Kaferelsheikh University
Faculty of Engineering
Department of Electrical Engineering
Year: Fourth
Subject: Elective Course (5): Microwave Engineering

Date: 09/06/2021
Time allowed: 3 Hours
Full Mark: 70 Marks
Final Exam: 3 Pages
Academic Number: ECE 4231

Answer the following questions

Illustrate your answers with sketches when neccessary

[1] Question One: (15 Marks)

a) A two-port network is driven at both ports such that the port voltages and currents have the following values ($Z_0 = 50\ \Omega$):

$$V_1 = 10\angle 90^\circ \quad ; \quad I_1 = 0.2\angle 90^\circ$$
$$V_2 = 8\angle 0^\circ \quad ; \quad I_2 = 0.16\angle -90^\circ$$

Determine the input impedance seen at each port, and find the incident and reflected voltages at each port. **(5 Marks)**

b) The input and output matching networks in a silicon BJT microwave amplifier are designed to produce $\Gamma_s = 0.5\angle 120^\circ$ and $\Gamma_L = 0.4\angle 90^\circ$. (i) Determine the power gain, the available power gain, the transducer power gain if the scattering parameters of the transistor are: $S_{11} = 0.6\angle -160^\circ$, $S_{12} = 0.045\angle 16^\circ$, $S_{21} = 2.5\angle 30^\circ$, and $S_{22} = 0.5\angle -90^\circ$. (ii) Calculate the power available from the source, P_{avs}, the average power delivered to the network, P_{in}, the power available from the network, P_{avn}, and the power delivered to the load, P_L, if $V_s = 10\angle 0^\circ$, $Z_S = 50\ \Omega$, and $Z_L = 50\ \Omega$. **(10 Marks)**

[2] Question Two: (15 Marks)

a) Use the μ-parameter test to determine which of the following devices are unconditionally stable and, of those, which has the greatest stability: **(5 Marks)**

Device	S_{11}	S_{12}	S_{21}	S_{22}
A	$0.34\angle -170^\circ$	$0.06\angle 70^\circ$	$4.3\angle 80^\circ$	$0.45\angle -25^\circ$
B	$0.75\angle -60^\circ$	$0.2\angle 70^\circ$	$5.0\angle 90^\circ$	$0.51\angle 60^\circ$
C	$0.65\angle -140^\circ$	$0.04\angle 60^\circ$	$2.4\angle 50^\circ$	$0.70\angle -65^\circ$

b) Using the scattering parameter data for the GaAs MESFET given in the following table, design an amplifier for maximum gain at 8.0 GHz. Design matching sections using open-circuited shunt stubs, and compute the gain. **(10 Marks)**

f (GHz)	S_{11}	S_{12}	S_{21}	S_{22}
4.0	$0.72\angle -103^\circ$	$0.12\angle 28^\circ$	$2.91\angle 86^\circ$	$0.53\angle -68^\circ$
8.0	$0.52\angle 179^\circ$	$0.14\angle -1^\circ$	$2.0\angle 20^\circ$	$0.42\angle -129^\circ$
12.0	$0.49\angle 103^\circ$	$0.17\angle -19^\circ$	$1.5\angle -38^\circ$	$0.44\angle 170^\circ$

انظر خلفه

[3] Question Three: (20 Marks)

a) Design a bandpass filter having a 0.5 dB equal-ripple response, with N = 3. The center frequency is 1 GHz, the bandwidth is 10%, and the impedance is 50 Ω. **(10 Marks)**

b) Design an amplifier to have a gain of 10 dB at 6.0 GHz, using a transistor with the following scattering parameters ($Z_0 = 50\ \Omega$): **(10 Marks)**

S_{11}	S_{12}	S_{21}	S_{22}
$0.61\angle-170^\circ$	0	$2.24\angle 32^\circ$	$0.72\angle-83^\circ$

Plot (and use) constant-gain circles for $G_S = 1$ dB and $G_L = 2$ dB. Use matching sections with open-circuited shunt stubs.

[4] Question Four: (20 Marks)

a) Design a high-pass lumped-element filter with a 3 dB equal-ripple response, a cutoff frequency of 3 GHz, and at least 30 dB insertion loss at 2.0 GHz. The characteristic impedance is 75 Ω. **(10 Marks)**

b) A GaAs FET has the following scattering parameters and noise parameters at 6.0 GHz ($Z_0 = 50$ Ω): **(10 Marks)**

S_{11}	S_{12}	S_{21}	S_{22}
$0.6\angle-60^\circ$	0	$2.0\angle 81^\circ$	$0.7\angle-60^\circ$

$F_{min} = 2.0$ dB, $\Gamma_{opt} = 0.62\angle 100^\circ$, and $R_N = 20\ \Omega$. Design an amplifier to have a gain of 6 dB and the minimum noise figure possible with this gain. Use open-circuited shunt stubs in the matching sections.

Hints:

$$G = \frac{P_L}{P_{in}} = \frac{|S_{21}|^2\left(1-|\Gamma_L|^2\right)}{\left(1-|\Gamma_{in}|^2\right)|1-S_{22}\Gamma_L|^2} \qquad G_A = \frac{P_{avn}}{P_{avs}} = \frac{|S_{21}|^2\left(1-|\Gamma_S|^2\right)}{|1-S_{11}\Gamma_S|^2\left(1-|\Gamma_{out}|^2\right)}$$

$$G_T = \frac{P_L}{P_{avs}} = \frac{|S_{21}|^2\left(1-|\Gamma_S|^2\right)\left(1-|\Gamma_L|^2\right)}{|1-\Gamma_S\Gamma_{in}|^2\,|1-S_{22}\Gamma_L|^2} \qquad \left|\Gamma_L - \frac{(S_{22}-\Delta S_{11}^*)^*}{|S_{22}|^2-|\Delta|^2}\right| = \left|\frac{S_{12}S_{21}}{|S_{22}|^2-|\Delta|^2}\right|$$

$$(S_{11}-\Delta S_{22}^*)\Gamma_S^2 + \left(|\Delta|^2-|S_{11}|^2+|S_{22}|^2-1\right)\Gamma_S + \left(S_{11}^*-\Delta^* S_{22}\right) = 0$$

$$g_S = \frac{G_S}{G_{S_{max}}} = \frac{1-|\Gamma_S|^2}{|1-S_{11}\Gamma_S|^2}\left(1-|S_{11}|^2\right) \qquad g_L = \frac{G_L}{G_{L_{max}}} = \frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2}\left(1-|S_{22}|^2\right)$$

$$\left|\Gamma_S - \frac{g_S S_{11}^*}{1-(1-g_S)|S_{11}|^2}\right| = \frac{\sqrt{1-g_S}\left(1-|S_{11}|^2\right)}{1-(1-g_S)|S_{11}|^2}$$

$$N = \frac{|\Gamma_S-\Gamma_{opt}|^2}{1-|\Gamma_S|^2} = \frac{F-F_{min}}{4R_N/Z_0}|1+\Gamma_{opt}|^2 \qquad \left|\Gamma_S - \frac{\Gamma_{opt}}{N+1}\right| = \frac{\sqrt{N\left(N+1-|\Gamma_{opt}|^2\right)}}{(N+1)}$$