RF Lab Module #2 — Vector Impedance Measurements

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***Abstract*—In this lab, the Agilent E5071C Network Analyzer was used to measure S-parameters over broadband frequencies. The systematic calibration technique Short Open Load Thru was conducted at the beginning of the measurement process to mitigate the effects of systematic error. Three major components had their S-parameters measured: a 50 Ohm Load, a 3dB attenuator, and a bandpass filter. These component tests allowed for familiarity with metrology in the RF environment to be gained.**

I. Introduction

EXPERTISE in Short Open Load Thru (SOLT) calibration was acquired through the preliminary portion of the RF Microwave Circuits laboratory. This calibration utilizes 2 physical standards. One standard contains the Short Open Load portions and the other contains the thru portion. After calibration, the single port parameters of the 50 Ohm Load were assessed. Next, the 2 port parameters of the 3 dB attenuator and bandpass filter were measured.

II. Analysis

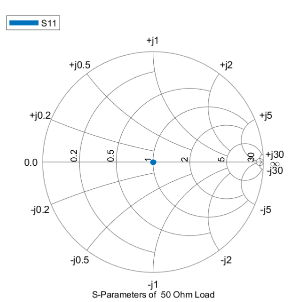

Fig. 1. Smith Chart showing $S_{1,1}$ of 50 Ω

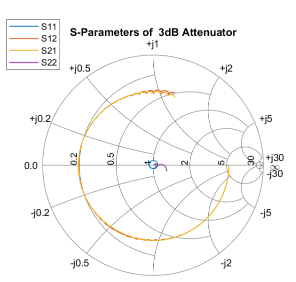

Fig. 2. Smith Chart showing S-parameters of 3 dB attenuator

III. Discussion and Summary

A. Questions to Consider

Why do we need to perform vector impedance measurements to design microwave amplifiers?

S-parameters/vector impedance measurements allow linear systems that operate at high frequencies to be characterized by few parameters that can predict the system's response. These fundamental parameters give the ability to predict how multiple components will interact without actually testing how they interact which facilitates design iteration time. These parameters can predict gain, loss, and the reflection coefficient of a group of components in a system. Vector impedance measurements are fundamental to designing microwave amplifiers because of their ability to describe a system at high frequency operating conditions.

What happens to our measurements if we do not achieve a "good" calibration?

Because calibration such as SOLT mitigates systematic errors, not achieving a "good" calibration means that the systematic error maybe over or under compensated for. Poor calibration results in all measurements containing the same systematic error.

Appendix A
Pre-Lab

Why do we use an SOLT calibration for a 2-port VNA calibration?

Short Open Load Through (SOLT) calibration allows the VNA to properly account for systematic error and thus its effects can be almost entirely removed. It is a common type of calibration that provides "broadband" calibration that is easy to perform.

How does a VNA work? (brief summary of how a VNA makes vector impedance measurements; Length: 1/2 page)

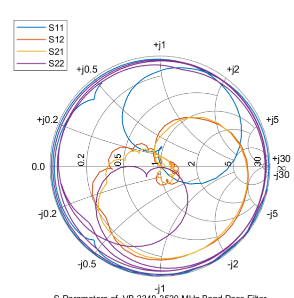

Fig. 3. Smith Chart showing S-parameters of band pass filter

A vector network analyzer (VNA) is comprised of a signal source, signal separators, receivers, and processors. Most sources allow for a signal to be swept across power or frequency. Signal separators allow different signal paths to be analyzed and measured independently. The separators allow for the incident signal to be measured and "ratioed" to the reflected and transmitted signals. The signal are measured with a tuned receiver. This receiver mixes the signal down to an intermediate frequency (IF) utilizing a local oscillator (LO). This frequency usually corresponds to the maximum frequency that the analog to digital converter can handle accurately, at least twice the converters Nyquist criterion. The mixed down signal is passed through a bandpass filter to hone in on the target signal. When the analog to digital convert processes the signal it is likely passed on to a dedicated digital signal processor or other type of computing chip. This chip further processes and formats the data to make it more easily understood by humans. Several algorithms such as the Fast Fourier Transform may be run to understand the frequency characteristics of the signals. Notably, because the received signals correspond to 3 parts of the flow: incident, reflected, and transmitted these digitized signals can be measured and the ratio can be taken between them. This allows a variety of different measurements to be conducted including S-parameters and Transmission/Reflection Tests. Specifically S-parameters/Vector Impedance measurements can be determined by performing mathematical operations between the incident, reflected and transmitted signals in the processor.

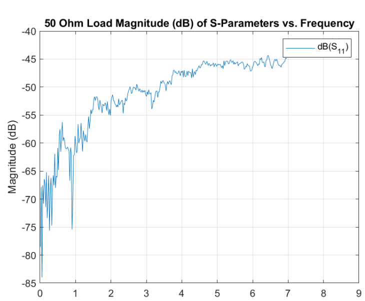

Fig. 4. Frequency plot showing S-parameters of 50 Ω Load

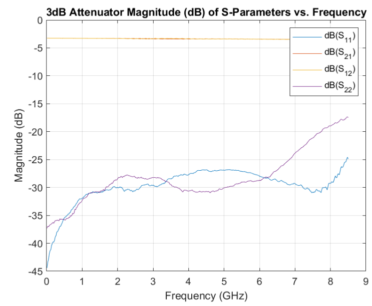

Fig. 5. Frequency plot showing S-parameters of 3dB attenuator

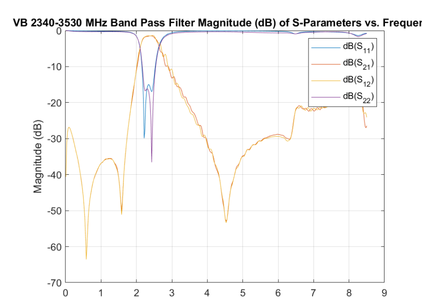

Fig. 6. Frequency plot showing S-parameters of band pass filter