APPLICATION NOTE

The Bird BNA Series
Basic Antenna Characteristics

Basic Antenna Characterization Using a Vector Network Analyzer

Antennas are critical components in numerous technological applications, ranging from telecommunications and broadcasting to navigation and wireless networking. The effectiveness of an antenna depends on its ability to transmit and receive electromagnetic waves, which are tuned to match the radio frequency wavelength at which the antenna is intended to operate. If an antenna is untuned or unmatched, it results in poor transmission and reception, reducing its range as well as causing loss of data and increased power consumption. Furthermore, an impedance imbalance can dramatically increase reflected power, which in some cases may lead to damage to the transmitter. Therefore, characterizing an antenna's performance using precise tools like a Vector Network Analyzer (VNA) is essential to ensure it meets the specifications required for its intended application.

This application note outlines the process of basic antenna characterization focusing on key performance metrics such as return loss, Voltage Standing Wave Ratio (VSWR), and impedance, each of which plays a critical role in determining whether an antenna's performance is deemed "good" or "bad." In the text that follows, Bird BNA100 VNA will be used to illustrate each of these measurements.

Measurement Calibration Note

Before proceeding with antenna characterization, it is crucial to ensure that the VNA is properly calibrated. Accurate calibration is fundamental to obtaining reliable measurements. Calibration should be performed using the connectors and cabling to reflect the true characteristics of the measurement setup with respect to the device under test (DUT). In instances where an adapter is needed to connect the antenna to the VNA, port extensions should be used to account for any additional discrepancies introduced by the adapter. This helps in maintaining the accuracy of the measurements across the adapted interface.

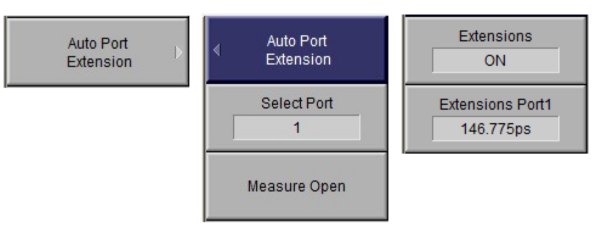

Figure 1: The Auto Port Extension feature provides an effortless means of accounting for losses due to connectors added outside of the regular calibration routine.

For a detailed discussion on the importance of VNA calibration and comprehensive steps on how to perform it, refer to the application note titled "Ensuring Precision: The Importance of Vector Network Analyzer Calibration."

Return Loss

Return loss measures how well the antenna is matched to the transmission line to which it is connected and is represented by the S-parameter measurement S11 made with the VNA **(Figure 2)**. It indicates the amount of power that is returned to the source due to impedance mismatch.

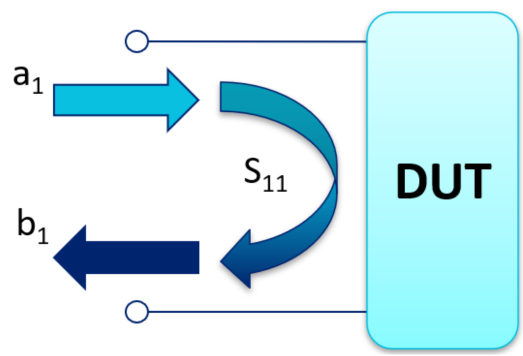

Figure 2: S11 scattering parameters can be used to help determine the return loss of a device.

A high return loss value (typically greater than 10 dB, with values around 15-20 dB being very good) indicates a better match, meaning less power is reflected and more is radiated by the antenna.

Figure 3 below shows a Bird ANT-800 center-fed dipole antenna connected to Port 1 of the VNA. This antenna is intended for UHF applications where the frequency ranges from 824 to 894 MHz, covering some of the land mobile radio (LMR) bands in the

United States. Prior to capturing return loss measurements, you will want to perform a measurement calibration covering a wider range of frequencies than the published antenna specification indicates to get an appreciation of what behaviors are apparent beyond the target operating band, perhaps 800 to 925 MHz. As noted earlier, you will want to ensure port extensions are enabled to account for the adapter needed to convert from Type N(m) to an SMA(f) connection. In this case the [Bird 4240-500-10] adapter was used.

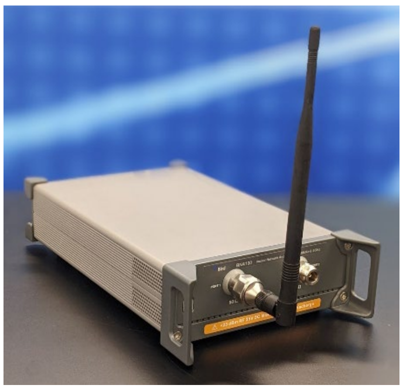

Figure 3: The Bird BNA100 hosting the antenna with a type N(m)-to-SMA(f) adapter in between.

To view the return loss, you should set the measurement for the active trace to "S11" and the format to "Log Magnitude". You will then want to enable three markers total: two to measure return loss at the start and stop points of the antenna's indicated operating range and one to monitor the greatest return loss point in between. **Figure 4** shows the marker measurements greater than 10 dB with most of the frequency band at over 15 dB, telling you that this antenna has good matching performance and low signal reflection.

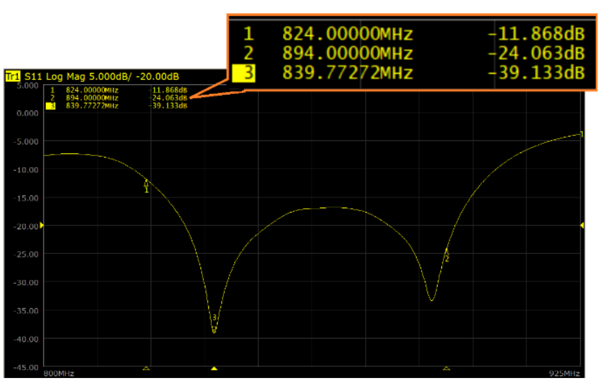

Figure 4: The VNA will display how much power is lost to reflections.

Voltage Standing Wave Ratio (VSWR)

VSWR is a measure of how effectively the antenna is transmitting the power that is supplied to it. It relates to the efficiency of power transfer in the transmission line and is also affected by the impedance matching. A VSWR value of 1:1 is ideal, indicating no reflection and perfect impedance matching. Practically, values below 2:1 are generally acceptable for most applications.

Return loss and VSWR are both means of understanding matching properties of an antenna or system, they are just presented differently. Return loss holds the advantage of having a logarithmic format that is convenient for mathematical calculations while VSWR is better for expressing linearity. Conversion between the two can achieved by way of the following formulas:

$$\text{Return Loss} = 20 * \log_{10} \frac{VSWR + 1}{VSWR - 1}\ dB$$

$$VSWR = \frac{1 + 10^{-\frac{RL}{20}}}{1 - 10^{-\frac{RL}{20}}}$$

The VNA eliminates the need for you to perform the computation of VSWR from the return loss swept frequency points, providing you a convenient way to visualize on a display.

Obtaining a view of VSWR is done by keeping the measurement as S11 but changing the VNA trace format setting to "SWR". You also have the option of modifying the existing trace or allocating an additional trace a view specifically for the VSWR measurement as is shown in **Figure 5**.

The closer the VSWR is to 1, the better the antenna's performance in terms of power transmission. In this example, you can verify that all measured points are within the acceptable range.

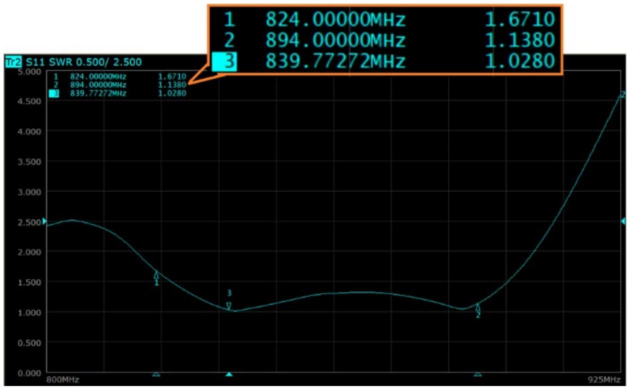

Figure 5: An additional trace added to the channel using S11 measurements and SWR format. All measurements are less than 2:1, and Marker 3 which corresponds to the greatest return loss point proves to have the best VSWR performance.

Impedance Measurements on the Smith Chart

The Smith Chart is a graphical representation used to plot complex impedance and other parameters, providing a visual means to analyze the impedance matching of the antenna over its bandwidth. The ideal point on a Smith Chart is the center, which represents 50 ohms impedance (common for many systems – see **Figure 6**). This center point indicates perfect matching. Additionally, the right-most centerline point represents an open while the left-most center point represents a short. Points falling above the horizontal center represent devices that are inductive in nature while those below are capacitive.

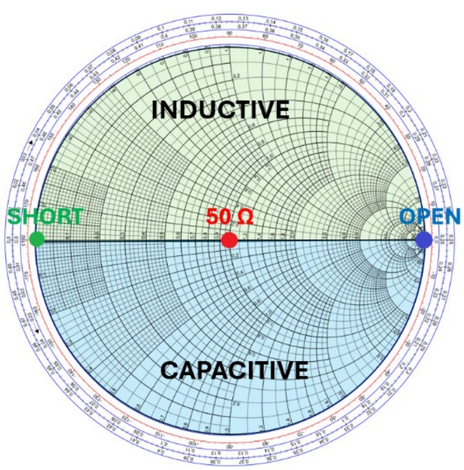

Figure 6: The ideal Smith Chart and summary notes on what the different points and regions represent.

With the antenna still connected to the VNA, you can view its complex impedance on a Smith Chart like the way you expanded your views for VSWR, this time selecting the “R + jX” format. The plot for the frequency band of interest should ideally encircle or gravitate toward the center – like what is shown in **Figure 7** – indicating that the impedance varies properly across the frequency range without straying too far from the 50-ohm mark. The Marker 3 point which corresponds with the best return loss and VSWR measurements is very near the center, reading 49.622 Ω. Note too in the image that the complex measurements listed at the far right for the marker points are all capacitive in nature which aligns with expectations when seeing these data points fall below the horizontal center line.

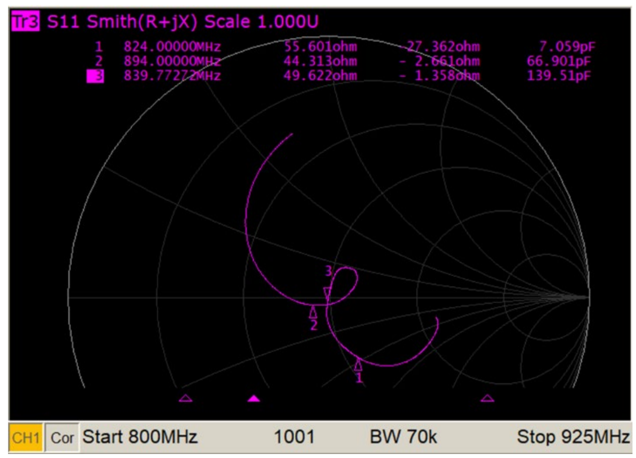

Figure 7: The Smith Chart plot of the antenna device showing complex impedance value comparable to 50 ohms, indicating a good match over the selected frequency range.

Conclusion

Proper characterization of an antenna using a VNA involves detailed measurements of return loss, VSWR, and impedance. By focusing on these three areas, one can effectively qualify an antenna as "good" (optimal performance and efficiency) or "bad" (poor performance and potential system issues). This characterization ensures reliability and efficiency in the antenna’s application, whether it be in complex systems like satellite communications or simple consumer electronics. The use of a VNA in these tests ensures that the antenna will operate effectively in its intended environment, providing assurance of performance before deployment.

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