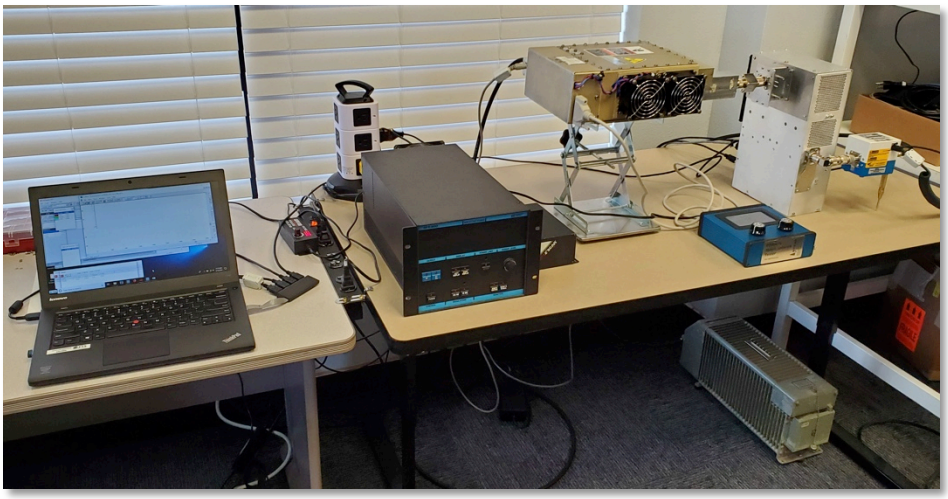
Frontier Technical Services

RF Test Bench:
Navigator Countermatch for RF Matching Network Testing
Technical Procedure



Procedure 506.1
September 2019

Preface

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Table of Contents

Network Analyzer Setup

Before performing the mapping procedure, ensure the network analyzer is properly calibrated and the correct COM port is selected. If the network analyzer has recently been calibrated and connected, **you can move directly to the next section**.

Verify TE3001 Network Analyzer Calibration

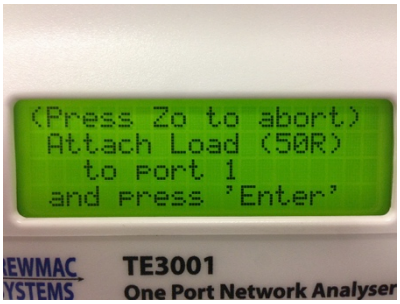
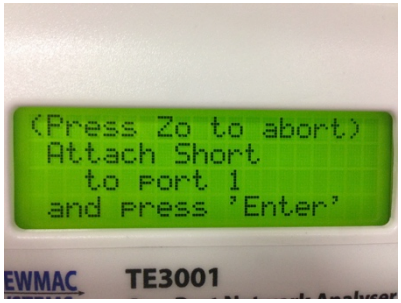
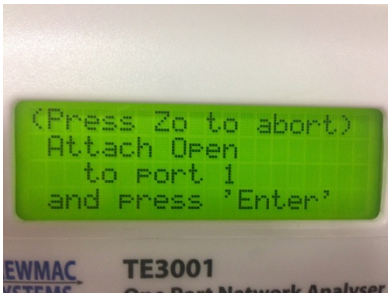
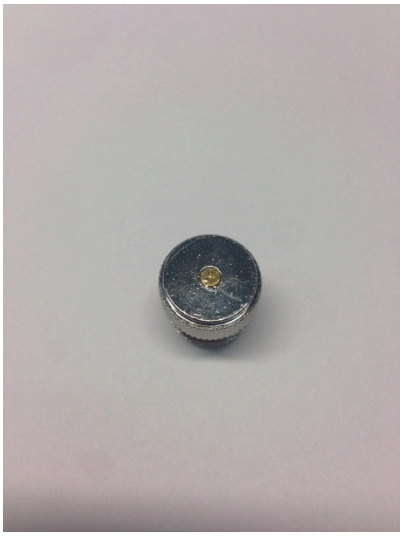
1. Turn on the network analyzer.
2. Connect the 50 ohm precision test cable to the network analyzer output port.
3. Install the 50R load at the end of the precision cable.
4. Press the 'Z' button to set the network analyzer to impedance mode.
5. Set to rectangular impedance by pressing the 'Format' button until screen shows "Rect Impedance".
6. Verify that the 50R load reads 50± j0.1 Ohm at 13.56 MHz.
   → If load does not read as above, perform following calibration procedure.

TE3001 Calibration Procedure

1. Press "System Z_o" to bring up the System Parameters menu.
2. Use the red arrows to scroll down to "Calibration…"
3. Press the Enter button to bring up the Calibration menu.
4. With the selection arrow pointing to "Cal Type" pressing Enter will alternate between Standard and Custom calibration. Select 'Custom'.
5. Arrow down and set the following parameters:
   - Cal Kit: N-female
   - Cal Start: 0.03 MHz
   - Cal Stop: 300 MHz
6. Arrow down to Enter when you have gotten to "Perform Cal" to start the process.
7. Arrow down and follow the on screen prompts, which will take you through the calibration process.
8. Install the 50R load at the end of the test cable when prompted, followed by the "short" load and finally the "open" load (See Fig. 1 and 2 on the next page)
9. When the calibration process is complete, scroll to "Done" and press Enter.

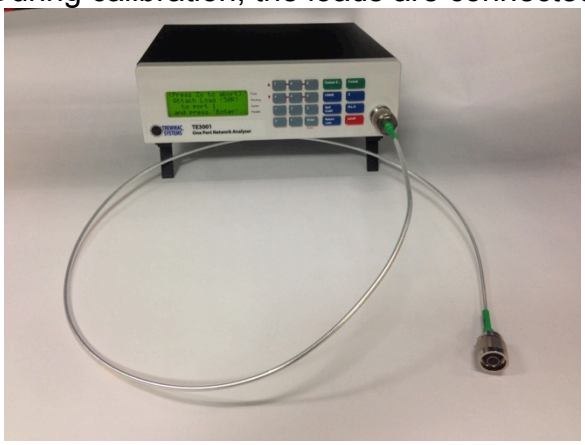
Custom S-O-L Calibration Loads

The N - type calibration kit comes standard with the TE3001

50R Load	"Short" Load	"Open" Load
		
		

TE3001 Calibration Setup

During calibration, the loads are connected to the precision test cable tip



Select Com Port

Ensure the COM port selected corresponds to the COM port on the computer that the network analyzer is plugged into. Selecting the incorrect port will result in a connection error.

1. Navigate to Windows > Device Manager > Ports (COM and LPT) > USB Serial Port (COM#). This number is the COM port you will be using.
2. In the Z'Analyze software, click the Edit Settings button.
3. Under Serial, select the corresponding COM port from step 1. COM ports higher than COM8 can be manually entered by typing in the configured COM port number, ex. COM17.
4. Select the button “Check connection…”
5. If successfully connected, a popup window will display “Connected to: TE3001 F/W V12.0”.
6. Repeat the Device Manager Ports procedure (step 1) to find the COM port for the USB to serial adapter to be used with the Navigator.

Mapping the Countermatch

Open Z'Analyze software and start a new file to map the countermatch impedance.

These steps are from the FTS manual Novellus Speed Matching Network Mapping, pages 8-15. For troubleshooting or further analysis of data collected in this step, refer to technical procedure **504 "Novellus Speed Matching Network Mapping"**, which can be downloaded at:

http://www.ftsplasma.com/manuals

Map Calibration Loads

Test the short, 50R, and open loads to verify they display properly on the Smith chart:

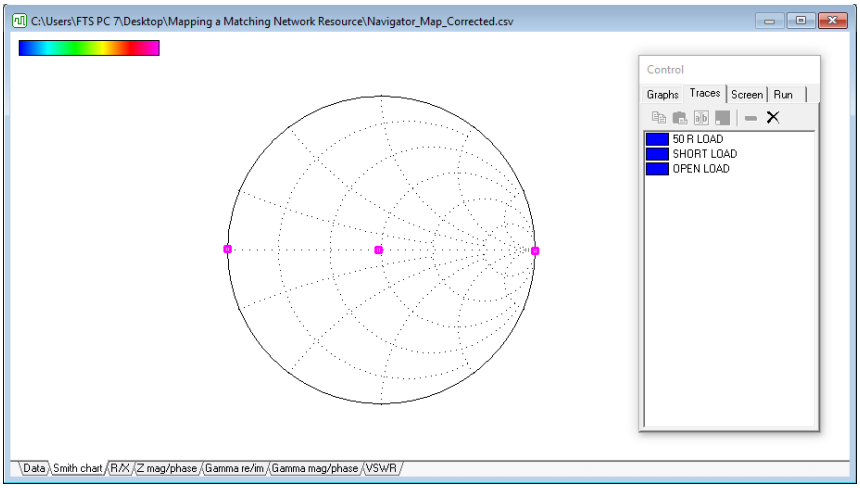
✓ **Be sure to name the new Z'Analyze file immediately to ensure auto save will work properly. Skipping the step may result in loss of important data if the PC crashes or automatically updates.**

1. Connect Network Analyzer to a USB port on your PC and open Z'Analyze software.

2. In Z'Analyze Software, under the "Run" tab of the Control Panel, set values to:
   - 1 freq. selected
   - 1 Samples
   - 32 Average
   - 13.56 f (MHz)

3. Install the open load on the network analyzer precision test cable tip. In Z'Analyze software, press "Run" to obtain a data point on the Smith chart.

4. Repeat these steps for the 50R and short load. This should result in 3 data points across the center Smith Chart:



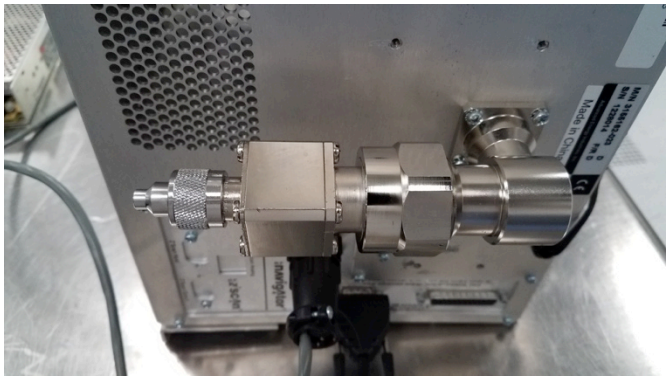
Mapped Calibration Loads (Short, 50R, Open)

5. If the three horizontal points do not display as above, ensure the network analyzer is properly set up and calibrated according to the previous sections.

6. When this process is completed, connect the network analyzer to the matching network output adaptor.

Connect the Matching Network

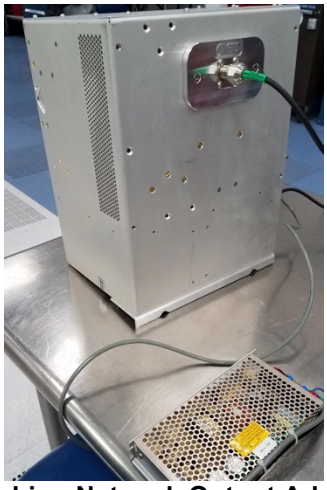
1. Connect a 50 ohm load to the matching network input connector and ensure interlock is made.



Matching Network Input Connector with 50 ohm Load

2. Install the matching network output adaptor on the output connector of the matching network.

3. Connect network analyzer test cable to the matching network output adaptor.



Matching Network Output Adaptor

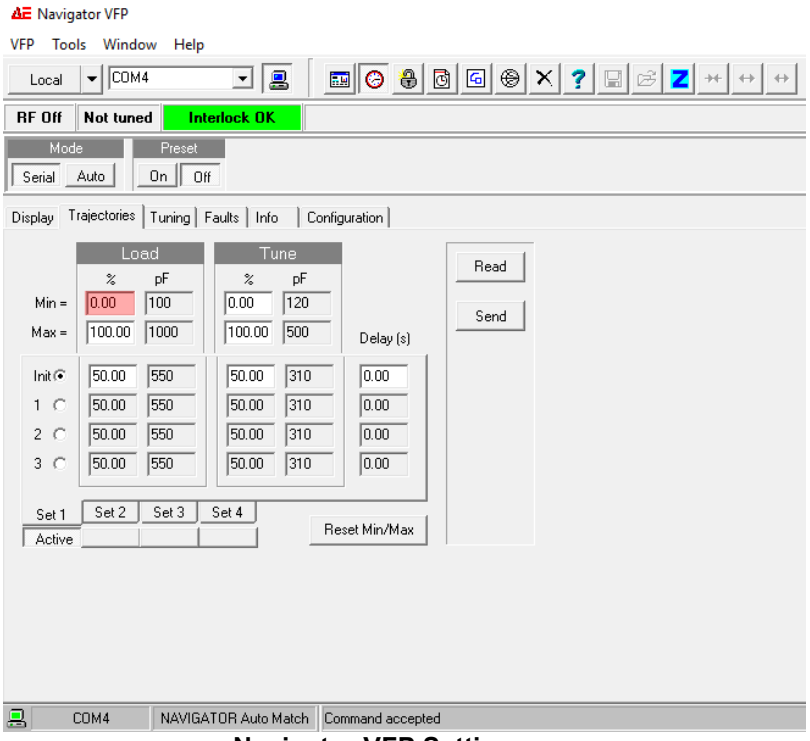
4. Using the USB to serial adapter with cable, connect the matching network to the Navigator host port to a USB port on a PC with *Frontier Technical Services Z'Analyze* Software and *Advanced Energy Navigator VFP* Software installed.

5. Repeat the Device Manager Ports procedure from the previous section to find the COM port for the USB to serial adapter to be used with the Navigator.

Matching Network Preset Positions

1. Open both FTS Z'Analyze Software as well as Advanced Energy Navigator VFP Software on your PC.

2. In the Navigator VFP software, connect to the matching network by selecting the corresponding COM port and clicking the computer icon directly right of it.

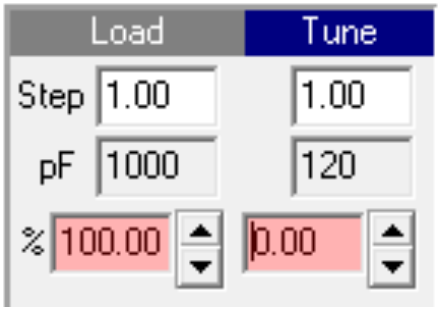


Navigator VFP Settings

3. Select 'Serial' under the Mode tab. (Note: mode should be set back to 'Auto' when procedure is completed. Otherwise this may interfere with future readings.)

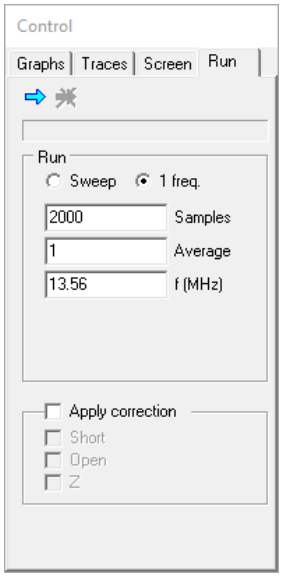
Mapping Procedure

1. In Navigator VFP Software, set Load % to **100.00** and Tune % to **0.00** in the right-hand column.



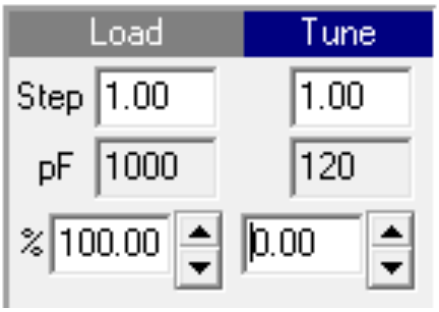
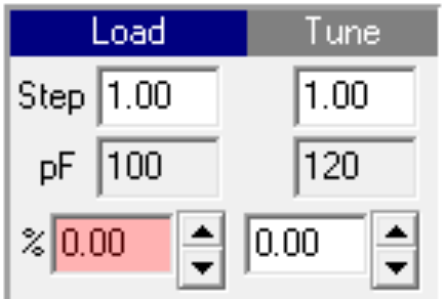
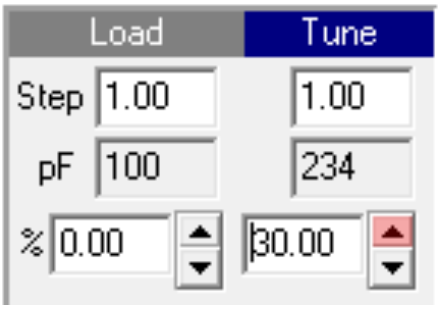
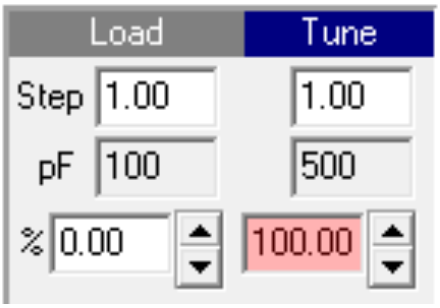
Highlighted Load and Tune in Navigator VFP

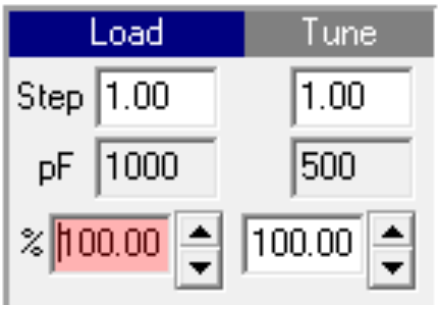
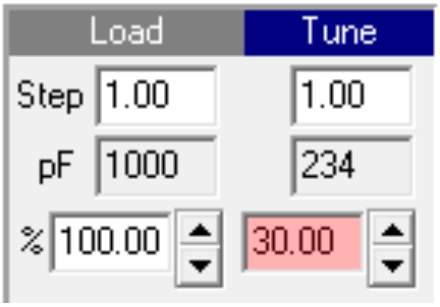
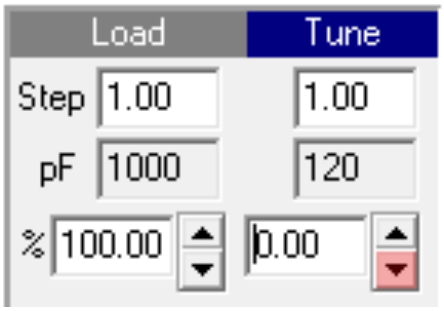
2. In Z'Analyze Software, under the 'Run' tab of the Control Window, set values to:
   - 1 freq. selected
   - 2000 Samples
   - 1 Average
   - 13.56 f (MHz)



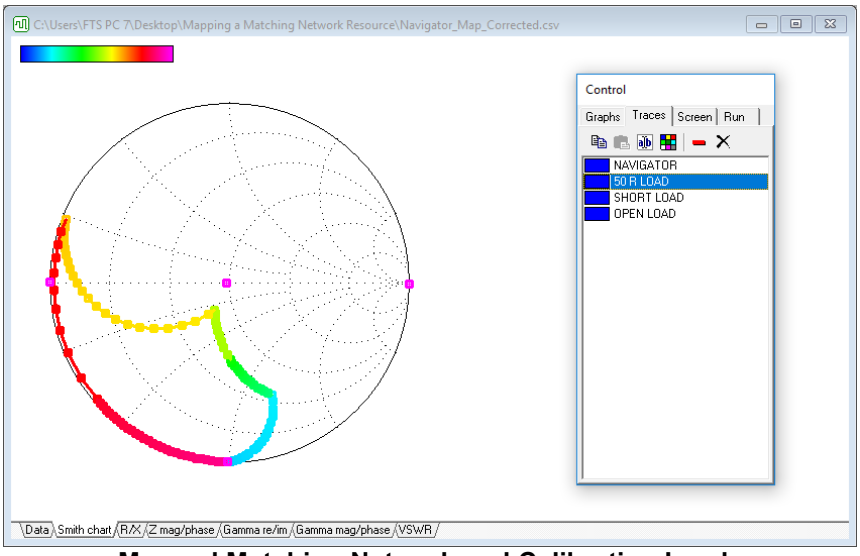
Z'Analyze Test Settings

3. Click ‘Run’ in Z’Analyze. Leave the program running in the background and switch over to Navigator VFP Software to begin navigator mapping:

Start: Load % should be set to **100** and Tune should be set to **0** before Z’Analyze scan is initiated.	
Step 1: In the Load % Box (highlighted red), type **0** and press enter.	
Step 2: Using the up arrow next to the Tune % box (highlighted red), click to slowly bring the value up to **30**.	
Step 3: In the Tune % box (highlighted red), type **100** and press enter.	

Step 4: In the Load % Box (highlighted red), type **100** and press enter.	
Step 5: In the Tune % box (highlighted red), type **30** and press enter.	
Step 6: Using the down arrow next to the Tune % box (highlighted red), click to slowly bring the value back down to **0**.	

4. After this process is completed, return to Z'Analyze software and click "Stop" to end run. Select the "Smith chart" tab in the main window. The resulting curve from a functioning matching network should resemble the following:



Mapped Matching Network and Calibration Loads

✓ **When the DUT is a Navigator matching network, it must be returned to production in the correct mode. After mapping is completed, set the Navigator back to 'Auto' mode in Navigator VFP software or the matching network will not work in production.**

Mapping the Reference Standard (Golden) Matching Network

These steps are from the FTS manual *Matching Network Diagnostics Using a Nykar Phase IV Match Network Tester*, pages 9-14. For troubleshooting or further analysis of data collected in this step, refer to technical procedure **405 "Nykar Network Tester Manual"**, which can be downloaded at:

http://www.ftsplasma.com/manuals

Required Tools

- Nykar Phase IV Match Network Tester
- Matching Network to be tested
- TE3001 Network Analyzer
- Windows PC with Z'Analyze Software Installed

Hardware Setup

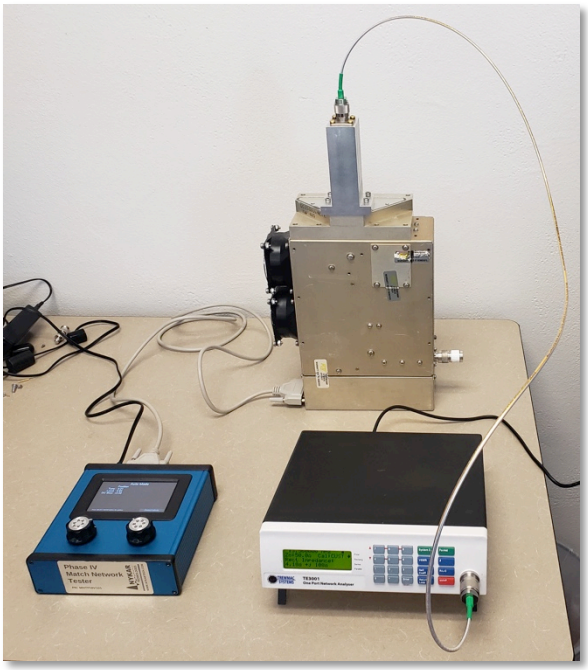
1. Plug the TE3001 Network Analyzer and Nykar Match Network Tester into a power source.

2. Terminate the DUT (Device Under Test) matching network input connector with a 50 ohm load.

3. Connect network analyzer precision test cable to the matching network output adaptor.

4. Using a DB25 connector cable, connect the Nykar Match Network Tester to the DUT matching network.

5. Using a USB cable, connect the network analyzer to a PC with *Frontier Technical Services Z'Analyze* Software installed.



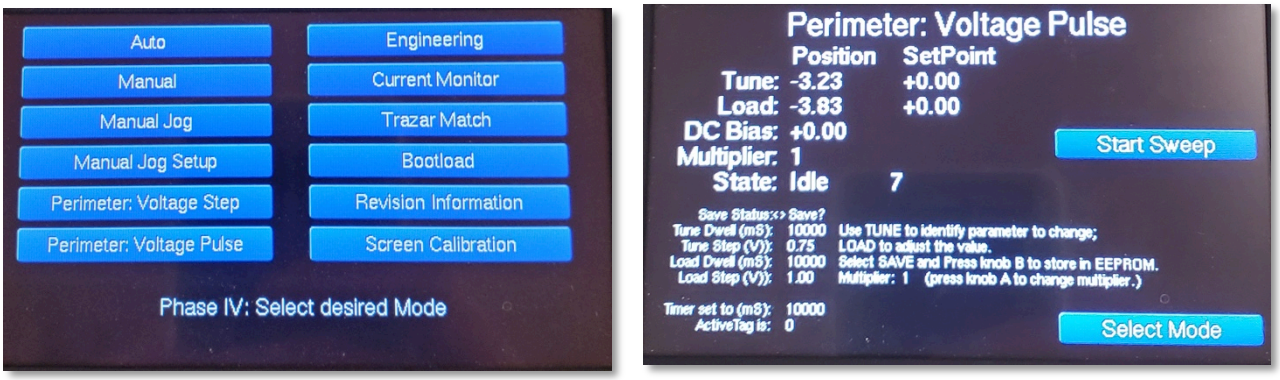
Testing a Match

✓ **Before testing, ensure calibration loads have been mapped (see previous section).**

1. Turn on the Phase IV Match Network Tester by flipping the switch located on the back of the device to the "**On**" position. After an automatic calibration, the match network tester will start in auto mode.

2. Using the rubber-tipped stylus included in the kit, press "**Select Mode**" in the lower right-hand corner of the touchscreen to open the menu.

3. Select "**Perimeter: Voltage Pulse**" in the left-hand column using the touch screen and stylus.



Nykar Match Network Tester Interface

4. In the bottom of the Perimeter Voltage Pulse screen, ensure the testing parameters are set to the optimal values for your match. The B dial on the Nykar Match Network Tester changes selection, marked with the " **< >** " symbol. Rotating the A dial changes value of the selected parameter. (See Voltage Pulse Parameters on page 12)

Starting Voltage Pulse Parameters:

Tune Dwell (mS):	**10000**
Tune Step (V):	**0.75**
Load Dwell (mS):	**10000**
Load Step (V):	**1.00**
Timer set to (mS):	**10000**
ActiveTag is:	**0**

5. Scroll up to "**Save Status**" with the B dial and press down on the dial to save changes. Ensure the text "**SAVED**" is displayed.

6. Press the "**Start Sweep**" button on the touch screen of the match network tester and let the device run though a full sweep. This will reset the match.

7. Open the Z'Analyze software with mapped calibration loads.

8. Set view to "**Smith Chart**" using the tab at the bottom of the main display window.

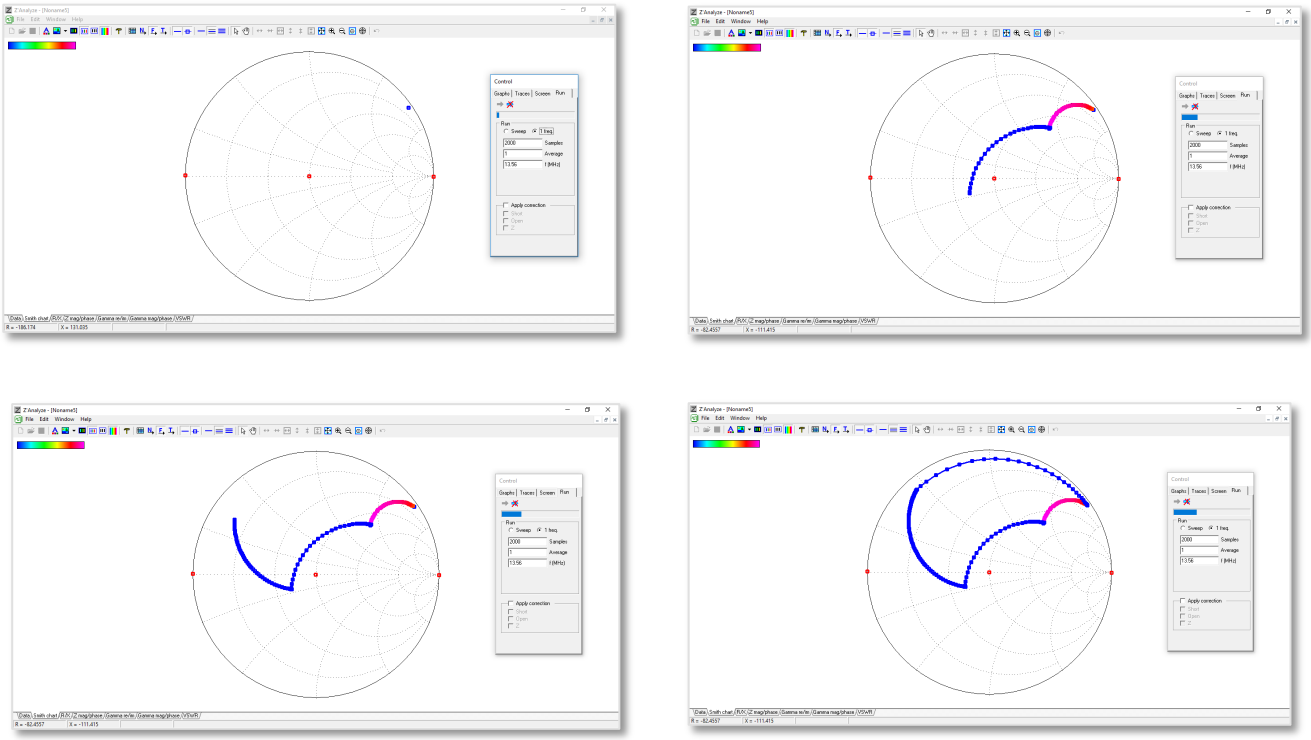
9. In the control panel under the run tab, change the settings to:
   - **1 freq. selected**
   - **2000 samples**
   - **1 Average**
   - **13.56 f (MHz)**

10. Press the blue "**Run**" arrow in the Z'Analyze Software control panel.

11. Then, press the "**Start Sweep**" button on the touch screen of the Nykar Match Network Tester.

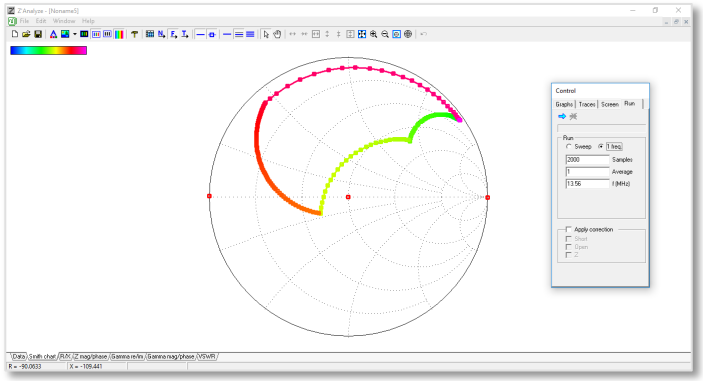
12. After a 10 second delay, the sweep will start.

The data points on the smith chart will move along a set of curves as the sweep runs:



13. Press the "**Stop**" button in Z'Analyze software once the data points on the smith chart return to the start position. This will also end the sweep on the match network tester.

The test should result in a completed impedance curve similar to the following. If the curve is incomplete, compressed, or choppy, see the next section to change the voltage pulse parameters in order to obtain a complete test.



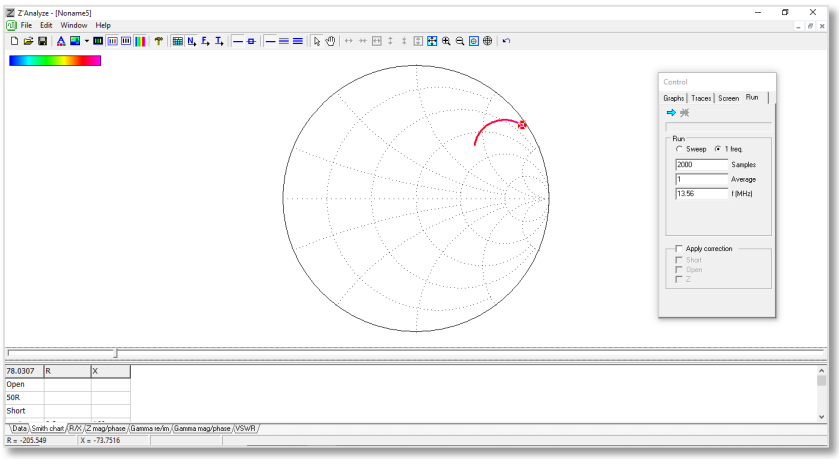
Completed Impedance Map

Voltage Pulse Parameters

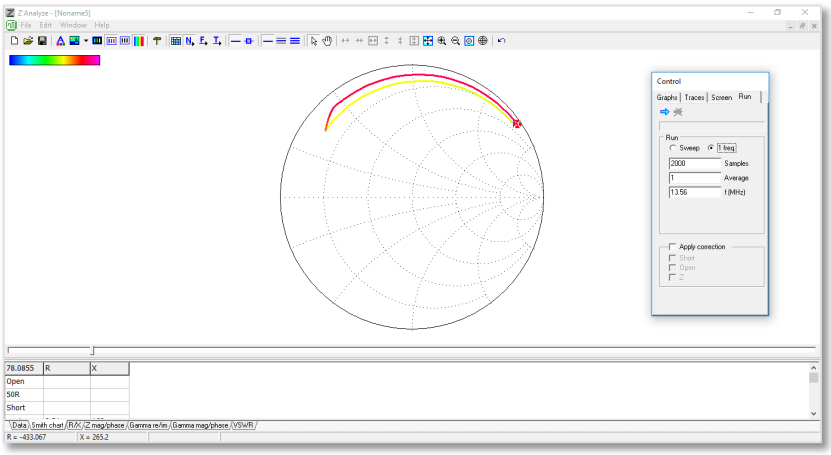
- **If a completed impedance map was obtained in the previous step, you can move to the next section.**

The parameters for Voltage Pulse will depend on the matching network and intended application. If the recommended values do not result in a completed impedance map similar to the example on the previous page, the Tune or Step values may need to be changed.

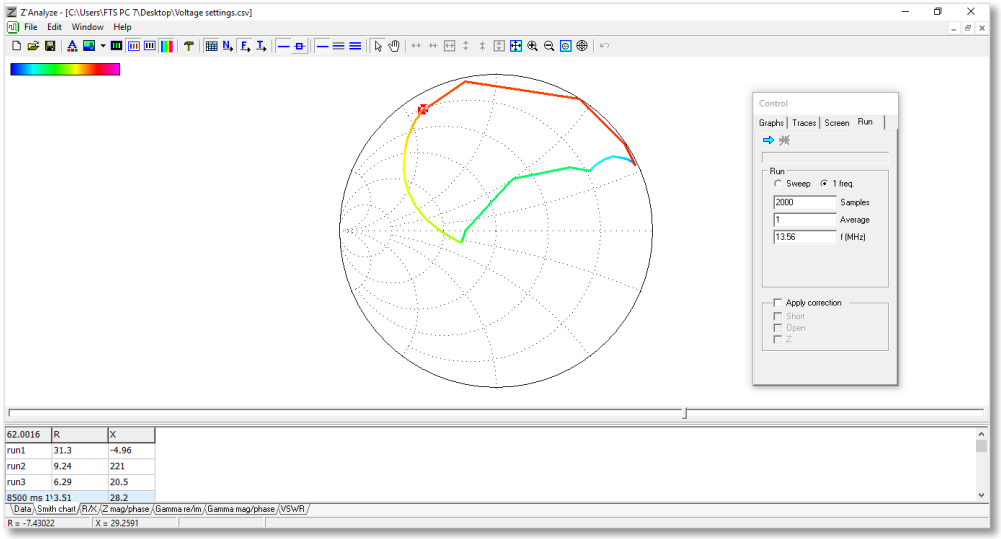
If the **Tune Step Voltage value is too low**, the sweep will not be able to move through the full curve. Perform the sweep again with a higher tune value:



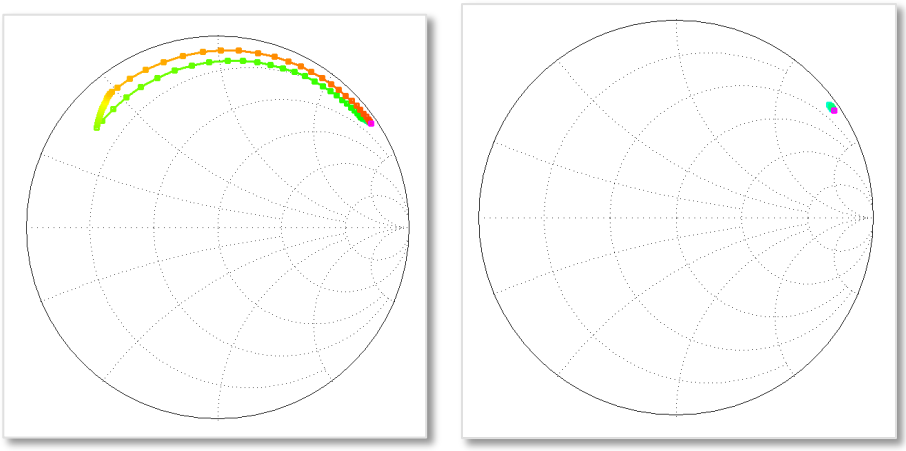
If the **Load Step Voltage value is too low**, the sweep will be compressed and missing curves. Perform the sweep again with a higher step value. (This map may also be caused by a Tune Dwell Time that is too low—see next page.)



If the RF elements are moving too quickly, the Tune values may need to be decreased. If the **Tune value is too high**, the curve will be choppy or jagged.



If the **Tune Dwell Time** is too low, the sweep will end before it has fully moved its component. If a test results in an incomplete map (pictured below), increasing the Tune Dwell value on the match network tester may solve this problem.



Match Evaluation

The matching network will be able to deliver power into the inverse of its impedance. The inverse is simply the same resistance (R) with the opposite sign reactance (X).

This step will allow you to take the impedance range of the DUT match and calculate the inverse.

Create an Inverted Trace of the DUT Match

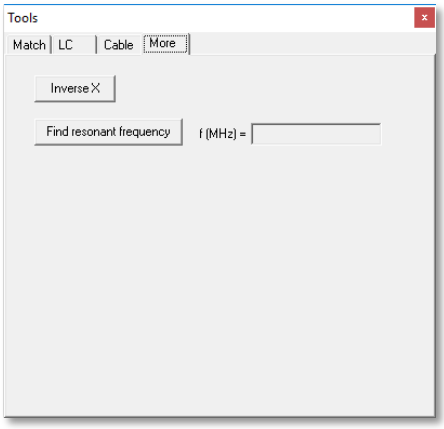
1. In the **Control** window of Z'Analyze software, click the **Traces** tab and select the trace obtained from the DUT match by clicking it.

2. Once highlighted, press **Copy selected traces** followed by **Paste traces** to create a duplicate.

Copy Trace Icon

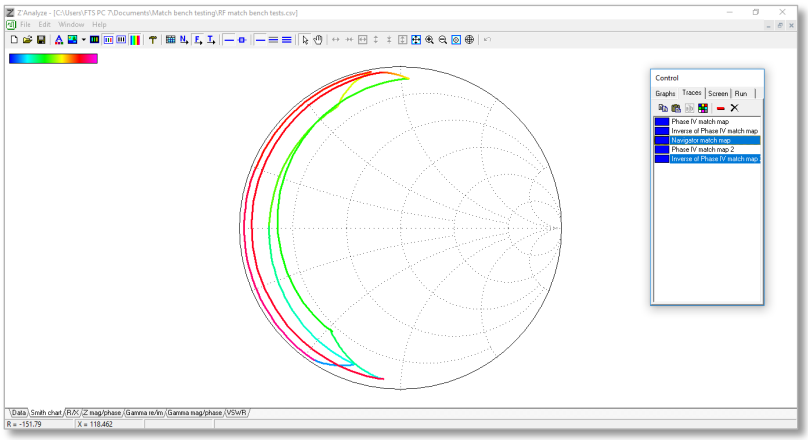
Paste Trace Icon

3. Click the tools icon in the top menu, and select the **More** tab. Click the **InverseX** button to invert the selected trace.



Z'Analyze - More tab

4. Using Ctrl + Click on your PC, select the Navigator match map and the inverse of the DUT match.



Overlap between the Navigator Match Map and the Phase IV Map Inverse

Ideally, there should be maximum overlap between the matches. This overlap can be evaluated to determine what loads are possible to test at.

Some of the loads you may want to test will not be possible on a given countermatch without adjusting the match components. However, while critical plasma load testing is important, every single load imaginable may not be necessary to determine fitness of a match.

DUT Matching Network Positions

The DUT match positions must be determined using a well performing match on a normal tool in order to ensure it reaches the required match positions while running designated processes.

A data collection tool or screen monitoring can give the voltages for the match positions during the critical processes of your match. These match positions are an indication of a properly functioning match and represent the process impedance. By taking a known good match off a running tool and getting these process set points, we can set the counter match impedances so another DUT match can be tested against the impedances programed into the countermatch which replicate the process impedances that were observed on the tool.

Below are some example test values from a counter match, which will be used to determine the tune and load positions of the DUT match.

EXAMPLE of Process Voltage Values:

Given Voltage Values	
Tune V	**Load V**
1.01	2.05
1.04	0.41
-0.20	1.88
0.63	-0.64
1.02	1.14

Countermatch Setup

Automatically Determining Tune and Load Positions (Recommended)

Tune and load positions can be determined using the Manual Jog Mode on the Nykar Network Tester in conjunction with Navigator VFP software.

SETUP:

NOTE: In this step we will reverse the power flow using the countermatch as the input and the DUT as the output.

1. Turn on the Navigator matching network.
2. For this step, remove the Bird power meter from the Navigator input connector.
3. Disconnect the “RF in” from the match input port and connect it to the Navigator input connector.
4. Connect the 50 ohm dummy load cable to the DUT match input port.

TESTING PROCEDURE:

1. Connect the Navigator to VFP software using the correct COM port.
2. Set the Mode in Navigator VFP software to **Auto**.

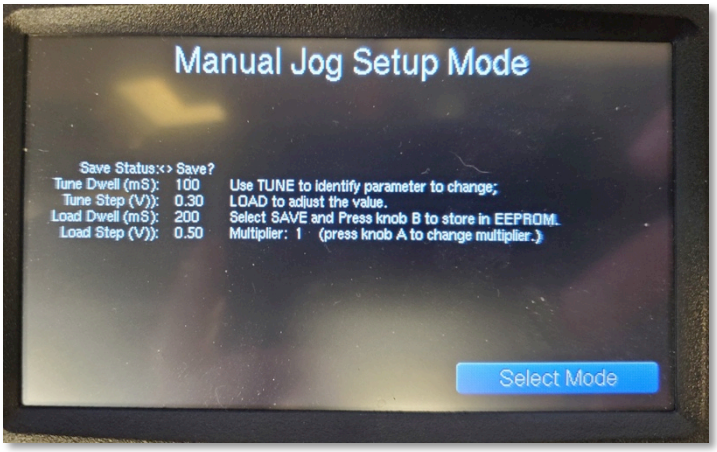
Auto Mode Selected in Navigator VFP

3. On the Nykar Network Tester, press **Select Mode** to bring up test options.

4. Select **Manual Jog Setup** and enter values optimal for your match. The B dial will change the current selection, marked with the " **< >** " symbol. Rotating the A dial changes value of the selected parameter.

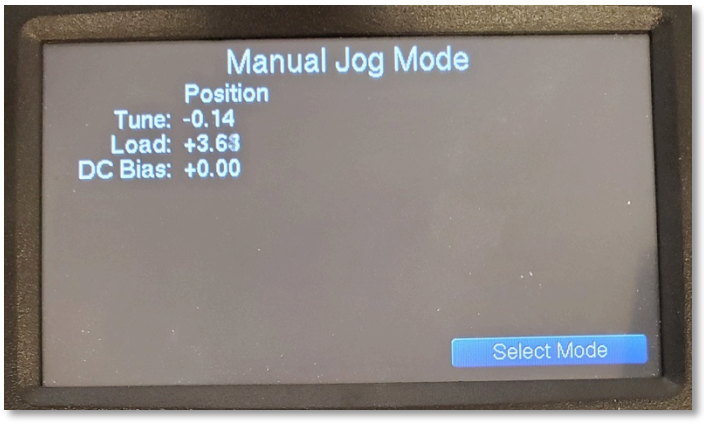
Recommended Manual Jog Setup Values	
Tune Dwell (mS)	100
Tune Step (V)	0.3
Load Dwell (mS)	200
Load Step (V)	0.5

5. Scroll up to "**Save Status**" with the B dial and press down on the dial to save changes. Ensure the text "**SAVED**" is displayed.



Successfully Saved Manual Jog Parameters

6. Press **Select Mode** to return to the menu and press **Manual Jog**.



Manual Jog Mode

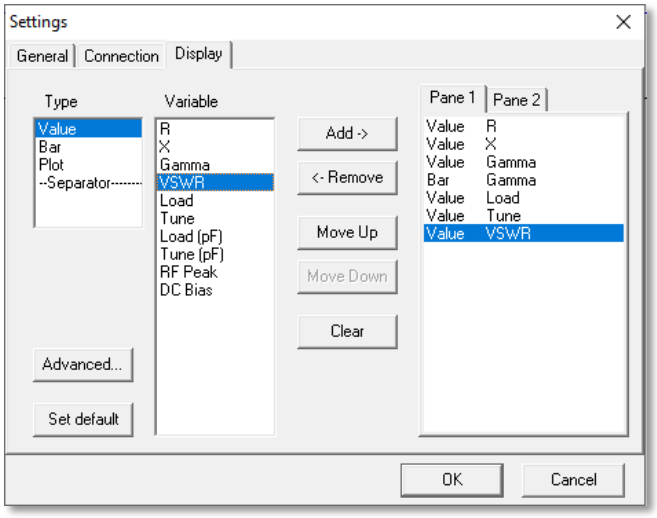
7. Turn RF on.

8. On the Nykar Tester, in Manual Jog Mode, set the Tune and Load values to the first voltage set in your Given Voltage Values Table. Use the A dial to adjust the Load value and the B dial to adjust the Tune value.

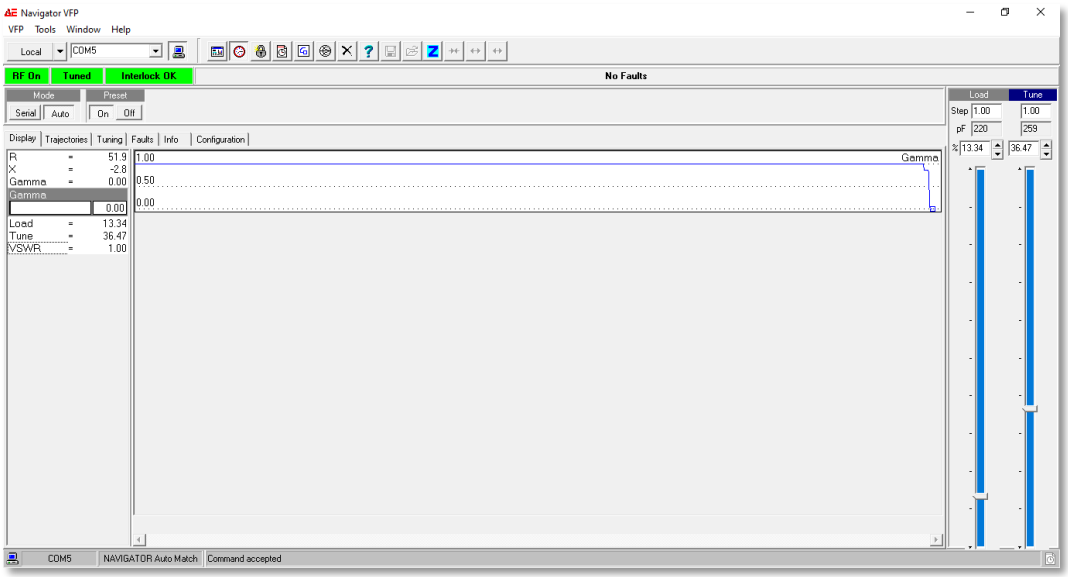
9. This will drive the Navigator and change the load and tune positions in the VFP software in the right hand column. Record these values in the table below.

10. To display VSWR in the left-hand column, click the **Settings** icon in the top row to open the Settings window.

11. Under the **Display** tab, set Type to **Value**. Then, Select VSWR under Variable and click the **Add ->** button. VSWR will now be displayed in your data table.



Enable VSWR Data Display



Navigator Software driven to Load 13.34% and Tune 36.47%, with a VSWR of 1.00

Test Value Data Table

Given Voltage Values		Test Values		
Tune V	Load V	Countermatch Load Position	Countermatch Tune Position	VSWR

Completed Test Value Data Table (with Example Data)

Given Voltage Values		Test Values		
Tune V	Load V	Countermatch Load Position	Countermatch Tune Position	VSWR
1.01	2.05	0.94	64.49	1.15
1.04	0.41	11.03	54.63	1.00
0.47	0.62	4.96	39.17	1.09
1.23	0.04	15.05	59.42	1.06
-0.59	0.60	14.39	36.93	1.15

Manually Determining Tune and Load Positions

Tune and load positions can also be manually determined using a network analyzer in conjunction with Z'Analyze and Navigator VFP software.

WARNING! Ensure RF is OFF and the coax cable is disconnected when the Network Analyzer is plugged into the system.

1. Plug in network analyzer test cable tip on the input side of the known good match. Plug the Network Analyzer USB connection into a PC with Navigator VFP and Z'Analyze software installed.

2. Set the Mode in Navigator VFP software to **Serial**.

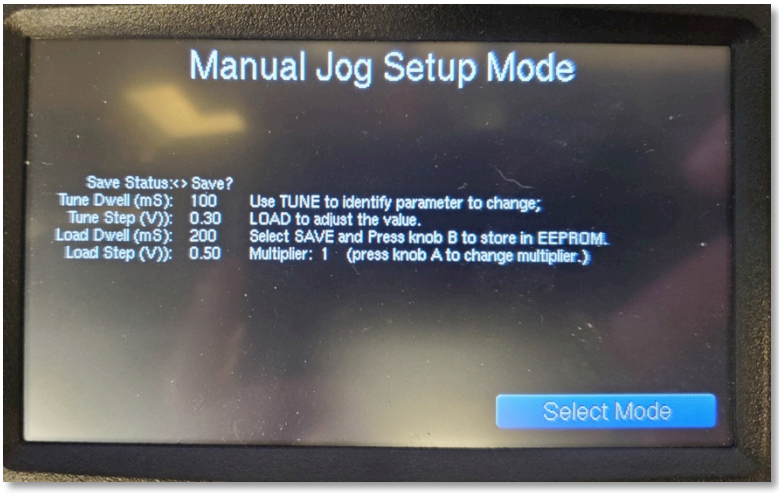
Serial Mode Selected in Navigator VFP

3. On the Nykar Network Tester, press **Select Mode** to bring up test options.

4. Select **Manual Jog Setup** and enter values optimal for your match. The B dial will change the current selection, marked with the " **< >** " symbol. Rotating the A dial changes value of the selected parameter.

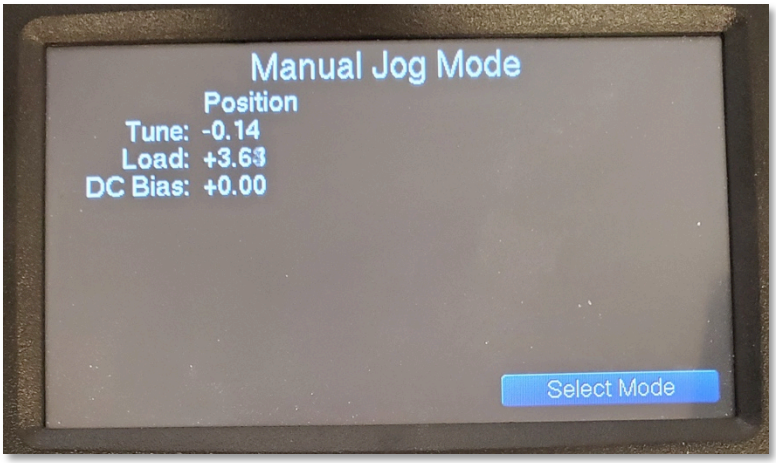
Recommended Manual Jog Setup Values	
Tune Dwell (mS)	100
Tune Step (V)	0.3
Load Dwell (mS)	200
Load Step (V)	0.5

5. Scroll up to "**Save Status**" with the B dial and press down on the dial to save changes. Ensure the text "**SAVED**" is displayed.



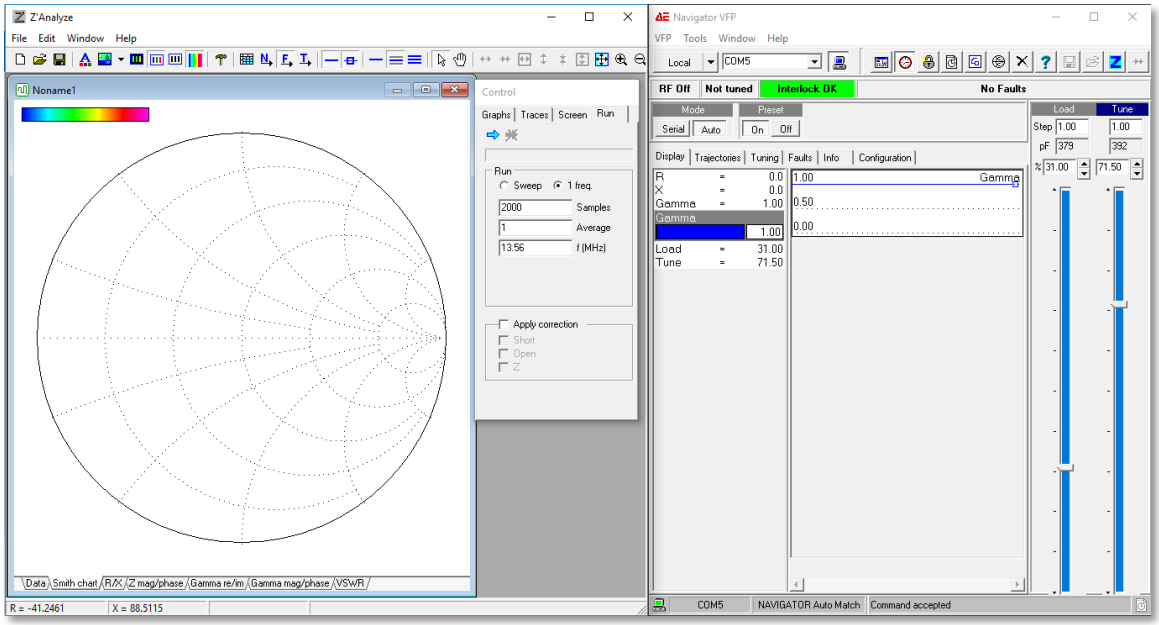
Successfully Saved Manual Jog Parameters

6. Press **Select Mode** to return to the menu and press **Manual Jog**.



Manual Jog Mode

7. On your PC, split screen with Navigator VFP and Z'Analyze software.



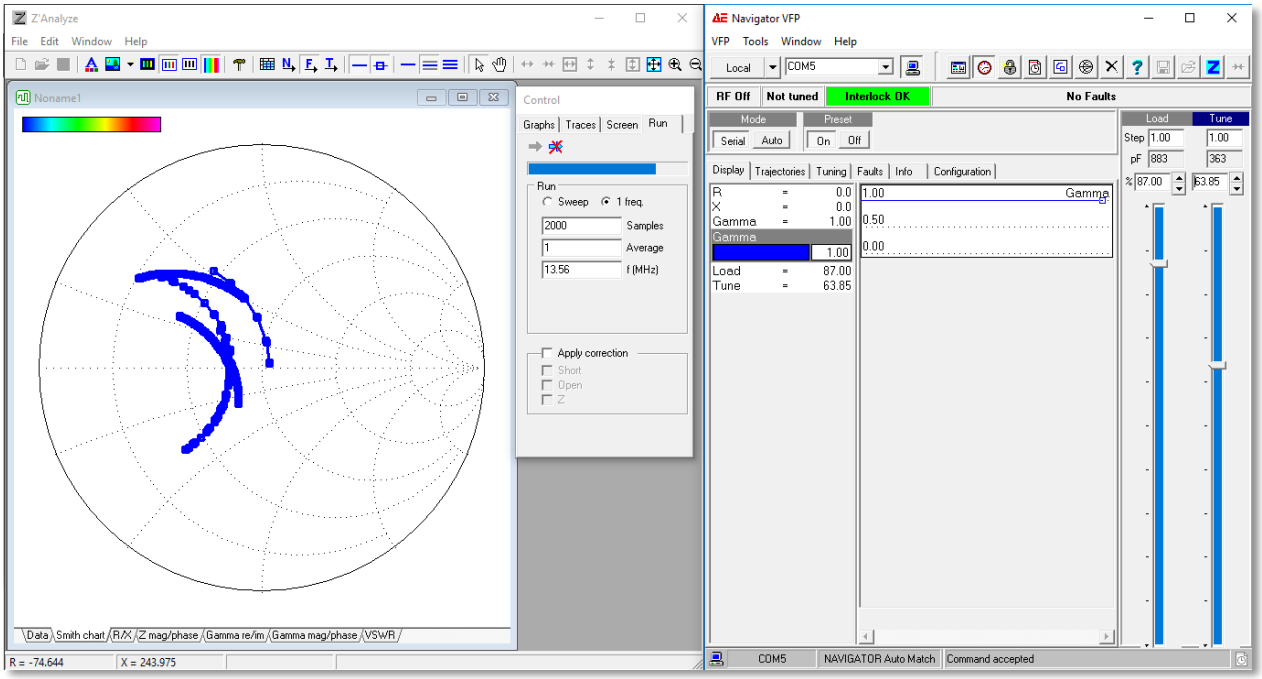
On-screen Software Setup

8. In Z'Analyze Software, under the 'Run" tab of the Control Panel, set values to:
   - 1 freq. selected
   - 2000 Samples
   - 1 Average
   - 13.56 f (MHz)

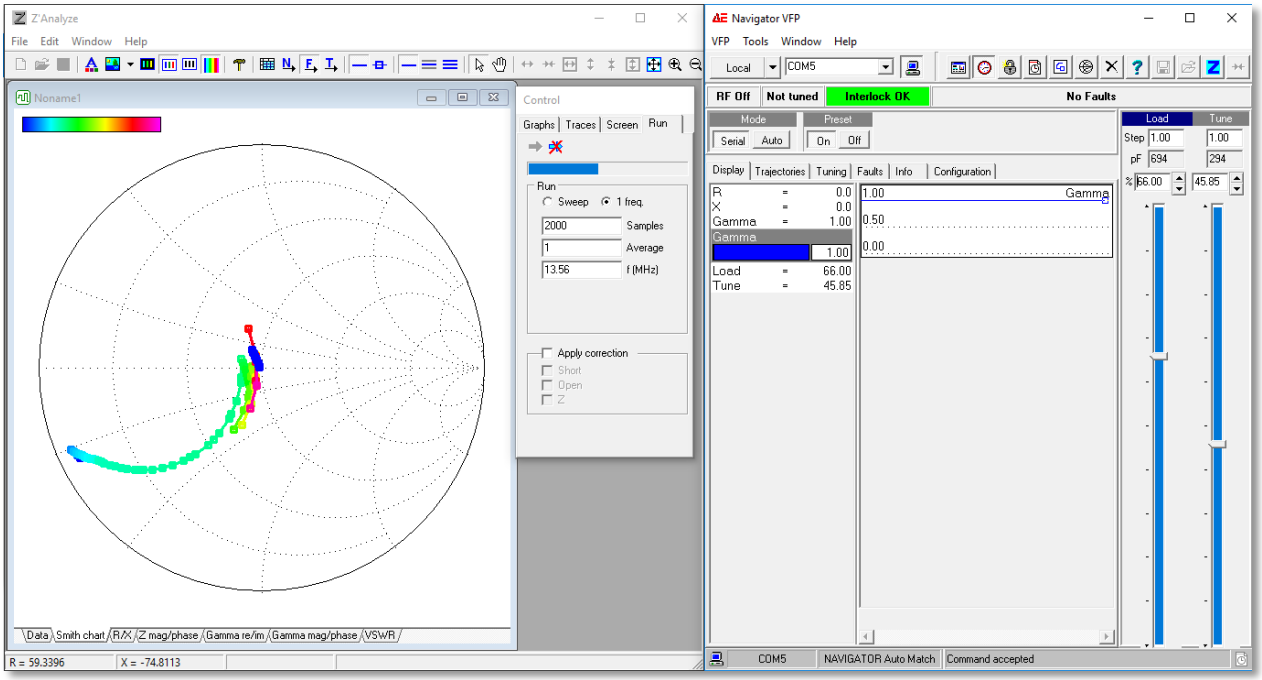
9. Click 'Run' to obtain a data point on the Smith chart. This point will change position as the tune and load percent are changed in the Navigator VFP software.

10. Using the up and down arrow buttons, drive Navigator tune and load to move the impedance point in Z'Analyze to the center of the Smith chart. This process is trial and error and may take several runs.

11. Once the impedance point has been successfully moved to the center of the Smith chart, record the countermatch tune and load positions in the Test Value Data Table.



Example of a successful run with impedance ending in the center of the smith chart.



Another example of a successful run.

Obtaining a VSWR will depend on the generation of network analyzer being used.

- If you are using a TE3001, press the VSWR button to obtain a reading.
- If you are using a TE3002, hold down the format button for several seconds until the “Alternative Formats” menu is displayed. Then press enter to select VSWR.

12. Record VSWR Value in data table.

13. Repeat process for each given set of voltage values.

Test Value Data Table

Given Voltage Values		Test Values		
Tune V	Load V	Countermatch Load Position	Countermatch Tune Position	VSWR

Completed Test Value Data Table (with Example Data)

Given Voltage Values		Test Values		
Tune V	Load V	Countermatch Load Position	Countermatch Tune Position	VSWR
1.01	2.05	0.94	64.49	1.15
1.04	0.41	11.03	54.63	1.00
0.47	0.62	4.96	39.17	1.09
1.23	0.04	15.05	59.42	1.06
-0.59	0.60	14.39	36.93	1.15

Match Network Testing

Once tune and load positions of the known good match have been determined, the DUT can be tested.

1. Disconnect the known good match from the test bench and replace it with the DUT match.

2. On the Nykar Network Tester, press **Select Mode** to bring up test options. Select **Auto Mode**.

   ✓ Note: If the Nykar Network Tester already boots in Auto Mode, it is still necessary to navigate out to the menu and re-select **Auto Mode**. Failure to do this will result in the DUT not activating its tune sequence and will show up as reflected power on the RF generator.

3. Change mode in Navigator VFP software to Serial.

Serial Mode Selected in Navigator VFP

4. Turn RF on.

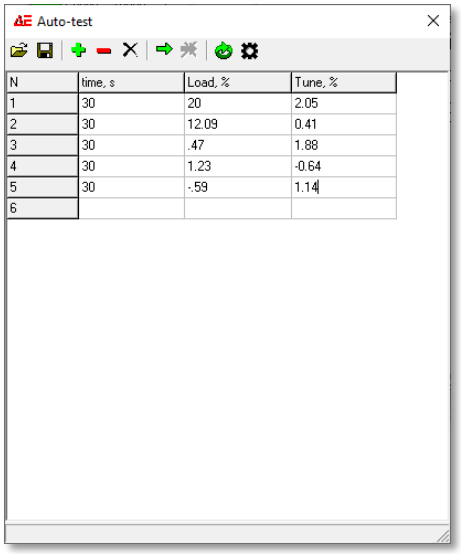
VFP Auto-test Settings

In Navigator VFP Software, open the **Tools** dropdown from the menu options and select **Auto-test** to open the Auto-test control panel.

Test settings can be opened from a file on your PC or entered manually.

To enter test parameters, click on the appropriate text box and enter the desired value.

A value must be entered in each column for the test to run.
Time is entered in seconds with a minimum value of 0.
Load, % and **Tune, %** are entered as values 0-100.

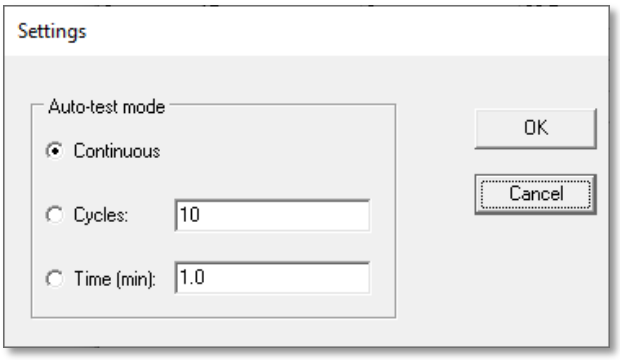


Example Test Cycle

CHANGE AUTO TEST MODE:

Click the **Settings** icon in the Auto-test control panel to open the Auto-test mode settings. Auto-test can be set to run a single time or in 3 continuous Modes:

Single (default) mode will perform a single run of the test parameters if the green circular arrow is left unselected.



Auto-test Settings

To enable continual testing, click the green circular arrow icon in the Auto-test control panel. If continual testing is unselected, the test will perform the default (single) run.

Continuous mode will perform a cycle of the test parameters until prompted to stop.
Cycle mode will run through the test parameters a set number of (times).
Time (min) mode will repeat test parameters for a given amount of time.

For this procedure, it is recommended that you select **Continuous** in the Settings window. Press OK to close menu.

Copy the tune and load positions obtained in the previous section into the Auto-test table in VFP.

You will be collecting data from the Nykar Network Tester, Z-Ware Software, and on-screen display of your Bird Power Meter for each data set. Because of this, enter a delay time that will be sufficient to record multiple readings. A 30-second delay is a good starting point, although you may want more time. (After 30 seconds, the test will move to the next data set.)

N	time, s	Load, %	Tune, %
1	30	20	56.4
2	30	12.09	54.49
3	30	0	30.7
4	30	14.86	37.49
5	30	10.76	56.46

Example Test Values with 30 second Delay

To run the test continuously, click the circular green arrow in the Auto-test control panel.

To run the test once, click the single green **Run** arrow.

Z-Ware Settings

To test the DUT match, you will need two windows of Z-Ware running simultaneously. One will be connected to the Z'Scan on the DUT match and one will be connected to the Z'Scan in the Navigator. These two windows will have slightly different settings and this section will outline how to set up both sensors for easy data collection on your PC.

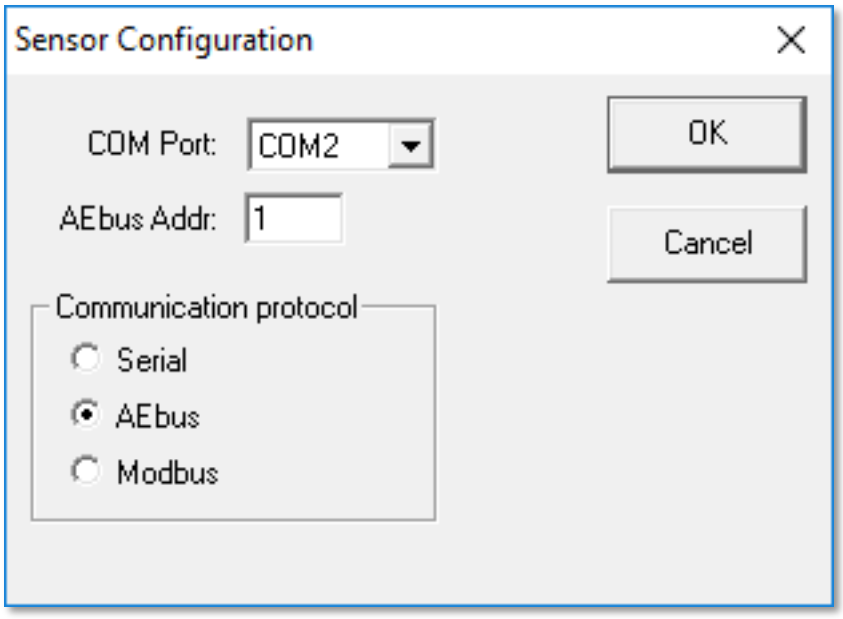
Connecting the Sensors

On startup, Z-Ware will allow you to open a settings list. We will be using **13.56 MHz RF test bench.ini** and **13.56 MHz Countermatch.ini**. These settings will need to be configured using Z-Ware set to 13.56 MHz and 100ms data collection.

Z-Ware will then prompt you to connect a device.

Select the correct COM port, ensuring Communication protocol is set to **AEbus**, and press enter to begin displaying sensor data.

Open another instance of Z-Ware by starting the program again.



Sensor Configuration Window

Z'Scan COM Port Settings

Note: Z'Scan must be on COM 1 - 8. A suitable COM port may need to be manually selected if your PC had assigned the Z'Scan COM9 or higher. This can be done by navigating to **Device Manager** on your PC and selecting **Ports (COM & LPT)**.

Right click the Z'Scan connection and select **Properties**. Click the **Port Settings** tab and select **Advanced…** at the bottom of the window.

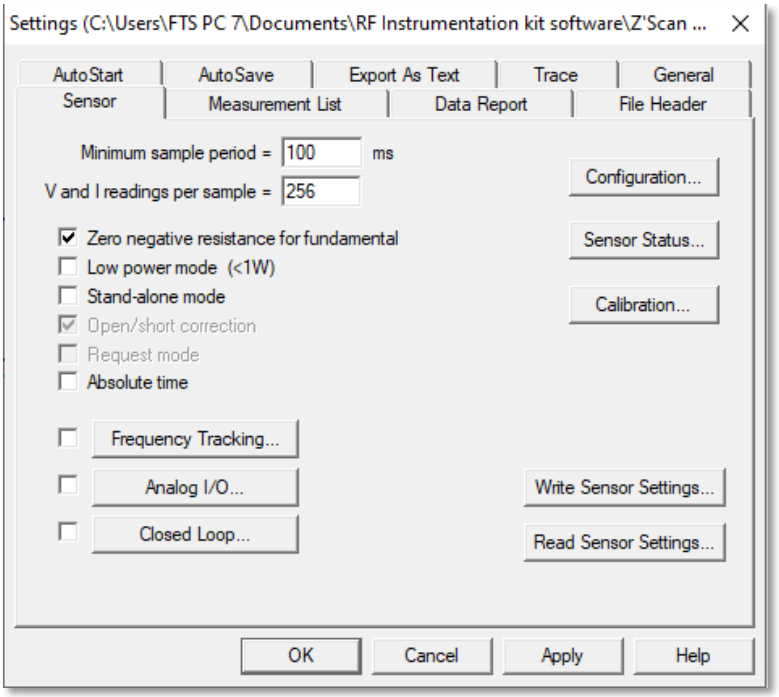
This will open a window titled "Advanced Settings for COM#". At the bottom of the window, use the drop down menu next to **COM Port Number:** to select a new COM port from COM1 – COM8.

Click **OK** to save changes.

Sensor Configuration

Sensor Configuration can also be accessed by navigating to **Settings…** (Wrench icon), selecting the **Sensor** tab, and clicking the **Configuration…** button.

The **Sensor Status…** button can also be used to ensure the correct device has been selected.



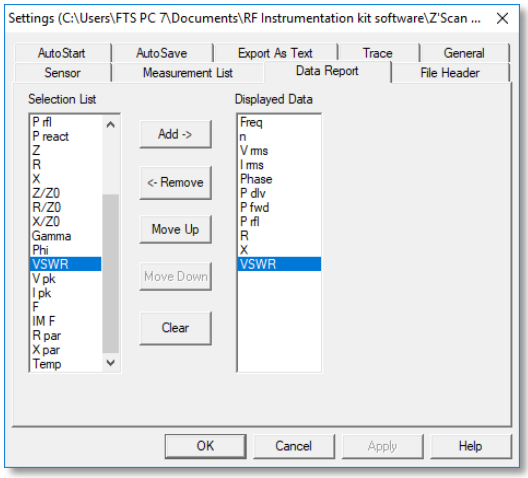
Sensor Settings Window

Displayed Data Settings

Data report settings can also be customized for this step. Navigate to **Settings…** (Wrench icon), select the **Data Report** tab, and Add/Remove the Displayed Data from the Section List.

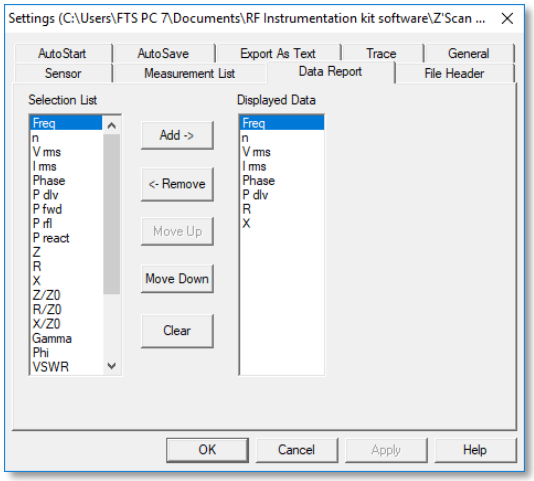
NOTE: The sensor data will not be displayed until you press the green **Run** arrow.

For the Z'Scan connected to the DUT match, it is helpful to display **Freq, n, V rms, I rms, Phase, P dlv, P fwd, P rfl, R, X, and VSWR** data.



Countermatch Z'Scan Displayed Data Settings

For the Z'Scan connected to the Navigator match, it is helpful to display **Freq, n, V rms, I rms, Phase, P dlv, R, and X** data.

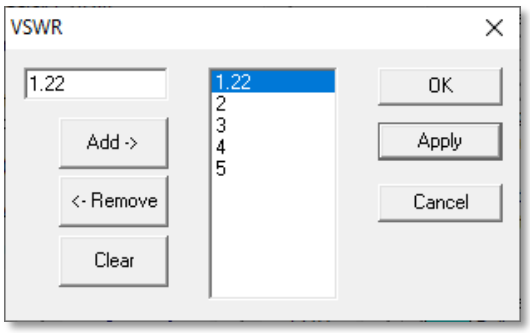


Navigator Z'Scan Displayed Data Settings

VSWR Settings

VSWR display settings can be customized by navigating to **Settings…** (Wrench icon), selecting the **Trace** tab, and clicking **VSWR…** button.

The desired VSWR specification for most commercial matches is 1.22 (1% reflected). Your matches might not perform as well, but you can relax the VSWR for what is acceptable for your process.



VSWR Ranges

In the Z-Ware window connected to the DUT, select **Show VSWR Circles** in the right hand column to display chosen VSWR ranges on the Smith Chart.

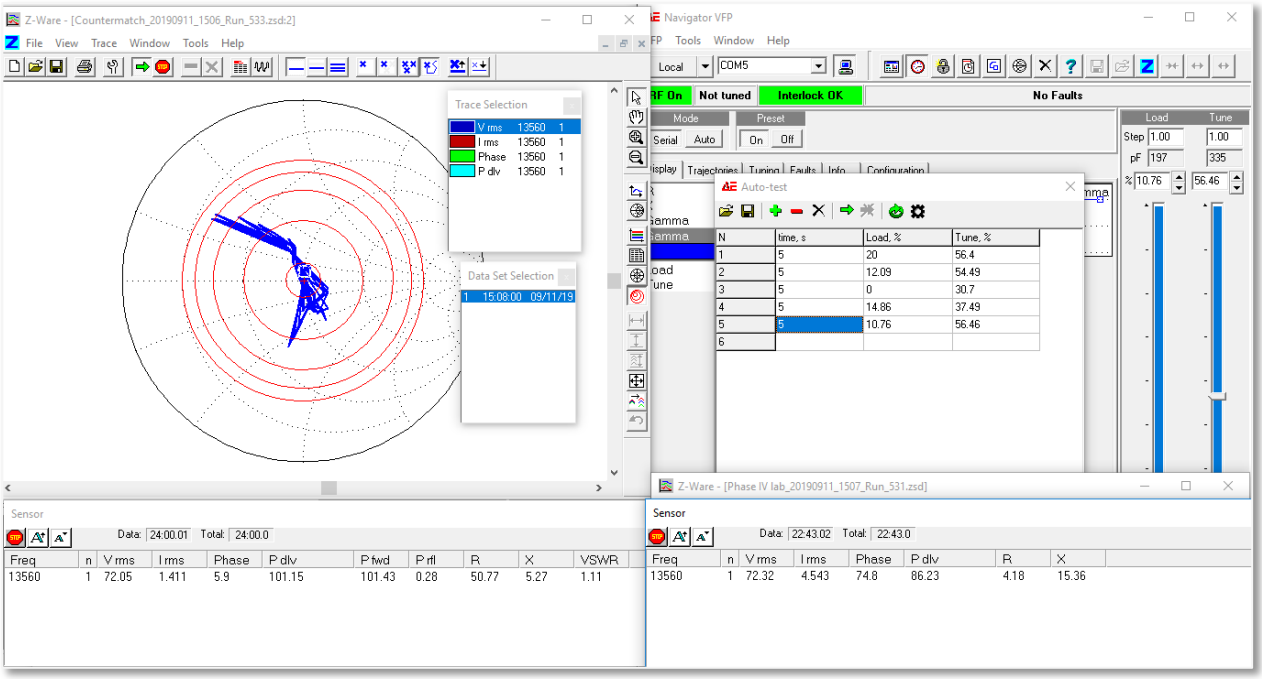
Show VSWR Circles Icon

For this test, ensure the **Display Only Selected** and **Line** modes are active in the top tools menu.

Display Only Selected and Line Modes

Interface Setup

During the test, you will be recording data from your PC from two separate windows of Z-Ware. It is helpful to arrange windows so the DUT data/Smith chart on the Left, with the countermatch Data on the right, and the auto test table above that.



Recommended Desktop Interface Setup

Running the Test

To run the test continuously, click the circular green arrow in the VFP Auto-test control panel.

VSWR Analysis

The data point on the smith chart will move out of the acceptable range as the match moves, but should ideally come to rest within the desired range. The desired VSWR specification for most commercial matches is 1.22. Your matches might not perform as well, but you can relax the VSWR for what is acceptable for your process.

If the VSWR is below 1.22 (1% reflected) in tests with the golden match but not the DUT, it is likely a problem with the DUT match.

ESR Analysis

ESR – equivalent series resistance of any device
In a matching network, the ESR will determine the power losses in the match when driven into a simulated or real plasma load. The ESR for a matching network is largely determined by its internal components and the settings they are placed at.

The power will be applied based on the ratio of the ESR versus the resistance of the load. In our system, the load is made up of the countermatch and has both resistance and reactance. Only the resistance is a factor here.

If, for example, the ESR of a matching network is 1 ohm resistive, and the resistance of the load is 4 ohm resistive, then the power will be split so that we see 20% losses in the matching network and 80% of the power is applied to the load.

ESR/(Load R + ESR) = % losses in match

Load R/(Load R + ESR) = % power applied to load

The ESR determines the amount of power applied to the load. The power applied to the load determines the plasma characteristics and therefore can be a critical factor in tool-to-tool matching. A high ESR match into a low R load can easily show 50% losses in the match and therefore match-to-match variability can be a big factor in tool variation.

Open the "**ESR (Match Equivalent Series Resistance) worksheet.slsx"** file provided in Microsoft Excel.

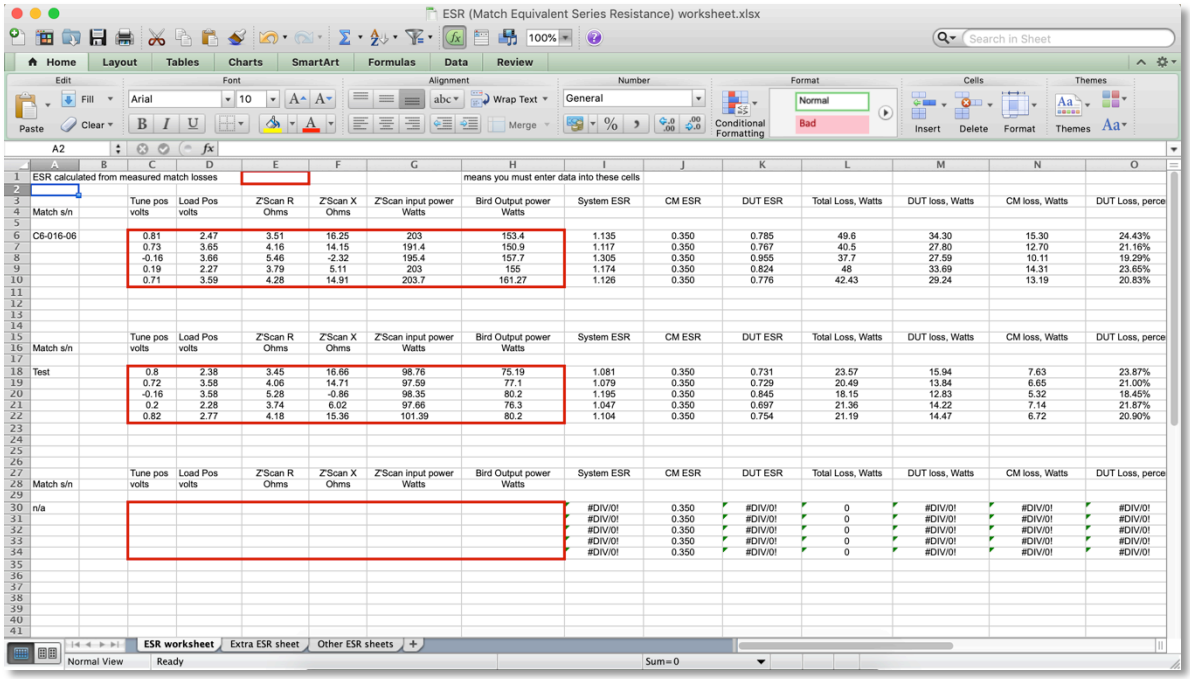
During the test, record the following parameters into the cells outlined in red:

Tune pos	Load Pos	Z'Scan R	Z'Scan X	Z'Scan input power	Bird Output power
volts	volts	Ohms	Ohms	Watts	Watts

Tune Position (V) – from Nykar Network Tester On-screen Display
Load Position (V) – from Nykar Network Tester On-screen Display
Z'Scan R (Ohms) – from Z'Ware (R) countermatch right window
Z'Scan X (Ohms) - from Z'Ware (X) countermatch right window
Z'Scan Input Power (Watts) – from Z'Ware (P dlv to DUT)
Bird Output Power (Watts) - from Bird Power Meter On-screen Display

Bird Power Meter On-screen Display Output Power

Once completed, the worksheet will calculate the system ESR, countermatch ESR, DUT Match ESR, Total Loss, DUT loss (Watts), CM loss (Watts), and DUT loss (percent).



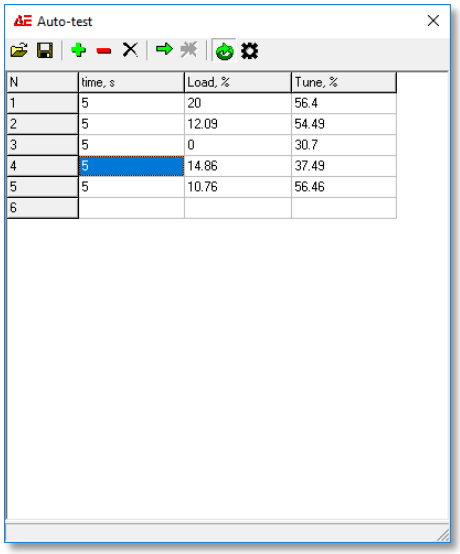
	A	C	D	E	F	G	H	I	J	K	L	M	N	O
1	ESR calculated from measured match losses						means you must enter data into these cells							
3		Tune pos	Load Pos	Z'Scan R	Z'Scan X	Z'Scan input power	Bird Output power	System ESR	CM ESR	DUT ESR	Total Loss, Watts	DUT loss, Watts	CM loss, Watts	DUT Loss, perce
4	Match s/n	volts	volts	Ohms	Ohms	Watts	Watts							
6	C6-016-06	0.81	2.47	3.51	16.25	203	153.4	1.135	0.350	0.785	49.6	34.30	15.30	24.43%
7		0.73	3.65	4.16	14.15	191.4	150.9	1.117	0.350	0.767	40.5	27.80	12.70	21.16%
8		-0.16	3.66	5.46	-2.32	195.4	157.7	1.305	0.350	0.955	37.7	27.59	10.11	19.29%
9		0.19	2.27	3.79	5.11	203	155	1.174	0.350	0.824	48	33.69	14.31	23.65%
10		0.71	3.59	4.28	14.91	203.7	161.27	1.126	0.350	0.776	42.43	29.24	13.19	20.83%
15		Tune pos	Load Pos	Z'Scan R	Z'Scan X	Z'Scan input power	Bird Output power	System ESR	CM ESR	DUT ESR	Total Loss, Watts	DUT loss, Watts	CM loss, Watts	DUT Loss, perce
16	Match s/n	volts	volts	Ohms	Ohms	Watts	Watts							
18	Test	0.8	2.38	3.45	16.66	98.76	75.19	1.081	0.350	0.731	23.57	15.94	7.63	23.87%
19		0.72	3.58	4.06	14.71	97.59	77.1	1.079	0.350	0.729	20.49	13.84	6.65	21.00%
20		-0.16	3.58	5.28	-0.86	98.35	80.2	1.195	0.350	0.845	18.15	12.83	5.32	18.45%
21		0.2	2.28	3.74	6.02	97.66	76.3	1.047	0.350	0.697	21.36	14.22	7.14	21.87%
22		0.82	2.77	4.18	15.36	101.39	80.2	1.104	0.350	0.754	21.19	14.47	6.72	20.90%
27		Tune pos	Load Pos	Z'Scan R	Z'Scan X	Z'Scan input power	Bird Output power	System ESR	CM ESR	DUT ESR	Total Loss, Watts	DUT loss, Watts	CM loss, Watts	DUT Loss, perce
28	Match s/n	volts	volts	Ohms	Ohms	Watts	Watts							
30	n/a							#DIV/0!	0.350	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
31								#DIV/0!	0.350	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
32								#DIV/0!	0.350	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
33								#DIV/0!	0.350	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!
34								#DIV/0!	0.350	#DIV/0!	0	#DIV/0!	#DIV/0!	#DIV/0!

ESR Worksheet with 2 Completed Match Datasets

Exercising the Matching Network

Once all data points have been recorded, you will want to run the match in auto mode to ensure that the match tuning is fast and repeatable. The continuous cycle testing will exercise the match tuning by moving the countermatch impedance so the match has to adjust itself to those impedances.

In Navigator VFP software, change the Auto-test time from 30 seconds to **5 seconds**.



N	time, s	Load, %	Tune, %
1	5	20	56.4
2	5	12.09	54.49
3	5	0	30.7
4	5	14.86	37.49
5	5	10.76	56.46
6			

Run the match sufficiently to ensure you are confident in the match's tuning ability. Most matches will fail within 30min if they have a problem.