CONSTRUCTION OF AN IMPEDANCE ANALYZER

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Abstract: The goal of this project is to build stand-alone impedance analyser for frequencies up to 1 GHz. Selected method for measuring is network analysis and device will contain 8-bit MCU with 10-bit ADC. High frequency sine signal is generated by external source, controlled by RS232. The design of impedance analyser and overview of network analysis is given in this paper.

Keywords: measuring, impedance, network analysis, reflection, directional coupler

1 INTRODUCTION

The aim of this project is to build an impedance analyzer for measurement impedances of antennas for frequencies up to 1 GHz. Choice of proper measurement method and the realization of hardware are discussed in details.

It is crucial to know exact value of antenna's impedance so it can be matched to characteristic impedance $\mathbf{Z_0} = 50\ \Omega$. It means, that accuracy of impedance analyzer has to be the greatest for impedances close to $\mathbf{Z_0}$ and for very low and very high values can be less accurate. This requirement greatly affects the choise of good measurement method.

In this paper, we will talk about selected method – its principle, accuracy and possible uncertainties – and hardware design of the analyzer.

2 MEASUREMENT METHOD

There are several possible methods for measurement at high frequencies (i.e. bridge or RF I-V methods) but for purpose of this project, the *network analysis* was chosen. This method is most accurate for impedances near characteristic impedance and it uses reflection of measuring signal, thus it is ideal for one-port devices like antennas [1].

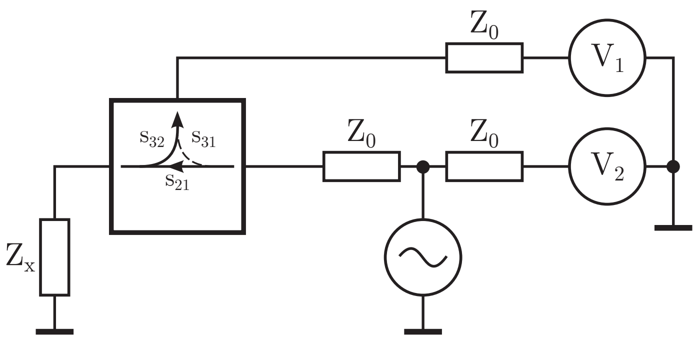


Figure 1: Block diagram of network analysis

Figure 1 shows simplified block diagram of network analysis method. Source of measuring signal at given frequency f_m is split into two paths – one goes straight into voltmeter V_2 (it is realized by AD converter) and second goes through *directional coupler* to DUT (*Device Under Test*) with unknown impedance $\mathbf{Z_x}$. Every signal paths (marked as $\mathbf{Z_0}$ in figure 1) has to have characteristic impedance, so reflection of measuring signal happens only between DUT and output port of directional couler. The reflected signal goes back from DUT and is coupled and then measured in V_1 (again, this is realised by ADC).

If DUT's impedance is not matched ($\mathbf{Z_x} \neq \mathbf{Z_0}$) then part of incident wave's energy is reflected back to its source. The ratio of the amplitude of the reflected and incident wave is called the *reflection coefficient* Γ [1, 4]. This coefficient is also defined as

$$\Gamma = \frac{\mathbf{z}-1}{\mathbf{z}+1} = \frac{\mathbf{Z_x}-\mathbf{Z_0}}{\mathbf{Z_x}+\mathbf{Z_0}} \ , \tag{1}$$

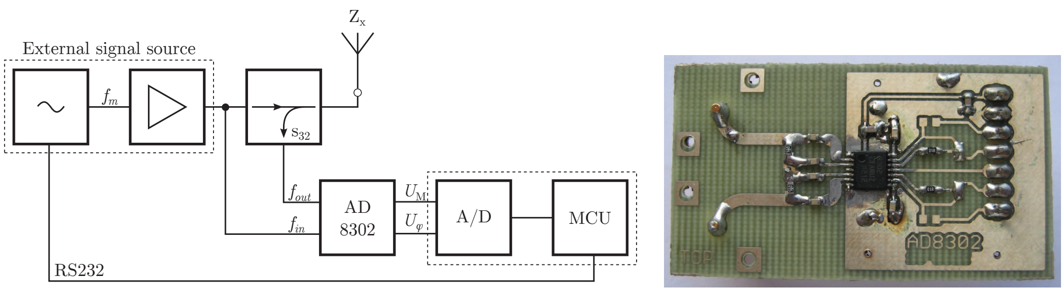
where $\mathbf{z}$ is normalised impedance $\frac{\mathbf{Z_x}}{\mathbf{Z_0}}$ and $\mathbf{Z_x}$, $\mathbf{Z_0}$, $\mathbf{z}$ a $\Gamma \in \mathbb{C}$. The equation (1) can be rewritten to

$$\mathbf{Z_x} = -\mathbf{Z_0}\frac{\Gamma+1}{\Gamma-1} \ [\Omega] \ . \tag{2}$$

It is obvious, that to determine impedance $\mathbf{Z_x}$ we need to know reflection coefficient only. Thus, it is cricital to measure ratio between incident and reflected wave's energy as accurate as possible. The main source of uncertainties is directional coupler – its parameters (called Scattering parameters or just S-parameters) are frequency dependent and non-ideal coupler poses losses in signal's pathways [3].

3 HARDWARE DESIGN

Figure 2(a) shows block diagram of proposed impedance analyser. Signal source will be external, controlled via RS232 (UART) by microcontroller. The early design contained DDS (*Direct Digital Synthesis*), so lower frequencies could be measured without external source. Though, output of DDS contains fundamental frequency and several harmonics, so complex filter would be needed for exact measurement. For this reason, the external function generator will be used.



(a) Block diagram with design of impedance analyser (b) Development board with AD8302

Figure 2: Block diagram with design (left) and development board (right)

Ratio of incident and reflected wave's amplitude is measured by AD8302 [2]. This analog integrated circuit converts high frequency signal's amplitudes and phase shifts to two DC voltages with 0-1.8 V range. This voltages can be easily digitalized by AD converter.

The development board with AD8302 was designed for purpose of measuring basic parameters of this circuit. The top side of this board is on figure 2(b) and figure 3 shows measured dependence of ratio of amplitudes to output voltage U_{M} of AD8302 on this development board for 1 MHz and 100 MHz.

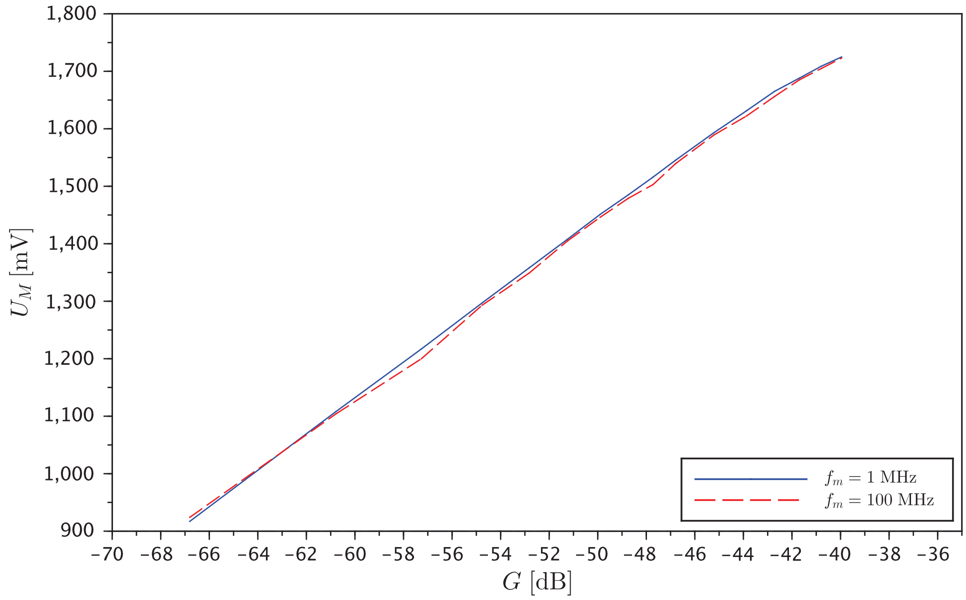


Figure 3: Amplitudes ratio to output voltage U_{M} of AD8302

The Atmel's ATMega328P is used for A/D and MCU block in figure 2(a). This microcontroller contains one 10-bits ADC with 8 channels, so convertion of U_{M} and U_{φ} signals is done by MCU and no external ADC is needed. Also, the 20×4 LCD display, 4×4 matrix keyboard and RS232 are conected and controlled by this MCU. For this digital circuitry, the separate board was designed.

Whole impedance analyser will contain three separated boards – analog board with directional coupler and AD8302, digital board with MCU and user interfaces and power supply board. The most critical part is analog board. All signals on this PWB has to have characteristic impedance and it has to be shielded to prevent electromagnetic interferences on radio frequencies.

4 CONCLUSION

Currently, the proper measurement method was selected (network analysis) and design of hardware was determined. The parameters of AD8302 was verified on development board and digital board was designed and realized. The directional coupler was selected from MiniCircuits' portfolio, so design of analog board has to be done.

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