Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2015/2016

COURSE NAME	:	RF AND MICROWAVE ENGINEERING
COURSE CODE	:	BEB40803
PROGRAMME	:	BEJ
EXAMINATION DATE	:	JUNE / JULY 2016
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FIVE (5)** QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **ELEVEN (11)** PAGES

Q1 A transmission line is a distributed parameter network, where voltages and currents can vary in magnitude and phase over its length.

(a) Sketch and label the lumped-element equivalent circuit of a transmission line. (4 marks)

(b) Show that, for a transmission line terminated with Z_L, characteristic impedance of Z_0 and length $l = \frac{\lambda}{4}$, the input impedance Z_{in} is,

$$Z_{in} = \frac{{Z_0}^2}{Z_L}$$

(4 marks)

(c) **Figure Q1(c)** shows frequency response of an antenna. At the center frequency, calculate :

(i) reflection coefficient (3 marks)

(ii) signal to wave ratio (3 marks)

(iii) return loss, and (3 marks)

(iv) percentage of power transmitted (3 marks)

Q2 (a) Show that the S-parameter for the circuit in **Figure Q2(a)** is

$$\begin{bmatrix} \frac{Z}{2Z_0+Z} & \frac{2Z_0}{2Z_0+Z} \\ \frac{2Z_0}{2Z_0+Z} & \frac{Z}{2Z_0+Z} \end{bmatrix}$$

(5 marks)

(b) Consider a two-port network as illustrated in **Figure Q2(b)**. Determine the S-Parameter of the system.

(15 marks)

Q3 (a) Microwave resonator forms the basic element for various devices including filter and amplifier.

(i) Sketch and label the response ($Z_{in}(\omega)$ vs ω/ω_o) for series resonant circuit resonator.

(4 marks)

(ii) Determine the resonance frequency for **Q3(a)(i)** if inductance L is given as 2.5 nH and capacitance C is given as 0.6 pF.

(4 marks)

(iii) If at any time, the frequency measured is 200 MHz below its resonance frequency. Calculate the input impedance Z_{in} of the resonance circuit. Assume that the resistance R is 200 Ω.

(4 marks)

(b) A defected ground structure (DGS) is designed on a substrate with thickness of 0.13 mm and the dielectric constant of 2.56. It is then simulated and the response is analyzed.

(i) Sketch the equivalent circuit of the DGS.

(4 marks)

(ii) Calculate the inductance L, and the capacitance C of the DGS equivalent circuit if the simulated cut-off frequency of the circuit is given as 2.87 GHz and the center frequency as 3.92 GHz. Assume that Z_o is 50 Ω.

(4 marks)

Q4 (a) Briefly describe **THREE (3)** practical responses of a microwave low pass filter and sketch the corresponding frequency response plot.

(3 marks)

(b) Design a microstrip low-pass filter with cut-off frequency of 2 GHz, 30 dB attenuation at frequency 3.5 GHz for Chebyshev attenuation response with 0.2 dB ripple. The source and load impedance are 50 Ohm. The filter is implemented on a microstrip board with a relative permittivity = 9.9, h= 0.63 mm and Tanδ = 0.0001. Determine:

(i) equivalent circuit of the filter,

(5 marks)

(ii) the value of series and shunt reactance components, and

(7 marks)

(iii) the width of the capacitor line impedance, W_c, when the impedance value is assumed to be Z_{0c} = 20 Ohms.

(5 marks)

Q5 (a) A coaxial cable uses polyethylene as the dielectric insulator with $\varepsilon_r = 2.1$. The ratio of the outer and inner layer is $b/a = 3.38$.

(i) The cable is used to connect a device to a source. To ensure maximum power delivery, calculate the ideal input impedance value Z_{in} of the device.

(5 marks)

(ii) Determine the highest usable frequency before the TE_{11} waveguide mode starts to propagate if $b = 1.4$ cm.

(3 marks)

(b) Calculate the width of a microstrip transmission line on a substrate board with $\varepsilon_r = 2.2$ and thickness of $h = 0.127$ cm that can match well with the coaxial cable in **Q5 (a)**.

(5 marks)

(c) Sketch the field patterns of the propagating fields in coaxial cable and strip line. Analyze the pattern and explain about their similarities and determine the corresponding propagation modes.

(7 marks)

Q6 (a) For an amplifier, give brief description for the three types of gain below:

(i) Transducer gain

(ii) Power gain

(iii) Available gain

(3 marks)

(b) The S-parameter for HP HFET-102 GaAs FET at 2 GHz with a bias voltage $V_{gs} = 0$ are given as follows (Z_o=50 Ω).

$$S_{11} = 0.894 \angle -60.6^o$$

$$S_{21} = 3.122 \angle 123.6^o$$

$$S_{12} = 0.02 \angle 62.4^o$$

$$S_{22} = 0.781 \angle -27.6^o$$

The source impedance is Z_s= 20 Ω and the load impedance is Z_L = 30 Ω.

(i) Compute the power gain, available gain and the transducer gain.

(9 marks)

(ii) Determine the stability of this transistor.

(8 marks)

- END OF QUESTION –

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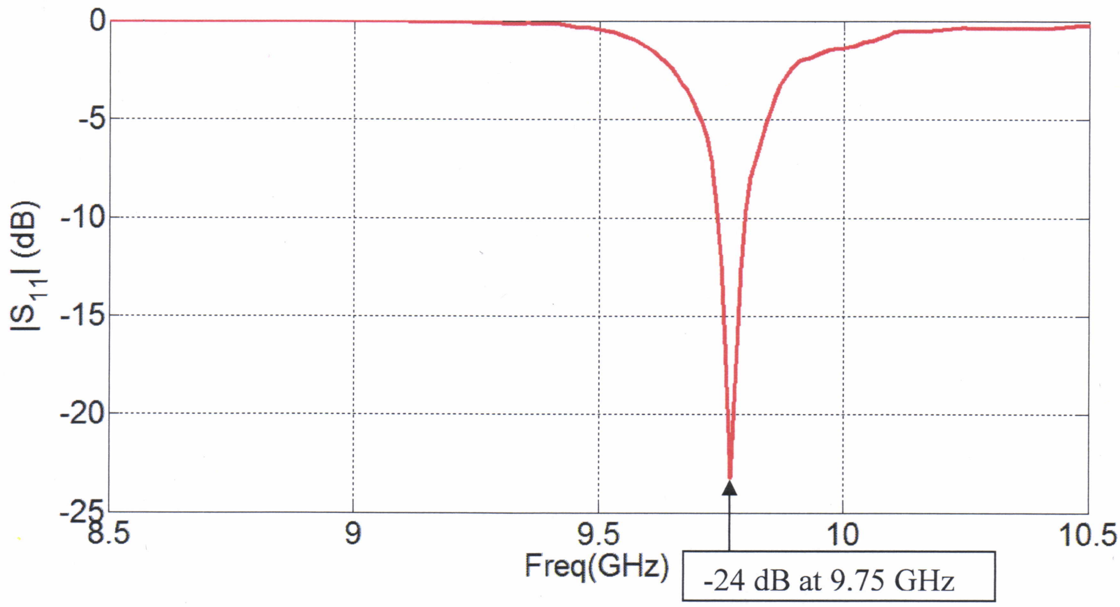

FIGURE Q1 (c)

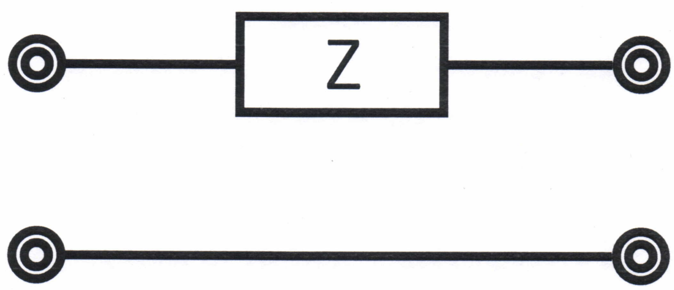

FIGURE Q2 (a)

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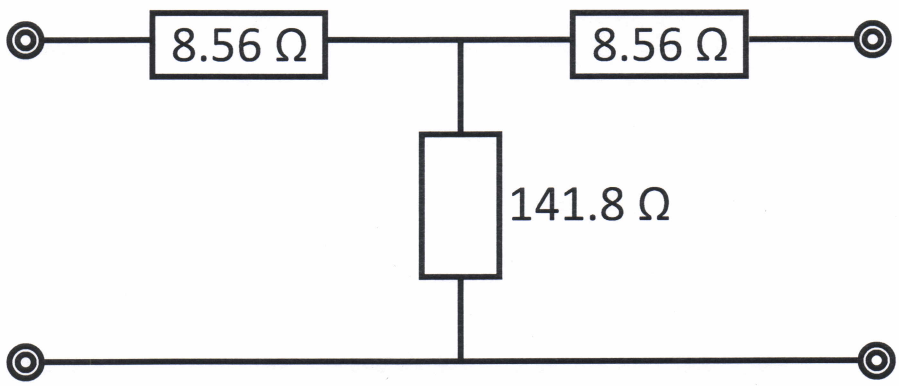

FIGURE Q2 (b)

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TABLE 1

The *ABCD* Parameters of Some Useful Two-Port Circuits.

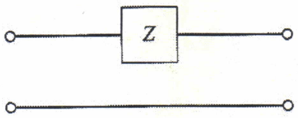
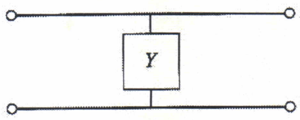
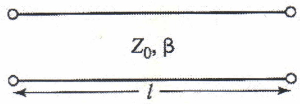
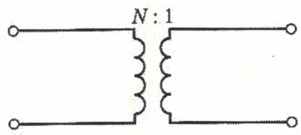
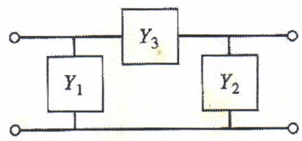
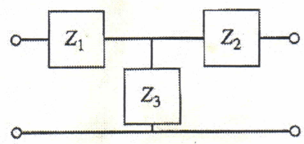
Circuit	*ABCD* Parameters	
	$A = 1$ $C = 0$	$B = Z$ $D = 1$
	$A = 1$ $C = Y$	$B = 0$ $D = 1$
	$A = \cos \beta l$ $C = jY_0 \sin \beta l$	$B = jZ_0 \sin \beta l$ $D = \cos \beta l$
	$A = N$ $C = 0$	$B = 0$ $D = \frac{1}{N}$
	$A = 1 + \frac{Y_2}{Y_3}$ $C = Y_1 + Y_2 + \frac{Y_1 Y_2}{Y_3}$	$B = \frac{1}{Y_3}$ $D = 1 + \frac{Y_1}{Y_3}$
	$A = 1 + \frac{Z_1}{Z_3}$ $C = \frac{1}{Z_3}$	$B = Z_1 + Z_2 + \frac{Z_1 Z_2}{Z_3}$ $D = 1 + \frac{Z_2}{Z_3}$

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TABLE 2

0.5 dB Ripple

N	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}
1	0.6986	1.0000								
2	1.4029	0.7071	1.9841							
3	1.5963	1.0967	1.5963	1.0000						
4	1.6703	1.1926	2.3661	0.8419	1.9841					
5	1.7058	1.2296	2.5408	1.2296	1.7058	1.0000				
6	1.7254	1.2479	2.6064	1.3137	2.4758	0.8696	1.9841			
7	1.7372	1.2583	2.6381	1.3444	2.6381	1.2583	1.7372	1.000		
8	1.7451	1.2647	2.6564	1.3590	2.6964	1.3389	2.5093	0.8796	1.9841	
9	1.7504	1.2690	2.6678	1.3673	2.7239	1.3673	2.6678	1.2690	1.7504	1.0000
10	1.7543	1.2721	2.6754	1.3725	2.7392	1.3806	2.7231	1.3485	2.5239	0.8842

3.0 dB Ripple

N	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}
1	1.9953	1.0000								
2	3.1013	0.5339	5.8095							
3	3.3487	0.7117	3.3487	1.0000						
4	3.4389	0.7483	4.3471	0.5920	5.8095					
5	3.4817	0.7618	4.5381	0.7618	3.4817	1.0000				
6	3.5045	0.7685	4.6061	0.7929	4.4641	0.6033	5.8095			
7	3.5182	0.7723	4.6386	0.8039	4.6386	0.7723	3.5182	1.0000		
8	3.5277	0.7745	4.6575	0.8089	4.6990	0.8018	4.4990	0.6073	5.8095	
9	3.5340	0.7760	4.6692	0.8118	4.7272	0.8118	4.6692	0.7760	3.5340	1.0000
10	3.5384	0.7771	4.6768	0.8136	4.7425	0.8164	4.7260	0.8051	4.5142	0.6091

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TABLE 3

	S	Z	Y	$ABCD$
S_{11}	S_{11}	$\frac{(Z_{11}-Z_0)(Z_{22}+Z_0)-Z_{12}Z_{21}}{\Delta Z}$	$\frac{(Y_0-Y_{11})(Y_0+Y_{22})+Y_{12}Y_{21}}{\Delta Y}$	$\frac{A+B/Z_0-CZ_0-D}{A+B/Z_0+CZ_0+D}$
S_{12}	S_{12}	$\frac{2Z_{12}Z_0}{\Delta Z}$	$\frac{-2Y_{12}Y_0}{\Delta Y}$	$\frac{2(AD-BC)}{A+B/Z_0+CZ_0+D}$
S_{21}	S_{21}	$\frac{2Z_{21}Z_0}{\Delta Z}$	$\frac{-2Y_{21}Y_0}{\Delta Y}$	$\frac{2}{A+B/Z_0+CZ_0+D}$
S_{22}	S_{22}	$\frac{(Z_{11}+Z_0)(Z_{22}-Z_0)-Z_{12}Z_{21}}{\Delta Z}$	$\frac{(Y_0+Y_{11})(Y_0-Y_{22})+Y_{12}Y_{21}}{\Delta Y}$	$\frac{-A+B/Z_0-CZ_0+D}{A+B/Z_0+CZ_0+D}$
Z_{11}	$Z_0\frac{(1+S_{11})(1-S_{22})+S_{12}S_{21}}{(1-S_{11})(1-S_{22})-S_{12}S_{21}}$	Z_{11}	$\frac{Y_{22}}{\lvert Y\rvert}$	$\frac{A}{C}$
Z_{12}	$Z_0\frac{2S_{12}}{(1-S_{11})(1-S_{22})-S_{12}S_{21}}$	Z_{12}	$\frac{-Y_{12}}{\lvert Y\rvert}$	$\frac{AD-BC}{C}$
Z_{21}	$Z_0\frac{2S_{21}}{(1-S_{11})(1-S_{22})-S_{12}S_{21}}$	Z_{21}	$\frac{-Y_{21}}{\lvert Y\rvert}$	$\frac{1}{C}$
Z_{22}	$Z_0\frac{(1-S_{11})(1+S_{22})+S_{12}S_{21}}{(1-S_{11})(1-S_{22})-S_{12}S_{21}}$	Z_{22}	$\frac{Y_{11}}{\lvert Y\rvert}$	$\frac{D}{C}$
Y_{11}	$Y_0\frac{(1-S_{11})(1+S_{22})+S_{12}S_{21}}{(1+S_{11})(1+S_{22})-S_{12}S_{21}}$	$\frac{Z_{22}}{\lvert Z\rvert}$	Y_{11}	$\frac{D}{B}$
Y_{12}	$Y_0\frac{-2S_{12}}{(1+S_{11})(1+S_{22})-S_{12}S_{21}}$	$\frac{-Z_{12}}{\lvert Z\rvert}$	Y_{12}	$\frac{BC-AD}{B}$
Y_{21}	$Y_0\frac{-2S_{21}}{(1+S_{11})(1+S_{22})-S_{12}S_{21}}$	$\frac{-Z_{21}}{\lvert Z\rvert}$	Y_{21}	$\frac{-1}{B}$
Y_{22}	$Y_0\frac{(1+S_{11})(1-S_{22})+S_{12}S_{21}}{(1+S_{11})(1+S_{22})-S_{12}S_{21}}$	$\frac{Z_{11}}{\lvert Z\rvert}$	Y_{22}	$\frac{A}{B}$
A	$\frac{(1+S_{11})(1-S_{22})+S_{12}S_{21}}{2S_{21}}$	$\frac{Z_{11}}{Z_{21}}$	$\frac{-Y_{22}}{Y_{21}}$	A
B	$Z_0\frac{(1+S_{11})(1+S_{22})-S_{12}S_{21}}{2S_{21}}$	$\frac{\lvert Z\rvert}{Z_{21}}$	$\frac{-1}{Y_{21}}$	B
C	$\frac{1}{Z_0}\frac{(1-S_{11})(1-S_{22})-S_{12}S_{21}}{2S_{21}}$	$\frac{1}{Z_{21}}$	$\frac{-\lvert Y\rvert}{Y_{21}}$	C
D	$\frac{(1-S_{11})(1+S_{22})+S_{12}S_{21}}{2S_{21}}$	$\frac{Z_{22}}{Z_{21}}$	$\frac{-Y_{11}}{Y_{21}}$	D

$\lvert Z\rvert = Z_{11}Z_{22} - Z_{12}Z_{21}$; $\lvert Y\rvert = Y_{11}Y_{22} - Y_{12}Y_{21}$; $\Delta Y = (Y_{11}+Y_0)(Y_{22}+Y_0) - Y_{12}Y_{21}$; $\Delta Z = (Z_{11}+Z_0)(Z_{22}+Z_0) - Z_{12}Z_{21}$; $Y_0 = 1/Z_0$

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$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\frac{1}{\sqrt{1 + 12\, d/W}}$$

$$Z_o = \begin{cases} \dfrac{60}{\sqrt{\varepsilon_e}} ln\left(\dfrac{8d}{W} + \dfrac{W}{4d}\right) & for\ W/d \le 1 \\ \dfrac{120\pi}{\sqrt{\varepsilon_e}[W/d + 1.393 + 0.667 ln(W/d + 1.444)]} & for\ W/d \ge 1 \end{cases}$$

$$\frac{W}{d} = \begin{cases} \dfrac{8\varepsilon^A}{e^{2A} - 2} & for\ W/d < 2 \\ \dfrac{2}{\pi}\left[B - 1 - ln(2B - 1) + \dfrac{\varepsilon_r - 1}{2\varepsilon_r}\left\{ln(B - 1) + 0.39 - \dfrac{0.61}{\varepsilon_r}\right\}\right] & for\ W/d > 2 \end{cases}$$

Where

$$A = \frac{Z_o}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right)$$

$$B = \frac{377\pi}{2Z_o\sqrt{\varepsilon_r}}$$