Project 1.

Microstrip line

The project is focused on the mapping of the basic parameters of microstrip lines. It should give estimations about practically achievable limits and also provide data needed in the following projects.

Substrates:

1) h = 1.27 mm	ε_r = 2.2	t = 17 μm	tgδ = 0.0009	Duroid 5880
2) h = 0.127 mm	ε_r = 2.2	t = 17 μm	tgδ = 0.0009	Duroid 5880
3) h = 1 mm	ε_r = 4.2	t = 30 μm	tgδ = 0.01	kuprextit
4) h = 0.635 mm	ε_r = 10.2	t = 17 μm	tgδ = 0.0023	Duroid 6010

Realizable characteristic impedance

a) Determine the maximum values of realizable characteristic impedance Z_{max}. Suppose etching technology with a minimum width of the strip w = 0.1 mm. Frequency $f = f_0 =$ 13 GHz.

b) Determine the minimum values of realizable characteristic impedances Z_{min} on frequency $f = f_0$. Single-mode propagation conditions must be satisfied.

Skin Depth

c) For all substrates, compute skin depth δ at your design frequency f_0 and check which frequency holds for t>5δ.

Loss factor

d) In the 0.1÷20 GHz frequency band, determine the frequency dependence of the loss factor in dB/cm for lines with characteristic impedance Z_v = 50 Ω realized on all substrates. Draw all dependencies into a single graph.graph.

e) Choose substrates 3) and 4), frequency $f = f_0$ and determine the dependence of loss factor in dB/cm on Z_v. Draw both dependencies into a single graph.

f) For a line with Z_v = 50 Ω realized on substrate 1) and 2) on $f = f_0$, determine the influence of the thickness of copper cladding on loss factor in dB/cm. Suppose the thickness of the copper cladding in the commercially available interval from 9 μm to 210 μm. The other dimensions remain constant. Draw both dependencies into a single graph. Comment on the odd results from the AWR simulation or limit maximal thickness in case of MATLAB solution.

Z_v dependences

g) Choose a substrate and choose those lines with maximum and minimum realizable Z_v designed on frequency $f = f_0$. Determine how Z_v changes due to t changes. Vary t in the interval 9 to 210 μm, the other parameters are constant. Draw both dependencies into a single graph. In case of MATLAB solution, limit the maximal cladding thickness.

h) For substrates 2 and 4 and lines with Z_v = 50 Ω designed on frequency $f = f_0$, determine how Z_v and effective permittivity ε_{ef} depend on frequency. Choose a frequency in the band from 0.1 to 20 GHz, let other parameters remain constant. Draw both dependencies into a single graph.

Project solution procedure

a) Open the TXLine utility (in AWR Tools/TXLine...) and fill in the substrate's material and physical characteristics of microstrip line (Thickness, Height, Width). The width of the microstrip line should be 0.1 mm. Click on the arrow pointing to the left and read the impedance of the microstrip line. It is independent of the line's length.

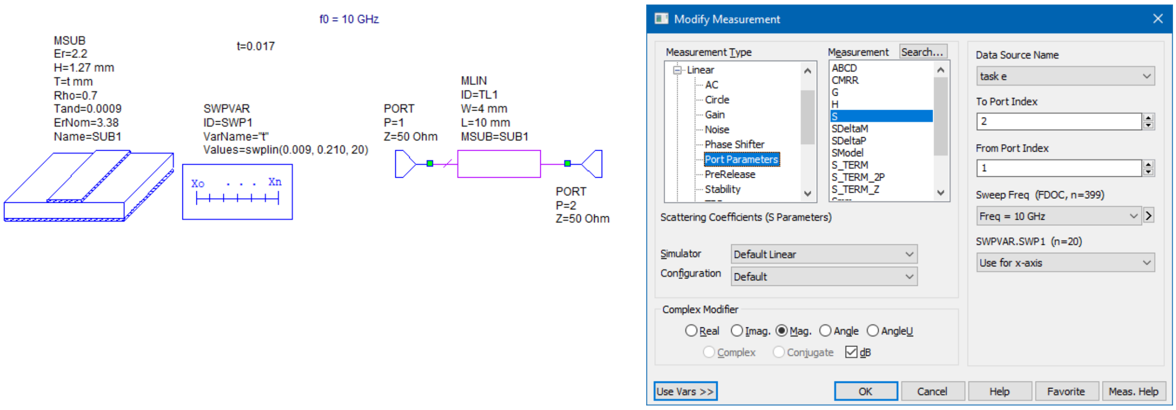
b) It is necessary to ensure single-mode propagation of the electromagnetic wave, i.e., the width of the microstrip line has to be limited. Let's consider your design frequency f_0 as the limit frequency of the first higher mode $f_{\mathrm{m}}^{\mathrm{TE10}}$, i.e., we consider the single-mode regime in the frequency band from DC up to f_0. The wavelength at your frequency f_0 has to be longer than two effective widths of the microstrip line to avoid propagation of the first higher TE10 mode. The minimal realizable impedance Z_v can be expressed from eq. (2.7.8) from slide 32 of the MIO lectures. It depends just on the height h of the substrate.

c) The skin depth and frequency, when $t>5\delta$, can be expressed from the framed equation on slide 31 of the MIO lectures. It depends only on copper cladding thickness and copper electric conductivity.

d) This can be simply performed using the AWR simulation with a 1-cm-long microstrip line (MLIN element) and the proper substrate definition (MSUB element). The resistivity of copper, relative to gold, is Rho = 0.7. The proper width of the microstrip line corresponding to Z_v = 50 Ω can be determined using TXLine. Then, analyze the transmission coefficient (S_{21}) of the MLIN elements using two 50 Ω ports and show it in decibels. The resulting graph is slightly wavy because the microstrip line is dispersive (its impedance is frequency dependent) whereas ports have constant impedance.

e) Choose approx. 5 impedances between Z_{min} and Z_{max} determined in task a) and b), design the width of the microstrip lines using TXLine to fulfill these impedances and read the losses in dB/cm. As the width of lines decrease conductive losses increase, but dielectric losses decrease (a higher fraction of energy is propagating via lossless air). This can't be simply performed by the AWR simulation because it would be necessary to change the port's impedances accordingly to suppress reflections. But this task can be effectively solved using MATLAB and RF Toolbox.

f) For certain f_0 design frequencies, it is not possible to design a multimode-free microstrip line with a Z_v = 50 Ω impedance on substrate 1. In that case, choose a different substrate. Using TXLine, compute the width of the 50 Ω microstrip line, define variable t=0.017 in the AWR schematic (the actual value is not important), define the substrate using the MSUB element with T=t, add the SWPVAR element to the sweep t variable, utilize function swplin to define start, stop and the number of points of the t sweep and create a 1-cm-long MLIN with two 50 Ω ports. The schematic and definition of the measurement is shown in Fig. 1. The values of t are utilized as x-axis values in the resulting graph and just one frequency point f_0 is selected. This task could be solved also using MATLAB RF Toolbox, but function `txlineMicrostrip` accepts maximal thickness of the cladding just H/10.



a) b)

Fig. 1 a) schematic of task f) with a single transmission line, b) measurement of the definition of task f).

g) It would be quite complicated to utilize just an AWR simulation to complete this task. The proposed method is to set the parameters of the substrate into TXLine and just change the thickness parameter of the line and read the resulting microstrip line impedance. This task can be also effectively solved using MATLAB and RF Toolbox.

h) The same case as in f). In all frequency points, also read the effective permittivity. The microstrip line fabricated on the substrate with higher permittivity is more dispersive. This task can be also effectively solved using MATLAB and RF Toolbox.