Instruction for using the program **Q0REFL7.m**

The theory of the reflection-type Q-factor measurement can be found in references [1-3].Create a folder where you will work with the program Q0REFL7.m, and all other data files that you have measured. I prefer the old Matlab version R2016a, because the graphics does not crash as often as in newer versions. After opening the program Q0REFL7.m from Matlab® software in that file, start the program by clicking on the green triangle "run." The dialog window appears, containing 4 lines: 1) file name: FD-40.mea, 2) stretch: y, 3) TL= 1, 4) comment: y. Click ok.

I. STRETCHING

The blue circles show the reflection coefficient values, and the green line indicates the *rarity* of the data, namely the relative distance between two neighboring frequency data on the Smith chart. When the frequency is close to the resonance, the data move faster on the Smith chart, thus the rarity increases. The blue minimum indicates the location of the resonance, while the green maximum indicates about the same. The data file contains 401 frequency points [3], and you want to prune only a part of the measured data. First, you want to stretch the data for better visibility. The prompt appears: "begin stretching the frequency." This operation will enable you to decide more precisely where your pruned region will begin and where it will end. The next prompt is; "choose the low frequency point." Using mouse, move the vertical black line to the left of the blue minimum, at about at 944 MHz and click, then to the high frequency end at about 945 MHz and click.

II. PRUNING

Now your display is stretched, and the prompt reads: "begin pruning." It is easy to see that the green maximum is at about same frequency where the blue data have a minimum. The horizontal dashed green line indicates where the rarity of data drops to one-half of the maximum. The two intersections of the horizontal and vertical green lines indicate the first guess for the best pruned region. Thus click ok and choose with the mouse the left and then right pruning points to coincide with these intersections. For an accurate measurement, it is safe to have between 20 to 50 points inside the pruned region. If the program estimates that your unloaded resonant frequency is not inside the pruned region, it will stop further computation and give you a warning, so you will have to start again, this time by choosing a wider pruning range, or even by changing your calibration of the network analyzer in order to increase the number of frequency points.

III. WRITING THE RESULTS FILE

Next, the program finishes its job, creating four figures and providing some intermediate results in the command window. The prompt is now: "enter a comment." Move the mouse into the command window and type short comment that will remind you of specifics about this particular measurement. This comment will be saved, together with the results of the loaded and unloaded Q factors, the coupling coefficient, and their estimated uncertainties. These values will be written into a file called "results.txt." Every further execution which involves comment will be added to the same "results.txt" file. When it becomes too long, erase the whole file.

If you do not need to perform the stretching, you can change the stretching option in the beginning dialog window from "y" to "n". Likewise, if your measurement does not involve the transmission line, you can choose "TL=0" option, and if you do not want to write the "results.txt" file, you may set the comment to be "n" in the dialog window.

At the beginning of the QREFL7.m program, lines 26 to 36 contain several input data. Only the first of the data is the measured result, the remaining data are the validation files for checking the proper functioning of the program. The names of the data contain letter k (for angle), letter n (for noise), and letter p (for decimal point). For instance, the file name v14k50n1.txt is an overcoupled case with the transmission line length theta=50°, and with an added noise of 1%. All v14 data are overcoupled, and v13 data are undercoupled. When you will be using your measured data, put the % sign in front of the FD-40.txt file, and add your line of data to the program listing. You can get the same situation by not changing anything in the program listing, but instead running the program as it is, and in the first dialog box replacing the name "FD-40.mea" with the name of your data file.

IV. FIGURES

When the program has finished processing the data, several detailed results will appear in the command window, and there will be four figures plotted.

Figure 1 shows the pruned region in blue circles, and the discarded superfluous data in red dots. The units of frequency (like Hz, MHz, or GHz) are the same as those in your input data file.

Figure 2 shows the value of the difference $\Delta\Gamma_d$ (see eq. (20) in [2]) as a function of transmission line length θ°. The first minimum for this example is located at 72°.

Figure 3 shows a semicircle with its center located on the real axis of the Smith chart. This is the reflection coefficient at port 0 of the equivalent circuit in Fig 2 of reference [2].

Figure 4 summarizes the results of the a posteriori estimates. The Smith chart is plotted for the reflection coefficient at port 1. Thus, the Smith chart is rotated according to the estimated value of 2θ. The heavy red dot indicates the position of the unloaded resonant frequency.

V. COMMAND WINDOW

Command window contains several intermediate results. In this particular example, the a-posteriori results indicate that $|\Gamma_d|=1.0041$, thus falling outside of the Smith chart, but not very much outside. Since this is a very small inconsistency, the program is not interrupted, but it continues working and it writes the comment “AUTOMATIC FORCED LOSSLESS, |Gamma sub d = 1 |.” The program continues with the assumption that the coupling is lossless ($R_s=0$). Function “kfita.m” is called to estimate the transmission line length by searching over all values from $\theta=0$ to θ=ndeg in steps of 1°. My result indicate that the best fit is obtained for $\theta=72°$.

The warning “eq. ckt. is NOT passive” is printed if any of the reflection coefficients falls outside of the Smith chart, or if $R_s<0$, or $Q_L<0$, or $Q_0<0$ or $k<0$. For this particular case it happened that $|\Gamma_d|>1$.

Note that the program cannot finish before you enter your comment in the command window. This can be avoided if you use the comment option “n” in the input dialog.

References

[1] D. Kajfez, *Q Factor Measurements Using Matlab®* Boston, MA, USA: Artech House 2011.

[2] D. Kajfez, ”A-posteriori estimation of random uncertainty for the reflection type Q-factor measurements” *IEEE Trans. Microwave Theory Tech* …..

[3] D. Kajfez, “Random and systematic uncertainties of reflection-type Q-factor measurement with network analyzer.” *IEEE Trans. Microwave Theory Tech.* vol. 51, no. 2, pp. 512-519, Feb. 2003.