Acknowledgments

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1. D. Scherer, "Design Principles and Test Methods for Low Phase Noise RF and Microwave Sources," HP Microwave Symposium, 1979.
2. "Frequency Stability Specification and Measurement, High-Frequency and Microwave Signals," U.S. National Bureau of Standards Technical Note 632.
3. R.A. Frohwerk, "Signature Analysis: A New Digital Field Service Method," Hewlett-Packard Journal, May 1977.

Allen P. Edwards

A native Californian, Allen Edwards earned his BSEE and MSEE degrees at Stanford University in 1971 and joined HP the same year. He worked as a design engineer on the 8558A Spectrum Analyzer, the 435A Analog Power Meter, and the 8481A Coaxial Power Sensor, and served as project manager for the 436A Digital Power Meter and the 8901A Modulation Analyzer. He is named as inventor on two patents. A resident of Palo Alto, Allen spends part of his spare time backpacking and bicycling; he also enjoys photography.

SPECIFICATIONS

HP Model 8901A Modulation Analyzer

RF Input

FREQUENCY RANGE: 150 kHz to 1300 MHz.

OPERATING LEVEL:

150 kHz - 650 MHz: 12 mV_{rms} (−25 dBm) to 7 V_{rms} (1 W_{peak}).
650 MHz - 1300 MHz: 22 mV_{rms} (−20 dBm) to 7 V_{rms} (1 W_{peak}).

Frequency Modulation

RATES: 150 kHz - 10 MHz: 20 Hz to 10 kHz.
10 MHz - 1300 MHz: 20 Hz to 200 kHz.[1]

DEVIATIONS:

150 kHz - 10 MHz: 40 kHz_{peak} maximum.
10 MHz - 1300 MHz: 400 kHz_{peak} maximum.[1]

ACCURACY:[2]

250 kHz - 10 MHz: ±2% of reading ±1 digit, 20 Hz to 10 kHz rates.
10 MHz - 1300 MHz: ±1% of reading ±1 digit, 50 Hz to 100 kHz rates. ±5% of reading ±1 digit, 20 Hz to 200 kHz rates.

DEMODULATED OUTPUT DISTORTION:[3]

400 kHz - 10 MHz: <0.1% THD, deviations <10 kHz.
10 MHz - 1300 MHz: <0.1% THD, rates and deviations <100 kHz.

AM REJECTION (for 50% AM at 400 Hz and 1 kHz rates)[2] <20 Hz peak deviation measured in a 50 Hz to 3 kHz BW.

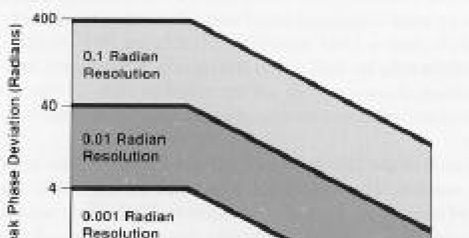
RESIDUAL FM (50 Hz to 3 kHz BW) <8 Hz_{rms} at 1300 MHz, decreasing linearly with frequency to <1 Hz_{rms} for 100 MHz and below.

Phase Modulation

CARRIER FREQUENCY: 10 MHz to 1300 MHz.

RATES: 200 Hz to 20 kHz.

DEVIATION AND MAXIMUM RESOLUTION:



ACCURACY:[2] ±3% of reading ±1 digit.

DEMODULATED OUTPUT DISTORTION: <0.1% THD.

AM REJECTION (for 50% AM at 1 kHz rate)[2] <0.03 radian peak in a 50-Hz-to-3-kHz BW.

Amplitude Modulation

RATES: 150 kHz - 10 MHz: 20 Hz to 10 kHz.
10 MHz - 1300 MHz: 20 Hz to 100 kHz.

DEPTH: to 99%.

ACCURACY:[2,4]

150 kHz to 10 MHz: ±2% of reading ±1 digit, 50 Hz to 10 kHz rates, >5% depth. ±3% of reading ±1 digit, 20 Hz to 10 kHz rates.
10 MHz to 1300 MHz: ±1% of reading ±1 digit, 50 Hz to 50 kHz rates, >5% depth. ±3% of reading ±1 digit, 20 Hz to 100 kHz rates.

FLATNESS (variation in indicated AM depth for constant depth on input signal):

10 MHz to 1300 MHz: ±0.3% of reading ±1 digit, 90 Hz to 10 kHz rates, 20 to 80% depth.

DEMODULATED OUTPUT DISTORTION: <0.3% THD for <50% depth, <0.6% THD for <95% depth.

FM REJECTION (at 400 Hz and 1 kHz rates, 50 Hz to 3 kHz BW)[2]

250 kHz to 10 MHz: <0.2% AM for <5 kHz_{peak} deviation.
10 MHz to 1300 MHz: <0.2% AM for <50 kHz_{peak} deviation.

RESIDUAL AM (50 Hz to 3 kHz BW): <0.01% rms.

Frequency Counter

RANGE: 150 kHz - 1300 MHz.

SENSITIVITY:

150 kHz - 650 MHz: 12 mV_{rms} (−25 dBm).
650 MHz - 1300 MHz: 22 mV_{rms} (−20 dBm).

ACCURACY: Reference accuracy ±3 counts of least significant digit.

INTERNAL REFERENCE:

FREQUENCY: 10 MHz.
AGING RATE: $<1\times10^{-6}$/month
(Optional: 1×10^{-9}/day after 30-day warmup).

	Standard	Option 002
Aging Rate	$<1\times10^{-6}$/mo.	$<1\times10^{-9}$/day
Temperature Effects	$<2\times10^{-7}$/°C	$<2\times10^{-10}$/°C
Line Voltage Effects (+5%, −10% line voltage change)	$<1\times10^{-6}$	$<6\times10^{-10}$
Short term stability		1×10^{-9} for 1s average

RF Level[5]

(Peak-voltage responding, rms sine wave power calibrated).

RANGE: 1 mW to 1 W.

INSTRUMENTATION ACCURACY: 150 kHz - 650 MHz: ±2 dB.
650 MHz - 1300 MHz: ±3 dB.

SWR: <1.5 in a 50Ω system.

Audio Filters

HIGH PASS (3-dB cutoff frequency): 50 Hz and 300 Hz.

LOW PASS (3-dB cutoff frequency except >20 kHz filter): 3 kHz, 15 kHz, >20 kHz.

DE-EMPHASIS FILTERS: 25 μs, 50 μs, 75 μs, and 750 μs. De-emphasis filters are single-pole low-pass filters whose 3-dB frequencies are 6366 Hz for 25 μs, 3183 Hz for 50 μs, 2122 Hz for 75 μs, and 212 Hz for 750 μs.

FLATNESS:

50 Hz HIGH PASS: <1% at rates >200 Hz.
300 Hz HIGH PASS: <1% at rates >1 kHz.
3 kHz LOW PASS: <1% at rates <1 kHz.
15 kHz LOW PASS: <1% at rates ≤10 kHz.
>20 kHz LOW PASS: <1% at rates ≤10 kHz.

Calibrators (Option 010)

AM CALIBRATOR DEPTH AND ACCURACY: 33.33% depth nominal, internally calibrated to an accuracy of ±0.1%.

FM CALIBRATOR DEVIATION AND ACCURACY: 33 kHz_{peak} deviation nominal, internally calibrated to an accuracy of ±0.1%.

General

TEMPERATURE: Operating: 0° to 55°C.

REMOTE OPERATION: HP-IB; all functions except the line switch are remotely controllable.

EMI: Conducted and radiated interference is within the requirements of methods CE03 and RE02 of MIL STD 461A (for inputs <10 mW), VDE 0871 Level B, and CISPR publication 11.

CONDUCTED AND RADIATED SUSCEPTIBILITY: Meets the requirements of methods CS01, CS02, and RS03 (1 volt/metre) of MIL STD 461A dated 1968.

POWER: 100, 120, 220, or 240 Vac (+5, −10%); 48-66 Hz; 200 VA max.

WEIGHT: Net 20 kg (44 lb).

DIMENSIONS: 190 mm H × 425 mm W × 468 mm D (7.5 in × 16.8 in × 18.4 in).

PRICES IN U.S.A.: 8901A Modulation Analyzer, $7500; Option 010 AM and FM calibrators, $500.

MANUFACTURING DIVISION: STANFORD PARK DIVISION
1501 Page Mill Road
Palo Alto, California 94304 U.S.A.

1. Maximum rate 20 kHz and peak deviation 40 kHz with 750 μs de-emphasis filter.
2. Peak residuals must be accounted for in peak readings.
3. With 750 μs de-emphasis and pre-display "off," distortion is not specified for modulation outputs >4 Vpeak. This can occur near maximum deviation for a measurement range at rates <2 kHz.
4. For peak measurements only, AM accuracy may be affected by distortion generated by the Modulation Analyzer. In the worst case, this can decrease accuracy by 0.1% of reading for each 0.1% of distortion.
5. The TUNED RF LEVEL mode is uncalibrated.

Modulation Analyzer Applications

by Allen P. Edwards

THE 8901A MODULATION ANALYZER is a useful tool for analyzing many types of signals. Often it can provide needed information that has been difficult to obtain, such as incidental FM or residual FM. It can replace large, complex test systems, and speed and simplify measurements.

The modulation analyzer is well suited for measuring mobile communications and other transmitters. This single instrument can be used in making most of the measurements normally made on transmitters, such as carrier power, carrier frequency and stability, AM depth, FM deviation, hum and noise, incidental AM or FM, modulation limiting (instantaneous and steady-state), and audio frequency response.

For avionics applications the 8901A can be very useful in measuring navigation signals. In testing ILS transmitters the analyzer can be used to measure depth of modulation very accurately. For broadcast AM and FM it can be used to measure AM depth or FM deviation, and it can accurately recover the modulation for making measurements such as stereo separation and distortion.

Its accuracy makes the modulation analyzer an excellent

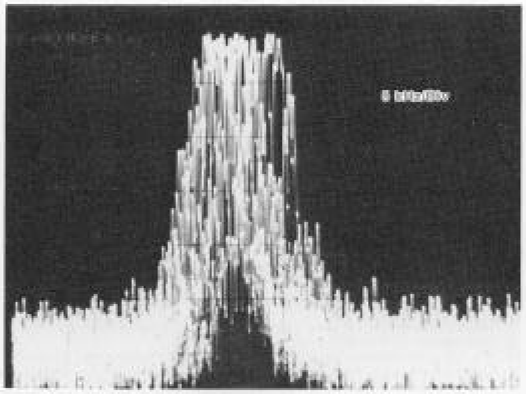


Fig. 1. *Spectrum analyzer display of a supposedly amplitude modulated signal is more typical of broadband FM than single-frequency AM.*

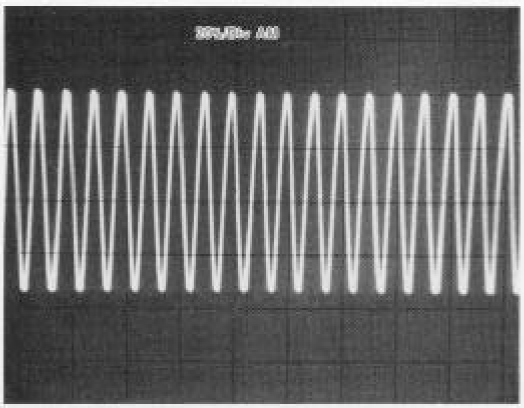


Fig. 2. *AM recovered by the 8901A modulation analyzer from the signal of Fig. 1 is a single-frequency sine wave.*

addition to a metrology laboratory. An example of its usefulness is in calibrating signal generators, especially high-performance signal generators such as the HP 8640B. The modulation analyzer's capabilities exceed those required to verify many signal generator specifications. Besides improving the accuracy of these measurements, it greatly reduces the time involved. Also, the optional calibrators provide a new level of modulation standard accuracy and help ensure accurate measurements.

Because the modulation analyzer is capable of characterizing all types of signals, it is useful in research and development laboratories for characterizing VCOs, measuring residual noise on crystal oscillators, measuring incidental modulation, measuring the frequency of low-level signals, and so on. When used with a signal source it can

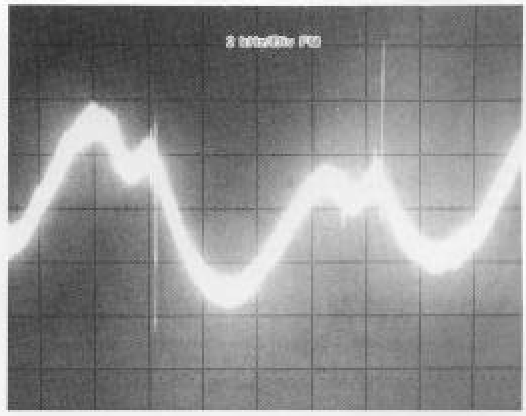


Fig. 3. *FM recovered by the modulation analyzer from the signal of Fig. 1 shows sharp spikes causing the broadband FM appearance of the signal's spectrum.*

characterize RF and IF designs, evaluate modulators, and test individual ICs or modules.

In the following sections, three specific applications are described that demonstrate the modulation analyzer's capabilities.

Solving a Signal Generator Problem

The 8901A's ability to separate amplitude modulation and frequency modulation is demonstrated by this example. Fig. 1 is a spectrum analyzer display of a signal coming from a high-power signal generator that was being amplitude modulated at 1 kHz. The spectrum is more typical of broadband FM than of single-frequency AM.

To see what was happening, the signal was applied to an 8901A. Fig. 2 shows the AM detected by the modulation analyzer, revealing that the signal is indeed being amplitude modulated at 1 kHz. However, the analyzer's FM output, Fig. 3, shows that the generator is also being frequency modulated with line-related interference and that the sharp spikes are causing the broadband FM we saw in the spectrum analyzer display. With these pictures, the

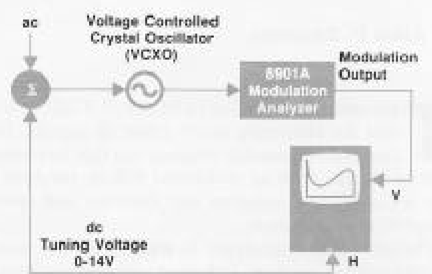


Fig. 4. *Using the modulation analyzer to characterize voltage-tunable oscillators. The low noise of the 8901A's local oscillator makes this application possible.*

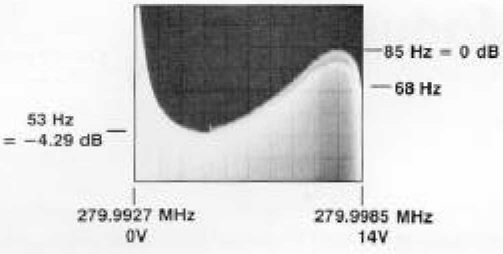


Fig. 5. *Oscilloscope display from the setup of Fig. 4. Ac input to the VCXO was adjusted to give 100-Hz deviation at the low end of the VCXO's tuning range. The display shows how the actual deviation varies as the VCXO is tuned across its band.*

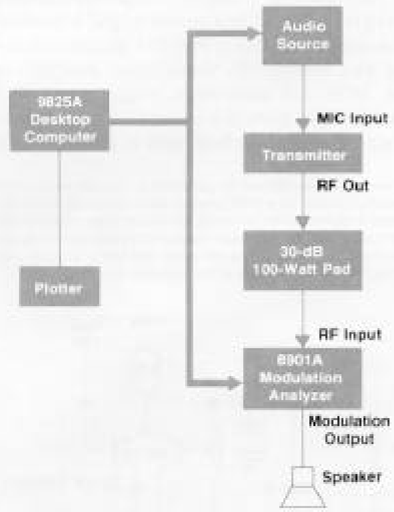


Fig. 6. *An automatic system for testing mobile transmitters. A desktop computer controls the modulation analyzer via the HP Interface Bus.*

manufacturer of this product might have been able to cure this problem by a little attention to the power supply rectifiers, which, one would suspect, are turning off very fast and causing the spikes.

Characterizing Voltage-Tunable Oscillators

The next application demonstrates how the 8901A is useful for characterizing VCOs and VCXOs. Fig. 4 shows a VCXO being measured by the 8901A. The VCXO is operating at 280 MHz and can be pulled 5800 Hz. The idea is to vary the dc tuning voltage from 0V to 14V, causing the VCXO frequency to change by 5800 Hz, while a small ac test signal of constant amplitude frequency-modulates the VCXO. The ratio of the ac frequency deviation to the ac test signal ($\Delta f/\Delta v$) is the gain of the oscillator at the dc operating point. With the ac test signal held constant, the ac frequency deviation is proportional to gain. An oscilloscope is used to plot the dc tuning voltage against the frequency modulation on the VCXO output, as detected by the 8901A. The envelope of the oscilloscope display shows the peak FM deviation of the VCXO as a function of center frequency.

Fig. 5 shows the oscilloscope display. Notice that the peak deviation of the VCXO output varies with center frequency, even though the FM input signal is constant. With this setup the oscilloscope display of gain allows the designer to optimize the circuit and get immediate results when changes are made.

So as not to disturb the measurement, the peak deviation of the FM at 0V is adjusted to only 100 Hz. This is done by adjusting the ac modulating signal while reading the peak deviation with the 8901A. The 8901A's 300-Hz to 3-kHz audio filters are used to limit the noise. The front-panel dB button is pushed to make the display read in dB. Resolution is better than 0.2 dB, which is more than enough for this application. The 8901A's post-peak-detector filter is selected using the analyzer's special function capability and a completely stable display is produced. For this setup, accuracy is limited by the resolution of 0.2 dB.

Assuming that everything was stable this measurement could be made with a counter by painstakingly plotting f_{out} versus tuning voltage and differentiating the plot. Obviously the modulation analyzer produces a more convenient method of analyzing the gain of this system. However, without the extremely low noise of the modulation analyzer's local oscillator, the deviation required to make this type of measurement might perturb the oscillator and limit the resolution of the measurement.

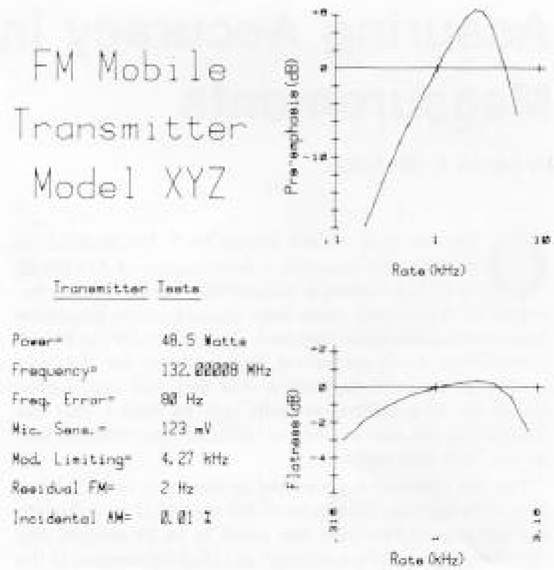


Fig. 7. *Output plot from the system of Fig. 6.*

Automated Tests

Fig. 6 shows an automatic system for testing mobile transmitters, taking advantage of the programmability of the 8901A Modulation Analyzer. An HP 9800 Series Desktop Computer controls the system. Fig. 7 shows a typical output plot.