EEE401 AUTUMN 2006/07
SOLUTIONS

1. a. Radio frequency emissions may be classified as being either "narrowband" or "broadband". Define these terms in an e.m.c. context and give examples of such emissions.

The terms narrowband and broadband must be used in comparison with the receiver bandwidth. i.e. a 10 kHz signal would be classed as narrowband if the receiver bandwidth was 1 GHz, but broadband if the receiver bandwidth was 100 Hz. Narrowband signals arise from oscillator harmonics whereas broadband signals arise from discontinuous switching operations and digital signals.

b. Describe in detail, with the aid of diagrams, a receiver suitable for carrying out radio frequency emissions testing at frequencies up to 1 GHz. Why should the receiver have a wide dynamic range and be provided with several types of detector?

Give block diagram of superhet receiver and explain its operation. Receiver must have switchable bandwidth and be able to cope with cw and pulsed signals – hence the need for different detectors – peak, averaging and quasi-peak. Need wide dynamic range to cope with signals which may be in the form of low duty cycle, high amplitude pulses. Receiver stages must remain linear in operation even though average detector output may appear to be low.

c. Describe the types of pickup transducer which might be used with such a receiver and explain, briefly, how they might be used in practice.

Log-periodic and biconical antennas used for far field emissions and susceptibility testing. E-field and H-field probes used for near field diagnostics on pcbs etc. Below 30 MHz, conducted measurements done using LISN and absorbing ferrite clamp.

d. A measurement receiver fitted with a quasi-peak detector is to be used to measure the radiated emissions from a laptop computer over the frequency range 30 MHz to 1 GHz. Using the data given below, estimate the time required to carry out the measurement.
Receiver 6dB bandwidth = 120 kHz
Charge time constant = 1mS
Discharge time constant = 550mS

*Time for 1 scan = frequency range*detector time constant / ½ receiver bandwidth*

*=(1000-30)*0.551 / 0.06 = 8907.8 sec = 2.474 hours*

2. a. Write brief descriptive notes, supported by diagrams where appropriate, on ***two*** of the following

(i) Radiated susceptibility testing

Diagram of either anechoic chamber or stirred mode chamber or GTEM cell. Need to measure incident field strength.

(ii) ESD testing

Diagrams of ESD gun and test environment. Distinguish between direct ESD and indirect ESD testing.

(iii) Measurement of shielding effectiveness

Diagram of coaxial test cell. Two measurements required of S21, without and with sample in place. Difference gives SE

b. Explain what is meant by sample testing to the so-called X%/Y% rule.

X% of the samples tested must pass the test with a confidence level of Y%

c. Explain the difference between a normal distribution and a t-distribution.

Normal distribution holds for a population of infinite size. For small populations, as used in random sample testing, the appropriate distribution is represented by the t curve. The shape of this curve changes with sample size to reflect the change in uncertainty in how representative the sample is of an infinite population.

d. The gain at a certain frequency was measured for a batch of 6 e.m.c. testing antennas that were randomly selected from a large production run. The results were as follows:

Sample No	1	2	3	4	5	6
Gain (dB)	9.9	10.1	9.8	9.7	9.9	10.2

Using the 90%/90% rule, determine whether the production run of these antennas meets the required gain specification of at least 9.5 dB.

All the measure results lie close together and certainly within one decade. Hence do the sums with the dB values rather than converting first to linear values. Resulting error will be small. Use the worst case scenario when doing the sums. The MathCAD document below shows that the specified gain requirement is met.

For 90% confidence level, value of t for 6 samples is

$t_6 := 2.015$

$N := 6$

6 samples - measured data follows

$x_1 := 9.9$

$x_2 := 9.9$

$x_3 := 10.1$

$x_4 := 10.2$

$x_5 := 9.8$

$x_6 := 9.7$

Let's do the calculations using the measured data as is (i.e. in dB rather than linear form)

$$\text{simmean} := \left(\frac{1}{N}\right)\cdot\sum_{i=1}^{N} x_i$$

$\text{simmean} = 9.933$

MEAN VALUE

$$simstd := \sqrt{\left(\frac{1}{N-1}\right) \cdot \sum_{i=1}^{N} \left(x_i - simmean\right)^2}$$

simstd = 0.186 *STANDARD DEVIATION*

USING LOWER LIMIT, hence - not +, as worst case

$$L_1 := simmean - t_6 \cdot \left(\frac{simstd}{\sqrt{N-1}}\right)$$

$L_1 = 9.766$

$$sig := simstd \cdot \sqrt{\frac{N-1}{N}}$$

sig = 0.17

$S := L_1 - 1.282 sig$

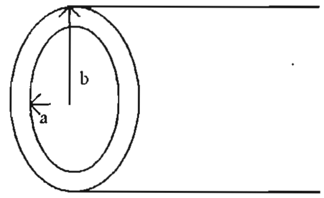
90% of samples will have gain better than S

S = 9.548 dB

Answers to questions 3 & 4 on EEE401_0607 and EEE6010_0607

Question 3a

For two concentric cylinders (ie co-axial cable) where the radius of the inner conductor is 'a' and the radius of the thin outer conductor is 'b' (a < b):

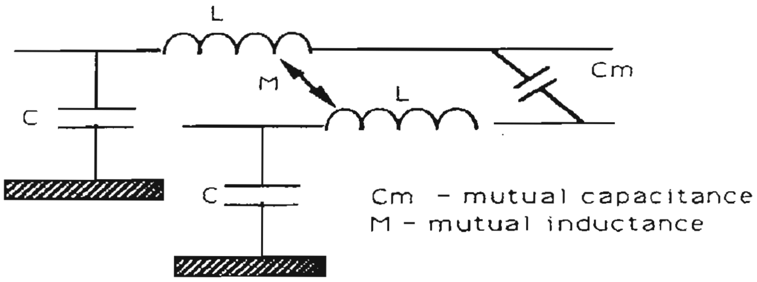


$$Z_o = \frac{1}{2\pi}\left(\frac{\mu}{\varepsilon}\right)^{\frac{1}{2}} \ln\left(\frac{b}{a}\right)$$

Here a=0.5mm and b=2mm, μ_r=1, ε_r=20

Z_o=18.6Ω

3b.



6 Elements in model

- 2 self inductances, 2 self capacitances of the wires.
- 1 mutual inductance and 1 mutual capacitance between the wires.
  - *Mutual inductance gives magnetic field coupling*
  - *Mutual Capacitance gives electric field coupling.*
  - *Ignoring resistances (line and dielectric)*
  - *Assumed weak coupling*

3c.

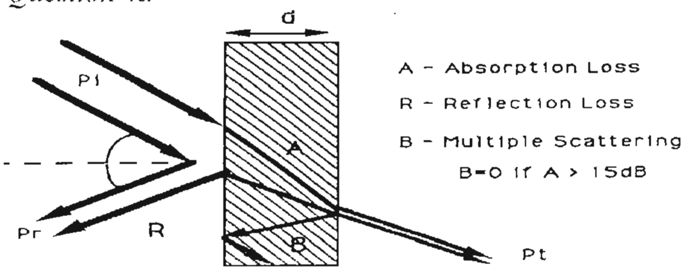
Given that the voltage induced in the victim circuit is a function of the mutual inductance between the circuits, and $V_m = -M.\frac{dI}{dt}$, where $V_m/2$ appears at each end of the victim line.

From graph, for 1mm separation, M=4nH/cm = 400nH/m. For a 10A/µsec rate of current rise, the induced voltage in the line V_m=4V, with 2V appearing at each end of the line, therefore the voltage on the input to the victim circuit will be 2V in magnitude.

3d.

To ensure the voltage induced at the input to the victim circuit remains below 1.2V, the induced voltage into the wire needs to remain below 2.4V, and hence for the same 10A/µsec rate of current rise, the mutual inductance between the wires should be below 2.4nH/cm, to ensure this, the separation should be further than 1.5mm (from graph), preferably further apart.

Question 4a

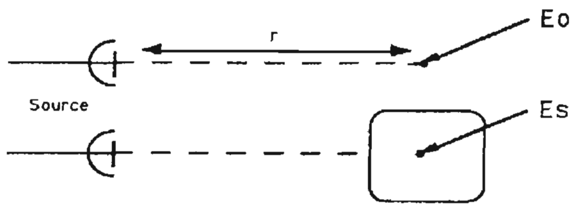


SE = 10Log(Pi/Pt) = A + R + B

Screening is dependant on 3 parameters:

- Loss due to absorption of energy within the shield
- Loss due to multiple scattering between two faces of the shield
- The reflective loss at the outer surface of the shield.

Also,



SE = 20 Log(Eo/Es)

Screening Effectiveness.

- Defined in IEE standards as the ratio of the field at a point with and without the shield in place.
- Eo - No screen in place
- Es - Screen in place

4b.

Ignoring B – multiple scattering in the above definition, we have

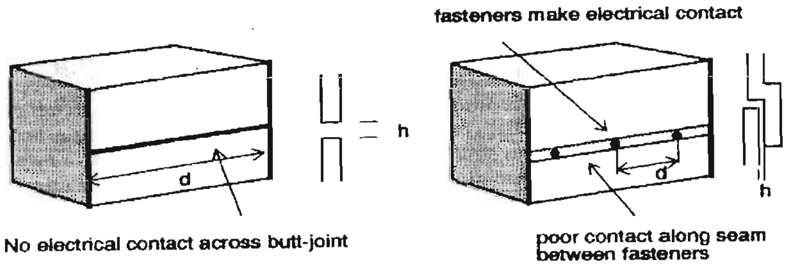
$$\delta = \frac{1}{\sqrt{\pi . f . \mu . \sigma}} \qquad A = 8.69\left(\frac{d}{\delta}\right)$$

$$R = 168 - 10.\log_{10}\left(\left(\frac{\mu_r}{\sigma_r}\right).f\right)$$

$$B = 20.\log_{10}\left(1 - e^{2\sqrt{2}(d/\delta)}\right)$$

For the values for mild steel, δ=21μm, therefore A=104dB, and R=78dB, therefore the shielding effectiveness =182dB.

4c.



Shielding effectiveness is compromised by gaps in the casing. The main problem being poor contact across the joints in a box, leading to an aperture through which EM radiation may pass.
Ways to improve the contact across a joint in a case may be overlapping the edges, as shown above with frequent fasteners, or any of the following: