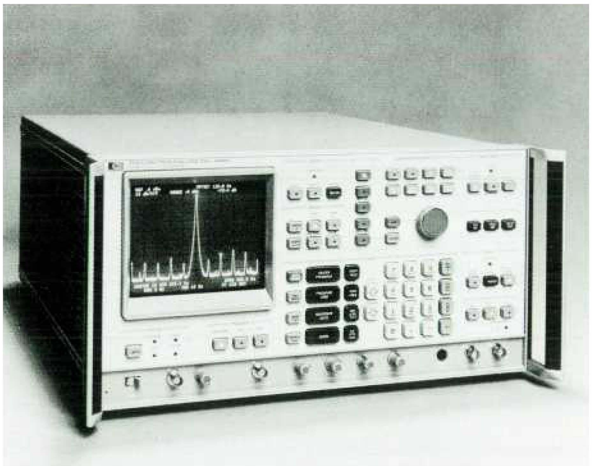
A Precision, Digitally-Controlled Spectrum Analyzer for the 20-Hz-to-40-MHz Frequency Range

by Robert E. Temple

Spectrum analyzer performance approaching that of a precision wave analyzer has been achieved by applying microprocessor control to an instrument for use in the audio-to-high-frequency (20 Hz - 40 MHz) range.

Amplitude measurements made by this analyzer (Model 3585A) are accurate within ±0.5 dB over the entire frequency range and an amplitude range of +30 dBm to −75 dBm. Even at −95 dBm, amplitude accuracy is within ±0.8 dB. This is achieved by a microprocessor-controlled calibration routine that uses an internal crystal-controlled 10-MHz reference signal to measure and compensate for frequency-tuning and system-gain errors, and an extremely flat internal tracking generator that measures and compensates for frequency-response and attenuator-ranging errors.



The total measurement range is −135 dBm to +30 dBm. The amplitude of any point identified by a movable marker on the displayed spectrum is measured and presented numerically on the CRT with 0.01-dB resolution, and the frequency is measured using a counter function with 0.1-Hz resolution.

Frequency measurements are accurate within ±0.3 Hz $\pm 1\times10^{-7}$/month. This accuracy was made possible by the use of synthesizer techniques, the tuning range of this instrument allowing all the local oscillator frequencies to be synthesized. Thus, the local oscillator frequencies are known precisely at any point in the tuning sweep so the signal at the output of the IF section can be measured by a counter and converted arithmetically by the microprocessor to arrive at the value of the input signal frequency.

Model 3585A is a triple-conversion receiver. The synthesizer that generates the local oscillator signals uses the fractional-N technique[1] to obtain very small frequency steps with phase coherence between steps. The frequency sweep is thus essentially continuous. In addition, a tracking generator output is derived from the synthesizer so the analyzer can be used for swept-frequency measurements of amplitude response.

The stability and low phase noise of the synthesizer enable the narrowest resolution bandwidth (3 Hz) to be used over the full frequency range to 40.1 MHz. Thus, Model 3585A can measure low-level frequency components lying very close to much larger frequency components. For example, it can measure 50-Hz or 60-Hz power line sidebands more than 80 dB below carriers with frequencies as high as 40 MHz.

Noise and distortion products generated internally are more than 80 dB below a −25-dBm full-scale input when using resolution bandwidths as wide as 3 kHz. Thus, it is not necessary to use narrow bandwidths with resultant very slow sweeps to find low-level signal-related distortion products.

Digital Control

Control of Model 3585A Analyzer by a microprocessor gives it many of the operating features of Model 8568A described in this issue. Thus, it has keyboard control of the instrument functions with variable parameters (center frequency, reference level, etc.) set by a knob, step keys, or numeric entry. Information that defines the displayed spectrum is presented on the CRT.

Resolution bandwidth, video bandwidth, and sweep time are automatically set by the choice of frequency span to simplify narrowing in on a signal. Instrument operation is further simplified by automatic ranging of the input attenuator in 5-dB steps with concurrent tracking of the reference level. Hence, the largest signal within the range of the instrument is automatically placed near the top of the CRT graticule.

The acquired spectrum is digitized into 1001 data points and stored in memory for repetitive read-out and display on the CRT. A second data memory allows retention of a reference spectrum for later display or for A−B measurements. The instrument can also operate in an offset mode for relative measurements, and in a MAX HOLD mode for measuring frequency drift or FM.

Model 3585A is fully HP-IB compatible for automating measurements or for further processing of acquired data. For example, the amplitudes of a signal's harmonics can be measured and transferred over the HP-IB to a computing controller for calculation of total harmonic distortion.

Automatic Calibration

The calibration routine occurs automatically about once every two minutes or whenever any control settings that affect instrument calibration are changed (center frequency, resolution bandwidth, etc.). First, the internal 10-MHz reference signal is switched to the analyzer input, the synthesizer tuning is swept across a narrow band of frequencies centered on the reference

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Raised in Newburyport, Massachusetts, Bob Temple earned a BA degree in physics at Harvard University and then migrated westwards to the University of Colorado where he obtained MS (1969) and PhD (1971) degrees in electrical engineering. In 1969, he joined HP's Loveland Instrument Division in Colorado where he worked on the 3320A and 3330A/B Frequency Synthesizers before becoming co-project leader on the Model 3585A. Bob is now a production engineer.