COLLEGE OF ENGINEERING & TECHNOLOGY

Department: Electronics and Communications Engineering
Lecturer: Associate Prof. Dr. Hussein H. M. Ghouz
Course: Microwave Technology
Course Code: EC546 **Time : 2 Hours**
Date : Thur. Jan., 15, 2015 **Total Marks : 40**

Answer the Following Questions (Fall-2014/2015)

Question No. 1: (15-Mark):
Three bipolar-junction transistors have the following scattering parameters at f_o=6.0 GHz:

BJT1: $S_{11}=\mathbf{0.55}\angle -140^{o}$, $S_{21}=\mathbf{2.6}\angle 50^{o}$, $S_{12}=\mathbf{0.01}\angle 60^{o}$, $S_{22}=\mathbf{0.6}\angle -65^{o}$

BJT2: $S_{11}=\mathbf{0.75}\angle -110^{o}$, $S_{21}=\mathbf{1.5}\angle 25^{o}$, $S_{12}=\mathbf{0.33}\angle 50^{o}$, $S_{22}=\mathbf{-0.85}\angle -45^{o}$

BJT3: $S_{11}=\mathbf{1.20}\angle -80^{o}$, $S_{21}=\mathbf{2.4}\angle 55^{o}$, $S_{12}=\mathbf{0.44}\angle 35^{o}$, $S_{22}=\mathbf{0.75}\angle -115^{o}$

(a)Select one of the given **BJT** elements to design a microwave amplifier having a maximum gain of **12.0** dB at $\mathbf{f_o}$ **(8-Mark)**
(b)Design the input-output matching circuits using a single shunt-stub terminated by short circuit (use smith chart paper) **(4-Mark)**
(c)If $\mathbf{S_{12}}$ is assumed to be approximate zero, find the maximum transducer power gain that can be achieved by the selected transistor in this case **(3-Mark)**

Question No. 2: (15-Mark):
(a)Draw the general block-diagram of a microwave transistor-oscillator. Discuss the required conditions to have steady-state-oscillation **(3-Mark)**

(b)Check the stability of a GaAs-FET transistor characterized by the following scattering parameters at f_o=6.0 GHz: $S_{11}=0.9\angle -90^{o}$, $S_{21}=6.1\angle 80^{o}$, $S_{12}=0.5\angle 70^{o}$, $S_{22}=0.6\angle -40^{o}$. Draw the input and output stability circles on the smith-chart paper. Is it possible to use this transistor as an oscillator at f_o=6.0 GHz **(6-Mark)**

(c)Explain the basic idea of microwave mixer, and then state the different types of microwave mixers. Draw the general circuit diagram of a microwave balanced mixer circuit, and then, explain its principles of operation **(6-Mark)**

Question No. 3: (5-Mark):
(a)Design a maximally flat (**MF**) bandpass filter with the following specifications: **(2-Mark)**
f_o=3.0 GHz, Z_o=50 Ω, and bandwidth=1000 MHz

The coefficients of **MF LP** proto-type filter is given by :**{ 1.0, 2.0, 1.0, 1.0}**
(b)Implement the designed filter and then, sketch roughly its frequency response **(3-Mark)**

Question No. 4: (5-Mark):
A single-hole waveguide directional coupler is designed to operate in dominant mode $\mathbf{TE_{10}}$. Assume rectangular waveguides are filled with a dielectric material of ε_r=10.0 and the desired coupling factor is **20.0** dB. The required output ports are as follows: **port#2**(through), **port#3** (isolated), and **port#4** (coupled). Assume, the waveguides cross section is axb=1.070x0.430cm^2. Select the correct frequency from the following frequencies to design the required directional coupler: **{f_o=6.0, f_o=10.0, f_o=14.0} GHz,** and then derived a closed form equations for location and radius of the hole aperture

P.T.O →

Formula Sheet

Filter Type	Frequency Transformation	Impedance Scaling
BPF	**$L_k \longrightarrow$ $L_k = L_k/(\omega_o\Delta)$, $C_k = \Delta/(\omega_o L_k)$** **$C_k \longrightarrow$ $L_k = \Delta/(\omega_o C_k)$, $C_k = C_k/(\omega_o\Delta)$** **$\Delta = (\omega_2 - \omega_1)/\omega_o$** **$(1/\Delta)(\omega/\omega_o - \omega_o/\omega) \longrightarrow \omega$**	**$L_k \longrightarrow L_k R_o$** **$C_k \longrightarrow C_k/R_o$**

Stability Test and Circles

$$K = \frac{1-|S_{11}|^2-|S_{22}|^2+|\Delta|^2}{2|S_{12}S_{21}|} \qquad |\Delta| = |S_{11}S_{22} - S_{12}S_{21}| \qquad C_L = \frac{\left(S_{22} - \Delta S_{11}^*\right)^*}{|S_{22}|^2 - |\Delta|^2} \qquad R_L = \frac{|S_{12}S_{21}|}{|S_{22}|^2 - |\Delta|^2}$$

$$C_S = \frac{\left(S_{11} - \Delta S_{22}^*\right)^*}{|S_{11}|^2 - |\Delta|^2} \quad R_S = \frac{|S_{12}S_{21}|}{|S_{11}|^2 - |\Delta|^2} \quad \Gamma_{in} = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1-S_{22}\Gamma_L} \quad \Gamma_{out} = S_{22} + \frac{S_{12}S_{21}\Gamma_S}{1-S_{11}\Gamma_S}$$

Amplifier Design Equations

$$G_{T\max} = G_S G_o G_L \qquad G_S = \frac{1}{1-|\Gamma_S|^2} \qquad G_o = |S_{21}|^2 \qquad G_L = \frac{1-|\Gamma_L|^2}{|1-S_{22}\Gamma_L|^2} \qquad \Gamma_S = \frac{B_1 \pm \sqrt{B_1^2 - 4|C_1|^2}}{2C_1}$$

$$\Gamma_L = \frac{B_2 \pm \sqrt{B_2^2 - 4|C_2|^2}}{2C_2} \qquad B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta^2| \qquad B_2 = 1 + |S_{22}|^2 - |S_{11}|^2 - |\Delta^2|$$

$$C_1 = S_{11} - \Delta S_{22}^* \qquad C_2 = S_{22} - \Delta S_{11}^*$$

Coupler Design Equations

$$A_{10}^+ = -jTr_o^3\left(T^+ \sin^2(\pi S/a) - T^o \cos^2(\pi S/a)\right) \qquad T^+ = \left(2\varepsilon/3 - 4\mu_o/3Z_{10}^2\right) \qquad \varepsilon_o = 10^{-09}/(36\times\pi)\ \text{F/m}$$

$$A_{10}^- = -jTr_o^3\left(T^- \sin^2(\pi S/a) - T^o \cos^2(\pi S/a)\right) \qquad T^- = \left(2\varepsilon/3 + 4\mu_o/3Z_{10}^2\right) \qquad \mu_o = 4\pi\times10^{-07}\ \text{H/m}$$

$$T = \omega A/P_{10} \qquad T^o = \left(4\pi^2\mu_o/3Z_{10}^2\beta^2a^2\right) \qquad P_{10} = ab/Z_{10} \qquad k = \omega/\upsilon$$

$$k_c = \sqrt{(m\pi/a)^2 + (n\pi/b)^2}$$

$$Z_{10} = k\eta/\beta \qquad \beta = \sqrt{k^2 - k_c^2}$$

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