

PocketVNA API documentation

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Brief Info

PocketVNA API allows reading raw (uncalibrated data) from a device. Right now, some calibration stuff is not exposed for external use. But there are simple formulas for [simple compensation](#) (they are [exposed Just in Case in API](#)). Also, there is an excellent [SKRF](#) library for python. It has a lot of RF Math functions along with some calibration algorithms:

SOLT/TOSM, LMR16, TRL...

PocketVNA API is provided as dynamic link library (shared object) with `*.dll` extension (on windows; on linux it is `*.so` and on macos -- `*.dylib`)

Supported platforms

- **Windows** 32bit and 64bit. Tested on Windows 10, 8.1 and 7. In theory, it should work on Windows XP
- **Linux** distributions: tested on OpenSUSE 42; Knipix 7; CentOS7 both 32/64bit, CentOS6.8 both 32/64; Fedora 23/24 64bit; Ubuntu 12 LTS 32bit, 17, 14, 15; Ubuntu 10 LTS but may work improperly :(Pay attention that libudev is used. On older systems there was `libudev0`, now there is newer on `libudev1`. So, for linux there are 4 versions: for `libudev0` x32 and x64 and for `libudev1` x32 and x64
 - So **Modern** distributions contain `libudev1.so`
 - **Old** distributions contain `libudev0.so`
 - Some distribution has actual and alive repos that provide support for elder libraries
- Some PocketVNA devices have a firmware with VCI-usb interface support. So API's for linux and windows may require a `libusb` library. In this case a bundle for Windows will provide it. Linux may require a `libusb` to be installed
- There is a version for **raspbian** jessie/stretch (Raspberry PI). For now, is provided by demand
- **Mac-OS** minimum tested version of Mac-OS is 10.12 Sierra. Apple cancels support 32 bit version, so 32 bit version will be available for older versions only on demand (and not guaranteed)

Package Content

Distributed API archive contains following

Examples and bindings

- `pocketvna.py` -- binding for python.
- Python examples:

- SOTL/TOSM calibration
 - **make_solt_standard.py** -- example script for collecting measurements for SOLT/TOSM calibration. This script collects data for SOLT calibration along with Raw Measurements and stores them into touchstones files.
 - **skrf_solt_calibration.py** -- example of performing SOLT calibration ([implementation from SKRF library](#)). It takes data from touchstones files from **make_solt_standard.py** script
- LMR16 calibration
 - **make_lmr16_standard.py** -- example script for taking calibration standards for LMR16 along with raw measurements. Taken data is stored into touchstone files
 - **skrf_LMR16_calibration.py** -- example of performing LMR16 ([from SKRF](#)). It loads data from **make_lmr16_standard.py** script
- Simple compensation
 - **make_simple_compensation_standard.py** -- example for collecting data for simple compensation
 - **simple_compensation_calibration.py** -- example of performing [Simple Compensation](#) (per network parameter separately)
- **force-unlock-devices.py** -- script to force unlock devices. Unfortunately, it is not a good idea to connect several concurrent connections to the same “PocketVNA” device simultaneously. On some Operating Systems (MacOS) it is performed automatically and a program/connection has exclusive access rights. But on others OS-es (Linux) do not restrict access so we need to imitate it manually. But if a program crashes unexpectedly or is killed a lock may survive. To remove such a lock this program may be used. It calls [force_unlock_devices](#) function
- **python_example.py** -- example of using API. Should work on pythons starting from 2.7
- **python_simplified_example.py** -- example of using simplified connection “[get_first_device_handle](#)”.
- **pyth_unittests.py** -- mostly for internal use. I've added it as an additional example of python API use. It tests pocketVNA 2.10 devices
- **pocketvna.h** -- C-header file for API
- **api_cpp_example** -- Example of using libPocketVnaAPI on C++:
 - Project file is qmake's “**cpp-simple-example.pro**”
- Octave binding Example (Just an example)
 - **pocketvna-octave.cc** -- example of octave module. For now it is just an example. Nothing more
 - **compile-pocketvna-octave.sh** -- script to compile octave module
 - **octave_usage_example.m** -- example of using octave pocketvna module. Just an example

- **CSharp_PocketVNA_Example** -- a visual studio (2015) solution, example of using API. [More details in the C# section below.](#)
- **firmware_hex** -- firmware versions
- device update
- **libPocketVnaApi[_x64|_x32].(so|dll|dylib)** -- shared object/dynamic library for our API

Windows Specific

Elder devices supported only one interface: **HID**. Newer devices/firmwares support 2 interfaces: **HID** and **VCI**. **VCI** is faster. On some devices drastically faster than **HID**. Unfortunately, on windows this **VCI** requires installation of a special driver. It either should be provided by a vendor (but we don't), or by using [zadig](#) or [UsbDk](#). **Zadig** is preferable. So, if your device supports both interfaces the list(enumeration) with available devices will have 2 connections for the device. You can choose a proper connection descriptor and connect against it instead of using simple helper argument-less open. You can find out the interface by a special field (`connectionInterface` get-accessor in C#; `InterfaceCode` field for python; `ciface_code` in C so on). Instructions on how to install a driver using zadig see another document ("PocketVNA-VCI-driver"). It has to be provided in an API or GUI bundle.

Linux Specific

- **98-pocketvna-udev.rules** -- rule file (to gain permissions for reading device) and script to install it
- **installPocketVNArule.sh** -- installer for rules file
- **README_PERMISSION** - brief information about permissions for usb devices

MacOS Specific

- Our API is distributed in a form of *.dylib file
- It may cause issues like this blocking error: `"...dylib" can't be opened because Apple cannot check it for malicious software. Even though it's a signed file. It seems that notarization fixed this issue for now. In case of the issue you can copy this file from a GUI app bundle`

Using API

Api is written using pure C and distributed as a dynamic library (shared object). Thus a wrapper may be written in any language that supports loading dynamic libraries. Number of such wrappers are provided. For example C++, C#, python, octave
Our Gui Application uses this API too. Looks kind of test

Workflow

Take measurements

Connect against the device. First:

- Check if any device is available. In other words **Enumerate Devices**
- If any device is available **Open** one, for example a first one. Unfortunately, on some systems it is hard to distinguish pocketVNA devices. So for now, use a first one

Or, second way, Instead of the previous 2 steps it is possible to use a newer helper function [get_first_device_handle](#). Which returns Ok status with a valid device handler if connection open successfully

Pay attention: that newer firmware supports 2 interfaces:

1. **HID** -- it is universal and easy. Supported by all platforms. But it is slow
2. **VCI** -- available since firmware V2.10. On Windows requires a special driver (for example [zadig](#)/Interface 1) It is faster. May be unavailable on Mac-OS

In this case both interfaces are listed as individual (separated/independent) items with the same Serial Number.

It is bad idea to connect both interfaces at the same time and especially bad to perform scan concurrently

Next

- If it is required, get device information like:
 - **Characteristic Impedance** (Z_0) . Right now the device should return it as 50Ω .
 - **Valid Range** -- if needed. A frequency range device can digest. Api accepts frequency of this range without error, but the results may be imperfect. For example, right now it is [1Hz ; 6GHz]
 - **Reasonable Range** -- a frequency range that produces good results. It is narrower than the **Valid Range**. For some devices now it is [500kHz ; 4GHz]
 - **Supported Network parameters** -- older devices (with older firmware) were **One Path** (forward only; S11 and S21). Whereas, newer devices (with a newer firmware) have full network support (S11/S21/S12/S22)
- Form an array of frequency points that are interesting. Take into account, it should fit into the **Visible Range**, but it would be better to fit it into **Reasonable Range**
- Call scan for these frequency points
- API returns raw non-calibrated data. So it must be calibrated or compensated. API provides [Simple Compensation](#) . Pay attention to [what is the calibration for "pocketVNA" devices](#).
- Close device if it is not required anymore.

Each function returns result code. If the query is successful it should be **OK**. Otherwise, it returns another code. Each code can be converted into a string representation. If the device is disconnected, any api call should return **InvalidHandle**.

Compensation/Calibration Data

The workflow for taking the compensation data is similar to [Taking measurements](#) above. You may organize it in a separate application and store the data into a file. Then, when you need to calibrate the raw measurements you just have to load the compensation data and pass it into Formulae ([reflection](#) or [transmission](#)) or into [functions](#) provided

Function Descriptions

Pay attention that each function is prefixed by "**pocketvna_**". As a complex number, "**SParam**" struct is used. In theory, it is compatible with **double complex** of C language (C99 type)

Driver routines:

- "**driver_version**" -- this function fills the first parameter (uint16) with driver version, and the second parameter (double64) with number PI. Also, this function always returns status OK. It is done for testing purposes, thus you can check if binding works properly. *It is not required to call this function*
- "**close**" -- It would be nice to call it when you do not need the library anymore. But it is not strictly necessary. This function clears internal resources. But, **pay attention**, on some OSes if you close driver but then use it for another subroutine the crash may happen
- "**result_string**" -- get string representation for **ResultEnum** code. Almost each function returns **ResultEnum**. This function returns text description for it

Connection Management:

- "**list_devices**" -- fills the first address with an array of **device descriptors** (**DeviceDesc** structure). Second parameter is filled with size. It returns status either **Ok** (if there is any device) or **NoDevice** (no device available).
- "**free_list**" -- frees memory taken with **device descriptors**. Notice that you can copy descriptor into process memory, thus you does not need to store device descriptors during a long period of time
- "**get_device_handle_for**" -- In other words, "open device" command, takes a **device descriptor** as the first parameter and fills the second parameter with a **device handle**. If a device descriptor contains a path equal to "**simulation**" then a **simulation handle** will be returned. **Device handle** will be used for any further device specific function. Returns statuses (most:
 - **BadDescriptor** -- invalid descriptor is passed

- **NoAccess** -- linux specific, it does mean that device looks available but you have no permission to access it. See README_PERMISSION (permissions/README)
- **FailedToOpen** -- it is failed to open for some “unknown” reason
- **Ok** -- connected. **Device handle** must become valid and should not be equal to Zero (null, NULL, None so on)
- **"release_handle"** -- in other words “close device”. In theory, it always returns **Ok**. After the call passing **Device handle** must become zero.
- **"get_first_device_handle"** -- just a helper For simplicity. The intended workflow is: call **list_devices**. If there is any device then call **get_device_handle_for** and freeing list's memory by **free_list**. But sometimes it is not convenient, especially for some languages because it requires definition of complex structures wrappers. This function opens any device if available. It accepts just an address of the handler. Function returns the same result as **get_device_handle_for**.

A simulation handle -- imitates a device which returns random data.

Device work:

All functions accept **Device handle** as the first parameter. If the device is disconnected, or the handler is not valid all these functions return **InvalidHandle**.

- **"is_valid"** -- checks if **Device handle** is valid. Returns **InvalidHandle** or **Ok**. Zero handler is **InvalidHandle** too
- **"version"** -- firmware version
- **"get_characteristic_impedance"** -- fills the second parameter (double64) with Characteristic Impedance (Z_0). It should be 50Ω
- **"get_valid_frequency_range"** -- frequency range device can accept
- **"get_reasonable_frequency_range"** -- a frequency range that produces good results
- **"is_transmission_supported"** -- check if Network parameter (transmission/mode) is supported. Elder devices (with elder firmware) were **One Path** (S11 and S21 only). Newer firmwares are full-network. Second parameter is one of **NetworkParam** items:
 - **Ok** -- network parameter is supported
 - **UnsupportedTransmission** -- network parameter is not supported. For example S12 on elder devices
 - **BadTransmission** -- unrecognized second parameter
- **"single_query"** -- take measurement for a single **frequency point**. It is better to use **"multi_query"** for it is more optimized.
 - Parameters
 - **frequency** -- uint64. Should be inside **valid range**
 - **average** -- third parameter, how many times to read network parameter (and take average for that)

- **Network Parameters** -- S11, S21, S12 or S22. Pay attention, it is possible to combine them with bitwise or statement, like: S11|S22 -- take only S11 and S22.
- 4 network parameters (s11, s21, s12, s22) -- each network parameter will be stored into the corresponding address. If Network Parameters do not contain any, the address will be unchanged.
- **"multi_query"** -- similar to **"single_query"** but for several **frequency points**. It is preferable to use this one
- **"multi_query_with_cproc"** -- like **"multi_query"**. But in contrast to **"multi_query"** it accepts a simple C function as progress callback. Previous function accepts struct with function pointer, to imitate function-objects
- **"range_query"** -- in contrast to **"multi_query"** it takes start and end frequencies. 2 distributions are available: Linear (logspace) and Linear (linspace)
- **"4p_scan..." family** -- you don't need it. It's for interaction with 4-port devices that are under development

Calibration purposes:

These functions expose a simple compensation (calibration) [algorithm](#) (see below). This compensation is applying for each network parameter separately. Pay attention, that frequency points for Raw Measurements and Calibration data should be the same

- **"rfmath_calibrate_reflection"** -- implementation of [compensation for reflection](#) parameters (S11 or S22).
- **"rfmath_calibrate_transmission"** -- implementation [of compensation for transmission](#) (S21 or S12)

Debug purposes:

These functions are for internal and debug/testing purposes. Probably, you do not.

- **"debug_response"** -- for testing purposes, for example to check binding (ABI). Accepts two arrays (last 2 parameters) of a particular size (2nd parameter) and fills it using pattern
 - Fills p1/p2 using pattern (i -- zero based index)
 - `p1[i].real = Pi / (i+1)`
 - `p1[i].imag = 1. / p1[i].real`
 - `p2[i].real = Pi * i`
 - `p2[i].imag = Pi ^ (i+1)`
- **force_unlock_devices** -- unlocks locked devices. To limit the number of connections to a single device a semaphore is used. But if an application crashes or it is killed it may cause semaphore leak. Mostly for linux. This function resets the semaphore.

Provided examples and bindings

Please treat examples as examples, not as high quality production code. Use them carefully. Probably later they will become well tested production code

C

Consists of the “`pocketvna.h`” header file. Pay attention that on Windows MinGW-GCC is used. This is the most tested binding, for we use it on our GUI project.

Examples of using can be found in “`api_cpp_example`” and “`pocketvna_octave.cc`”. API has a [Simple Compensation](#) algorithm exposed. **Pay attention:** Now, these 2 examples should be treated as examples.

Visual Studio

Although dll is compiled with MinGW-GCC on windows it is not hard to use it from Visual C++. But VSCPP does not support using dll directly. Also it does not support *.a archives. So only *.lib file. If it is not provided in a bundle It can be generated manually. Some instructions can be found here: <https://wiki.videolan.org/GenerateLibFromDll>

Recently we have included a DEF (Module Definition) file into the API bundle. So the last step of generating a lib file is required only. Generating lib file from a DEF file:

- Patch `pocket-vna.def` (the DEF file) itself so that it has the correct **LIBRARY** section. For example if `PocketVnaApi_x32.dll` is used then the first line should be “`LIBRARY PocketVnaApi_x32`” (or rename `PocketVnaApi_x32.dll` into `PocketVnaApi.dll` :))
- Open Visual Studio Native Tools Command Prompt
- Execute the following command

```
lib /def:"pocket-vna.def" /out:PocketVnaAPI_x32.lib /machine:x86
```
- Pay attention that for 64 bit machine should be “`x64`”

```
lib /def:"pocket-vna.def" /out:PocketVnaAPI_x32.lib /machine:x64
```
- That is all.

Now It can be used in a project

- Include `pocketvna.h`
- Add library `PocketVnaAPI_x32.lib` into project properties in the linker section. Alternatively, for simplicity, `#pragma comment(lib, "PocketVnaApi_x32.lib")` can be used
- Make sure that `PocketVnaApi_x32.dll` and `libusb1.0.dll` (if required) are available in PATH whatever it means
- That's all. API can be used

Python

Binding is in “[pocketvna.py](#)”. It would be nice if you have **numpy** and [skrf](#) installed. If **numpy** is not installed then the API returns a python list as results. If **numpy** is installed API returns **numpy**’s arrays and this is much more convenient.

Please pay attention to skrf (<http://scikit-rf.readthedocs.io>) library. It has a lot of interesting RF related routines along with a variety of calibration algorithms. Check python scripts inside the package to learn how to use it. Basic example: “[python_example.py](#)” and “[pyth_unittest.py](#)”. Examples for calibration algorithm are provided too

In a few words:

- Make sure “[pocketvna.py](#)” and PocketVnaApi (.dll, .so, .dylib) are in the same directory
- Import “[pocketvna.py](#)”
- Connect device
- Read raw data

C# example

CSharp_PocketVNA_Example folder contains Visual Studio (2015) solution for C# project. “PocketVNA.cs” -- simple binding, And “PocketVNADevice.cs” -- wrapper for “PocketVNA.cs” that is more convenient for use.

To use PocketVNA API

- just import “PocketVNA.cs” and “PocketVNADevice.cs”
- Add reference to “[System.Numerics](#)” which provides Complex numbers support
- Make sure PocketVnaApi.dll is available. (PocketVnaApi_x32.dll or PocketVnaApi_x64.dll depending on selected bitness). It is 13-19 lines in “PocketVNA.cs”. It can be done either by hardcoding path to library or by modifying variable: Solution Explorer > Properties > Debug > Working Directory

The solution contains following projects

1. PocketVNA_Example -- it contains binding files and some examples of using it
 - a. PocketVNA.cs -- binding to PocketVNA.dll
 - b. PocketVNADevice.cs -- wrapper for PocketVNA.cs.
 - c. UsingSimpleAPIExample.cs -- example of using PocketVNA class
 - d. UsingBuiltInCalibrationExample.cs -- example of using [compensation algorithm](#) provided by PocketVNA.dll
 - e. CompensationCollector.cs -- example of collecting calibration data for [compensation algorithm](#)
 - f. CompensationAlgorithm.cs -- using C# implementation of [compensation algorithm](#)
2. Example_OpenDeviceLocally -- demonstrates that device can be opened only when needed and closed immediately

3. `Example_CollectFullCalibrationData` -- Example how to take calibration data and dump it into a **simplest binary file**
4. `Example_TakeMeasurementsAndCalibrateOverDumpedData` -- Demonstrate how to take measurements and calibrate them over calibration data loaded from the **simplest binary file**.
5. `Example_TakeMeasurementsAndPlot` -- GUI example. **Please note** that it uses **Microsoft Chart Controls** library. The example demonstrates a simple window with a chart. It is possible to initiate scan (if device present); It allows switching port to be shown on a chart; It also allows switching between formats. If the **simplest binary file** made by `Example_CollectFullCalibrationData` is found then it is possible to switch between calibrated and uncalibrated data .

Octave

There is no possibility in octave to load C PocketVnaApi.dll (so, dylib). It can be done with C++ api.

In Linux it is required to install "Octave development package" and `patchelf`.

Example of API binding is inside: `"pocketvna-octave.cc"`

There are Instructions for compilation in `"compile-pocketvna-octave.sh"`

https://www.gnu.org/software/octave/doc/interpreter/index.html#SEC_Contents

https://www.gnu.org/software/octave/doc/interpreter/Oct_002dFiles.html#Oct_002dFiles

Example of using such a binding is in `"octave_usage_example.m"`

These files are just examples and may be very imperfect. Now it is rather a proof of concept.

May be enhanced on demand

MATLAB

Example of using Matlab exists. For now it is done using `loadlibrary`

<https://www.mathworks.com/help/matlab/ref/loadlibrary.html> with automatic binding generation.

`@protofile` is not provided for now. This means that you have to have GCC available. On

Windows you need to install MinGW. Some instructions are provided inside example

`pocketVNAMatlabExample.m`.

Binding is done for `PocketVnaApi_x64.dll`. For other OSes or for 32bit either rename the library or patch example file.

LabView

LabView examples are available separately. NI LabView 2018 x32 bit for Windows is used.

There are two examples of using API:

1. `_Example_GetForSinglePoint.vi` -- taking measurements for a single frequency step. Pay attention on Parameters enum: S11, S21, S12, S22, Full can be selected

2. `_Example_GetProperties.vi` -- getting some properties from a device such as frequency range, Z0, version, supported network parameters
3. `_Example_ListScan` -- collect data for frequencies list and plot S11 on a chart. It uses [Ramp Pattern](#) for generating `linspace` frequency. This feature may be unavailable on Base version
4. `_Example_UsingMultiScan.vi` -- collect data and show it on a chart.
5. `_Example_DebugTestBindingWorks.vi` -- for debug purposes. I may help to test compatibility on linux or 64bit
6. `_Example_EnumerateConnections.vi` -- example of enumerating available connections/devices. Pay attention that one device may have 2 interfaces available and each one is enumerated as a separated thing:
 - a. HID -- universal but pretty slow
 - b. VCI -- On firmware V2.10. Requires drivers on windows. Faster
7. `GetValueByPointer VI` (`<LabVIEW>\vi.lib\Utility\imports\GetValueByPointer\GetValueByPointer.xnode`) is used. I hope it is available on most systems. It is used to dereference `const wchar_t * string`
8. `_Example_ConnectByDescriptor.vi` -- example of choosing device/connection by a descriptor/index.
9. **Disclaimers**
 - a. The example is made on the 32bit version. In case of using the 64bit version make sure that all handlers are "Unsigned Int 64". Because by default LABVIEW uses a 32bit integer that may lead to bugs and crashes on 64bit version. I've changed the pointer type to "Pointer sized Unsigned Int". Hope it works but it is not tested.
 - b. `DeviceHandle` and `DeviceDesc * list` are pointers
 - c. Connection to `pocketVNA.dll` is rigid. There are two folders: `dll_x32` and `dll_x64`. Each one contains its own `PocketVNA.dll`. Opening on the 64bit version requires changing the path to `pocketVNA.dll`: choose `dll_x64/PocketVNA.dll`.
 - d. On the newer versions of "API" there is `libusb1.0.dll`. This file is important
 - e. The example is made using NI LabView 2018. For the older version I can use the ["Saving for a Previous Version"](#) feature on demand.
 - f. Make sure that you do not have several LabView examples unpacked. It may happen that the current example references the older version of `PocketVNA.dll`.
 - g. **I'm labview-ignorant**. So treat these examples as "Just Examples". They are ugly, have a bad look
 - h. Probably, it would be better to use C# or even python. It looks like it is not hard to use them from LABVIEW

The simplest workflow to scan anything

- Call `pocketvna get first device handle.vi`
- If getting device handle succeeded (error code is 0 and handle is not 0)
 - Call `pocketvna single query.vi` for each frequency point that is interesting for you
 - If device is not required anymore call `pocketvna release handle.vi`

The simplest workflow to get some device properties

- Call `pocketvna get first device handle.vi`
- If getting device handle succeeded
 - Call `get characteristic impedance.vi` for Z0/Characteristic Impedance
 - Call `pocketvna get reasonable frequency range.vi` to get a reasonable frequency range. It is a range which device produces
 - `pocketvna get valid frequency range.vi -- get valid frequency range for a device`
 - `pocketvna is transmission supported.vi -- check if transmission supported`
 - If device is not required anymore call `pocketvna release handle.vi`

It is very important to “release handle”. Especially on linux systems. Especially if you don’t want to re-open LABVIEW each time.

Simple Compensation

Algorithms are applied to each parameter separately. It means you don’t need a full network. You can collect data that is interesting for you and omit others.

What is a calibration/compensation for pocketVNA device

One Important Note:

1. For our device a calibration does not belong to the device itself. Rather it belongs to measurements. So probably, it would be better to use “Compensation” instead of “Calibration” term.
2. Calibration data taken for one device may be incompatible with another device.
3. When you take measurements from the device you receive raw, calibrated and "meaningless" data. These raw measurements must be calibrated (or compensated).
4. When you take calibration data nothing will be changed inside the device. Nothing will be changed inside the API.
5. Neither the device nor the API does not know whether calibration data are taken or not.
6. To calibrate these raw measurements you have to apply a calibration/compensation algorithm. You have to pass the calibration data and the raw measurements into formula
7. By taking calibration data you do not affect the next scan.
8. After taking calibration data you'll receive very similar raw measurements as were before
9. That's why you don't have to make a "calibration" each time you run an application or connect a device

Reflection mode

$$Z_{dut} = Z_{std} \frac{(Z_o - Z_{sm})(Z_{xm} - Z_s)}{(Z_{sm} - Z_s)(Z_o - Z_{xm})}$$

Zs -- calibration Z11 (impedance, complex) short parameter

Z_o -- calibration Z_{11} (impedance, complex) open parameter for particular frequency point
 Z_{sm} -- calibration Z_{11} (impedance, complex) load parameter for particular frequency point
 Z_{xm} -- calibration Z_{11} (impedance, complex) measurement data for particular frequency point
 Z_{std} -- reference resistance. 50 by default

* Taken from “The Impedance Measurement Handbook” Agilent Technologies

** Pay attention this formula requires Impedance API returns Gamma (S): $S \Leftrightarrow Z$

$$Z = Z_0 \frac{1 + \Gamma}{1 - \Gamma}, \text{ where } Z_0 = R_0 = Z_{std} \text{ (Usually } 50\Omega\text{)}$$

$$\Gamma = \frac{Z - Z_0}{Z + Z_0}$$

Transmission/Through mode

$$S_{dut} = \frac{S_{xm} - S_o}{S_{thru} - S_o}$$

- S_{xm} -- S21 (S12) measurements data
- S_o -- S21 (S12) open data taken from calibration data for particular **frequency point**
- S_{thru} -- S21 (S12) through data taken from calibration data for particular **frequency point**

Implementation

Pay attention: python has an excellent [skrf](#) library which provides a variety of routines for operations over Rf-Networks along with calibrations algorithms: TRL, LMR16, TOSM so on

These compensation functions are exposed in [api](#). Pay attention, that functions in API accept S-parameters. No conversion is required. In other words:

- collect calibration data and store them **as is**
- Read raw measurements and store them **as is**
- Pass needed parameters **as is** into these functions.
- Get calibrated data

C/C++

Functions are exposed in [api](#). See “[api_cpp_example/calibration-example.cpp](#)”

C#

It contains 2 examples:

1. Using built-in api that can be found in "UsingBuiltInCalibrationExample.cs". It is designed as a test. So it is more preferable to rely on this example.
2. Another, is an example of implementation of the simple compensation formulas on C#. There is `pocketvna.PocketVNADevice.Math` class which has 2 functions: `ReflectionCompensation` and `TransmissionCompensation`. They implement those formulas above
 - "CompensationCollector.cs" contains example of collecting data for compensation algorithm
 - "CompensationAlgorithm.cs" represents example of applying the algorithm

Python

Using built-in [api](#) functions are exposed in "pyth_unittest.py". See class `TestRfMathCalibration`

Also there are some additional examples of collecting data and calibrating/compensating it. Pay attention `numpy` and `skrf` are required

Simple Compensation

- "make_simple_compensation_standard.py" -- collecting measurements
- "simple_compensation_calibration.py" -- example of applying those compensation formulas

GUI's calibration files (*.cali)

Our calibration file's format is pretty simple:

- It is a plain text file
- Measurements are located between "{STARTCALI:" and "}ENDCALI" tags
- First line shows titles
- Each line contains measurements for a particular frequency
- Numbers are semi-colon (;) separated
- First parameter in a line contains frequency always
- Rest are complex numbers separated with comma (,)
- The only thing is all parameters are S-Parameters even though column titles contain 'z' suffix

API bundle may contain "additional examples" which provide a python script for loading calibration files.

- “additional-examples\pocketvna_calibration_loader.py” -- loader for GUI Application’s calibration file
- “additional-examples\calibration_example_TOSM.py” -- example of loading TOSM/SOLT calibration file using [scikit-rf](#) ([skrf](#)). Interpolation is done using skrf’s built-in functions
- “additional-examples\calibration_example_SIMPLE.py” -- example of loading simple compensation. Interpolation is done using scipy inside “pocketvna_calibration_loader.py”

Results may be slightly different from GUI’s. There are different ways to interpolate points. **Pay attention:** if a frequency set of DUT measurements is different from calibration’s one then there is a need to interpolate calibration data to DUT’s frequencies.

Signal Generator

Currently there is no dedicated function for this purpose. Gui Application implements this feature using usual scan functions like [multi_query](#) (or [range_query](#)) . By passing a frequency a f (or range $[f; f]$), and parameter `S11` for port-1 or `S22` for port-2. Device works as a state machine: the frequency signal remains on the port until the next new frequency point requested. If it’s required to remove signal from the port the scan for the opposite port may be used:

For example run signal on **port-1**:

```
frequencies = { 1_GHz }
quality = 1
multi_query(frequencies, quality, NetworkParams.S11) # run 1GHz on
port-1 (no signal on Port-2)
```

Remove signal from **port-2**:

```
multi_query(frequencies, quality, NetworkParams.S22) # remove signal from
port-1 (1GHz on port-2)
```

Regarding periodic signals: we don’t have such a feature. It would be imitated using the above algorithm but there are some limitations: setting up frequency on a device requires some time. Also there are some limitations for interactions with USB and OS.

FAQ

- **Is it possible to connect two devices for the same application?**
- **Is it possible to select between two devices that are connected simultaneously**
 - Yes it is. But there are some notes:
 - DeviceDesc should be a valid path. Otherwise vip/pid will be used which is the same for all devices.
- **Is lower level protocols available**

- Rather No. Device's firmware is pretty simple: it accepts frequency points and returns S-parameter codes for each one. Decoding, enhancements and fixes (also depending on firmware/device version) are hidden inside the API library. Exposing them is not a good idea.
- Moreover, Firmware is harder to update, so in case of some issue it is easier to update the API than the firmware. Providing support of such protocols would be a headache.
- **How can I be sure the firmware on the VNA is not crashed?**
 - Usually Firmware does not crash on an operable (non-fault) device. In case of a crash a device can not be recognized with an Operating System. For example with `usbview.exe`.
 - Api has `is_valid` function to check if the handler is still valid.
 - If device was disconnected for some reason (including issues in OS) any operation returns `HandlerInvalid` error code (instead of OK)
 - In case of time consuming blocking call like `multi_query` or `range_query` the callback function can be passed which can, for example, notify progress so that you may know if operation performs or hang-up
 - In case of a crash in our Software (API dll) you app/thread/process will be crashed too :)
- **Where can I find an API for GUI's calibration file (*.cali)?**
 - We don't have such an API exposed. But if you need such a thing see [the section above](#).
- **Which IDE is used for python?**
 - <https://code.visualstudio.com/>