QSmith
A Simple Tool for Designing Matched Transmission Lines

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1 Introduction

In this project we were aiming to make a interactive simulation of a transmission line using Smith Chart. we can classify the goals of this project in these ways:

- As an applied software, to make the design of a matched transmission lines easier.
- As a teaching tool, by simultaneous visualizing the results on a Smith-Chart, it is a tool for teaching the fundamental topic and notions about the Smith Chart.

The software is written by Qt4.6.2 and is publicly released for free use and further development. In Fig.1 the main layout of the QSmith is shown. At the following sections, we are going through introducing several applications of QSmith.

2 Basics of QSmith

As it is shown in Fig.1, the QSmith includes three main parts:

- A sample transmission line, which is laid at the bottom of the GUI. There is a slider in the line that indicates the position of measurement probes. The probes are measuring the information of the line, toward the load. By default, the probe is laid next to the load. Thus the initial impedance, measured by the probe is the same as the load. It is possible to enter desired values as a load. Under the samples line, the characteristics of the load is laid. As depicted, it is essential to enter values for following parameters:

  $$\gamma = \alpha + j\beta$$

  Where α is attenuation coefficient and β is wave number. In the case of a lossless line we know that $\alpha = 0$.

  $$Z_0 = R_0 + jX_0$$

  Where Z_0 is characteristic impedance of the line. The typical value for the characteristic impedance is $R_0 = 50\Omega, X_0 = 0\Omega$.

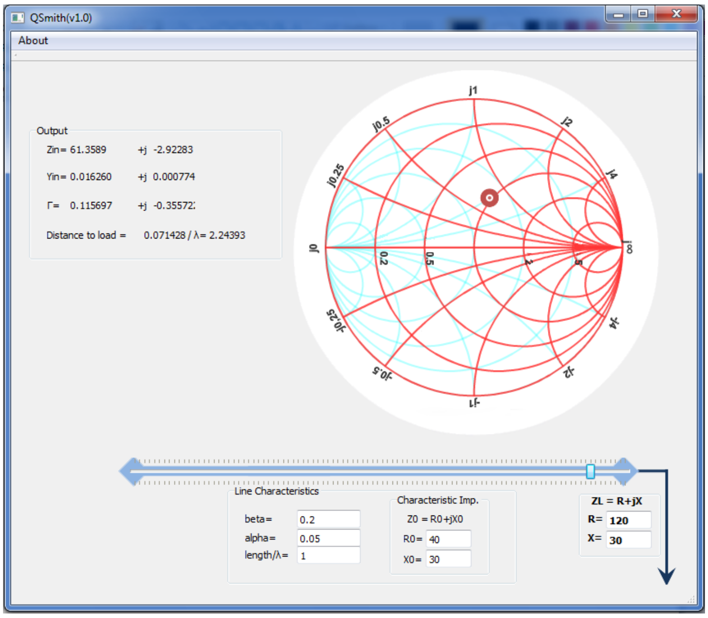

Fig. 1. Layout of QSmith

- The Smith Chart, which is laid at top-right of the GUI. A red circle on the chart show the impedance at the current position of the slider.
- The output box, laid on top-left, that shows the characteristics of line, at the position of the slider.

3 Input impedance of a stub

Problem[1]:

Using QSmith we want to find input impedance for a section of 50Ω lossless transmission line that is 0.1 wavelength and is terminated in a short circuit.

$$Z_L = 0, R_0 = 50\Omega, l = 0.1\lambda$$

Solution:

To solver this problem, first we set the load impedance to zero, i.e. $Z_L = 0.0 + j0.0$. As shown in Fig.2, when the slider is just clinging to the load impedance, the measured impedance, Z_{in} is zero, the reflection coefficient, $\Gamma = -1$ and the corresponding point, as shown on smith chart, is at the leftmost side, on the real axis. Next, we set $Z_0 = 50 + 0j\Omega$ and "length/$\lambda = 0.2$" for getting more exact

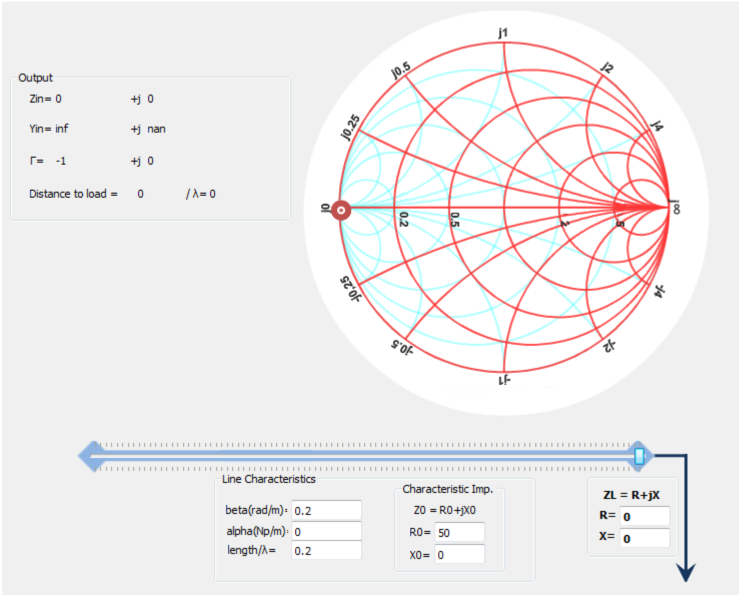

Fig. 2. A short circuited line.

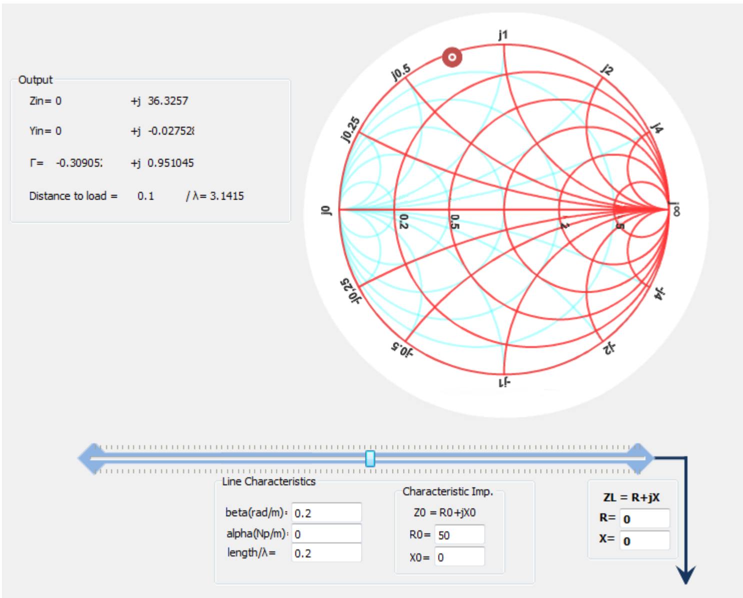

Fig. 3. input impedance for a section of 50Ω lossless transmission line that is 0.1 wavelength and is terminated in a short circuit.

result, when we are measuring at the distance of $l = 0.1\lambda$. Now, by moving the slider to the distance $l = 0.1\lambda$, as shown in Fig.3, we have:

$$Z_{in} = +j0.36.3257, Y_{in} = -0.02752, \varGamma_{in} = -0.30905 + j0.951045$$

Take care that in this problem, the value of $\beta > 0$ is not important. Because all the distances are expressed based of wavelength. So in every equation that we are dealing with βl we can equivalently write $\frac{2\pi}{\lambda} l$. The exact theoretical answer to this question is:

$$Z_{in} = jR_0 \tan \beta l = j50 \tan \left(\frac{2\pi}{\lambda} 0.1\lambda \right) = j36.3\varOmega$$

Problem[1]:

A lossless transmission line of length 0.434λ and characteristic impedance $100\varOmega$ is terminated in an impedance $260 + j180\varOmega$.

a. The voltage reflection coefficient?
b. The standing-wave-ratio(SWR)?
c. The input impedance?
d. The location of a voltage maximum in the line?

Solution:

To solve this problem with QSmith, we set Z_L, Z_0 and move the slider to the position of $l = 0.434\lambda$. As shown in the Fig.4:

$$Z_{in} = 70.9765 + j122.437, Y_{in} = 0.003543 - j0.00611, \varGamma_{in} = 0.226768 + j0.553716$$

For calculating SWR and position of maximum voltage, we move slider to find the first point that the cursor on Smith Chart meets the positive real axis. In that point $SWR = z_{in} = \frac{Z_{in}}{R_0} = 3.97$ and that point is the position of the maximum voltage. As shown in Fig.5:

$$SWR = 3.97, l_{\max} = 0.02857$$

The exact answers for this problem are:

a. $\varGamma = 0.2150 + j0.5601$
b. $SWR = 4$
c. $Z_i = R_0 z_i = 100(0.69 + j1.2) = 69 + j120\varOmega$
d. The location of maximum voltage is 0.030λ

Problem: Lossy Line:

In a short-circuited lossy transmission line of length $2m$ characteristic impedance is 75 $\varOmega$, $\alpha = 0.029Np/m$ and $\beta = 0.2\pi rad/m$.

a. Find input impedance.
b. Determine the input impedance if the short-circuit is replaced by a load impedance $Z_L = 67.5 - j45\varOmega$.

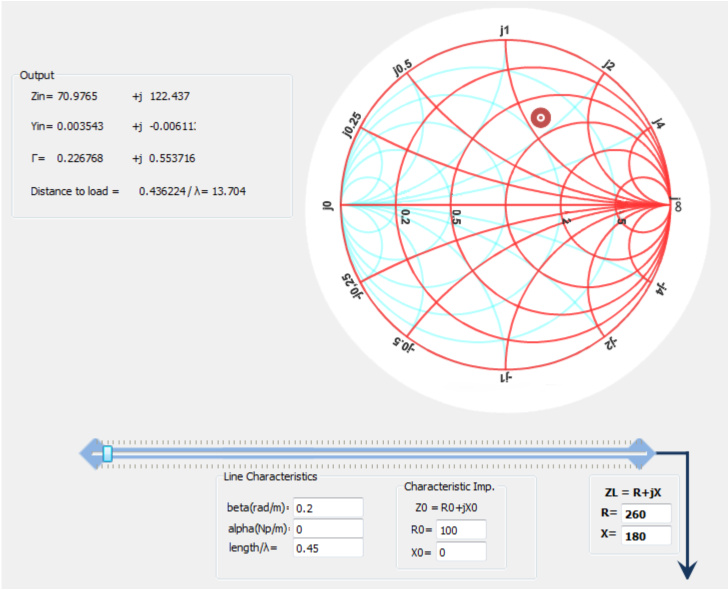

Fig. 4. Input impedance for a lossless transmission line of length 0.434λ and characteristic impedance 100Ω is terminated in an impedance $260 + j180\Omega$

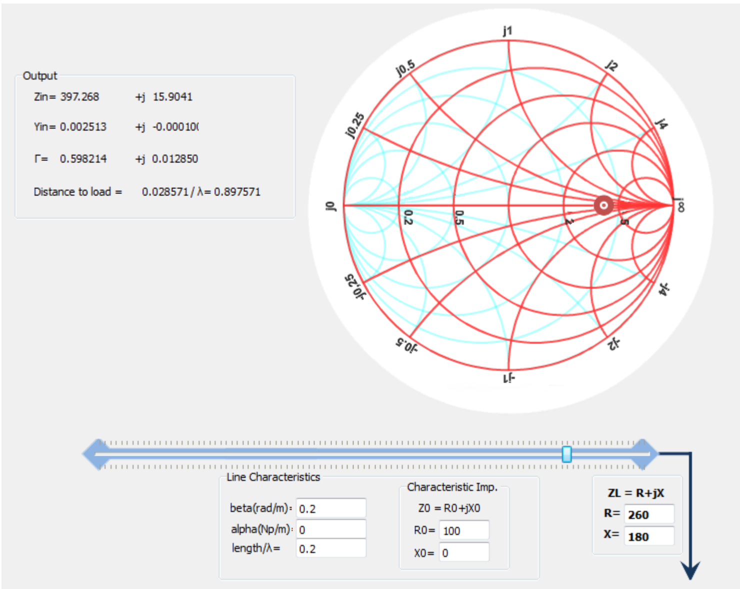

Fig. 5. SWR for a lossless transmission line of length 0.434λ and characteristic impedance 100Ω is terminated in an impedance $260 + j180\Omega$

Solution:

First we set Z_L, β, α and then we move the slider to the position of $2m$. As shown in Fig.6 the input impedance, $Z_{in} = 46.8535 + j229.369\Omega$.
By resetting load impedance to $Z_L = 67.5 - j45\Omega$ and moving the slider to the distance of $2m$ from the load, we read the input impedance: $Z_{in} = 48.0889 + j20.6149$.

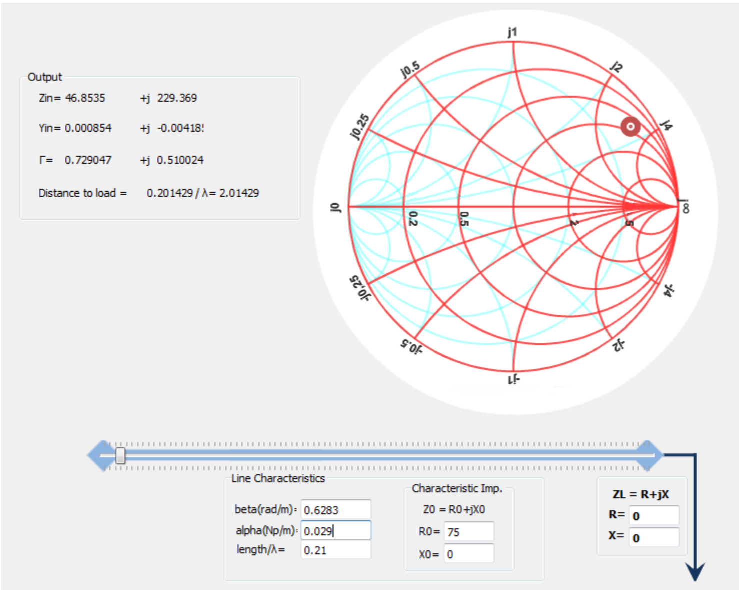

Fig. 6. Input impedance for a short-circuited lossy transmission line of length $2m$ characteristic impedance is 75 Ω, $\alpha = 0.029Np/m$ and $\beta = 0.2\pi rad/m$

The exact solution is :

a. $Z_{in} = 45 + j225\Omega$
b. $Z_{in} = 75(0.64 + j0.27) = 48.0 + j20.3$

Problem[1]:

Given $Z_L = 96 + j20\Omega$ and $Z_0 = 50\Omega$, find Y_L.

Solution:

The QSmith, in every position gives us both Z_{in} and Y_{in}. Hence, it is enough to enter the load impedance and read the admittance of the load. By doing so, we read $Y_{in} = 0.009983 - j0.002079S$. One other solution for finding admittance, is to move $\lambda/2 \equiv \pi$ along Smith Chart, which will give us the same answer.
The exact answer is $Y_L = 10.07 - j2.12(mS)$.

Problem[1]:

Find the input admittance of an open-circuited line of character impedance 300Ω and length $0.04\lambda(m)$

Solution:

First we set the load impedance to a pseudo-infinity value, a very big value! As shown in Fig.7, $Y_{in} = j0.0008589S$.
The exact answer is $Y_{in} = \frac{1}{300}(0 + j0.26) = j0.87(mS)$

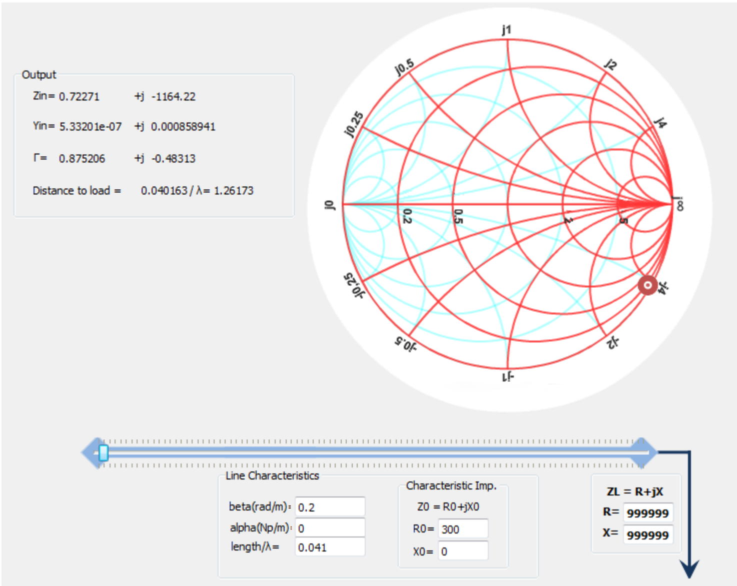

Fig. 7. Input impedance for a open-circuited lossless transmission line of length 0.04λ

4 Single-stub matching

Problem[1]:

A 50Ω transmission line is connected to a load impedance $Z_L = 35 - j47.5\Omega$. Find the position and length of a short-circuited stub required to match the line.

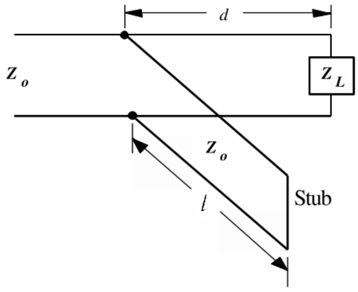

Fig. 8. Single-stub matching.

Solution:

At the first step, we enter the value of Z_L and move the slider until reaching to the intersection with the unit admittance circle on Smith Chart. As shown in Fig.9, this point is $d = 0.0.061020\lambda$ and input admittance is $Y_{in} = 0.0206353 + j0.0241817\Omega$. Note that if we write the normalized admittance, $y_{in} = 1.0318 + j1.2091\Omega$ in which the real part is almost 1. Now we need to design a stub whose input admittance is pure imaginary and equals to $y_{in,stub} = -j1.2091\Omega$ or $Y_{in,stub} = -j0.0241817\Omega$. The solution using QSmith is $l = 0.110204\lambda$, as it is shown in Fig.10. In sum, our designed matched line is:

$$d = 0.061020\lambda, l = 0.110204\lambda$$

The exact answer to this question is:

$$d = 0.05894469\lambda, l = 0.11117792\lambda$$

References

1. David K. Cheng: *Field and Wave, Electromagnetics*, Addison-Wesley Series in Electrical Engineering.
2. Some idea are inspired from: http://www.fourier-series.com/rf-concepts/flash_programs/SmithChart4/

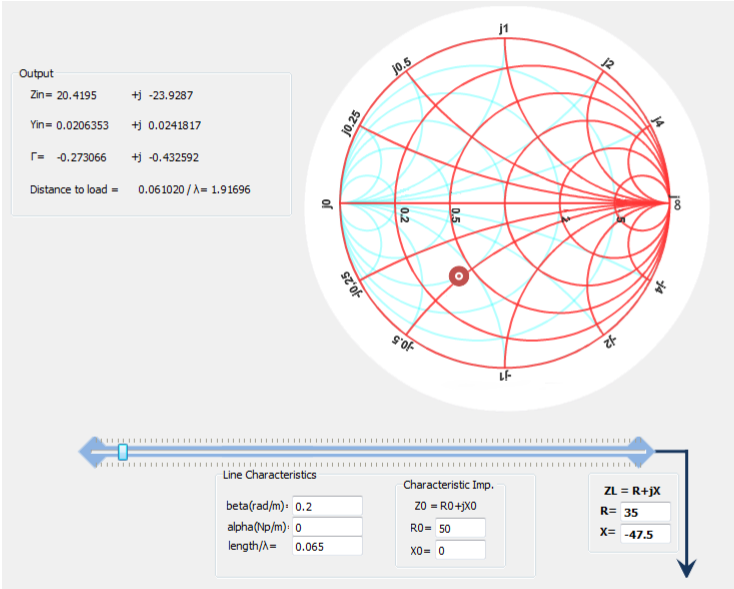

Fig. 9. The point which input admittance of the short-circuited transmission is $y_{in} = 1 + jx$

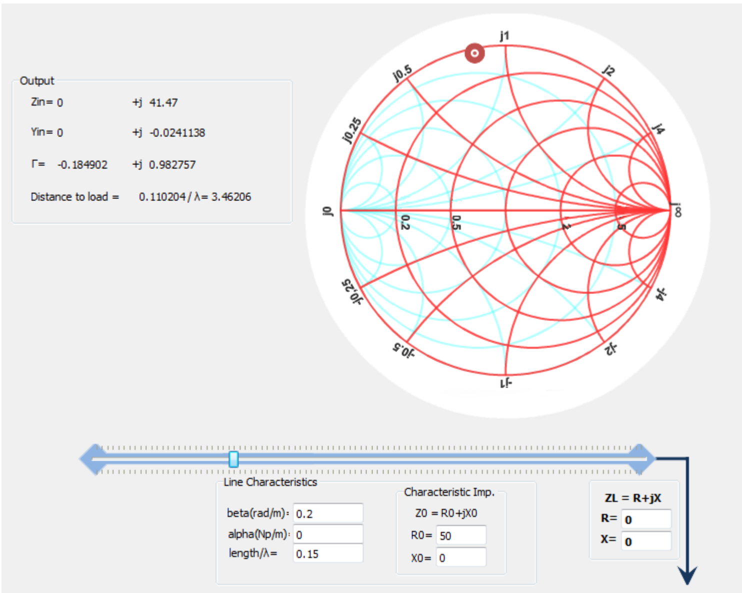

Fig. 10. Finding length of a short-circuited stub that has input admittance of $Y_{in,stub} = -j0.0241817\Omega$