

## **Summary of Changes Made Between MSA Software version 115 and version 116 12/31/10**

### **USB Interface**

The MSA hardware may now be interfaced to the computer by means of USB. Information on installing the necessary driver is posted on the Yahoo group site. A Cypress-based controller board is required. It can interface with the parallel port control board, or can directly interface with the various MSA modules. It is necessary to run the Configuration Manager and specify that the control board type is USB.

### **Updating Calibrations**

It is easy to repeat a line calibration to adjust for phase drift that occurred since the previous calibration, but it is more of a pain to repeat OSL calibration. You can now select Update Calibration in the same menu as Perform Calibration. In reflection mode, this will allow you to re-scan the Open standard, and the entire calibration will be adjusted for any phase or magnitude changes. If there is a current line calibration, it can also be adjusted from the data obtained from the Open. Likewise, if you do Update Calibration in Transmission mode, you will re-scan the Through calibration and also have the option to update any current OSL calibration with the data received from the Through calibration.

This update procedure is useful to compensate for drift within the MSA and possibly within the reflection bridge. However, to the extent the external signal path is different for Reflection and Transmission, that portion of external drift may differ for the two modes and an updating scan in one mode may not fully compensate the other mode.

### **Automated Switching**

Version 116 implements several automated switches, in addition to the resolution bandwidth switch of prior versions. These are implemented through hardware latch U4, containing 8 bits as follows:

- bit 0 VS0 Video Filter Address, low order bit
- bit 1 VS1 Video Filter Address, high order bit
- bit 2 BS0 Band Selection, low order bit
- bit 3 BS1 Band Selection, high order bit
- bit 4 FR DUT Direction, Forward (0) or Reverse
- bit 5 TR VNA Selection, Transmission (0) or Reflection
- bit 6 Spare
- bit 7 PS Pulse Start (a/k/a Latch Pulse), common to all latching relays.

Of course, whether these possible switches actually exist in hardware depends on the actual build. In the Configuration Manager, the user can specify which automated switches actually exist. The possible switches are:

Video Filter: Four possible selections controlling the capacitors that filter magnitude and phase.

Band selection: 1, 2 or 3 to indicate 1G, 2G or 3G. These switches are set based on the user's settings in the sweep parameters window.

DUT direction: 0 indicates forward, 1 indicates reverse. These switches are set based on the user's settings in the sweep parameters window.

Transmission/Reflection: 0 indicates we are measuring transmission; 1 indicates we are measuring reflection. These switches are set based on whether we are in Transmission or Reflection mode.

The Band selection, DUT direction and Transmission/Reflection switches may be implemented in various ways, one of which is the use of latched relays. A latched relay will respond to the control setting only when it receives a pulse to indicate that it should respond. That pulse can be generated in hardware when the control bits change, or it can be generated from the Pulse Start (aka Latch Pulse) signal, which is triggered by software whenever the control data changes. The Pulse Start signal goes from high to low, and then returns to high after 2-200 us, to indicate something has changed. The user may respond to that signal, or may directly respond to changes in the control signals for Band selection, DUT direction and Transmission/Reflection. The issue with trying to directly respond to changes in the control signal is that on startup, the control signals may not change, but they also may not match the current state of the relays. To deal with this issue, the control signals will be changed several times on startup, to get the relays in sync with the control signals.

Latched relay switches may require significant current, but that current is only required briefly at spaced intervals. This means that such relays may be powered by slowly charged capacitors, and should not change state more frequently than allowed by the recharge time of the capacitors. For the possibly latched switches described above, two successive changes in state will be separated by at least 750 ms during startup, and after that they will normally not change more than once per sweep.

The MSA needs to know which automated switches are actually installed. This is done in the Configuration Manager, which now has a list of switches. The user can mark the ones that are installed.

## Video Filter Configuration

For various reasons, it is useful for the MSA to know the actual values of the filter capacitors used for the magnitude and phase filters. These are now specified in the Configuration Manager. Even if you have previously performed configuration, you will have to run the Configuration Manager to specify the capacitor values. With the advent of the automated video filter switch, there are four possible filters, and the "standard" values are as follows:

Wide--Mag=0.002 uF, Phase=0.011 uF—These are the values with no capacitors in the video filter switch.

Mid—Mag=0.1 uF, Phase=0.1 uF

Narrow—Mag=10 uF, Phase=10 uF

XNarrow—Mag=100 uF, Phase=10 uF

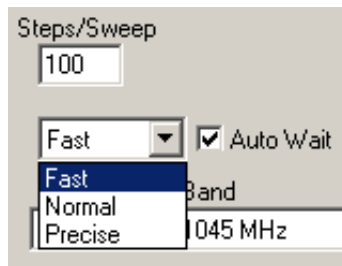
The Wide filter provides the fastest scanning. The Narrow filter provides good noise immunity. The XNarrow filter provides the most noise immunity but requires very slow scanning, and is likely to be used only for special purposes. One such purpose is initial path calibration when calibrating the lowest signal levels.

Note that the phase filter maxes out at 10 uF. There is an inherent limitation to the value of phase filtering. The PDM measures phase from 0 to 360 degrees. If one reading is 1 degrees and the next is 359 degrees, the algebraic average (which is what the filter capacitors produce) is 180 degrees, but the desired average would be 0 degrees. This problem is alleviated by the fact that the MSA inverts the PDM in order to keep raw readings away from 0 and 360 degrees. Still, large amounts of noise can wreak havoc, and this problem, unlike the magnitude noise problem, cannot be solved with large capacitors. The lowest level at which phase can reasonably be measured is likely to be 10-15 dB higher than that for measuring magnitude.

## Auto Wait

Prior software versions allowed the user to specify an explicit wait time in milli-seconds. The software would wait that amount of time between scan points, to allow necessary settling. The required settling time is determined primarily by the video filters. The stronger (narrower) the filter, the longer the required wait time. In the event that the PDM is inverted, an extra long wait time is required, and the software would make a guess as to how much extra time to add.

Now, the process is more automated. Next to the Wait box is a checkbox to activate Auto Wait. When that is clicked, a list replaces the wait time. The list contains 3 precision settings: Fast, Normal and Precise, as shown in Figure 1.



**Figure 1—Auto Wait Selection**

When Auto Wait is active, the software repeatedly reads mag and phase at each step until it considers the reading stable. Between reads it waits one time constant of the magnitude video filter. A reading is considered stable when the change from the previous reading falls below a pre-calculated level that is nominally aimed at achieving enough settling time to reach the following precision:

Fast--1 dB, 1.5 degree

Normal (SA mode)--0.25 dB

Normal (other modes)--0.1 dB, 0.1 degree

Precise--0.03 dB, 0.03 degree

Other factors may create more error than shown above; Auto Wait deals only with the settling time required by the filter capacitors. For example, phase drift due to temperature changes may create more than 0.03 degrees error when Precise Auto Wait is used. But if there are not other sources of error, Fast and Normal usually allow less error from settling times than specified above.

With a noisy signal, two successive readings may never be close, so readings are also deemed "stable" when the change between successive readings reverses direction.

Auto Wait is based on the idea that, after an initial short period of possible craziness, the magnitude and phase readings will settle toward a final reading based on the RC time constant of the video filter. It is important that the MSA know the values of the video filter capacitors for various filter settings. The assumption is also made that the phase filter time constant is not dramatically longer than that for the magnitude filter.

### **Two-Port Module**

In prior software versions, VNA data was handled one individual parameter—S11 or S21—at a time. It is still gathered one parameter at a time, but there is now a Two-Port module which allows a full set of S-parameters to be assembled and manipulated.

The Two-Port window is opened with the new Two-Port menu. Here is what it looks like:

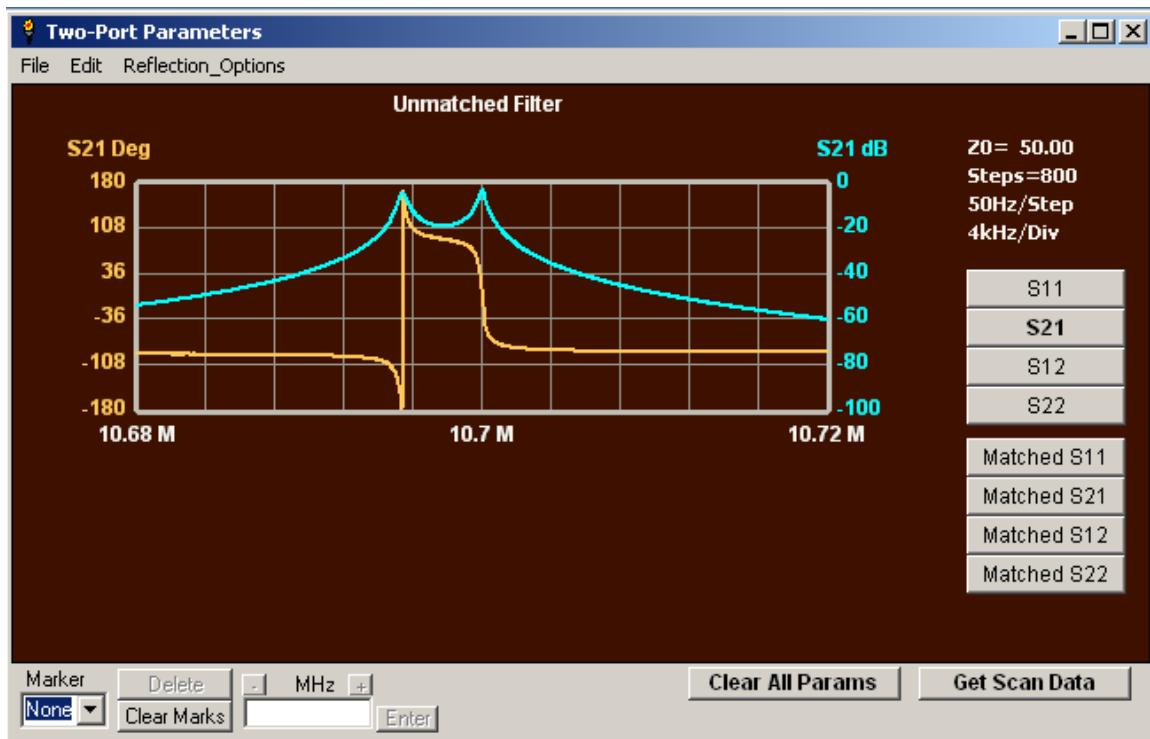


Figure 2—Two-Port window

Figure 2 shows a graph of S21 from a set of S-parameters that was loaded from a file. The Two-Port window adopts the appearance of the main graph window; when it is open, the main graph window is still on the screen but is disabled. Sweep parameters cannot be set in the Two-Port window, because those settings are taken directly from the data loaded into the window. However, the user can use menu Edit→Modify to modify the sweep range of the data, by trimming off points, deleting every other point, or interpolating the data to a new sweep setting.

One way to gather the two-port parameters is to do individual scans and transfer the data to the Two-Port module. When the Two-Port window is opened, the option is provided to transfer the existing scan data, if the sweep settings of that data match the sweep settings of any data already in the Two-Port module. For example, you can scan S21 in Transmission mode, switch to Reflection Mode and scan S11, and then open the Two-Port window. You will be given the option to transfer S11 and/or S21. You may transfer S11 to S11 and/or S22 of the Two-Port module, and S21 to S21 and/or S12 of the Two-Port module. You can then close the Two-Port module, go back and scan more data, and re-open the Two-Port window; its previous data will still be there.

Two-Port parameters can also be loaded directly from a file. If the file contains a full set of four S-parameters, they will all be loaded. If it contains only a single parameter, you will be asked where to transfer that data.

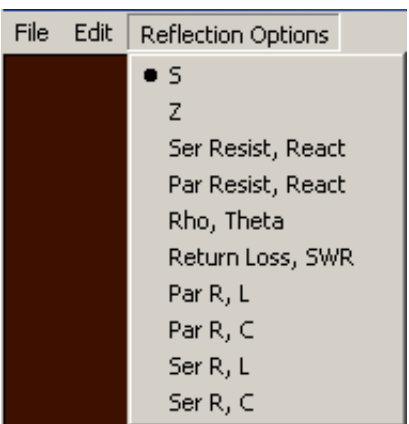
A related change has been made to the scanning process. Previously, if you switched between Transmission and Reflection modes, all the data from the prior mode was lost. Now, it will be preserved as long as the sweep settings of the two modes match. This allows you to gather both S11 data and S21 data and retain both. There is also an option in the sweep parameters window to set the DUT direction. If you indicate that you are scanning in reverse, then the measured parameters will be labeled S22 and S12, and if you have the F/R switch installed, it will be set appropriately. Likewise, if you have the T/R switch installed, it will be set to Transmission when you enter Transmission mode, and Reflection when you enter Reflection mode.

With the T/R and F/R switches, it is possible to measure all S-parameters without fiddling with the connections of the DUT, though you still must "manually" change the switch settings in the software as you proceed. The MSA software still does not have 6-term or 12-term calibration, so the accuracy of the S-parameters is dependent on the DUT seeing 50-ohms (or whatever the chosen reference impedance) at all switch settings. As a practical matter, this probably limits the use of the switches to 100 MHz and below. Future versions of the software will have fancier calibrations.

Once you have a full set of S-parameters, certain calculations can be made. The parameters can be converted to a different reference impedance ( $Z_0$ ). Hypothetical matching components can be attached to input and output, and the parameters can be recalculated with those components in place. Any of the parameters can be graphed, with or without the matching components. There is an Auto Match button to automatically calculate matching components for a simultaneous conjugate match at input and output.

For amplifiers, the K stability factor or Mu stability factor can be graphed. For an amplifier to be "unconditionally stable" (i.e., stable with all combinations of source and load impedances) each of these must exceed 1. (It is actually only necessary to look at one of them.) The Mu stability factor has the advantage that the greater it is, the more stable the amplifier; that is not necessarily the case with K stability.

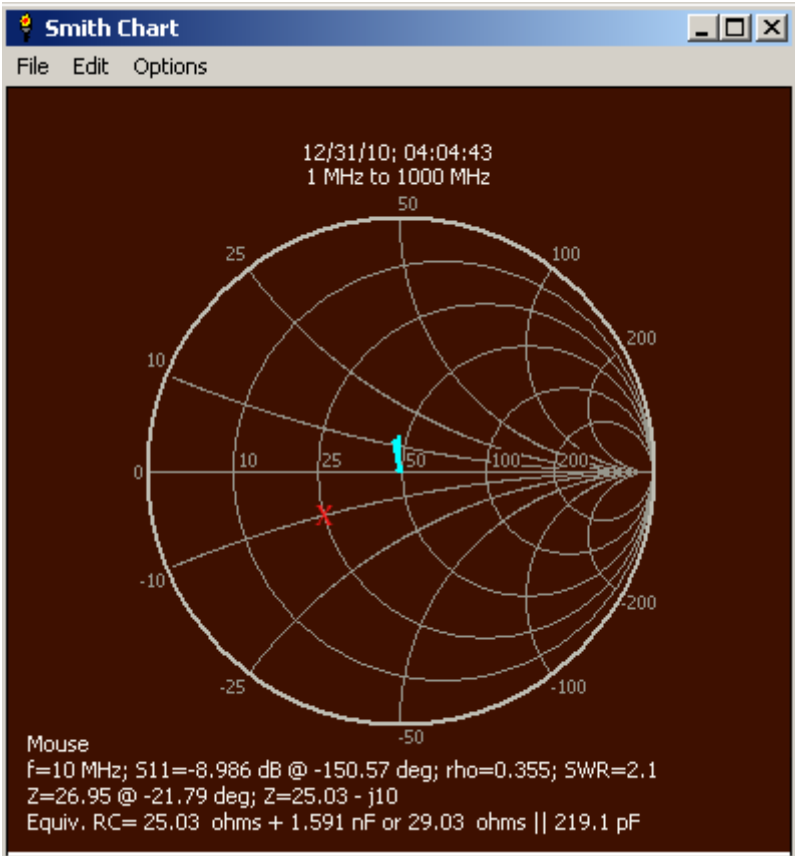
When reflection parameters are graphed (S11 or S22), there are numerous options as to how to graph them. They can be graphed in normal dB/angle form, in rho/theta form, as impedance or as equivalent RC or RL circuits. The selection is made from the menu shown in Figure 3.



**Figure 3—Selection of reflection graph options**

**Smith Chart**

The Smith chart has always shown information for the graph location represented by the currently selected marker, if any. Now, you can hold the left button down and move the mouse around on the chart, and data will be displayed for the mouse location, as shown in Figure 4.



**Figure 4—Display of data at mouse position  
Left-click occurred at the red X.**

Note that this is information about the location on the chart, and is not specific to whatever is being graphed. Each location represents a certain reflection coefficient and impedance. In addition, the impedance can be represented as a parallel or series RC or RL combination, though this equivalent-circuit information is valid only at a particular frequency. (An Options menu item allows that frequency to be specified.) When the left button is released, the display returns to the information for the currently active marker.