Tech Expo, Spring/Fall 2026 – Team 11

Vector Network Analyzer

PURDUE UNIVERSITY®

Polytechnic Institute

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Problem Statement

- The development of affordable and accessible test equipment remains a challenge in engineering education, particularly for tools such as two-port vector network analyzers (VNAs), which are often cost-prohibitive and complex to operate. This project addresses the need for a low-cost, user-friendly, and accurate two-port VNA suitable for educational environments. The design must achieve adequate measurement accuracy, maintain strong signal integrity, provide sufficient dynamic range, and ensure reliable performance over extended periods of use.

Customer Background

The customer for this project, Indiana Micro, is a company based in West Lafayette, IN. Indiana Micro specializes in tunable/static microwave filters as well as research within the field of RF technology. To aid their research and development endeavors, Indiana Micro has worked with our group over the past 2 semesters to develop a low-cost Vector Network Analyzer (VNA) that is comparable to high-end commercial VNAs. This low-cost VNA can save the company up tens of thousands of dollars without sacrificing the quality of the device.

Requirements

Several requirements for the VNA were agreed upon by the client and the group. One of the key metrics of a vector network analyzer is the frequency range, so the requirement for this project was 50 kHz – 6 GHz. This range allows for 5G, Wi-Fi, microwave, filters, and other devices to be properly tested. A dynamic range of more than 50 dB allows for more accurate measurements of S-parameters. A 2 port VNA allows for measurements of full sets of S-parameters, so having multiple ports on the device was another requirement of the project. A computer is needed as a GUI and interface for the user to configure testing, so a PC or phone connection from the VNA was required. Lastly, the goal was to have the system powered off a single USB connection or power supply. The low voltage ensures that all components of the device are not being overloaded.

Feature/Spec	Concept 1: SDR	Concept 2: NanoVNA	Concept 3: LibreVNA
Cost	< $500	> $500	> $500
Freq. Range Max	3 GHz	3 GHz	6 GHz
Dynamic Range	~ 50 dB	~60 dB	~70 dB
Directivity	< 30 dB	~30 dB	35+ dB
Phase Stability	+/- 5°	+/- 3°	+/- 2°
Reflection Tracking	< 0.2 dB	< 0.2 dB	< 0.2 dB
FPGA?	No	No	Yes
Interface with PC?	Yes, USB	No, has own display	Yes, USB
Sweep Points	Flexible	Flexible	Flexible

FAQ: Concepts and Parameters

Q: What is a Vector Network Analyzer?

A: an instrument used to characterize RF and microwave components by measuring their network parameters (S-parameters), evaluating how they transmit and reflect signals

Q: What are S-parameters?

A: S11 = Reflection seen looking into port 1

- S21 = Forward transmission from port 1 to port 2
- S12 = Reverse transmission from port 2 to port 1
- S22 = Reflection seen looking into port 2

Q: What is the purpose of this VNA project?

A: The purpose of this project is to make a low cost VNA that is affordable and excellent to use for students

Q: What comes next?

A: We will try to better refined our PCB layout and will be integrating all of our separate PCBs into one complete PCB in the end for better packaging and standardization use.

Final Design

The final design of our low-cost Vector Network Analyzer consists of 7 subsystems. These subsystems include the Power Supply, Microcontroller, Clock Distributor, HF Source, Local Oscillator, ADC, and Attenuators and Switches.

Power Supply: This subsystem distributes power to the rest of the subsystems in the VNA. It receives a 6V input, which is then either converted into 5V or 3.3V for voltage, and either 200mA or 350mA for current. This is done using several linear, buck, and boost regulators to send to the microcontroller, ADC, and LO circuits.

HF Source: Provides a stable, known reference signal for accurate, S-parameter measurements. Routes the signal to the appropriate measurement port. Feeds the rest of the RF front-end (couplers, switches, receivers)

Local Oscillator: This subsystem drives mixers to translate signals between RF and intermediate frequencies, enabling accurate measurement of amplitude and phase. By sweeping the LO across frequencies while staying phase-locked to a reference, the VNA achieves precise, coherent characterization of a device under test.

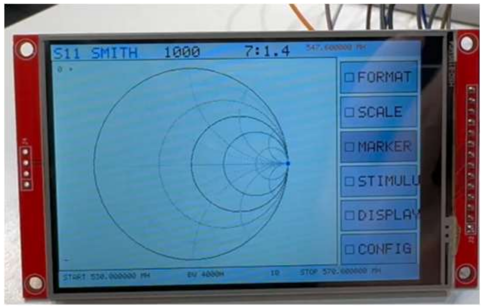
Attenuators / Switches: This subsystem manages signal power levels by using attenuators that are controlled digitally to help optimize the dynamic range of the receiver. High-isolation RF switches are used to route signals to the appropriate corresponding measurement ports.

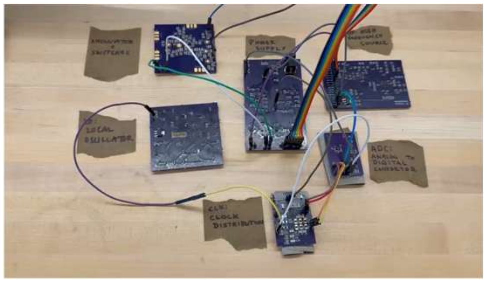
Microcontroller: The microcontroller section is responsible for updating the LCD graphics so users can view and select the on-screen options through the touchscreen LCD interface. It also receives data from the RF front-end boards, processes those signals, and converts the measurement results into the line graphics that are displayed on the LCD.

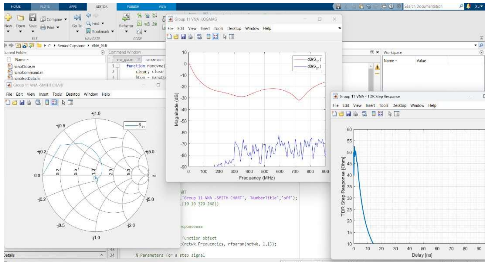
Local Oscillator: This subsystem generates and routes highly stable, phase-synchronized timing signals critical for coherent operation. By locking the local oscillator, ADC, and RF source to a single precision reference, it minimizes phase noise and ensures accurate phase-shift measurements across the entire operating frequency range.

ADC: The Analog-to-Digital Converter subsystem digitizes the down-converted Intermediate Frequency (IF) signals from the RF front-end. It features high-speed, high-resolution sampling to capture wide dynamic range signals, providing the microcontroller with precise digital data necessary for computing accurate magnitude and phase parameters.

Testing and Results







Our integration of the VNA project in the end can output a frequency of up to 6GHz and has a dynamic range of 70dB. The simulation was tested on MATLAB before final integration to ensure proper and correct output waveform graphs. The team was also able to output the correct VNA user interface with screen touch features. Unfortunately, due to the limited budget and time, we weren't be able to get our physical integration of the boards fully working at a high speed. We will further improve our PCB layout and schematic design in the future.