S-Parameter Utilities v1.0

Introduction

This is a collection of RF centric "utilities" that complement and extend RF Toolbox functions. The list includes:

1) One Port (s1p) file viewer (Smith, SWR/Q, Real(Z)&Imag(Z), Mag(Z) and Phase(Z))
2) Two Port (s2p) file viewer (S11,S22 Smith or Return Loss, S21 and S12 Mag and Phase)
3) One or Two Port viewer but Single Axes (expanded plotting area)
4) N Port (SnP) file viewer (Smith + Mag/Phase)
5) Enhanced (IMO !) Smith Chart
6) S Parameter file writer that incorporates User Notes and Measurement State
7) S Parameter file reader that extracts User Notes and Measurement State
8) "T Check" method for VNA Calibration Checking (s2p file input)

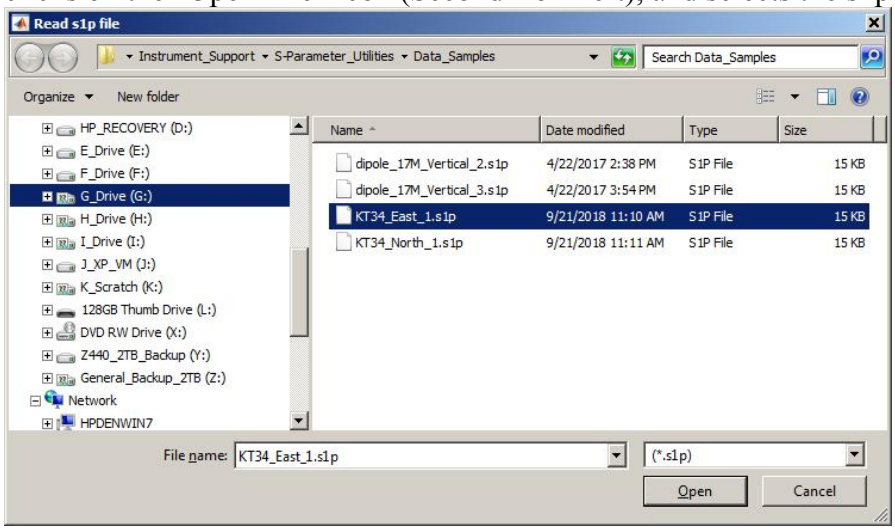
Prerequisites

MATLAB 2015a or later and the RF Toolbox are required.
I recommend creating a directory/folder (eg "S-Parameter_Utilities") and placing it on the MATLAB Path. These functions will be required if any of my other RF centric applications are employed. Also, "Short Cuts" (remember those?) to the "viewers" (items 1 through 4 above) are handy to have.

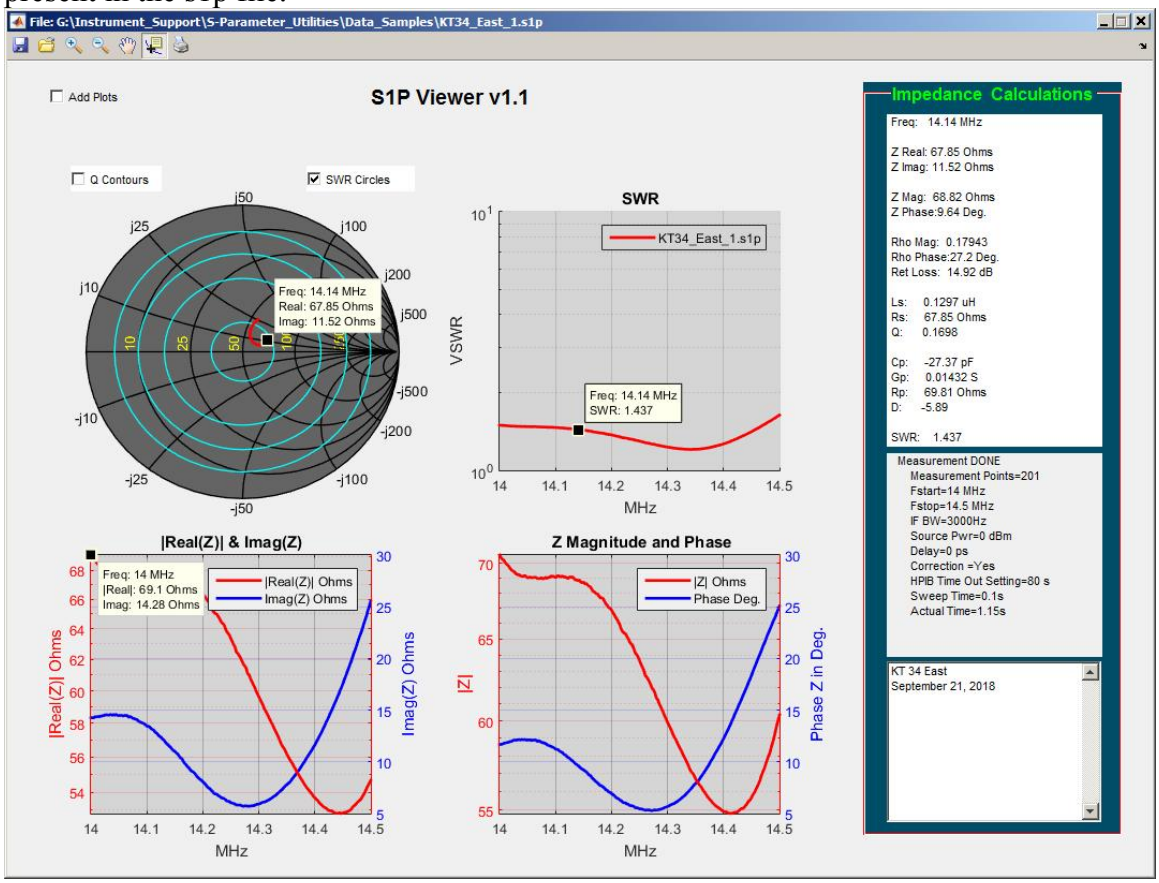
One Port File Viewer (s1p_viewer.m)

One Port VNA measurements can be displayed in a remarkable number of formats. The prime function of this application is to easily display some of the common formats with cursor readout support.

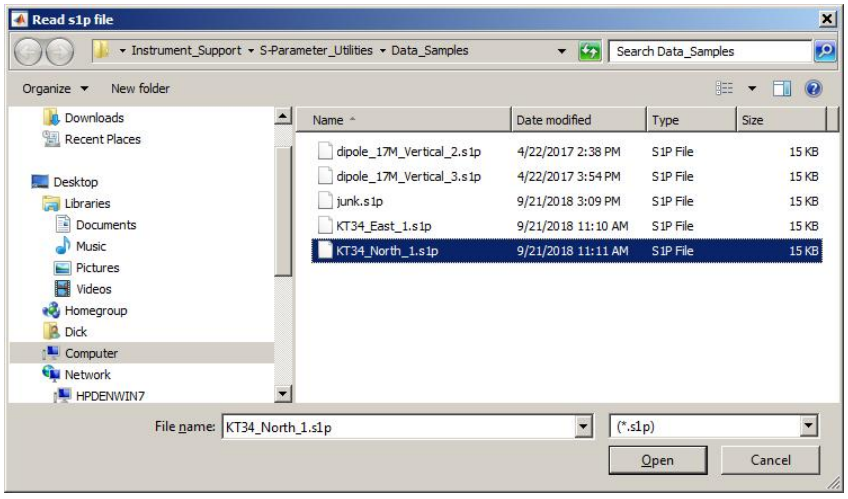
Here is a simple antenna measurement example. After launching the program, one simply clicks on the "Open File" Icon (Second from left), and selects the s1p file to be displayed.



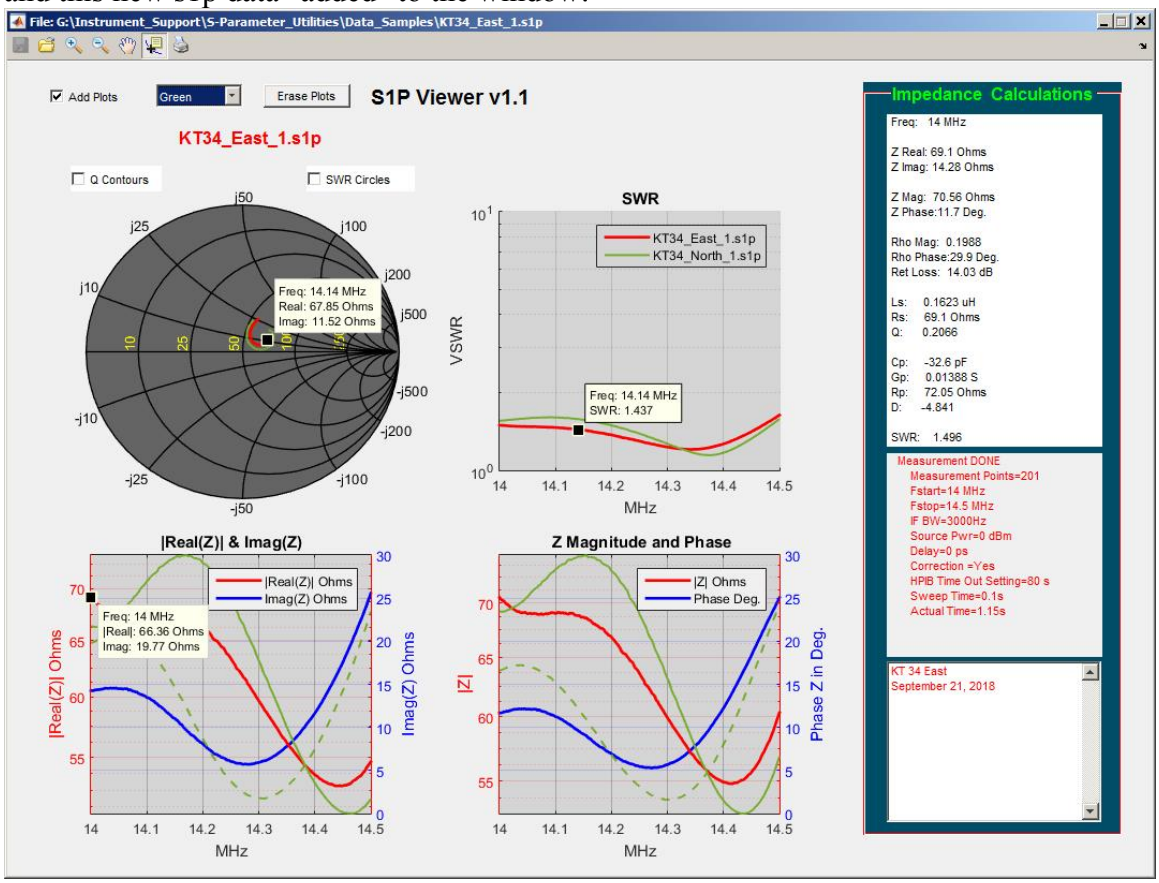
And the s1p data is plotted along with the VNA setup State and user Notes IF they are present in the s1p file.



Clicking on the "Add Plots" check box allows one to add more s1p file results to the plot windows which is very handy for comparison purposes. Select the color and then select the file:

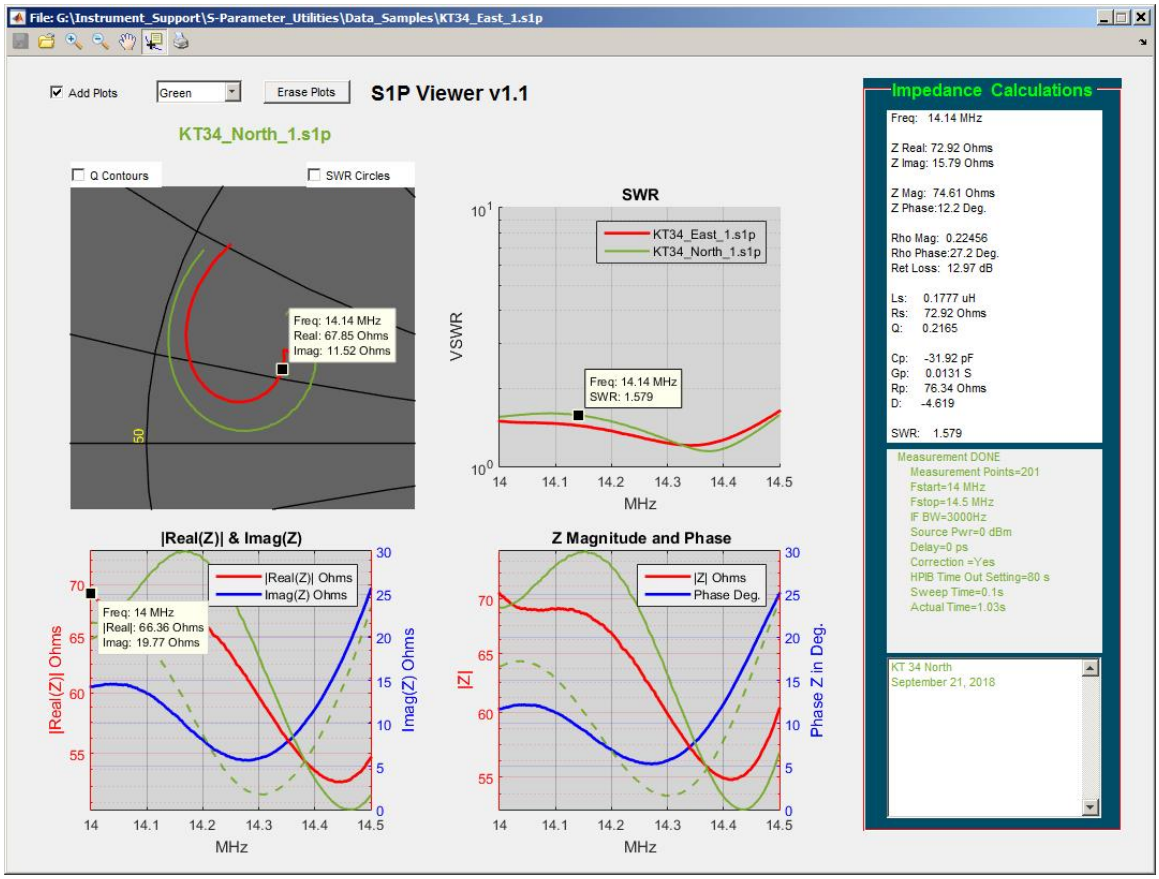


The antenna was rotated 90 degrees to aim North and the measurement was repeated, and this new s1p data "added" to the window:



Note that the text regarding the user Notes and VNA setup State are now red indicating that they correspond to the previous East conditions which has red as the primary line color, blue being used for the imaginary part and phase.

Clicking on a green plot line shows the State and Notes for the North based data in the same color as the line:

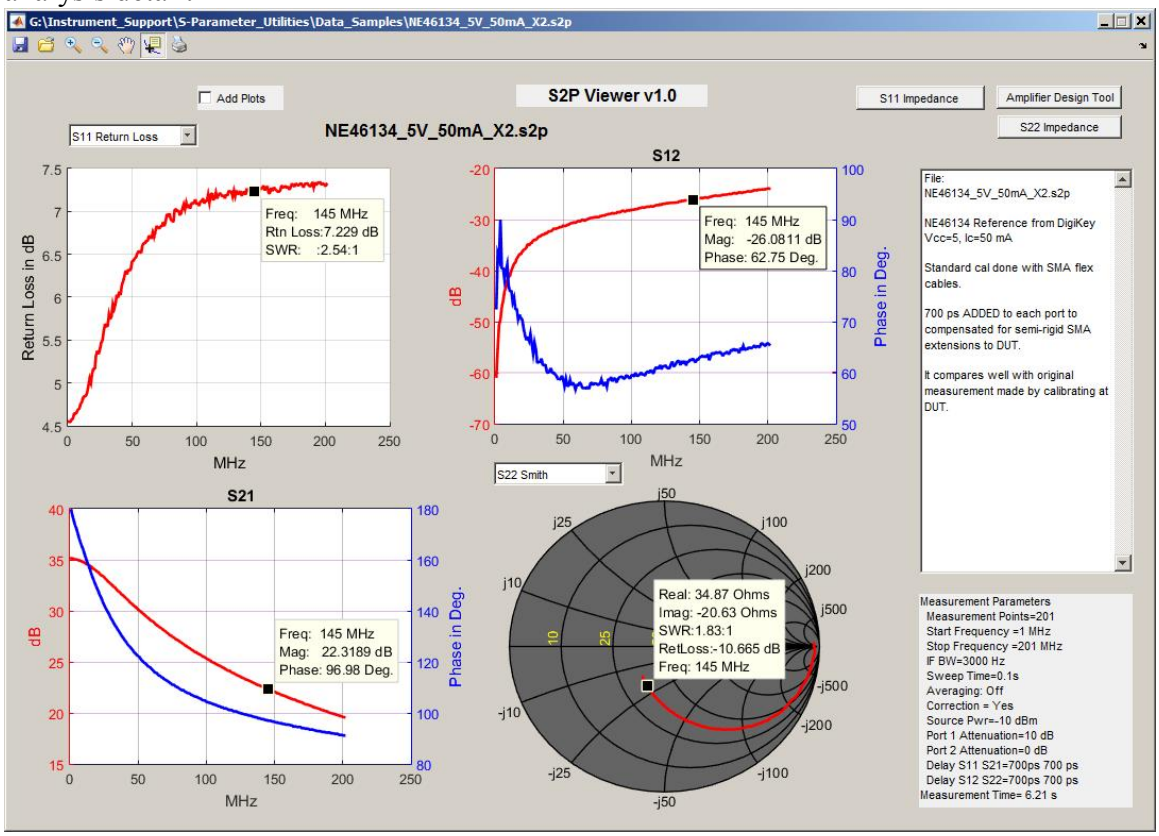


The Smith Chart was for more detail.

You can edit the user Notes and re-save the s1p file, but only if a single data file is being used. The File Save icon (far left) is disabled when multiple files are being viewed.

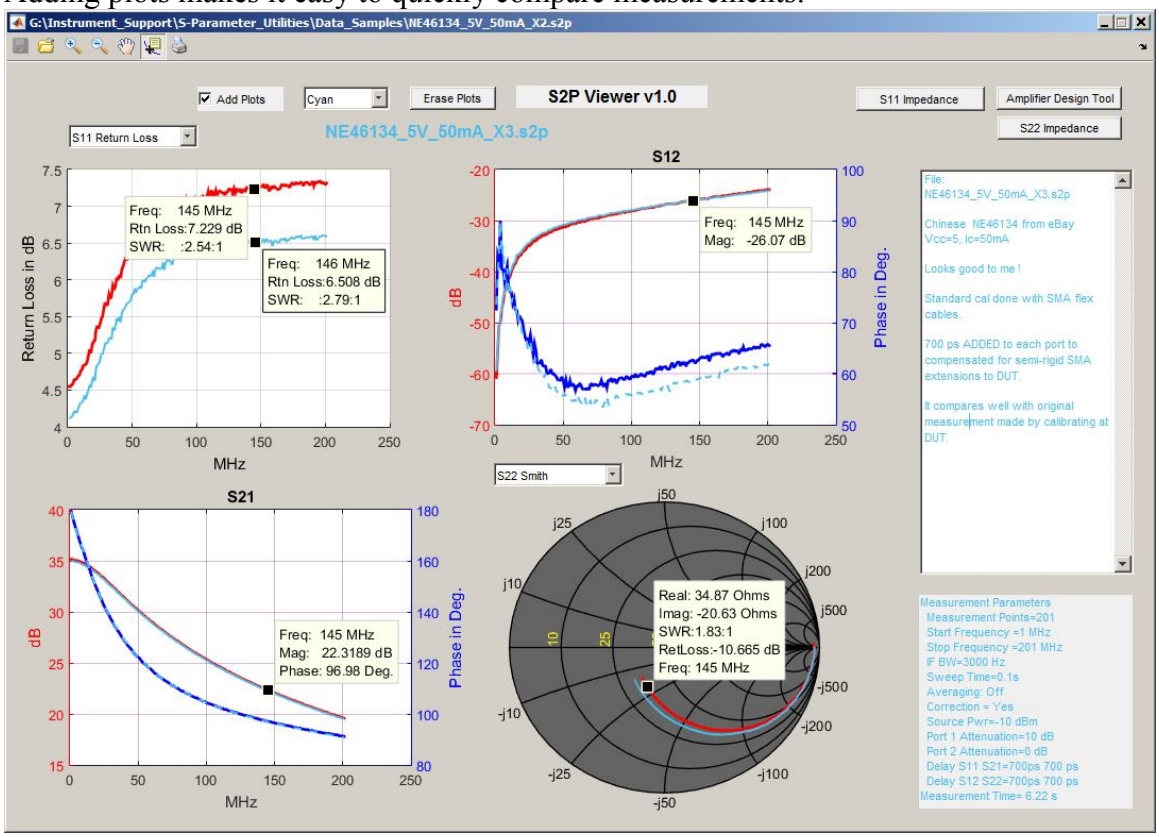
Two Port File Viewer (s2p_viewer.m)

This program is basically an extension of the s1p_viewer, but lacking the Impedance analysis detail.



It can display s11 and s22 in either a Smith Chart format or Return Loss.

Adding plots makes it easy to quickly compare measurements:

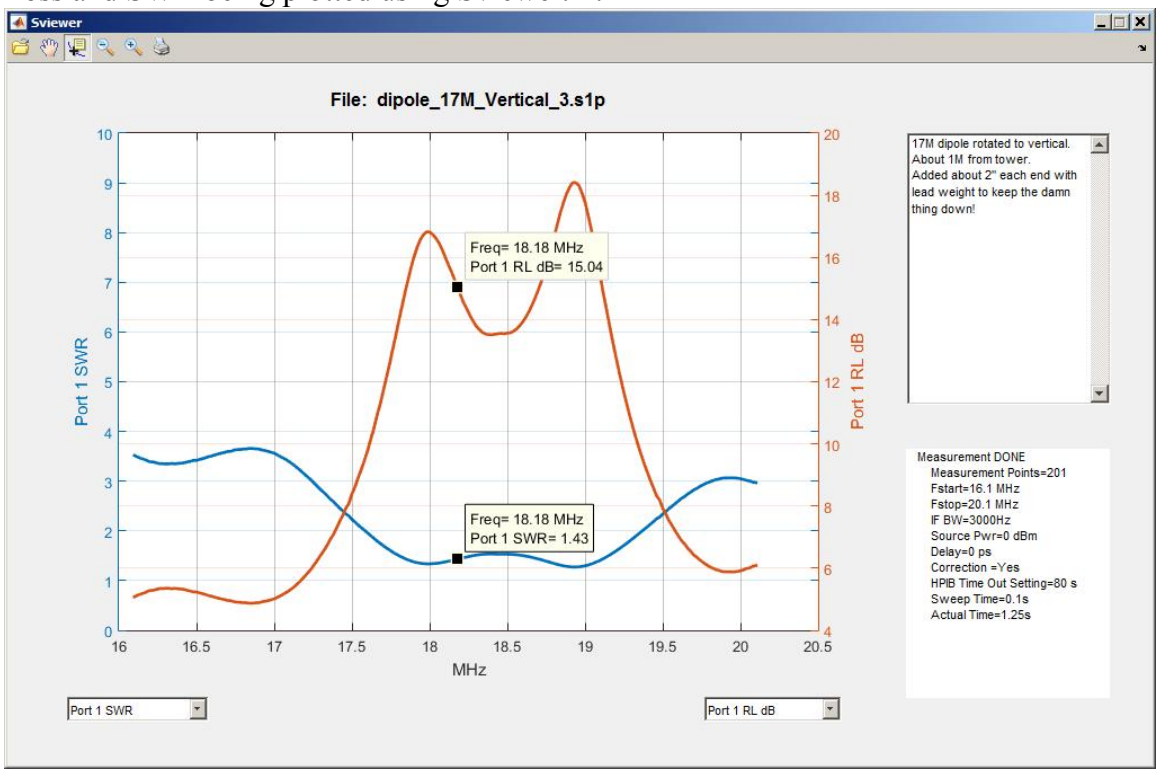


If the s1p_viewer is found on the MATLAB Path, the S11 Impedance and S22 Impedance push buttons appear. Clicking on these pipes the S11 or S22 data over to the One Port Viewer for more Impedance detail if desired.

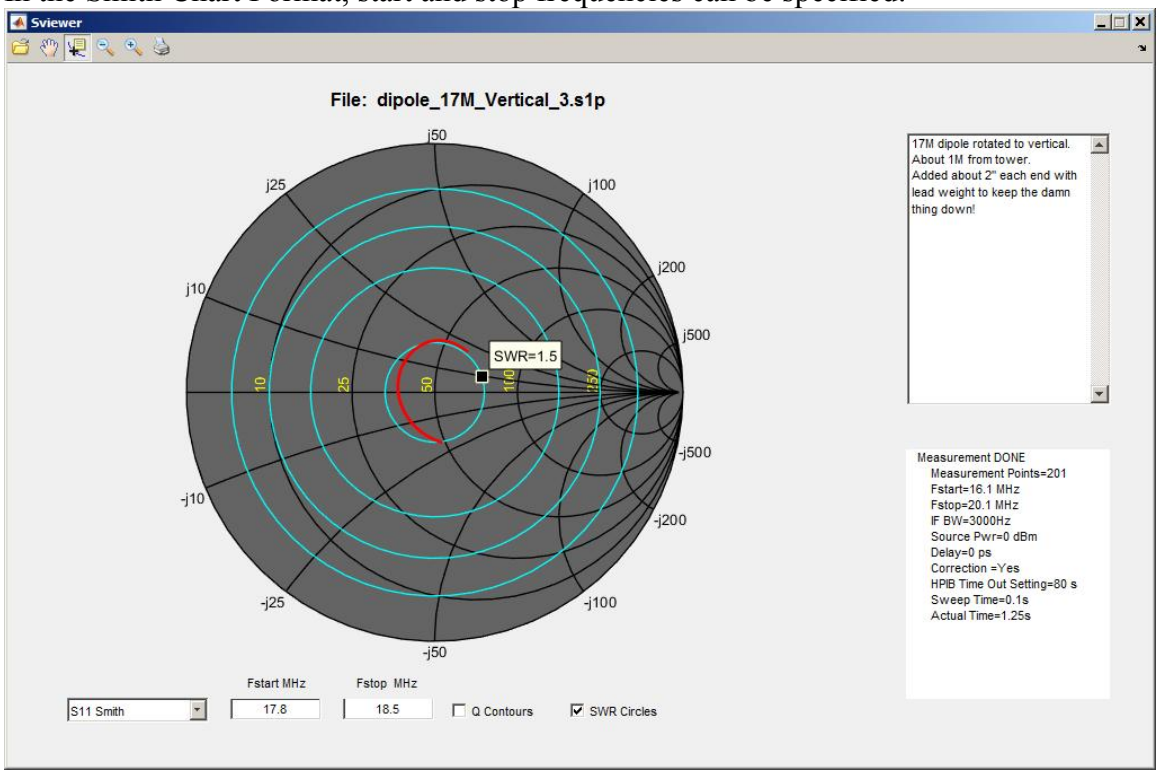
If the Amplifier Design Tool (AmplifierDesignTool.m) is found on the Matlab Path, the Amplifier Design Tool button will be present. Clicking on this transfers the two port S-Parameter data to this program. This tool is a separate download and install and is documented by way of its own PDF.

One or Two Port Single Axis Viewer

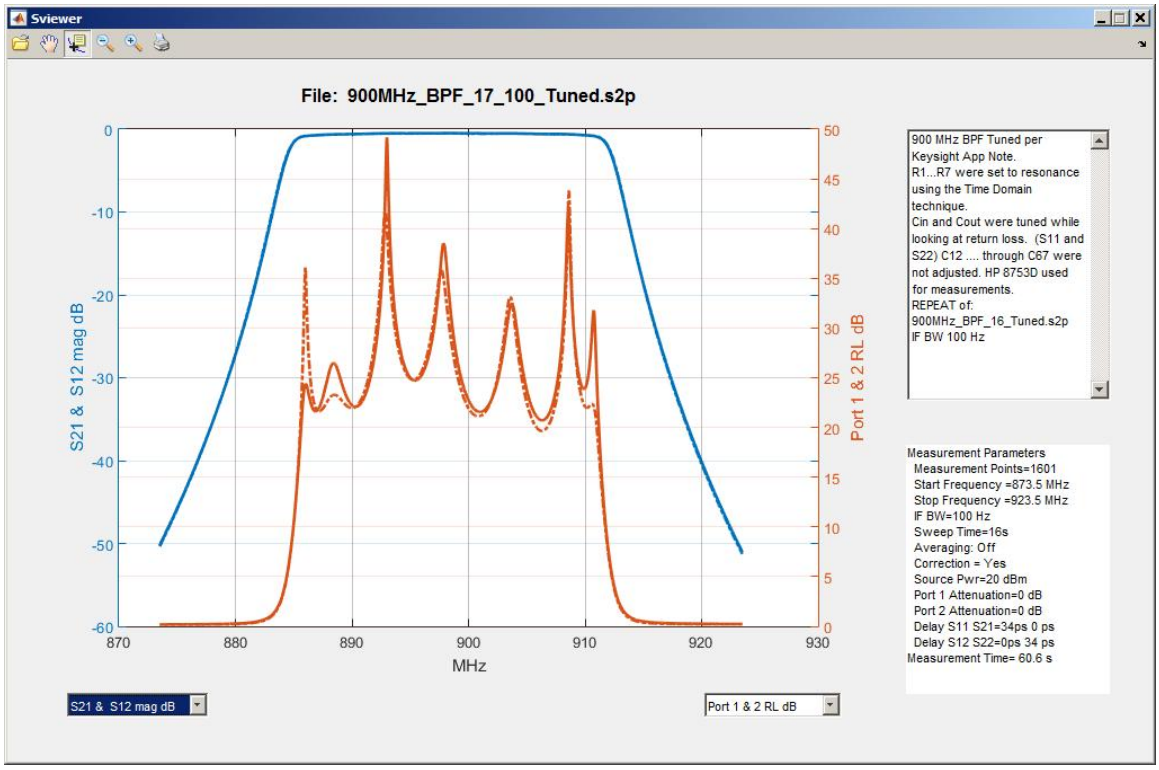
Yes, yet another twist on plotting S-Parameter data! Here is an s1p file with both Return Loss and SWR being plotted using Sviewer.m:



In the Smith Chart Format, start and stop frequencies can be specified:



With Two Port Measurements, yet more combinations are possible.
Here is a 900 MHz Band Pass Filter:

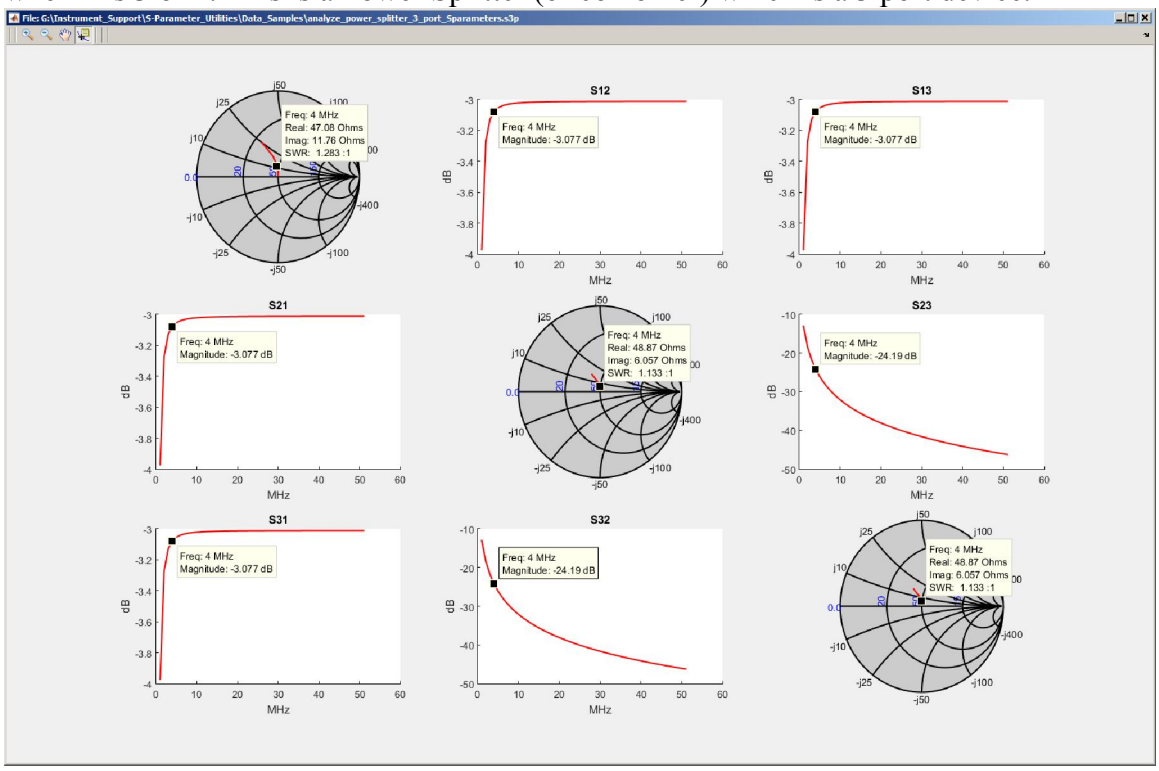


S21 and S12 are essentially identical as it should be for a passive device. The Return Loss for each port is very close, but not identical.

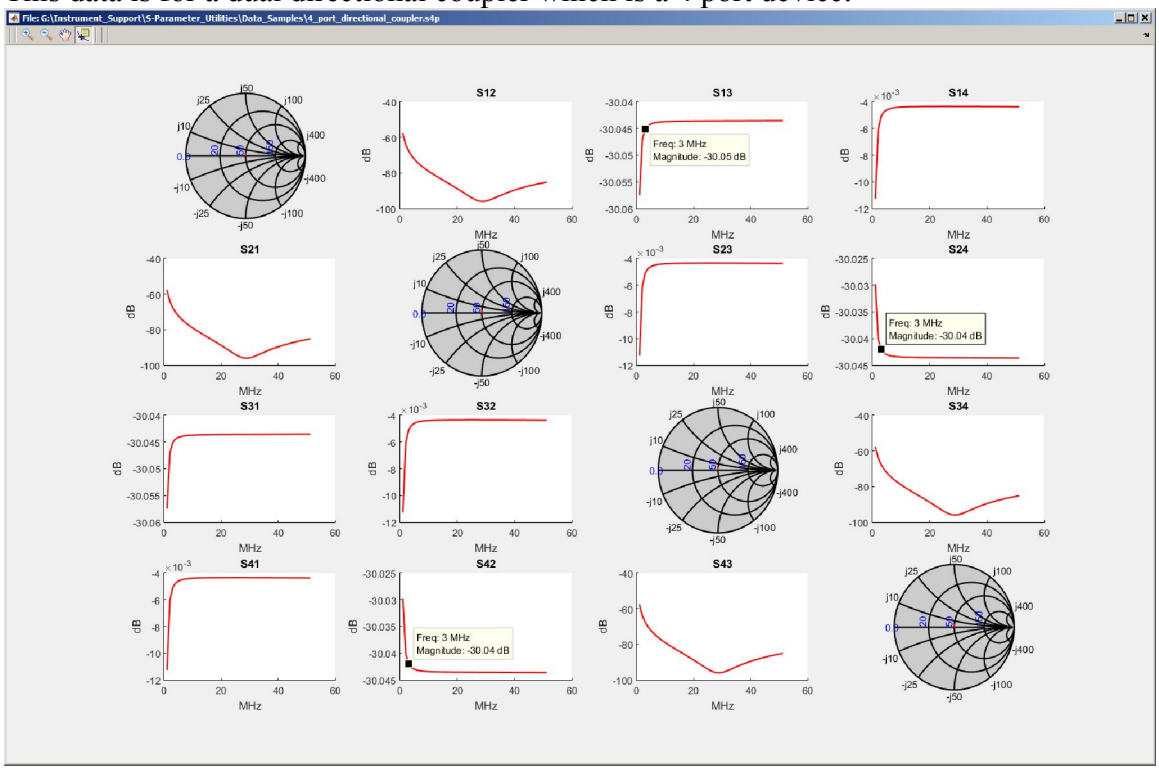
The variations are endless!

N Port Plotting

Finally, a simple program (SnP_view.m) for quick looks at SnP files and in particular when n is 3 or 4. This is a Power Splitter (or combiner) which is a 3 port device:



This data is for a dual directional coupler which is a 4 port device:



When one gets beyond 4 ports with 16 S Parameters to plot, it is probably time for a different tool!

Enhanced Smith Chart

The RF toolbox Smith Chart functions (smithchart() , smith()) fell short of my needs. One that fit my needs was created: smith_rab_v2.m .

It is called with two arguments:

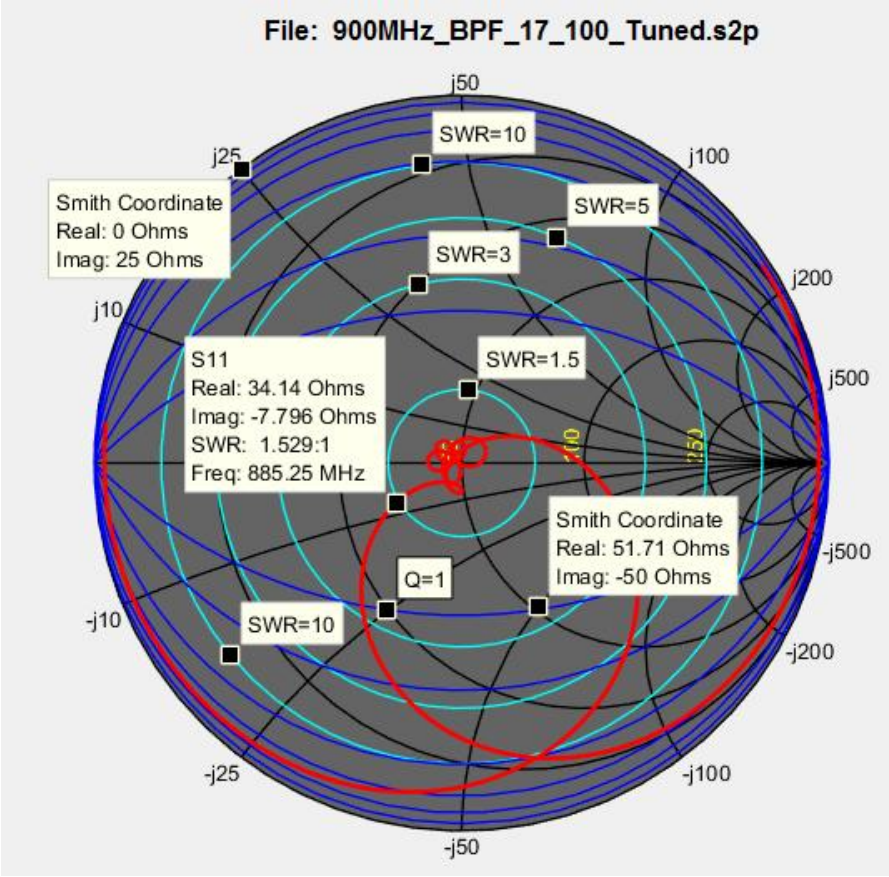
1) The handle of the axes that the Smith Chart coordinates will be placed in.
2) A structure with parameters that define the Smith Chart properties.

The function returns a structure of handles to the graphic objects in the chart to allow further control if needed. Here is the function header:

```
function h = smith_rab_v2(hax,SP)
    % hax=handle to the axis object that this chart will live in
    % SP.Rvalues a vector of Real(z) coordinate curves eg
    %                    [0 10 25 50 100 250];
    % SP.Xvalues a vector of Imag(z) coordinate curves eg
    %                    [10 25 50 100 200 500];
    % SP.Zo, typically 50 but sometimes 75 ohms.
    % SP.Nseg = number of line segments in the coordinate curves eg 61
    % SP.LW     linewidth.
    % SP.Colors is a structure with four fields eg:
    %    colors.grid= [0 0 0];
    %    colors.fill= [ 1 .9 .2]*0.8;
    %    colors.text= [0 0 1];
    %    colors.swr = [0 1 1];
    %    colors.Q   = [0 0 1];

    % optional SP.swr_circles, []=none
    %    and this defines 4 circles:   swr_circles = [10 5 3 1.5]
    %    SP.LW_swr  swr line width

    % optional Consatnt Q contours
    %   SP.Q_pts  []=none, number of line segments in a contour
    %   SP.Q_contours  eq Qs of [50 20 10 5 2 1];
    %   SP.LW_Q  countours line width

   % Handles are returned in a structure (h) to all objects.
    %      h.lx are all line objects
    %      h.txt is all text objects
    %      h.swr are line objects for swr circles
    %      h.Q  are the constant Q lines
    %      h.fill is a fill object for background color
    % This allows control of their visibility.
    % The swr circles have tags set to 'SWR=xx' xx is the swr.
    % The Q contours have tags set to 'Q=xx' xx is the Q
    % Regular coordinate lines have tags set to 'Smith_grid'.
```

There is quite a bit of flexibility in this function.
"Tags" have been preset to facilitate "datatip" readouts of the chart's coordinates, Q contours and SWR circles.

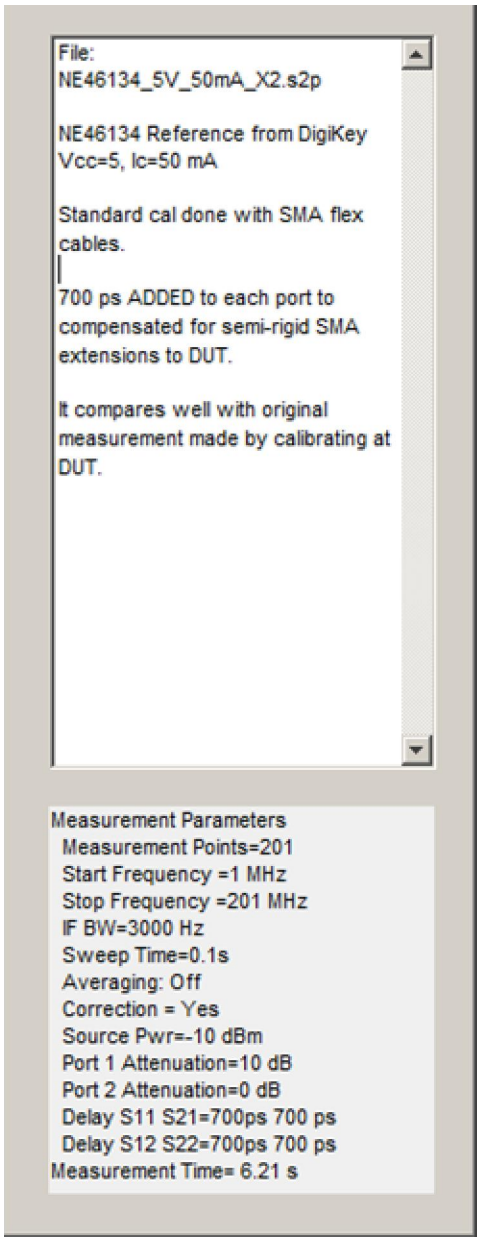
For instance:



And yes, the above is overdosed with "datatips" for the sake of demonstration.
For use examples, look in the previous viewers (s1p_viewer , s2p_viewer).

S Parameter file write and read

You may have noticed that the viewers typically include information above and beyond the S-Parameter data. For instance:



This upper text box is referred to as user Notes that can be used to document the conditions that were present when the S-Parameters were measured. VERY handy, after all, there is only so much information that can be packed into a file name!

This information is created by the user and entered into the text box when the measurement is made. It can be edited at a later time and the sNp file re-saved.

This text box contains a summary of how the VNA hardware was setup when the measurement was made. It is automatically generated by the program that controlled the VNA hardware making the measurement. It can be edited, but you would have to dig into the sNp file with a text editor. In general, this is not meant to be changed.

S-Parameter data files are TEXT and the exclamation point "!" as used a comment delimiter. Therefore one can easily add text to the end of the file after the S-Parameter data as follows:

```
# MHz S RI R 50
! S-Parameters data
! Freq    reS11    imS11    reS21    imS21    reS12    imS12    reS22    imS22
1.0000000000           0.5916748047           -0.0289001465    ..............
2.0000000000           0.5896606445           -0.0593261719    ..............
3.0000000000           0.5838623047           -0.0890808105    ..............
4.0000000000           0.5774841309           -0.1209106445    ........
.
.
.
198.0000000000         -0.4171447754          -0.1051940918    ............
199.0000000000         -0.4177246094          -0.1050109863    ............
200.0000000000         -0.4188842773          -0.1049499512    ............
201.0000000000         -0.4181213379          -0.1036376953    ............
!$Notes
!File:
!NE46134_5V_50mA_X2.s2p
!
!NE46134 Reference from DigiKey
!Vcc=5, Ic=50 mA
!
!Standard cal done with SMA flex cables.
!
!700 ps ADDED to each port to compensated for semi-rigid SMA extensions to DUT.
!
!It compares well with original measurement made by calibrating at DUT.
!$State
!Measurement Parameters
!  Measurement Points=201
!  Start Frequency =1 MHz
!  Stop Frequency =201 MHz
!  IF BW=3000 Hz
!  Sweep Time=0.1s
!  Averaging: Off
!  Correction = Yes
!  Source Pwr=-10 dBm
!  Port 1 Attenuation=10 dB
!  Port 2 Attenuation=0 dB
!  Delay S11 S21=700ps 700 ps
!  Delay S12 S22=700ps 700 ps
!Measurement Time= 6.21 s
```

Two new delimiters are used : **!$Notes** and **!$State** . These separate the Notes and State appended text fields. Notes and State can be in either order and one or the other or both can be missing.

The spar_write.m function accepts 4 input arguments:

```
function spar_write(path,name,rf_obj,Notes,State)
    % spar_write(path,name,rf_obj,Notes,State)
    % Write S-Parameters to a file.
    % Add Notes and Status text as comments to sNp file
```

The RF Toolbox "rf_object" contains the data, and Notes, State the optional text cell arrays. Simply set one or both to [] if there is no notes or state info.
Note that for 1 and 2 port S-Parameters, only S-Parameters are written (no Noise etc.)

The spar_read.m simply inverts the write:

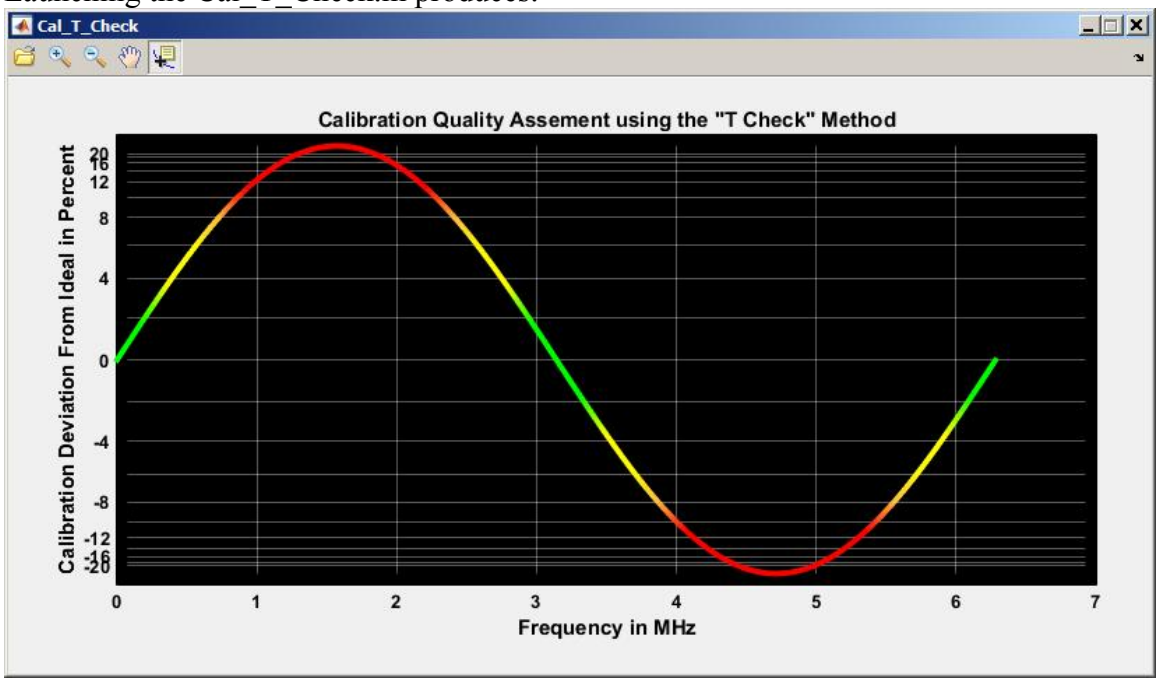
```
function [rf_obj,Notes,State]=spar_read(path,name)
    % [rf_obj,Notes,State]=spar_read(path,name)
    % Read S-Parameters, Notes, and State text from sNp file
```

It uses the RF Toolbox read function, therefore data above and beyond the S-Parameters will be captured in the rf_obj if it exists in the sNp files. The s1p_viewer.m or s2p_viewer.m serve as examples of usage.

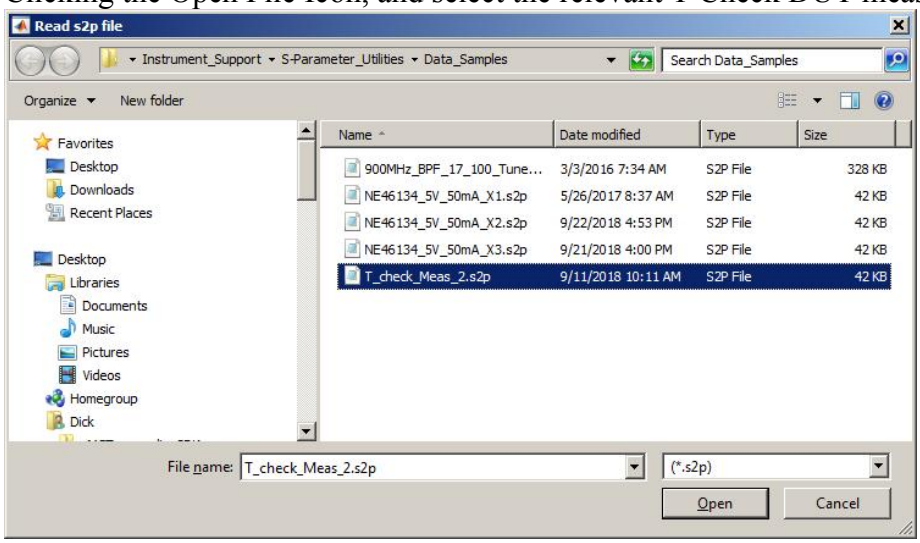
Calibration and the "T-Check"

Calibration for VNAs is always recommended for best accuracy. The "T Check" application (Cal_T_Check.m) is handy for checking the quality of the VNA calibration. It requires a simple DUT that can be made from an SMA T and a 50 ohm termination:

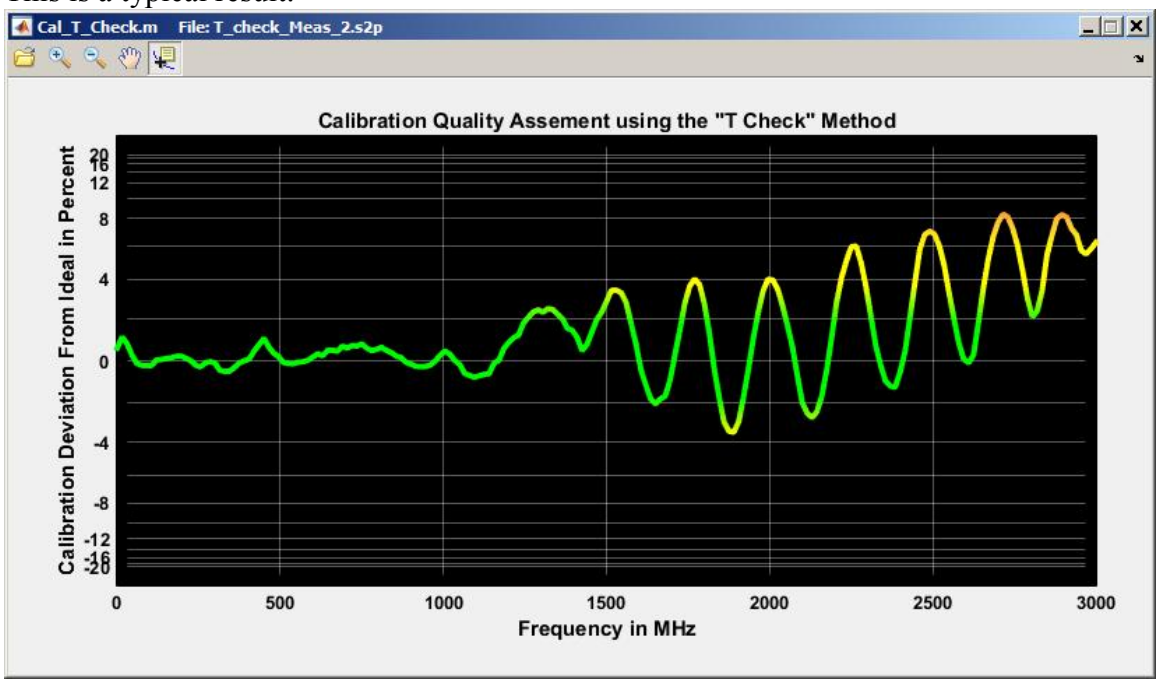
A two port measurement is made on the T Check DUT and saved to a file. Launching the Cal_T_Check.m produces:



Clicking the Open File Icon, and select the relevant T Check DUT measurement:



This is a typical result:



Green is good, yellow not bad, and red not too hot!

For more information on the T-Check method, Google: T Check Accuracy Test, and a link to the Rhode-Schwarz application note should appear.

Dick Benson
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