A PC-Controlled, Low Cost, Scalar Network Analyzer

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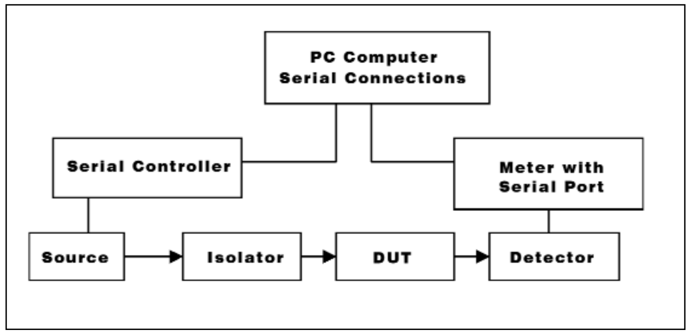
Recent articles in this magazine [1, 2] have stressed the importance of analyzers for measuring parameters related to microwave circuits and devices. A.G. Neto, et al., proposed that a scalar network analyzer (SNA) could be built at a relatively modest cost by using common electronic equipment likely to be found in an electronics laboratory [1]. In that particular system, a voltage-controlled oscillator (VCO) was used as the source of microwave power, and a semiconductor diode was used to detect the microwave radiation. The article [1] suggested that some form of data acquisition would be advantageous in the building of the analyzer. This article describes a system controlled by a PC that uses a synthesized microwave source in place of the VCO, used in the setup discussed in Neto's article [1].

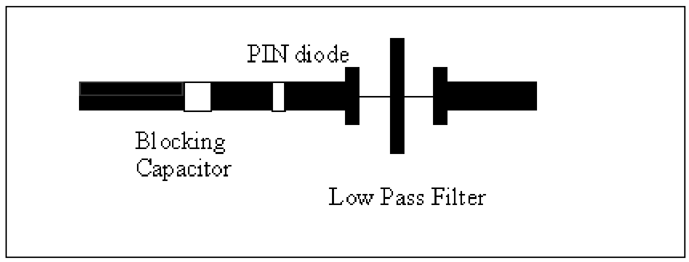
Clearly, data manipulation and display are major advantages in connecting any experimental system to a computer; a microwave system is no exception. Techniques such as data smoothing, background subtraction and many other forms of data manipulation are available in packages such as *Excel* or *Lotus*.

To extend the facilities of the system previously described [1], it was necessary to make reflection as well as transmission measurements. By including a directional coupler and calibration to a short, reflected microwave power can be assessed. Since it is preferable to avoid connecting microwave power sources directly to shorts, an isolator was placed immediately after the synthesized source.

The system described in this article allows measurements of insertion loss and return loss to be made. The accuracy of this data is determined by the quality of components used in the system.



▲ **Figure 1. A microwave sweep system under PC control.**



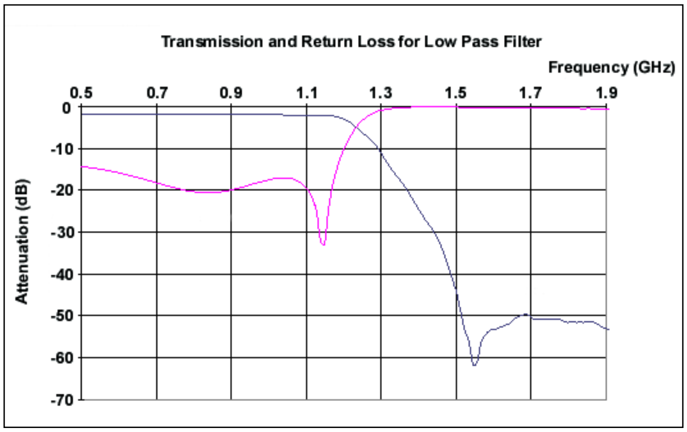
▲ **Figure 2. A microstrip circuit consisting of a capacitor, PIN diode and low-pass filter. SMA conncectors are fitted to each end of the board.**

Experimental details

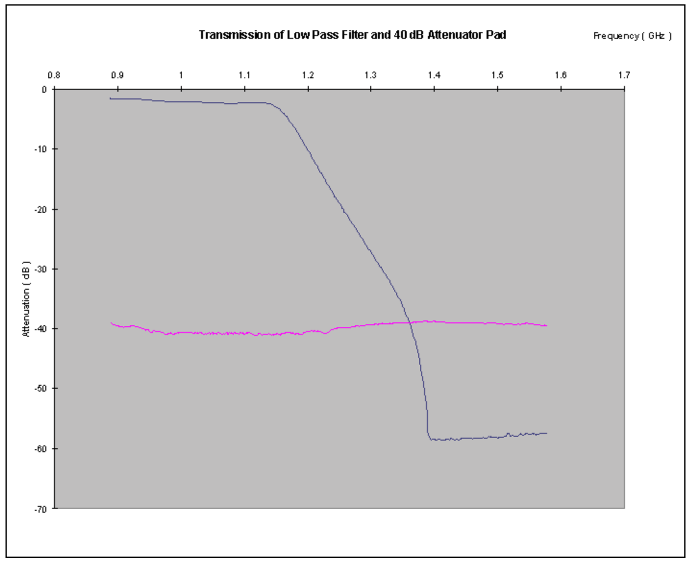
A block diagram of the microwave system is shown in Figure 1. The system shown is for transmission measurements with the micro-wave circuit, depicted by arrow connections. For reflection, a directional coupler is inserted between the isolator and the device under test (DUT). The detector is then connected to the output port on the coupler. The serial controller [3] uses one serial port of the PC to provide output lines to step the frequency of the synthesized source [4] through its entire range. At each frequency step, the detector output [5] is recorded via the second serial port. As a function of frequency, the microwave power, which is transmitted by the DUT, is either recorded on-screen or saved as a file. To obtain the previous results, a background test in which the DUT was simply a low loss line was run first. Reflection data was recorded in a similar manner; zero return loss corresponded to the reflected power from a short that was attached to the directional coupler.

The circuit elements given in Figure 1 are, relatively speaking, standard items. The serial controller was constructed from a single chip microprocessor (83C750) and was programmed to give 16 TTL output lines. For the source, an off-the-shelf development board (Q0410) was used. By operating 12 of the TTL output lines, the frequency of the microwave oscillator was scanned over the range 0.8 to 1.6 GHz in steps of 1.25 MHz.

It was preferable to adopt AC amplification methods, so the source was connected to a microstrip circuit containing a PIN diode (BA585) to modulate the microwave



▲ **Figure 3. Transmission and reflection data for a commercial low-pass filter.**



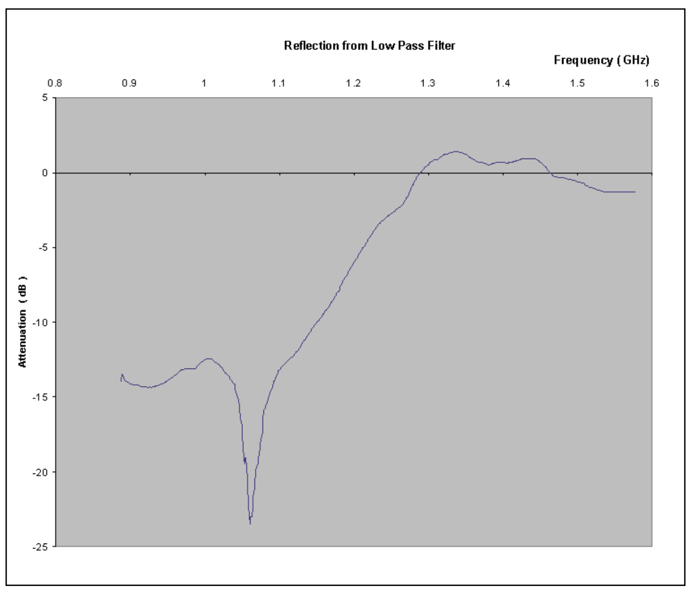
▲ **Figure 4. Transmission of a commercial low-pass filter together with a calibration trace of the transmission through a 40 dB attenuator.**

signal at approximately 1 kHz. This was followed by a microstrip low pass filter with a cut-off frequency of 2 GHz to minimize spurious effects due to higher harmonics in the source output. The circuit layout is shown in Figure 2.

The isolator was selected to give an attenuation for forward transmission of better than 1 dB, with a reverse transmission that is lower than 20 dB. A diode detector was AC coupled to an amplifier tuned to 1 kHz, and the rectified output was then connected to a logarithmic amplifier (Analog Devices 759P). This signal was finally connected to a multimeter (Thurlby-Thandar 1906) whose serial port provided a link with the computer.

Overall costs of such a system were difficult to estimate, since the PC and multimeter were already used in the laboratory. The microstrip circuit and tuned amplifier were constructed within the department, and synthesized sources typically cost approximately $435 to $587. Thus, a cost of hundreds rather than thousands of American dollars was the investment needed for such a system.

Note that where only one serial port is available, a port expander can be used [6].



▲ **Figure 5. Return loss from the low-pass filter.**

Experimental results

To assess the performance of this computer-controlled system, its measurements were compared with measurements taken from a Hewlett Packard network analyzer, HP8753. The DUT in this case was a low-pass filter. Figure 3 shows data obtained with the HP8753. As expected, the filter exhibits about 20 dB return loss in the frequency spectrum where transmission occurs and where almost zero return loss occures after cut-off.

Figure 4 was generated using the PC-controlled system, and covers the frequency range 0.8 to 1.6 GHz. The corresponding return loss data is shown in Figure 5. The curve showing return loss is in fair agreement with Figure 3, but the positive values above 1.3 GHz are likely to be caused by mismatch of the detector.

Conclusions

The results obtained by using the PC-controlled system are qualitatively similar to those obtained using the HP8753. Quantitative agreement with attenuation data, however, is likely to be in error by up to 2 or 3 dB. Since the dynamic range of the system is 50 dB at best, attenuation readings at greater than 40 dB can be problematic. Data acquisition may take several seconds, but this clearly depends on the software as well as the type of PC being used. This inconvenience of time of acquisition is greatly offset by having the data stored as a file.

This article has described a system that is a useful complementary tool to that described by Neto et al. [1], and it has proved student-proof in the teaching laboratory. Although this article has described results in the frequency range 0.8 to 1.6 GHz, the development board [4] can be fitted with VCOs (type Q3500) that cover the frequency range 100 MHz to 3.5 GHz.

In addition, the system operates equally well with a VCO in which the control voltage is derived from a digital/analog convertor powered by the serial controller. Operating frequencies over a wide range are available with such a system. ■

References

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6. F. Thompson, "An RS232 Switch-box," *Electronics World,* November 2000 (in press).

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