FIJI NATIONAL UNIVERSITY
College of Engineering, Science & Technology

SCHOOL OF ELECTRICAL & ELECTRONICS ENGINEERING

BACHELOR OF ENGINEERING

EEE747 – Radio Frequency (RF) Principles

SEMESTER 1, 2014

DAY/DATE: As timetabled DURATION : Three hours
ROOM: As timetabled

INSTRUCTION TO STUDENTS

1. You are allowed 10 minutes extra reading time during which you are **NOT** to write.
2. Answer ALL questions in Section A and FOUR questions in Section B
3. **Begin the answer to each Question** on a fresh page and use both sides of the sheet.
4. Write clearly the number of the question attempted on the top of each sheet
5. Write your candidate number at the top of each sheet & attach them.
6. Insert all written foolscaps, graph paper etc. in their correct sequence and secure with a string.
7. All sheets of paper on which rough/draft work has been done, cross it through and attach all of them to your answer scripts.
8. Where ever possible, draw clear neat diagrams

Section A (Answer ALL questions)

(20 marks)

1. Drawing the **E** and **H** fields, explain the mode of propagation of electromagnetic waves in free space, coaxial transmission lines and twin wire transmission lines. (3 marks)

2. A load Z terminates a transmission line of length ℓ characteristic impedance Z_0. The impedance Z_ℓ seen at the other end of the line is

$$\frac{Z_\ell}{Z_0} = \frac{\frac{Z}{Z_0} + j\tan\gamma}{1 + j\frac{Z}{Z_0}\tan\gamma} \qquad \text{where} \qquad \gamma = \frac{\omega\ell}{v} = \frac{2\pi\ell}{\lambda}$$

Show that small section of shorted at one end can be used as **either** a capacitor or an inductor in RF circuits. (6 marks)

3. A load (Z = 20 Ω) terminates a transmission line of characteristic impedance 50 Ω. A voltage wave of amplitude 45 V is incident on the load. Using the Smith Chart or otherwise calculate the amplitude of the reflected voltage. (3 marks)

4. The impedance (Z) matrix of a network is $[Z] = \begin{bmatrix} 4 & 3 \\ 3 & 5 \end{bmatrix}$

The currents in port 1 and port 2 are 0.4A and 0.7A respectively. Calculate the port voltages.

(4 marks)

5. A carrier RF is frequency modulated by a signal of frequency 400Hz. For the modulation index used, it was found that up to the fourth order Bessel function, the amplitudes are significant. Calculate the bandwidth of the modulated RF.

(4 marks)

Section B (Answer FOUR questions only)
(Each question carries 20 marks)

B1. a) Define the distributed parameters of a transmission line and explain how these parameters arise and their importance at *RF*. (4 marks)

b) If a high frequency source is connected to the transmission line, obtain the wave equation for the voltage along the line. (4 marks)

c) Assume a solution to the wave equation as $v = (A\,e^{-Px} + B\,e^{Px})\,e^{j\,\omega\,t}$, where *P* is the propagation coefficient. Explain what does $A\,e^{-Px}\,e^{j\omega t}$ and $B\,e^{-Px}\,e^{j\omega t}$ represent.

(4 marks)

d) Write down the expression for *P* and obtain the expression for the current as: $i = \frac{1}{Z_0}(A\,e^{-Px} - B\,e^{Px})\,e^{j\,\omega\,t}$.

Hence obtain the expression for the characteristic impedance of the transmission line.

(4 marks)

e) For a lossless transmission line, inductance *L* = 250nH/m, and *C* = 100 pF/m, calculate the characteristic impedance of the line and the phase velocity of the waves along the line.

(4 marks)

B2. i) The voltage and current waves on the transmission line are:

$v = (A\,e^{-Px} + B\,e^{Px})\,e^{j\,\omega\,t}$ and $i = \frac{1}{Z_0}(A\,e^{-Px} - B\,e^{Px})\,e^{j\,\omega\,t}$.

Figure B2 shows a transmission line of characteristic impedance Z_0 is terminated by a load *Z* at one end. The origin of the coordinate system is assumed to be at the load.

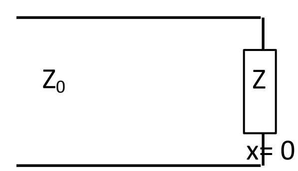


Figure B 2

a) Derive the voltage reflection coefficient at the load as: $R_v = \frac{Z - Z_0}{Z + Z_0}$ (6 marks)

b) A lossless transmission line having resistive characteristic impedance Z_0 Ω is terminated by a resistive load *Z* Ω.

Discuss the nature of the reflected wave for loads

i) Z is a short circuit; *ii*) $Z < Z_0$

iii) $Z > Z_0$ *iv*) Z is an open circuit

v) $Z = Z_0$ (5 marks)

ii) a) A load *Z* = (75 – *j* 50) Ω terminates a line of characteristic impedance Z_0 = 75 Ω. **<u>Calculate</u>** the magnitude and phase angle of the reflection coefficient. (5 marks)

b) If the voltage wave incident on the load is 500 cos (2 x π x 300 x10^6 *t*), obtain an expression for the reflected wave. (4 marks)

B3. The coaxial cable RG 223/U has the following parameters: L = 223 nH/m; C = 112 pF/m; R and G are negligible. This cable feeds a signal of frequency 400 MHz to an antenna of impedance $Z = 73 + j42$.Using the Smith Chart or otherwise, calculate:

a) The VSWR of the wave. (4 marks)

b) The reflection coefficient at the load (amplitude an phase). (3 marks)

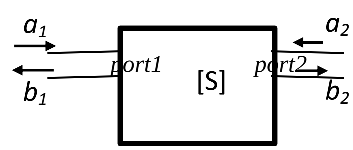
c) The normalized admittance of the antenna. (3 marks)

In order to perfectly match the terminating antenna with the transmission line using a short circuited stub line

d) Determine the location of the stub in meters. (5 marks)

e) The length of the stub line in meters. (5 marks)

B4. A power wave feeds a two port network as shown in the diagram.



i) The Scattering matrix [S] of the network is given by

$$\begin{bmatrix} \boldsymbol{b_1} \\ \boldsymbol{b_2} \end{bmatrix} = \begin{bmatrix} \boldsymbol{S_{11}} & \boldsymbol{S_{12}} \\ \boldsymbol{S_{21}} & \boldsymbol{S_{22}} \end{bmatrix} \begin{bmatrix} \boldsymbol{a_1} \\ \boldsymbol{a_2} \end{bmatrix}$$

a) Define the quantities a_n and b_n where n = 1,2. (3 marks)

b) Explain the significance of the coefficients $\boldsymbol{S_{11}}$ and $\boldsymbol{S_{21}}$ of the scatter matrix.

(4 marks)

ii) The measured scattering matrix of a two port device at a specific frequency is given as shown:

$$S = \begin{bmatrix} 0.1 & j0.5 \\ j0.5 & -0.2 \end{bmatrix}$$

$Z_0 = 50\Omega$. The transmission line from port 2 is terminated on a matched load. If the voltage incident on port 1 is $(-j)\ 2\ e^{-j\beta x}$ calculate

a) The port voltages (4 marks)

b) The port currents (4 marks

c) The power, in watts, flowing into Port 1 (3 marks)

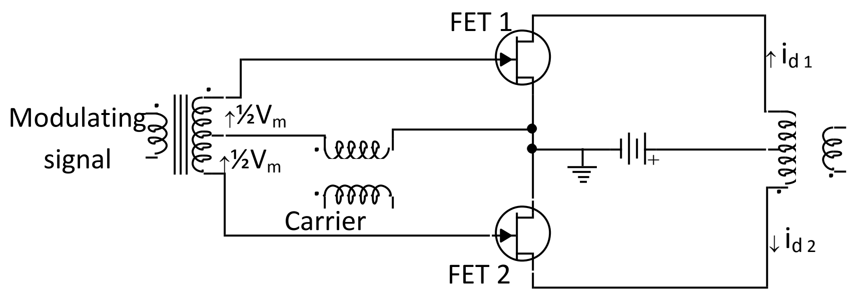
d) Express this power in dBm. (2 marks)

B5. i) a) An RF carrier wave $V_c = V_{c\max} \sin(\omega_c t)$ is amplitude modulated by an information signal $V_m = V_{m\max} \sin \omega_m t$. Show that the amplitude and frequency of the information signal is in the side bands of the modulated wave. (4 marks)

b) Explain what is *over modulation* in amplitude modulation and explain why this condition should be avoided in practical application. (3 marks)

c) If $V_c = 300 \sin(2\pi \times 600 \times 10^6 t)$ and $V_m = 75 \sin(2\pi \times 500)t$ calculate the *modulation index* and the band width of the modulated signal. (3 marks)

ii) Explain how the circuit shown behaves like a Double Side Band Suppressed Carrier modulator.



(7 marks)

iii) Define *modulation index* in FM signals and what its significance is.

(4 marks)

THE END