Special Signal Source Tests Modulation Analyzer

by Leslie E. Brubaker

BECAUSE THE 8901A MODULATION ANALYZER (see article, page 3) is designed to test the highest-quality transmitters and signal generators, it has to be more stable, noise-free, and distortion-free than these signal sources. Where, then, does one find a signal source good enough to test the 8901A?

The answer is a special-purpose signal source, Model 11715A AM/FM Test Source (Fig. 1). This easy-to-use, low-distortion AM and FM source has extremely flat modulation characteristics. Although intended for verifying 8901A performance, it is versatile enough to be useful for other purposes if its restricted frequency coverage matches a particular application. It provides especially high-quality FM in the 88-to-108-MHz frequency range.

While the 8901A's accuracy is determined by its optional built-in AM and FM calibrators, this calibration represents only a single-point performance test. For a complete test, it is also necessary to determine how the 8901A responds when changing the modulation rate (flatness) and the modulation level (linearity). The function of the 11715A is to provide AM and FM signals of sufficient flatness and linearity to characterize the 8901A. In addition, a signal with extremely low residual FM is provided to verify the residual FM of the 8901A at a particular frequency.

The AM output of the 11715A is designed to have very low noise so that it can be used to check the residual AM of the 8901A. The 11715A is also designed to have low distortion, so that the distortion of the 8901A's AM and FM demodulators and audio section can be checked. Finally, the AM source is designed to have low incidental ΦM and the FM source is designed to have low incidental AM.

What's Inside

The block diagram of the 11715A is shown in Fig. 2. The

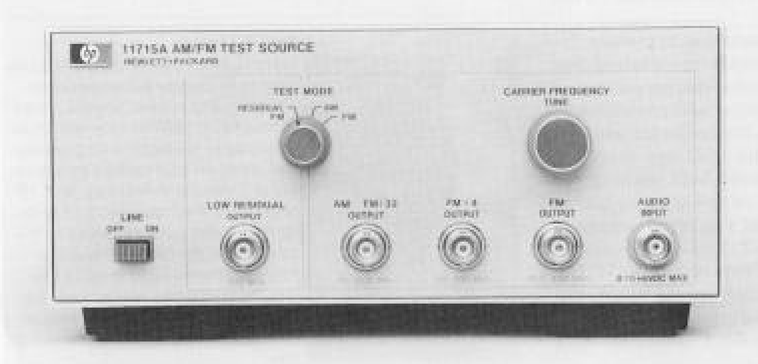

Fig. 1. *Model 11715A AM/FM Test Source provides AM and FM signals of sufficient flatness and linearity to characterize the 8901A Modulation Analyzer.*

test source contains two oscillators. A crystal oscillator generates the low-residual-FM output. This oscillator is followed by a full-wave frequency doubler and appropriate filtering. The output residual FM is much less than 0.1 Hz in a 50-Hz-to-3-kHz bandwidth.

The other oscillator, which generates the AM and FM outputs, is a varactor-tuned voltage-controlled oscillator (VCO) with a frequency range of 352 MHz to 432 MHz. The VCO output is buffered, filtered and brought to the front panel. This front-panel output can be modulated at up to 400-kHz peak deviation and 200-kHz rate. Its residual FM at 400 MHz is typically 15 Hz in a 50-Hz-to-15-kHz bandwidth. The VCO output is also applied to an ECL (emitter coupled logic) divide-by-four counter whose output is filtered and brought to the front panel. This output covers the FM broadcast band and allows up to 100-kHz peak deviation. After another division by eight, the VCO output becomes the local oscillator for an amplitude modulator. The output of the modulator can supply both FM and AM carriers from 11 MHz to 13.5 MHz. The FM deviation from this output can be as high as 12.5 kHz at a rate of 10 kHz. The AM can be as high as 99% at rates from 20 Hz to 100 kHz.

Since the FM÷4 and FM÷32 outputs are generated by digital division, the FM linearity between the two outputs is ideal. This property can be used to check the range-to-range accuracy of the audio section of the 8901A Modulation Analyzer. Setting a particular deviation on one range with the FM÷32 output, then changing to the FM÷4 output, should cause the 8901A to show exactly eight times the modulation.

The center frequency control varies the bias on the varactors and thus sets the VCO RF frequency. The audio input is applied to the VCO through a relay and a 30-dB attenuator. The audio is applied to the mixer through the relay, a dc blocking capacitor, and a 20-dB attenuator. The relay and blocking capacitor are positioned within the series branch

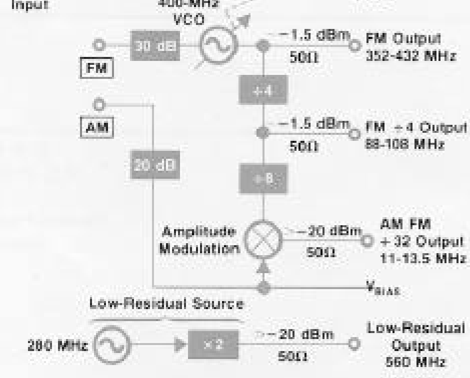

Fig. 2. *Model 11715A AM/FM Test Source has a low-residual-FM crystal oscillator, a VCO to generate the FM outputs, and a modulator (a double-balanced mixer) to generate the AM output.*

of the attenuator, rather than at the input, to minimize the effects of their impedance variations as functions of frequency. At the input the relay would switch a 50Ω source to a 50Ω load, while within the attenuator, it switches between a 50Ω source and a 300Ω load. The effects of loss variations due to relay contact impedance are reduced by about a factor of 3. The FM input is dc-coupled and therefore the 11715A can be phase-locked to an external reference. The dc coupling and extreme flatness of audio response imply very good stereo separation throughout the FM audio range. With a stereo test signal applied to the 11715A's audio input, stereo separation of >60 dB at 1 kHz was measured at 100 MHz using the 8901A Modulation Analyzer.

The power supply uses simple three-terminal regulators mounted on a separate printed-circuit board from the oscillator circuits. This was done to eliminate the effect of the power supply diodes modulating the RF and appearing as 120-Hz sidebands on the VCO output.

Except for the power supply, the entire circuit is mounted within an enclosure that is shock mounted to reduce microphonic noise. (The enclosure also acts as a shield to prevent electromagnetic interference.)

Obtaining VCO Linearity

The design of the 11715A VCO took advantage of one of the features of the 8901A: the RF track mode of operation. Since the 8901A can automatically acquire and track a sweeping RF signal, it is possible to make a real-time plot of VCO FM sensitivity versus VCO center frequency, or differential linearity. The technique is to apply a constant amount of audio to the 11715A's audio input, and a slowly varying signal to the 11715A's frequency tune input and the horizontal input of an oscilloscope. The 11715A RF output is applied to the 8901A and demodulated. The demodulated audio is applied to the vertical input of the oscilloscope. A change in the amplitude of the resulting plot is a change in sensitivity of the VCO. A description of the technique and a typical oscilloscope display appears in the article on page 19 (see Figs. 4 and 5 of that article).

By adjusting component values, a nearly flat envelope, indicating little change in sensitivity, was achieved quite readily. Operating at the flattest portion of the curve results in minimum FM distortion. At 400 MHz the 11715A has less than 0.025% total harmonic distortion (THD) for 400 kHz peak deviation at a 100 kHz rate.

AM Generator

The modulator used to generate AM is a double-balanced mixer. A constant bias is applied to the mixer IF port and the divided VCO signal is applied to the LO port. This up-converts the dc to the LO frequency, causing an RF level at the RF port that is directly proportional to the dc bias. If an audio signal is summed with the dc, the total bias changes at the audio rate. This causes the RF level to vary at the audio rate, and the result is AM. A peak audio equal to the dc bias gives 100% AM.

Since it isn't feasible to build an AM detector and prove its distortion and linearity with a sufficiently high level of confidence to call it a standard detector, it was necessary to verify the 11715A's AM performance with measurements on the AM generating system itself. AM distortion is related to mixer compression and LO-to-RF isolation. If LO-to-RF isolation is not ideal, at high AM percentages the minimum value of RF is greater than desired. For example, if the LO is 40 dB below the carrier, the minimum value of RF is ideally 0.01 of the carrier level. At 99% AM the desired level is 0.01, but the resulting level is $\sqrt{2}$ (0.01) because of LO feedthrough, which is at 90° to the desired RF. This causes clipping, resulting in distortion and nonlinearity. Further, since the resultant RF is at an angle other than 0°, incidental phase modulation is generated.

Mixer compression causes the peak of the AM to be clipped. A conservative approximation to the relationship between RF level and compression is that compression is reduced as the cube of the RF level reduction. By measuring the compression at a level considerably higher than the operating level, it is possible to predict a worst-case distortion.

For mixer compression of less than 0.05 dB at a −5 dBm RF output level, LO-to-RF isolation of 68 dB and an unmodulated RF level of −17 dBm, the AM distortion is less than 0.05% and the AM linearity is better than 0.08% to 95% AM. Also, the incidental phase modulation is less than 0.005 radian for 50% AM.

Verifying Flatness

FM flatness is determined by the audio circuits between the input and the varactors, while AM flatness is determined by the components between the audio input and the IF port of the mixer. This assumes no frequency response variation in the varactors for FM or in the mixer for AM. By characterizing the components, including the relay and coupling capacitor, the frequency response can be calculated. The result of this model indicates flatness much better than we can measure. Therefore, the 11715A AM flatness specification is closer to our measuring system performance than to the calculated value. An additional measurement is made at 10 MHz to ensure that none of the components is unusually lossy.

Acknowledgments

The author wishes to thank Stuart Carp, who did the original design work on the VCO and crystal oscillators, and Bob DeVries for his excellent product design. Also, thanks to Russ Riley for his assistance with the performance analysis.

SPECIFICATIONS
HP Model 11715A AM/FM Test Source

FM OUTPUTS

FREQUENCY RANGE: 11 to 13.5 MHz at AM FM ÷ 32 output.
88 to 108 MHz at FM ÷ 4 output.
352 to 432 MHz at FM output.

FM PEAK DEVIATION: >12.5 kHz, 11 to 13.5 MHz carrier.
>100 kHz, 88 to 108 MHz carrier.
>400 kHz, 352 to 432 MHz carrier.

FM DISTORTION: <0.025% THD (<−72 dB)

Carrier Frequency	Peak Deviation	Modulation Rate
12.5 MHz	12.5 kHz	<10 kHz
100 MHz	100 kHz	<100 kHz
400 MHz	400 kHz	<100 kHz

FM FLATNESS: ±0.1%, dc to 100 kHz rates; ±0.25%, dc to 200 kHz rates.

INCIDENTAL AM: <0.08% (100 MHz carrier; <50 kHz peak deviation; 1 kHz rate; 50 Hz to 3 kHz bandwidth).

AM OUTPUT

FREQUENCY RANGE: 11 to 13.5 MHz at AM FM ÷ 32 output.

AM DEPTH: to 99%.

AM DISTORTION: <0.05% THD (<−66 dB) for 50% AM; 20 Hz to 100 kHz rates.
<0.1% THD (<−60 dB) for 95% AM; 20 Hz to 100 kHz rates.

AM FLATNESS: ±0.1%, 50 Hz to 50 kHz rates; ±0.25%, 20 Hz to 100 kHz rates.

INCIDENTAL ΦM: <0.008 rad peak (12.5 MHz carrier; 50% AM; 1 kHz rate; 50 Hz to 3 kHz bandwidth).

AM LINEARITY: ±0.1%, <95% AM; ±0.2%, <99% AM.

RESIDUAL AM: <0.01% rms, 50 Hz to 3 kHz bandwidth.

LOW RESIDUAL OUTPUT

RESIDUAL FM: <3 Hz rms, 50 Hz to 3 kHz bandwidth.

General

LINE VOLTAGE: 100 or 120 Vac +5% −10% 48 to 440 Hz; 220 or 240 Vac +5% −10% 48 to 66 Hz.

POWER DISSIPATION: 40 VA maximum.

CONDUCTED AND RADIATED ELECTROMAGNETIC INTERFERENCE: Conducted and radiated interference is within the requirements of methods CE03 and RE02 of MIL STD 461A, VDE 0871 (Level B), and CISPR publication 11.

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

NET WEIGHT: 4.4 kg (9.5 lb) nominal.

DIMENSIONS: 102 mm H × 212 mm W × 444 mm D (4.0 × 8.4 × 17.5 in) nominal.

TEMPERATURE:
OPERATING: 0 to 55°C.
STORAGE: −55 to 75°C.

PRICE IN U.S.A.: $1550.

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