A Microwave Receiver for Wide-Bandwidth Signals

The HP 71910A wide-bandwidth receiver extends modular spectrum analyzer operation for more effective measurements on modern communications and radar signals.

by Robert J. Armantrout

The microwave spectrum analyzer is an invaluable instrument for making measurements on signals with frequencies ranging from 100 Hz to 110 GHz with a variety of modulation formats. The spectrum analyzer is primarily a tool for the frequency domain. The measurements for which it excels are those in which the signal parameters of interest are accessible in this domain.

For the most part, these measurements are made in a test environment, in which the signals usually originate from a signal source or from the device under test and where a physical connection is made to the spectrum analyzer with coaxial cable. In this environment, there is usually a high degree of knowledge about the signals present and the number of signals that must be characterized. Also, there is often some control over the power level of the signals present. The spectrum analyzer is normally used in swept mode. The emphasis is on the fundamental signal parameters, not on the information content present in the modulation.

Microwave spectrum analyzers are also used in the operational environment. In contrast to the test environment, the signal or signals of interest in the operational environment usually come out of the air rather than from a device under test. This means that the spectrum analyzer is connected to an antenna rather than to a device under test. Another contrast to the test environment is the number of signals present at the input to the antenna. Depending on the frequency coverage of the antenna or antennas used, the number of signals present can number in the hundreds or even thousands. In the operational environment the emphasis is on searching for signals of interest and extracting the information content of those signals. The information can have many forms including voice, video, or data. To extract this information, it is necessary to tune to the signal of interest with a bandwidth comparable to the signal's bandwidth and apply the correct demodulation.

Although the spectrum analyzer plays a major role in signal searching, it has not gained acceptance outside this role because of the limitations discussed below. Rather than the spectrum analyzer, a microwave receiver is normally used to perform the down-conversion and demodulation of wide-bandwidth microwave signals.

Bandwidth Limitations. One of the most predominant trends in modern microwave signals is the move toward wider bandwidths. This trend has been growing since the mid-1970s as satellite communications developed and radars began employing a form of spread spectrum known as chirp.

The trend continues to be evident in all areas of satellite and terrestrial microwave communications. Signal bandwidths of 30 MHz or more are typical. Furthermore, various forms of spread spectrum, such as frequency hopping or direct sequence, whether used for multipath mitigation, noise immunity, lower power density, or increased security, have led to increased bandwidths for otherwise narrowband signals.

For such signals, the bandwidth that is adequate for spectrum display or parametric measurements may not be sufficient to

Fig. 1. (left) HP 71910A receiver. (right) HP 71910A Option 011 (a display module like the one at right may be added).

preserve the information content of the signal for demodulation.

Frequency-Domain Limitations. In addition to having wider bandwidth, many modern microwave signals employ more complex modulation formats such as PSK (phase-shift keying) and QAM (quadrature amplitude modulation). Parametric measurements made in the frequency domain are not adequate to characterize these complex signals fully. Modern microwave signals can also have characteristics that vary during the sweep of a conventional microwave spectrum analyzer, making accurate characterization difficult. Finally, pulsed, bursted, gated, and time division multiplexed signals all have characteristics and information that are difficult if not impossible to extract in the frequency domain.

Amplitude-only Limitations. Because the traditional spectrum analyzer employs an envelope detector, it provides only scalar information, and phase information is lost. Since much of the information in modern complex signals is conveyed with phase shifts or variations, this limitation is significant.

Solutions

All three of the spectrum analyzer limitations mentioned above have been recognized and have led to the development of new types of instruments such as modulation-domain analyzers[1] and vector signal analyzers.[2] Although these instruments can aid greatly in the analysis of a complex signal, they do not operate at microwave frequencies and are not well-suited for direct connection to an antenna as required in an operational environment.

The HP 71910A wide-bandwidth receiver (Fig. 1) combines the attributes of a microwave receiver with the strengths of a microwave spectrum analyzer. The spectrum analyzer strengths include wide frequency coverage, synthesized 1-Hz tuning, excellent phase noise, and amplitude accuracy. The microwave receiver attributes include wider IF bandwidths and demodulation.

The HP 71910A provides easy interfacing to vector signal analyzers and modulation-domain analyzers and extends the measurement capability of these instruments into the microwave frequency range. Finally, the HP 71910A provides standard connection to commercial communications demodulator products.

Description

The HP 71910A is an MMS (Modular Measurement System) product which includes a new IF module, the HP 70911A, and a new revision of system firmware. The firmware revision permits operation of the HP 70911A with an existing microwave spectrum analyzer, the HP 71209A Option 001, and provides improved performance for signal searching (see the firmware description on page 84). The HP 70911A, which is described on page 89, provides the functions usually associated with a microwave receiver, including IF bandwidths from 10 to 100 MHz and pulse detection. The HP 70911A also offers options for FM demodulation, 70-MHz IF output, and 70-MHz channel filters. Another feature not found in other microwave receivers is the I-Q output option.

The two most common configurations of the HP 71910A operate over the frequency range of 100 Hz to 26.5 GHz.

The standard HP 71910A (Fig. 1, left) provides both microwave spectrum analyzer and microwave receiver operation. An alternate configuration, Option 011 (Fig. 1, right), provides microwave receiver operation only. The rest of this article will focus on the HP 71910A Option 011 configuration.

Receiver Hardware

A block diagram of the HP 71910A Option 011 is shown in Fig. 2. The optional preamp module provides improved sensitivity and includes an internal bypass switch. The HP 70900B LO module provides the local oscillator and 300-MHz reference signals to the HP 70910A RF module. The HP 70900B also provides the firmware control of the modules that make up the HP 71910A. For operation as a spectrum analyzer or a receiver, the HP 71910A modules are slaves to the HP 70900B. The HP 70910A RF module provides microwave preselection and frequency conversion to a 321.4-MHz IF output, which provides the input to the HP 70911A module.

RF Module. The HP 70910A RF module was developed to provide wide bandwidths in the front end of the receiver. Aspects of the design important for microwave receiver operation include:
- Increased-bandwidth YTF (YIG-tuned filter) preselector
- Preselector bypass
- Mixer microcircuit for improved sensitivity
- Programmable gain at 321.4-MHz IF output.

The partial block diagram of the HP 70910A RF module in Fig. 3 shows four signal paths. The first is the low-band path, which is used for frequencies up to 2.9 GHz. There are two microwave paths, preselected or bypassed, which can operate from 2.7 GHz to 26.5 GHz. Finally, there is an IF input for use with external mixers covering from 26.5 GHz to 110 GHz (millimeter-wave frequencies).

The minimum bandwidth of the microwave preselector in previous spectrum analyzer designs ranged from 25 to 30 MHz. The design goal of the HP 70910A was to improve the minimum bandwidth of the YTF to at least 36 MHz. This was accomplished by modifying the doping profile of the YIG spheres used in the YTF. A YTF bypass path is included
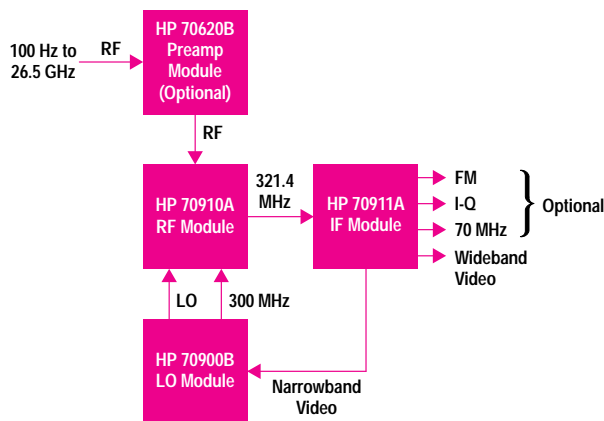

Fig. 2. A simplified block diagram of the main components of the HP 71910 Option 011 receiver.
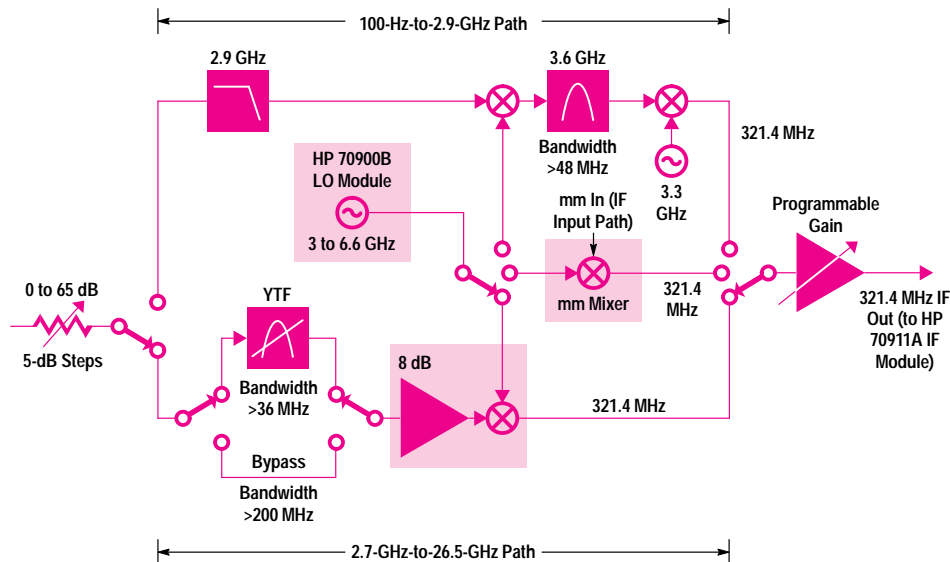
Fig. 3. A partial block diagram of the HP 70910A RF module.

to allow unpreselected operation when appropriate. When in bypass, the bandwidth of the microwave path is much wider than the bandwidth of the preselector. In addition, the group delay performance is improved when the preselector is bypassed.

The preamp-mixer microcircuit following the preselector improves sensitivity in two ways. First, the preamp compensates for the loss of the YTF while retaining acceptable intermodulation performance. Second, the mixer design takes advantage of a special diode configuration to minimize conversion loss in the harmonic-mixing bands.

The final 321.4-MHz block is the programmable-gain amplifier. The purpose of this amplifier is to maintain a constant gain from the RF input to the 321.4-MHz IF output as a function of frequency. The gain is set based on lookup table values determined during final test.

IF Module. The design goals for the HP 70911A IF module included:
- 100-MHz bandwidth variable in 10% steps
- 70-dB gain in accurate 10-dB steps
- Pulse detector for 10-ns pulses
- 70-MHz IF output

- FM demodulator.

Variable bandwidths and accurate gain are standard in spectrum analyzers, but typically at center frequencies of 3 MHz or 21.4 MHz. In the HP 70911A all variable gains and bandwidths are centered at 321.4 MHz. The higher center frequency and the higher fractional bandwidth presented significant design challenges.

An envelope detector for AM and pulse detection is also standard in spectrum analyzers, but in the HP 70911A design we had to accept a 321.4-MHz input and have bandwidth consistent with recovering 10-ns wide pulses.

Wide-bandwidth FM signals are common in both satellite and terrestrial microwave communications. For this reason, wideband FM demodulation, not found in spectrum analyzers, was an important design goal in the HP 70911A.

Within the communications industry, 70 MHz is a standard IF frequency. Most commercial communication demodulators accept 70-MHz inputs. For this reason, a 70-MHz IF output was considered essential for interfacing to demodulators for formats other than wideband AM or FM.
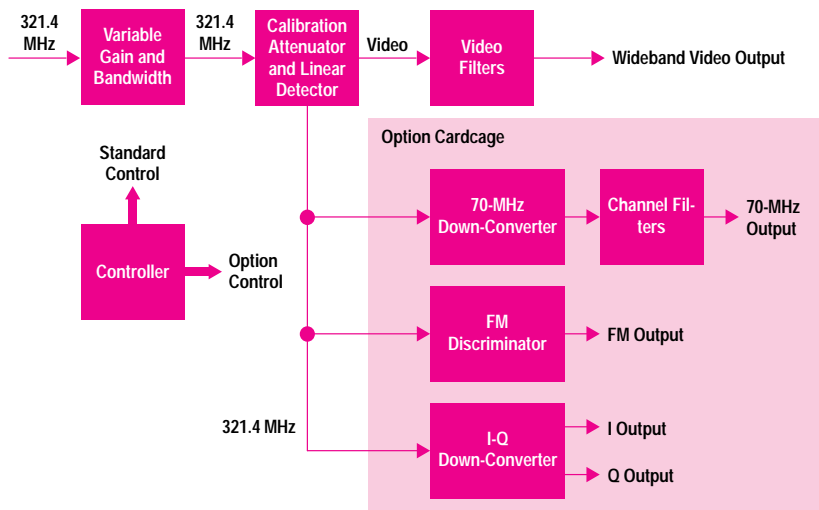

Fig. 4. The major functional blocks that make up the HP 70911A IF module.

Fig. 4 shows the major functional blocks that make up the HP 70911A. The variable gain and bandwidth block includes a bandpass filter with bandwidth that varies from 10 to 100 MHz with DAC control. The filter is a five-pole synchronously tuned design. The gain consists of seven stages of step gains interspersed with the poles of the filter.

The calibration attenuator and linear detector block includes a precision attenuator with 15-dB range and an envelope detector with 100-MHz bandwidth. The detector is followed by video gain and level control.

Several optional functions can be added for expanded receiver capability. These plug into an option card cage and are controlled over a common internal bus.

FM Discriminator. This block includes a delay line discriminator with excellent linearity and a maximum bandwidth of 40 MHz. Two sensitivity positions, 10 MHz/V and 40 MHz/V, can be selected.

70-MHz Down-Converter. This block consists of a down-conversion path and a fractional-N synthesized local oscillator. The tuning range of the LO provides, with a change of output filter, 140-MHz and 160-MHz IF outputs.

Channel Filters. The standard IF bandwidths are of the synchronously tuned class and provide very good response for pulses but lack the shape factor desired for communication signals. The channel filters provide a selection of five six-pole Chebyshev filters centered at 70 MHz for use as prefilters for the communication demodulators.

I-Q Down-Converter. This block provides I and Q baseband outputs with a 50-MHz bandwidth for each output. The local oscillator for the down-conversion is synthesized and the design is the same as that used for the 70-MHz output.

A more detailed discussion of the design and implementation of the HP 70911A is given on page 89.

Receiver Bandwidth Improvements
The increase in bandwidth for the HP 71910A is dependent on the frequency band selected. The receiver bandwidth, which depends on the bandwidth of both the RF and the IF modules, ranges from 36 MHz to 100 MHz. The RF bandwidth of the low-band path is set to 48 MHz minimum by the bandpass filter in the 3.6-GHz second IF. In the preselected microwave path, the bandwidth of the RF module ranges from 36 MHz to 60 MHz over the 2.7-GHz-to-26.5-GHz frequency range. However, when the preselector is bypassed the bandwidth of the microwave path approaches 200 MHz. Finally, when using external mixers for frequencies above 26.5 GHz, the bandwidth of the RF path will be set by the mixers, but is at least 200 MHz. The resulting receiver bandwidth for each path is summarized in Table I.

Table I
HP 71910A Receiver Bandwidths

HP 70910A Signal Path	IF Output (MHz)		
	321	140	70
Low-Band	48	48	40
Preselected	36 to 60	36 to 60	36 to 40
Unpreselected	100	70	40

Receiver Operation
To simplify the HP 71910A's operation as a microwave receiver, a personality downloadable program was created. This program, which is loaded into the HP 70900B LO module, presents the user with the display shown in Fig 5. This screen provides information to assist the user in establishing the correct gain through the receiver when other processors, instruments, or demodulators are connected at the outputs. The RF/IF Gain annotation shows the total gain from the RF input to the 70-MHz IF output. It accounts for fixed or variable gain and attenuation in both the RF and the IF modules.

In addition to calculating and displaying gain through the receiver, the receiver personality extends the gain resolution available to the user. In normal spectrum analyzer operation, the IF gain resolution is 10 dB. However, for the HP 70911A IF module, the personality combines the 10-dB resolution of the step gains with the 1-dB resolution of the internal calibration attenuator to provide 1-dB gain setting resolution over a 70-dB range.

The receiver personality also provides control of the optional receiver functions such as FM, I-Q, and channel filtering. This partitioning from the basic firmware control of the HP 70911A was made to allow for adding options in the future without the need for a firmware revision.

In addition to providing an interface for manual control, the receiver personality card also provides a programming interface for automatic operation. After the receiver personality is loaded and initialized, control extensions appear as additional programming commands not present in the basic firmware.

Microwave Vector Signal Analysis
As mentioned earlier, vector signal analyzers have baseband processing capabilities which when used with RF or microwave down-converters permit a more complete characterization of wide-bandwidth signals.

The I-Q down-conversion option of the HP 71910A was designed specifically for use with other HP digitizers and oscilloscopes. This option can also be used with a dual-channel vector signal analyzer such as the HP 89410A to
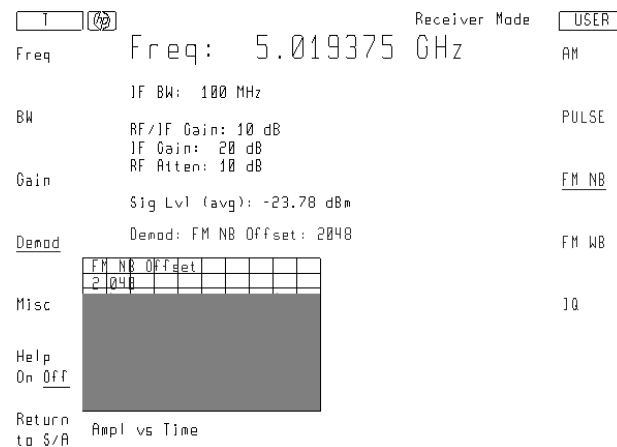

Fig. 5. The user interface screen provided by the HP 71910A receiver personality. The shaded area above is the time-domain display of an FM signal.

extend both the measurement bandwidth and the frequency range of vector signal analysis. This configuration is shown in Fig 6. A special processing mode and careful attention to calibration are required for this configuration. The HP 89410A and vector signal analysis are briefly described on page 87.

Applications
Although much of the early definition work on the HP 71910A focused on radar applications, the attention in later phases of the design shifted to microwave communications. For example, in satellite communications, which requires extensive prelaunch testing, postlaunch qualification, and periodic quality monitoring of live traffic after commissioning, the HP 71910A has much to offer.

The large investment necessary to launch a modern communications satellite makes it imperative to test the satellite and the satellite payloads thoroughly during development and manufacturing and just before launching (called high-bay testing). The number of tests required to fully characterize performance combined with aggressive launch schedules make testing throughput a major consideration.

One of the most time-intensive measurements is spurious testing. This is because of the complexity of satellites and the nature of the measurements taken using the typical spectrum analyzer approach. Sweeping a spectrum analyzer over the full transponder band with the narrow resolution bandwidth necessary for spurious testing leads to very slow sweep times and therefore very long measurement times.

Fortunately, vector signal analyzers such as the HP 89410A have much faster sweep times for the resolution bandwidths of 1 kHz or less, which are used for spurious (spur) testing. By connecting the I-Q outputs of the HP 71910A to the two input channels of the HP 89410A as shown in Fig. 6, it is possible to perform rapid spur search over a 20-MHz span. Repeating this process by step tuning the HP 71910A over all the satellite bands provides nearly a ×10 improvement in spur search speed over sweeping the spectrum analyzer with the same bandwidth over the same frequency range.

Once a satellite is commissioned and carrying live traffic, it is important to maintain the quality of the signals since failure to do so can lead to reduced revenues. One important measurement is the total power of the down link. The total

Firmware Design for Wide-Bandwidth IF Support and Improved Measurement Speed

The addition of a wideband linear IF module to a Modular Measurement System (MMS) spectrum analyzer presented two main challenges to the firmware: providing sufficient operational speed and adding new features and operations. The concern over operational speed was heightened by the fact that many of the applications targeted by this product required speed similar to that obtained by instruments that did not have to account for either software calibration or modularity.

Operational Speed
The challenges associated with operational speed involved finding a way to apply calibration in near real time and efficient handling of incoming data and temporary variables.

Calibrated Operation. To obtain calibrated data from an MMS spectrum analyzer, every trace data point obtained from the ADC must be corrected using the appropriate calibration data. This needs to be done as close to real time as possible or the lag between the incoming raw data and the completion of the correction processing will quickly become the dominant factor in the retrace dead time.

The particular calibration data that must be applied and the algorithms that must be used to apply it are dependent upon the currently active signal path of the instrument. This can change as the user selects different IF bandwidths, different ADCs, and so on. This situation is complicated further by the desire to be able to do trace math (such as calculating the difference of the active trace and a baseline trace) as the data is received. Finally, the trace data needs to be sent to the remote display (if one is active) as the processing is completed. All of these complications exist even without a linear IF module.

If a conventional program is used to apply the per-point calibration, the time to perform the necessary number of conditional tests would overwhelm the actual calculation times. An alternative approach has been used since the beginning by the MMS spectrum analyzers. Instead of performing the conditional tests for each data point, an efficient state machine constructs a program to perform the necessary calculations for the current instrument state. This is done by properly combining machine code program fragments. The construction of this program (known as the RAM program) is properly synchronized with the appropriate state changes and trace operations.

During the execution of the RAM program, calibration and interpolation table addresses and calibration constants are stored in the CPU registers whenever possible. A preloaded register set is prepared at the same time that the RAM program is constructed. If the RAM program catches up with the incoming data stream, the process running the RAM program can swap out to allow other operations to occur. By keeping all the necessary data in the CPU registers, this swapping occurs quickly.

To account for a linear IF module, various additions to the RAM program were required. Previously, all IF modules supported by the system were log IF modules. Since all data calibration occurs after the signal has traversed the IF section, it made sense to keep almost all of the correction factors in dB. This has the additional advantage of allowing simple addition and subtraction to be used to apply the calibration data. Further simplification is achieved by storing the correction factors as 16-bit, fixed-point values. A scaling factor of 100 is used. For example, a value of 10.34 dB would be stored as 1034.

With the addition of a linear IF module, the assumption of logged incoming data was no longer valid. The main alternatives were either to rework the RAM program to be able to handle linear data (including the need to do multiplication and division instead of simply addition and subtraction) or to translate the incoming linear data to log data (preinterpolation). The latter approach is much quicker at performing the calculations, but it also has the potential for a loss of accuracy. However, with the ADCs currently supported by the MMS spectrum analyzer, both the accuracy and the range are limited by the ADC, not by an initial interpolation. Thus, the preinterpolation approach was taken.

Later experimentation showed that, with the reference level set properly, a 38.5-dB range could be achieved with the required accuracy. This was sufficient for the intended use of the product. When a display of linear voltage or power is desired, a table lookup and postinterpolation is performed toward the end of the RAM program.

Hardware Caches. At fast (short) sweep times, even the RAM program, running on a 20-MHz MC68020, is not fast enough to keep up with the incoming data stream. At this point, the data is buffered for the RAM program to process when it can. At the fastest sweep times, the data acquisition loop is actually locked in

power may come from one wideband carrier or it may be the sum of hundreds of narrowband carriers. In either case, the instantaneous power over the full transponder bandwidth is desired. Using swept spectrum analyzer techniques for this measurement can limit speed and degrade accuracy. However, when the channel filters option of the HP 71910A is used with the HP 70100A power meter module, a single accurate power measurement of the full transponder bandwidth, or individual measurements of carriers with specified standard bandwidths, can be performed (see Fig. 7).

Terrestrial microwave communications is an application that involves wide-bandwidth signals with complex modulation schemes. For monitoring microwave link performance, the HP 71910A offers an optional 70-MHz IF output for connection to products that can demodulate these complex modulations. This feature might be used for assessing the BER (bit error rate) performance of the communications link. The BER performance of the HP 71910A was characterized during development. The results of those measurements are shown in Fig 8.
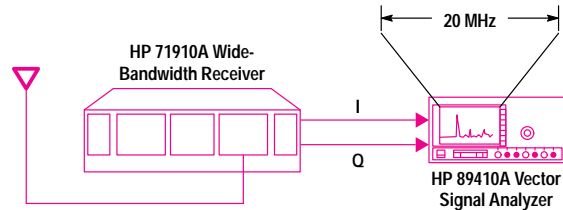

Fig. 6. The HP 71910A configured with the HP 89410A vector signal analyzer.

Other aspects of link performance are often assessed using a constellation display. The I-Q output option of the HP 71910A can be used to display the signal constellation on an oscilloscope (see Fig. 9).

Although swept spectrum analyzers have been used for characterization of radar signals for many years, the trend toward narrow pulses and intrapulse modulations have limited their usefulness primarily to spectrum displays. By connecting the HP 71910A outputs to high-speed oscilloscopes it is possible to extract much more information about the radar.

the MC68020 instruction cache to minimize memory accesses for this time-critical operation.

Software Caches. In addition to the hardware cache built into the MC68020, the MMS spectrum analyzer firmware makes use of software caches as appropriate. Because of the modular nature of the instrument, a change of state can impose a heavy calculation burden. This burden must be borne by an affordable CPU.

Detailed timing and analysis of the operation of the instrument revealed several intensive calculations that could be identified by a minimal number of internal state variables. These variables are used as tags for software caches. This approach saves 60 ms or more for some common state change operations. Use of these caches was integrated with the RAM program so that a register could access the cache data directly, avoiding costly data copying.

Further performance improvements were realized by recognizing situations in which a calculation might need to be redone because of further user inputs before a data acquisition is performed. In such cases, if it is possible, calculation is delayed.

Additional Adaptations for a Wideband Linear IF
Adding more features and operations to the MMS spectrum analyzer involved advertising the capabilities of the IF module to the analyzer and preselector centering.

Configuration Support. In addition to the changes to the RAM program, the main signal routing algorithms had to be enhanced to account for the linear IF module. In the MMS spectrum analyzer, all modules advertise their capabilities to the control module via an ASCII capability string. This machine readable string is effectively a logical block diagram of the module, including all inputs, outputs, and switching capabilities. Some of the elements of this model are named so that the control module can properly manipulate the hardware via a standardized command language.

The addition of support for a linear IF module required minimal additions to the capability string language. Most of the components of the module had already been modeled. Support for an additional value to an existing option flag was the only thing required.

Preselector Centering. The wideband IF module presented an additional difficulty with preselected systems. With a narrowband IF, the tuning of the preselector is done via peaking. In peaking a test signal is injected into the system and the preselector hardware is tuned to provide a maximum response. This approach does not work for a wideband IF module, since the peak of the passband may not be near the center. Hence, using preselector peaking with a wideband IF module could easily result in a substantially reduced available signal bandwidth.

The proper approach for adjusting a preselector to work with a wideband IF module is to center the filter based upon a user-configurable signal delta value (typically 6 dB). Centering occurs in three main stages. First, a coarse search sketches the shape of the curve and identifies where to search for the peak value. Next, a fine search identifies the actual peak. Both of these steps are similar to what occurs for preselector peaking, except that coarse values are saved. The final step involves fine searches in the areas of the curve that correspond to the user-specified delta from the peak value. In all searches, an appropriate amount of overlap is used since the curve might not be locally monotonic.

The initial implementation worked correctly, but test users sometimes complained that the preselector still wasn't being centered correctly. The typical situation was that a user had a band-limited signal path that had not been previously connected to a narrowband spectrum analyzer. Thus, the user was not aware that the signal path was the problem.

The solution to this situation is to display the centering graphically as it occurs. All of the coarse and fine points are plotted so that the user can see what is happening. In addition, the user can examine and change the selected centering setting.

Conclusion
By using the techniques described above, we were able to add support for a wideband linear IF module into the MMS spectrum analyzer family and achieve speed that matches or even exceeds that of instruments with less functionality and configurability.

Thomas A. Rice
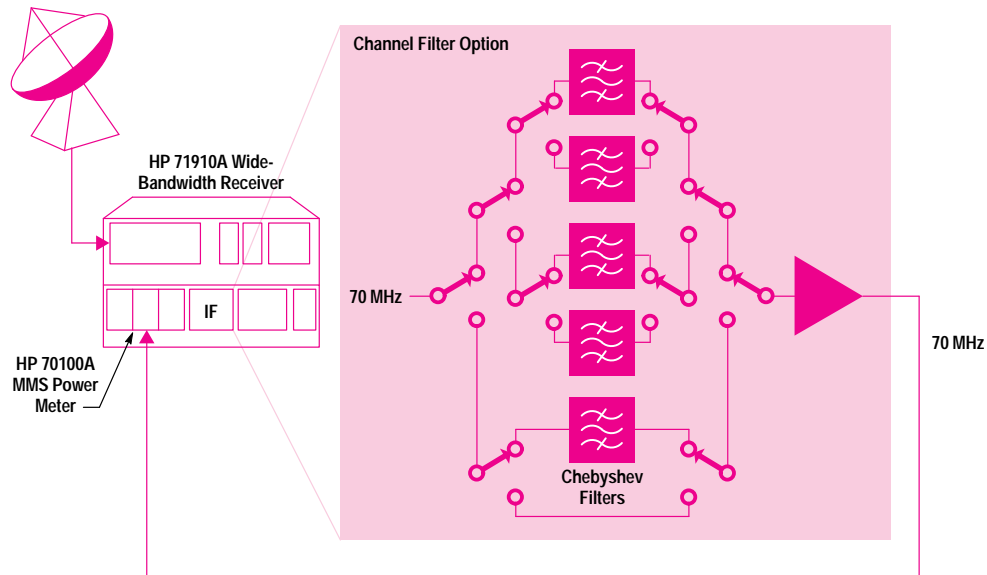Development Engineer
Microwave Instruments Division

Fig. 7. The HP 71910A channel filters configured with an HP 70100A power meter to measure transponder bandwidth.
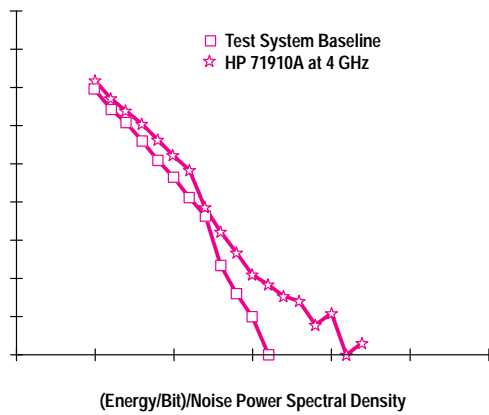

(Energy/Bit)/Noise Power Spectral Density

Fig. 8. Results of a 64 QAM 150-Mbit/s bit error rate (BER) test for the HP 71910A.
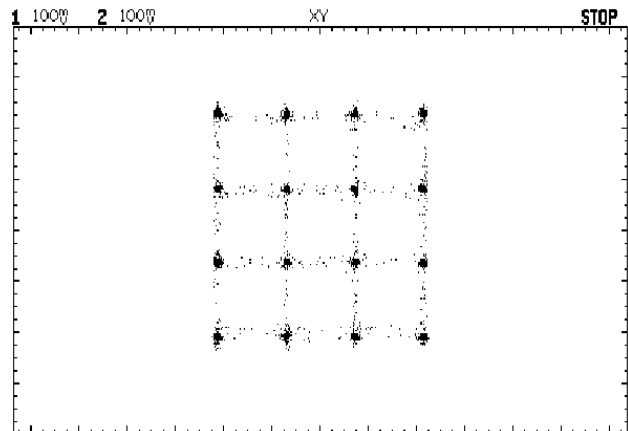

Fig. 9. A 16-QAM constellation plot from an HP 54600A oscilloscope, captured using the I-Q option of the HP 71910A.

The HP 89400 Series Vector Signal Analyzers

The HP 89400 Series vector signal analyzers are designed specifically for today's complex signals. They provide insight into a signal's time-domain, frequency-domain, and modulation-domain characteristics. The HP 89440A and HP 89441A analyzers are limited in frequency coverage to 1.8 GHz and 2.65 GHz respectively. Both are limited to a 7-MHz information bandwidth, where the information bandwidth is the widest-bandwidth signal that can be analyzed without any loss of information. The HP 71910A microwave spectrum analyzer and HP 89410A vector signal analyzer can be used together to obtain frequency coverage to microwave frequencies and information bandwidths to 20 MHz.

By itself, the HP 89410A is considered to be a two-channel baseband analyzer. Each input channel incorporates an anti-alias filter, an ADC operating at a 25.6-MHz sample rate, and dedicated hardware to perform digital signal processing. Normally, these channels are used independently. However, when used with a quadrature down-converter, such as the HP 70911A Option 004, the in-phase (I) and quadrature-phase (Q) signals from the down-converter are each connected to an input channel on the vector signal analyzer where they are digitized and then recombined into a single complex signal of the form I+jQ. Fig. 1 shows an example of the measurements obtained when the HP 89410A and HP 70911A are used together. Although the I and Q signals are each limited to 10-MHz bandwidth by the analyzer's anti-alias filters, the combined complex signal has a bandwidth of 20 MHz.

Complex Signals

In any system where the I and Q signals are analog, the accuracy of the system and its dynamic range will be limited by the orthogonality of the signals and by the match between the I and Q signal paths. Calibration routines can be used to measure and improve system performance (see Fig. 2). The system errors observed during calibration are reduced using both hardware adjustments (performed electronically) and digital signal processing techniques. Table I lists the system errors and the action taken to reduce the effects of the errors.

A program has been developed that performs the system calibration and provides some level of instrument control. This program is compatible with the HP 89410A's HP Instrument BASIC Option IC2, eliminating the need for an external controller.

Bibliography

1. *Extending Vector Signal Analysis to 26.5 GHz with 20-MHz Information Bandwidth*, Publication Number 5964-3586E, Hewlett-Packard, 1995.
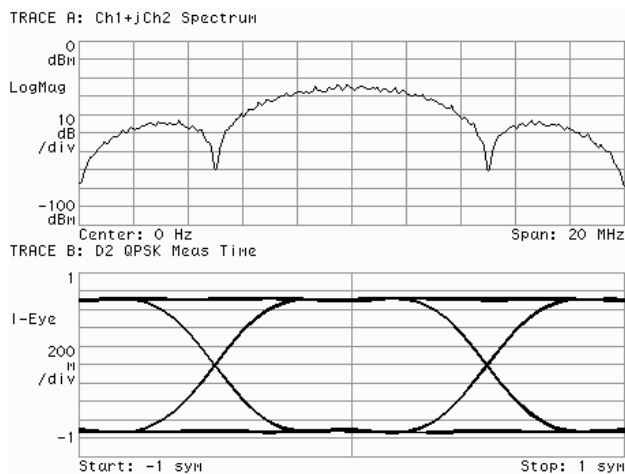
Fig. 1. The upper trace shows the spectrum of a QPSK signal operating at 10 MBits/s. The lower trace is the eye diagram obtained using the HP 89410A's optional digital demodulator.
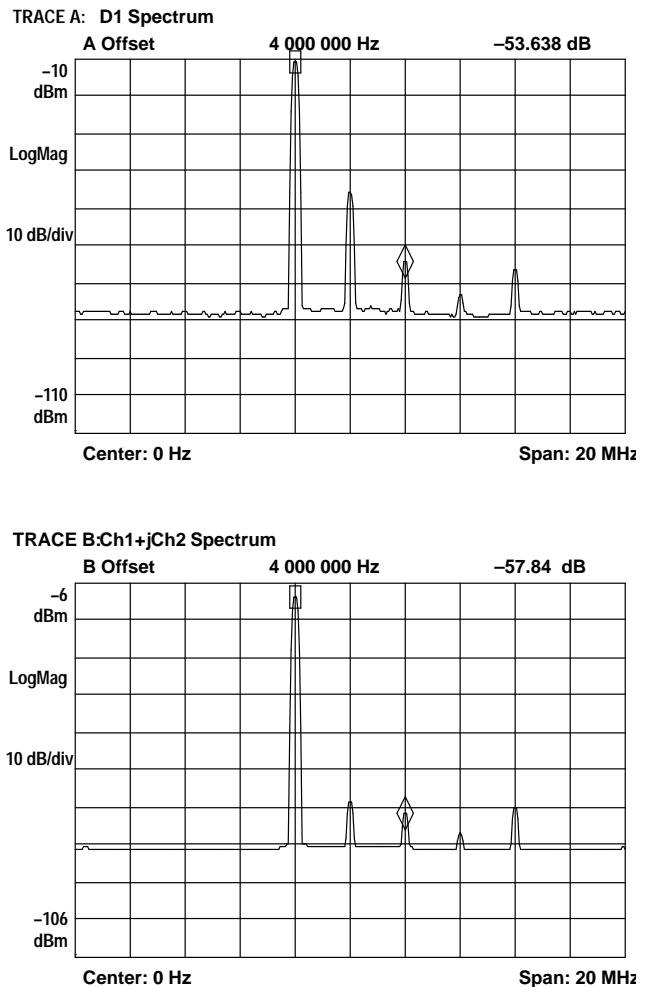

Fig. 2. The upper trace shows the spectrum computed using the I-Q signals without calibration. The lower trace is the same spectrum after calibration. Only the largest component should be present. After calibration the spectral line (center) caused by residual dc on I and Q is substantially reduced. The large spectral component has an image to the right of the center. This image, which has also been reduced in amplitude, is caused by channel mismatch.

Table I
Summary of Analyzer System Errors and Methods to Reduce Them

Source of Error	Method Used to Reduce Error	
	Microwave Signal Analyzer	Vector Signal Analyzer
I-Q Quadrature	Hardware Adjust	
I-Q DC Offset	Hardware Adjust	
I-Q Gain Match		Digital Signal Processing
I-Q Delay Match		Digital Signal Processing

by Robert T. Cutler
Development Engineer
Lake Stevens Instrument Division
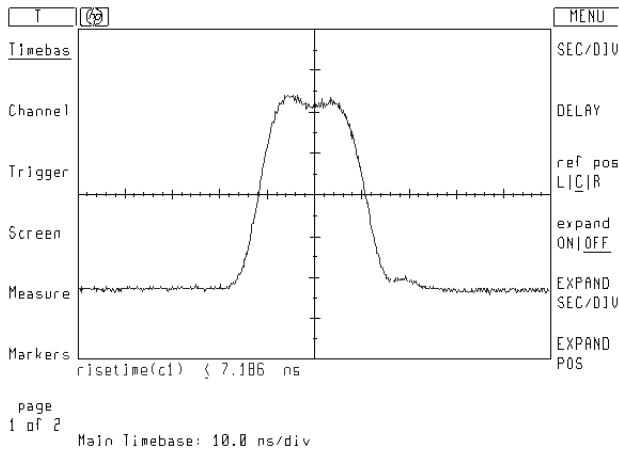
(a)
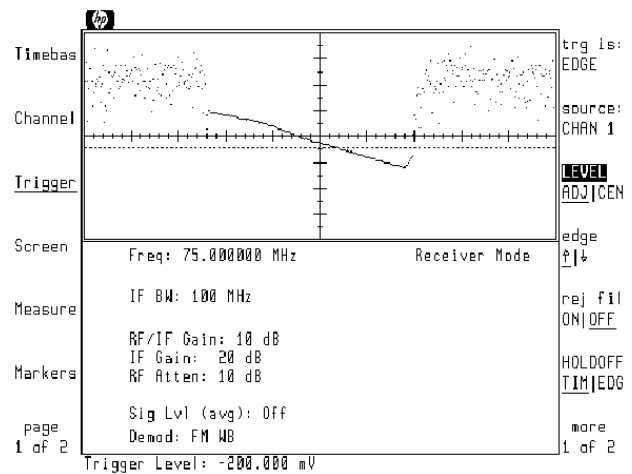
(b)

Fig. 10. Connecting the outputs of the HP 71910A to an HP 70703A high-speed oscilloscope enables the capture and display of much information from a radar signal. (a) A narrow 20-ns pulse. (b) An FM chirp.

Fig. 10a shows a narrow pulse produced by using the video output of the HP 70910A, and Fig. 10b shows an intrapulse chirp produced by using the FM output of the microwave receiver.

Acknowledgments

The author would especially like to thank John Fisher for his initial management of the project and for his support and guidance throughout. Others who made significant contributions to the project include: Ed Barich for project management and preamp-mixer microcircuit design on the HP 70910A, Mark Coomes for project management and design of the system firmware, Bill Walkowski for his efforts on

market research and product definition, and Nancy McNeil who developed the receiver personality downloadable program. Finally, the author would like to thank the entire management team for their patience and support during development.

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