Training Simulator for Tuning and Matching of an NMR Probe

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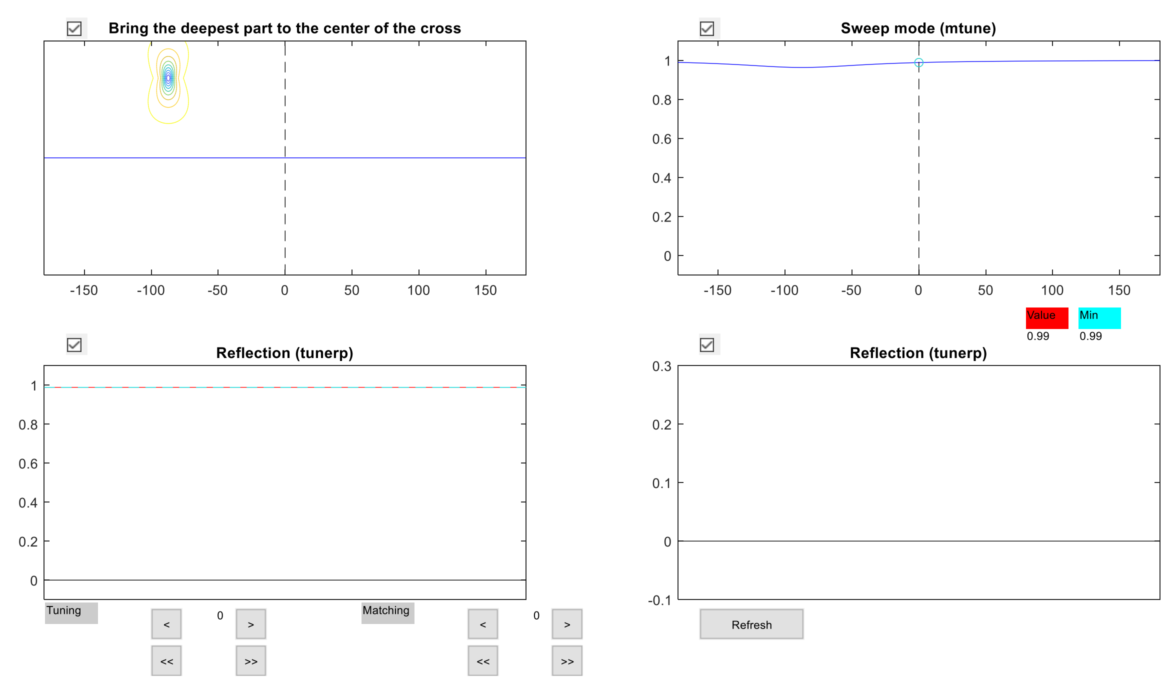
Purpose

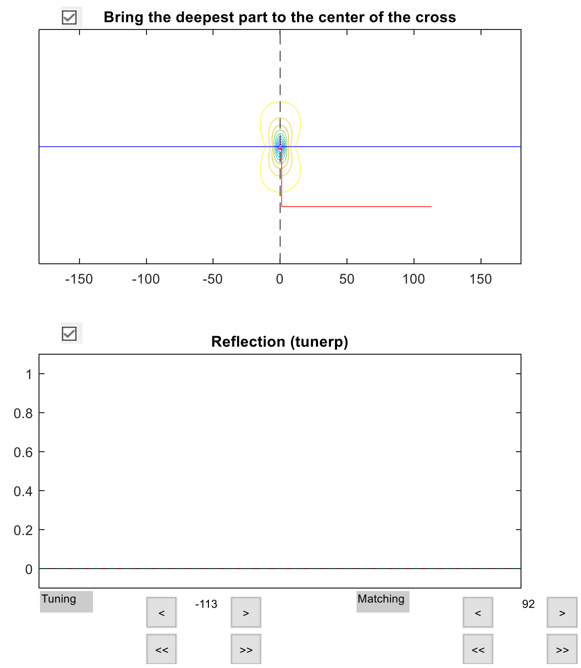
The NMR beginners sometimes struggle with the tuning and matching process of an NMR probe due to some interactions between tuning and matching capacitors. They sometimes turn tuning and matching rods unnecessarily due to less understanding of the behaviors of tuning and matching. This may cause a severe damage to the probe. The purpose of this simulator is to train NMR beginners for tuning and matching of an NMR probe before they touch an actual probe. This simulator visually displays the interactions between tuning and matching and the trainees can learn how a wobble curve and/or reflection power level change through the tuning and matching process.

How to Visualize Tuning and Matching

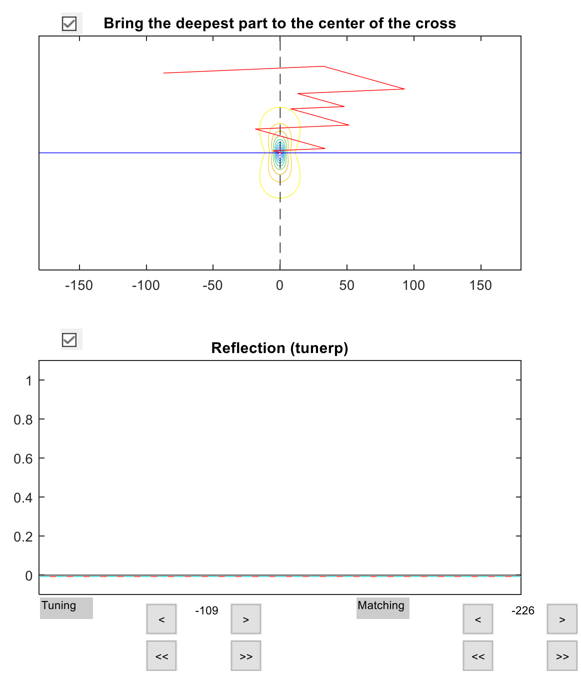
The simulator can show four plots to visualize the process of tuning and matching. The top-right plot shows a wobble curve (the center is at the transmitter frequency). The bottom plots show a reflection power level (the right one is vertically expanded from the left one). The reflection power level corresponds to the efficiency at the center of the wobble curve (shown as a cyan circle). Lastly, the top-left plot shows a circuit efficiency as a function of frequency (horizontal) and impedance (vertical) of the circuit (let's call it concave plot). The wobble curve is a slice of this concave by a plane indicated as a blue horizontal line in the plot. When the center of the concave is at the center of the plot, the circuit frequency is at the transmitter frequency and the impedance is matched to 50 ohm. Thus, tuning and matching process of a circuit can be visualized as a trajectory of the concave in the plot.



If there are no interactions between tuning and matching capacitors (i.e., they are independent), only two steps are necessary to bring the concave to the center of the plot. The first step is to bring the deepest point of the map onto the dashed line by tuning. The second step is to bring the deepest point onto the blue line by matching (or vise versa). Again, this is an ideal case as tuning only changes frequency and matching only changes impedance.



In the real world, however, matching changes not only the impedance but also the frequency of the circuit. Tuning behaves similarly although it doesn't affect the impedance largely. In such case, it is necessary to take iterative steps to obtain a better (or very close to the best) circuit condition. You can see such steps in the trajectory of the concave plot shown below.



How to Use the Simulator

The simulator does not require any MATLAB Toolboxes. Also, it will work on recent MATLAB versions. To start the simulator, type

>> TuningSimulator

in the MATLAB command window then a panel with the four plots appears. The initial condition of the offset (i.e., the position of the concave) is different each time. The "Refresh" button at the bottom section restarts the simulator with a new offset position.

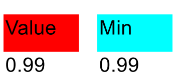
To begin the training, it is helpful to display all four plots. Then, the trainee focuses on the concave plot and try to move the deepest point to the center of the plot by changing the tune and match values with the buttons at the bottom section (they correspond to the rotations of tuning and matching rods).

This process is easy because the trainee can directly see how matching affects not only the impedance but also the frequency in the plot (vise versa for tuning). Simultaneously, the trainee should monitor the wobble curve and/or reflection power level how they change when the concave moves.

In the next step, the trainee focuses on monitoring the wobble curve. At this point, it is fine to display the concave plot. Then try to make the wobble curve as deep as possible at the center position by changing the tuning and matching values. If the trainee can't reach the smallest value ("0" in this simulator), monitor the concave plot and learn how the tuning and matching values should be changed. This is a transition process from the concave plot to the wobble curve.

Once the trainee gets used to obtain a smaller (or the smallest) value in the previous step, then turn off the the concave plot by unchecking the checkbox and have practices with only the wobble curve.

Some users may have to tune and match the circuit by monitoring the reflection power level. In such case, they can learn the relationship between the wobble curve and reflection power level visually using the simulator. Initially, try to get the smallest reflection level while display the wobble curve. Then the trainee can connect two motions in the mind; one is the change of the reflection level and the other is the motion of the wobble curve. Once the trainee gets used to do that, turn off the wobble curve and have practices with only the reflection power level. The final step will be to tune and match with only monitoring the reflection value. The simulator also shows the minimum value achieved so you can compare it with the current value and decide to which directions you should turn the tuning and matching rods.



Change of Some Parameters in the Simulator

Degrees of the interactions between tuning and matching are defined as T_ang and M_ang in the program code. They are angles in degree. If T_ang = 0, tuning only affects frequency, i.e., the concave moves horizontally with tuning. To simulate some degree of the effect of tuning to the impedance, put a small value in T_ang so that the trajectory of the concave by tuning gets a bit tilted. The default value is 5. If M_ang = 90, matching affects only the impedance, i.e., the concave moves vertically with matching. For less effect of matching to the frequency, use a value close to 90. In the opposite scenario, use a value close to 180. The default value is 150.

Notes

The calculations in this simulator are not based on any theories of the electronic circuit. For example, the Lorentzian function is used as a shape of the wobble curve for convenience.