MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

6.013 – Electromagnetics and Applications

Problem Set 7 (five problems)

Suggested Reading: Course notes: Sections 7.2.3, 7.3.1–7.3.2, 8.3.1, 3.5

Problem 7.1

A lossless air-filled TEM line operating at f [Hz] is terminated with a load R_L, and $|\underline{V}(z)|$ across the line is measured, as illustrated.

(a) Based on the illustration, what are:

(i) f [Hz]?

(ii) VSWR?

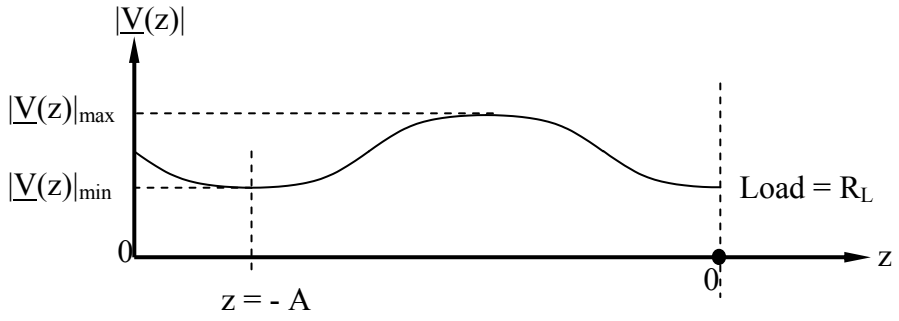
(iii) Z_o [Ohms]?

(iv) C [F/m] of the line?

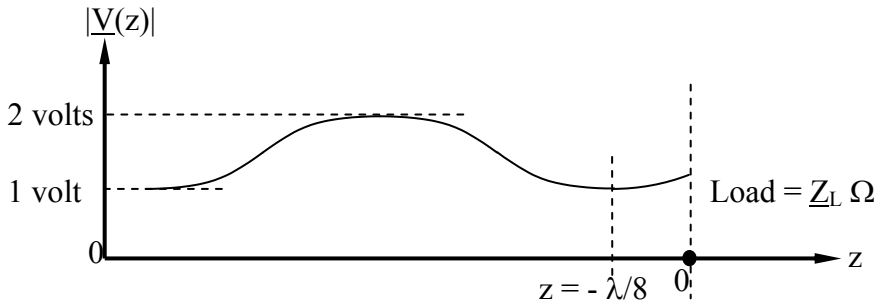
(v) L [Hy/m] of the line?

(vi) $\underline{\Gamma}$?

(vii) Fraction of power reflected by the load?



(b) Based on the second figure, what is the unknown complex load impedance $\underline{Z}_L$? A Smith chart is attached and may be used.



(c) The load of part (b) is matched using a capacitor C_m shunting the TEM line at $z = -A_m$; what values of C_m and A_m produce a match with minimum A_m? A second Smith chart is attached and may be used. "Shunting" means placed across the line rather than in series with it.

Problem 7.2

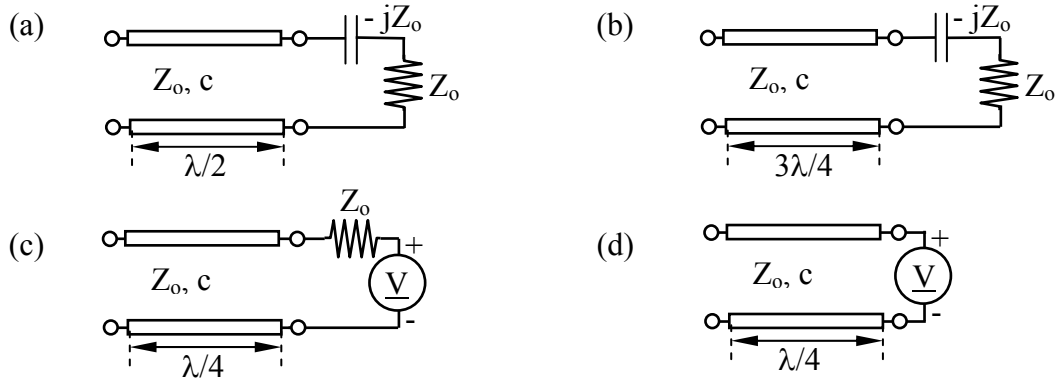
A radio ham with a low budget wants to match her antenna for better performance at 50 MHz. She therefore tests her antenna with a small pickup coil and tiny neon bulb that lights up every d = 2 meters as she slides it along the powered Z_o = 300-ohm twin-lead antenna feed wire.

(a) The VSWR = 3 on the twin lead antenna feed wire, and the bulb is brightest one meter from the antenna port. What is the complex impedance $\underline{Z}_A$ of the antenna port?

(b) The ham now wants to add in either series or parallel with the antenna feed line the shortest possible short-circuited stub of 300-ohm twin-lead wire that would achieve a near-perfect match for the antenna. (i) How long should this stub be (S), (ii) should it be in series or parallel with the feed line, and (iii) how far (A) from the antenna port should it be attached?

Problem 7.3

Determine the Thevenin equivalent for each circuit below.



Hint: For parts (c) and (d) it may be helpful to use the basic equations for $\underline{V}(z)$ and $\underline{I}(z)$ to relate voltages at one position to those at another.

Problem 7.4

An environmentalist coats the top surface of his solar cells with a quarter-wave transformer to reduce reflections and boost electrical output.

(a) Assume (for this problem) that the solar cell $\varepsilon = 4\varepsilon_o$, and that in the absence of reflections the cell yields constant power over the wavelength band 0.4-0.6 microns and zero elsewhere. Approximately what coating thickness d and permittivity ε_{coat} would be best?

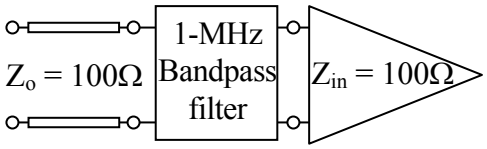
(b) What fraction of the solar power is reflected at one-micron wavelength by your coating?

Problem 7.5

We wish to design a 1-MHz RLC resonator with R = 100Ω and an internal Q_l of 20.

(a) What are L and C for a series resonance? (Ignore the figure for parts (a) and (b))

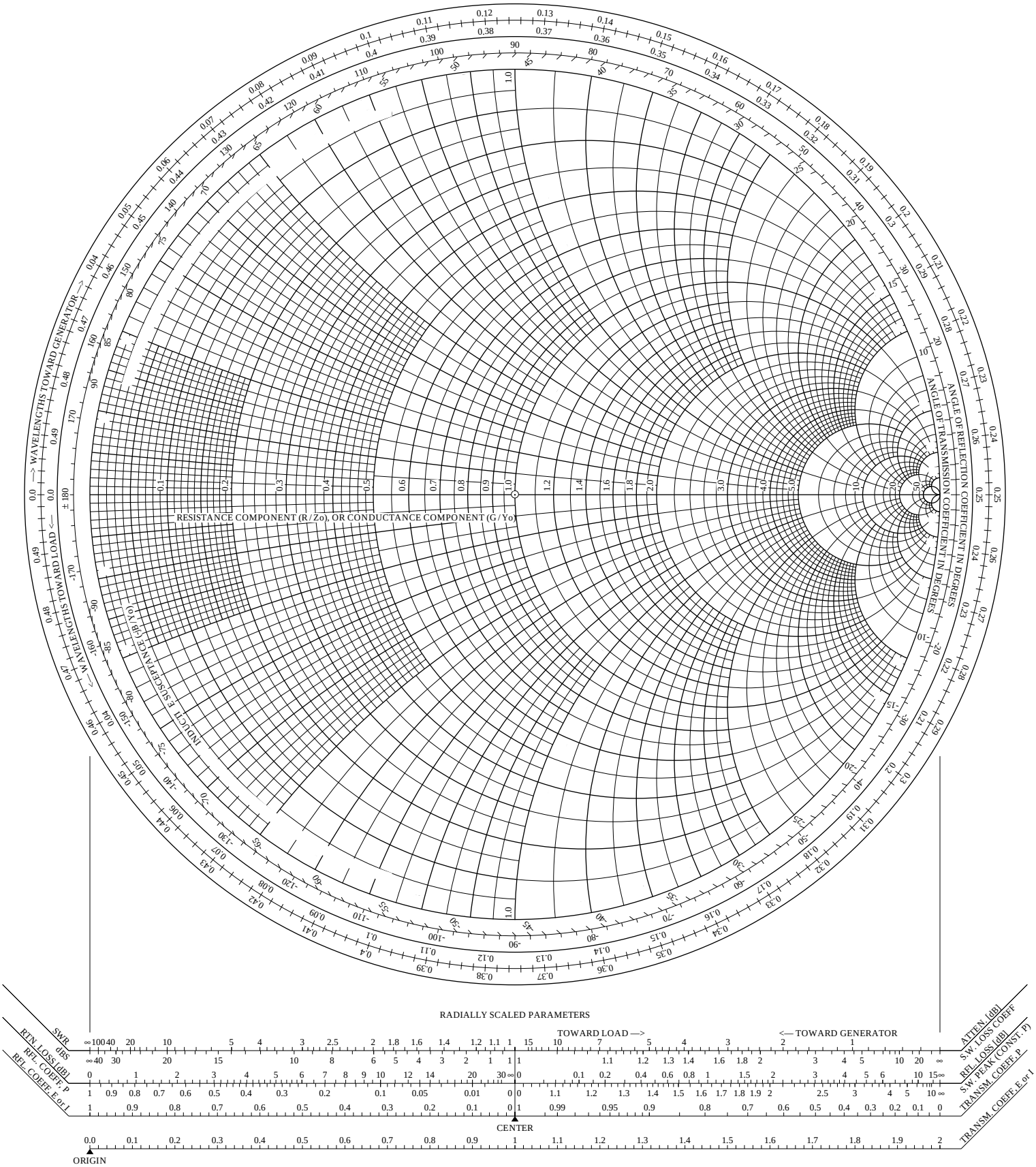
(b) What are L and C for a parallel resonance?



(c) We now wish to add a lossless 1-MHz bandpass filter, as illustrated, to a 100-ohm amplifier so that the combination is matched to a 100-ohm transmission line at resonance, yields a 3-dB bandwidth of 50 MHz, and approaches a short circuit far from resonance. Please sketch the arrangement of parts inside the filter and indicate their numerical values.

The Complete Smith Chart

Black Magic Design



The Complete Smith Chart

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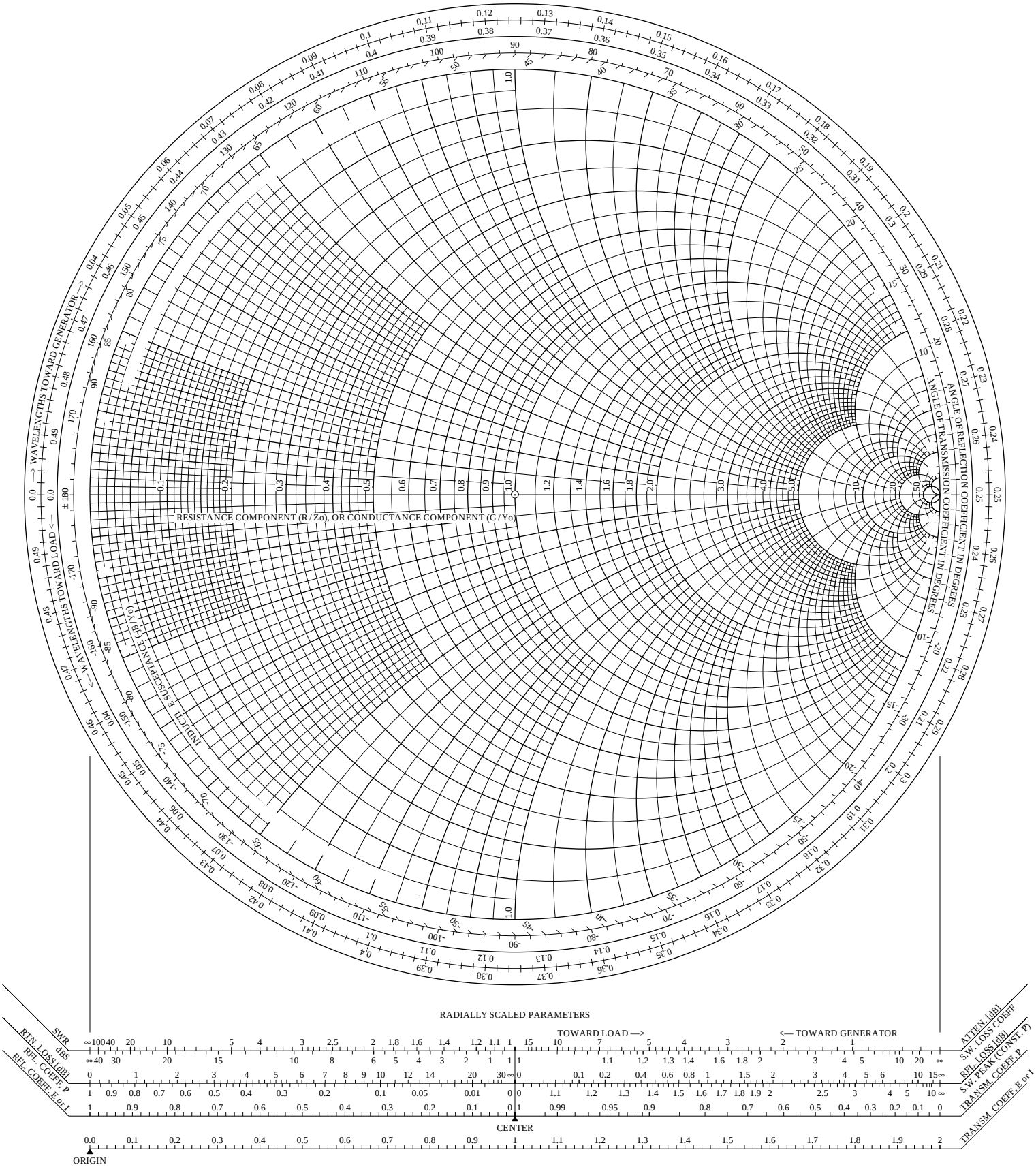

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