ELEC 351 Notes Set #22

Last Assignment - Antennas
9.8, 9.14, 9.18, 9.19, 9.20

Fact Sheet for the Final Examination
There will be a fact sheet attached to the final exam. You can get a copy from the course web site.

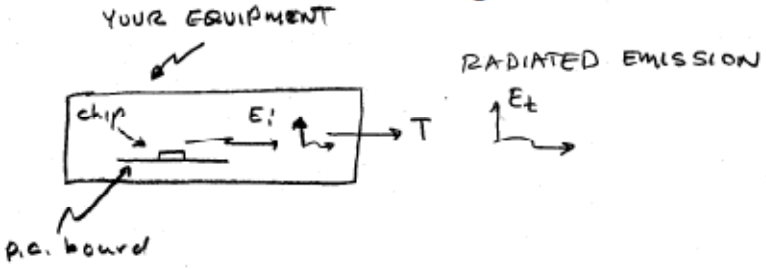
Calculators
You must use one of the two calculator models specified by the Dean's Office in the final exam. Get an ENCS sticker for your calculator from the help desk on the 7th floor of the EV building.l

ELEC351 Final Exam

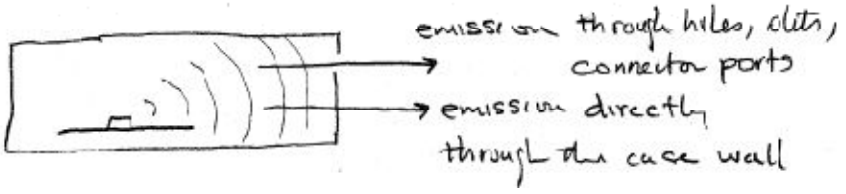
1

Electromagnetic Compatibility

Radiated Emissions and Shielding Effectiveness



- Every chip, circuit interconnect, etc., inside your equipment radiates some electric field.
- The net effect is an "ambient" field strength E_i inside the case of your equipment.
- Some of this field "leaks out" as a radiated emission from your equipment.



- The "shielding effectiveness" of the box measures the ability of the box to prevent the internal field E_i from getting out of the box and becoming an external field E_t.
- Define the "Shielding Effectiveness" as the ratio of the field outside E_t to the field inside E_i expressed in dB as:

$$SE = -20\log\left(\frac{|E_t|}{|E_i|}\right)$$

- The walls of the box have a transmission coefficient T given by the formulas above:

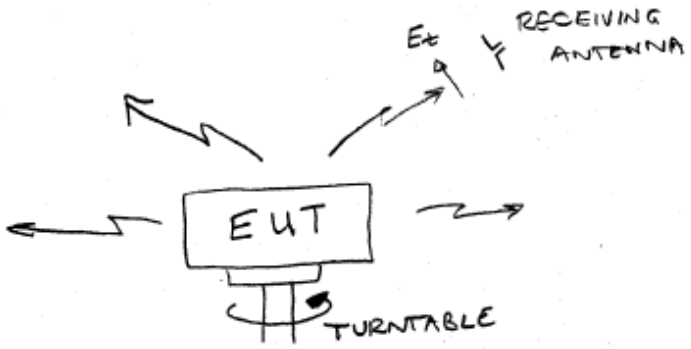
$$|T| = \left|\frac{4\eta_0\eta_w e^{-j\beta_w d}}{(\eta_0+\eta_w)^2 - (\eta_0-\eta_w)^2 e^{-2j\beta_w d}}\right|$$

- The SE of a wall of thickness d is given by

$$SE = -20\log(|T|)$$

- This is the largest possible reduction in field strength that would be obtained if the box were solid with no holes or openings and no connectors!
- Including openings reduces the "net" shielding effectiveness very substantially as fields "leak out" through such openings.

Radiated Emission Testing



- EUT = Equipment Under Test
- Manufactured devices are restricted by government regulations to a very limited "radiated" field strength leaking out of the case.
- To market a device, you must prove by measurement that your device "leaks" or emits fields that are smaller than the permitted values.
- Hence "**radiated emission testing**" is required:
  - operate the equipment in a controlled environment
  - measure the "emitted" field over the required frequency range
  - show that the emission is less that the permitted value.

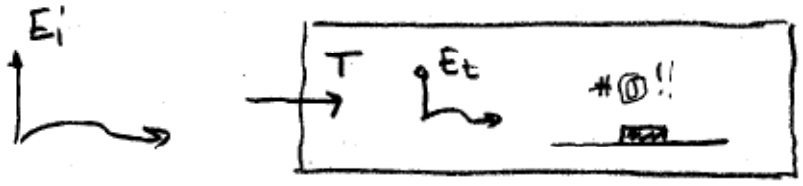
4

- The test must be done in a "quiet" electromagnetic environment such as a shielded anechoic chamber (very expensive) or in a facility located well away from urban areas (inconvenient!), where the "ambient" field strength is small.
- Typically the EUT is on a turntable so that it can be rotated 360 degrees, to measure the field all around it.
- An antenna is used to measure the field strength at various locations around the EUT.
- The signal from the receiving antenna is typically fed to a "spectrum analyzer" which measures the amplitude of the received voltage as a function of *frequency*.

5

Electromagnetic Susceptibility

- Your equipment can malfunction if it is exposed to an external field which is strong enough.
- Engineers say that your equipment is "susceptible" to interference from an external field.



- This figure illustrates electromagnetic susceptibility:
  - Outside the box there is an "ambient" field strength E_i due radio stations, TV stations, cell phones, police radio, thousands of other computers "leaking" fields, etc.
  - Some of this field will enter your equipment's box by traveling through the walls, and through holes and openings.

6

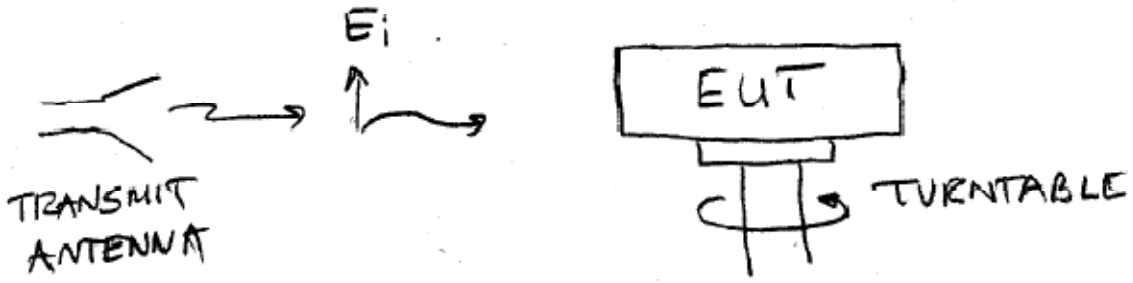
- The "shielding effectiveness" defined above measures the ability of the box to EXCLUDE external fields:

$$S.E. = -20\log\left(\frac{E_t}{E_i}\right)$$

- If the "ambient" field strength E_i is sufficiently large, your equipment can malfunction.
- Your equipment is said to be "susceptible" to external fields.
- The largest external field strength that your equipment can tolerate is called the "**immunity level**" or simply the "immunity".
- Typical immunity levels for equipment are 3 to 10 V/m.
- The "ambient" field strength in urban regions can exceed 1 V/m so that there may be only a small safety margin.
- Close to equipment the field strength due to radiated emissions can be large (because the field strength decreases as 1/distance).
- Putting a radio next to a computer often leads to interference with the radio station that you are trying to hear. Try it!

7

Susceptibility Testing



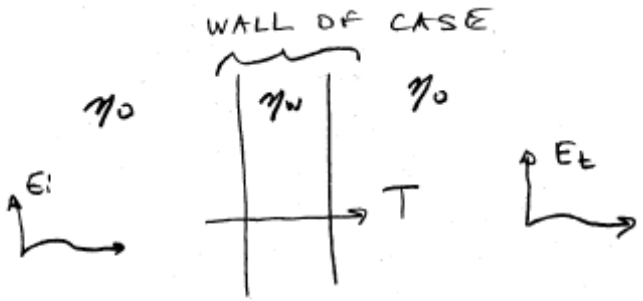
- "Susceptibility Testing" is used to determine the **immunity level** of equipment at a specific frequency.
- The EUT (equipment under test) is placed on a turntable and illuminated with a field strength of known value at the desired frequency.
- The field strength is gradually increased until the EUT fails.
- This determines the immunity level at one frequency.
- The "failure" of the EUT can be:
  - "Non-destructive", meaning that when the external field is turned off, the EUT will work properly;
  - Or it can be "destructive", meaning that the EUT is damaged and will not work until repairs are made!

8

- Susceptibility testing is done much more rarely than radiated emission testing because for the most part there are no standards.
- In the medical industry, there is a "voluntary" standard that the immunity level shall be 10 V/m over a wide frequency range.
- For legal reasons, medical equipment is tested for susceptibility to ensure that it conforms to the voluntary standard.
- Equipment with LOW radiated emissions will generally have a HIGH immunity level!

9

The Shielding Effectiveness of an Equipment Case



- Consider the case of an instrument, which is typically sheet metal of a certain thickness.
- We can use our transmission coefficient formula to find the Shielding Effectiveness:

$$SE = -20\log|T| = -20\log\left|\frac{4\eta_0\eta_w e^{-j\beta_w d}}{(\eta_0+\eta_w)^2-(\eta_0-\eta_w)^2 e^{-2j\beta_w d}}\right|$$

10

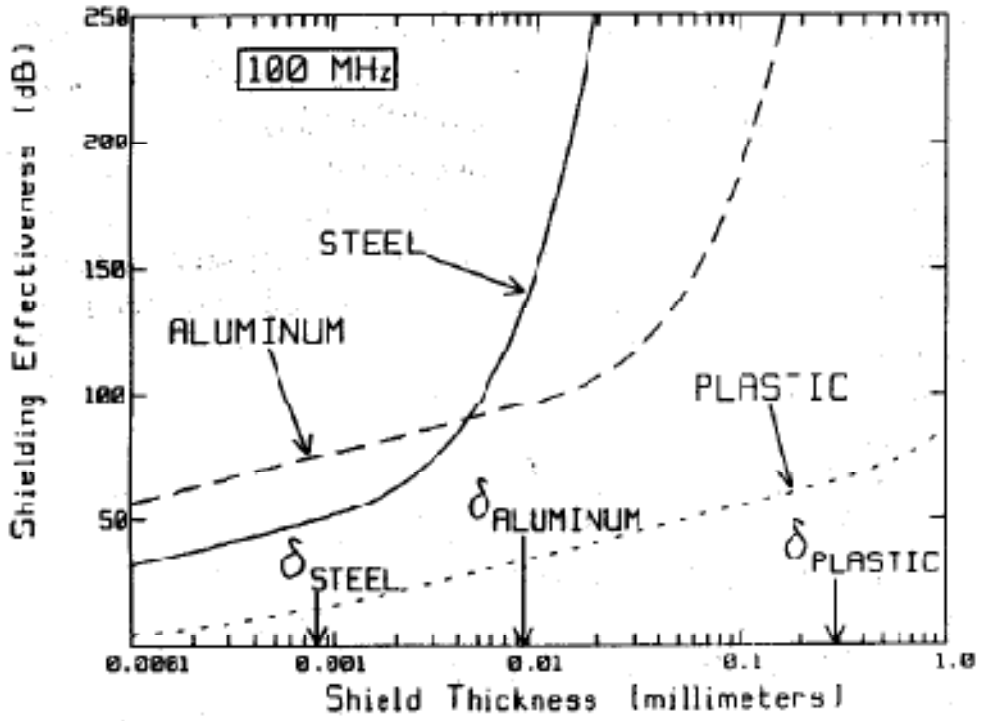


Fig. 1. The shielding effectiveness of three materials as a function of sheet thickness at 100 MHz.

11