Novel Software Techniques for Automatic Microwave Measurements

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Abstract: Although many microwave measurement techniques are heavily based on special purpose software, the application of modern software techniques like object oriented programming and new programming language like C++ is seldom used. The impact of such new software solutions can drastically improve the overall design of a microwave test set. The paper presents the design and implementation of a new multiport network analyzer with particular attention to the control program architecture. The use of Object Oriented Programming techniques results in a clear and easy to maintain solution which boosts both the user interface and the overall test set organization.

I INTRODUCTION

The comprehensive characterization of microwave devices, complex circuits and subsystems for application in telecommunications is rapidly becoming an indispensable tool in any RF/microwave design.
The available instrumentation for network analysis is almost entirely devoted to the characterization of two-port devices under small signal excitation, but the increasing complexity of microwave circuits demands for novel techniques to characterize multiport circuits, such as high speed digital circuits, beam forming network, mixers and multifunction MMICs.
The main problems which constrain the development of multiport (i.e. more than 2 ports) NWA are the calibration technique, the high complexity of the required instrumentation and a simple and flexible user interface.
In this paper we present a simple low cost Frequency and Time Domain Multiport Network Analyzer architecture and, in particular, the design and the features of its control software. The code widely uses the Object Oriented Programming (OOP) paradigm both for the instrument driver organization and the user interface. The result is a clear and easily to expand software architecture, where all the traditional sections of a microwave automatic measurement program: Reading, Calibration and Presentation have been integrated in a series of interacting objects. First a brief description of the multiport test set will be given, then we will focused the attention on the particular software solutions which allow simple and user friendly procedures both for calibration and measurement.

II TEST SET DESCRIPTION

The block diagram of the four port ANA is shown in figure 1. The system comprises essentially a microwave transition analyzer (MTA) used as a frequency/time domain receiver and a test set based on two switching matrices and 4 dual directional couplers. The source switching matrix routes the RF signal source to the various device ports. One of the two channels of the MTA is used as fixed phase (trigger) reference while the other samples in turn all the forward and reverse waves through the receiver switch. This solution provides frequency and time domain measurements and it is easily expandable just by adding more channels into the switching matrices and more couplers. On the other hand the number of possible measurements dramatically increases respect to an ordinary two port NWA. Over the possible measurements that we could get with an ordinary transition analyzer (time domain waveform analysis, frequency domain response), with such multiport scheme, we have to take also into account the possibility of mixed port excitation, harmonic frequency measurements over different ports, simultaneous device measurements of two port devices and so on. Some measurements examples that could be obtained with this system are:

1) single tier four port device S parameter
2) time domain waveforms of mixer and other non linear devices
3) on wafer measurement of complex MMIC
4) digital bus response at microwave frequencies
5) simultaneous measurements of two port devices to increase the production testing speed
6) EMC measurement of complex structure up to microwave frequencies

An effective calibration procedure is also mandatory to reduce the number of standard insertions and, in particular, where geometric or mate problems arise.

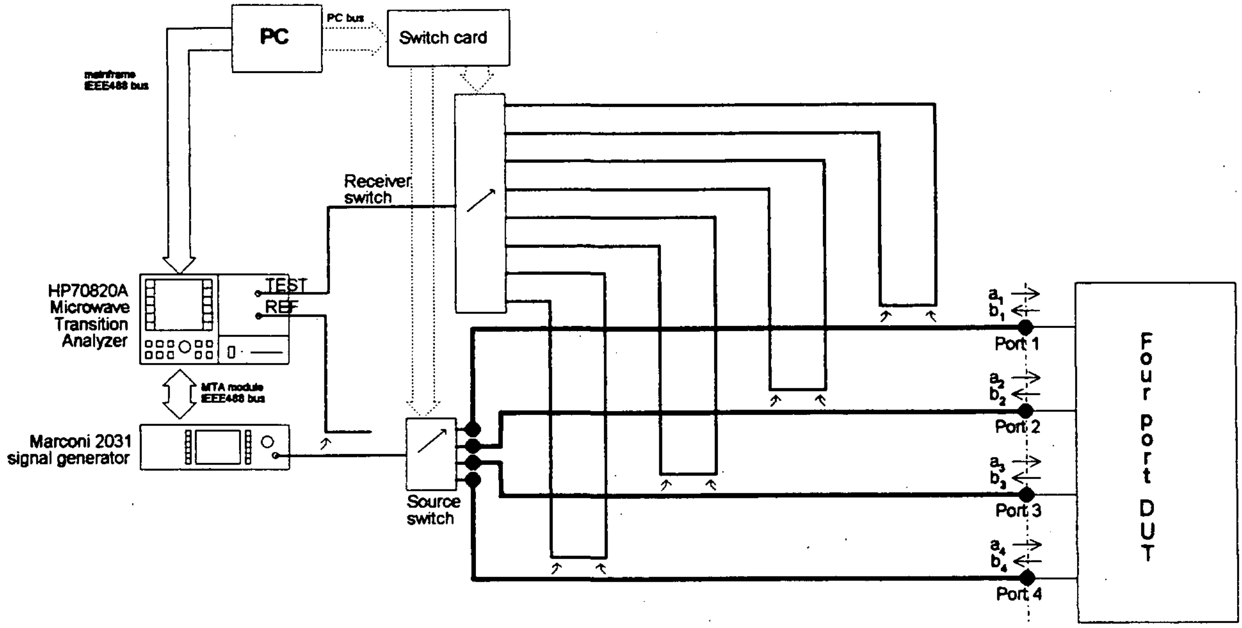

Figure 1: Multiport Time/Frequency Domain Network Analyzer block scheme

Two calibration techniques are derived from [1] and optimized for on wafer environment: the first is a TRL-like technique, while the second uses fully known open and short standards. Note that, due to the geometrical constraints, if the probe position is fixed, a straight line thru can be used. only between faced probes (probes 1-4 of figure2).
Thus to compute the error box terms which links two side probes, an undefined thru technique have to be used [2]. Finally, to allow an absolute power-phase calibration for on-wafer time domain measurements, a technique similar to [3] is adopted.

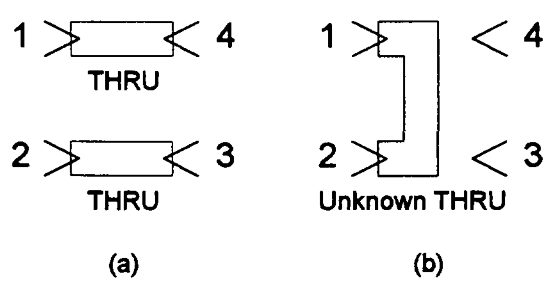

Figure 2: Standard displacement problem,normal thru connection for two faced probes (case a), an unknown thru is necessary for side by side probes (case b).

III SOFTWARE DESIGN

The targets for the design software were:

1) A simple and user friendly interface
2) Extreme flexibility on the microwave receiver type, such that a different one rather than the MTA could be used
3) Easy expandability of the measurement capabilities with extra measurement modules such as multitone measurements.

The use of a Windows PC-based approach is mandatory to obtain a simple and user friendly interface. Rather than using the classical procedural approach to handle the several system functions, Object Oriented Programming (OOP) paradigm has been widely used for the design of the control software and the user interface. Although commercial software based on OOP like LabView is now available, the complexity of the microwave measurement problem suggested a fully new development in C++. The OOP approach offers a better way to model the complexity of our measurements which result in a well defined series of interacting objects, as shown in figure 4.
As example, the calibration problem is handled through a calibration object based on two other basic objects (see figure 3): a collection of standards and a collection of error coefficients. Each member of the standard collection computes its frequency response based on its physical parameters (inserted in a standard specific insertion

dialog). If a new standard model is added there is no need to change any part of the old code but simply add an item to the collection. According to the traditional procedural paradigm, on the contrary, a single function, containing a switch-case statement, would compute the frequency response for the different standard models, thus to add a new one this basic routine needs to be changed. Furthermore, if the new model requires more parameters than the old one, the overall internal structures, which contains the standard data, and the user interface to input the model parameters have to be changed. In the OOP approach each standard has its own data and user input dialog while the only link with the other parts is the frequency response.

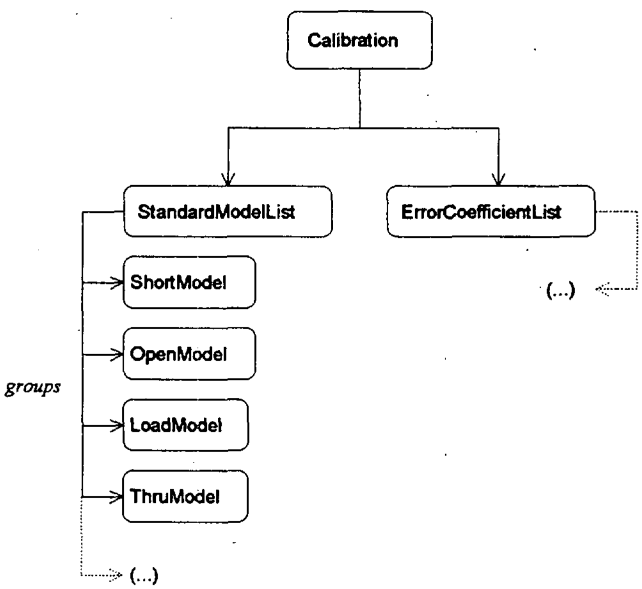

Figure 3: Calibration objects hierarchy

Another example is given by the basic instrument hierarchy (see figure 4). We have a single NWA object which is a part of a test-set object and includes both the data and the measurement functionality. On the other side, the traditional procedural paradigm would have a series of routines for the NWA data acquisition and common or local arrays for data storage. A typical consequence of a traditional design is the need of different high level routines when different instruments are used as a network analyzer (i.e. an MTA or a more traditional HP8510). Instead, in an OOP technique there are several NWA objects, one for each particular actual instrument, and the upper level objects do not need to know which type of instrument is used.

Probably the more useful application of OOP techniques in this design is the so-called custom measurement approach. We defined a common measurement object which handles the basic test set functionality thus automatically gives to each derived object the access to the measurement data (such as complex waveform). This solution leaves to the high level object the organization of the measurement process and the user interface for the particular application. The user is so free to design his own measurement, such as complex mixer multitone characterization, or particular digital measurements. As example, the time domain object shares the same basic data as the S-parameter one, but than owns a different method to correct the raw data and to show the corrected results. The measurement objects are grouped in a measurement list which allows to easily add new custom modules.

IV CONCLUSION

A new software organization applied to a multiport NWA is presented. The software model of the measurement reality offers a better understanding of the processes involved and it is easy to expand and suitable for re-use.
The use of the OOP has been fully exploited both for the user interface and the more critical calibration and measurement processes.

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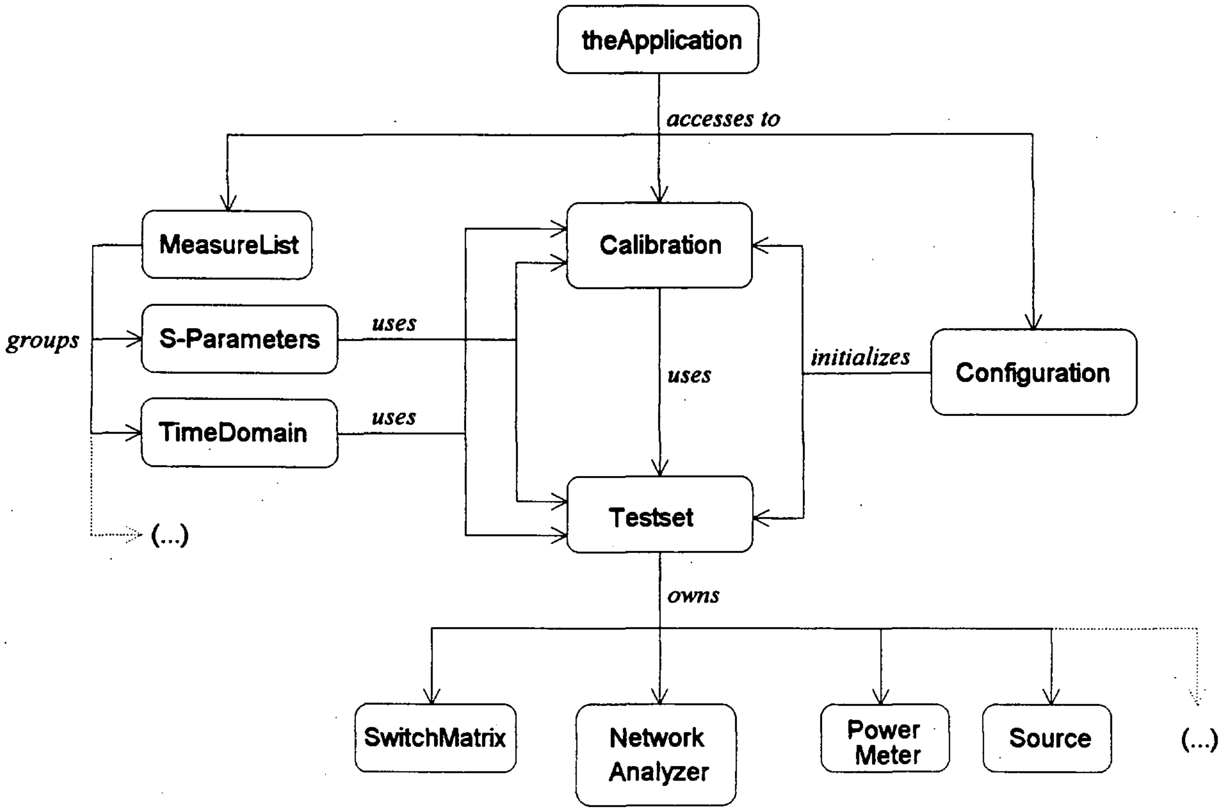

Figure 4: Measurement Software Object Oriented Model