9e UGent - FirW DOCTORAATSSYMPOSIUM

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| Het Pand | Onderbergen 1 | 9000 Gent |

UNIVERSITEIT GENT

FACULTEIT INGENIEURSWETENSCHAPPEN

Mathematics

Mechanics

Low-cost kHz-to-GHz Harmonic Vector Network Analyzer for Embedded Applications

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Abstract— **In this article, a new low-cost Vector Network Analyzer (VNA) is introduced. Many instrumentation companies focus on very expensive, high performance VNA's with extensive measurement options, which are perfect for any specialized RF-laboratory. On the other hand several applications need a VNA-functionality without the performance of the commercial VNA's described earlier. Unfortunately the low-cost easily integrateable VNA-systems, which are the main focus of this research, still haven't taken their rightful place in instrumentation business. Also a new harmonic measurement concept is suggested which increases the bandwidth to GHz-frequencies.**

Keywords—**Vector Network Analysis, Harmonics, S-parameters, Monitoring**

I. Introduction

SEVERAL applications involve the reception of a self-transmitted signal after it is sent through an unknown medium, often with the intention of acquiring some information on the medium. In addition to the textbook example called Radar, this method is used in multiple monitoring applications which measure the quality of a cable- or fibre-connection over time, detect a leak in a reservoir or a breach in a fence. Often the transmitted signal is a pulse train of which the reflections are measured in time-domain (Time-Domain-Reflectometry).

This time-domain information can also be obtained through execution of an inverse Fourier transform to the frequency response of a system. This can be acquired by measuring reflected or transmitted continuous sine waves at different frequencies. These measurements can be done with a VNA. In most applications the interesting frequencies are limited to 100 MHz and the dynamic range doesn't have to be state-of-the-art. This considerably decreases the cost of the VNA. Other applications are impedance meters and small educational VNA's. Although there clearly is a business opportunity in low-cost VNA's, instrumentation companies have been slow to respond.

II. Vector Network Analysis

A Vector Network Analyzer characterizes a device under test (DUT) by means of Scattering- or S-parameters in the frequency domain. The S-parameter S_{XY} is the result of the division of the reflected or propagated wave b_X at port X, and the sole incident wave a_Y at port Y, measured at the same frequency, when all ports are terminated at a known impedance Z_0 (usually 50 or 75 Ω) (Fig. 1).

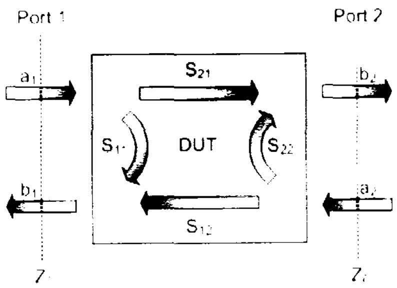

Figure 1. Two-port S-parameters

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Given that a_Y and b_X are sine waves of the same frequency, $S_{XY} = |S_{XY}|e^{j\Theta}$ with $|S_{XY}|$ the amplitude ratio and Θ the phase difference of b_X and a_Y. S_{XX} and S_{XY} are also known as the reflection coefficient at Port X and the complex linear gain respectively. S_{XX} is often represented on a Smith chart.

As S-parameters are small-signal parameters, the DUT still has to behave linearly when stimulated by the incident wave a_Y. This imposes a restriction on the power of a_Y. Often the output power of the VNA-transmitter can be changed over several dB.

III. Harmonic Vector Network Analyzer

One of the biggest problems when constructing a VNA is the generation of the measure and reference signals. These signals have to cover the whole frequency and power range needed for the application. In high performance VNA's this is accomplished by generating high frequency signals by means of Phase-Locked-Loops (PLL's). Those signals are then downconverted to match the needed span.

A much easier and cheaper way is employing Direct Digital Synthesis (DDS) to generate the needed sine waves directly. A disadvantage of this method is the spurs generated by the DDS. However, this is acceptable for applications that don't need an exceptional dynamic range. Another drawback of most DDS-chips is that the output bandwidth is limited to approximately 150 MHz. While this is enough for most applications, it can be easily increased by transforming the output sine wave to other known periodic signals, sending them through the DUT and using the higher harmonics. One of the more interesting signals is a square wave, as it has powerful high harmonics and is easily generated by sending a sine wave through an invertor. When using a very fast invertor, this results in a good approximation of an ideal square wave to 1 GHz (Fig. 2).

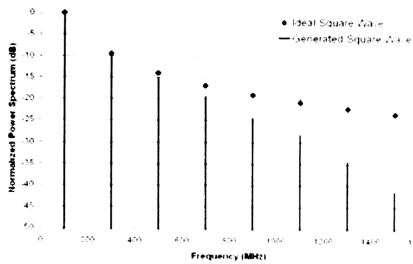

Figure 2. Comparison of a generated and an ideal 100 MHz square wave

The transmitter output amplitude has to be chosen thus the DUT behaves linear, as any occurring distortion will be measured at higher frequencies. Also, more filtering will be necessary in the VNA-receiver when measuring at higher harmonics. These are the main disadvantages of this new Harmonic Vector Network Analyzer concept.

IV. Conclusions

In this article a low-cost kHz-to-100MHz Vector Network Analyzer architecture for embedded applications has been introduced. This VNA can be easily adjusted to cover the kHz-to-GHz-range. Also, several problems with this concept have been revealed, which give an incentive for future research.

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