Measuring Receiver Creates Benchmark for RF Power and Modulation Measurements

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When Hewlett-Packard introduced the HP 8902A measuring receiver in 1981, IBM had just announced the personal computer, the World Wide Web was just a glimmer in the mind of Tim Berners-Lee, and microprocessor clock speeds were in single digits. Nevertheless, HP was able to produce a metrology instrument for attenuator calibration and signal generator performance testing in calibration laboratories that delivered such a high level of performance that it quickly attained "reference standard" status. This title still holds today, even though Agilent Technologies (formerly Hewlett-Packard) stopped production in 2002. Agilent has now introduced a new precision measuring receiver system called the N5530S that promises to continue this tradition and deliver even better performance in key areas than the 8902A and has many other useful attributes that 21st Century technology allows.

The Agilent Technologies N5530S was designed to provide an easy migration path from the 8902A, which is used by the majority of calibration laboratories throughout the world, as well as by companies that have many signal generators or attenuators and perform their own calibration. It is composed of a PSA spectrum analyzer (models E4440A, E4443A or E4445A), an EPM or EPM-P power meter (models E4416A, E4417A, E4418B or E4419B), one or more sensor modules (model N5532A), a PC, and software.

The new measuring receiver performs key calibration measurements with better-specified accuracy than the 8902A. Its software (PSA Option 233) provides a familiar-looking manual user interface along with a modern, industry-standard remote user interface. The software handles all housekeeping functions such as instrument calibration and license verification, and new capabilities like batch processing (for stringing multiple measurements together).

Unlike the 8902A, which was dedicated exclusively to metrology applications, the N5530S is composed of commercial, off-the-shelf Agilent test equipment. The frequency coverage of the N5530S base configuration is 3 GHz versus 1.3 GHz in the 8902A, and when configured for microwave applications, it is smaller and less expensive than an equivalent 8902A-based system. The N5530S can optionally perform measurements to 26.5 GHz without the need for external downconverters, which are required for the 8902A above 1.3 GHz.

In addition, the N5530S improves productivity by reducing measurement time and complexity. For example, the 8902A has three amplitude measurement ranges, and after initial calibration, calibration must again be performed when crossing over into the next two lower ranges. The N5530S only has two

Agilent Technologies' N5530S Measuring Receiver.

measurement ranges, eliminating one of the interim recalibrations. The N5530S also has a greater selection of bandwidths, which allows noise floor to be reduced further than the 8902A, a desirable attribute when measuring very low signal levels.

The performance benchmark for the N5530S was the 8902A with Option 050 (a popular option chosen by the most buyers because it delivered improved power measurement specifications). The N5530S meets or exceeds all key 8902A/Option 050 specifications, compared in Table 1. Specified measurements include frequency, absolute power, tuned RF level, modulation analysis (AM, FM, and PM), modulation rate and distortion, and spectrum analysis.

Other key advantages of the N5530S include:

- Ability to reduce the noise floor by using a narrower resolution bandwidth
- A minimum RF bandwidth of 1 Hz, versus 200 Hz in the 8902A
- 160 resolution bandwidths and several detectors versus two resolution bandwidths and two detector types in the 8902A
- A modern, easily-supportable platform
- Three sensors choices: 100 kHz to 4.2 GHz, 10 MHz to 18 GHz, and 30 MHz to 26.5 GHz
- Integrated demodulation distortion measurement capability without the need for an external distortion analyzer
- Traceability to the ANSI Z540 and ISO 17025 standards

A Fresh Approach

From an architectural perspective, the N5530S is very different than its predecessor, relying as it does on commercially available instruments (Figure 1a and b). For the user, there are significant advantages to this approach. The PSA spectrum analyzer and EPM/EPM-P power meters are popular instruments and many are in service throughout the world. Anyone who owns one or the other (or both) already has the majority of the system in place, which obviously provides significant cost savings. Even if all the elements of the system must be purchased, the owner gets not just a measuring receiver system, but a full-featured spectrum analyzer and power meter that can also be used for other measurement tasks.

From a design perspective, the difference between the 8902A and N5530S begins at the intermediate frequency (IF). The 8902A employed a superheterodyne front end to convert the incoming signal to IF. Once the signal was downconverted, the signal could be conditioned with various high-pass or low-pass filters, then analyzed with AM or FM demodulators. The instrument had an integrated distortion analyzer and frequency counter to measure the incoming RF signal. An integral power meter connected directly with the power head in the sensor module.

The new N5530S measuring receiver system also uses a superheterodyne swept front end and downconverts to IF just like the 8902A. However, here the similarity ends. The PSA spectrum analyzer has a digital IF section, using an analog-to-digital converter to perform the conversion. The I/Q (in-phase and quadrature) data pairs are fed to an external PC in which software performs the required digital signal processing. While Agilent's EPM power meter is a separate instrument, it functions just like the power meter in the 8902A and is connected directly to the power head located in the sensor module. Both the spectrum analyzer and power meter are connected to the PC via a GPIB interface.

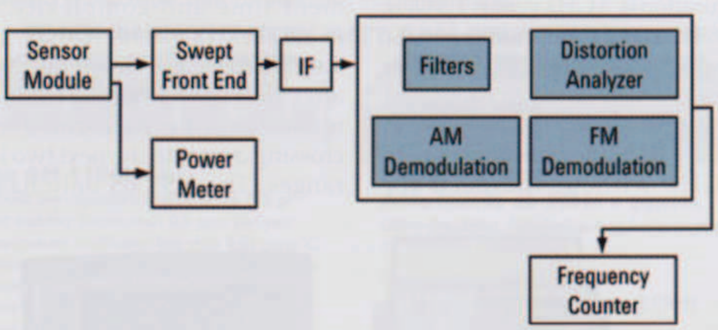

Figure 1a. The 8902A and N5530S architectures.

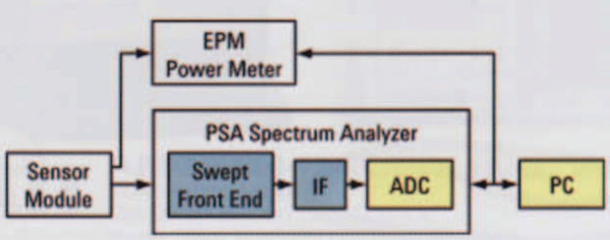

Figure 1b. The N5530S architecture.

A Familiar Look

One of the major differences between the 8902A and N5530S measuring systems is the user interface. When the first 8902 models were introduced, microprocessor-based systems were in their infancy, local area networks (LANs) were yet to come, and modern graphical user

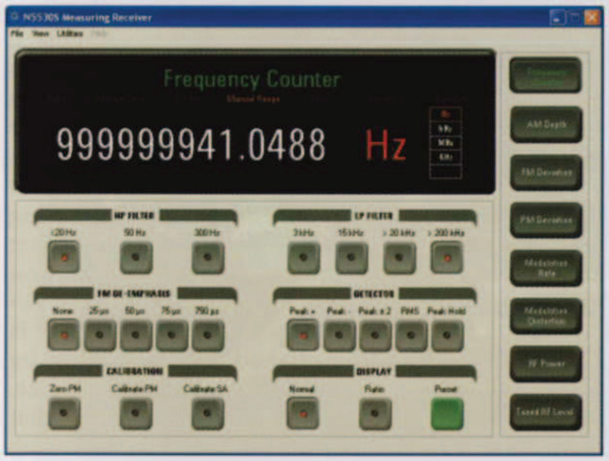

Figure 2. The N5530S in standard mode will be quite familiar to 8902A users.

interfaces awaited their introduction by Apple Computer. As a result, all functions were orchestrated by buttons on the instrument's front panel. While front panel control is still mandatory for many measurement environments, in others instruments are remotely controlled with a PC over a LAN.

The user interface of the N5530S is software based, which makes it much more flexible and easy to save data, paste it into reports generated by Microsoft Excel or other spreadsheet programs, print hard copies, and transfer data and measurement routines to virtually anywhere over the Internet using standard Windows-based tools.

The N5530S has three modes of operation: standard, advanced and batch. Standard mode, which is what the user sees when loading the software, will be familiar to the many people who have been using the 8902A for years (Figure 2). The display looks very much like the front panel of the 8902A, which makes it easy to begin using the system. There are "buttons" like those on the 8902A; even the readout mimics the 8902A's LEDs.

In advanced mode, the display is slightly different, giving users greater control over the measurement process. Functions like changing filters, detector types, or the number of averages performed in a measurement is very simple. In batch mode, the user can automate the measurement process by selecting individual measurements and executing them in the desired sequence controlling external devices via GPIB. For example, the signal generator under test can be commanded to change power levels, or when testing a programmable attenuator, a command could be sent to add 5 dB attenuation. Measurements can be chained together in any order. A pause can be entered so that a change can be made before the routine continues, or a comment can be displayed, such as "connect cable now", etc.

The Sensor Module

The N5532A sensor module in the N5530S is housed in the same enclosure as its predecessor and still provides a single connection to the device under test for both power and RF measurements. However, the mechanical RF switch used with the 8902A that transferred the signal to either the power meter or spectrum analyzer has been replaced by a splitter. This approach, based as it is on a passive component, provides greater reliability and repeatability, which is essential in the metrology environment (and others of course).

In addition, improved matching is obtained on the RF branch because its 6 dB of attenuation reduces VSWR, which in turn reduces measurement uncertainty. At microwave frequencies, where the highest possible levels of sensitivity are required in order to measure low-level signals, the new design has 4 dB less attenuation in the spectrum analyzer path than the earlier 11792A sensor module.

Overall, It's Smaller

In terms of its footprint, the N5530S system configured for microwave applications requires less space than an 8902A-based system configured for microwave measurements. The two are compared in Figure 3, which shows a typical microwave attenuator test system. The 8902A-based system requires a separate downconverter and

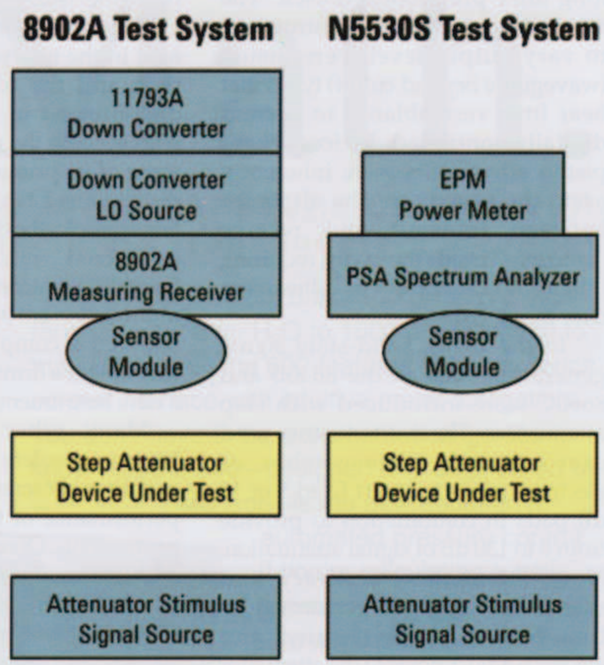

Figure 3. The N5530S configured for microwave attenuator calibration reduces the number of components and the overall size of the solution.

The 8902A— Born of Necessity, Maintained by Technology

George Brandle
Hewlett-Packard Co.

Like many innovations developed at Hewlett-Packard's legendary Stanford Park laboratories, the HP 8902A was created to solve an internal measurement need (using the "next-bench syndrome"). It was hand-crafted using novel techniques to achieve the best possible performance so that the company's signal generators and attenuators could be calibrated.

Signal generators were a major part of HP's early product line (as they are today at Agilent Technologies, which was spun off from HP in 1999), and Bill Hewlett and David Packard were directly involved in their development. The efforts of the HP team resulted in "sig gens" such as the vacuum-tube-based 608 and 612 instruments that continued to be used long after production ceased. The attenuators used in these instruments to vary output level were piston (waveguide beyond cutoff) types that bear little resemblance to current digitally-controlled devices. These piston attenuators were inherently accurate based on the distance between transmit and receive "antennas" inside the cavity, requiring little to no calibration or adjustment over many years.

In the 1970s, solid-state signal generators such as the 8640B and 8660C were introduced with step attenuators. These attenuators used cam-actuated microswitches or electrical relays to insert fixed 5 or 10 dB pads in combination to provide from 0 to 130 dB of signal attenuation. Now, attenuation accuracy and calibration had to be performed by time-consuming mechanical and electrical adjustments to the attenuator components to achieve rated performance.

To accurately calibrate these new attenuators and signal generators, HP created test fixtures they called ET's (Electronic Tools). For example, the signal generator output would be downconverted with a LO free of spurious responses through a precise RF chain to a fixed intermediate frequency to precisely measure signal generator output levels, all the way to the maximum sensitivity of the instrument (about -120 dBm). Since the ETs were not production instruments and had to be calibrated in a calibration laboratory, the need remained for a solution that was "production-test compatible".

At the same time, calibration laboratories, especially at military facilities, were clamoring for HP to create a signal generator and attenuator calibration system that was more measurement solution than laboratory curiosity. They needed to calibrate thousands of FM two-way radios with signal generators, which required an instrument to which the signal generators themselves could be calibrated. From this market-driven need, the 8902A was born.

That was more than two decades ago. In the intervening years between then and the time the 8902A was discontinued in 2002, HP was faced with keeping the product current while some of its primary components were discontinued by their manufacturers. For example, the 8902A initially used an industrial microprocessor from Fairchild Semiconductor, the F8, which ultimately went out of production. This required a complete rewriting of the instrument's firmware to accommodate a new instrument controller.

Many other components also became obsolete over the years, and each time HP scrambled to maintain the performance of the 8902A with new components. Of course this is a common problem for any electronic product that has a long-term production run. However, few products of any kind are still in production 20 years after their introduction, which created a continuing series of challenges for HP (and ultimately Agilent) designers. Nevertheless, the 8902A weathered the challenges, and Agilent has pledged to support the instrument through the end of 2012.

A feature of the 8902A that will not be missed is the process of invoking "special functions", such as choosing IF bandwidths and modulation filters, which allow certain capabilities to be enabled. This is accomplished in the 8902A by pressing a key to select the mode, keying-in a sequence of digits that enables the mode, and then pressing another key to begin the measurement process. The 8902A has many of these special functions, and enabling them requires a considerable amount of knowledge that can only be obtained by experience and extensive reading and interpretation of manuals and application notes. With the introduction of the N5530S, the special function has been relegated to history.

Regardless of its shortcomings, the 8902A has not only survived but maintained its preeminence in the last two decades, testament to the efforts of engineers who were dedicated to creating the best possible performance by using design techniques that were not only ahead of their time, but could stand the test of time as well.

After receiving his BSEE in 1976 from Stanford University, George Brandle joined Hewlett-Packard Co. in Palo Alto, CA. As a product marketing engineer, he introduced the HP 8901A to the market (the predecessor to the 8902A). Today he is an application engineer at the Wireless Division of Agilent Technologies in Spokane, WA, where he supports customers using the E5515C Wireless Communications Test Set. He also still provides a bit of application support for the 8902A.

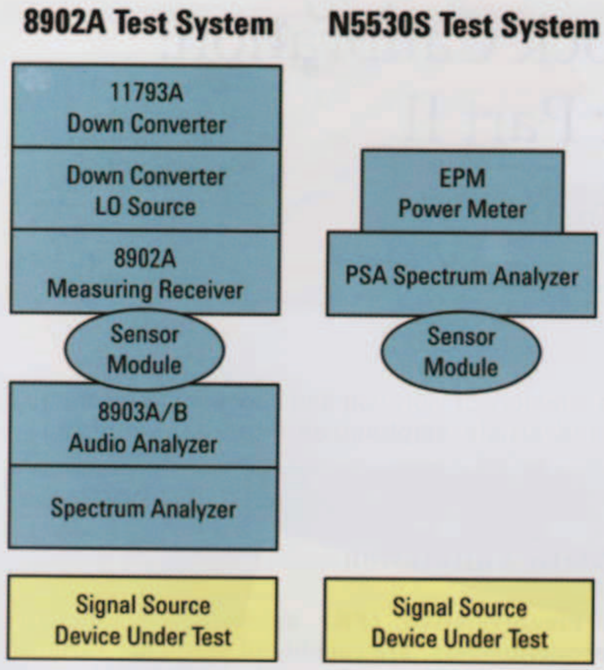

Figure 4. When configured for microwave signal generator calibration, the N5530S is much less complex than its predecessor

a microwave synthesizer to act as the down converter LO, none of which are required with the N5530S for measurements up to 26.5 GHz. A similar comparison of old and new systems for calibrating signal generators is shown in Figure 4.

Simplified Set-up

To achieve the high level of performance required in metrology applications, all instrument settings must be precisely set. This requires a considerable level of skill if performed manually, and even veterans can still make mistakes. The measuring receiver software that is part of the N5530S system automatically optimizes the PSA and EPM to make precise measurements.

The software will run on most any reasonably-current PC running Windows 2000 or Windows XP, and requires only a 300-MHz Pentium or AMD K-6 processor, 256 Mbytes of RAM, 8 Mbytes of video RAM, and 110 Mbytes of available space on a hard drive. A CD-ROM drive and GPIB interface (available from Agilent) are also required.

Code Compatibility

While it would have been desirable to have code compatibility between the old and new instruments, achieving it would have been extremely difficult and would have limited the performance potential of the N5530S. The 8902A used proprietary programming codes that were developed before the SCPI standard existed. However, users who have automated their 8902A-based systems by writing test routines could install both the N5530S measuring receiver software (PSA Option 233) and their own revised test code on the same PC.

The N5530S uses a standard Microsoft COM API (Application Programming Interface), so the user's automation test code will use COM calls to control the measuring receiver software, which in turn controls the test instruments over GPIB. To use existing 8902A code, users must either rewrite it to support COM, or develop an 8902A-to-COM translator. Agilent can provide assistance to users faced with this situation.

Summary

In every respect, the N5530S carries on the tradition of the 8902A as the standard-bearer for signal generator and attenuator calibration by which others are judged. It has better performance, a modern user interface, is composed of commercial test equipment, has a higher frequency range in its base model, is easier to program and operate, and at frequencies above 3 GHz, is smaller as well.

Equally important is the fact that every owner of a PSA spectrum analyzer or EPM/EMP-P power meter already owns some of the system's ingredients. In addition to the industry's foremost measuring receiver, owners of the system also have a high-performance spectrum analyzer and RF power meter that can also be used for a wide variety of measurements in the lab. Taken together, these improvements made the N5530S a worthy successor to the twenty-one-year reign of the 8902A.

Table 1. Models 8902A and N5530S Specifications Compared

Specification	8902A opt 050	N5530S
Time base accuracy	± 3.66 Hz @ 25°C ± 3.77 Hz, 0 to 55°C	± 2.52 Hz @ 25°C ± 3.08 Hz, 0 to 55°C
Frequency counter accuracy	± 396 Hz	± 252.6 Hz
Relative amplitude accuracy (over 50 dB range, 0 to -100 dBm)	± 0.040 dB	± 0.024 dB
Absolute amplitude accuracy (0 to -100 dBm)	± 0.145 dB	± 0.125 dB
Sensitivity	-144.8 dBm/Hz	-150 dBm/Hz
Power meter accuracy	± 0.108 dB (with sensor module 11722A)	± 0.106 dB (with sensor module N5532A)

William M. Kilpatrick joined Agilent Technologies in 1993, after fourteen years in the United States Marine Corps Metrology field. He currently works as an RF/microwave Application Engineer supporting metrology labs.