Exam

Examiner: Olli-Pekka Lundén

Students are allowed to use any types of calculators and any written material. Use of mobile phones, laptops, or other communication devices is prohibited. Students may keep the problem sheet. Evaluation shall be based on the evidence student demonstrates about the learning outcome statements of this course.

To solve the problems students may also need: a compass and either a ruler or a set square.

Problem 1: The following claims may contain inaccuracies or falsities that you must *identify* and *explain what is wrong*. In addition, you have to *provide a fully corrected sentence*, corrected with *minimum editing.* The actual claim is in bold-font. The normal-font text should always be correct. If the claim is completely correct you must state this to be the case and not comment or edit it.

(a) **Transmission lines are homogeneous conductor constructions that are comparatively long; in practice, at least 5 mm long.**

(b) Consider a transmission line and a load. **Reflection coefficient corresponding to load impedance of $Z_L = 75\ \Omega$ is $\Gamma_L = 0.2$, in all cases.**

(c) The amplitude of a voltage wave reflected from a 75-ohm load is 50% of the incident wave. **In this case the characteristic impedance of the transmission line is $25\ \Omega$ or $250\ \Omega$.**

(d) An *impedance inverter* made of microstrip line on FR4 ($\varepsilon_r \approx 4$) is 30 mm long. **The frequency of interest is 1.25 GHz.**

(e) The transducer power gain of a two-port is defined as $G_T = P_L/P_{avg}$, where P_L is the power delivered to a load and P_{avg} is the power available form a generator. **The voltage gain of a two-port $A_V = V_L/V_{in} = \sqrt{G_T}$, where V_L is the voltage across the load and V_{in} is the voltage across the two-port's input.**

(f) Consider a (theoretical) two-port with $S_{12} = 0$. **Such a two-port is necessarily *unconditionally stable*, or, in other words, it cannot possibly show negative input or output resistance.**

Each subproblem yields 1 point at max.

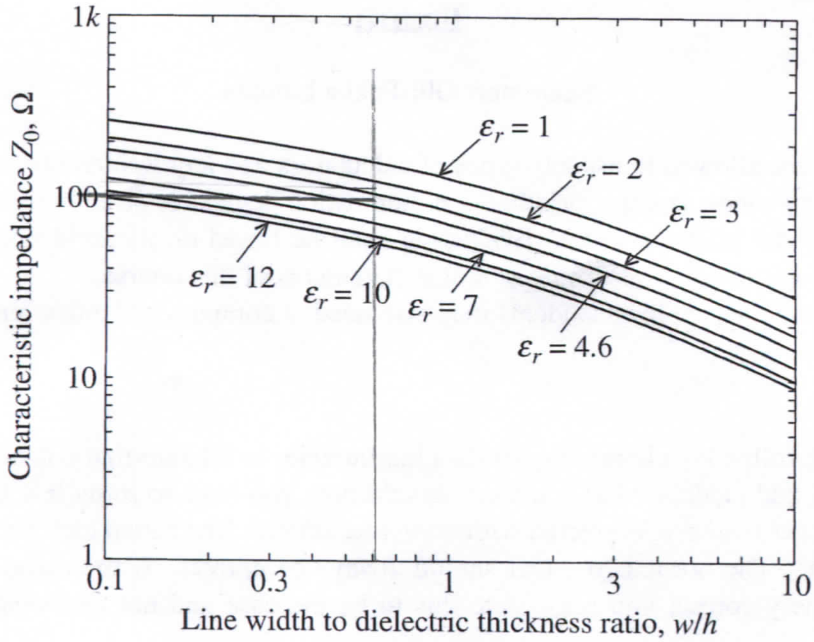


Figure 1: Microstrip characteristic impedance for several relative permittivities ε_r. Source: Reinhold Ludwig and Gene Bogdanov, RF Circuit Design, Theory and Applications, 2nd ed. Prentice Hall, 2009.

Problem 2: Certain rules-of-thumb say there is always x nanohenries of parasitic series inductance for every millimeter of (thin) wire, while x varies between 0.5 and 1. In this problem, you are studying the grounds for this rule-of-thumb using transmission line theory:

(a) First estimate the characteristic impedance of a 1-mm wide *microstrip line* printed on 1.6-mm thick FR4 ($\varepsilon_r \approx 4$). You may use Figure 1.

(b) Assume you have a 5-mm long segment of this microstrip line ($l = 5$ mm) and that the line is ideally shorted at its end. Calculate its input impedance Z at some frequency, such as 450 MHz.

(c) Find the inductance L that gives the same impedance Z at the same frequency according to $Z = \frac{1}{j\omega L}$. $Z = j\omega L \Rightarrow L = Z/j\omega$

(d) Calculate L/l in nH/mm and compare your result to the x of the rule-of-thumb mentioned above.

(e) Contemplate the limitations of the rule-of-thumb, such as what comes to the physical dimensions and frequency.

Subproblems (a) through (d) yield 1 point at max, but (e) can yield 2 points.

Problem 3: Under certain conditions, transistor BFG520 should "see" generator and load reflection coefficients $\Gamma_{MG} = 0.67\angle 40^\circ$ and $\Gamma_{ML} = 0.38\angle 55^\circ$, respectively, in order to provide maximum gain at 450 MHz.

(a) Choose the topologies for input and output impedance matching. Motivate your choice with good reasons.

(b) Design the *input* impedance matching network for an external generator having 50-ohm internal impedance. Give all the needed the transmission line dimensions or discrete component values.

Subproblems (a) and (b) may yield 2 and 4 points, respectively.

Problem 4: Figure 2 shows the measured S_{11} of an amplifier. Determine the *10-dB input return loss-bandwidth*[1] of that amplifier.

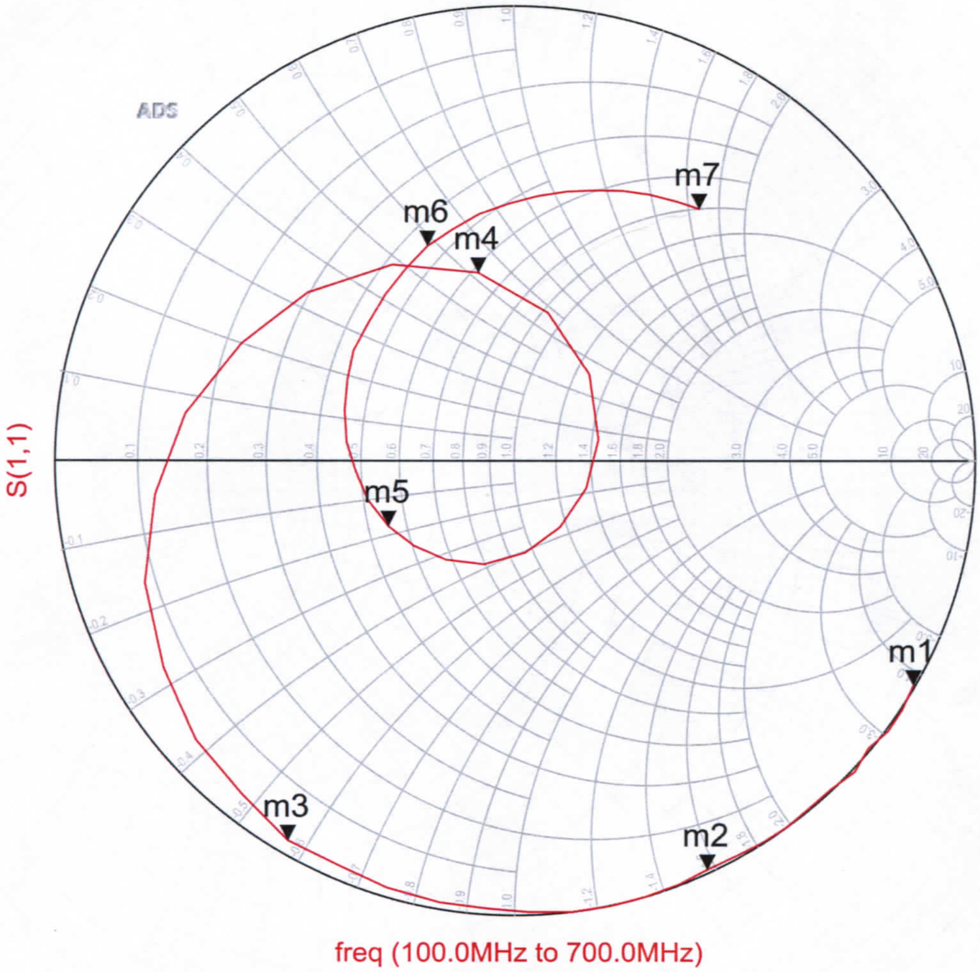
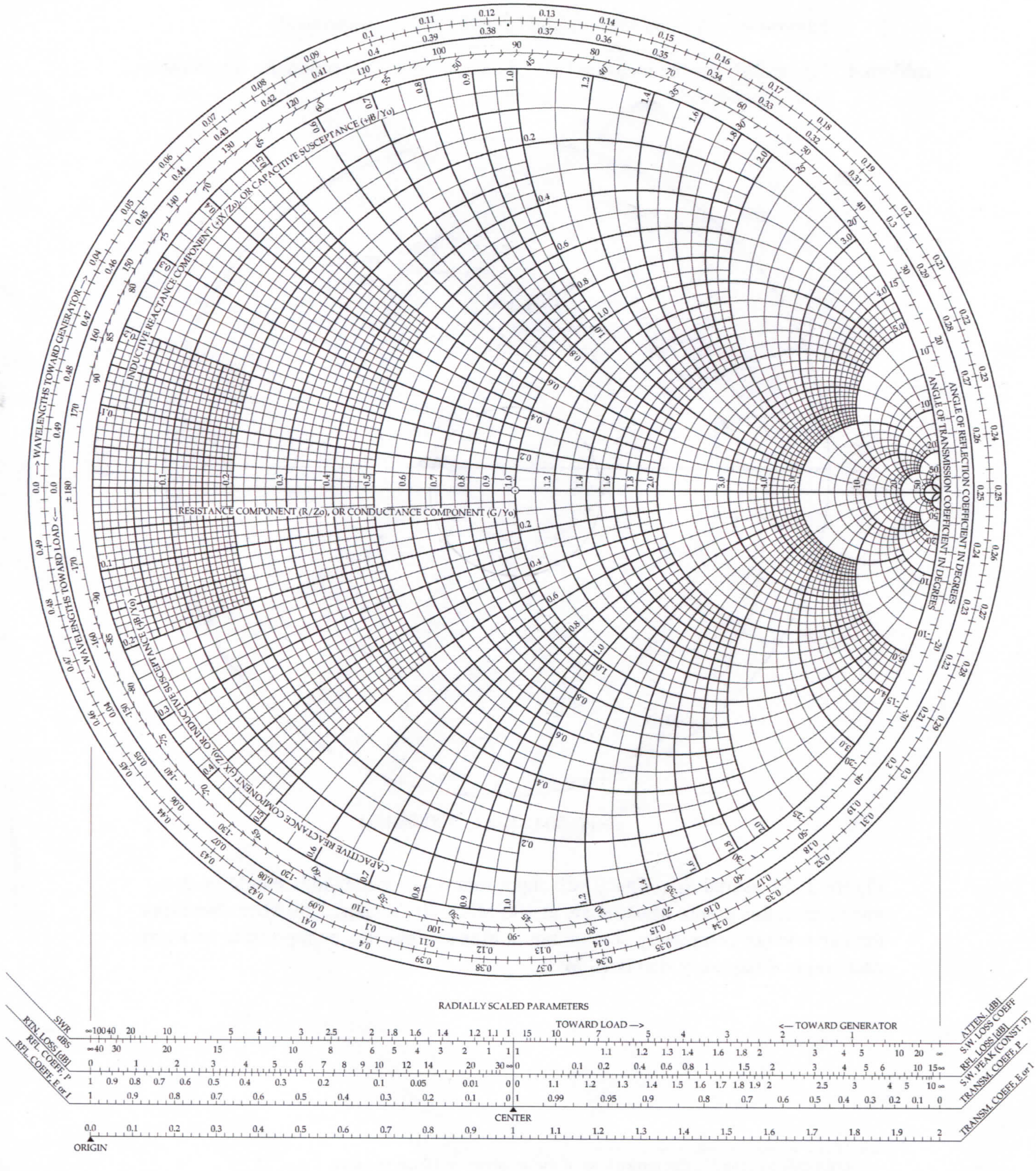


Figure 2: Measured S_{11}. The 10-dB input return loss-bandwidth should be determined from this graph. Markers are at 100 MHz, 200 MHz,. . . 700 MHz. Note that the curve is not completely smooth but is uses straight-line extrapolation between data points. Frequency step is 10 MHz.

[1]Over this bandwidth, the return loss of the amplifier is 10 dB or more.


0.0 —> WAVELENGTHS TOWARD GENERATOR —>
<— WAVELENGTHS TOWARD LOAD <—
INDUCTIVE REACTANCE COMPONENT (+jX/Zo), OR CAPACITIVE SUSCEPTANCE (+jB/Yo)
CAPACITIVE REACTANCE COMPONENT (-jX/Zo), OR INDUCTIVE SUSCEPTANCE (-jB/Yo)
RESISTANCE COMPONENT (R/Zo), OR CONDUCTANCE COMPONENT (G/Yo)
ANGLE OF REFLECTION COEFFICIENT IN DEGREES
ANGLE OF TRANSMISSION COEFFICIENT IN DEGREES
RADIALLY SCALED PARAMETERS
TOWARD LOAD —>
<— TOWARD GENERATOR
SWR
dBS
RTN. LOSS [dB]
RFL. COEFF, P
RFL. COEFF, E or I
ATTEN. [dB]
S.W. LOSS COEFF
RFL. LOSS [dB]
S.W. PEAK (CONST. P)
TRANSM. COEFF, P
TRANSM. COEFF, E or I
CENTER
ORIGIN