1. (a) Consider the transmission line (Tx-line), of distributed parameters per unit length L', C', G' and R', and operated at a radial frequency ω.

(i) Define the parameters L', C', G' and R' and provide a representation of an ideal transmission line with these distributed parameters.

(4 marks)

(ii) Using these distributed parameters, explain the conditions that these parameters have to satisfy to obtain a lossless Tx- line. Do the same for a low-loss Tx-line.

(2 marks)

	Complex Wave Propagation Constant $\gamma = \alpha + j\beta$		**Phase Velocity** v_p	**Characteristic impedance** Z_0	**Wavelength** λ
	Attenuation constant, α	Propagation constant, β			
Lossy Tx-line	$\sqrt{(R' + jL'\omega)(G' + jC'\omega)}$		$\frac{\omega}{\beta}$	$\sqrt{\frac{R' + jL'\omega}{G' + jC'\omega}}$	$\frac{2\pi}{\beta}$
Low-loss T-x line					
Lossless T-x line					

(iii) Complete the entries of the table above for the attenuation constant α, the propagation constant β, the phase velocity v_p, the characteristic constant Z_0 and the wavelength λ in the two cases of a low-loss and a loss-less T-x line. For each entry, explain the derivation of your results.

(10 marks, 1 mark per entry)

/Cont...

/Cont…1.

(b) A transmission line operating at 500 MHz has a characteristic impedance $Z_0 = 80\ \Omega$, conductor losses per unit length $R' = 3.2\ \Omega/\mathrm{m}$, an attenuation constant $\alpha = 0.04$ Np/m and a propagation constant $\beta = 1.5$ rad/m.

(i) Assuming that the T-x line is low-loss, calculate the parameters L', C' and G'. Verify then your assumption that the T-x line is low-loss.

(4 marks)

(ii) Verify that the Tx-line is also distortion-less.

(3 marks)

(iii) Calculate the phase velocity v_p and wavelength λ.

(2 marks)

2. Consider the transmission line circuit shown in the figure below (Figure 2). The load is an inductor of inductance L. The circuit has various lossless line characteristic impedances Z_{01}, Z_{02} and Z_{03}.

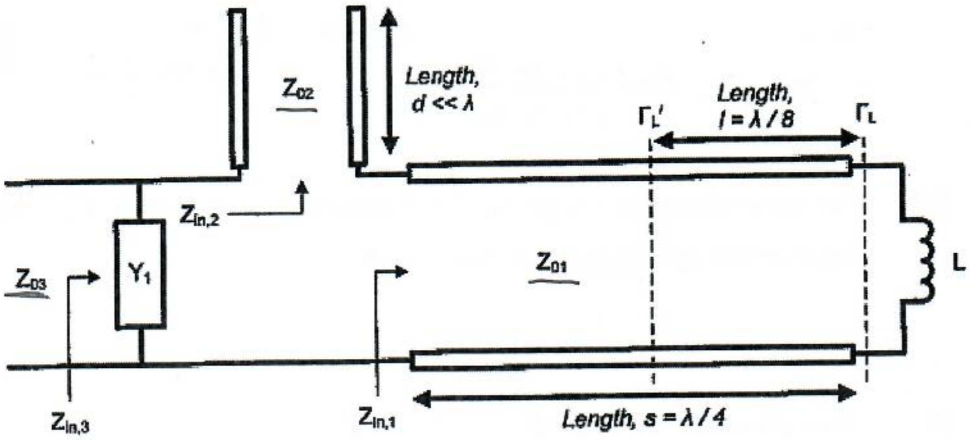

Figure 2

Derive or determine the following:

(a) The reflection coefficient at the load, Γ_L.

(2 marks)

(b) The value of the reflection coefficient, $\Gamma_{L'}$, at a distance $l = \lambda/8$ away from the load. You might want to use either the general formula of the impedance along a line or the general formula of the reflection coefficient.

$$Z_{in} = Z_0 \frac{Z_L + jZ_0 \tan\beta l}{Z_0 + jZ_L \tan\beta l} \qquad \Gamma_l = \Phi \frac{1 + \Gamma_L e^{-2j\beta z}}{1 - \Gamma_L e^{-2j\beta z}}$$

(4 marks)

(c) The input impedance $Z_{in,1}$ defined in Figure 2 above.

(5 marks)

/Cont...

/Cont...2.

(d) The input impedance $Z_{in,2}$ defined in Figure 2 above. You might want to use the general expressing of an input impedance for this and use the fact that the length of the open circuited stub is very small with respect to λ.

$Z_L \to \infty$ $\quad l \ll \lambda$

$$Z_{in} = Z_0 \frac{Z_L + j Z_0 \tan \beta l}{Z_0 + j Z_L \tan \beta l}.$$

$\beta l = \frac{2\pi}{\lambda} \cdot l = 2\pi \frac{l}{\lambda} \to 0.$

(5 marks)

(e) An equivalent circuit given the 3 loads $Z_{in,1}$, $Z_{in,2}$ and Y_1. Calculate the equivalent admittance of this circuit.

Y

(5 marks)

(f) The admittance Y_1 such that $Z_{in,3} = Z_{03}$

(4 marks)

Provide your solutions using just variables; i.e. no numerical values are required.

Helpful hint: sin(x) ~x and cos (x) ~1 for small angles.

4. (a) Draw the circuit diagram for a Wilkinson power splitter using basic transmission line sections. This splitter is to connect to other transmission lines, which have a characteristic impedance of 50 Ω.

Make sure to include and clearly label the following on your circuit:

(i) The transmission line impedances,

(ii) Ports of the circuit,

(iii) Any resistors, inductors, and capacitors, and

(iv) Any critical lengths.

(5 marks)

(b) Draw the circuit diagram for a branch line hybrid coupler using transmission line sections. This coupler is to connect to other transmission lines, which have a characteristic impedance of 75 Ω.

The following must be included and clearly labeled on your circuit.

(i) The transmission line impedances,

(ii) The isolated and the through ports

(iii) Any critical lengths.

(5 marks)

/Cont…

3. (a) Describe the importance and drawbacks of designing matching networks using stub circuits. In particular draw shunt and series open-circuited and short-circuited stub circuits.

In your short essay, the following terms must be given and described: single stub matching, double stub matching, microwave integrated circuits, bandwidth, flexibility, shunt and series stub circuits.

(5 marks)

(b) The 0.1λ long transmission line has a characteristic impedance of $Z_0 =$ 50 Ω and is terminated with a load impedance of load impedance $Z_L =$ 5 + j25 Ω. Use the Smith chart to determine the following parameters:

(i) Locate the load impedance and admittance.

(3 marks)

(ii) What is the impedance at the other end of the transmission line?

(4 marks)

(iii) The voltage standing wave ratio along the transmission line,

(3 marks)

(iv) Calculate the reflection coefficient of the line.

(3 marks)

(v) What is the reflection coefficient at the further end of the line from the load?

(3 marks)

(vi) The relative positions from the load of the maximum and minimum values of the voltage.

(4 marks)

/Cont…4.

(c) A four-port coupler has the following scattering matrix, which was determined using matched loads.

$$S = \frac{1}{\sqrt{2}}\begin{vmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & -1 \\ 1 & 0 & 0 & 1 \\ 0 & -1 & 1 & 0 \end{vmatrix}$$

Find the following:

(i) The directivity,

(ii) The coupling,

(iii) The isolation,

(vi) The return loss, and

(v) The phase change for one Watt of power when injected into port 2 and with respect to port 4.

(5 marks)

(d) (i) Design a lossless T-junction divider with a 100 Ω reference impedance at the input port. A 2:1 power split for the output is required to be achieved. You will also need to include quarter-wave transformers to convert the impedances of the output lines to 100 Ω. Also make sure to provide a circuit diagram.

(6 marks)

/Cont…

/Cont…4(d)

(ii) Given your solution, determine the following S-parameters for your circuit, which uses the noted 100 Ω reference impedance.

(A) S_{22}

(B) S_{33}

(C) S_{12}

(D) S_{31}

(4 marks)

END OF PAPER