32nd Linear Accelerator Conference (LINAC2024),Chicago, IL, USA JACoW Publishing
ISBN: 978-3-95450-219-6 ISSN: 2226-0366 doi: 10.18429/JACoW-LINAC2024-MOPB061

DATA ACQUISITION AND CHARACTERIZATION SOFTWARE FOR RADIO-FREQUENCY (RF) SYSTEMS

S. K. Suthar*, B. Popovic
Accelerator Systems Division, Argonne National Laboratory, Lemont, IL, USA

Abstract

In accelerator physics, radio-frequency (rf) systems play a pivotal role in particle beam acceleration and diagnostics. This work presents a graphical interface designed with Python for interaction with rf instruments, enabling efficient data acquisition, processing, and visualization. Leveraging advanced software tools, the system enables efficient management and analysis of rf data. This capability is crucial for optimizing experimentation and streamlining data flow. The modular architecture is implemented on various systems and is demonstrated with the current 200kW Solid State Amplifier (SSA) test setup at the Advanced Photon Source.

INTRODUCTION

Measurement and characterization of rf systems involve a variety of instrumentation, but retain the fundamental process of experimentation: measurement, acquisition, processing, and modelling. The Advanced Photon Source (APS) has a variety of rf systems and structures in operation. To streamline interfacing with these systems, instrumentation can be automated and centralized. Creating these capabilities allows for powerful organization and handling of rf data, which is important for advanced characterization.

METHODOLOGY

Python is employed as the primary development tool for this project. Libraries such as vxi-11, pyvisa, and rs-instrument are used for instrument communication. For data processing matplotlib, numpy, and an in-house rf-based toolboxare used. This choice of software provides compatibility and modularity for the proposed use case. Furthermore, streamlining, centralizing, and automating data acquisition for rf instruments allows for an organized scheme to characterize rf systems. Additionally, industry standard touchstone files are supported for import and exportation of scattering parameters.

DEVELOPMENT

Figure 1 shows some modules of the full GUI. The developed software tool contains modules to interface with many instruments including: Vector Network Analyzers (VNAs), pulsed and CW power meters, and signal generators. By using standardized instrumentation protocols, implementing support for additional instruments can be done easily. Additionally, the system incorporates various functions to process and visualize data.

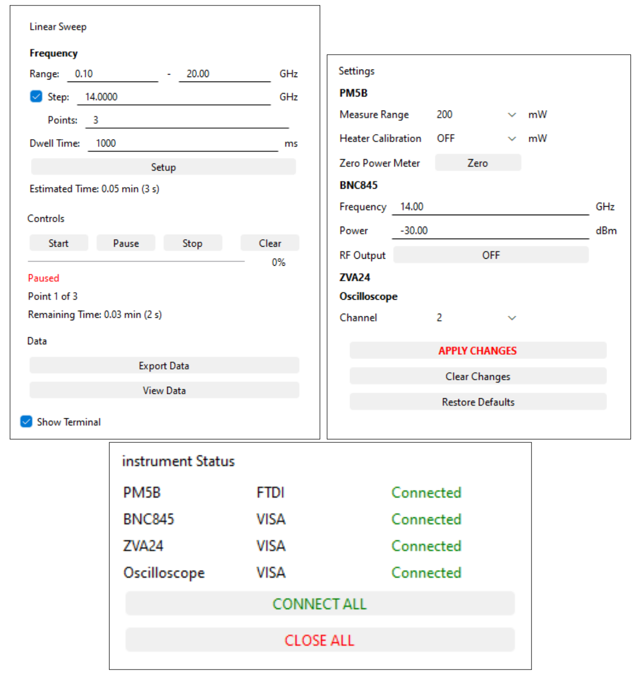

Figure 1: Instrument and experiment modules Left: Experiment module for running sweeps, Right: Settings module for instrument parameter control, Bottom: Instrument connection interface.

As seen in Fig. 2, the plotter module facilitates the analysis of scattering parameter data. A multitude of parameters can be derived from datasets and visualized in various different plot types. Also, various traces and measurements can be overlapped to allow for comparative analyses.

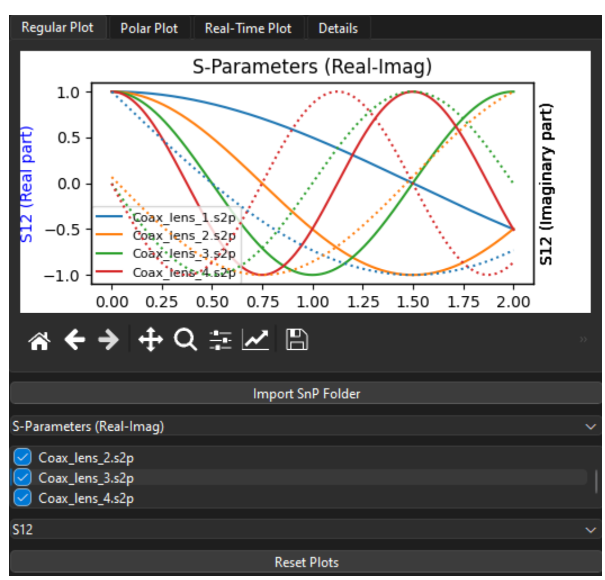

Figure 2: Reader-friendly plotter module.

* sohumksuthar@gmail.com | ssuthar@anl.gov

ISBN: 978-3-95450-219-6 ISSN: 2226-0366 doi: 10.18429/JACoW-LINAC2024-MOPB061

IMPLEMENTATION

Laboratory Experimentation (mm-Wave Lab):

Measurements are performed within the millimeter-Wave laboratory, utilizing advanced rf instruments to collect and characterize data. The software tool interfaces with a VNA in the mm-Wave lab to perform measurements remotely.

Figure 3 depicts an experimental setup with a 2 port attenuator (non-amplified). The VNA is an Rohde & Schwarz ZVA-24 Vector Network Analyzer. Initial sweeps are performed to establish a coarse measurement of the device under test (DUT), providing crucial data for further analysis, shown in Fig. 4.

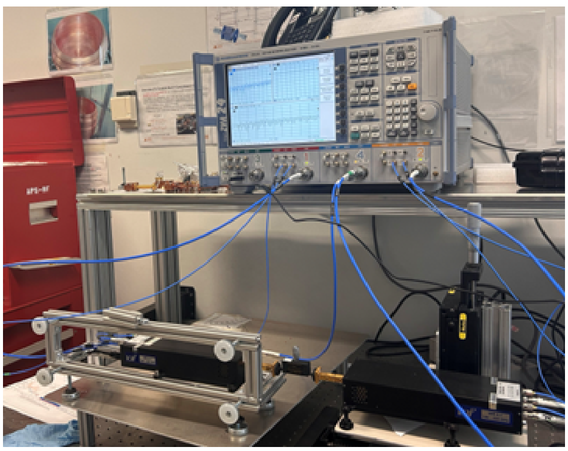

Figure 3: 2-port 140-220GHz attenuator response measurement.

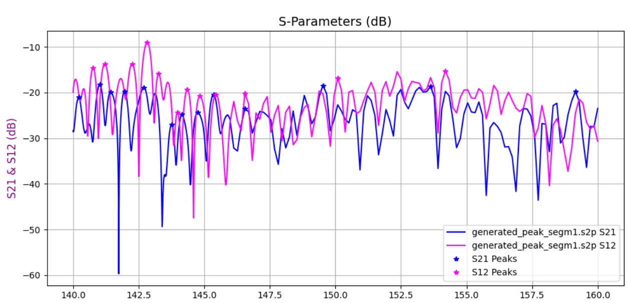

Figure 4: Peaks found from peak-finding algorithm.

The S-parameters are saved via industry-standard touchstone files and plotted within the software.

Measurement techniques, such as segmented sweeps, are employed to gather more detailed data by focusing on specific frequency ranges of interest.

An example of this application, shown in Fig. 5, is an algorithm that finds local and global peaks and then automatically runs a sweep remotely to characterize peaks with a finer resolution. This resolution allows for more advanced analysis. The generated file is a dataset that reflects the points of interest within a measurement with a denser sample rate.

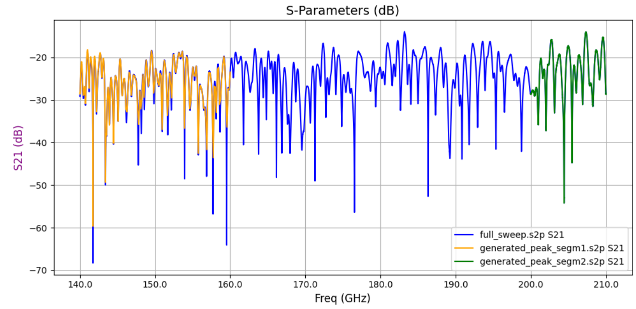

Figure 5: High resolution overlapped S12 result from full segmented sweep.

Similarly, simulation data can be imported and plotted using the plotter module from many different software including CST and COMSOL using touchstone (.SnP) files.

RF Systems Monitoring (SSA)

The GUI developed for modular rf instrumentation was used as a template to include a dedicated module for controlling and monitoring the SSA. This module allows for logging, plotting, and remote instrument control of the instruments in the SSA rack. The interface is designed to monitor the SSA remotely, in real-time.

Data is acquired from the SSA through a secure pipeline between the accelerator network and the Argonne-auth network Fig. 6. A custom Python module is created specifically to interface with the LAN gateway device to provide abstracted control for the individual instruments.

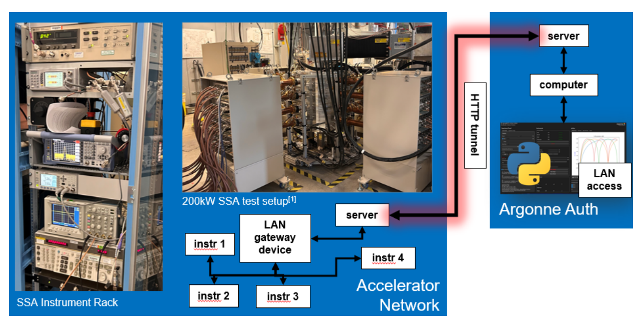

Figure 6: Network diagram of SSA monitoring system [1].

Instruments can be controlled using the interface and new instruments added in-situ to be controlled via the command center shown in Fig. 7.

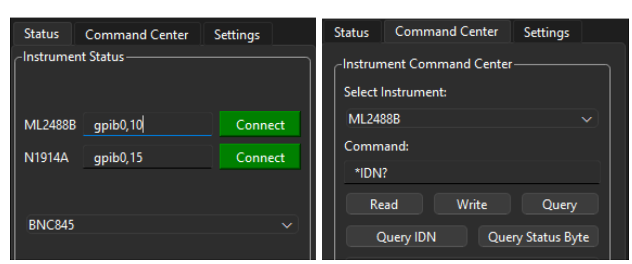

Figure 7: Remote instrumentation control modules.

ISBN: 978-3-95450-219-6 ISSN: 2226-0366 doi: 10.18429/JACoW-LINAC2024-MOPB061

Figure 8 shows real time feedback from instruments being logged along with the data-flow being plotted. This interface is backwards compatible with its parent software and is designed to be seamless and efficient for usage and maintenance.

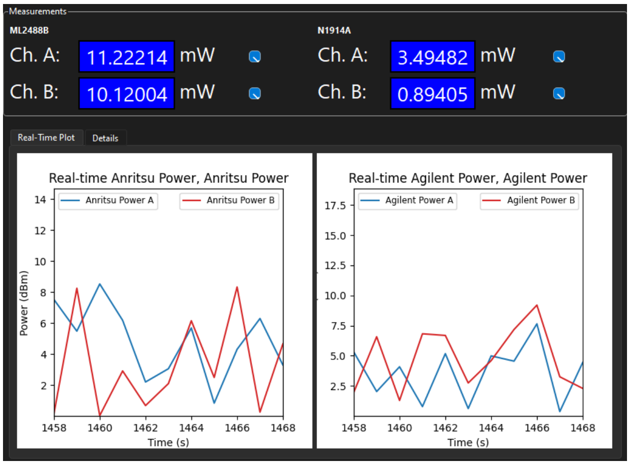

Figure 8: Real time acquisition module for the SSA.

CONCLUSION

The software described provide a modular method for data acquisition and processing. This software proves to be highly capable of rf instrumentation, integrating automation, and detailed visualization. The flexible and modular design allows for easy maintenance and development,

ACKNOWLEDGEMENTS

Luke Adelman for his preliminary development on this project.

REFERENCES

[1] G. J. Waldschmidt, D. J. Bromberek, A. Goel, D. Horan, and A. Nassiri, "High-Power Design of a Cavity Combiner for a 352-MHz Solid State Amplifier System at the Advanced Photon Source", in *Proc. NAPAC'19*, Lansing, MI, USA, Sep. 2019, pp. 113–115. `doi:10.18429/JACoW-NAPAC2019-MOPLM09`