

Virtual Laboratory for Microwave Devices

D. S. Gubsky, I. V. Mamay, and V. V. Zemlyakov

Physics Department, Southern Federal University, Russia

Abstract— The method of computer simulation of microwave devices and special laboratory workshops is described. Simulated laboratory has a module structure. The basis for constructing a model of the specific workshop is a concept of the abstract “device” with layout is identical to the installation of a real one. As an example the laboratory work which includes sweep frequency generator, VSWR/Attenuation Scope and a band-pass waveguide filter was simulated. The software interface allows changing the frequency tags and filter configuration to carry out all necessary measuring characteristics.

1. INTRODUCTION

Nowadays, computer simulation of operating principles of measurements equipment and microwave devices is of great importance [1–3]. It allows making computer simulators of laboratory works with practically no difference between the simulation and real equipment behavior. Virtually created laboratory works represent operating principles of measurement units, test devices and their interactions which is enough to gain operational experience and to study basic physical properties of test devices. It is also significant that virtual laboratory works can find their application also in distance and online education [3]. It is important to note that alternatively to “real” laboratory work virtual laboratory work has no limits in a number of working places. First of all, virtual laboratory works should be aimed at studying physical processes of test devices and training student to operate laboratory equipment which means that there must be practically no difference in interface and execution order between the “real” laboratory work and virtual one.

In this paper the technology of computer simulations of microwave equipment, devices and special laboratory works is presented.

2. LABORATORY WORKSHOP STRUCTURE

Any laboratory work comes with measurement units and test devices combined in a single installation. Each measurement unit could be described with the set of input and output signals (e.g., indicator unit receives signal from test device and management signals from generator). Additionally, each measurement unit has determined functions. Moreover, microwave test devices also could be described with sets of input and output signals and functions (e.g., signal of defined frequency and value at the input of the filter is converted to output signal according to filter “function”). Therefore, the behavior of device can be described by set of input and output signals and their transfer function (Figure 1).

Simulated laboratory works have modular construction. At the basis of laboratory works simulations a conception of abstract “device” is used. Those abstract devices could be combined into installation, identically to real devices, i.e., connection of output signals with input signals. Device’s behavior is described with notion of “signal” and “function”. Each device has set of input and output signals and it is possible to connect devices to each other in a certain way. Each device module is an autonomous software element. For this reason the functionality of software package is easily expandable and depends only on module set.

A laboratory work for software package is information about set of essential modules, number of copies of each device and the way they are connected with each other. Therefore, it is possible to construct function chains and trees, there first members are independent and last are recursive dependent on all previous (Figure 2). By this means any measurement unit and test device could be assembled from modules and their behavior is described by sets of functions which transform input signals into output signals. The process of input signals transformation to output signals depend only on way of device realization.

For software package any test device could be represented in form of abstraction with define property set and behavior with reference to other devices. Device’s properties are: type, name, input signals, output signals, unique identifier.

In case of connection the correspondence is established between input signal of receiving device and output signal of transmitting device. Therefore, any input signal of the device unlike output

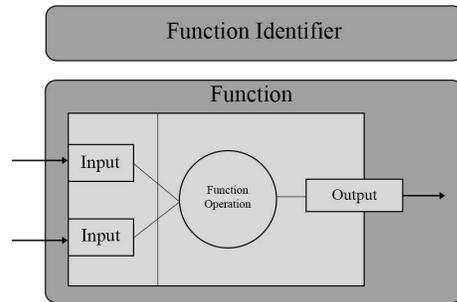


Figure 1: Signals and functions organization.

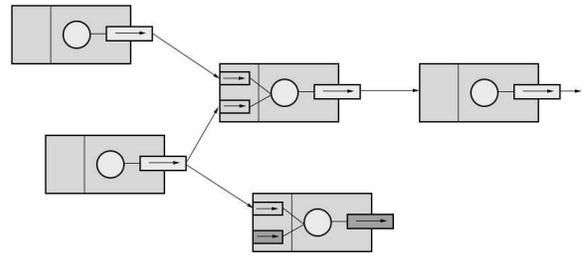


Figure 2: Signal interaction.

signal is not an autonomous object but it is a pointer to output signal of another device. That allows connecting devices with each other in unspecified way.

Device's modules are dynamic libraries with common public interface which is a functional of abstract device's "factory". Device's "factory" creates a sample of the device. Modules are loaded and used during the main application execution and don't have direct connection with package's core. This conception allows making package core independent from device's modules set. Moreover, common abstract interface makes possible modules development totally independent from each other which mean that functionality of one module is totally independent from functionality of another.

So the target device is inheritor of abstract device and has a set of output signals which could be connected to other modules, and set of input signals which are necessary for device self functionality. Those signals mostly determine functionality of whole device. Certain "factory" has information about existence of target device and can create any number of its samples. The "factory" itself is inheritor of abstract device "factory". So, for user the interface of abstract "fabric" is available which allows making realization of devices with abstract device interface.

Software package for microwave device simulations and connection of microwave device modules is developed with programming language C++ on Microsoft Visual Studio IDE 2008. As package's basis a cross-platform toolkit for applications and user interface development Nokia Qt 4.7.3 was chosen. Because of small volume of stored information the database SQLite 3.7 was used.

3. VIRTUAL LABORATORY WORK EXAMPLE

Let us describe a process of laboratory works creation. The measurement units which were created before and represented in a package as device's modules or new measurement units could be used.

Let us consider a process of new measurement units design to study the parameters of waveguide filter which consists of Sweep Frequency Generator, VSWR/Attenuation Scope and filter model.

Abstract device "Sweep Frequency Generator (SFG)" act as control program interface which operates with start and stop scanning frequency values and frequency markers. Abstract device "VSWR/Attenuation Scope" act as control program interface which operates with markers, test line position values and the range of measurement values. This unit controls abstract grid area by applying the above values.

At this stage of simulation there is no sets of output and input signals but it is expected that indicator unit won't have any of output signals.

So, by combining devices listed above it is possible to create one of the most simple laboratory works which scheme is represented at Figure 3.

For the module "Sweep Frequency Generator" operator can perform such actions: shifting between start and stop scanning frequency values and markers values to visualize data on digital display; changing start and stop scanning frequency values and markers values. For the module "VSWR/Attenuation Scope" operator can perform such actions: changing position of test line (in this case attenuation value will be displayed on certain display panel); changing markers position; changing value of additional signal gain.

The test device — "Blackbox" is of special interest. This abstract device doesn't provide any additional universal program interface. All functionality of "Blackboxes" should be contained in its output signals which behavior is studied in corresponding laboratory work. For "Blackbox" the basic data are: analytical transformations of input signal values; experimental data, saved in

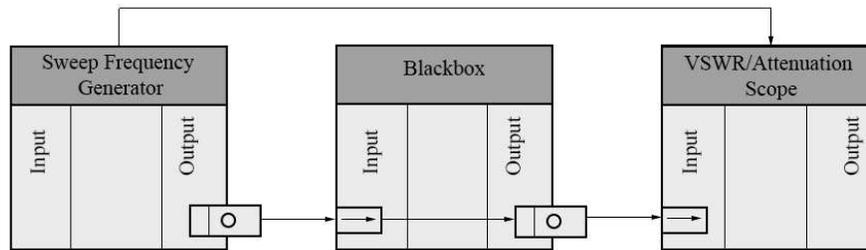


Figure 3: Simplest laboratory work.

certain unify format; computation data obtained from external application packages for microwave device simulations (for example CST Microwave Studio).

Analytic transformations of input signal values are the software implementation of analytical expressions. Experimental or computation data are convenient to report in binary data. The final format of such data depends on certain sets of values and number of such sets.

In this work the target module of “Blackbox” device — the “band-pass filter” was created. This device has one output signal and expects connection of one input signal.

The model of band-pass filter is a section of rectangular waveguide with grating and two rods with user-defined insertion. S -parameters describing electrodynamic properties of filter were calculated for series rods positions with certain step.

Band-pass filter was simulated with CST Microwave Studio software. Received simulation data was converted to binary form and exported to module of abstract device “Blackbox”.

Since the set of received values is discrete for proper construction of amplitude-frequency characteristic it is necessary to interpolate the received values. It is shown that Newton’s quadratic polynomial interpolation is good enough for this purpose. The operator can change the rods insertion depth. After changing insertion depth the certain set of corresponding values are loaded and polynomials are calculated.

By using interactive configuration tool all simulated devices are combined together and create laboratory work for studying properties of microwave filter based on rectangular waveguide. After launching laboratory work and loading all necessary modules the laboratory unit user interface is displayed on PC monitor (Figure 4). User can change the range of signal, frequency markers, rods insertion depth in test filter and calculate all necessary properties.

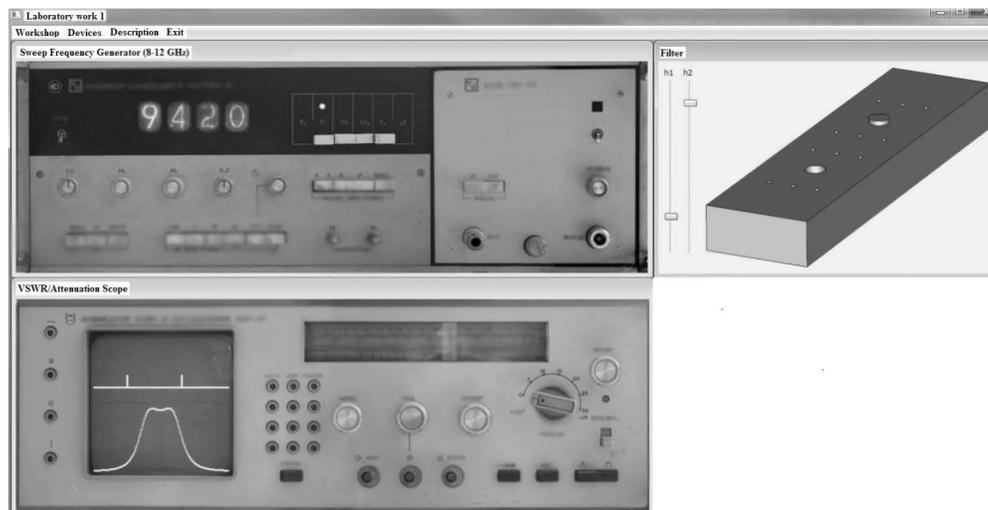


Figure 4: Laboratory unit interface.

4. CONCLUSION

As a result of current investigation the software package for constructing virtual laboratory workshop was designed. It could be used in education process as interactive tutorial. Designed virtual laboratory is based on autonomous independent components modules which allows to expand and edit the set of devices used for simulations without interactions with package core. The main feature of this realization is representing test devices as “Blackboxes” which behavior depends on mathematical model or on output values of external applications for microwave device simulations and also could be based on real experimental data. All components included in presented laboratory work are identical to real devices.

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