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Radio Frequency Circuits Laboratory

Excercise 2
The Smith Chart

Aim of the exercise

The aim of this exercise is to get acquainted with the Smith chart and learn how to read the parameters of the transmission line from it.

Introduction

The Smith chart presents the characteristics of the voltage reflection coefficient of the load impedance of the transmission line given in the polar form. Voltage reflection coefficient Γ is defined as the ration of the voltage of reflected wave to the voltage of incident wave. It is equal to zero when the load impedance is equal to the characteristic impedance $Z_L=Z_0$. When the line is short-circuited ($Z_L=0$), then Γ=-1, the voltage wave is reflected with the change in phase and cancels the incident wave so the voltage at the end of the transmission line is zero. In case when the transmission line is open-circuited at its end, $Z_L=\infty$, than the voltage wave reflects without the change in phase, what causes the voltage at the end of the line to be doubled. In this case Γ=1. The dependence between the load impedance of the transmission line Z_L the reflection coefficient Γ is:

$$Z_L = \frac{1+\Gamma}{1-\Gamma} Z_0 \qquad (1)$$

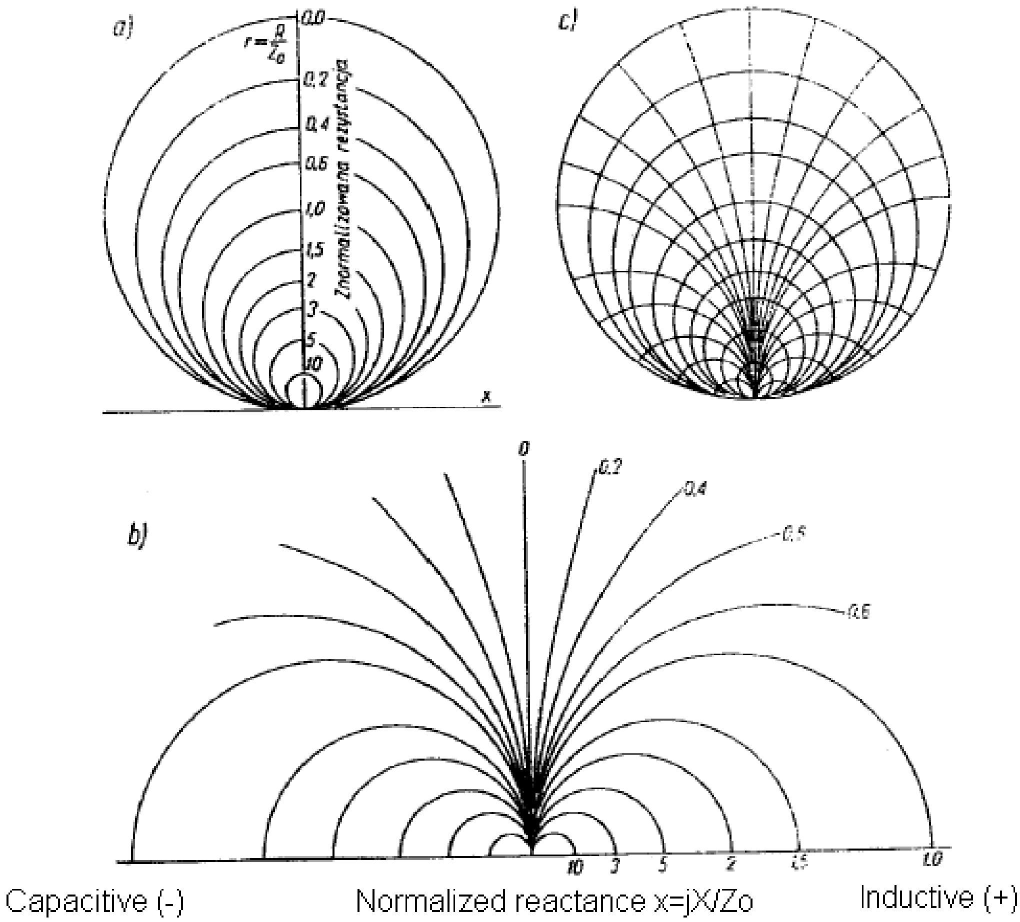

Fig. 1. Smith chart elements: a) constant resistance circles, b) constant reactance circles, c) composed plots a) and b)

The Smith chart allows also for finding the dependence between the standing wave coefficient (WFS) ρ and an absolute value of the reflection coefficient |Γ|:

$$|\Gamma| = \frac{\rho - 1}{\rho + 1} \qquad (2)$$

From equation (1) we know, that for each value of Γ coefficient there is assigned only one value of load impedance Z_L. These two parameters can be read directly from the Smith chart (fig. 1c). The chart consists of the circles representing constant resistance values and the arcs representing constant reactance (fig. 1b). The centers of the circles are located on the same straight line (fig. 1a). The resistance and reactance values are normalized with respect to characteristic impedance of the transmission line Z_0. The Smith chart includes also the lines of the constant phase of Γ coefficient (fig. 2a) given in angular form or as $l\lambda$, where l is a distance from the end of the transmission line and λ is a wavelength. Since the impedance values are repeated periodically every $\lambda/2$, then on the Smith chart we have $(l\lambda) \subset \langle 0, 0.5 \rangle$. There are also the circles representing the constant values of WFS ρ (fig. 2b). The complete Smith chart is presented in fig. 3. Using this chart it is possible to estimate also the values of WFS and input impedance of the transmission line at the given distance from its end for given load impedance Z_L.

Measurement Procedure

You have to perform the measurement of the load impedance and other parameters of the transmission line.

1. Turn on the analyzer.
2. Connect measuring cable to port 1 and appropriate connectors (from 7mm type to N type and from N type to BNC type).
3. Perform the calibration of the analyzer for the frequency band 30kHz-100MHz and BNC standard.
4. Connect the load.

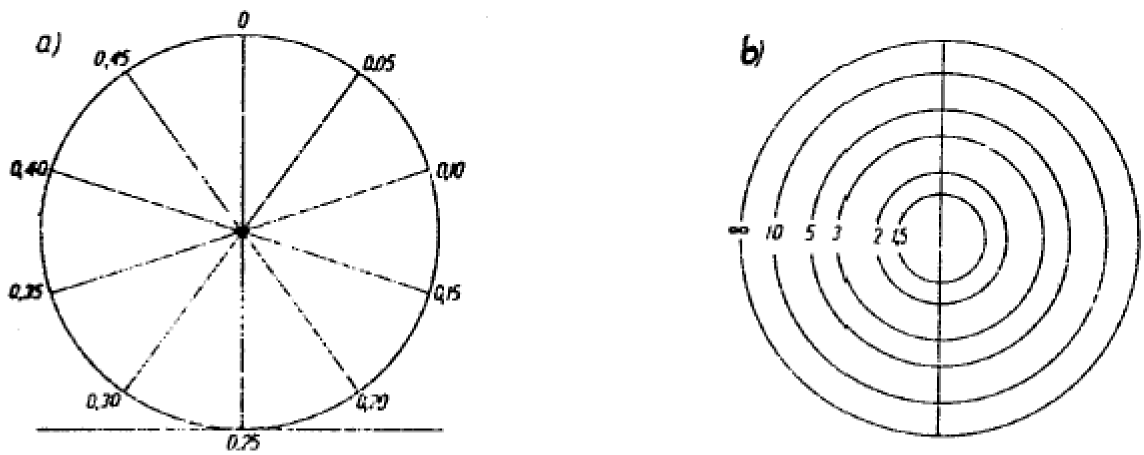

Fig. 2. Lines representing the constant phase of the reflection coefficient Γ (a), circles representing the constant WFS.

5. Select the S_{11} parameter measurement mode (reflection coefficient) pressing:
   MEAS Refl:FWD S11
6. Display the result by pressing:

SCALE REF AUTOSCALE
7. Press
FORMAT SMITH CHART
8. Press
MARKER MARKER MODE MENU SMITH MKR MENU R+jX MKR
9. Using the knob in the numeric block read the resistance and reactance values for every point of the ?przebieg? ?wykreślić? by the analyzer. Estimate the resonant frequency of the examined load.
10. For the frequency of 50MHz read the resistance and reactance values, and the amplitude and the phase of the reflection coefficient Γ for given load. To do this press LIN MKR
11. For the same frequency read the value of WFS by pressing FORMAT SWR
12. Mark the resistance and reactance values read in point 8 on the ?universal? Smith chart that you were given with the instruction. For this point find the amplitude and the phase of the reflection coefficient Γ and the value of WFS for the given load.

ATTENTION: the ?universal? Smith chart is scaled with respect to the matching impedance of the transmission line Z_0=50Ω

13. Repeat the measurements and the calculations from points 4-12 for other loads.

Report

For all examined loads:

- include all Smith charts generated by the analyzer;
- present values of load impedance, reflection coefficient Γ and WFS for the frequency of 50 MHz (those read from the analyzer and those calculated from ?universal? Smith chart);
- compare obtained results.