http://gadget.renesas.com/en/contest/2017/ASEAN/cmn/img/logo.png**GR PEACH DESIGN CONTEST 2017**

Low-cost vector network analyzer – VNA for measuring the antenna of IoT devices

* 1. **Introduction**

The project presents a device that analyzes qualities of the antenna in IoT devices by using the low cost embedded modules. It's used for developing wireless communication devices. The low cost VNA based on the principle of comparison between transmitted wave and reflected wave on the antenna to compute the reflected factor and appreciate qualities of the antenna.

Nowadays, the IoT field is developing significantly, so the quality requirements of IoT devices is not only about the stable operation of itself but also a good ability in communicating with other IoT devices. Therefore, the demand of analyzing qualities of the antenna is more necessary. However, the solutions, as well as devices that analyze the quality of the antenna, are still not popular and expensive.

To measuring the quality of antenna, the RF loss that is created by antenna will be analyzed. There are some machines/devices can do this task such as:

* + - * **Voltage Standing Wave Ratio Meter (SWR Meter or VSWR Meter)[[1]](#footnote-1)**
* The SWR meter or VSWR (voltage standing wave ratio) meter measures the standing wave ratio in a transmission line. The meter can be used to indicate the degree of mismatch between a transmission line and its load (usually a radio antenna), or evaluate the effectiveness of impedance matching efforts. Unless there is any reflection from the antenna in a transmission line, the standing wave ratio is 1.
* The **advantage** of SWR is using software to simplify the hardware and reduce cost.
* Themain **disadvantage** of SWR is that SWR meter does not measure the actual impedance of a load (the resistance and reactance), but only the mismatch ratio.
  + - * **Scalar Network Analyzer (SNA)[[2]](#footnote-2)**
* SNA is a device used for characterizing or measuring the response of devices at RF or even microwave frequencies. SNA works just as a spectrum analyzer in combination with a tracking generator but only measures the amplitude properties of the device under test.
* The main **advantage** of SNA is that the hardware required for down-conversion and power detection is relatively simple and inexpensive. In addition, because the detectors are broadband devices, it is unnecessary to re-tune the receiver to measure power at a different frequency.
* There are some **disadvantages** of SNA. Broadband detectors are susceptible to spurious tones and broadband noise. In addition, because the calibration is scalar in nature, it is not as accurate as full vector calibration. Due to their lack of selectivity, scalar network analyzers tend to have limited dynamic range compared to vector network analyzers.
  + - * **Vector Network Analyzer (VNA)[[3]](#footnote-3)[[4]](#footnote-4)**
* VNA is a basic type of network analyzers like SNA that measures both amplitude and phase properties.
* There are 2 main types of VNA:
* Normal VNA:
* **Pros**: Broadband, popular.
* **Cons**: High cost, large size.
* System on chip VNA:
* **Pros**: Broadband, small size (System on chip).
* **Cons**: Using complex VLSI technology, production expense is high, still in research.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Cost** | **Size** | **Frequency** |
| **SWR Meter** | Low | Small | Low (Under 600MHz) |
| **SNA** | Low | Large | High |
| **Normal VNA** | High | Large | High |
| **SoC VNA** | Still in research | Small | High (4GHz – 32GHz) |

Table 1. Comparison of different devices

After reviewing these solutions as well as devices, our team decides to make a device having all advantages above and get rid of all disadvantages:

* Cost: Low (Under 100$)
* Size: Small
* Frequency: ISM band such as 433 MHz band, 900 MHz band, 2.4 GHz band
* Intuitive and easy to use
  1. **Target, content and plan**
     1. **Target**

Research and fabricate a device that analyzes qualities of the antenna in IoT devices with the low cost, lightweight and meet the frequency band requirements. The device contains following modules:

* **Generator**: IM881a generates the RF to perform measuring.
* **Coupler**: include capacitor and inductor to separate wave into transmitted wave and reflected wave using for comparison.
* **Power Meter**: IC AD8302 which receiving the transmitted wave and reflected wave for comparing show the Power of the RF.
* **MCU + Transceiver**: Via Analog to Digital Converter module, MCU receives the Power from the **Power Meter**. With 2 parameters and the frequency which is generated in the **Generator** to analyze the reflected wave in the antenna. After that, show the result on the LCD or other devices through Bluetooth.

Figure 1. The block diagram of the proposed device

* + 1. **Content and plan**
* **Content 1**: Review these solutions as well as devices

**Content**: Review these solutions as well as devices and show its advantages and disadvantages.

**Plan**: Read and analyze.

**Expected Result**: Hardcopy report.

* **Content 2**: Design schematic and block diagram

**Content**: Base on the normal VNA and the RF modules on market, design the block diagram and the schematic.

**Plan**: List all necessary modules and design the block diagram and the schematic.

**Expected Result**: List of modules, block diagram and schematic design.

* **Content 3**: Programming libraries for the MCU to communicate with other modules, layout PCB

**Content**: Programming libraries for the MCU to communicate with other modules, layout PCB as the same time.

**Plan**: Programming and layout PCB.

**Expected Result**: Libraries and PCB.

* **Content 4**: Connecting modules

**Content**: Follow the schematic to connect modules.

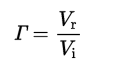
**Expected Result**: Completed device.

* 1. **Result**

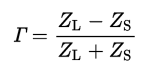
A device that analyzes qualities of the antenna in IoT devices with small size, low cost and meet the frequency requirements.

## Electrical

In metallic conductor systems, reflections of a signal traveling down a conductor can occur at a discontinuity or impedance mismatch. The ratio of the amplitude of the reflected wave Vr to the amplitude of the incident wave Vi is known as the reflection coefficient .

 {\displaystyle \Gamma }.

When the source and load impedances are known values, the reflection coefficient is given by



where ZS is the impedance toward the source and ZL is the impedance toward the load.

Return loss is the negative of the magnitude of the reflection coefficient in dB. Since power is proportional to the square of the voltage, return loss is given by,



where the vertical bars indicate magnitude. Thus, a large positive return loss indicates the reflected power is small relative to the incident power, which indicates good impedance match from source to load.

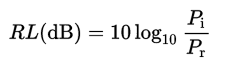
When the actual transmitted (incident) power and the reflected power are known (i.e., through measurements and/or calculations), then the return loss in dB can be calculated as the difference between the incident power Pi (in dBm) and the reflected power Pr (in dBm),



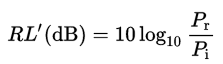
## Sign

Properly, loss quantities, when expressed in decibels, should be positive numbers.[note 1] However, return loss has historically been expressed as a negative number, and this convention is still widely found in the literature.[1]

The correct definition of return loss is the difference in dB between the incident power sent towards the Device Under Test (DUT) and the power reflected, resulting in a positive sign:



However taking the ratio of reflected to incident power results in a negative sign for return loss;



where RL'(dB) is the negative of RL(dB).

Return loss with a positive sign is identical to the magnitude of Γ when expressed in decibels but of opposite sign. That is, return loss with a negative sign is more properly called reflection coefficient.[1] The S-parameter S11 from two-port network theory is frequently also called return loss,[2] but is actually equal to Γ.

Caution is required when discussing increasing or decreasing return loss since these terms strictly have the opposite meaning when return loss is defined as a negative quantity.

So with all of this formula, we calculate with different antenna.











We also compare with the orther profesional VNA in Viettel Company

LTE ANTENNA

8.600000000000000E8 -7.810154860489025 1.205938263712412E2

8.606250000000000E8 -7.638691814462096 1.173469879710136E2

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1. **The ARRL Antenna Book** (21st ed.), The American Radio Relay League, Inc., 2007, ISBN 0-87259-987-6 [↑](#footnote-ref-1)
2. **Introduction to Network Analyzer Measurements Fundamentals and Background** - National Instruments, http://www.ni.com/rf-academy [↑](#footnote-ref-2)
3. **Highly Integrated 4–32-GHz Two-Port Vector Network Analyzers for Instrumentation and Biomedical Applications**, Johannes Nehring, Marco Dietz, Robert Weigel [↑](#footnote-ref-3)
4. **Introduction to Network Analyzer Measurements Fundamentals and Background** - National Instruments, http://www.ni.com/rf-academy [↑](#footnote-ref-4)