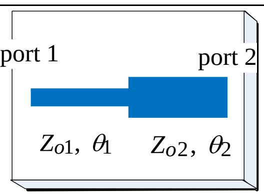
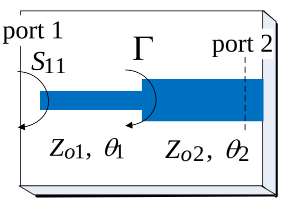
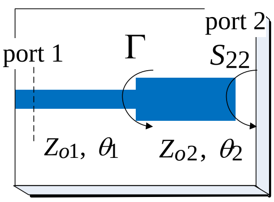
Microwave Circuits Midterm Examination Solution 2016.11.29

<table>
<tr><th>1. Give simplified answer (50%)</th><th>(solution)</th></tr>
<tr><td>(1) In case that the load impedance of a double-stub tuner is inside the forbidden region, what does one use a double-stub tuner as a matching circuit?</td><td>One can use a transmission line to move the load impedance outside the forbidden region along a VSWR circle.</td></tr>
<tr><td>(2) There are different types of coaxial connectors in page 134 of “point of interest”. Why does a smaller diameter of connector have a higher operating maximum frequency?</td><td>Smaller dielectric radial length can increase the maximum frequency of the operating TEM mode.</td></tr>
<tr><td>(3) In case that the input impedance of a microwave device is outside of the Smith chart, what is the physical meaning of this device?</td><td>The device has $|\Gamma_{in}|>1$ or $|R_{in}|<1$ to be oscillating.</td></tr>
<tr><td>(4) Can you design a lossless matching circuit to match the load impedance of $Z_L=0$ to be $Z_{in}=Z_o$? In case that your answer is “Y”, give an example your lossless matching circuit. In case that your answer is “N”, can you design the matching circuit to be lossy?</td><td>A lossless matching circuit cannot change $Re(Z_L)$ to be $Re(Z_L)>0$. A loosy circuit (or an attenuator) can then increase $Re(Z_L)>0$ then a lossless matching circuit can get to be $Z_{in}=Z_o$.</td></tr>
<tr><td>(5) Calculate the S-matrix of a microwave circuit having two series lossless transmission lines with lengths of l_1 and l_2 and characteristic impedances of Z_{o1} and Z_{o2}.</td><td>


for S_{11} and S_{21} for S_{22} and S_{12}





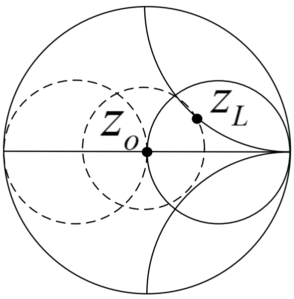
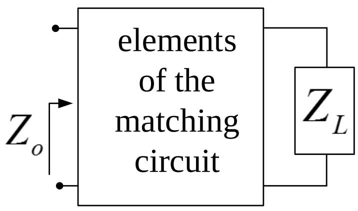
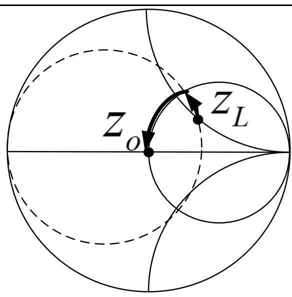
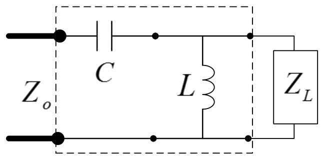
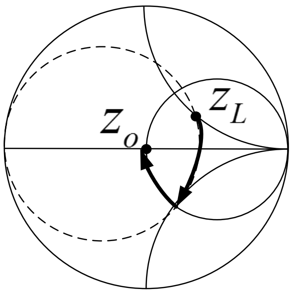
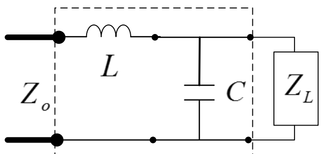
$$\Gamma=\frac{Z_{o2}-Z_{o1}}{Z_{o2}+Z_{o1}}, T=1+\Gamma=\frac{2Z_{o2}}{Z_{o2}+Z_{o1}}$$

$$\Rightarrow S_{11}=\left.\frac{b_1}{a_1}\right|_{a_2=0}=\frac{Z_{o2}-Z_{o1}}{Z_{o2}+Z_{o1}}e^{-j2\beta l_1}=\frac{Z_{o2}-Z_{o1}}{Z_{o2}+Z_{o1}}e^{-j2\theta_1}$$

$$S_{21}=\left.\frac{b_2}{a_1}\right|_{a_2=0}=\frac{2Z_{o2}}{Z_{o2}+Z_{o1}}e^{-j\beta(l_1+l_2)}=\frac{2Z_{o2}}{Z_{o2}+Z_{o1}}e^{-j(\theta_1+\theta_2)}$$

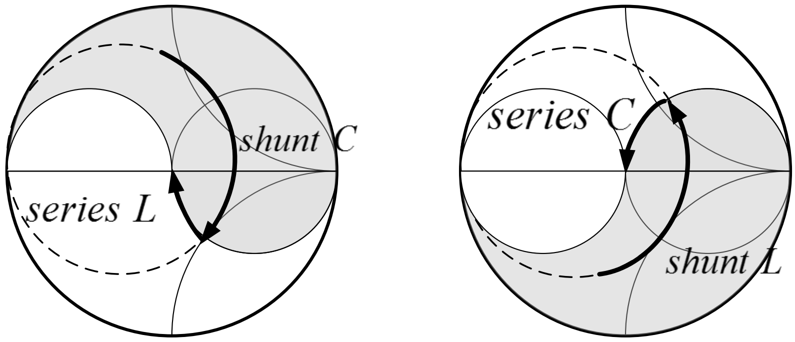
$$\Rightarrow S_{22}=\frac{Z_{o1}-Z_{o2}}{Z_{o1}+Z_{o2}}e^{-j2\beta l_2}=\frac{Z_{o1}-Z_{o2}}{Z_{o1}+Z_{o2}}e^{-j2\theta_2}$$

$$S_{12}=\frac{2Z_{o1}}{Z_{o1}+Z_{o2}}e^{-j2\beta(l_1+l_2)}=\frac{2Z_{o1}}{Z_{o1}+Z_{o2}}e^{-j(\theta_1+\theta_2)}$$
</td></tr>
</table>

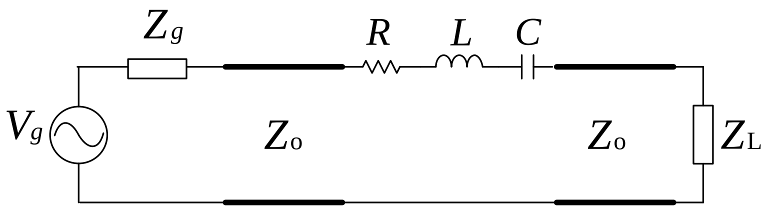
(6) The quality factor Q_u of a mirostrip resonator is smaller than those of coaxial resonator and rectangular cavity resonator. What can you provide two approaches to give higher Q_u value of microwave resonator?	One can reduce α_d and α_c to get the equivalent resistor R to be smaller.
(7) Explain four reasons to use S-matrix for microwave circuits.	(1) The match load has a broadband range. (2) The measurable S-matrix are in terms of incident, reflected and transmitted waves. (3) The termination of Z_o causes no oscillation. (4) It is convenient to use microwave network analysis.
(8) Describe five approaches to reduce the characteristic impedance Z_o of a microstrip line.	(1) microstrip width W↑(C↑, Zo↓) (2) substrate dielectric constant ↑ (C↑, Zo↓) (3) substrate thickness ↓ (C↑, Zo↓) (4) top metal thickness ↑ (W↑, C↑, Zo↓) (5) top metal cover distance ↓ (C↑, Zo↓) (6) additional dielectric material on a microstrip line (C↑, Zo↓) (7) additional a parallel microstrip line (C↑, Zo↓)
(9) Explain the physical use of ε_{eff} for a microstrip line.	One can then use a quasi-TEM line in terms of ε_{eff} to calculate α_d, β and Z_o for a microstrip line.
(10) Design two matching circuits from Z_L to Z_o by plotting the moving traces in the Smith chart and related elements.  	 

2. (20%) For the Example 5.1 in page 231, two L-section matching circuits in Fig.5.3(b) are shunt-series matching circuits. Solution 1 is a shunt C-series L matching circuit and solution 2 is a shunt L-series C matching circuit. In Note slide 5-8, it is not able to design a series-shunt matching circuit. It indicates that the load is in a certain region of the Smith chart to give a related L-section matching circuit. Try plot and identify the available region for the load of this example in Smith charts for (1) a shunt C-series L matching circuit for solution 1 and (2) a shunt L-series C matching circuit for solution 2.

Solution 1 Solution 2



3. (30%) A series RLC resonator with R=1Ω, L=$\frac{150}{\pi}$nH, C=$\frac{5}{3\pi}$pF in series with a transmission line with V_g=1V, Z_g=Z_o=Z_L=50Ω is shown as the following circuit.



Calculate

(1) the resonant frequency f_o,	$f_o = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{\frac{150}{\pi}10^{-9}\frac{5}{3\pi}10^{-12}}} = 1GHz$
(2) the unloaded $Q_U(f_o)$,	$Q_U(\omega_o) = \frac{\omega_o L}{R} = \frac{2\pi 10^9 \frac{150}{\pi}10^{-9}}{1} = 300$
(3) the external $Q_e(f_o)$,	$Q_e(\omega_o) = \frac{\omega_o L}{2Z_o} = \frac{2\pi 10^9 \frac{150}{\pi}10^{-9}}{2\times 50} = 3$
(4) the loaded $Q_L(f_o)$,	$Q_L(\omega_o) = \frac{\omega_o L}{R+2Z_o} = \frac{2\pi 10^9 \frac{150}{\pi}10^{-9}}{1+2\times 50} = 2.97$
(5) the coefficient of coupling g of the resulting circuit,	$g = \frac{Q_U}{Q_e} = 100$

(6) the 3dB bandwidth of the resulting circuit,	$BW_{3dB} = \frac{f_o}{Q_L} = \frac{1}{2.97} GHz \approx 337 MHz$
(7) the power generated from the source,	$P_{inc} = P_{avs} = \frac{1}{2}\left\|\frac{V_g}{Z_g + Z_g^*}\right\|^2 R_g = \frac{1}{2}\frac{\|V_g\|^2}{4R_g^2} R_g = \frac{1}{2}\frac{\|V_g\|^2}{4R_g}$ $= \frac{1}{2}\frac{1}{4\times 50} W = 2.5 mW = 3.98 dBm$
(8) the power delivered to the load at f_o,	$P_L = \frac{1}{2}\left\|\frac{V_g}{Z_g + Z_L + R}\right\|^2 R_L = \frac{1}{2}\left\|\frac{1}{50+50+10}\right\|^2 50$ $= 2.45 mW = 3.89 dBm$ $= P_{inc}(\frac{2Z_o}{2Z_o + R})^2 = P_{inc}(\frac{Q_L}{Q_E})^2$
(9) the insertion loss of the RLC resonator.	$IL = 3.98 - 3.89 = 0.09 dB$
(10) What type of this circuit with specific values?	It is a bandpass filter with its center frequensy at $1 GHz$ with $Q_L = 2.97,\ BW_{3dB} = 337 MHz$ and $IL = 0.09 dB.$