# 1. TRANSMISSION LINES AND RADIOFREQUENCY CIRCUITS

1) A telephone line has the following distributed parameters:

   R=30 Ω/km     L=100 mH/km     G=0     C=20 μF/km

   At 1 kHz, find:
   a. its characteristic impedance
   b. its propagation constant
   c. its phase velocity

2) A 2-wire air line has the following line parameters:

   R=0.404 mΩ/m     L=2.0 μH/k     G=0     C=5.56 pF/m

   For operation at 5 kHz, determine:
   a. the attenuation constant
   b. the phase constant
   c. the phase velocity
   d. and the characteristic impedance

3) A 2 km transmission line with $Z_0=100\Omega$ and $\beta=10$ rad/m is connected to a load of $50\Omega$. To get a voltage on the load of $V_L= 7V$, what is the input voltage to the line?

4) A generator with 10 $V_{rms}$ and $R_G=50\Omega$, is connected to a $75\Omega$ load thru a $0.8\lambda$ $50\Omega$-lossless line. Find the voltage on the load.

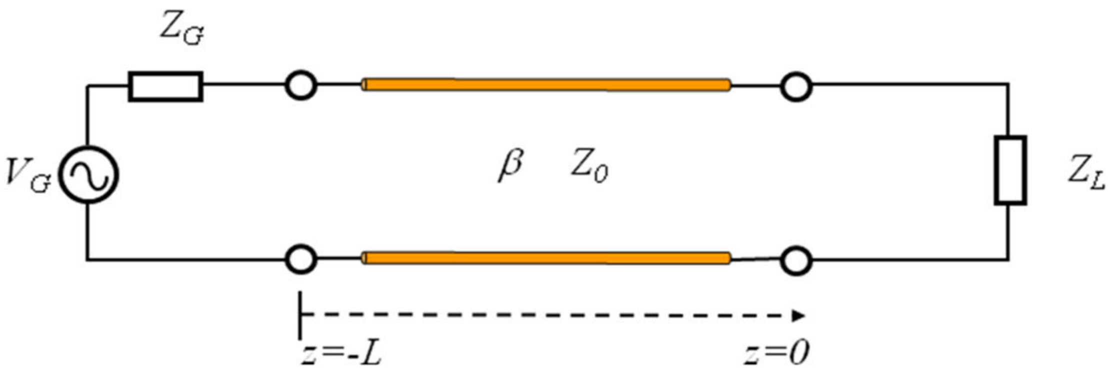
5) For a $50\Omega$ lossless transmission line terminated in a load impedance of $Z_L=100+j50\ \Omega$, find the fraction of the average incident power reflected by the load.

6) A 300Ω feedline is to be connected to a 3 m long, 150Ω line terminated in a 150Ω resistor. Both lines are lossless and use air as the insulating material, and the operating frequency is 50 MHz. Determine:
   a. the input impedance of the 3 m long line
   b. the voltage standing wave ratio on the feedline
   c. the characteristic impedance of a quarter-wave transformer to be used between the two lines in order to achieve S=1 (or VSWR=1) on the feedline.

7) Find the time-domain equation corresponding to the current in a short-circuited transmission line. The current phasor $I(z)$ is given. Remember that in general $V_0^+$ is a complex number:

$$I(z) = 2\frac{V_0^+}{Z_0}\cos(\beta z)$$

8) Consider a coaxial transmission line carrying a wave of 300 MHz. The voltage and current phasors along the line are described by the equations below:




$$V(z) = -\frac{5j}{18}\left(e^{-j\frac{8\pi}{3}z} + \frac{1}{5}e^{j\frac{8\pi}{3}z}\right)$$

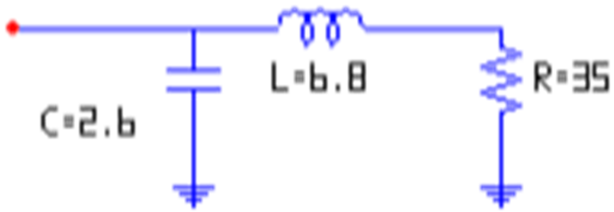
$$I(z) = -\frac{j}{180}\left(e^{-j\frac{8\pi}{3}z} - \frac{1}{5}e^{j\frac{8\pi}{3}z}\right)$$

Being $V_G$= -2j/3$V_{peak}$, $Z_G$=75Ω, $v$=75%·$c$, and $L=\lambda$, answer the following questions:

a. Find the equation of the wave impedance as a function of the position on the line, that is Z(z).
b. Calculate the characteristic impedance $Z_0$ of the line and the wavelength inside the line.
c. Find the reflection coefficient at the input port of the line, and the impedance at the load.
d. Find the power dissipated in the load.

9) A quarter wave transmission line is used to match a 100Ω resistive load to a 50Ω line at a given frequency.
   a. Calculate the characteristic impedance of the matching section.
   b. Calculate the VSWR on the main line with matching transformer when the frequency is increased by 20%.

10) A television transmitter operating at channel[1] 33 has an internal impedance of 75Ω and an available power of 150W. The transmitter is connected to an antenna whose impedance (from channel 21 to 60) can be modelled by the equivalent circuit of the figure (values in Ω, pF, and nH).




The connection between the antenna and the transmitter is done by means of a 5m length coaxial cable (75 Ω, propagation velocity 80%) having negligible losses. Calculate:

a. the wavelength and the primary line constants of the cable (loop resistance, loop inductante, insulator conductance and insulator capacitance per meter);
b. the impedance at the input of the transmission line (that is the impedance seen by the transmitter);
c. the net power (incoming minus reflected) that the source delivers to the line (and consequently arriving to the antenna and being radiated).

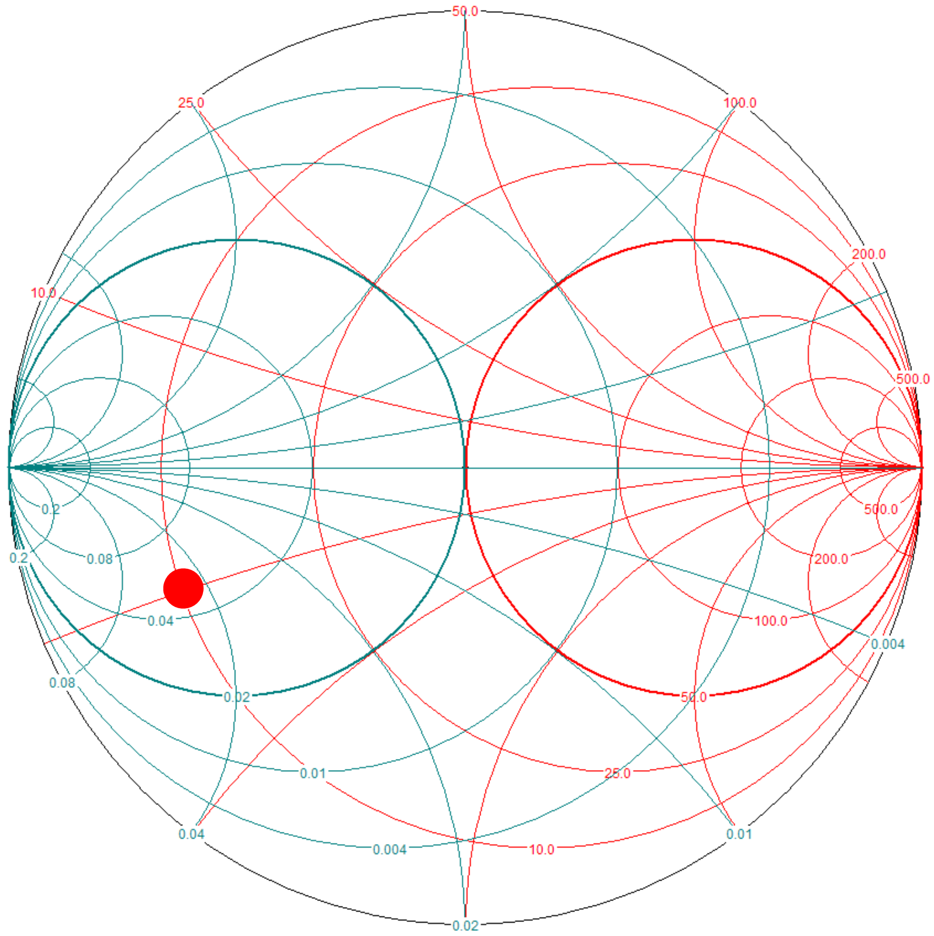
NOTE 1) Channel 20 is centered at 474 MHz. Channel bandwidth is 8 MHz.

(10 Cont'd) The antenna has to be matched to the transmitter. Use the following methods[2] :

d. lumped elements connected to the antenna (provide two different solutions using only two elements);
e. a coaxial cable stub (open-circuited or short-circuited) placed somewhere in the cable connecting the transmitter to the antenna (provide two solutions).

NOTE 2) In any case the values of the lumped elements and the length of the transmission line should be provided.

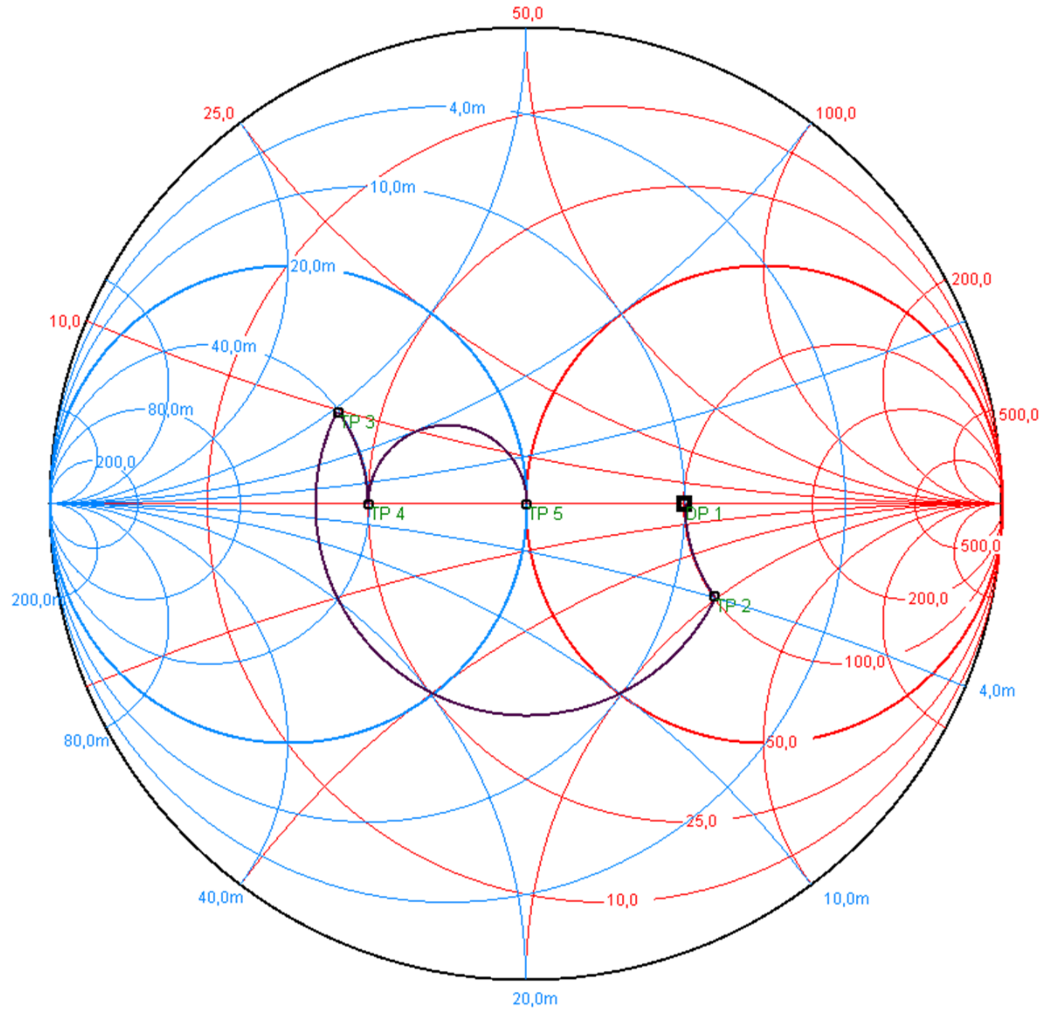
11) A 1 GHz source having an internal impedance of 50 Ω is connected to a load $Z_L$ being its value plotted in the Smith Chart attached:



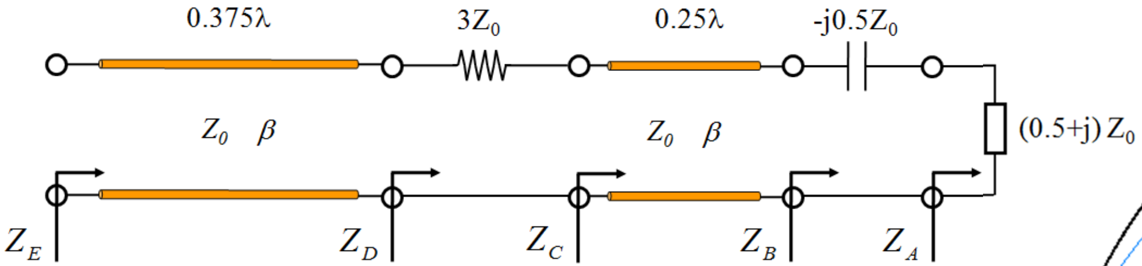

a. Find the normalized and denormalized value of $Z_L$. Draw all the possible matching networks having just two or less than two lumped elements (inductors or capacitors). Plot on the Smith chart the matching procedure and calculate the values of the lumped elements.

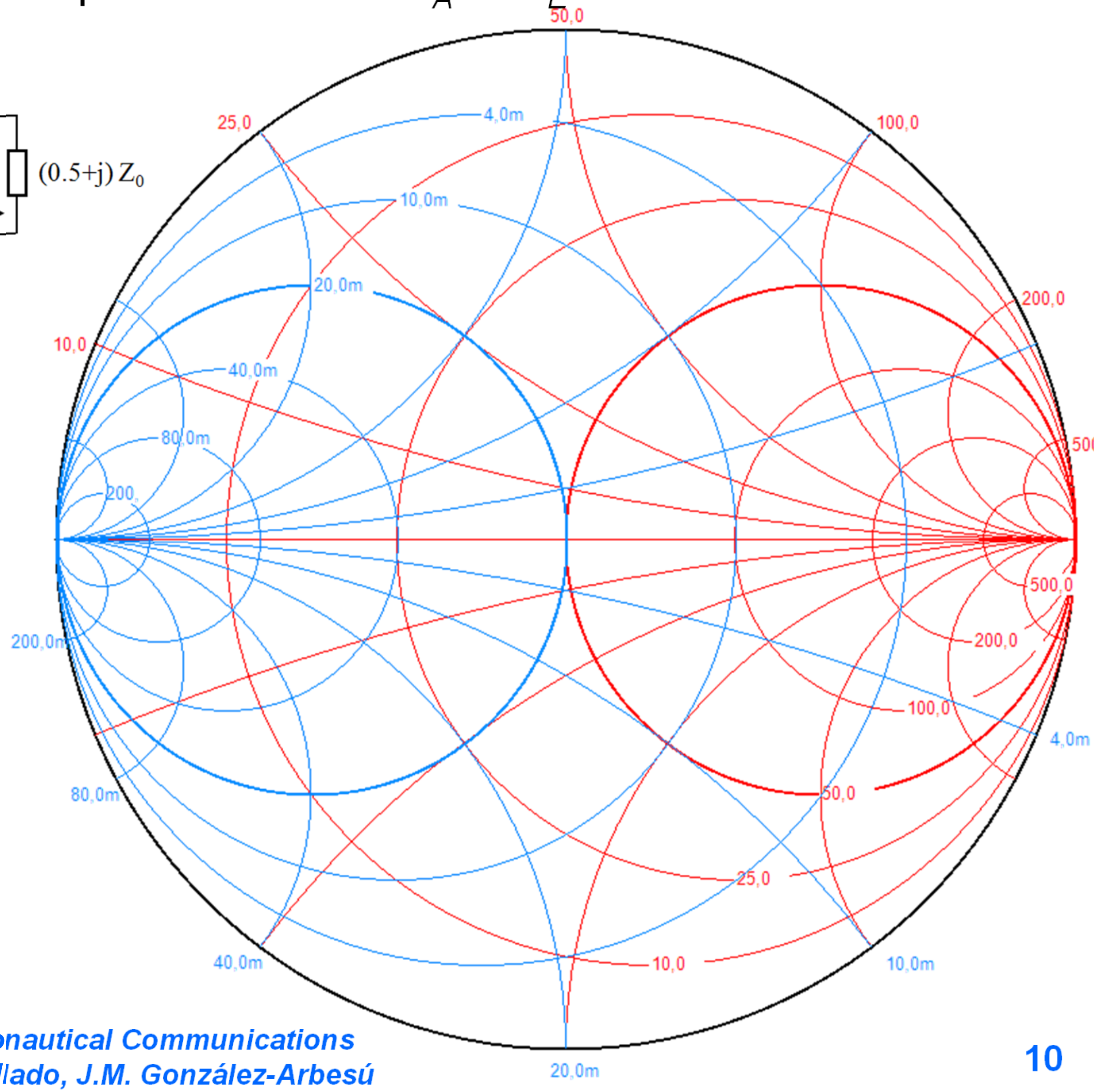
b. Match $Z_L$ using 50Ω transmission lines. Indicate two possible solutions: one using an open-circuited stub and the other using a short-circuited stub. Plot on the Smith chart the matching procedure and calculate the length of the lines.

12) Draw the schematic that generates the shifts on the Smith chart attached. For each element of the cascade, you should indicate the kind of element (resistor, inductors, capacitor, transmission line) and its value (resistance, capacitance, inductance, transmission line length and characteristic impedance in either case), and if they are shunt or in-series. The reference impedance is 50Ω, the operating frequency is 300 MHz, and the propagation velocity *c*. **The network does not include lossy elements.**

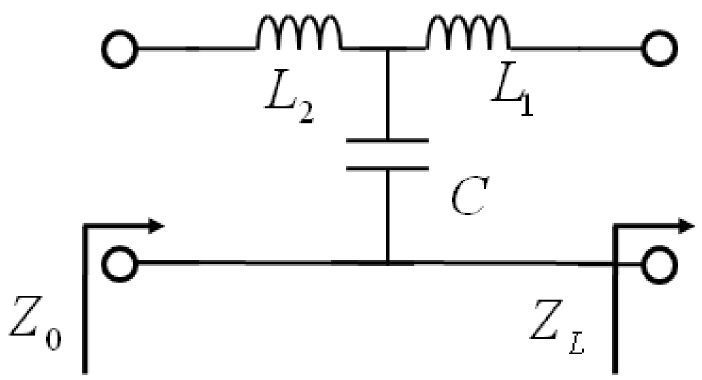


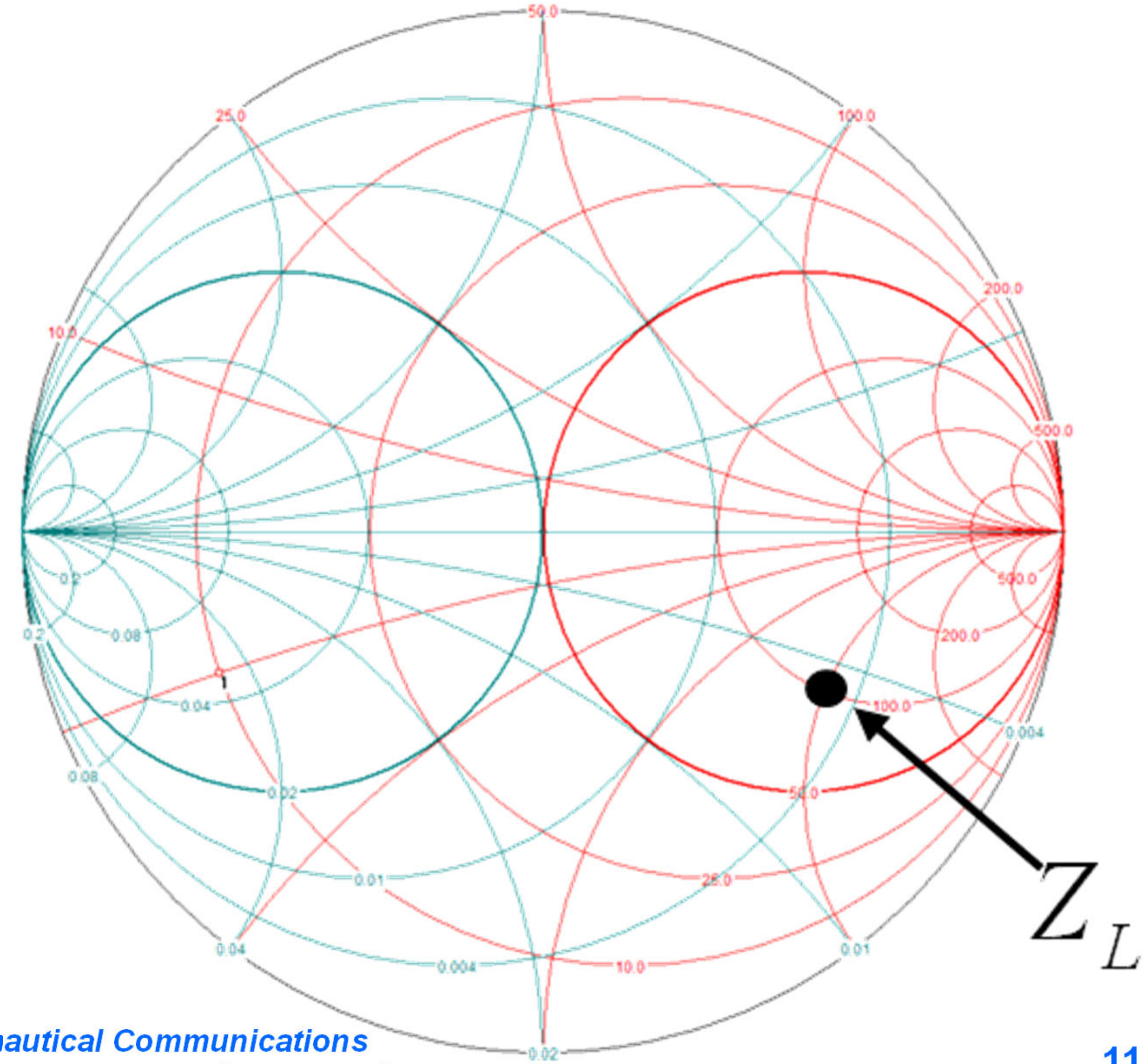
13) Plot on the Smith Chart the circuit impedances from $Z_A$ to $Z_E$.



14) Knowing that the network of the figure matches to $Z_0$ an impedance $Z_L$, plot on the Smith Chart the shifts due to the network. Calculate the values of the elements if the operating frequency is 1 GHz.



15) Using a ZY Smith chart*, plot the following charges and make the required conversions between parameters (no calculator and/or computer allowed). The characteristic impedance is 50 Ω.

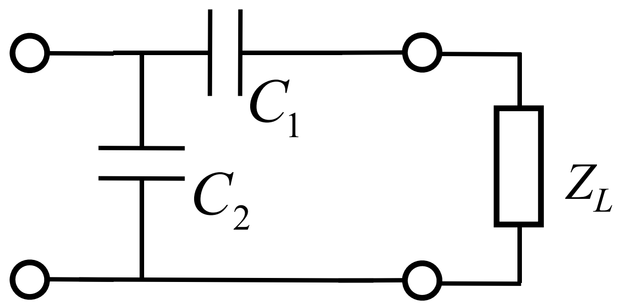
$$\overline{Z} = 1.5 - j0.5 \quad \rightarrow \quad Y?$$

$$Y = 0.04 - j0.01 \quad \rightarrow \quad \rho? \text{ (mag. and phase)}$$

$$RL = 3\text{dB} \text{ and } \arg(\rho) = -45^0 \quad \rightarrow \quad Z?$$

NOTE: http://www.just.edu.jo/~khodier/EE%20528/smith_chart_zy.pdf

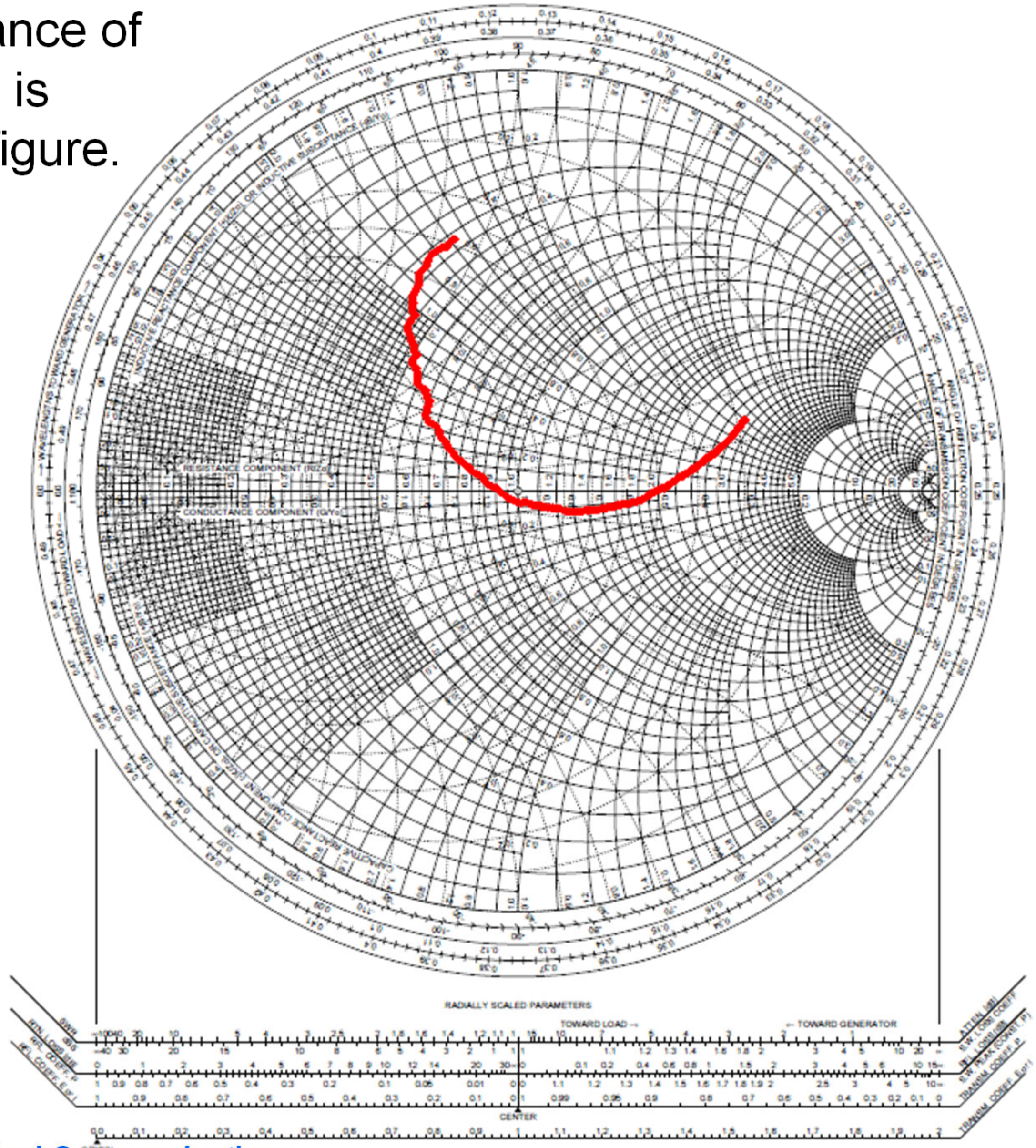
16) A load having a reflection coefficient of $\rho_L = 0.82 \underline{|135^0}$ at 1GHz is matched to 50Ω using the network of the figure. Find the values of $C_1$ and $C_2$ that match the load. Use a Smith chart if required.



17) Two TV antennas (75Ω) are connected to a TV set using as a matching network quarter-wave sections of a RG-58 cable (53Ω). Being the characteristic impedance 75Ω, the question is: Is this a good matching network? Justify the answer. Find the power arriving to each antenna with and without the matchig network when the power available from the source is 30W.

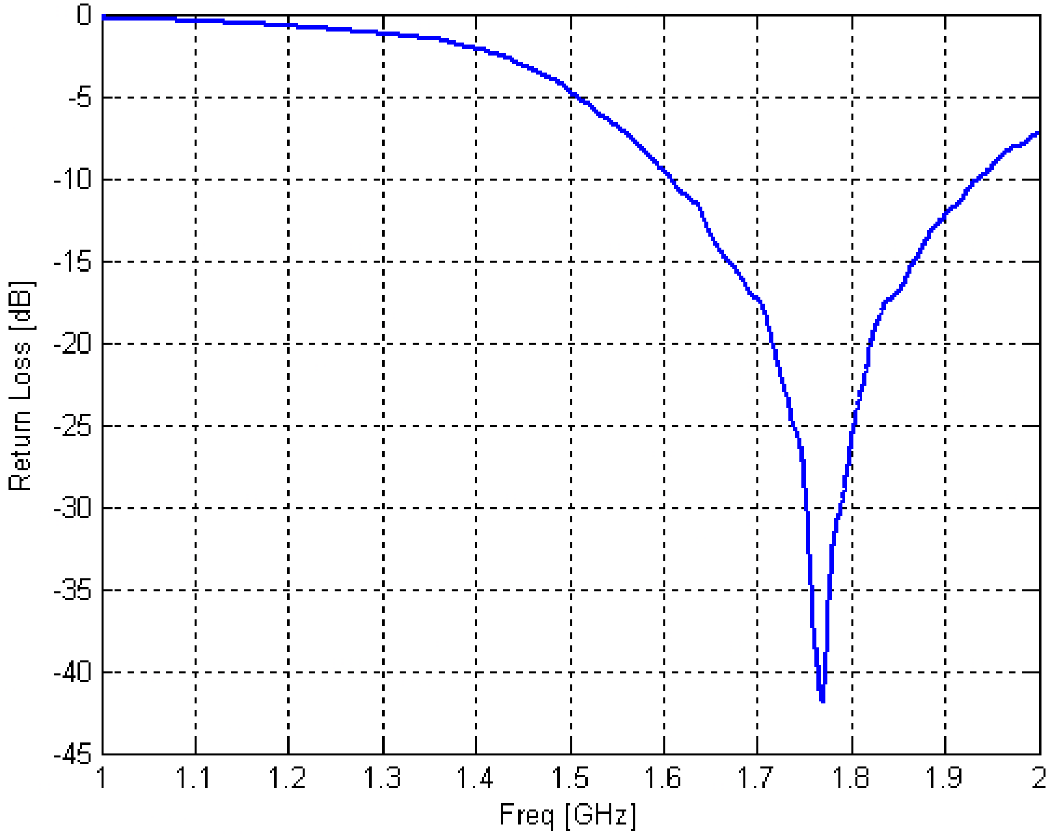
19) The dependence of the input impedance of an antenna with respect to frequency is shown on the ZY Smith Chart of the figure.

a. Draw a cross at the frequency where the antenna is best matched.
b. At this frequency, which is its RL, SWR, and complex reflection coefficient. Use the Smith chart to perform the calculations.
c. If the frequency at which the reactive part of the impedance is zero is called **resonance frequency**, draw a diamond at the resonance frequency of this antenna.
d. Suggest a matching network using just transmission lines that matches the antenna at this frequency. The network should be fabricated in microstrip technology without via holes. Draw the paths introduced by each element of the network on the Smith chart, but it is not required to calculate its dimensions.

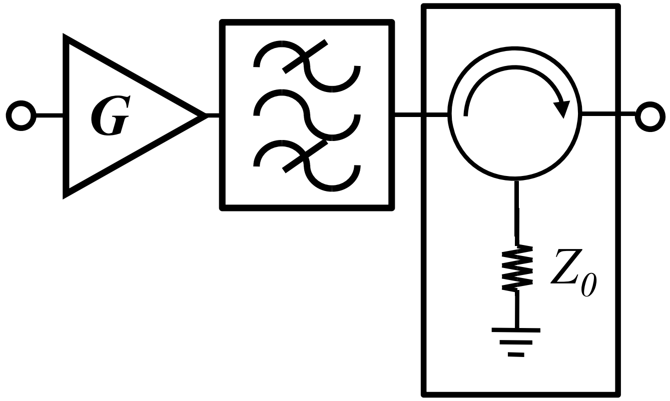


20) Occasionaly, instead of the Smith Chart, a Cartesian plot is used to show the return loss of a network with respect to frequency. Given the plot of the return loss of an antenna:

a. Find the frequency at which the system is best matched and the return loss at this frequency.
b. Calculate the SWR.
c. Find the -10 dB bandwidth and the fractional bandwidth.



21) Given the cascade of networks below (the loaded circulator is a two port device):




a. Which are the ideal scattering matrix of each component at $f_0$.
b. Find the scattering parameters of the whole cascade (if required use the conversion table from Pozar's book).

22) A 10GHz wave with a power density of -97dBW/m$^2$ reaches a parabolic reflector with 40dB gain. Which is the maximum power transferred to the receiver?

**a)** -101.5 dBW **b)** -100 dBW **c)** -98.5 dBW **d)** -97 dBW

23) Consider a wireless link between an ATC and an aircraft. If the distance between the tower and the aircraft is doubled, the received power (e.g. in the aircraft) is expected to be reduced by a factor of:

**a)** 2 dB **b)** 3 dBW **c)** 4 dBW **d)** 6 dB

24) A parabolic reflector operating at a frequency $f$ has a radiation efficiency of $e_{rad}$. Its -3 dB-beamwidths in two orthogonal planes are $\Delta\theta$ and $\Delta\phi$. Consequently, its gain $G$ must be close to:

**a)** $10\log\left(e_{rad}\,\dfrac{4\pi}{\Delta\theta\,\Delta\phi}\right)$ **b)** $10\log\left(\dfrac{4\pi}{\Delta\theta\,\Delta\phi}\right)$ **c)** $20\log\left(e_{rad}\,\dfrac{4\pi}{\Delta\theta\,\Delta\phi}\right)$ **d)** $20\log\left(e_{rad}\left(\dfrac{f}{c}\right)^2\dfrac{4\pi}{\Delta\theta\,\Delta\phi}\right)$

25) Calculate the polarization loss factor of a linearly polarized antenna when receiving a linearly polarized wave, being the respective polarization vectors given by the following equations:

$$\vec{\rho}_a = \hat{x} + a\hat{y} \qquad \vec{\rho}_i = a\hat{x} + \hat{y}$$

**a)** 0 **b)** $4a^2$ **c)** $\frac{2a^2}{\left(1+a^2\right)^2}$ **d)** $\frac{4a^2}{\left(1+a^2\right)^2}$

26) The gain of an antenna is 23 dB and its input impedance is Z=100+j100 Ω. If the reference impedance is 50 Ω, which is the realizable gain of the antenna?

**a)** 19 dB **b)** 21 dB **c)** 23 dB **d)** 25 dB

27) A parabolic reflector has a -3 dB beamwidth of, respectively, 2º in the H plane and 4º in the E plane. Its directivity is around:

**a)** 15 dBi **b)** 37 dBi **c)** 43 dBi **d)** 86 dBi

28) Specify the range ($r$) dependency of the antenna gain. Consider its definition:

$$G = e_{rad} \frac{4\pi U}{P_{rad}}$$

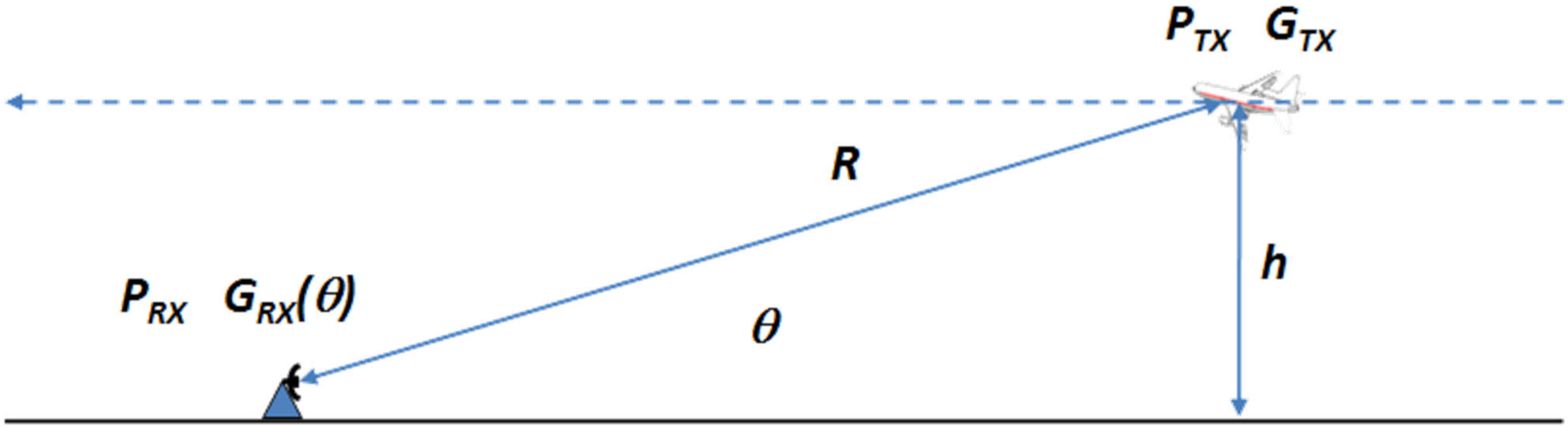
**a)** $G$ does not depend on $r$

**b)** $G$ increases with $r$

**c)** $G$ increases with $r^2$

**d)** $G$ decreases with $r^2$

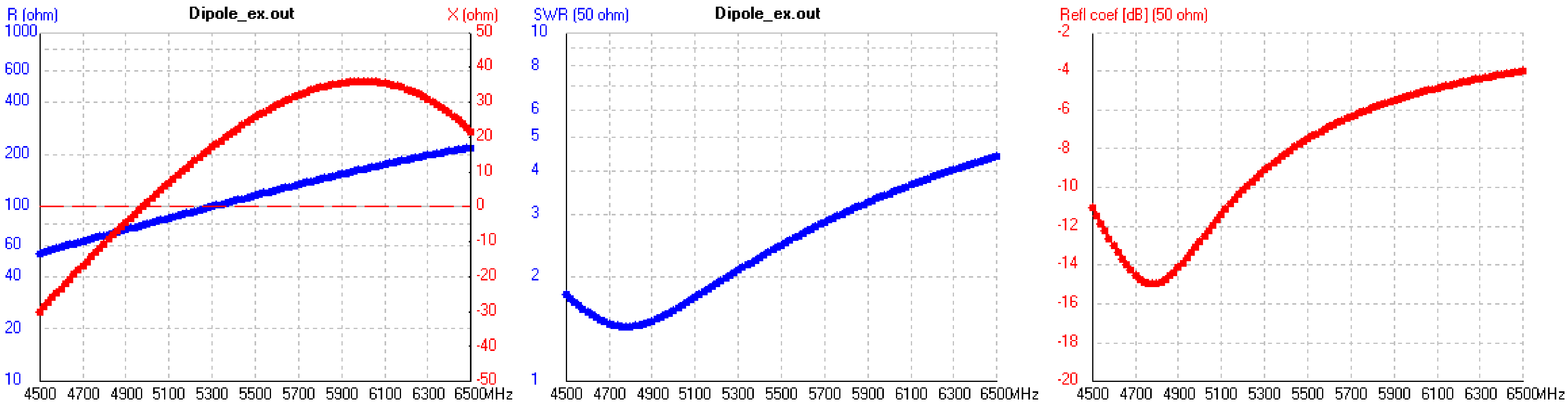
29) An aircraft flights at constant altitude ($h$) approaching to an earth station. The aircraft transmits signals with constant power $P_{TX}$ using an (lets assume) omnidirectional antenna with gain $G_{TX}=G_{TX,0}$. On earth, a receiver at a slant range $R$ from the airplane, uses an antenna having a vertical pattern $G_{RX}=G_{RX,max}\cdot f(\theta)$. Find the angular dependence of the antenna receiver in order to have a constant received power on earth $P_{RX}$. The graph below could help to understand the problem.




NOTE: Assume neither antenna mismatch nor polarization losses.

SOL: $f(\theta)=K/\sin^2(\theta)$ being $K$ a real constant.

30)A half-wavelength dipole antenna has been characterized in terms of its input impedance versus frequency. Given its simulated performance in the graphs below answer the following questions:




a. Find the frequency at wich the antenna is resonant and the frequency at wich the antenna is matched.
b. Which are the input impedance and the return losses of the antenna at 4.8GHz?
c. Assuming that the radiation efficiency of the antenna is 95%, which is the antenna efficiency at 4.8GHz.
d. Make an estimate about the length of the dipole.

31) Given the following array current distributions (assuming isotropic basic elements):

Distribution 1: $I_n = \{I_0, 2I_0, 3I_0, 2I_0, I_0\}$

Distribution 2: $I_n = \{2I_0, 2I_0, 2I_0, 2I_0, 2I_0\}$

Distribution 3: $I_n = \{I_0, I_0, I_0, I_0, I_0\}$

Distribution 4: $I_n = \{0.5I_0, I_0, 1.5I_0, I_0, 0.5I_0\}$

a. Which is the one expected to have maximum directivity? Justify your response.
b. Which is the one expected to have maximum radiated field instensity in the maximum direction? Justify your response.