Keysight Technologies

Use N/W9063A Analog Demodulation Measurement Application to Replace HP 8901 Modulation Analyzers

Application Note
# Table of Contents

- **HP 8901 Modulation Analyzers** ................................................................. 3
- **Overview of the N/W9063A Analog Demodulation Measurement Application** ...................................... 4
  - Keysight X-Series signal analyzers (hardware) ........................................... 5
- **Using the N/W9063A for the First Time (Self-Guided Demonstration)** ........ 5
- **Making Common Measurements on FM Radio Transmitters** ................... 9
  - FM deviation .................................................................................................. 10
  - Hum and noise ratio (residual FM) ............................................................... 11
  - Audio distortion (SINAD, THD, etc.) ............................................................ 12
  - Tx tests with sub-audible signaling ............................................................... 13
  - Attack and transient behavior .................................................................... 14
  - RF output power ........................................................................................ 15
  - RF frequency (carrier frequency stability) ..................................................... 15
- **Five Reasons Why the N/W9063A Is Better than HP 8901 Modulation Analyzers** ................................. 16
  - 1. Flexible spectrum analyzer platform and many applications ................ 16
  - 2. Rich displays for full insight ................................................................... 16
  - 3. Superior accuracy including FM deviation ................................................. 16
  - 4. Precise drift-free digital analysis ............................................................... 17
  - 5. Built-in audio analysis (SINAD, distortion, etc.) ....................................... 17
- **Conclusion** .................................................................................................. 18
- **Frequently Asked Questions (FAQs)** ........................................................ 19
  - Tuning, locking, tracking ............................................................................ 19
  - Different results .......................................................................................... 20
  - Audio analysis, HP 8903, SINAD or THD, and modulation out .................. 21
  - HP 8902, 8903, and 8920 ........................................................................... 25
  - Systems, code compatibility ....................................................................... 26
- **Appendix** .................................................................................................... 27
  - Appendix A: Block diagram of instrument and N/W9063A application .... 27
  - Appendix B: Analog out ............................................................................. 28
  - Appendix C: Considerations with respect to TIA-603 ................................ 29
  - Appendix D: Measuring ACP ..................................................................... 32
  - Appendix E: Software enhancements for N/W9063A in A.14 (~May 2014) .... 34
- **References and Additional Information** ...................................................... 35
HP 8901 Modulation Analyzers

The HP 8901A/B modulation analyzers were the “gold standard” instruments for radio
testing in the ’80s and ’90s. They made precision modulation measurements of AM
(Amplitude Modulation), FM (Frequency Modulation) and PM (Phase Modulation).
Although radio technologies have evolved, there is still a need for analog modulation
measurements. Many HP 8901s are still in use.

The HP 8901 typically tested RF signals from the Tx (transmitter) side of the radio, up to
1300 MHz, including:

- Carrier power
- Carrier frequency and stability
- FM deviation (or AM depth)
- Hum and noise
- Incidental AM or FM
- Modulation limiting
- Audio frequency response

For the narrow-band FM radio industry, the HP 8901 had an impressive 1% accuracy for
FM deviation, and featured a novel built-in calibrator to fight drift. The instrument was
programmable by GPIB, and was the cornerstone of automated test systems.
The HP 8901B was discontinued in 2002; support life ended in 2012. The N/W9063A
analog demodulation measurement application, running on any X-Series signal analyzer,
is the recommended replacement for HP 8901A or B.
Overview of N/W9063A Analog Demodulation Measurement Application

The Keysight N/W9063A analog demodulation measurement application is a software application that characterizes analog AM, FM, and PM modulation. It is one of many measurement applications available for the X-Series signal analyzers.

The N/W9063A application measures the RF carrier, performs modulation analysis, and has built-in post-demodulation audio analysis. It is an excellent replacement for the HP 8901A/B, making the same measurements faster, more completely, and with better accuracy.

This application note describes the N/W9063A solution and compares it to the tried-and-trusted HP 8901A/B. The note features example measurements for typical narrow-band analog FM radio. (However, it is also capable of AM and PM, wide-band modulation, simple FSK or PSK, and more.) The application provides complete analysis of RF signals from a Tx; key results for a typical analog radios include:

- Tx RF carrier power
- Tx RF carrier frequency, and frequency error
- FM deviation (Peak or RMS), also AM or PM, plus mod limiting
- Audio (post-demod) frequency and distortion (SINAD)
- Residuals (Hum and Noise)

Instrument software (firmware) is updated frequently. At the time this note was written, the latest release is A.14.xx. Several features described here require this release (see Appendix E). Press the keys System >> Show >> System to check your version. New versions can be downloaded at www.keysight.com/find/xseries_software

Software licenses enable the functions of the N/W9063A. Press System >> Show >> System to check licenses related to N/W9063A. Visit www.keysight.com and search for N9063A or W9063A to obtain the trial license that fits your particular requirements.
X-Series Signal Analyzers (Hardware)

The N/W9063A runs on various models of Keysight X-Series signal analyzers; see Table 1. The features, functions, user interface (keys and menus), and remote interface (SCPI codes) are identical in all models. However, the performance varies according to the performance of the instrument. For FM measurements, the most significant differences are in the phase noise of the LO; this parameter drives residual FM, Tx Hum and Noise, and ACP dynamic range. See details elsewhere in this note.

Table 1. The X-Series signal analyzers

<table>
<thead>
<tr>
<th>Model</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N9030A</td>
<td>PXA</td>
<td>Highest-performance to address the most demanding applications; best phase noise, lowest residual FM, and best ACP dynamic range.</td>
</tr>
<tr>
<td>N9020A</td>
<td>MXA</td>
<td>Mid-range performance with versatility to quickly adapt to evolving needs; fast-tuning varactor LO.</td>
</tr>
<tr>
<td>N9010A</td>
<td>EXA</td>
<td>Flexible model that covers diverse needs with a single tool; solid mix of speed and performance.</td>
</tr>
<tr>
<td>N9000A</td>
<td>CXA</td>
<td>Lowest-cost tool for essential and cost-effective signal characterization.</td>
</tr>
</tbody>
</table>

1. The W9063A application applies only to the CXA. The N9063A application applies to the PXA, MXA and EXA.

Using the N/W9063A for the First Time (Self-Guided Demonstration)

The following is a brief “tour” of the N/W9063 application to help familiarize a first-time user with its operation and displays. The examples are based on measurements of typical narrow-band FM signals.

1. Connect a signal source to the SA input. Note: Be certain the RF power level into the SA is below its Max Level; use external attenuation if needed. If the DUT is an actual FM radio transmitter, set it up and “key” it on appropriately. For our examples, the source settings are:
   a. Power Output = −10 dBm
   b. Frequency = 750 MHz
   c. Modulation = FM
   d. Frequency Deviation = 3 kHz
   e. Modulation Frequency = 1 kHz

2. Press Mode key. Find the “Analog Demod” application in the list of modes (use the Next key to page down, if needed), and launch it. Press Mode Preset to initialize settings.

3. Press the Meas key, and select FM. (You can select AM or PM, or FM Stereo, but the rest of this tour assumes FM.)

4. Press the Frequency key, and enter the frequency of the RF carrier (750 MHz). This must be close to the actual input signal frequency. The analyzer does not “scan” or “lock onto” the incoming signal; the user must set it.
5. Check for Input Overload or other error conditions (in lower right corner); if needed, press AMPTD >> Attenuation and increase the value of mechanical attenuator.

6. Press Meas Setup >> Auto BW & Scale; this causes the analyzer to assess the signal and automatically optimize several settings for you. One of the most important settings is Channel BW, indicated by the vertical green lines in the RF Spectrum window. It is important that most (> 99%) of the energy in the carrier and sidebands is within the green lines. To adjust them, press BW >> Channel BW and enter a value in Hz.

7. By default, the application is in “Quad” view. Let us pause here and look at each window in Figure 3.

![Figure 3. Quad view.](image-url)
a. RF Spectrum (FFT). The spectrum of the pre-demod RF carrier. You can vary start/stop or center/span, and ResBW filter, just like any SA. Use this window to verify that the analyzer is tuned to the signal, that signal is on (with enough power), and that modulation is turned on. Use to adjust the Channel BW correctly, so that most of the sideband energy is between the green lines.

b. Demod Waveform. Similar to observing the post-demod waveform on an oscilloscope. Check that audio waveform is being recovered, and is not distorted.

c. AF Spectrum (FFT). The spectrum of the post-demod audio frequencies or test tones. The start/stop frequencies and RBW of the audio spectrum can be changed. Both horizontal and vertical axes are quantitative. You can check both deviation and rate of multiple tones or view harmonic distortion.

d. Metrics. A collection of numerical results. FM deviation is featured, with both peak and RMS detectors; also SINAD or THD from the built-in audio analyzer.

8. The RF Spectrum and AF Spectrum displays have all the basic SA controls. Press BW >> RF RBW and reduce the resolution BW to 100 Hz; the RF Spectrum now resolves the FM sidebands and the noise floor drops. Press Freq >> AF Stop Freq, and enter 5 kHz; the AF Spectrum now spans 0 to 5 kHz horizontally.

9. The Window Control Keys are important in the N/W9063A. In particular, the Next-Window key moves the “focus” – indicated by the bright green border – to the next window. Certain functions are window-specific; their actions apply to the window in focus.

For example, let us work with the AF Spectrum window. Press the Next-Window key twice, to highlight AF Spectrum with the green box. Now press Y-Scale >> Ref Value, and enter 10 kHz, changing the value of the top line in AF Spectrum. (The Y-Scale functions change to suit the window that is in focus and will be different for RF Spectrum or Demod Waveform.) Now press Marker and Peak Search; note that the Marker appears in the AF Spectrum window.
10. **Markers** are available for any trace, in any window. Press **Marker >> Select Marker** to choose a marker, then **Normal**, **Delta**, or **Fixed** to change its type. New Markers appear by default in the window with “focus” (green border). But for any Marker, you can press **Marker >> Properties** to modify Marker Trace used. Only the “selected” Marker has a read-out in the upper-right corner of its window. See Figure 5.

![Figure 5. Markers are available for any trace in any window; marker types include Normal, Delta, and Fixed.](image)

11. Press **Meas Setup >> Filters**. Here you will find a wide range of post-demod audio filters:
   a. High-pass (HPF)
   b. Low-pass (LPF)
   c. Band-pass (BPF), including CCITT, CCIR, and various noise-/response-weighted audio filters
   d. De-emphasis filters (De-Emph), FM only
   e. Signaling notch filter, to eliminate sub-audible tones

12. Press **Meas Setup >> Avg/Hold** to explore the averaging function. Note that Averaging reduces noise in all traces and all metrics. In addition, Averaging invokes a set of Max Hold metrics for deviation, plus max/min hold traces in the Demod Waveform.

13. The Restart key is very useful when Averaging is on: it will “flush out” old data in the Max Hold column, and de-clutter the Min/Max traces in Demod Waveform.

There are many more functions, set-up controls, and displays. We will visit some of these in the next section. See the built-in Help or manual for more information.
Making Common Measurements on FM Radio Transmitters

A 2-way radio transceiver has both transmitter (Tx) and receiver (Rx) parts. Figure 6 shows a simplified test diagram. (Note: Attenuators, couplers, combiners, and/or switches may be needed but are not shown.)

The DUT Tx has an audio input (microphone), and an RF output (antenna). The suggested audio source is the Keysight U8903A audio analyzer. The N/W9063A application will test the Tx output.

The DUT Rx has an RF input (antenna), and audio output (speaker). The RF is provided by an RF signal generator; additional RF sources are needed to test blocking/selectivity. The recommended audio analyzer is the U8903. The remainder of this note does not address Rx testing.

The following paragraphs describe typical tests for narrow-band analog FM Tx, using N/W9063A. References in brackets, for example "(2.4.12)", refer to paragraphs of TIA-603-D, Methods of Measurement for Tx; see Appendix C.

Note: Be certain the RF power level into the SA is below its Max Level; use external attenuation if needed.
FM deviation

For FM radios, measuring FM deviation is fundamental. Several tests from TIA-603 require FM deviation measurements:

{2.2.3} Modulation Limiting
{2.2.5} Audio Sensitivity
{2.2.6} Audio Frequency Response
{2.2.10} Acoustic Microphone Sensitivity
{2.2.15} Audio Low Pass Filter Response
{2.4.10} Tx Modulation Limiting

This result is displayed directly in the Metrics window, for all four detectors (see Figure 7):

- Peak+ (positive peak)
- Peak- (negative peak)
- \((\text{Pk-Pk})/2\) (half of peak-to-peak, or average of Peak+ and Peak-)
- true RMS (root-mean-square)

If Averaging is On, each detector type has an “Average” and a “Max Hold” column. These are similar to such detectors from HP 8901.

In addition, FM deviation can be viewed on the vertical axis of the Demod Waveform graticule (vs time), and on the AF Spectrum response (vs frequency). If Averaging is On, the traces are also averaged, using the appropriate type: RF Spectrum (power avg), Demod Waveform (linear arithmetic avg), and AF Spectrum (log avg).
Modulation rate periodic. Yes (default) means the input signal is modulated by a single periodic waveform; the analysis algorithms are optimized for this case. If the input signal is modulated by multi-tone or complex audio signal (the audio components are not harmonically related), select No; then different algorithms are used, which make no assumptions about the audio modulating tone.

Multi-tone and marker table [NEW]. If the audio contains several tones, you can put a marker on each tone and see all markers summarized in a table. To do this, press Next-Window to put AF Spectrum in “focus”. Select View >> AF Spectrum & Metric, then Marker >> More >> Marker Table to On. Now turn on and position markers; use Peak Search if you like. See Figure 10. (Requires A.14 and –AFP.)

Hum and noise ratio (Residual FM)

When there is no audio at the Tx input, the RF carrier should not be modulated at all. Any modulation that remains is “residual FM” or “hum and noise”. This measurement is made using the RMS detector, relative to a reference FM level, with specific post-demod filters in place.

{2.2.8} FM Hum & Noise Ratio
{2.2.9} AM Hum & Noise Ratio

The key steps to make the measurement are:

1) Set up the Tx for “standard test modulation”. A typical value is 3 kHz of peak FM deviation, with LPF = 15 kHz and De-Emph = Off.
2) On N/W9063A, set HPF = 300 Hz; LPF = 3 kHz; and De-Emph = 750 us. Read the RMS deviation in the Average column (typically ~440 Hz). This reference deviation gets stored automatically when you press View >> More >> Metrics Settings >> RMS Ratio.
3) Eliminate the audio input to the Tx.
4) Measure the residual FM with RMS detector, relative to the value from Step 2, in dB. See Figure 8.

Figure 8. FM hum and noise. Uses RMS detector, and is relative to Reference, expressed in dB.
Manual entry of reference [NEW]. In many cases, the reference established by Steps 1) and 2) is known in advance; for example, 3 kHz peak. The conversions from peak to RMS (0.707), and impact of 750 us de-emphasis at 1 kHz (0.2076) are also known. So, instead of Step 1) and 2), the user simply enters the value (e.g. 0.440 kHz), by pressing View >> More >> Metrics Settings >> Ratio Reference Manual and entering 440 Hz. (Requires A.14 and –AFP.)

AM hum & noise. AM noise represents the amplitude noise on the RF carrier. The TIA-603 procedure requires a diode detector and voltmeter. But the N/W9063A can measure AM directly, with the same input connection, and no diode.

Internal noise limitation. The phase noise of the local oscillator (LO) inside the instrument can limit the range of hum and noise measurements. The parameter varies with the model and configuration of the X-Series signal analyzer hardware. See FAQ section.

Audio distortion (SINAD, THD, etc.)

The Tx should faithfully convert the audio input into FM deviation. Modulation quality is tested by applying a single pure audio tone (typically 1 kHz) at the mic input, sending the RF output to a reference demodulator, and measuring distortion on the recovered audio.

\{2.2.7\} Audio Distortion
\{2.4.13\} CTCSS Tone Distortion
\{2.4.14\} Tx SINAD

The N/W9063A has a built-in post-demod audio analyzer. (It analyzes RF input signals after demod; it does not support audio inputs.) It can measure SINAD, SNR, distortion, or THD; see “Built-In Audio Analysis” section in the “Five Reasons Why” chapter for more details. And there is a full set of audio filters. There is no need to use an external audio analyzer for Tx test. See Figure 9.

Note that an audio source is needed to drive the mic input for Tx test. And a audio analyzer with audio inputs is needed for receiver (Rx) testing. The Keysight U8903 is recommended for these purposes.

Figure 9. Audio distortion and AF spectrum.
AF spectrum. In addition to the audio Metrics, the AF spectrum display is extremely useful to see audio-frequency distortion (harmonics), spurs, and noise versus frequency. Note that the AF spectrum is quantitative in both FM deviation (Y-axis) and audio frequency (X-axis). See Figure 9.

Channel BW. Distortion results will be degraded (could be increased or decreased), if the Channel BW is not set wide enough to include all the significant RF sidebands.

Tx tests with sub-audible signaling

Early analog FM radios had simple forms of “signaling” to allow multiple radios to share the same frequency channel. The signaling used sub-audible tones (<250 Hz), superimposed on the voice, either Continuous Tone-Coded Squelch System (CTCSS) or Continuous Digital-Coded Squelch System (CDCSS) (an FSK sequence). Specific test methods were developed to check Tx performance with these additional tones:

2.4.14) Tx SINAD with Sub-Audible Signaling
2.4.16) Tx FM Hum and Noise with Sub-Audible Signaling

Both cases required a post-demod notch filter to eliminate the sub-audible tone. In the case of SINAD, this means there are two notch filters: one for sub-audible tone, and one for the 1 kHz audio tone. The N/W9063A application now provides a signaling notch filter for these measurements. The user turns the signaling notch On or Off, and sets its frequency, manually. The other notch filter used for SINAD is still tuned automatically to the largest remaining audio tone. (Requires SW Rev A.14 and license –AFP.)

The sub-audible tone remains visible in the AF spectrum; however, it is notched out for the SINAD result and FM deviation RMS detector used for hum and noise. See Figure 10.

Figure 10. Signaling notch filter for sub-audible tones. The signaling notch filter is enabled at 123 Hz. Although visible in the AF spectrum, it is removed before the SINAD and FM deviation RMS detector (used for hum and noise). The marker table makes it easy to read both tone frequency and deviation for each tone. (Note: Filter and de-emphasis settings do not reflect TIA-603 procedures, for clarity in this example.)
Attack and transient behavior

Push-to-talk (PTT) radios must meet certain specs governing power and frequency during the brief transition from Tx off to Tx on. There are also PTT timing specs for CTCSS and CDCSS tones.

- Carrier Attack Time
- Transient Frequency Behavior
- Encoder Response Time
- Tx Squelch Tail Elimination Burst

In the past, these tests have been complex and challenging, because:
(a) the signals are transient (i.e. occur quickly and only once), so need a trigger;
(b) the results need to be viewed in time domain, so need an oscilloscope-like display with persistence (storage).

The N/W9063A simplifies these tests with a new “Attack/Release Time” view. This view has two graphs:

a) the upper graph shows RF amplitude vs time, showing how the “attack” of the RF Tx turning on (or off); and
b) the lower graph shows frequency vs time, showing carrier frequency settling, or turn-on of CTCSS tones, or special FM signaling.

This view is typically used in “single-shot” mode, with an external trigger coming from the PTT signal. The upper and lower graphs normally share the same time-axis, so amplitude and frequency changes can be easily related. The vertical axis read directly in amplitude or frequency units; there is no need to relate some arbitrary or uncalibrated voltage to the quantity you want to measure. No storage scope is required. See Figure 11. (Requires SW Rev A.14 and license -AFP.)

Figure 11. Attack/Release Time View.
**RF output power**

The transmitter’s power output is a fundamental parameter. Standards documents normally call out a power meter for Tx power measurements:

(2.2.1) Conducted Carrier Output Power Rating.

However, the N/W9063A displays Carrier Power level directly in the Metrics window, in either dBm or Watts. It is very convenient to see this result along with the others, and avoid dis-connecting/re-connecting another instrument. If external attenuation is used, its loss can be entered to offset the indicated power. Like a power meter, the X-Series signal analyzers have a 50 MHz power reference standard built-in; it is measured during periodic alignments to eliminate drift. Unlike a power meter, the X-Series signal analyzer is frequency-selective, which means:

- a) The N/W9063A is insensitive to harmonics, intermods, spurs, and other out-of-channel interference (a power sensor will detect all signals within its very wide bandwidth);
- b) The N/W9063A can measure down to much lower power levels with greater accuracy (a power sensor has a fairly high noise floor).

**RF frequency (carrier frequency stability)**

Transmitters must stay on-channel with good carrier frequency accuracy and stability. Test procedures normally call for an RF frequency counter to check this:

(2.2.2) Carrier Frequency Stability

However, the N/W9063A measures and displays Carrier Frequency Error in the Metrics window. It is convenient to see all critical results at once, and avoid dis-connecting/re-connecting to another instrument. The X-Series signal analyzer is fully synthesized and the IF is fully digital; hence, its frequency accuracy is directly linked to the reference time-base. There are several ways to get the accuracy you need:

- a) Check the standard X-Series signal analyzer specs -- they will likely meet your needs;
- b) Lock the X-Series signal analyzer to a user-provided standard such as 10 MHz “house” standard or a GPS-based clock, via its Ext Ref Input connector;
- c) Order Option PFR (precision frequency reference), available on some models, to configure a better internal reference;
- d) Order the Keysight J7203A atomic frequency reference (AFR), a small cesium-based high-stability clock; AFR is powered by USB and “disciplines” the internal reference to give ~100x better long-term stability (aging) versus Option PFR.
Five Reasons Why the N/W9063A Is Better than the HP 8901 Modulation Analyzers

The N/W9063A analog demodulation measurement application is an excellent replacement for the HP 8901A and B modulation analyzers. But it is much more. The N/W9063A will make your measurements faster, easier, more completely, and more accurately.

1. Flexible spectrum analyzer platform and many applications.

The N/W9063A application runs inside a fully-enabled X-Series signal analyzer. You can switch to “SA” mode any time to measure ACP or radiated emissions, to examine carrier harmonics or spurious oscillations, and search for interference.

The X-Series signal analyzers cover a wide range of performance levels, frequency ranges, and bandwidths. You can configure and pay for only the performance you need. Despite this, the N/W9063A application has the same features, same user interface, and same remote programming commands on all configurations. Users need to learn how to use the application only once.

The X-Series solution goes far beyond just a modulation analyzer. With its many capabilities, the test set-up is simplified, saving time, avoiding mistakes, and conserving space on the bench or in a rack. See Table C1 in Appendix C.

A wide range of other applications -- including APCO, TETRA, and LTE, EMC pre-compliance, phase noise, and noise figure, are all available by downloadable software licenses, and run inside the same instrument.

2. Rich displays for full insight.

The N/W9063A has a large color display (see Figure 3), with four result windows, detailed annotation, bright traces, and marker functions. By comparison, the HP 8901A/B had only a single numerical display. The usefulness of these rich displays cannot be over-stated.

You can see the RF Spectrum and instantly tell if the RF carrier is present, stable, at the expected frequency, and with expected sidebands. You can easily optimize the Channel BW (sample rate) to demodulate all signal sidebands while minimizing noise.

You can see the demodulated waveform (deviation or modulation versus time), and check for tone stability, distortion, peaking, and noise. There is no need for an oscilloscope. You can see the AF spectrum and easily check for distortion or noise. You can also quantitatively determine the FM deviation caused by each tone individually, in the case of multiple tones. Every result is instantly visible, saving time and reducing errors.

3. Superior accuracy including FM deviation.

FM deviation is a key measurement. The HP 8901 made the measurement using analog limiters and a charge-count discriminator, with 1% accuracy – a break-through at the time. The HP 8901 also featured a built-in calibrator to fight drift.

In contrast, the N/W9063A measures modulation depth (e.g. FM deviation) digitally, processing data from the sampled IF. The digital methods are more precise, with low variance box-to-box, and zero drift. There are four detectors: Peak+, Peak-, and (Pk-Pk)/2 ... plus a true RMS detector to sense noise and non-sinusoids correctly. See Table 2 for a comparison.
<table>
<thead>
<tr>
<th>HP 8901A/B</th>
<th>X-Series signal analyzer + N/W9063A</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM deviation accuracy</td>
<td>PXA: 0.35% of reading + 0.2% of rate</td>
</tr>
<tr>
<td>(warranted specs)</td>
<td>MXA: 0.9% of reading + 0.2% of rate</td>
</tr>
<tr>
<td>+ 1 digit</td>
<td>PXA: 0.2% * (reading + rate) (nominal)</td>
</tr>
<tr>
<td></td>
<td>MXA: 0.4% * (reading + rate) (nominal)</td>
</tr>
<tr>
<td></td>
<td>EXA: 0.4% * (reading + rate) (nominal)</td>
</tr>
<tr>
<td></td>
<td>CXA: 0.4% * (reading + rate) (nominal)</td>
</tr>
</tbody>
</table>

Example:
3 kHz deviation, 1 kHz rate, warranted spec
31 Hz for RMS
PXA: 13 Hz (nominal same for RMS)
MXA: 29 Hz (nominal same for RMS)

**Wider dynamic range**
The N/W9063A measures FM deviation over a very wide range of input power levels – about 25 dB wider than the HP 8901.

**Auto carrier frequency**
By default, the FM demodulator is DC coupled and passes carrier frequency error into the audio analyzer. If this is not wanted, turn on the Auto Carrier Frequency function (requires A.14 and –AFP), or simply use any HPF or BPF.

4. Precise drift-free digital analysis.
The N/W9063A is fully synthesized and uses all digital processing. The RF signal is down-converted to IF, then digitized; all further down-stream processing is numerical. This means minimal drift with temperature, low variance due to component values, and superior noise suppression. All filters are digital, which eliminates instrument-to-instrument variations. Internal alignments correct for IF flatness and other errors. There is no need for time-consuming calibration of analog demodulators. The result is better accuracy and tighter specs, over time and temperature.

5. Built-in audio analysis (SINAD, distortion, etc.).
Audio analysis here means measuring the distortion on the audio signal, after demodulating the RF signal from the DUT Tx. There are several measurement methods and several terms for the results (which are frequently confused); see Table 3.

In the original HP 8901, audio analysis was usually done in combination with the HP 8903 audio analyzer (a completely separate instrument). The HP 8901 did the RF demodulation, passing the post-demod audio signal out of the modulation output connector to the HP 8903.

The N/W9063A has post-demod audio analysis built in, along with all necessary filters. The notch filter is tuned automatically to the strongest audio signal found (not limited to 1 kHz or 400 Hz.) It operates on the RF input after demodulation (there is no audio-frequency input). See Table 3 for equivalent measurements.
Table 3. Audio analysis types

<table>
<thead>
<tr>
<th>HP 8901 and 8903 distortion metric</th>
<th>N/W9063A distortion metric</th>
<th>Expressions</th>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SINAD</td>
<td>SINAD</td>
<td>$\frac{(S+N+D)}{(N+D)}$</td>
<td>dB</td>
<td>A narrow notch filter removes the S term; traditional notch-filter and ratio method.</td>
</tr>
<tr>
<td>29.0 SPCL, 1 kHz DISTN</td>
<td>29.0 SPCL, 400 Hz DISTN</td>
<td>$\frac{(N+D)}{(Total-S)}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIG/NOISE or SNR</td>
<td>SNR</td>
<td>$\frac{(S+N+D)}{(N)}$</td>
<td>dB</td>
<td>Intended to emulate HP 8903 on/off method; similar to SINAD, except D term is removed from denominator, since harmonics of S would not be produced in DUT when audio input is off.</td>
</tr>
</tbody>
</table>

| DISTN                             | Distortion/Total           | $\frac{(N+D)}{(S+N+D)}$ | % or dB | Simply the inverse of SINAD; uses same notch filter concept. |
| AUDI0 DISTN                       | (Total-S) \((\frac{(Total)}{(N+D)})\) | $\frac{(S+N+D)}{(N)}$ |       |             |
| n/a                               | THD                        | $\frac{(S)}{(D)}$ | % or dB | Harmonics H2...H10 are added, then ratioed to S. |

| DISTN LEVEL                       | n/a                        | N+D | Total-S | V | An amplitude measurement, not a ratio. |

1. These expressions are a short hand, summarizing the terms in numerator and denominator; the actual equations used are more complex. S denotes the strongest single audio tone found, often a test tone at 1 kHz. D demotes harmonic distortion. N denotes noise, which in practice includes all audio energy except harmonics (spurs, hum, intermods, etc.), integrated over a bandwidth filters or SINAD BW. All terms are subject to audio filters and the SINAD BW control. N means noise, integrated over some bandwidth. In practice, N includes all non-harmonic sources, including hum, intermods, sub-harmonics, spurs, etc. D means distortion, the sum of harmonics of the fundamental signal S (but excluding S itself). The series is limited to 10th harmonic, or by a filter, or by a bandwidth setting (whichever is lowest). All terms in Volts RMS; ratios are without units. 20*\log(x) converts to dB. 100*x converts to percent.

2. Units can be selected under View/Display >> Distortion & THD Unit/.

3. SNR emulates the function used by HP 8903 when used with HP 8901. SNR is similar to SINAD when D is small.

Audio filters
The N/W9063A includes all of the post-demod filters available in both the HP 8901A and 8903A, including most optional filters (except filters for NMT and AMPS). All filters are digitally implemented with zero drift and no component variance. A special notch filter is available to remove the sub-audible signaling tones, used for CTCSS or CDCSS. This filter must be manually tuned within the 50 to 300 Hz range. This filter is in addition to the audio notch filter used for SINAD, which is automatically tuned.

Conclusion
The N/W9063A analog demodulation measurement application makes an excellent replacement for the HP 8901A/B modulation analyzers (now out of support life). This application runs on any X-Series signal analyzer with identical features; performance varies by configuration. Many features in release A.14 make it possible to perform nearly all TIA-603 Tx tests with a single instrument. (See Appendix C.)
Frequently Asked Questions (FAQs)

Tuning, locking, tracking

Did you say the N/W9063A application does not lock automatically to the input signal so I have to tune it manually?
Yes. The HP 8901 would automatically search for, and lock to, the incoming RF signal. If the input was "drifty", the HP 8901 would "track" it. In contrast, the N/W9063A must be manually fixed-tuned by the user to the expected RF frequency.

What if I do not know the carrier frequency?
If the frequency is completely unknown, use the spectrum analyzer (SA) mode to find it. (SA mode is always available in X-Series signal analyzers.) In fact, the center frequency from SA mode can be shared or imported into analog demod mode. To do this, start in SA mode and find the carrier. If the carrier is a strong signal, you can use Freq >> AutoTune, or Marker to Peak then Marker to Center Freq. Then under Mode Setup, set Global Center Freq to On. Now, when you switch to the N/W9063A (press Mode >> Analog Demod), it will automatically inherit the center frequency you found with SA.

Do I need to tune the N/W9063A exactly to the RF frequency of my DUT?
No. As long as the carrier and sidebands are within the Channel BW, the demodulation analysis will work. In most cases, the analyzer is tuned to the expected carrier frequency and the measured difference is called Carrier Frequency Error. Note that for FM, this frequency error is included by default in several metrics.

What FM metrics are affected by Carrier Frequency Error?
FM is frequency modulation; so a constant frequency error (difference between DUT’s unmodulated carrier frequency and N/W9063A Center Freq) is a constant or DC frequency offset. This error will:

– Add to the Peak+, Peak-, and RMS deviation detectors (although (Pk-Pk)/2 is not affected);
– Give rise to a response in the AF spectrum at 0 Hz (left edge); and
– Add to the noise term (N) of SINAD, SNR, and distortion ratios, causing them to degrade.

If you want to exclude this error, apply any HPF or BPF to block the DC term; or turn on Auto Carrier Frequency (requires A.14 and –AFP). Of course, the Carrier Frequency Error metric will continue to indicate this error correctly.

My oscillator is free-running and will drift. Can the N/W9063A track the slow-changing drift?
The N/W9063A acquires a time-interval of data, then analyzes it, with each measurement cycle. If Auto Carrier Frequency is on, then the average frequency error over the acquisition interval will be subtracted from FM measurements. The correction is updated with each acquisition. The effect is similar to tracking. Just be sure the Channel BW is wide enough to contain the drift, and consider turning off Averaging.
Different results

The N/W9063A seems to always measure FM deviation too low, compared to my HP 8901B. What’s wrong?

Many customers have developed a faith that HP 8901 is “right”. However, the N/W9063A specs can be even better (depending on X-series signal analyzer model). See comments under Superior Accuracy. If comparing results from two instruments:

a) Adjust Channel BW on N/W9063A optimally -- just wide enough to contain energy from all sidebands (the HP 8901 has no comparable control);

b) Set the post-demod audio filters (HPF, LPF, BPF) the same; if FM and using de-emphasis, set de-emphasis filters the same; and turn PRE-DISPLAY on for the HP 8901;

c) If the input waveform is noisy or has noise-spikes that you want to measure, turn Averaging to Off and/or read the Max Hold metrics on the N/W9063; unlike the Average column, these will catch brief bursts of post-demod noise;

d) For the FM case, check if Carrier Frequency Error (i.e. the carrier is not exactly the same as the tune frequency of the N/W9063A) is adding to Peak+ and Peak-detectors. While the HP 8901 will lock to the RF input, the N9063A does not. To delete this term:
   -- Turn on the new “Auto Carrier Frequency” feature, which subtracts the average Carrier Freq Error. (A similar feature exists for PM.) Requires release A.14.xx or later.
   -- Use the (Pk-Pk)/2 metric instead of Peak+ and Peak- (for FM); in this metric, the Carrier Freq Error cancels out.
   -- Apply any HPF, which will strongly attenuate the DC term in the post-demod FM audio. However, use of a HPF prevents use of a BPF.

How can I know if the N/W9063A is more accurate? Is there a signal generator that is good enough to test it?

FM deviation specs of signal generators are probably not good enough to directly test the accuracy of the N/W9063A. Instead, use the Bessel Null Method method to independently establish an RF signal with a known and trusted FM deviation. This method needs a signal generator with high quality FM, but does not rely on its specs. See References.

How can the N/W9063A be so good?

For FM deviation accuracy, the N/W9063A has three main advantages over the HP 8901:

a) Demodulation is completely digital, using digital signal processing (DSP) on IQ data sampled in the Digital IF. By comparison, the HP 8901 used analog circuits for demod and deviation detection; these can drift or vary under different conditions.

b) The IF bandwidth is user-adjustable (via the Channel BW control), and can be relatively narrow (15 to 30 kHz typical for narrow-band FM). This reduces the noise on the IF signal and improves the signal-to-noise-ratio (SNR) into the demodulator. By comparison, the HP 8901 has only two choices for pre-demod IF BW: ~2.3 MHz or ~200 kHz. These may admit excessive noise.

c) Digital averaging on by default, and applied in 2 layers. The 1st layer finds multiple peaks in the Demod Waveform, over a single acquisition, and averages them into the Peak+ and Peak- metrics. This averaging is applied even when the Avg/Hold number is 1. The 2nd layer of averaging operates across successive acquisitions. As a result, the N/W9063A is less sensitive to noise than the HP 8901, so typically the Peak metrics are slightly lower (and more stable).
My signal is modulated by two different audio tones at the same time. Why won’t the N/W9063A measure this correctly?
By default, the N/W9063A assumes there is a single periodic modulating tone. Its algorithms and averaging functions are optimized for this case. However, for the multi-tone case (not harmonically related), you can select Meas Setup >> Modulation Rate Periodic to No. If averaging is on, you will also find Max Hold values tend to be similar to the HP 8901 results for this case. Note that the RMS detector in N/W9063A indicates true RMS; other instruments might not. Finally, note that the AF spectrum can display all tones – and indicate the deviation contributed by each one. You can use markers on each, and enable Marker Table as well.

The hum and noise results are lower than HP 8901. What is wrong?
Hum and noise are types of residual or noise measurement. The measured value is a combination of the noise from the DUT, plus the noise from the instrument. If you make side-by-side measurements on the same DUT, and the N/W9063A measures a lower (better) value, that means the DUT’s actual performance was being hidden by the noise of the HP 8901. The user should not expect results from N/W9063A to match those from HP 8901 exactly; a lower result is better. (The reverse can also be true; see Table Q1 and comments elsewhere about LO phase noise, residual FM, hum and noise, and ACP variations by model.

The FM hum and noise reading from MXA X-Series signal analyzer and N9063A is comparable to HP 8901 in the 700/800 MHz band but not as good in VHF band. How can that be?
Both HP 8901A/B and X-Series signal analyzers use mixers, driven by local oscillators (LOs), to convert the RF input signal to an IF frequency. The phase noise of the instrument’s LO combines with that of the input signal in the mixer. The measured noise is combined from both sources and cannot be separated. This internally-generated noise limits the meaningful measurement floor.

Phase noise for HP 8901A/B was not explicitly specified; therefore, direct comparisons with the X-Series signal analyzers can only be made via the residual FM spec. Furthermore, the HP 8901A/B residual FM varies with input frequency:

- 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

This is because the primary oscillator ranges 320 to 650 MHz, which is then multiplied or divided by 2n before being mixed with the RF input signal to give an IF of 1.5 MHz. The multipliers/dividers also increase/decrease the phase noise, by 6 dB for each factor of 2. So at lower RF frequencies, the instrument’s residual FM is lower. For X-Series signal analyzers, phase noise does not vary by frequency (for any input < 3.6 GHz) – but does vary by model/configuration because they use completely different LO designs.

Instrument LO phase noise usually dominates the floor (smallest measurable value) for several tests critical to FM radios: residual FM, the FM hum and noise floor, and ACP. Table Q1 compares the HP 8901 with various models/configurations of the X-Series signal analyzers.
<table>
<thead>
<tr>
<th>Key specifications related to phase noise of LO</th>
<th>HP 8901A/B</th>
<th>X-Series signal analyzer¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>at 135 MHz (VHF)</td>
<td>at 750 MHz</td>
</tr>
<tr>
<td>Phase noise (dBc/Hz SSB) 1 GHz, 10 kHz offset, 20 to 30 °C</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Residual FM (Hz RMS)</td>
<td>~2 Hz RMS</td>
<td>~6 Hz RMS</td>
</tr>
<tr>
<td>HPF = 50 Hz</td>
<td></td>
<td></td>
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<tr>
<td>LPF = 3000 Hz</td>
<td></td>
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<td>ChanBW = 15 kHz</td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tx hum and noise (dB)</td>
<td>-79 dB (nominal)</td>
<td>-79 dB (nominal)</td>
</tr>
<tr>
<td>HPF = 50 Hz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPF = 3000 Hz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>De-Emph = 750 µs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ref = 3 kHz deviation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACP Dyn Range (dB)</td>
<td>90 dB²</td>
<td>90 dB²</td>
</tr>
<tr>
<td>Meas BW = 14 kHz</td>
<td></td>
<td></td>
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</tbody>
</table>

1. EP2 and EP3 are indicators of improved LO phase noise in the MXA and EXA respectively; these shipped as standard in MXA/EXA models beginning ~August 2013. While these codes appear in the System >> Show >> System table, there is no need to order them for new purchases and no possibility to upgrade units shipped before this change.

2. The HP 8901 measured ACP using optional adjacent-channel filters designed for 12.5 or 25 kHz bandwidth. At 750 MHz, the published specification could be met only by substituting an external ultra-low phase noise source in place of the internal LO of the HP 8901.

3. ACP measurements are made in SA mode, not within the N/W9063A application. ACP dynamic range figures for X-Series signal analyzers presented here are estimates using: (Phase noise @ 1 GHz carrier @ 10 kHz offset) + 42 dB. This estimate applies to the ACP offsets near 10 kHz, and assumes that phase noise is flat over the measurement bandwidth. The factor 42 dB comes from 10 log (14 kHz), where 14 kHz is the measurement bandwidth called for by TIA-603 or other standards. A similar estimate can be made for other values of measurement bandwidth. These estimates are not warranted specifications. See Appendix D.
Audio analysis, HP 8903, SINAD or THD, modulation out

How do I use the N/W9063A with my HP 8903 audio analyzer? Does it have a modulation out connector?

The HP 8901A/B was commonly paired with an HP 8903A audio analyzer; it would provide an audio source, and perform Tx post-demod audio analysis on the modulation output (front panel BNC). The N/W9063A has built-in post-demod audio analysis functions. It provides post-demod audio amplitude, audio frequency, audio distortion (whether SINAD, THD (harmonics) or Distortion/Total ratio), audio spectrum, and offers a wide range of audio filters. In other words, if the signal to be analyzed is RF (from Tx antenna output), then the post-demod analyzer is built-in. But a true audio analyzer may be needed for other cases; the U8903 is recommended for:

- Audio source to drive the mic input of Tx
- Audio source to drive the modulation input of an RF signal generator, if not using a built-in modulation source, for Rx testing;
- Audio analysis of audio signals from speaker output when Rx testing (i.e. signals at audio frequencies, not those that started as RF)

But I need to use the HP 8903 (or U8903) to measure SNR, right?

The HP 8903A/B had a SIG/NOISE feature, used with the HP 8901. Its audio source tone turns alternately on and off; this goes through the Tx, and the ratio of audio output powers in the two states is displayed as signal-to-noise ratio (SNR) of the Tx. The N/W9063A's internal audio analyzer cannot synchronize to the source as it changes states; however, there are several alternatives:

a) Use the SINAD result instead. In practice, the results are often similar.
b) Use the SNR result, a feature in rev A.14 designed to emulate this mode. It uses a notch filter to eliminate the signal, but also ignores harmonics in the denominator (since these are absent when the mic input tone is off).
c) Control the audio source manually and use the RMS ratio feature to measure the signal deviation and noise (separately), and compute the ratio for you.

Using Analog Out is possible, but not recommended. Users should evaluate and validate this method for their use. See Appendix B.
But my test specs require use of a special CCITT weighted filter. So I will need a true audio analyzer for that, right?
The N/W9063A audio analyzer includes every audio filter offered in the HP 8901, 8902, 8903, and 8920. See Table Q2.

Table Q2. List of audio filters

<table>
<thead>
<tr>
<th>HPF</th>
<th>LPF</th>
<th>BPF6</th>
<th>De-Emphasis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>20 Hz</td>
<td>300 Hz&lt;sup&gt;3&lt;/sup&gt;</td>
<td>CCITT</td>
<td>25 µS (6366 Hz)</td>
</tr>
<tr>
<td>50 Hz</td>
<td>3 kHz&lt;sup&gt;2&lt;/sup&gt;</td>
<td>A-Weighted&lt;sup&gt;1,7&lt;/sup&gt;</td>
<td>50 µS (3183 Hz)</td>
</tr>
<tr>
<td>300 Hz</td>
<td>15 kHz&lt;sup&gt;3&lt;/sup&gt;</td>
<td>C-Weighted&lt;sup&gt;1&lt;/sup&gt;</td>
<td>75 µS (2122 Hz)</td>
</tr>
<tr>
<td>400 Hz&lt;sup&gt;1,2&lt;/sup&gt;</td>
<td>30 kHz</td>
<td>C-Message&lt;sup&gt;1&lt;/sup&gt;</td>
<td>750 µS (212 Hz)</td>
</tr>
<tr>
<td></td>
<td>80 kHz</td>
<td>CCIR-1k&lt;sup&gt;1,5,9&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>300 kHz</td>
<td>CCIR-2k&lt;sup&gt;1,10&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 20 kHz Bessel&lt;sup&gt;1,4&lt;/sup&gt;</td>
<td>CCIR Unweight&lt;sup&gt;1,9,11&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manual&lt;sup&gt;1,5&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Used to attenuate CTCSS & CDCSS tones, also 50/60 Hz hum.
3. Filters were previously 3-pole designs, changed to 5-pole designs in rev A.14 to better emulate HP 8901.
4. Bessel filters have maximally flat group delay so they can be a good choice for CDCSS, FSK, and other square way modulation, where one desires to avoid delay distortion (overshoot, ringing) of the harmonic series.
5. User-settable for high-rate FM
6. Turning on any BPF will turn off all HPF and LPF.
7. Previously provided with FM Stereo only; as of rev A.14, available in AM, FM, or PM.
8. Also known as ITU-R 468-2 or DIN 45 405
9. Certain CCIR filters are specified with quasi-peak detection (QPD); filters in the N/W9063A do not have true QPD responses, but are compensated to indicate accurately for typical signal conditions.
10. Also known as ITU-R 468 Average-Responding Meter, or ARM, or Dolby filter.
11. Also known as ITU-R 468 Unweighted
12. De-emphasis for FM demod only; described with time constant in µs, but equivalent to 1-pole LPF with corner frequency indicated.

TIA-603 used the test receiver output as an input to an oscilloscope, counter, and other instruments. So I still need a demod output, right?
Probably not. Remember, the N/W9063A displays a Demod Waveform trace — FM deviation versus time — internally. This is better than an oscilloscope because the vertical axis reads directly in Hz or kHz of deviation, not some voltage arbitrarily scaled to deviation. You can adjust the vertical and horizontal (time) axes, and even use markers, to suit your needs. And the Metrics window displays the tone frequency, if needed. In addition, several TIA-603 measurements look at transients at the instant the PTT (push-to-talk) button is keyed or released. The N/W9063A application has a new Attack/Release Time view — a single instrument replaces a complicated set-up with test receiver, oscilloscope, crystal detector, and more. (See Attack and Transient Behavior in the Common Measurements on FM Radio Transmitters section.)

The AF Spectrum has a sharp step or drop-off at higher frequencies. This low-level trace cannot be real. What is going on?
The AF spectrum is an FFT of the post-demod audio. The maximum frequency is limited by the sample rate, which is set by controls linked to the RF Spectrum. Specifically:

\[
\text{FreqMaxAFSpectrum} = \left(\frac{1}{2}\right) \times \max \{\text{Channel BW}, \text{RF Span}\}
\]

The AF spectrum results are valid below this point. You can increase either Channel BW or RF Span to increase this maximum value. In addition, you can reduce AF Stop Freq (under Freq key) to display only the valid range in AF spectrum. Finally, note that post-demod filters (like LPF or De-Emph) will attenuate noise at higher frequencies (but with a gentle roll-off).
HP 8902, 8903, and 8920

Does the N9063A also make a replacement for the HP 8902A?
The HP 8902A measuring receiver was used primarily for calibrating signal generators. It combined the AM/FM/PM measurements of the HP 8901A/B with the absolute power accuracy of a power sensor and meter, plus accurate power measurements to very low levels using the tuned RF level (TRFL) feature. To do all this, the Keysight N5531S microwave measuring receiver (MMR) is the recommended replacement for HP 8902.

However, the N/W9063A can make the modulation measurements (AM/FM/PM) of the HP 8902, without the power meter and TRFL measurements. The demod specs for N9063A, running in the PXA, are very good; however, hard specifications currently extend to only 3.6 GHz.

Can the N/W9063A replace the HP 8903?
If analyzing audio quality after demodulating an RF input, then yes, the audio analyzer is built-in. But the N/W9063A cannot analyze audio inputs needed for Rx testing, and does not provide an audio source. See FAQ about audio analysis.

Can the N/W9063A be used to replace the HP 8920A/B?
The HP 8920A/B was a full analog transceiver tester, promoted as 22 instruments in one. The N/W9063A performs all the RF analyzer functions for Tx test, most of the AF analyzer functions (including audio filters and SINAD/Distn) for Tx, plus spectrum analyzer and post-demod scope views. However, the N/W9063A does not have several major functions, including:

- Duplex "RF IN/OUT" port, high power handling 60 to 100 Watts
- RF generator
- Audio inputs to AF analyzer from Mic In, etc. (only post-demod RF In)
- Audio generator
- SSB modulation
- Squelch
- Signaling encoder nor decoder (Tone, DTMF, CDCSS, etc.)
- Scripting

Thus, the N/W9063A is only a partial replacement.

Specs, calibration, traceability

Are there warranted/hard specs for N/W9063A?
As of April 2014, there are warranted specs for N9063A when running an X-Series PXA or MXA signal analyzer, up to 3.6 GHz. Please see the specifications guide for the specific X-Series signal analyzer model (e.g. PXA) for more details.

Are these specs traceable?
Yes, warranted specs are traceable to NIST and other national standards.

Does the N/W9063A solution have a built-in calibrator for FM?
The HP 8901 had an innovative built-in calibrator, providing a precisely-known AM or FM signal, used to offset demod measurements. The N/W9063A has no need for this analog calibrator, and (depending on the X-Series signal analyzer model) still provides more accurate deviation measurements.
Systems, code compatibility

Can the N/W9063A be substituted in systems?
Various HP systems were built around the HP 8901, 8903, and signal generators (e.g. HP 8656). The HP 8953 transceiver test set is one example. An X-Series signal analyzer with N/W9063A is a good functional replacement for the Tx side. The Keysight U8903 can replace the HP 8903; and modern sources can test the Rx.

The HP 8954A transceiver interface performed the audio routing, RF switching/combing, and push-to-talk (PTT) signaling needed for connect-once transceiver testing. Keysight has no direct replacement but can build-to-order if required; most customers build their own. Note that the audio routing functions for Tx test are much simpler because the audio analyzer is built in.

Is N/W9063A drop-in programming code compatible with HP 8901?
No. All functions are programmable but follow a modern SCPI convention. See the Keysight N/W9063A User/Programmer Guide or use the built-in Help function.

How do I test the receiver (Rx) side of my DUT?
This note does not cover Rx test. Depending on the tests, you need 1 or 2 RF signal generators (to generate RF input to Rx, plus interferers), and an audio analyzer (to examine Rx audio out). As with the Tx side, the narrow channels of analog FM demand instruments with very low phase noise. An example configuration is:

Keysight N5181B MXG signal generator

- Option 503, frequency range of 100 kHz to 3GHz
- Option UNT, AM, FM and phase modulation
- Option 303, internal function generator
- Option UNX or UNY, Enhanced Phase Noise
Appendix

Appendix A: Block diagram of X-Series signal analyzer and N/W9063A application

The analyzer hardware is a traditional spectrum-analyzer front end. The input signal is up-/down-converted through mixers, with low-pass and band-pass filters along the way. The final IF (analog) is sampled and converted to digital IQ pairs (data) in the Digital IF (DIF). The data flows into capture memory (RAM) during an acquisition, and then read out into the CPU to be processed. These batch acquisitions are normally brief and repetitive; but the user can, as needed, request a longer capture or use triggers to start the acquisition at a specific instant. The IQ sample rate and capture time are set by:

Actual SampleRate = 1/(1.25 x InfoBW) = 1/(1.25 x max [RF Span, ChannelBW])
Actual AcqTime = max [2.0/(RF RBW), 2.0/(AF RBW), 2.2* Demod Wfm Sweep Time, Demod Time]

The main analysis algorithms of the N/W9063A are performed digitally in the CPU, then displayed. There are many advantages in using digital methods. For example, log fidelity error is quite small, compared to analog loggers used in older instruments. RMS detection is always true RMS, for both strong and weak or noise-like signals. The accuracy is also improved, thanks in part to factory calibration data and/or built-in run-time alignment routines that help correct for temperature drift, component tolerances, flatness, noise, etc.

In addition to the above, the DIF contains a real-time (continuous) AM/FM/PM demodulator. See Appendix B.
Appendix B: Analog out

The X-Series signal analyzer has a real-time (continuous) FPGA-based digital AM/FM/PM demodulator, followed by a reconstruction DAC, to drive the speaker/earphone jack and allow the user to listen to the demodulated audio. The signal is also routed to the multi-purpose rear-panel Analog Out BNC connector. By default, when the N/W9063A is running, the FPGA demodulator is enabled and routed to Analog Out, even when the speaker is off.

Although the signal is similar to the modulation output of the HP 8901, the analog out of the X-Series signal analyzer was not designed as a metrics-quality output. In addition, the signal processing path for analog out is quite different from the main N/W9063A algorithms; therefore, the features and the fidelity of analog out can be different compared to N/W9063A results.

As of software rev A.14, the quality of this demodulation output has been significantly improved. It makes the scaling more stable and eliminates clipping and glitches for most FM cases. (The AM and PM cases were similarly improved in rev. A.14.5)

Even with these improvements, Keysight recommends that customers use the internal audio analysis features of N/W9063A; i.e., the waveform oscilloscope, AF spectrum analyzer, and distortion/SINAD meter. If you have a special use for this output, you should carefully evaluate its suitability for your application, and bear in mind the following:

- Analog out is un-specified for distortion, flatness, and other parameters;
- Scaling gain (e.g., $V/f_{\text{Dem}}$) and DC offsets are not the same as HP 8901, and vary depending on the model and option configuration of your X-Series signal analyzer;
- Filtering (HPF, LPF, BPF) and de-emphasis are quite limited, and will only roughly approximate the filter settings of the app;
- Carrier recovery and phase ramp tracking are different from the app;
- Other issues may exist or appear and not all will be addressed.
Appendix C: Considerations with respect to TIA-603

Standard documents from various organizations define radio performance, both to (a) assure interoperability between radios and (b) to prevent interference and assure compliance with spectrum allocations. These standards may evolve over time, and are often regionalized.

TIA-603 is a common reference for analog FM radios. Although its test procedures were written around instruments that were available in the 1980s, the standard serves as a guide for selecting test equipment and states that test equipment used is left to the manufacturer’s discretion.

Table C1 lists some of the instruments called for in TIA-603-D for Tx test, with comments about substituting X-Series signal analyzer and N/W9063A.

<table>
<thead>
<tr>
<th>TIA-603 recommended test equipment (for Tx)</th>
<th>Replace with X-Series signal analyzer and N/W9063A?</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF power meter</td>
<td>Possibly. N/W9063A measures carrier power with very good accuracy, but please examine specs to check suitability versus power meter.</td>
</tr>
<tr>
<td>RF counter</td>
<td>Probably. Carrier frequency accuracy is likely good enough.</td>
</tr>
<tr>
<td>Test receiver</td>
<td>Yes. Measures FM deviation, with Peak+, Peak-, (Pk-Pk)/2, and RMS detection.</td>
</tr>
<tr>
<td>RF detector and storage oscilloscope (for 2.2.4 Carrier Attack)</td>
<td>Yes. N/W9063A features an attack release time view, which can replace several separate instruments.</td>
</tr>
<tr>
<td>RF detector and oscilloscope (for 2.2.9 AM Hum &amp; Noise)</td>
<td>Yes. Use built-in AM demodulator.</td>
</tr>
<tr>
<td>Distortion meter (audio) (SINAD, Distortion %, THD%, or SNR)</td>
<td>Yes. Post-demod audio quality analysis is built-in. (This operates on RF signals from Tx; the N/W9063A cannot analyze audio outputs from Rx.)</td>
</tr>
<tr>
<td>Spectrum analyzer</td>
<td>Yes. Measure sideband spectrum, emissions, ACP, etc.</td>
</tr>
<tr>
<td>Adjacent channel power (ACP) analyzer or measuring receiver (for 2.2.14 ACPR)</td>
<td>Yes. Use SA mode and integrated channel method with built-in RBW filters. Does not require special channel filter, but does require excellent LO phase noise. See Appendix D.</td>
</tr>
<tr>
<td>Audio spectrum analyzer or audio freq/level meter</td>
<td>Yes. Includes FFT spectrum of post-demod audio.</td>
</tr>
<tr>
<td>Modulation domain analyzer (for 2.2.19 Transients)</td>
<td>Yes. Attack/release time view.</td>
</tr>
</tbody>
</table>
Tables C2 and C3 list the individual procedures for Tx testing from TIA-603-D, with comments about the capabilities of X-Series signal analyzers and N/W9063A. Table C3 is specifically for cases with sub-audible CTCSS and CDCSS tones added.

**Table C2.** TIA-603. Methods of measurement for Tx (excludes sub-audible signaling)

<table>
<thead>
<tr>
<th>Description</th>
<th>X-Series signal analyzer and/or N/W9063A suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2.1 Conducted carrier output power rating</td>
<td>Measure RF power into load. Procedure uses power meter. Possible to use signal analyzer instead of power meter. Please see specs.</td>
</tr>
<tr>
<td>2.2.2 Carrier frequency stability</td>
<td>Carrier freq error versus ideal, in ppm. Does not include stability over time, only accuracy versus ideal. Yes. Specs for Carrier Frequency Error are likely good enough.</td>
</tr>
<tr>
<td>2.2.3 Modulation limiting</td>
<td>Measure FM deviation, both dynamically (at large audio input step), and steady-state over 300 to 3000 Hz audio, for both +ive and -ive peak FM deviation. Yes. Use Peak+ and Peak- detectors with Max Hold. May need trigger to catch dynamics.</td>
</tr>
<tr>
<td>2.2.4 Carrier attack time</td>
<td>Trigger with PTT button, examine time to achieve 50% of maximum power. Yes, all in a single instrument. Use attack/release time view.</td>
</tr>
<tr>
<td>2.2.5 Audio sensitivity</td>
<td>Find audio input level needed to achieve 60% of rated FM deviation. Yes, measure FM deviation.</td>
</tr>
<tr>
<td>2.2.6 Audio frequency response</td>
<td>Method 1: Relative to 1 kHz tone and 20% of rated FM deviation, measure audio level needed to achieve same deviation across 300 to 3000 Hz audio. Method 2: Relative to 1 kHz tone and 20% of rated FM deviation, sweep 300 to 3000 Hz audio at constant amplitude, measure FM deviation. Result = 20 log ratio in both cases. Yes, measure FM deviation; but need an audio source also.</td>
</tr>
<tr>
<td>2.2.7 Audio distortion</td>
<td>Measure distortion at 1 kHz tone 40% of rated FM deviation. Yes, audio analyzer built-in.</td>
</tr>
<tr>
<td>2.2.8 FM hum and noise ratio</td>
<td>Relative to full rated FM deviation, measure residual FM deviation with no audio input. Use RMS ratio feature, with reference deviation either measured or manually entered.</td>
</tr>
<tr>
<td>2.2.9 AM hum and noise ratio</td>
<td>Measured on envelop of un-mod RF carrier. Relative to peak-detected Vdc from RF out at nom Tx power, measure residual AM (the Vac component). Result is 20 log ratio. Yes. Use N/W9063A, but select Meas = AM, measure modulation depth using RMS detector, convert to decimal form, then calculate 20 log (1/m).</td>
</tr>
<tr>
<td>2.2.10 Acoustic microphone sensitivity</td>
<td>Using specified audio coupling into mic, find audio level needed to achieve 60% of rated FM deviation. Yes, measure FM deviation.</td>
</tr>
<tr>
<td>2.2.11 Sideband Spectrum</td>
<td>Use SA, with RBW at 100 or 300 Hz. Establish 0 dB ref with no audio. Apply 2500 Hz audio at 16 dB above that level needed for 50% of rated FM deviation (limited); check spectrum against appropriate mask shape. Yes, use SA mode.</td>
</tr>
<tr>
<td>2.2.12 Unwanted emissions: radiated spurious</td>
<td>EMC-like measurement, using antenna into SA. Yes, use SA mode.</td>
</tr>
<tr>
<td>2.2.13 Unwanted emissions: conducted spurious</td>
<td>Apply 2500 Hz audio at 16 dB above that level needed for 50% of rated FM deviation (limited). Notch filter the carrier, and check spectrum against appropriate mask shape. Yes, use SA mode.</td>
</tr>
<tr>
<td>2.2.14 Unwanted emissions: ACP ratio</td>
<td>Apply 2-tone audio input (650 and 2200 Hz), levels set high. Measure lower/upper adjacent channel power, Ch spacing 12.5, 20, 25, or 30 kHz; compute ratio. Yes, use SA mode, with built-in ACP measurement or band power markers. Adjust bandwidth per Appendix D.</td>
</tr>
<tr>
<td>2.2.15 Audio low pass filter response</td>
<td>Determine Tx LPF freq by sweeping audio in region above 3 kHz, relative to 1 kHz. Yes, measure FM deviation as vary audio input frequency.</td>
</tr>
<tr>
<td>2.2.16 Intermodulation attenuation</td>
<td>Drive RF interferer into Tx output, via directional coupler, measure IMD. Yes, use SA mode to measure IMD.</td>
</tr>
<tr>
<td>2.2.17 Radiated power output</td>
<td>Over-the-air power measurement, using standard antenna. Yes, use SA mode.</td>
</tr>
<tr>
<td>2.2.18 Transmitter stability into VSWR</td>
<td>Measure Tx spurious while driving a highly reflective and variable load (load pull). Yes, use SA mode.</td>
</tr>
<tr>
<td>2.2.19 Transient frequency behavior</td>
<td>Examine frequency of RF carrier over time, confirm stays within limits during Tx turn-on (t1, t2) and turn-off (t3) transitions. No audio input. Yes. Use attack /release time view, and trigger with PTT signal.</td>
</tr>
</tbody>
</table>

**Note:**
1. 2.1.1 thru 2.1.22 Methods of measurement for Rx not covered here
2. 2.3.1 thru 2.3.9 Methods of measurement for unit characteristics are not RF-oriented tests
### Table C3. TIA-603. Methods of measurement for sub-audible signaling

<table>
<thead>
<tr>
<th>Description</th>
<th>X-Series signal analyzer and/or N/W9063A suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4.10 Tx mod limiting</td>
<td>Yes, measure FM dev’n. Use Max Hold, and long enough acquisition to include CTCSS tone. May need to trigger or repeat to catch step.</td>
</tr>
<tr>
<td>2.4.11 Encoder resp time</td>
<td>Yes. Use attack/release time view, trigger on PTT signal.</td>
</tr>
<tr>
<td>2.4.12 CTCSS encoder freq</td>
<td>Yes, the modulation rate will indicate CTCSS tone if that is strongest audio.</td>
</tr>
<tr>
<td>2.4.13 CTCSS tone distortion</td>
<td>Yes, the THD metric will indicate distortion on CTCSS tone if that is strongest audio.</td>
</tr>
<tr>
<td>2.4.14 Tx SINAD</td>
<td>Yes, use signaling notch filter to cut out CTCSS tone before SINAD of 1 kHz tone.</td>
</tr>
<tr>
<td>2.4.15 CDCSS waveform distortion</td>
<td>Yes, examine demod waveform with markers for droop artifacts.</td>
</tr>
<tr>
<td>2.4.16 Tx FM H and N</td>
<td>Yes, use signaling notch filter to cut out CTCSS tone before measuring residual.</td>
</tr>
<tr>
<td>2.4.17 Tx sub-audible deviation</td>
<td>Yes, measure FM deviation with only CTCSS tone.</td>
</tr>
<tr>
<td>2.4.18 Tx squelch tail elim burst</td>
<td>Yes, use attack/release time view, with trigger from PTT signal, and examine FM waveform.</td>
</tr>
</tbody>
</table>

**Note:**
1. 2.4.1 thru 2.4.9 Rx tests not covered here
Appendix D: Measuring ACP

Adjacent channel power (ACP) or adjacent channel power ratio (ACPR) are measurements of undesired energy from a transmitter appearing in channels adjacent to the one intended. Radio compliance standards call out a maximum allowed ACP of X dB, at various offset frequencies from the carrier, within a certain bandwidth, relative to the power in the intended channel. The specs vary by band, channel spacing, and device type.

The instrument used to measure ACP must be very frequency-selective; i.e., the instrument itself must have lower leakage from the intended channel into the adjacent channels, or the measurement is meaningless. This requires a filter with excellent selectivity (steep stop-band roll-off), plus excellent phase noise, and a sufficiently low noise floor (DANL).

TIA-603, ETSI EN 300, and other standards allow two methods for measuring ACP:

1) ACP measuring receiver, with a fixed IF filter meeting a specified selectivity characteristic (mask), followed by a power measuring device; or

2) Spectrum analyzer, using a narrow RBW filter (much narrower than the channel spacing), and integrating the power over these RBW sub-bands to give total power in the adjacent channel.

The HP 8901 used method (1); Keysight X-Series signal analyzers use method (2).

In the X-Series signal analyzers, ACP measurements are performed in the SA mode (not the N/W9063A Analog Demod app), using either of these features:

a) In the SA mode, press Meas >> ACP, and enter a set of offsets and channel widths. The set-up of this measurement is lengthy but it will measure many offsets at once; once done, the measurement state can be saved for later recall.

b) In the SA mode, use marker functions instead. A delta-pair of band/interval-power markers gives the same result as ACP. The setup is far simpler but only measures a single offset as a time, so is suited for ad-hoc measurements.

There are two optional refinements to measuring ACP, applicable to (a) or (b):

i. The user selects the RBW filter to be used in the ACP measurement. For narrow-band FM radio, the RBW filter must be set quite narrow to meet the steep selectivity specs of the filter. Some standard documents spell out the RBW to be used for method (2); e.g., 100 Hz or < 2% of measurement bandwidth. However, Keysight has determined that -- given the shape of the filters in the X-Series signal analyzers -- an RBW of 1.0 kHz or even 1.3 kHz meets the selectivity requirement, while sweeping much faster. Of course, an RBW of 100 Hz can be used if desired. Some standards call specifically for swept or swept mode measurement; for a modern SA, there is no need to force this sweep mode.

ii. The spectrum analyzer will integrate the power over a range of frequencies, making up the measurement bandwidth. This range is called the ACP channel width, and is a parameter the user enters when setting up the ACP measurement. Standards documents define the measurement bandwidth to be used. However, most standards (e.g., TIA-603 and ETSI 300) define the bandwidth in term of -6 dB bandwidth (typical of measuring receivers), while spectrum analyzer bandwidths are based on -3 dB bandwidth. Therefore, a simple compensation factor is used to adjust the measurement bandwidth slightly narrower to account for this difference:

\[
\text{MeasBwAdj} = \text{MeasBwNom} - (0.536 \times \text{RBW})
\]
where MeasBwNom is the channel width defined in the standards; RBW is the RBW filter setting actually used from (i); and MeasBwAdj is the adjusted channel width to set up the ACP measurement. The difference can be significant (~10%) when the RBW is 1.0 or 1.3 kHz, and measurement bandwidth is narrow; see Table D1. The compensation described in (ii) is negligible if using a narrow RBW filter (e.g., 100 Hz).

Table D1. Impact of measurement bandwidth adjustment

<table>
<thead>
<tr>
<th>Band (MHz)</th>
<th>Channel spacing (kHz)</th>
<th>Measurement bandwidth (nominal) (kHz)</th>
<th>Measurement bandwidth adjusted for RBW = 1.3 kHz (kHz)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>All except 700 MHz</td>
<td>&gt; 25.0</td>
<td>16</td>
<td>15.256</td>
<td></td>
</tr>
<tr>
<td>700 MHz</td>
<td>20.0</td>
<td>14</td>
<td>13.256</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15.0</td>
<td>8.5</td>
<td>7.756</td>
<td>9% change</td>
</tr>
<tr>
<td></td>
<td>12.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>700 MHz</td>
<td>12.5 or 25</td>
<td>6.25</td>
<td>5.506</td>
<td>12% change</td>
</tr>
<tr>
<td></td>
<td>25.00</td>
<td>24.256</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>100.00</td>
<td>99.256</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>29.256</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Keysight asserts that its ACP measurement methods, and selectivity of its RBW filters in the X-series signal analyzers, described above, are compliant with TIA-603, ETSI EN 300, and other comparable standards for ACP.

Phase noise of the instrument’s LO may ultimately limit ACP dynamic range. This is true for both (1) ACP Measuring Receiver or (2) Spectrum Analyzer. The standards do not spec phase noise; however, they require the instrument be “designed in a way that the measurement of the adjacent channel power on a low-noise unmodulated transmitter, whose self-noise has a negligible influence on the measurement result, yields a measurement value of ≤ –90 dB for channel separations of 20 kHz, 25 kHz, and 30 kHz and ≤ –80 dB for a channel separation of 12.5 kHz, referenced to the carrier of the oscillator” [from TIA-603-D, 1.5.8]. In other words, the instrument’s performance is described via a test method, using a “transmitter” (signal generator) that it known to have negligible noise in the adjacent channel (low phase noise), such that you are testing the instrument’s (spectrum analyzer’s) ACP dynamic range. To verify the SA’s phase noise, you can use an Keysight PSG with Option UNY (no modulation needed). Set up the ACP measurement, tune the sig gen to the middle of the intended channel, and measure the adjacent channel.

A similar test can verify that a 1.0 or 1.3 kHz RBW has sufficient selectivity (as compared to 100 Hz RBW).

Of course, it is much easier to estimate ACP dynamic range from the SA phase noise specs. Find the phase noise spec in dBC/Hz for a carrier in the 100 MHz to 1 GHz range, at an offset equal to the Channel Spacing. Then integrate over frequency, by adding 10*log(MeasurementBandwidth) in dB. This assumes that phase noise is approximately “flat” around these offsets. (Example: PXA at 1 GHz carrier, at ~10 kHz offset, is about -133 dBC/Hz nominal. Note that phase noise is flat vs offset here. Then 10*log(8500 Hz) gives 39.3 dB. Add to -133, gives estimated ACP dynamic range of 93.7 dB.) See Table Q1 for other examples.
Appendix E: Software enhancements for N/W9063A in software update A.14

For history prior to A.14, please see www.keysight.com/find/xseries_software.

- Added Attack/Release View, which displays ramp of RF carrier power and post-demod FM waveform, versus time, top and bottom. This is useful for Tx Attack and Tx Release measurements, also source settling/switching/stepping response. Waveform has fine horizontal resolution, to see encoder response and squelch tail elimination burst. Not available for AM and PM. Supports limit line import (but not pass/fail testing), from user-supplied file.

- Added marker table for AF spectrum, enabling faster and easier analysis of multi-tone audio (CTCSS, DTMF, etc.), audio flatness response, command destruct telemetry, etc.

- Added many post-demod audio filters, such that the HP 9063A offers a superset of all filters from HP 8901A/B, 8903A, and 8920A/B. In addition, some existing audio filters were modified (number of poles) to better match these HP products. All filters are digital.

- Added signaling notch filter to remove sub-audible CTCSS or CDCSS tones from SINAD and hum and noise measurements.

- Added user entry of Ref for RMS ratio, using keypad. (Previously, the Ref was established only by making a measurement.)

- Extended bandwidth to full capabilities of instrument; e.g., 10, 25, 40, 80, or 160 MHz, depending on option configuration (no longer limited to 8 MHz). Added user-defined LPF, to band-limit FM demod noise at arbitrary cut-off frequencies.

- Auto BW & Scale function improved, and no longer resets filters.

- Added more choices of units: RF power in Watts or dBm; AF spectrum in linear or log units (e.g., dBJz for FM); PM in radians or degrees; and distortion in % or dB.

- Added export of long full-rate post-demod waveforms, up to 3.6 MSa, via SCPI query and save to file. Uses attack/release time view, for FM only. Export array is no longer subject to decimation or truncation (as for displayed trace).

- Added SINAD BW control.

- Added auto carrier frequency and auto carrier phase to omit constant frequency or phase offsets.

- Added audio SNR (signal-to-noise ratio) metric, to emulate the sig/noise function of the HP 8903 audio analyzer.

- Improved analog out signal (more stable, eliminate discontinuities at each acquisition). Added user-scaling of FM out. Limited to 8 MHz BW.

- Revised warranted (hard) specifications for several X-Series signal analyzer models of. (See specific model’s specifications guide for appropriate details.) Updated and added nominal specs, in some cases.
References and Additional Information

- N/W9063A Analog Demodulation X-Series Measurement Application Technical Overview, literature number 5989-6535EN

- Specifications guides for PXA/MXA/EXA/CXA (as appropriate); see chapter related to the N/W9063A Analog Demodulation Measurement Application

- Application Note 150 Spectrum Analysis Basics, literature number 5952-0292

- Application Note 150-1 Spectrum Analysis: Amplitude and Frequency Modulation, literature number 5954-9130

- Technical article Make Adjacent-Channel Power Measurements by Joe Gorin, Microwaves & RF, May 1992

- Technical article Using The Bessel Null Method To Verify FM Deviation Measurements by Dave Engelder, RF Globalnet, May 1, 2014
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