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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2015/2016

COURSE NAME	:	RF AND MICROWAVE ENGINEERING
COURSE CODE	:	BEB 40803
PROGRAMME	:	BACHELOR OF ELECTRONIC ENGINEERING WITH HONOURS
EXAMINATION DATE	:	DECEMBER 2015 / JANUARY 2016
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FIVE (5)** QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

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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) A telephone line has $R = 6$ ohms/km, $L = 2.2$ mH/km, $C = 0.005$ μF/km, and $G = 0.05$ μmho/km. Determine Z_o, α, β at 1 kHz. If the line length is 100 km, determine the:

(i) attenuation of the signals,
(ii) phase shift of the signals, and
(ii) phase velocity of the signals.

(12 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 ABCD-matrix of the system.

(15 marks)

Q3 (a) A Wilkinson power divider can be made to give arbitrary power division. It has the useful property of being lossless when the output ports are matched.

(i) Sketch and label the circuit for a Wilkinson equal-split power divider.
(8 marks)

(ii) Design an equal-split Wilkinson power divider for a 50 Ω system impedance at frequency 2 GHz.
(6 marks)

(b) A 20 dB single-section coupled line coupler is designed in stripline with a 0.158 cm ground plane spacing, dielectric constant of 2.56, a characteristic impedance of 50 Ω, and a center frequency of 3 GHz.

(i) Determine the even- and odd-mode characteristic impedances of the coupler.

(4 marks)

(iii) Calculate the width and separation of the conductor for the coupler if $W/b = 0.72$ and $S/b = 0.34$.

(2 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 ε_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 ε_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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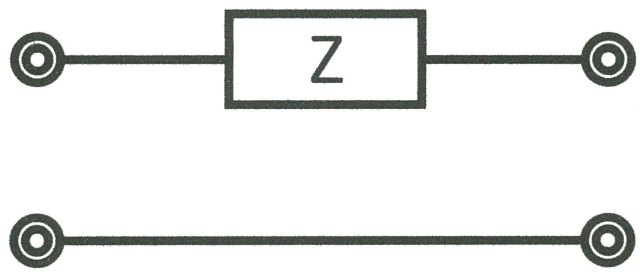

FIGURE Q2 (a)

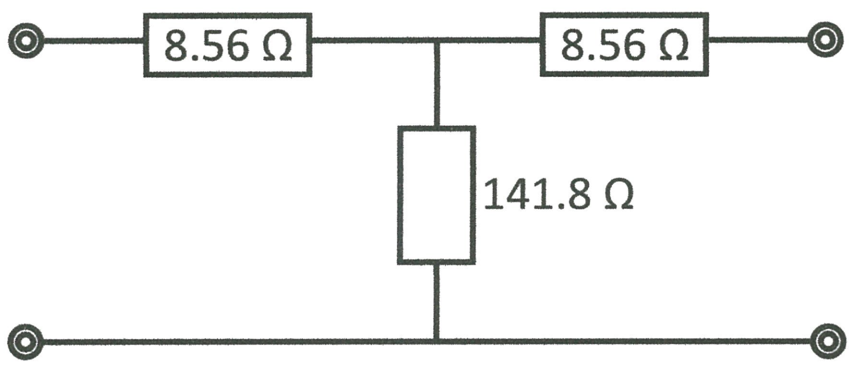

FIGURE Q2 (b)

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TABLE 1

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

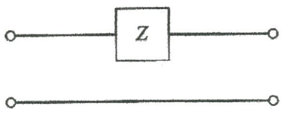
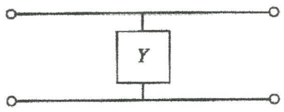
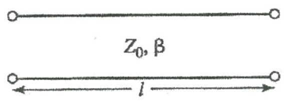
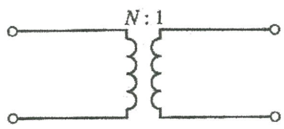
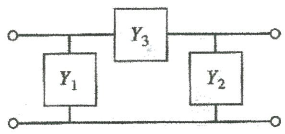
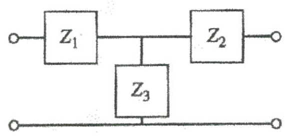
Circuit	*ABCD* Parameters	
	$A = 1$ $C = 0$	$B = Z$ $D = 1$
	$A = 1$ $C = Y$	$B = 0$ $D = 1$
	$A = \cos \beta l$ $C = jY_0 \sin \beta l$	$B = jZ_0 \sin \beta l$ $D = \cos \beta l$
	$A = N$ $C = 0$	$B = 0$ $D = \frac{1}{N}$
	$A = 1 + \frac{Y_2}{Y_3}$ $C = Y_1 + Y_2 + \frac{Y_1 Y_2}{Y_3}$	$B = \frac{1}{Y_3}$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

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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

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

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

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

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

Where

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

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