnetic field around the conductors. Even if the line may be open circuit at the other end, the generator does not (yet) know this and supplies current; the product of current and voltage is the rate at which energy is supplied to the line.

The ratio of voltage to current (up one line, down the other) has dimensions of impedance or resistance. At a single frequency, on a lossless line, the current is in phase with the voltage and the impedance is real. It is called the "Characteristic Impedance". It does not depend on what is connected to the ends of the line, but only on the line geometry and material construction.

Presentations in PHYS 401

Today's presentations:

If it weren't for Michael Faraday (electromagnetic induction), there'd be no rock 'n roll!

Marc L'Heureux	"Guitar - Pickups"
Alex Shyr	"Guitar - Amplifiers"

Next week :

Mar.7	Gary Chan	Doorbells
	Kevin Mitchell	Electrodynamics of Vacuum Tubes
Mar. 9	Tudor Costin	Relativistic Potentials or Abraham-Lorentz Radiation Reaction
Mar. 11	Ricky Chu	Plasma Physics, subtopic TBA

If you need me to print some slides for you (PDF files please!), or get a demo, or if you want to use the LCD projector, please let me know at about 24 hours beforehand.

Please use your same marking scheme for all presentations.