

# Multiport Extension for Measuring N-Port Networks using a Two-Port VNA

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**Introduction:** Many applications require accurate measurements of multiport networks. A particular area of interest considers advanced wireless charging solutions that no longer simply consist of two magnetically coupled coils, but an entire array of coils that can localize, track and charge multiple devices simultaneously. To characterize and optimize such systems, the impedance matrix of the entire system must be known accurately. In the radio frequency range (typically starting at a few MHz and extending well into the hundreds of GHz), this task is usually performed using a vector network analyzer (VNA). These instruments feature a high dynamic range, enabling accurate measurements of very low coupling impedances. However, they typically only feature two to four measurement channels; instruments with more channels are very expensive and not readily available. Measuring multiport networks with two- or four-port VNAs becomes a (prohibitively) tedious and error-prone endeavor and may fail to achieve the required accuracy.

**Objective:** The goal of this thesis is to develop a multiport network extender for network measurements in the frequency range from 50 to 200 kHz and ideally up to 15 MHz. The extender shall provide at least 10 extended ports to a two-port VNA by means of a switching matrix. Because of the expected very low coupling coefficients (typically  $0.001 < k < 1.0$ ) between the coils, very low signal levels are to be expected. Hence, calibration, stability and isolation are key parameters for accurate measurement results. In addition to the hardware development, the evaluation of different switching matrix approaches, the development of a calibration method, an estimation of the achievable accuracy, as well as providing a software solution for handling the VNA and port extender, are part of the project.

**Result:** Two 16-port extenders have been developed (Fig. 2); one is based on a solid-state matrix and the other features a more conventional relay matrix. Both technologies have been pursued, to be able to compare the off-isolation performances (Fig. 3). Both approaches work well in the desired frequency range from 50kHz to 15 MHz. However, at frequencies above 1 MHz, some limitations in the measurement range exist for weak coupling coefficients ( $k < 0.1$ ). These limitations are due to the finite isolation between the on and off channels in the two active extended ports. Various calibration and de-embedding routines have been evaluated, implemented and tested. The resulting accuracy of port-extended measurements has been evaluated via simulations and by comparison to measurements without port extension.

The two extenders have the same mechanical dimensions and interfaces, feature a galvanically decoupled USB interface with the same protocol and are housed in a custom sheet metal housing that shields against electromagnetic interference. A host PC command line interface has been developed to automatically acquire the full impedance matrix of all selected ports.

Fig. 1: The port extender can be used to measure up to 16 networks using a two-port vector network analyzer (VNA). Own presentation

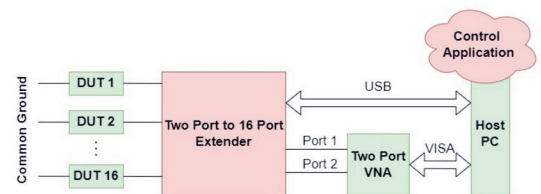


Fig. 2: The finished product features 16 extended ports in a compact form factor and comes in a custom enclosure. Own presentation

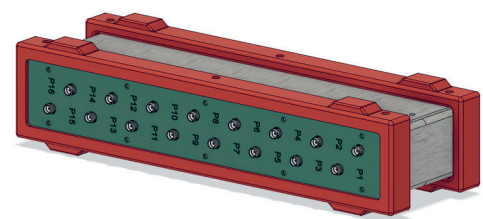


Fig. 3: The solid state port extender board assembled with front panel during testing. Own presentation

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