Dual Probe Use for the Remote Measurement of an Antenna Under Test

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Abstract

This paper explores an alternative to the previous remote impedance measurement of antennas to improve the dynamic range of the needed data for the measurements. Previous work evaluated the refection coefficient of a source antenna as a function of the termination on the antenna under test (AUT). The loads used in the measurement are the classic open-short-load, with measured data used for the actual termination impedances. The impedance of the AUT is determined by a standard calibration approach. For current vector network analyzers, the dynamic range of the analog-to-digital converter limits the impedance estimate, particularly if the distance between the source and AUT is increased to reduce interaction affecting the impedance of the AUT. The new approach separates the transmit and receive functions to allow the use of a LNA to improve the receive signal strength and offer the opportunity to overcome some of the limitations of the reflection approach.

1. Introduction

The remote impedance measurement of antennas was introduced [1-4] to remove the need for a direct connection to the antenna that is often a major source of error, particularly for handhelds. The measurement is basically a calibration process of a reflection measurement system, except that the source reflection in the classic calibration model becomes the desired antenna reflection coefficient. Various aspects have been considered in terms of modeling with *Y*-parameters or *Z*-parameters to more closely represent the effect of the antenna in free space. For instance, the proximity effects of a half-wave dipole are substantially reduced if it is considered open circuit in the model, implying the use of *Y*-parameters. The last paper [5] looked at the dynamic range issue of the measurement system by considering the pattern of the antenna during the measurement (not necessarily recommended for impedance measurement, but providing a guide to the dynamic range issue of the measurement within a vector measurement system).

The major problem with the impedance measurement using reflection coefficient of the source antenna is the trade-off between distance (increased distance is desired to minimize proximity effects) and dynamic range (the required data is often found in the third or fourth decimal place of reflection coefficient data. Keep in mind that the desired data is embedded reflection measurement of the source antenna. An alternative that allows the addition of an amplifier to improve the link budget between the antenna under test (AUT) and the measurement antennas is to use separate transmit and receive antennas to observe the AUT. The limiting factor in such a measurement is the cross-talk between the transmit and receive antennas. This cross-talk can potentially be reduced with cross-polarization. The work to be investigated and presented at the assembly includes the addition of an amplifier in the receive path and consideration of cross-polarization. The data to be presented at the assembly will focus on experimental results of the AUT in an anechoic chamber.

Other sources of error that may be considered in the presentation include variations in the environment and error limits where possible. The environment has been found to be important in the reflection measurement series. For instance, if a chamber or other structure is not used for antenna isolation, the effects of a person walking down the hall next to the room can have a small effect. So the environment and repeatability of the measurements are also critical for good results. The remainder of this paper will review some of the theory of the measurement concept and some of the past results for the reflection measurement to support the viability of the process. The proposed system will then be presented in a theoretical form.

2. The Reflection Measurement of Previous Work

The remote impedance measurement of an AUT is generally a reflection calibration type of measurement using a vector network analyzer. The basic setup for the measurement is shown in Fig. 1. The load is placed on the AUT connector and is the calibration standards used for typical OSL (Open-Short-Load) calibration. In a production environment, an optically switched module would be used to switch the open, short, and load, all of which would be measured in a regular impedance measurement to provide known standards for the load.

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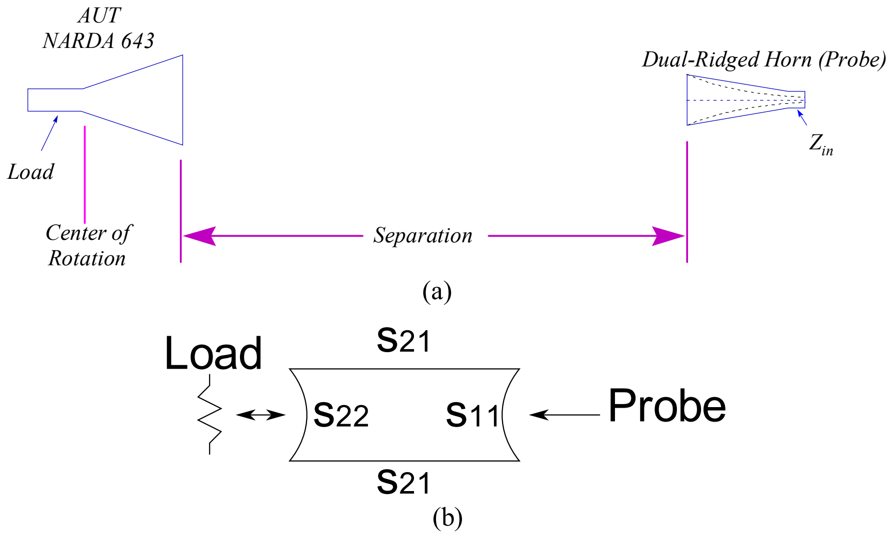

Figure 1: The Reflection Measurement Setup (used by permission).

The equation defining the input reflection versus load is given by

$$\Gamma_i = s_{11} + \frac{s_{21}^2 \Gamma_{Li}}{1 - s_{22}\Gamma_{Li}} \tag{1}$$

and with three independent, known loads may be solved to obtain

$$\Gamma_{\mathrm{AUT}} \approx s_{22} = \frac{(\Gamma_1 - \Gamma_3)\frac{1}{\Gamma_{L1}} - (\Gamma_2 - \Gamma_3)\frac{1}{\Gamma_{L2}}}{(\Gamma_1 - \Gamma_2)} \tag{2}$$

and the termination, Γ_{L3}, set to zero (ideal termination). The observation is that the difference in the reflection measurement for the three separate loads provides the basic information needed to determine the properties of the AUT. The approximation has been used to properly account for the mutual interaction of the source antenna on the AUT that is desired to be minimal.

Results for a sample of the reflection system are shown in Fig. 2. Above the cutoff frequency of the waveguide, the reflection magnitude comparison is excellent. Below the cutoff, the meaning of the data becomes questionable, but is easily seen in the substantial reduction of the s_{21} of the measured data and also the apparent errors in the differences of the reflection data used in the computation.

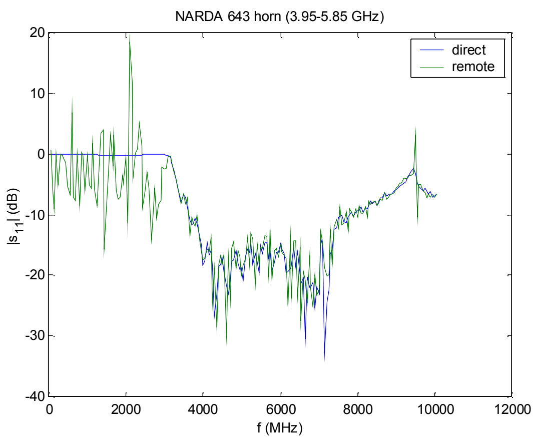

Figure 2: Direct and Remote Measured Reflection Magnitude for a NARDA 643 Horn (used by permission) [http://www.nardamicrowave.com/east/index.php?m=Products&e=details&id=1249].

3. The Dual-Antenna System

To reduce the errors caused by the dynamic range of the reflection system, separate transmit and receive antennas are proposed for the system along with the possible addition of an amplifier. The basic system is shown in Fig. 3.

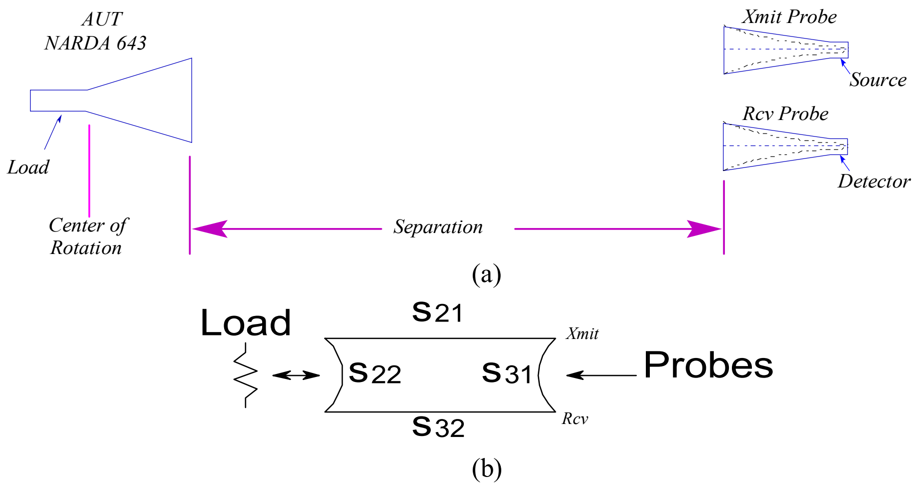

Figure 3: Two-Antenna Probe System (used by permission).

In the dual-probe system, the model can be simplified to neglect the transmitter and receiver properties without a loss of generality. In addition, and amplifier may be inserted in the receive path to increase the signal level within the limits of the cross-talk of the two probes. Including an amplifier does not change the basic results of the data that gives us

$$s_i = s_{31} + \frac{s_{32}s_{21}\Gamma_{Li}}{1 - s_{22}\Gamma_{Li}} \tag{3}$$

and with three independent, known loads may be solved to obtain

$$\Gamma_{\text{AUT}} \approx s_{22} = \frac{(s_1 - s_3)\frac{1}{\Gamma_{L1}} - (s_2 - s_3)\frac{1}{\Gamma_{L2}}}{(s_1 - s_2)} \tag{4}$$

and the termination, Γ_{L3}, set to zero (ideal termination). The amplifier would simplify increase the values of the s_i and scales out of the end result of the equation. However, the data will be able to be measured at a higher signal level and not be limited by the dynamic range of the analog-to-digital converter typically used in a vector network analyzer and bring the received signal level further above from the noise limits of the system.

5. Conclusion

This paper presents an alternative method to performing remote impedance measurements of antennas. Data will be presented at the conference, but the basic concept has been presented in this paper. The goal is to reduce the limits on the precision imposed by the dynamic range of the network analyzer used to perform the measurement and the sensitivity level of process.

7. References

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