<u>Solutions to EEE 6010, First semester 2007/8 - B. Chambers</u>

Q1 (a) For free-field (i.e. far-field or quasi far-field) measurements, antennas having a very wide bandwidth are needed. Typically, these will be either a bi-conical or a log-periodic. A rough sketch of each is required. For near-field measurements, either an E-field or H-field probe is used. The former is simply a piece of coaxial cable whose outer braid id stripped back to reveal $\lambda/4$ of inner conductor. The latter is basically an electrically small loop which again can be made from coaxial cable. A rough sketch of each is required.

(b) The antenna factor AF is defined as $AF = \dfrac{E}{V_R}$

where E = incident field strength, V_R = voltage at receiver input

If the receiver input resistance is R_R, then received power, P_R is $P_R = \dfrac{V_R^2}{R_R}$

Also, $P_R = A_e S_{av} = A_e \dfrac{E^2}{Z_0}$

where

A_e = effective aperture of the receiving antenna
S_{av} = time-average power density of the wave incident on the antenna.
Z_0 = characteristic impedance of free-space ≈ 377 Ω

From antenna theory,

$$A_e = \frac{MG_R\lambda^2}{4\pi}$$

where
G_R = gain of receiving antenna
M = impedance mismatch factor

M = 1- $|\rho|^2$ where ρ is the reflection coefficient

Then

$$P_R = \frac{MG_R\lambda^2 E^2}{4\pi Z_0}$$

Hence $AF = \dfrac{2}{\lambda}\sqrt{\dfrac{\pi Z_0}{G_R R_R M}}$

Note that G_R and M will vary with the antenna height and orientation with respect to the ground

(c) In practice, AF is measured since the above calculation takes no account of the antenna's surroundings or accidental damage or deformation during use.

(d) E(dBμV/m) = V(dBμV) + AF(dB/m) + cable loss(dB)

At 200 MHz, E = 10.0 + 17.0 + 0.5 = 27.5 dBμV/m

Since the cable loss varies as the square-root of frequency, at 1000 MHz the cable loss is larger than at 200 MHz by a factor of $\sqrt{5} = 2.236 = 10 \log_{10}(2.236) = 3.49$ db

i.e. cable loss at 1000 MHz = 0.5 + 3.49 = 3.99 dB

Hence new E is

E = 10 + 25.1 + 3.99 = 39.1 dBμV/m

Q2 (a) It is not practical to test every item from a large production run and so random sample testing is used together with statistical methods to estimate the performance of the whole batch. To satisfy the X% / Y% rule, at least X% of the production run has to comply with the required emission limit with a Y% confidence level.

(b) For the given sample data, the mean value is

$$\text{propmean} := \left(\frac{1}{N}\right)\cdot\sum_{i=1}^{N} 10^{0.05\cdot x_i}$$

$$\text{propmean} = 3.932\times 10^{5}$$

$$\text{propmeandB} := 20\cdot\log(\text{propmean})$$

$$\text{propmeandB} = 111.891$$

$$\text{propstd} := \sqrt{\left(\frac{1}{N-1}\right)\cdot\sum_{i=1}^{N}\left(10^{0.05\cdot x_i} - \text{propmean}\right)^2}$$

$$\text{propstd} = 2.699\times 10^{5}$$

$$L_2 := \text{propmean} + t_5\cdot\left(\frac{\text{propstd}}{\sqrt{5-1}}\right)$$

$$L_2 = 6\times 10^{5}$$

$$\text{sigi} := \text{propstd} \cdot \sqrt{\frac{5-1}{5}}$$

$$\text{sigi} = 2.414 \times 10^5$$

$$S_2 := L_2 + 0.841 \cdot \text{sigi}$$

$$S_2 = 8.03 \times 10^5$$

$$S_{2dB} := 20 \cdot \log(S_2)$$

$S_{2dB} = 118.095$ dBμV/m

Let's check this result using the short-cut formula

$$SS_2 := \text{propmean} + \left[\left(\frac{t_5}{\sqrt{5-1}}\right) + 0.841 \cdot \sqrt{\frac{5-1}{5}}\right] \cdot \text{propstd}$$

$$SS_2 = 8.03 \times 10^5$$

$$SS_{2dB} := 20 \cdot \log(SS_2)$$

$SS_{2dB} = 118.095$ dBμV/m

This value is less than 120 dBμV/m. Hence the batch meets the specification.

(c) Three main types of detector are:
Peak - has fast response time and can follow the envelope of a signal.
Average - will measure the same value as a peak detector for a c.w. signal but will indicate a lower value when measuring a pulsed signal.
Quasi-Peak - has weighted charge and discharge times which correct for subjective human response to pulse-type interference.

To obtain an accurate measurement, a signal presented to a detector must be undistorted at very much higher levels than the output of a detector, e.g. the r.f. and i.f. stages of the receiver must be overloaded by up to 43.5dB (CISPR bands 3and 4) and remain linear. Average detectors cannot be used to measure pulsed signals accurately.

(d) LISN: Answer to include a circuit diagram and connections for a single phase supply - common and differential measurements.
GTEM cell: Answer to include a cross-sectional sketch which should include the positioning of the equipment under test. Discussion of broad-band cell termination.

Question 3 a

$$C=\frac{2\cdot\pi\cdot\varepsilon 0\cdot\varepsilon r}{\ln\left(\frac{b}{a}\right)}$$

$$L=\frac{\mu 0\cdot\ln\left(\frac{b}{a}\right)}{2\cdot\pi}$$

$$Z:=\sqrt{\frac{L}{C}}$$

$$Z=\frac{1}{(2\cdot\pi)}\cdot\left[\mu 0\cdot\frac{\ln\left(\frac{b}{a}\right)^2}{(\varepsilon 0\cdot\varepsilon r)}\right]^{\left(\frac{1}{2}\right)}$$

$Z:=50$

$\varepsilon 0:=8.854\cdot 10^{-12}$ $\quad \varepsilon r:=2$

$\mu 0:=4\cdot\pi\cdot 10^{-7}$

$a:=1\cdot 10^{-3}$

$$b:=e^{\left(\frac{2}{\mu 0}\cdot\pi\cdot\sqrt{\mu 0\cdot\varepsilon 0\cdot\varepsilon r}\cdot Z\right)}\cdot a$$

$b=3.252\cdot 10^{-3}$ 3 marks

$$C:=\frac{2\cdot\pi\cdot\varepsilon 0\cdot\varepsilon r}{\ln\left(\frac{b}{a}\right)}$$

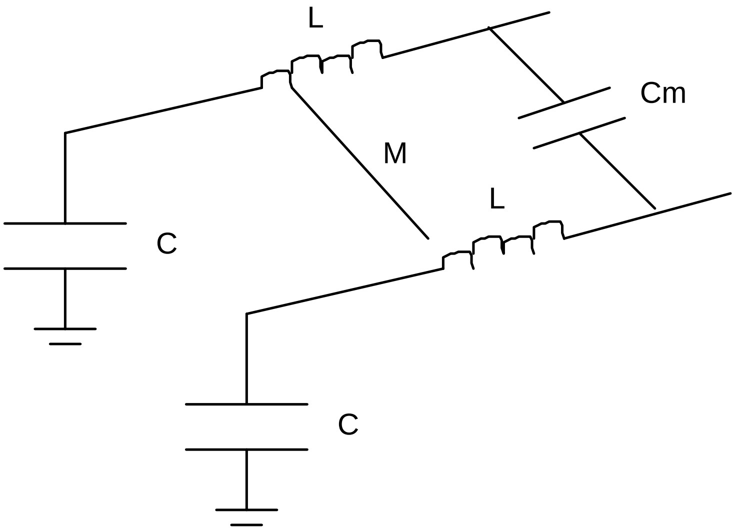
1 mark

$C=9.435\cdot 10^{-11}$

$$L:=\frac{\mu 0\cdot\ln\left(\frac{b}{a}\right)}{2\cdot\pi}$$

$L=2.359\cdot 10^{-7}$ 1 mark

Question 3 b



3 marks for correct circuit

1 mark each for M and Cm

Question 3 c

$Vm = -M \cdot \frac{di}{dt}$ 1 Mark

From figure 1

$m := 4 \cdot 10^{-9}$ H / cm $L := 200$ cm

$M := m \cdot L$

$M = 8 \cdot 10^{-7}$ H 1 Mark

$Vm := M \cdot 5 \cdot 10^{6}$ 1 Mark

$Vm = 4$

Hence at end of cable

$V := \frac{Vm}{2}$

$V = 2$ 2 Marks

Question 3 d

$V := 0.4$

$Vm := 2 \cdot V$

$Vm = 0.8$ 1 Mark

$M := \frac{Vm}{5 \cdot 10^{6}}$

1 Mark

$M = 1.6 \cdot 10^{-7}$ H

$m := \frac{M}{L}$

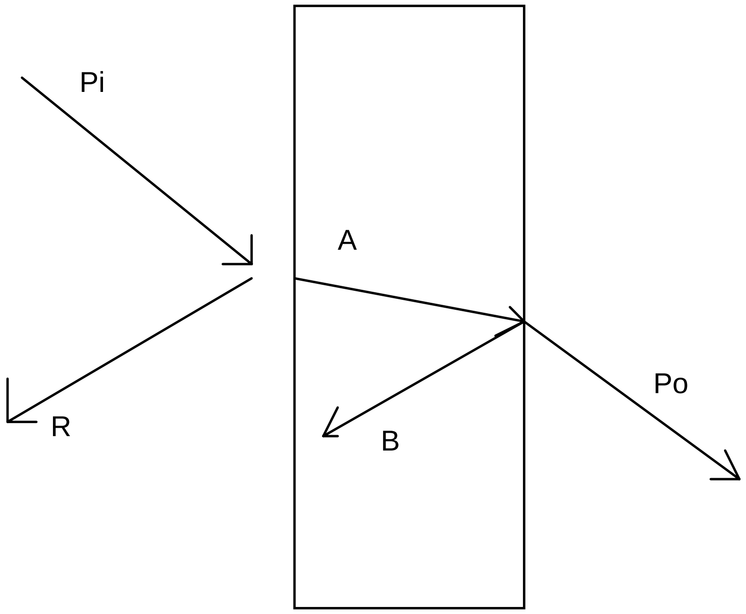
1 Mark

$m = 8 \cdot 10^{-10}$

2 Marks

Hence from figure 1 the distance should be at least 3mm

Question 4 a



A = Absorption loss

B = multiple reflections

R = reflection loss

SE = 10log(Po/Pi)= R+A+B

The answer should include a discussion of the above diagram stating absorption loss, multiple reflections and reflection loss

Question 4 b

$f := 50 \cdot 10^{6}$ $\sigma r := 0.1$ $d := 0.3 \cdot 10^{-3}$

$\sigma := 0.1 \cdot 5.8 \cdot 10^{7}$ $\mu r := 1$

$$\delta := \frac{1}{\sqrt{\pi \cdot f \cdot \mu 0 \cdot \sigma}}$$

$\delta = 2.955 \cdot 10^{-5}$ 2 Marks

$$A := 8.69 \cdot \frac{d}{\delta}$$

2 Marks

$A = 88.21$

$$R := 168 - 10 \cdot \log\left(\frac{\mu r}{\sigma r} \cdot f\right)$$

2 Marks

$R = 81.01$

$SE := A + R$

2 Marks

$SE = 169.221$

Question 4 c

A joint will form an aperture. To approximate the SE of an aperture use SE =10log(λ/2d) and will be 0 if λ=2d. (3 marks)

1 mark each for discussing the following

Using rivets
Conducting gaskets
Copper fingers