Application Note: Antenna characterization at the push of a button

1. Introduction

This application note explains how the Tekbox Vector Network Analyzer TBVNA-6000 enables you to measure antenna return loss, VSWR, antenna gain and the antenna factor with the push of a button.

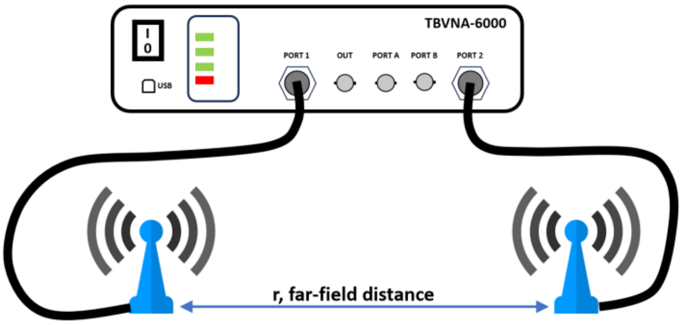
You may just wish to characterize an antenna during development or ensure that a third-party antenna performs as expected when mounted on a housing. A critical performance criterium for ISM band radio transmitters is the power that it radiates from the antenna. The radiated RF power must be high enough to achieve a reliable link between the transmitter and receiver, yet it must not be so high that it exceeds the radiation limits established in Part 15.231 of the FCC Regulations and similar standards. To determine the effective isotropic radiated power, you need to multiply the RF power at the antenna connector with the isotropic gain of the antenna.

One of the methods to measure antenna gain is the “Two antenna method”. This approach measures the path loss between two identical antennas, set up at a far-field distance with respect to each other.

The path loss is measured using a Vector Network Analyzer. S21 data is normally downloaded from the analyzer and copied into an Excel sheet to calculate gain. This time-consuming procedure can be simplified to the push of a button thanks to the features of the TBVNA-6000 Vector Network Analyzer from Tekbox.

2. Two antenna method

Two identical antennas are set up at a distance r. Coupling loss can be measured by connecting one antenna to Port 1 and the other antenna to port 2 of a VNA.



Picture 1, 2-antenna method setup

For aligned identical antennas, the Friis transmission equation gives:

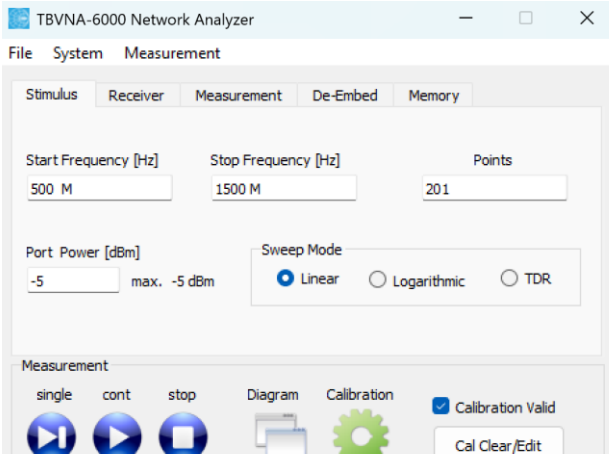
Equation 1: $$Gain\ [dB] = \frac{1}{2}\left[20\log\left(\frac{4\pi r}{\lambda}\right) + S21\right]$$

Equation 2: $$Antenna\ Factor\ [dB/m] = 20\log\left(\frac{9.73}{\lambda\sqrt{G(num)}}\right) \quad with\ G(num) = 10^{\left(\frac{Gain[dB]}{10}\right)}$$

3. VNA setup

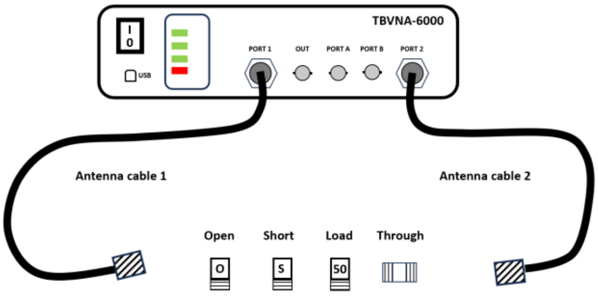
In order to get maximum information with our setup, we will configure the TBVNA-6000 to measure antenna return loss S11, VSWR, path loss S21, gain and antenna factor at the push of a button.

In our example, we want to measure the characteristics of a 900 MHz ISM antenna. We will set the start frequency to 1 MHz, stop frequency to 2 GHz, linear sweep, 201 measurement points and the port power to -5 dBm:



Picture 2, stimulus setup

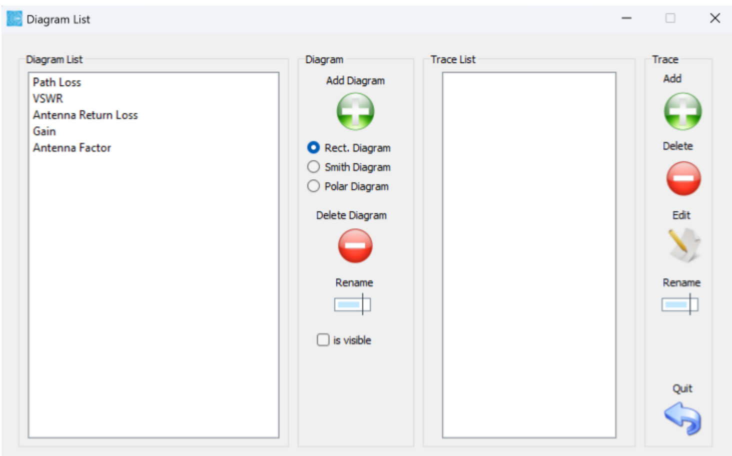
Setup the analyzer for a full 2-port calibration. The coaxial cables used must be the same ones used to connect the antennas. The reference planes for calibration are at the open end of the coaxial cables.



Picture 3, OSLT calibration setup

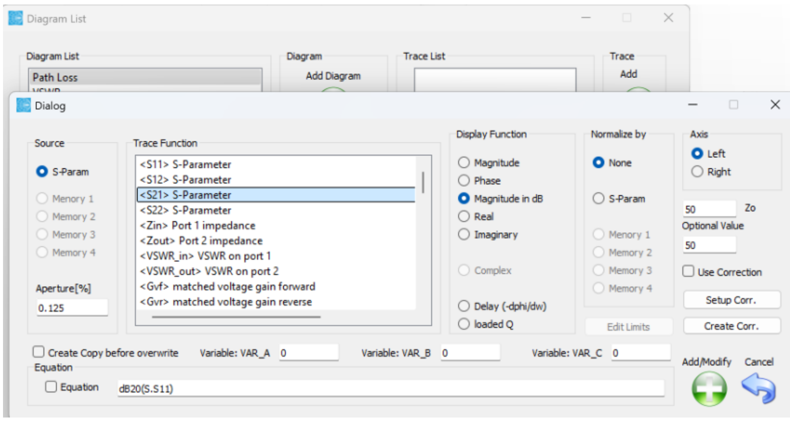
Press the CALIBRATION-button to carry out a 2-port OSLT calibration. For detailed information on the calibration procedure, read chapter 2 of the TBVNA-6000 getting-started manual.
Save the calibration as *Antenna_Gain.xcf*

Press the DIAGRAM-Button to set up the measurement plots. Use the ADD DIAGRAM-button to set up five rectangular diagrams. Use the RENAME-button to name the diagrams *Path Loss, VSWR, Antenna Return loss, Gain* and *Antenna Factor*.



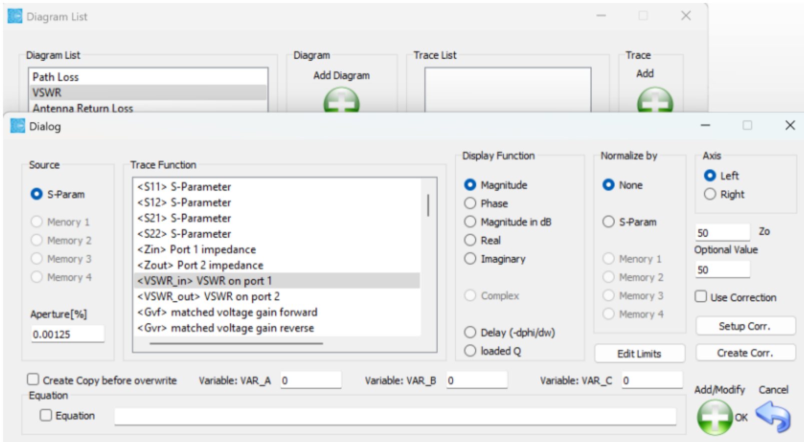
Picture 4, Diagram utility

Assign measurements to the diagrams. Highlight the *Path Loss* diagram and press the ADD TRACE-button. In the Trace dialog, select *S21* and press the ADD-button.



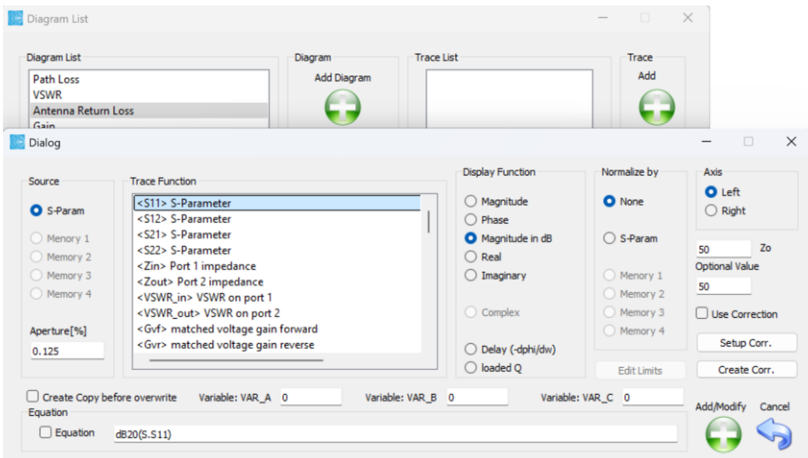
Picture 5, Trace dialog, S21 selected

Highlight the *VSWR* diagram and press the ADD TRACE-button. In the Trace dialog, select *VSWR on Port1*, click Display Function *Magnitude* and press the ADD-button.



Picture 6, Trace dialog, VSWR Port 1 selected

Highlight the *Antenna return Loss* diagram and press the ADD TRACE-button. In the Trace dialog, select *S11* and press the ADD-button.

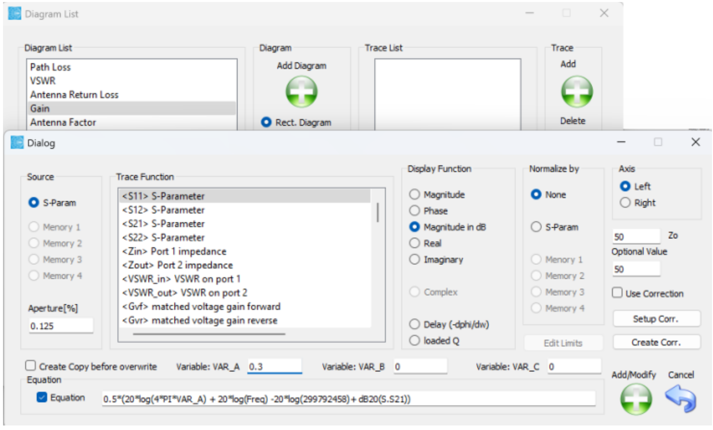


Picture 7, Trace dialog, S11 selected

To implement the Gain measurement, we use the Equation feature. Highlight the *Gain* diagram and press the ADD TRACE-button. In the Trace dialog, activate the EQUATION - box and enter Equation 1 from chapter 2:

0.5*(20*log(4*PI*VAR_A) + 20*log(Freq) -20*log(299792458)+ dB20(S.S21))

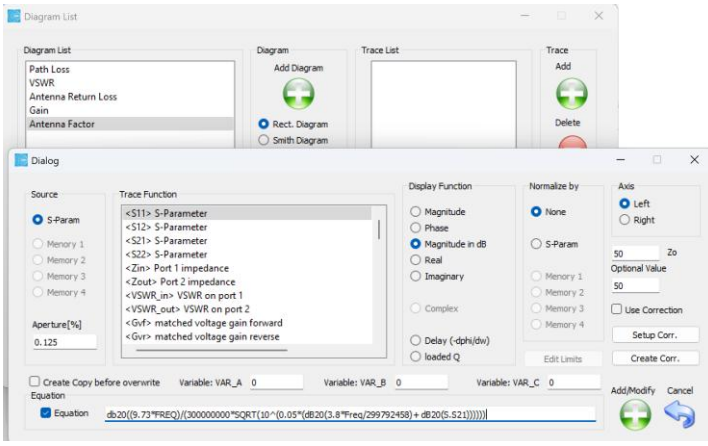
For the antenna spacing r, we make use of variable VAR_A, instead of entering the value directly into the equation. This allows easy modification of the antenna spacing value. Enter a value of 0.5 for 50 cm. After entering the equation, press the ADD Trace-button.



Picture 8, Trace dialog, Gain equation

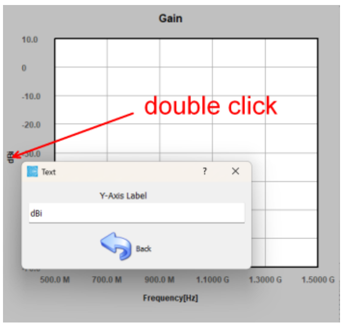
To implement the Antenna Factor measurement, we use the Equation feature. Highlight the *Antenna Factor* diagram and press the ADD TRACE-button. In the Trace dialog, activate the EQUATION - box and enter Equation 2 from chapter 2:

db20((9.73*FREQ)/(300000000*SQRT(10^(0.05*(dB20(3.8*Freq/299792458)+ dB20(S.S21))))))



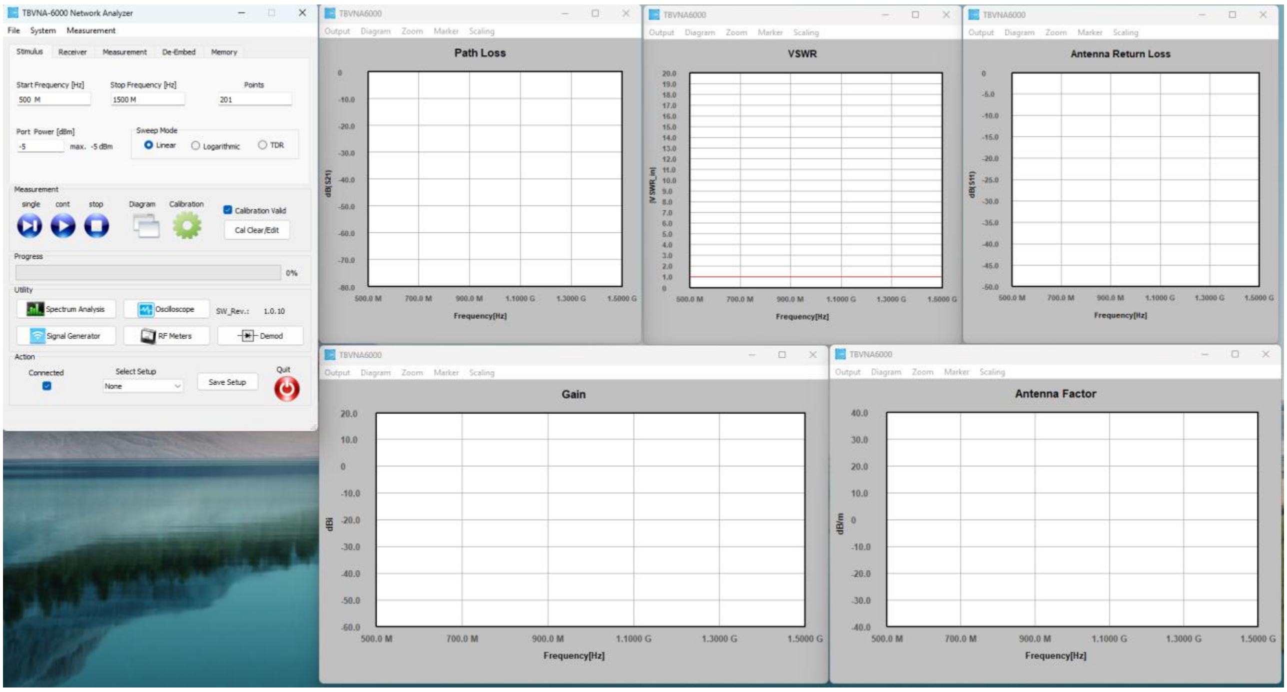
Picture 9, Trace dialog, Antenna factor equation

Quit the diagram utility and open the Gain Plot window. Double click the Y-axis unit and enter *dBi*.



Picture 10, Gain Plot, entering Y-axis unit

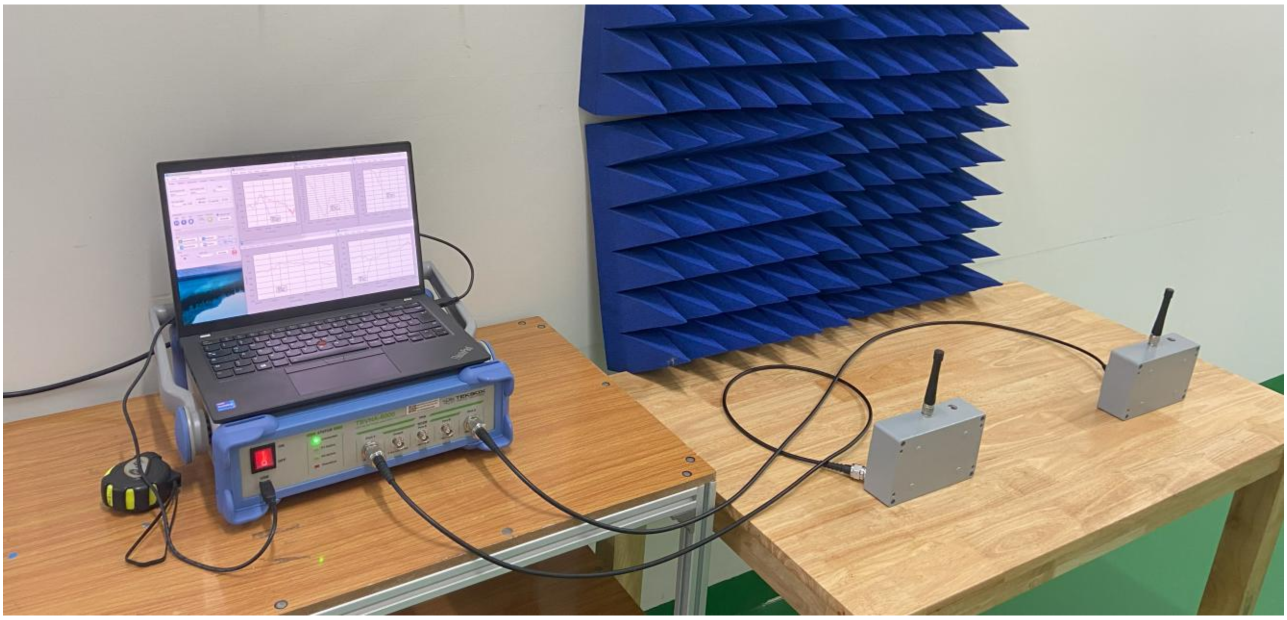
Open the Antenna Factor plot window and enter dB/m as Y-axis unit. Arrange the windows to fit your monitor.



Picture 11, Plot window arrangement

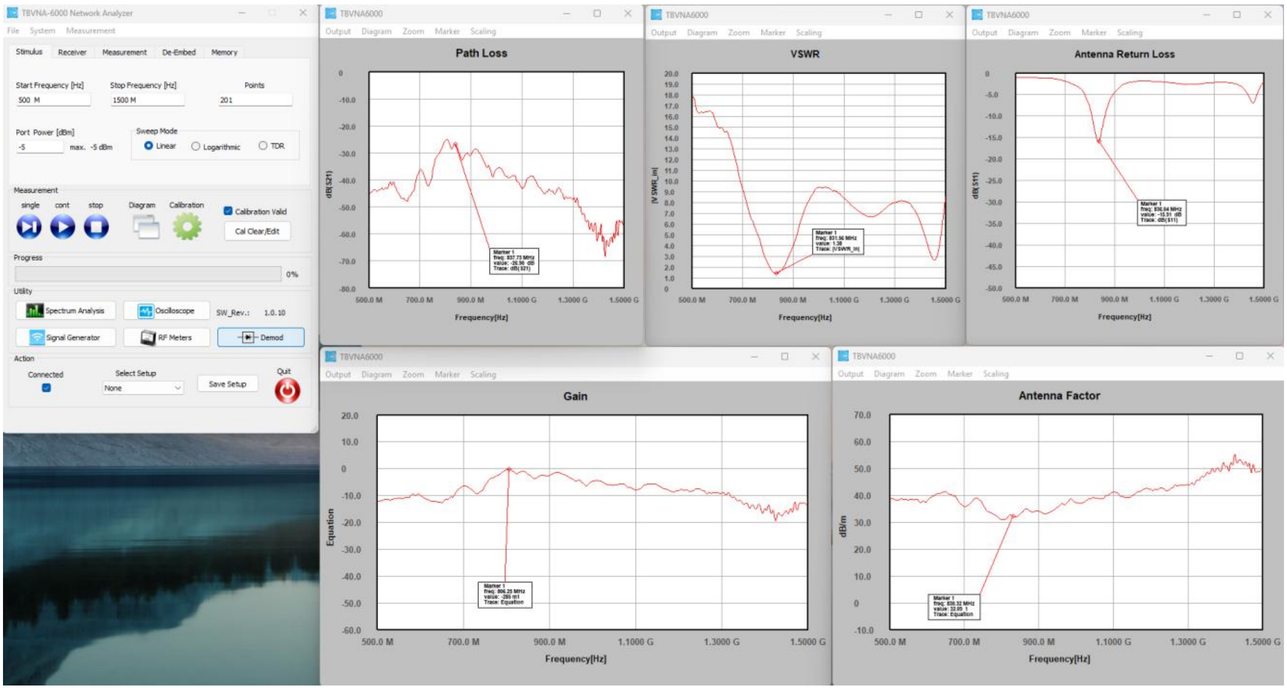
Save the configuration to a setup file, such as *2_Antenna_Measurement_500M_1500M_Lin.suf*.
When you need to perform another antenna test at a later time, simply load the Setup-file and you're good to go.

All that remains is to set up the antennas and push the measurement button.



Picture 12, Measurement setup

Format the measurement results using diagram utility features such as scaling, markers, labels, and many more.



Picture 13, Measurement example

4. Summary

The TBVNA-6000 Vector Network Analyzer provides with its equation editor a powerful tool to customize its measuring capabilities. It eliminates time-consuming postprocessing and contributes to a more efficient design process, reducing time to market.

Version	Date	Author	Changes
V 1.0	27.02.2025	Mayerhofer	Creation of the document