Second Semester Examination
2017/2018 Academic Session

May/June 2018

EEE 322 – RF & MICROWAVE ENGINEERING
(KEJURUTERAAN GELOMBANG MIKRO & RF)

Duration : 2 hours
(Masa : 2 jam)

Please ensure that this examination paper consists of **TEN (10)** pages and **SIX (6)** pages of printed appendices material before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **SEPULUH (10)** muka surat dan **ENAM (6)** muka surat lampiran yang bercetak sebelum anda memulakan peperiksaan ini.]*

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.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

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1. Standing wave is a phenomenon resulted from colliding waves with similar attributes. This also applies in transmission line analysis when determining the performance of any RF products.
Gelombang menegak adalah fenomena hasil pertembungan gelombang yang ada persamaan atribut. Ia juga diguna dalam analisa talian penghantar RF dalam menentukan prestasi mana-mana produk RF.

(a) A microstrip line constructed on FR-4 with microstrip width, w = 3.058 mm, FR-4 relative permittivity, ε_r = 4.4, microstrip line thickness, t = 0.1 mm, FR-4 substrate height, h = 1.7 mm is terminated by load impedance of 400 Ω. The operating frequency is at f = 2.45 GHz. Estimate analytically (using calculation) for the specifications given:

Satu talian mikrostrip yang dibina menggunakan FR-4 dengan kelebaran talian, w = 3.058 mm, ketelusan relatif FR-4, ε_r *= 4.4, ketebalan talian mirostrip t = 0.1 mm, ketinggian substrat FR-4, h = 1.7 mm dimatikan oleh pemalar beban sebanyak 400 Ω. Frekuensi operasi adalah pada* f *= 2.45 GHz. Anggarkan secara analitik (menggunakan kiraan) untuk spesifikasi yang diberikan:*

(i) the characteristic impedance, Z_0 of the w = 3.058 mm line;
galangan kecirian, Z_0 *untuk talian w = 3.058 mm;*

(10 marks/*markah*)

(ii) the load reflection coefficient, ρ;
pemalar pembalikan beban, ρ*;*

(10 marks/*markah*)

(iii) the characteristic impedance of the quarter-wave transformer, Z_{0T} that could be used to match the load;
galangan kecirian untuk pengubah suku-panjang gelombang Z_{0T} *yang boleh digunakan untuk menyamai beban;*

(10 marks/*markah*)

(iv) the width of the quarter-wave transformer section
lebar talian pengubah suku-panjang gelombang;

(10 marks/*markah*)

(v) the voltage standing wave ratio, VSWR;
nisbah voltan gelombang menegak, VSWR;

(10 marks/*markah*)

(b) It is important for a load to have a matched impedance with the source so that the power delivered from the source to the load is maximized.
Ia adalah penting untuk beban mempunyai galangan yang sama dengan punca supaya kuasa yang dihantar ke beban adalah semaksima yang mungkin.

(i) Figure 1 contains a 2-elements matching circuit with L-configuration to match a load impedance to a 50 Ω source. Decide what are the lumped elements for this matching circuit and calculate their values accordingly. Use f *= 1.5 GHz.*

Rajah 1 mengandungi litar padanan 2 elemen dengan konfigurasi-L untuk memadankan beban galangan kepada satu punca 50 Ω. Tentukan apakah elemen-elemen yang digunakan untuk litar padanan ini dan hitung nilai-nilai tersebut. Gunakan f *= 2.45 GHz.*

(20 marks/*markah*)

(ii) There is also an alternative matching circuit for the mismatched load impedance. Decide what are the alternative elements for the matching circuit and calculate their values accordingly. (Hint: show the matching circuit on a Smith Chart)

Terdapat satu alternatif litar padanan untuk memadankan beban ini ke puncanya. Tentukan apakah elemen-elemen yang digunakan untuk litar padanan alternatif ini dan hitung nilai mereka. (Petunjuk: tunjukkan litar padanan ini di dalam carta Smith)

(30 marks/*markah*)

Figure 1

Rajah 1

2. Each stage in a RF Receiver Front End comes with challenges of its own. For example, design limits imposed by additional fringing field capacitances and PCB manufacturing tolerance on specific transmission line can degrade its performance.

Setiap peringkat dalam seni bina penerima akhir depan RF mempunyai cabarannya. Sebagai contoh, kekangan dalam mereka bentuk adalah bebanan penambahan nilai kapasitan medan terpinggir dan toleransi dalam pembuatan PCB mampu menurunkan prestasi sesebuah talian penghantar.

(a) Microwave filter functions to selectively pass or attenuate a particular band of frequencies and is a crucial element of the receiver front end architecture.

Penapis gelombang mikro berfungsi untuk membenarkan atau melemahkan sesebuah frekuensi secara selektif dan merupakan penting dalam seni bina penerima akhir depan.

(i) Design a 5-element low-pass filter with a 3 dB point at 600 MHz using Ls and Cs component. The filter is to have a Butterworth response, and is to work between terminating impedances of 50 Ω.
Reka bentuk satu penapis lulus rendah 5-elemen dengan titik 3 dB pada 600 MHz menggunakan komponen L dan C. Penapis perlu mempunyai tindak balas Butterworth dan dipadankan pada galangan 50 Ω.

(30 marks/*markah*)

(ii) Design a 5-element high-pass filter with a 3 dB point at 600 MHz using Ls and Cs component. The filter is to have a Butterworth response, and is to work between terminating impedances of 50 Ω.
Reka bentuk satu penapis lulus tinggi 5-elemen dengan titik 3 dB pada 600 MHz menggunakan komponen L dan C. Penapis perlu mempunyai tindak balas Butterworth dan dipadankan pada galangan 50 Ω.

(30 marks/*markah*)

(b) Directional coupler is normally used to split the input signal and distributed power by isolating, eliminating or combining signals in microwave signal routing and radio frequency.

Pengganding berarah biasanya digunakan untuk membahagikan isyarat masukan dan kuasa edaran dengan kaedah pengasingan, penyingkiran atau penggabungan isyarat di dalam penghalaan isyarat gelombang mikro dan frekuensi radio.

(i) Describe, using illustrations, a hybrid ring coupler showing all 4 ports and relevant information.
Terangkan, menggunakan gambarajah, pengganding lingkaran hibrid dengan menunjukkan kesemua 4 port dan maklumat yang berkaitan.

(20 marks/*markah*)

(ii) Define the Scattering Parameter (S-parameter) of a reciprocal 20 dB hybrid ring coupler.
Takrifkan parameter berselerak (S-parameter) untuk 20 dB coupler lingkaran hibrid yang bertimbal balik.

(20 marks/*markah*)

3. (i) Explain the operation of RF type microwave link. Give your example of the microwave link by the help of block diagram.

Terangkan operasi rangkaian gelombang mikro jenis RF. Berikan contoh rangkaian gelombang mikro tersebut dengan bantuan rajah blok.

(15 marks/*markah*)

(ii) Briefly discuss the fundamental concept of feedback type microwave oscillator and what are the criteria's to ensure the oscillation will occur.

Secara ringkas bincangkan konsep asas pengayun gelombang mikro jenis suapbalik dan apakah kriteria untuk memastikan ayunan berlaku.

(15 marks/*markah*)

(iii) Explain the concept of microwave diode mixer and design the 5 GHz microwave mixer using branch line coupler topology or rat-race coupler on Duroid 4003C with the thickness of 0.813 mm and ε_r of 3.38.

Terangkan konsep pencampur diod gelombang mikro dan reka bentuk pencampur gelombang mikro menggunakan topologi pengganding talian cabang atau pengganding larian tikus pada Duroid 4003C dengan ketebalan 0.813 mm dan ε_r *3.38.*

(35 marks/*markah*)

(iv) The microwave radio link operating at 6 GHz for a distance of 3 km. If the received power at the receiver is -50 dBm, calculate the transmitter power of the microwave radio link.

Rangkaian radio gelombang mikro beroperasi pada frekuensi 6 GHz untuk jarak sebanyak 3 km. Jika kuasa yang diterima pada penerima adalah -50 dBm, hitung kuasa pemancar untuk rangkaian radio gelombang mikro tersebut.

(35 marks/*markah*)

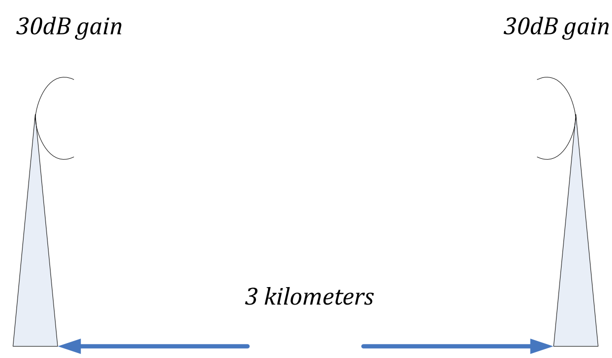

Figure 3: Microwave Radio Link

Rajah 3: Rangkaian Radio Gelombang Mikro

4. PHEMT ATF 35143 having the S-parameter and noise parameter at 6.0 GHz as follows:

PHEMT ATF 35143 mempunyai parameter-S dan parameter hingar pada 6.0 GHz seperti berikut:

Table 1: S-parameter for ATF 35143

Jadual 1: Parameter-S untuk ATF 35143

Common Source, Zo = 50Ω, VDS = 1.5V, ID = 10 mA							
S_{11}		S_{21}		S_{12}		S_{22}	
Mag	Ang	Mag	Ang	Mag	Ang	Mag	Ang
0.75	-120	2.91	87	0.067	25	0.58	-108

Table 2: Noise parameter for ATF 35143

Jadual 2: Parameter Hingar untuk ATF 35143

F_{min} (dB)	Γ_{opt}		R_n/Z_o
	Mag	Ang	
0.43	0.79	83	0.13

Design a LNA operating at 6 GHz. Choose Γ_{in} at C_i and use F_r at 0.5 dB. Microwave laminate having the thickness of 0.78 mm with ε_r, 2.5 should be used.

Reka bentuk LNA beroperasi pada 6 GHz. Pilih Γ_{in} pada C_i dan menggunakan F_r pada 0.5 dB. Laminat gelombang mikro mempunyai ketebalan 0.78 mm dengan ε_r, 2.5 perlu digunakan.

(i) Calculate the center of the input noise circle point C_i.
Hitung titik pusat bagi bulatan masukan hingar C_i.

(20 marks/*markah*)

(ii) Calculate the radius of the input noise circle R_i.
Hitung jejari bagi bagi bulatan masukan hingar R_i.

(20 marks/*markah*)

(iii) By using the Smith chart, design the input noise figure matching.
Dengan menggunakan carta Smith, reka bentuk padanan masukan hingar.

(30 marks/*markah*)

(iv) Based on calculated C_i, calculate the load reflection coefficient Γ_L and design the output matching.
Berdasarkan C_i yang telah dihitung, hitung pekali balikan beban Γ_L dan reka bentuk padanan keluaran.

(30 marks/*markah*)

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APPENDIX A

LAMPIRAN A

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\frac{1}{\sqrt{1 + 12\left(\frac{h}{W}\right)}}\right]$$

$$W/_h = \frac{377}{Z_0\sqrt{\varepsilon_r}} - 2$$

$$Length = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} - 0.824h\left(\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)}\right) \text{ m}$$

Low-Pass Butterworth Filter

Penyaring lulus rendah Butterworth

$$g_k = 2\ \sin\frac{(2k-1)\pi}{2n}$$

$$L_k = \frac{Z_0 g_k}{\omega_c}$$

$$C_k = \frac{g_k}{Z_0\omega_c}$$

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

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

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

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

USEFUL CONSTANTS & EXPRESSIONS FOR TRANSMISSION LINE ANALYSIS

Speed of light, m/s	$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$	**Input impedance, Z_{in} when $z_{direction}$= length, l**	$Z_{in(z=l)} = Z_0 \frac{Z_L + jZ_0 \tan\theta_l}{Z_0 + jZ_L \tan\theta_l}$
Wave Transmission	$V(z) = V^+ e^{-\gamma z} + V^- e^{+\gamma z}$	**Effective dielectric constant (Simple)**	$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2}$
Wave Propagation in time domain	$\lvert V(z,t)\rvert = \lvert V^+ e^{-\alpha z} \cos(\omega t - \gamma z + \phi)\rvert + \lvert V^- e^{+\alpha z} \cos(\omega t + \gamma z + \phi)\rvert$	**Complex Propagation Constant**	$\gamma = \alpha + j\beta$ or $\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$
Dielectric Loss Tangent, (nepers/m)	$\alpha_D = \tan(\delta) . \frac{\omega C' Z_0}{2}$	**Characteristic Impedance (Lossy)**	$Z_0 = \sqrt{\frac{(R + j\omega L)}{(G + j\omega C)}}$
Voltage Standing Wave Ratio	$VSWR = \frac{V_{max}}{V_{min}}$	**Standing Wave Ratio**	$SWR = \frac{1 + \lvert\Gamma\rvert}{1 - \lvert\Gamma\rvert}$
Conductor loss (nepers/m)	$\alpha_c = \frac{R'}{2Z_0}$	**Complex Reflection Coefficient (at any z position)**	$\Gamma_z = \lvert\Gamma_z\rvert \angle\theta$
Resistivity	$\rho = \frac{1}{\sigma}$	**Electrical Length (radians)**	$\theta = \frac{4\pi l_{min}}{\lambda} - \pi$ or $\theta = \beta l$
Dissipation factor	$Df = \tan\delta$	**Minimum Physical Length to load @ V_{min}**	$l_{min} = \frac{\lambda}{4\pi}\theta + \pi$
Skin depth	$\delta = \sqrt{\frac{2}{\omega\mu\sigma}}$	**Load Reflection Coefficient**	$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0}$
Conductivity (sheet)	$\sigma = \frac{G' \times length}{Area}$	**Impedance @ distance in z-direction , l,**	$Z(l) = Z_0 \frac{1 + \Gamma(l)}{1 - \Gamma(l)}$
Relative permeability	$\mu_r = \mu_0 \mu_r$	**Normalization (to Z_o)**	$\bar{z}(l) = \frac{Z(l)}{Z_0}$

Complex Relative Permittivity (lossy dielectric)	$\varepsilon_r = \varepsilon_r' + j\varepsilon_r' \tan\delta$ $\varepsilon_r' = \varepsilon_0 \varepsilon_r$	**Reflection Coefficient (Amplitude)**	$\lvert\Gamma\rvert = \frac{SWR - 1}{SWR + 1}$
Phase Velocity	$v = \frac{\omega}{\beta}$	**Return Loss (dB) @ 1 port**	RL= $10\ log(\frac{V^-}{V^+})$
Phase Constant	$\beta = \frac{2\pi}{\lambda}$	**Transmission Coefficient**	$T = 1 - \lvert\Gamma\rvert$

Course Outcomes (CO) – Programme Outcomes (PO) Mapping

Pemetaan Hasil Pembelajaran Kursus – Hasil Program

Questions *Soalan*	**CO**	**PO**
1	CO1	PO4
2	CO2	PO7
3	CO2	PO4
4	CO2	PO4
5		
6		