UNIVERSITI SAINS MALAYSIA

First Semester Examination
2015/2016 Academic Session

June 2016

EEE 322/4 – RF & MICROWAVE ENGINEERING

[KEJURUTERAAN GELOMBANG MIKRO & RF]

Duration : 2 hours
[Masa : 2 jam]

Please check that this examination paper consists of **THIRTEEN (13)** pages of printed material and **TWO (2)** pages of Appendix before you begin the examination. English version from page **TWO (2)** to page **SEVEN (7)** and Malay version from page **EIGHT (8)** to page **THIRTEEN (13)**.
*Sila pastikan bahawa kertas peperiksaan ini mengandungi **TIGA BELAS (13)** muka surat bercetak beserta Lampiran **DUA (2)** mukasurat bercetak sebelum anda memulakan peperiksaan ini. Versi Bahasa Inggeris daripada muka surat **DUA (2)** sehingga muka surat **TUJUH (7**) dan versi Bahasa Melayu daripada muka surat **LAPAN (8)** sehingga muka surat **TIGA BELAS (13)**.*

Instructions: This question paper consists of **FOUR (4)** questions. Answer **ALL** questions. All questions carry the same marks.
*[**Arahan:** Kertas soalan ini mengandungi **EMPAT (4)** soalan. Jawab **SEMUA** soalan. Semua soalan membawa jumlah markah yang sama]*

Use separate answer booklets for **Part A** and **Part B**.
*[Gunakan dua buku jawapan yang berasingan bagi **Bahagian A** dan **Bahagian B**.*

Answer to any question must start on a new page
[Mulakan jawapan anda untuk setiap soalan pada muka surat yang baharu].

"In the event of any discrepancies, the English version shall be used".
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai].

ENGLISH VERSION
PART A

1. For this question, use the operating frequency of 1.5 GHz.

   (a) Figure 1(a)(i) contains different types of L-matching circuit. There are 4 circuits in total. Using $Z_o = 50\ \Omega$, synthesize renormalized L-matching circuit with correct load impedance and assuming $V_s = 1V$ and $Z_g = Z_o$. Use Table 1 to show your answer in sequence starting from the load to generator. (Redraw the table in your answer sheet). Use Figure 1(a)(ii) as a guide and all values are renormalized.

(35 marks)

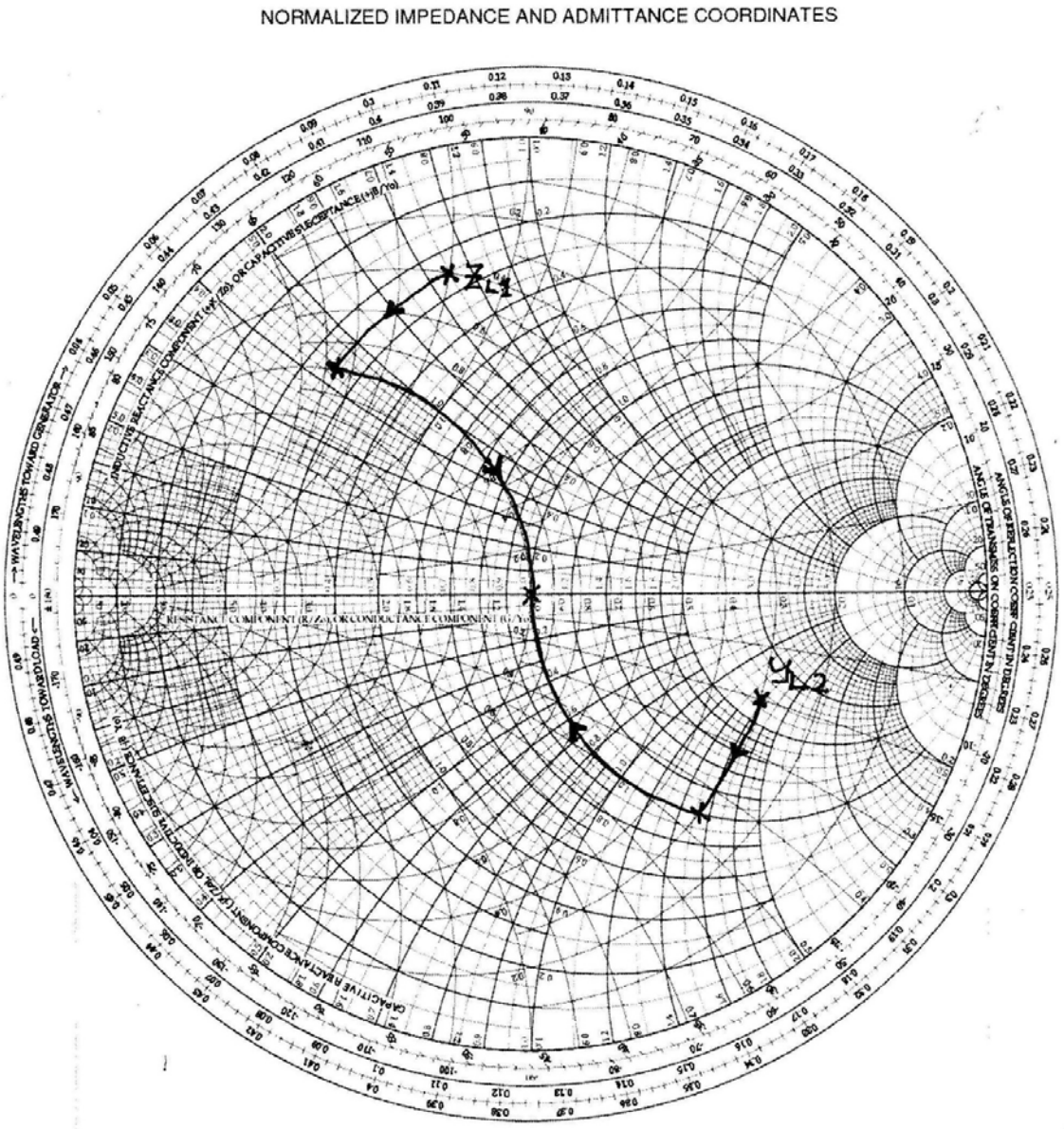

Figure 1(a)(i)

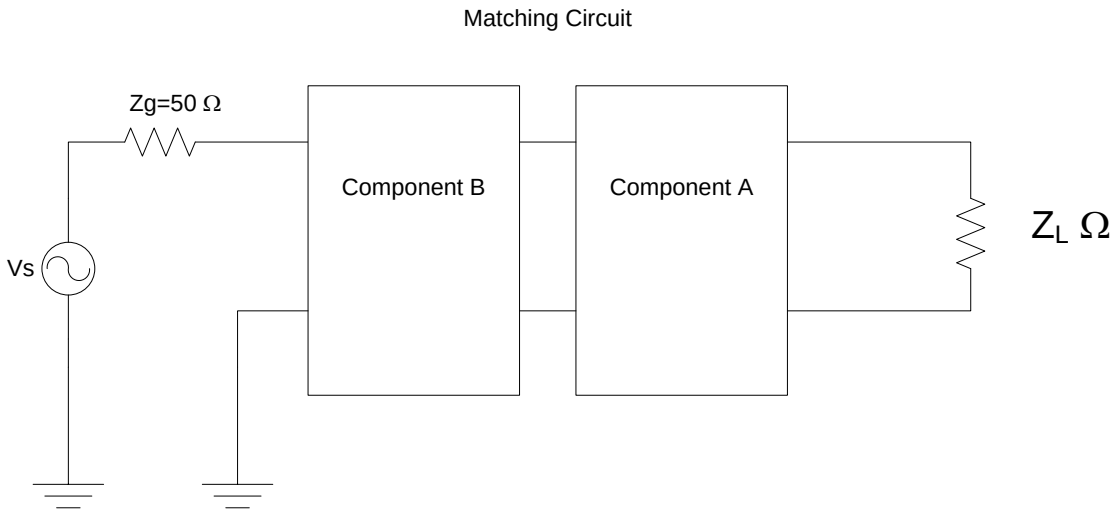

Figure 1(a)(ii)

Table 1

Load (Ω)	*Component A*			*Component B*		
	Shunt/Series	L or C	Value	Shunt/Series	L or C	Value
Z_{L1} =						
Y_{L2} =						

(b) (i) A circuit is given in Figure 1(b) shows a matching circuit connected to another system. This system has a complex schematic diagram. Provide **a solution** using lumped element for *Matching Circuit* box. Present your working solution clearly.

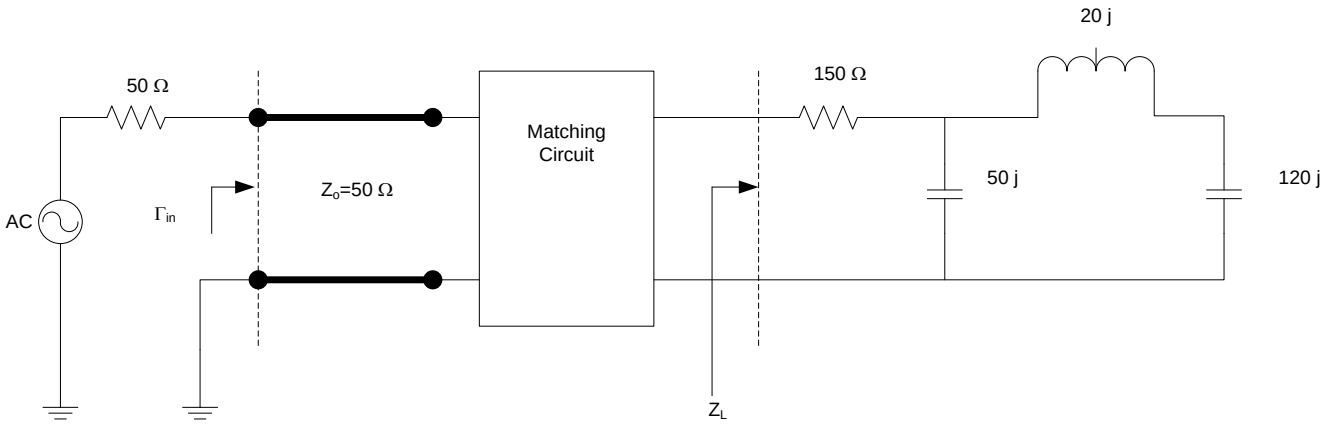

Figure 1(b)

(35 marks)

(ii) Prove that **the solution** is **acceptable** by using circuit theory and transmission line theory, provided that the $\Gamma_{in} \approx 0$.

(30 marks)

2. Two circuits are given as in Figure 2(a) and Figure 2(b).

(a) Using Figure 2(a), assuming the circuit is lossless, *calculate* $\Gamma_{in.}$ Then, prove that your answer is correct using Smith Chart after moving 0.375 λ. Show each steps clearly.

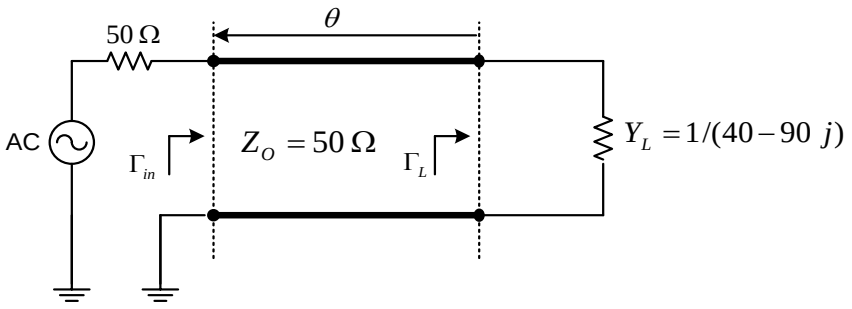

Figure 2(a)

(50 marks)

(b) (i) Figure 2(b) shows two interconnecting transmission line. If $Z_1 = Z_G$ and $Z_2 = Z_L$, produce suitable equation for the following information when $\theta_1 = \theta_2 = \frac{1}{8}\pi$. Note that $Z_L = Y_L^{-1}$ as in Part 1

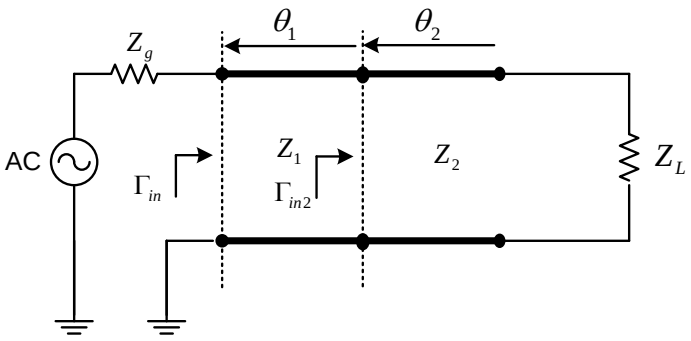

Figure 2(b)

(a) Γ_{in2}

(b) Z_{in2}

(c) SWR at Γ_{in2}

(d) Return Loss at Γ_{in2}

(20 marks)

(ii) Z_L needs to match with Z_1 (where Z_L is equal to R_L and $Z_1 = Z_G = R_G$). *Suggest* a length for θ_2 in **electrical length** format and possible equation for Z_2 to match with Z_1 using a suitable equation provided that $\theta_1 = \frac{1}{8}\pi$. *Discuss thoroughly* your choice of method.

(20 marks)

(iii) If R_L = 100 Ω and R_G = 50 Ω, what is the length of θ_2 in millimeter if f = 1.5 GHz.

(10 marks)

PART B

3. (a) Explain the basic principal of the IF type microwave repeater with the help of a block diagram.

(20 marks)

(b) A microwave radio link is operating at frequency of 5 GHz. The distance between the transmitter and receiver is 10 km. The transmission power is 29 dBm over the 30 dBi parabolic antenna gain. The receiver received the signal through 20 dBi gain of parabolic antenna. What is the level of the received signal at the receiver in dBm.

(20 marks)

(c) Based on the following wave signals, explain the basic principal of the downconversion for diode mixer.

$$V_{LO}(t) = \cos 2\pi f_{LO} t \qquad V_{RF}(t) = \cos 2\pi f_{RF} t$$

(25 marks)

(d) Design a 7 GHz microwave mixer using branch line coupler topology on Duroid 4003C with the substrate thickness of 0.813 mm and ε_r is 3.38.

(35 marks)

4. The transistor ATF 38143 having the S-parameter, gain and noise parameter as in the AVAGO datasheet provided in Appendix 2.

(a) Calculate the stability factor of the transistor

(20 marks)

(b) Determine the gain of the transistor at frequency of 5 GHz

(20 marks)

(c) Design an LNA using the transistor operating at frequency of 5 GHz. Choose Γ_{in} at C_i and using Fr at 0.7 dB. Microwave laminate having the thickness of 0.318 mm with ε_r 3.8 should be used. The following important formulas may be useful.

(60 marks)

$$C_i = \frac{\Gamma_{opt}}{(1+N_i)}$$

$$Zo \approx \frac{377}{\sqrt{\varepsilon_r}(\frac{w}{h}+2)}$$

$$R_i = \frac{1}{1+N_i}\sqrt{N_i^{\,2} + N_i(1-\left|\Gamma_{opt}\right|^2)}$$

$$Ni = \frac{\left[(Fr - F\min)\left|1+\Gamma_{opt}\right|^2\right]}{4\frac{R_n}{Z_o}}$$

$$\Gamma_L = \left(S_{22} + \frac{S_{12}S_{21}\Gamma_{in}}{1-S_{11}\Gamma_{in}}\right)^*$$

$$K = \frac{1-\left|S_{11}\right|^2 - \left|S_{22}\right|^2 + \left|\Delta\right|^2}{2\left|S_{12}S_{21}\right|}$$

$$\Delta = S_{11}S_{22} - S_{12}S_{21} \langle 1$$

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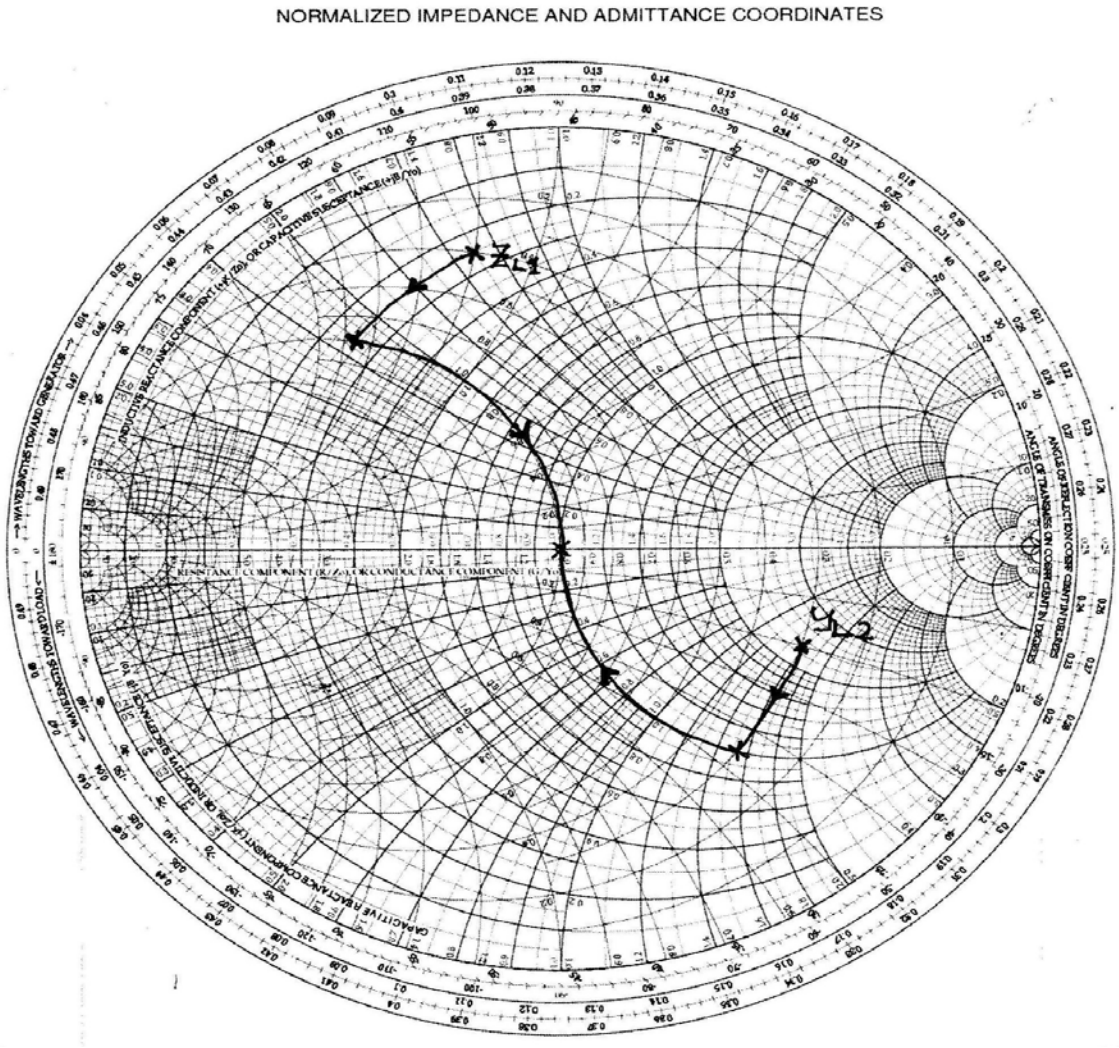
VERSI BAHASA MELAYU

BAHAGIAN A

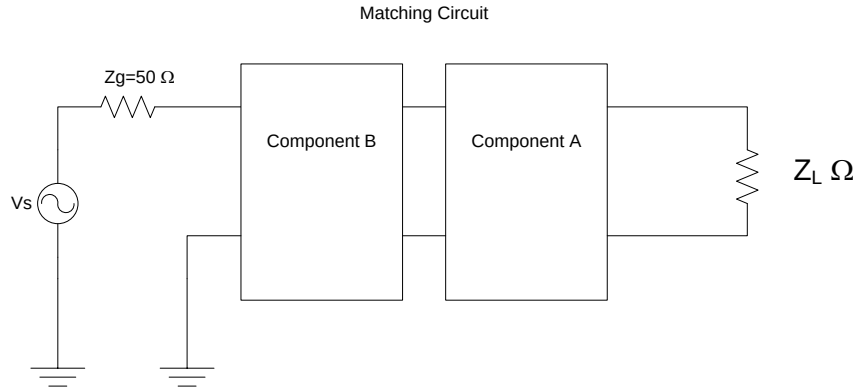
1. *Untuk soalan ini, gunakan frekuensi operasi sebanyak 1.5 GHz.*

   (a) *Rajah 1(a)(i) menunjukkan pelbagai jenis litar Padanan-L. Terdapat 4 kesemuanya. Dengan menggunakan Z_o=50 Ω, sintesiskan Padanan-L ternormal beserta galangan beban yang betul serta andaikan V_s= 1 V dan $Z_g = Z_o$. Nyatakan jawapan anda dengan mengunakan Jadual 1 secara berturutan dari beban hingga ke generator. (Lukis jadual tersebut dalam kertas jawapan). Guna Rajah 1(a)(ii) sebagai rujukan dan semua nilai adalah ternormal semula.*

(35 markah)



Rajah 1(a)(i)

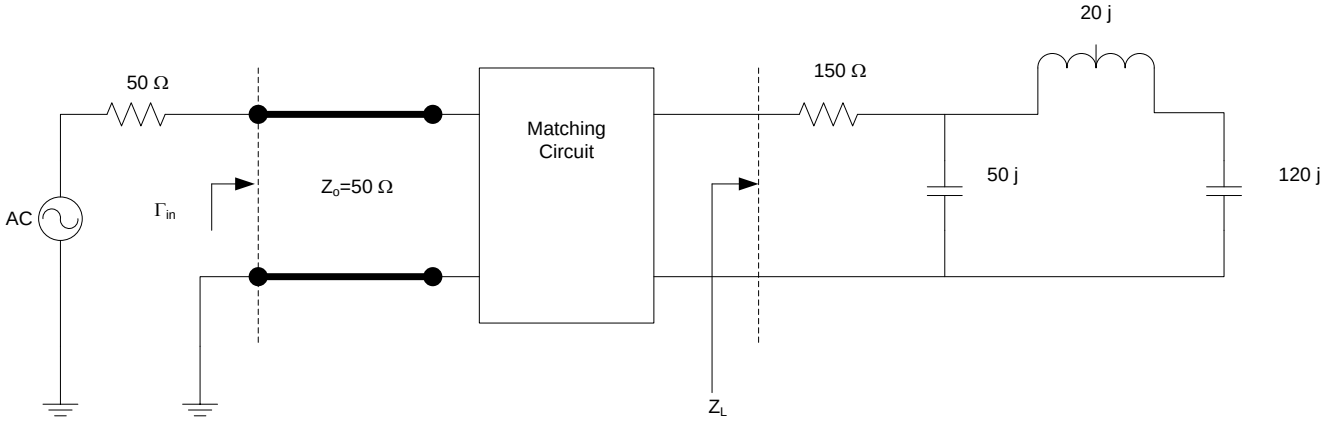


Rajah 1(a)(ii)

Jadual 1

Load (Ω)	*Component A*			*Component B*		
	Shunt/Series	*L or C*	*Value*	*Shunt/Series*	*L or C*	*Value*
Z_{L1} =						
Y_{L2} =						

*(b) (i) Litar yang diberikan di Rajah 1(b) menunjukkan litar padanan bersambung dengan sistem yang lain. Sistem ini menunjukkan skema rajah kompleks. Berikan **satu penyelesaian menggunakan** model elemen tergumpal untuk kotak Litar Berpadanan. Tunjukkan jalan penyelesaian dengan jelas.*



Rajah 1(b)

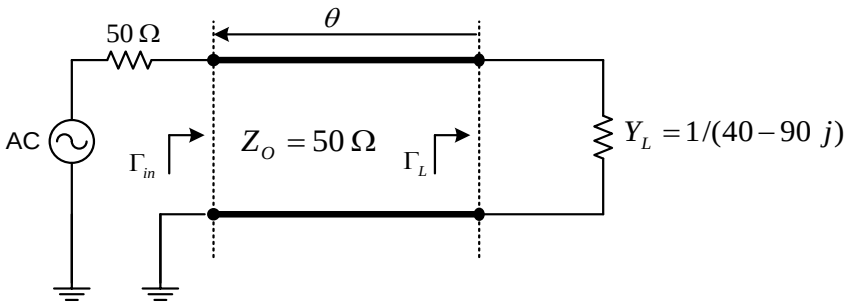
(35 markah)

*(ii) Buktikan bahawa **penyelesaian tersebut** adalah **bersesuaian** dengan diberikan Γ_{in}≈0 melalui teori litar dan teori talian penghantaran.*

(30 markah)

2. *Dua litar adalah diberikan seperti Rajah 2(a) dan Rajah 2(b)*

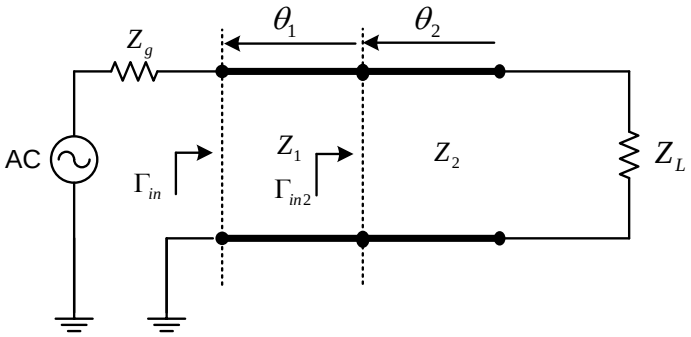
(a) *Dengan menggunakan Rajah 2(a), andaikan litar tersebut tanpa kehilangan, hitung* Γ_s. *Kemudian, buktikan jawapan anda betul melalui Carta Smith setelah berjarak sebanyak 0.375* λ. *Tunjukkan setiap langkah dengan jelas.*



Rajah 2(a)

(50 markah)

(b) (i) *Rajah 2(b) menunjukkan 2 penyambung-antara talian penghantaran. Jika* $Z_1 = Z_g$ *dan* $Z_2 = Z_L$, *berikan persamaan untuk informasi berkenaan jika* $\theta_1 = \theta_2 = \frac{1}{8}\pi$.



Rajah 2(b)

(a) Γ_{in2}

(b) Z_{in2}

(c) SWR di Γ_{in2}

(d) Pembalikan Terhilang di Γ_{in2}

(20 markah)

(ii) *Z_L diperlukan untuk memadan nilai Z_1 (dan Z_L adalah bersamaan R_L, serta $Z_1 = Z_g = R_G$). Cadangkan panjang θ_2 dalam bentuk* ***panjang elektrik*** *melalui persamaan yang sesuai untuk mengira nilai Z_2 untuk memadani Z_1 melalui persamaan yang sesuai dengan diberikan $\theta_1 = \frac{1}{8}\pi$. Bincangkan secara mendalam kaedah pemilihan anda.*

(20 markah)

(iii) *Jika R_L = 100 Ω and R_G = 50 Ω, apakah nilai Z_2 dan panjang θ_2 dalam milimeter jika f =1.5 GHz.*

(10 markah)

BAHAGIAN B

3. (a) *Terangkan prinsip asas pengulang gelombang mikro jenis IF dengan pertolongan rajah blok.*

(20 markah)

(b) *Sebuah rangkaian radio gelombang mikro adalah beroperasi pada frekuensi sebanyak 5 GHz. Jarak diantara pemancar dan penerima adalah 10 km. Kuasa pemancaran adalah 29 dBm melalui gandaan parabola antenna 30 dBi. Penerima menerima isyarat melalui antena parabola bergandaan 20 dBi. Apakah aras penerimaan isyarat pada penerima dalam dBm.*

(20 markah)

(c) *Berdasarkan isyarat gelombang berikut, terangkan prinsip asas pencampur diod penukarturun.*

$$V_{LO}(t) = \cos 2\pi f_{LO} t \qquad V_{RF}(t) = \cos 2\pi f_{RF} t$$

(25 markah)

(d) *Rekabentuk pencampur gelombang mikro 7 GHz menggunakan topologi pengganding talian cabang pada Duroid 4003C dengan ketebalan substrat 0.813 mm dan ε_r ialah 3.38.*

(35 markah)

4. *Transistor ATF 38143 mempunyai parameter-S, gandaan dan parameter hingar seperti dihelaian data dalam Lampiran 2.*

(a) *Hitung faktor kestabilan transistor tersebut*

(20 markah)

(b) *Tentukan gandaan transistor pada frekuensi sebanyak 5 GHz*

(20 markah)

(c) *Rekabentuk sebuah LNA menggunkan transistor tersebut beroperasi pada frekuensi sebanyak 5 GHz. Pilih Γ_{in} pada C_i dan menggunakan nisbah hingar Fr pada 0.7 dB. Laminat gelombang mikro mempunyai ketebalan sebanyak 0.318 mm dengan ε_r 3.8 perlu digunakan. Formula berikut mungkin berguna.*

(60 markah)

$$C_i = \frac{\Gamma_{opt}}{(1+N_i)} \qquad Zo \approx \frac{377}{\sqrt{\varepsilon_r}(\frac{w}{h}+2)}$$

$$R_i = \frac{1}{1+N_i}\sqrt{N_i^{\,2} + N_i(1-\left|\Gamma_{opt}\right|^2)}$$

$$Ni = \frac{\left[(Fr - F\min)\left|1+\Gamma_{opt}\right|^2\right]}{4\frac{R_n}{Z_o}} \qquad \Gamma_L = \left(S_{22} + \frac{S_{12}S_{21}\Gamma_{in}}{1-S_{11}\Gamma_{in}}\right)^*$$

$$K = \frac{1-\left|S_{11}\right|^2 - \left|S_{22}\right|^2 + \left|\Delta\right|^2}{2\left|S_{12}S_{21}\right|} \qquad \Delta = S_{11}S_{22} - S_{12}S_{21} \langle 1$$

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Appendix 1

Lampiran 1

Some (might be) useful equations:

Persamaan (yang mungkin) berguna:

$$Z_{in} = Z_0 \frac{Z_L + jZ_0 \tan \beta\ell}{Z_0 + jZ_L \tan \beta\ell}$$

$$V(z) = V_0^+ e^{-j\beta z} + V_0^- e^{+j\beta z}$$

$$V_0^- = \frac{Z_L - Z_0}{Z_L + Z_0} V_0^+$$

$$\beta\lambda = 2\pi$$

Appendix 2

Lampiran 2

ATF-38143 Typical Scattering Parameters, $V_{DS} = 2$ V, $I_{DS} = 10$ mA

Freq.	S_{11}		S_{21}			S_{12}			S_{22}		MSG/MAG
(GHz)	Mag.	Ang.	dB	Mag.	Ang.	dB	Mag.	Ang.	Mag.	Ang.	(dB)
0.5	0.97	-29	17.41	7.423	158	-27.74	0.041	72	0.53	-26	22.58
0.8	0.93	-47	17.00	7.081	145	-24.01	0.063	61	0.51	-40	20.51
1.0	0.91	-58	16.69	6.834	136	-22.50	0.075	55	0.48	-50	19.60
1.5	0.83	-85	15.69	6.086	117	-20.00	0.100	40	0.42	-72	17.84
1.8	0.78	-100	15.02	5.634	107	-19.17	0.110	33	0.39	-85	17.09
2.0	0.76	-109	14.57	5.350	100	-18.71	0.116	28	0.37	-94	16.64
2.5	0.71	-131	13.38	4.665	86	-17.99	0.126	18	0.33	-114	15.68
3.0	0.68	-150	12.22	4.083	73	-17.65	0.131	9	0.31	-132	14.94
4.0	0.65	180	10.24	3.251	50	-17.27	0.137	-5	0.28	-163	13.75
5.0	0.65	153	8.68	2.716	30	-17.08	0.140	-18	0.28	172	12.88
6.0	0.66	129	7.35	2.330	11	-16.95	0.142	-30	0.28	147	12.15
7.0	0.68	107	6.03	2.003	-9	-16.95	0.142	-42	0.29	122	11.49
8.0	0.71	87	4.72	1.722	-27	-17.27	0.137	-53	0.32	99	9.09
9.0	0.73	68	3.57	1.509	-43	-17.46	0.134	-62	0.35	83	7.94
10.0	0.75	53	2.71	1.366	-60	-17.27	0.137	-72	0.40	70	7.55
11.0	0.79	36	1.61	1.204	-78	-17.39	0.135	-83	0.45	52	7.27
12.0	0.82	20	0.47	1.055	-94	-17.65	0.131	-94	0.50	35	6.84
13.0	0.84	8	-0.93	0.898	-110	-18.34	0.121	-104	0.54	17	5.72
14.0	0.85	-4	-2.24	0.773	-125	-18.86	0.114	-112	0.59	2	4.77
15.0	0.87	-18	-3.45	0.672	-140	-19.17	0.110	-122	0.63	-8	4.42
16.0	0.88	-31	-4.63	0.587	-153	-19.49	0.106	-131	0.67	-19	3.85
17.0	0.88	-41	-5.81	0.512	-167	-19.74	0.103	-141	0.70	-32	3.03
18.0	0.89	-51	-7.27	0.433	-179	-20.54	0.094	-148	0.74	-41	2.34

ATF-38143 Typical Noise Parameters

$V_{DS} = 2$ V, $I_{DS} = 10$ mA

Freq.	F_{min}	Γ_{opt}		$R_{n/50}$	G_a
GHz	dB	Mag.	Ang.	-	dB
0.5	0.18	0.66	13	0.17	24.1
0.9	0.19	0.64	22	0.16	21.0
1.0	0.20	0.63	26	0.15	20.4
1.5	0.23	0.60	43	0.14	17.9
1.8	0.25	0.57	60	0.12	17.0
2.0	0.28	0.56	67	0.12	16.1
2.5	0.32	0.54	81	0.10	15.2
3.0	0.39	0.52	98	0.08	13.9
4.0	0.52	0.44	129	0.06	11.9
5.0	0.65	0.44	166	0.04	10.8
6.0	0.75	0.45	-165	0.04	9.6
7.0	0.84	0.48	-135	0.08	8.7
8.0	0.95	0.51	-106	0.16	7.7
9.0	1.10	0.55	-84	0.29	7.0
10.0	1.20	0.56	-65	0.46	6.8

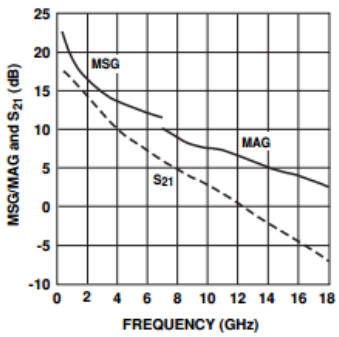

Figure 19. MSG/MAG and $|S_{21}|^2$ vs. Frequency at 2 V, 10 mA.