Exam

Examiner: Olli-Pekka Lundén

Students may use own calculators (including programmable types) and *any* hand written or printed materials, including books, lecture materials, and own notes, but *not* mobile phones, laptops, nor any other communication devices. Students may keep the problem sheet. Evaluation shall be based on the evidence student demonstrates about the learning outcome statements of this course.

Problem 1: The following **claims** may contain inaccuracies or falsities. First you must *identify* them and *explain* what is wrong. Then you must provide a corrected[1] claim. If the claim is already correct, you must state this to be the case, and not comment or edit it.

(a) **The wavelength of an RF signal (voltage or current) at 3 GHz is 10 cm in a coaxial cable, such as the one shown in Figure 1.**
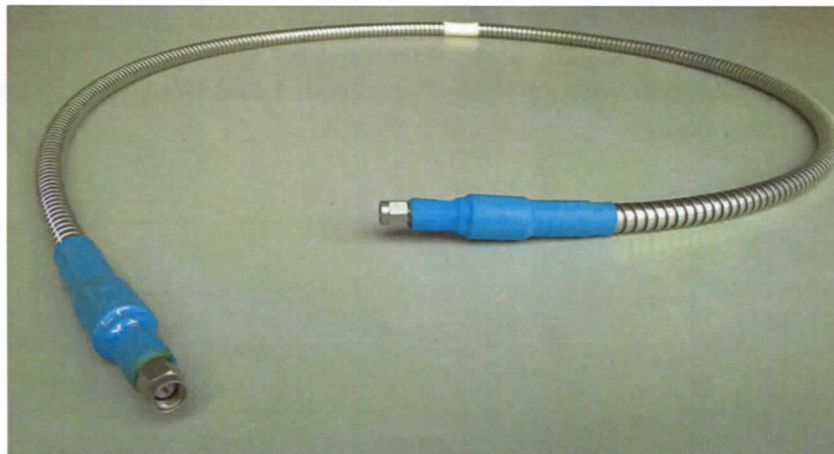

Figure 1: Coaxial cable Huber+Suhner Sucoflex 104. The insulator of cables is foamed polytetrafluoroethylene, that has effective relative permittivity of $\varepsilon_r = 1.7$. The cable loss is less than 1.1 dB/m up to about 18 GHz.

(b) Consider two microstrip lines on a 1-mm thick alumina substrate (Al_2O_3, $\varepsilon_r = 9.6$) with different widths: $w_1 = 1$ mm and $w_2 = 2$ mm. Suppose their *electrical length* is the same, $\theta_1 = \theta_2 = \pi/4$. **The line with greater width is longer when measured in millimeters.**

(c) A two-port (Figure 2) is described by its S-parameters that are referenced to 50 Ω. With the given component values, $S_{11} \approx 0$ at 1 GHz. **The S_{22} -parameter of this circuit is also zero, moreover, its transducer power gain and reverse isolation are very close to 0 dB at 1 GHz.** Hint: You will not have to calculate anything.

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[1]General instructions: Corrections should be made with *minimum editing*. However just negating a sentence is not appreciated. If the claim is "Bats are birds", you should *not* correct it as "Bats are *not* birds" but rather as "Bats are *mammals*". The actual claim is in bold-font. The normal-font text should always be correct.
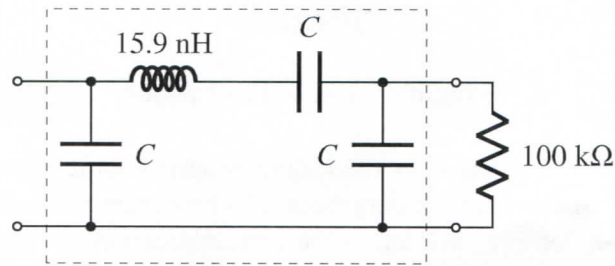
Figure 2: A two-port (within the dashed line) is connected to a high-resistance load. Each capacitor is 3.2 pF.

(d) Consider now the input reflection coefficient (Γ_{in}) of the two-port in Figure 2. **Now, because the load resistance is high, $|\Gamma_{in}| \approx 1$, at all frequencies.**

(e) A particular transistor (BFG520) is going to be used for a single-transistor, common-emitter RF amplifier. The amplifier is supposed to be unconditionally stable. Figure 3 shows a typical Edwards-Sinsky stability factor μ of this transistor. **There is no need for stabilization as long as the operating frequency is anything from 1 to 2 GHz and the DC operating point is $V_{ce} = 6$ V / $I_c = 30$ mA.**
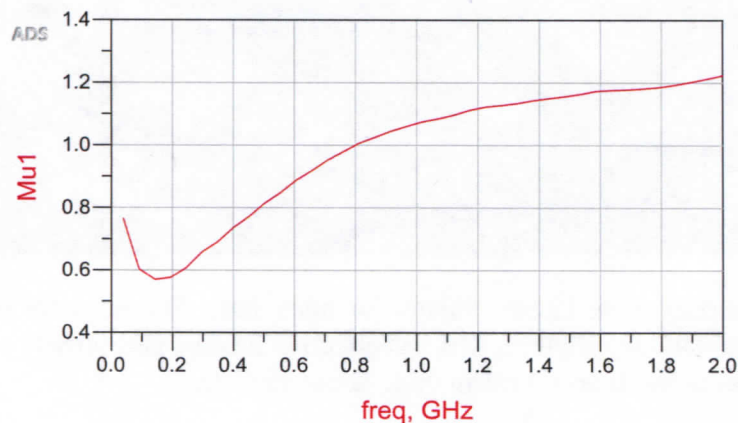

Figure 3: Typical stability factor μ of BFG520 transistor from 40 MHz to 2 GHz in the DC operating point of $V_{ce} = 6$ V and $I_c = 30$ mA.

(f) The reflection coefficient Γ_L of a load is indicated by a red circle in Figure 4. **This load can be matched to 50 ohms using two capacitors, one series-connected and one parallel-connected, in either order,** as suggested in Figure 5.
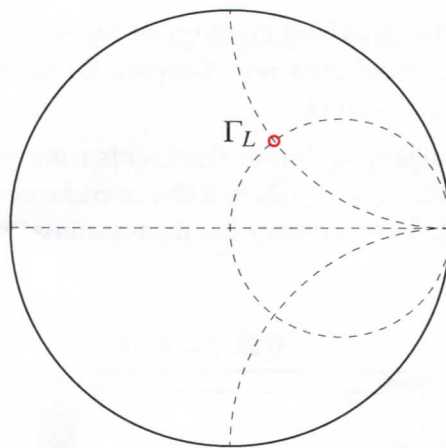
Each subproblem yields 1 point at max.

Figure 4: A simplified Smith chart. Γ_L indicates a load reflection coefficient. Assume the chart uses 50 ohms as the reference impedance.
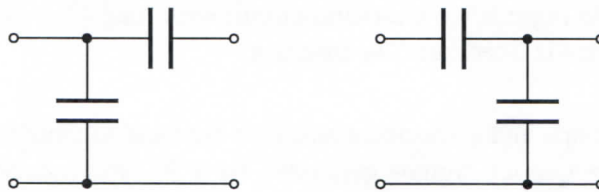

Figure 5: Suggested matching circuits for Γ_L.

Problem 2: Still considering the load reflection coefficient Γ_L in Figure 4:

(a) What is the respective load impedance? (*1 point*)

(b) Which one of the generators shown in Figure 6 is the one that provides more power to this load? Consider this problem without any impedance matching networks inserted, just having a generator directly connected to the load. (*1 point*)

(c) How many microwatts is that power? (*2 points*)

(d) How high will the peak-to-peak voltage across the load be in that case? (*2 points*)

$(50+j50)\ \Omega$ $(50-j50)\ \Omega$

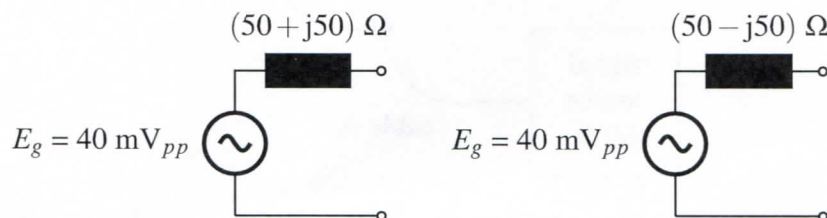$E_g = 40\ \text{mV}_{pp}$ $E_g = 40\ \text{mV}_{pp}$

Figure 6: Two sinewave generators. Note that the electromotive force is a peak-to-peak value, $2\sqrt{2}$ times the r.m.s. value.

Problem 3: A simple impedance matching topology of Figure 7 uses a segment of transmission line and a shunt capacitor. Suppose the characteristic impedance of the transmission line is 50 Ω.

Plot, on the accompanying Smith chart, either the locus or the area of normalized impedances $z_L = Z_L/Z_0$ that this impedance matching topology can match to 50 Ω if C were arbitrary but the transmission line length were fixed to $\lambda_g/8$.

$$Z_0 = 50\ \Omega,\ l = \lambda_g/8$$

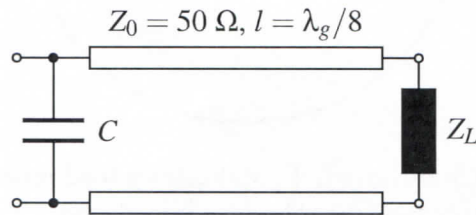Figure 7: A simple impedance matching circuit with load (Z_L). Suppose the transmission line length l is fixed but C is arbitrary.

Problem 4: An oscilloscope and a spectrum analyzer are used to simultaneously monitor fairly low-frequency signals generated by a 50-ohm source as illustrated in Figure 8.

Give a reasonable estimate for the upper frequency limit of this measurement setup.

The input impedance of the spectrum analyzer is 50 Ω while that of the oscilloscope is high. Oscilloscope is connected directly, without a probe head. All cables are of the Huber+Suhner Sucoflex 104 type, each 120 cm long, also shown in Figure 1.
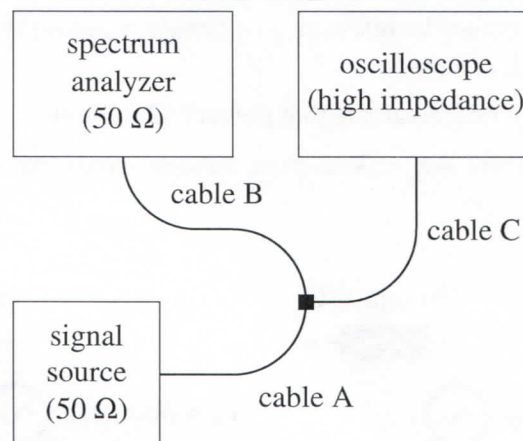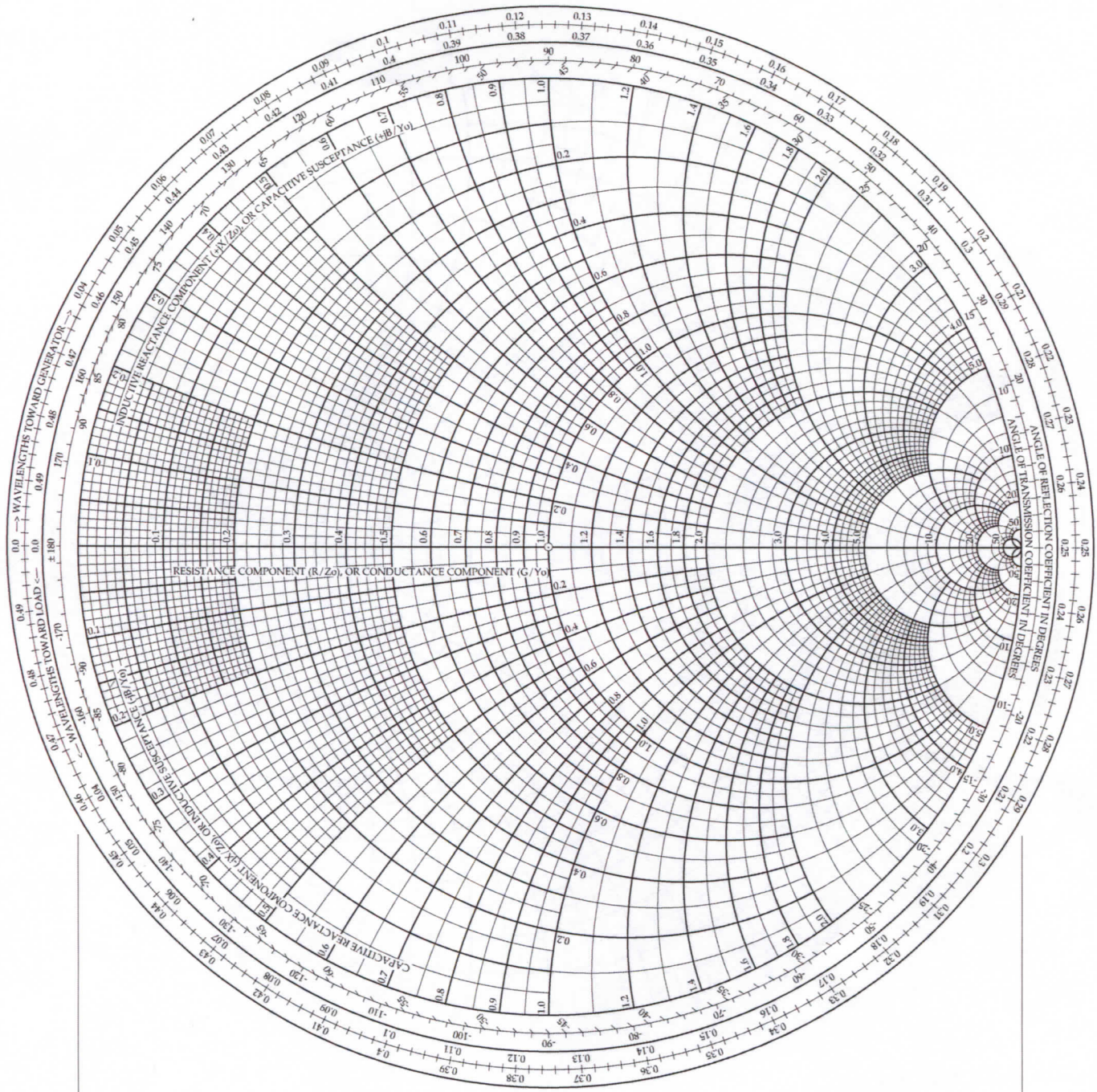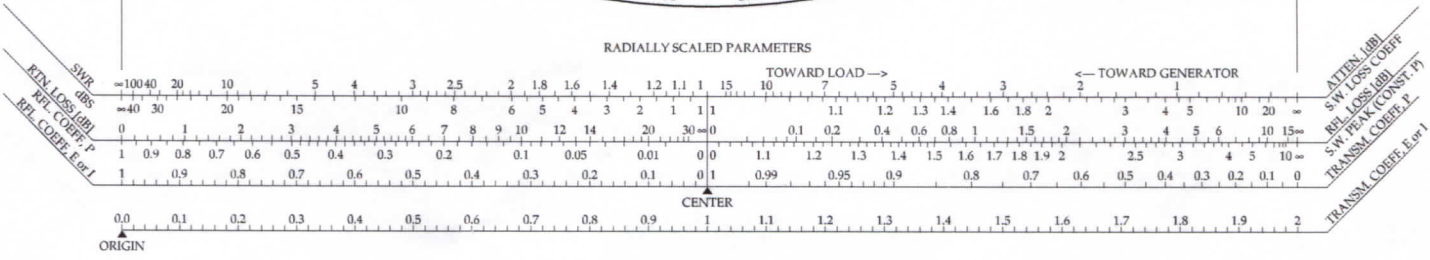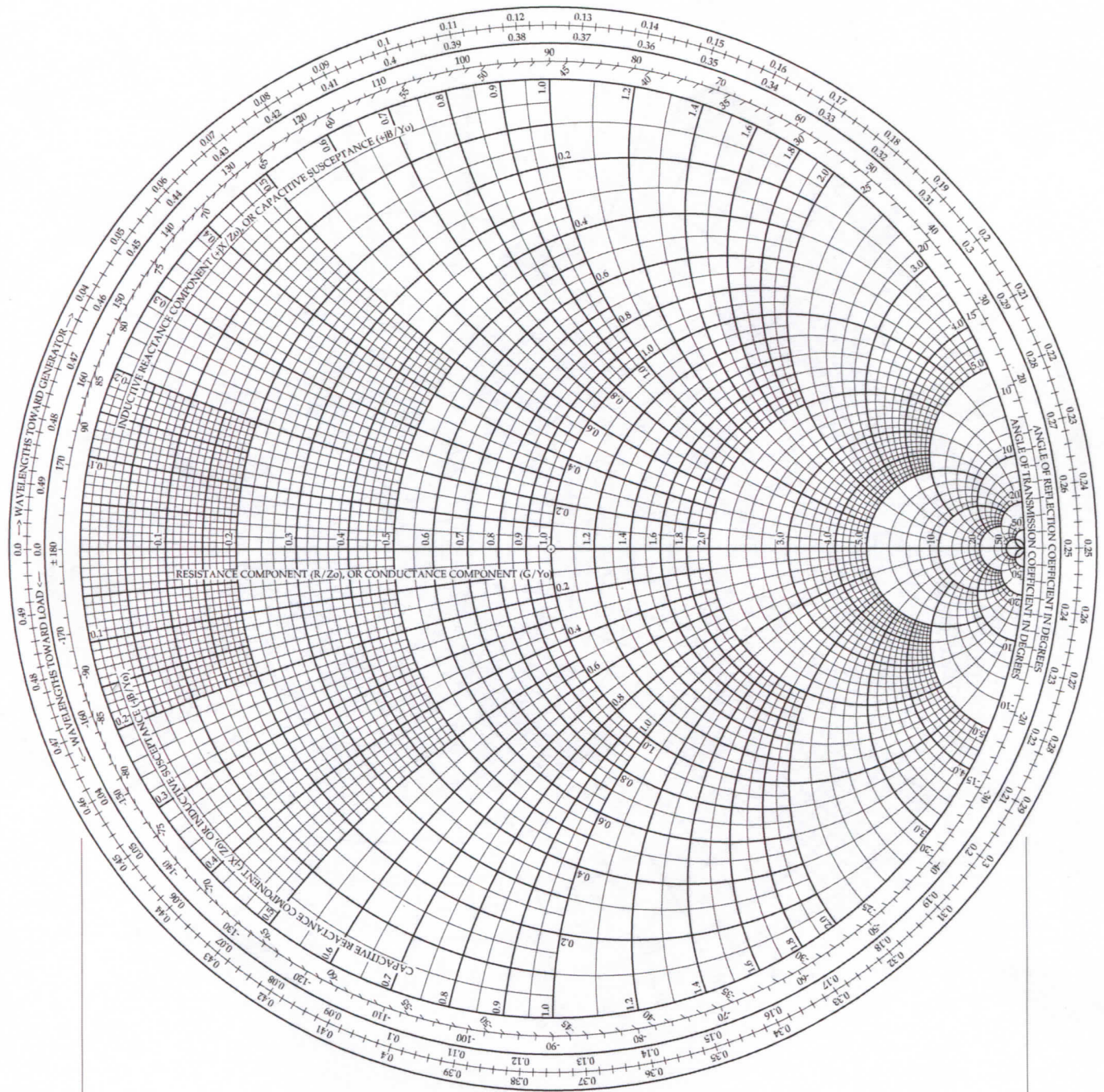

Figure 8: The test setup uses three 50-Ω cables each 120 cm long and a T-junction.

Smith Chart

RADIALLY SCALED PARAMETERS

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