

# A Walk Through the MSA Software

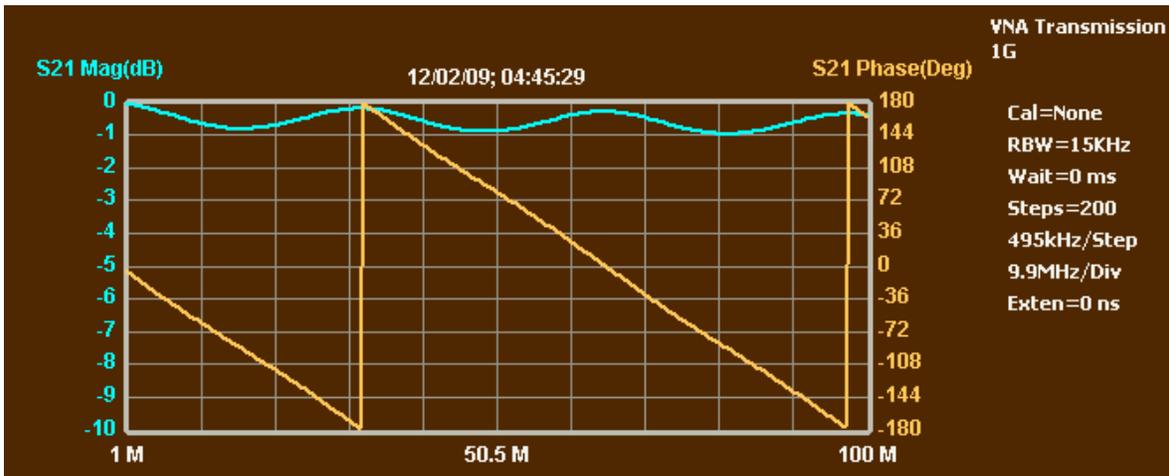
## Vector Network Analyzer Transmission Mode

12/18/09

This document is intended to familiarize you with the basic features of the MSA and its software, operating as a Vector Network Analyzer in Transmission mode, without the need for you to have the MSA hardware. All that is necessary is that you have installed the software per Scotty's instructions. It is assumed that you have done the Walk-Through of the MSA in Spectrum Analyzer Mode.

### Basic Operation in Transmission Mode

1. To start the program, double-click the icon for the MSA software.  
**Warning: You may resize the MSA graph window, but you must be sure the scan is halted (click Halt) before doing so. Resizing while a scan is in progress has a 50-50 chance of crashing the program, due to a Liberty Basic bug.**
2. Select menu Mode→VNA Transmission. The software will switch to VNA Transmission mode, in which it would normally measure the transmission coefficient of a device, which when expressed in dB is usually referred to as S21. Here we will operate with simulated data. There is no need to worry about Final IF filters or Video filter settings, but normally in Transmission mode you would use a Final IF filter in the 2-10 kHz range and set the Video filter to Mid or Narrow.
3. Double-click under the frequency axis to open the Sweep Parameters window. Select a start frequency of 1 MHz, a stop frequency of 100 MHz, and a number of steps/sweep equal to 200. In the Data Mode box, select item 5 (Simulated RLC/coax). Close the window.
4. A window will be presented allowing you to select the type of coax and the RLC components to use for the simulation. To start, we want to simulate a coax cable running from the TG output to the MSA input. Be sure the Resistance, Inductance and Capacitance checkboxes are all cleared, to indicate we have no such components. Select the Series fixture type. In the Transmission Line Connection box, select RG59B. Enter 10 as the length of the coax (ft). Click OK to close the window.
5. Double-click outside the S21 Mag(dB) axis to open the Y-axis window; enter -10 as Bot Ref; close the window. Click Restart and then Halt At End. A graph similar to the following will be produced:

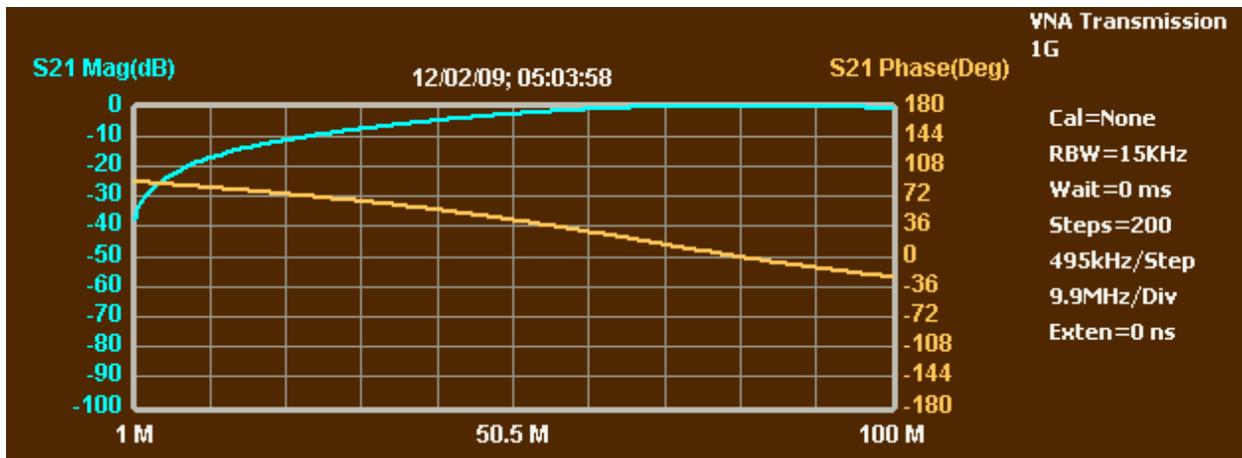


Your axes may be reversed; for these scans, the primary axis was set to 1 using menu Setup→Primary Axis. This scan presents the transmission characteristics of 10 feet of RG-59B, with the magnitude of the transmitted signal on the left and the phase on the right. There is wiggle in the magnitude response because of reflections arising at the ends of the 75-ohm cable, where it meets a 50-ohm environment. There is also a slightly downward trend in magnitude, due to cable losses. The phase becomes steadily more negative (wrapping-around at -180 degrees), representing the fact that as frequency increases, the fixed time delay of the cable translates into more degrees of delay.

6. Normally, a transmission measurement is preceded by a calibration scan, to allow the MSA to record the strength and phase of the signal transmitted with a direct connection from TG out to MSA in. However, this is not required for simulated data.
7. Open the Sweep Parameters window and click OK. This will re-open the window in which you specified the type of coax cable. Select RG-58C and click OK. Click Restart and Halt At End. A new graph will be produced similar to the last one, except the wiggle will be gone from the magnitude response, because we now have 50-ohm coax.

### RLC Analysis

1. Open the Sweep Parameters window and click OK. In the window that opens, select a coax type of None. In the RLC area, select Series, Resistance, Inductance and Capacitance. Specify zero for resistance, 200n for inductance and 20p for capacitance. Leave the inductor and capacitor Q at high values. This represents a 200 nH inductor in series with a 20 pF capacitor, both in series from the TG output to the MSA input. Click OK to close the window.
2. Open the Y-axis window for S21 Mag and enter -100 in the Bot Ref box. Close the window. Click Restart and then Halt At End. This will produce a scan similar to the following:



At low frequency, the transmission is largely blocked by the capacitor. Near 80 MHz, where the phase line crosses zero, the circuit reaches resonance, where most of the signal is transmitted. Above resonance, the signal gradually gets blocked by increasing inductance.

3. Select menu Functions→RLC Analysis. Indicate that the components are in Series, and that the fixture is a Series fixture. Click Analyze. The software will determine the resonant frequency and the -3 dB points; here the upper -3 dB point is off the right edge of the scan, but the MSA only needs one of those points. From that information, it will calculate and display the series resistance, inductance and capacitance:



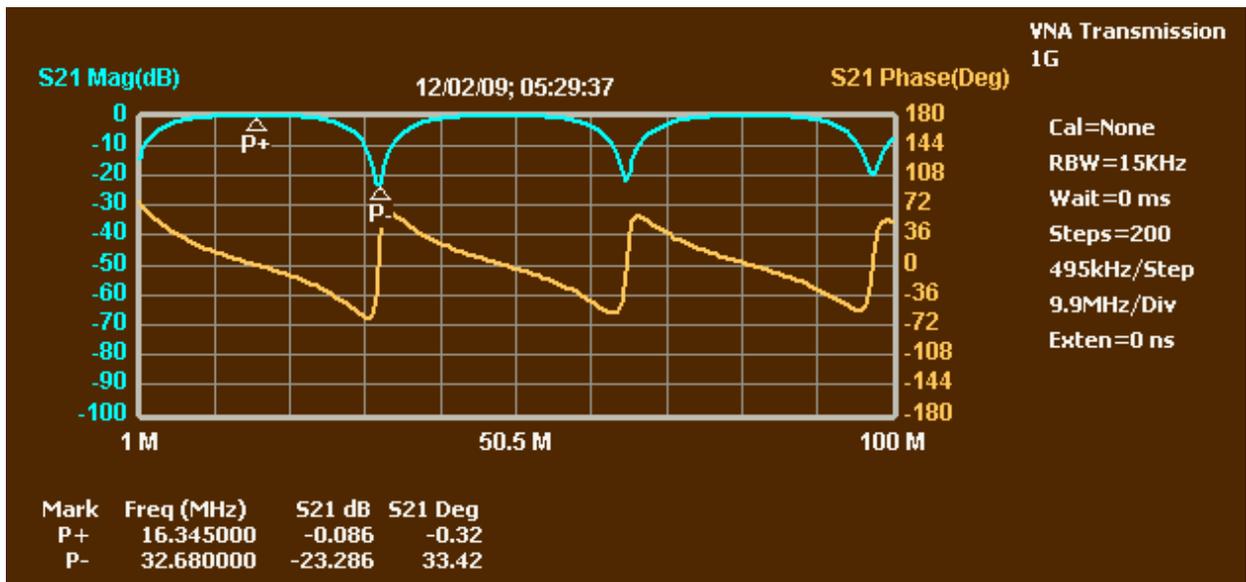
The values will not exactly match the simulated values, because an infinite-resolution scan would be required to perfectly identify the resonance and -3 dB points.

4. Close the RLC Analysis window. You can open the Sweep Parameters window and click OK to get the RLC window, and enter other component values. Any parallel or series RLC combination is allowed, and that combination can be mounted in a series fixture (in series from TG out to MSA in) or a shunt fixture (shunted to ground from a 50-ohm line connecting TG out to MSA in). You can then run a simulated scan and perform RLC Analysis.

### Transmission Line Stubs

1. Open the Sweep Parameters window and click OK. In the window that opens, select the Shunt fixture and RG-58C coax, with a length of 10 feet. Select Series RLC, turn off the inductance and capacitance, turn on the

resistance and set it to zero. You are now simulating a 10 foot coax shorted stub. Click OK to close the window. Click Restart and then Halt At End. Place the P+ and P- markers by selecting each one and then double-clicking on the graph. Your graph should look something like this:



The P+ marker shows the peak resulting at quarter-wave resonance, where the shorted stub acts like a nearly-open circuit, causing no attenuation of the signal running past it. The P- marker shows the dip resulting at half-wave resonance, where the shorted stub acts like a nearly-short circuit. “Nearly”, because the losses in the coax prevent it from ever acting like a perfect open or short circuit.

2. You can experiment with other cable types to examine the effect of varying cable losses on the performance of the stub. Or change the termination to a large resistor value to simulate an open stub.

### Crystal Analysis

1. The Functions menu also contains a function for Crystal Analysis, which will determine the parameters of crystals. There is no simulated data for crystals. Their series resonance can be simulated as a series RLC circuit. But with simulated data, the process is much like regular RLC analysis and the results are not especially interesting.

### Component Meter

1. Open the Sweep Parameters window and be sure the Data Mode is set to item 5 (Simulated RLC/coax). Close the window. In the RLC window that opens, select the Shunt fixture and coax type None. Turn off the resistance and inductance, but turn on the capacitance and enter a value of 120 p. You are now simulating a 120 pF capacitor attached to a shunt fixture. Close the window.

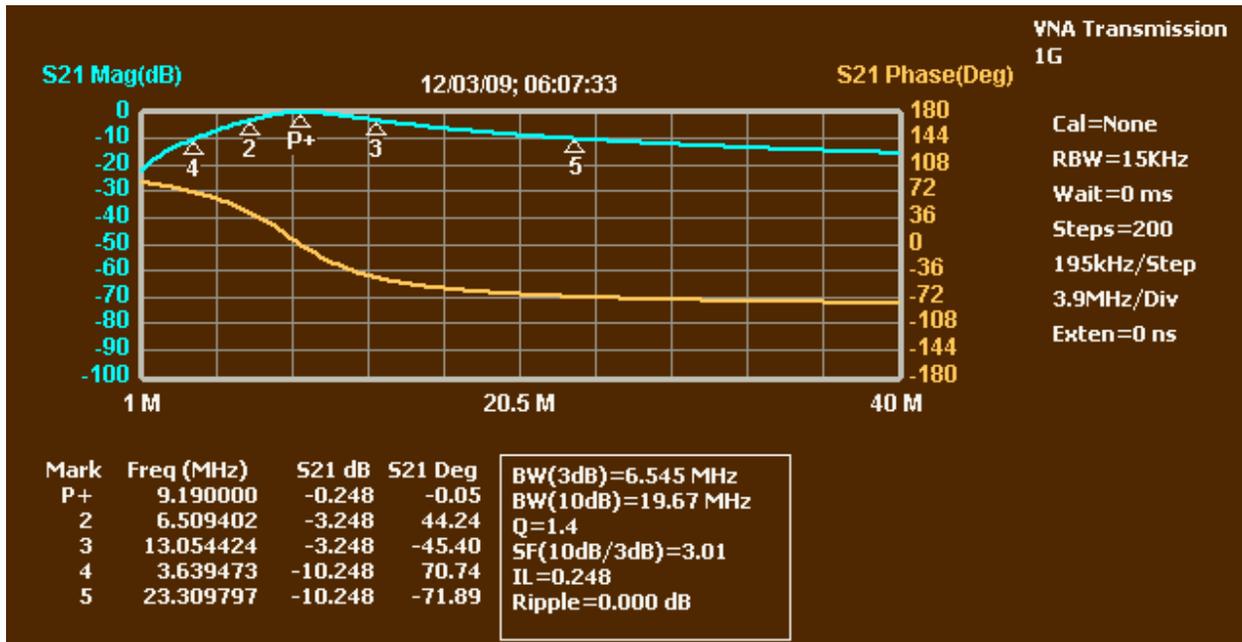
2. Select menu Functions→Component Meter. Select the Shunt fixture, and Capacitor. Click Calibrate. The calibration actually accomplishes nothing for simulated data. When the Measure button becomes active, click it. The MSA will now repeatedly scan the component and display its value. Click Stop. The MSA will stop at the end of the current scan. The display will look like this:



3. Click on the –Freq button to get the measurement at the next lower frequency, which will actually differ slightly from 120 pF. At low frequencies, the impedance of the capacitor becomes very high, which is difficult for the Shunt fixture to measure precisely. High impedances in shunt allow almost all the signal to pass by, and small changes in the impedance have very little impact on the transmitted signal. In the simulation, those small changes result from rounding errors.
4. Component Meter can make continuous measurements as one component is swapped for another, but when using simulated data, changing components requires quitting Component Meter and returning to the RLC specification window.

### Filter Analysis

1. A transmission scan of a parallel LC circuit shunted to ground will show a peak at resonance. Filter Analysis is designed to analyze such peaks. Open the Sweep Parameters window. Enter a start frequency of 1 MHz and a stop frequency of 40 MHz. Select Data Mode item 5 (Simulated RLC/Coax). Close the window; the RLC window will appear. Select Shunt Fixture and coax type None. In the RLC area, select Parallel and turn the inductance and capacitance on and the resistance off. Enter capacitance of 1n and inductance of 300n. For QL, enter 50. Close the window. Click Restart and then Halt At End. A graph will be produced showing the response of the specified parallel LC circuit.
2. Select Functions→Filter Analysis. This lets you identify two sets of “dB” points to locate. The first is already set to 3 dB. Enter 10 dB in the second box. Close the window. The graph will look something like this:



The MSA added the P+ marker at the peak, markers 2 and 3 at the -3 dB points, and markers 4 and 5 at the -10 dB points. The values of all markers are displayed below the graph. In addition, the display shows the bandwidth at the -3 dB and -10 dB points, Q, shape factor (10 dB bandwidth divided by 3 dB bandwidth), insertion loss and ripple. This response declines monotonically around resonance, so the ripple is zero.

3. Select Function → RLC Analysis. Select the Parallel component configuration and Shunt fixture, to match the simulated data. Click Analyze. The following values will be displayed:

Fp=9.19 MHz; R=862.2 ohms; L=299.7 nH; C=1.001 nF; Qu=49.83 ; QL=1.404 ; serR=0.347

The L and C values are close to the specified 300 nH and 1 nF, and the  $Q_U$  value is close to what was specified as the inductor Q. The R value represents the parallel resistance that would create that  $Q_U$  value. serR is the resistance in series with the inductor that would create that  $Q_U$  value. In this case, a model with the resistance in series with the inductor is the more realistic.