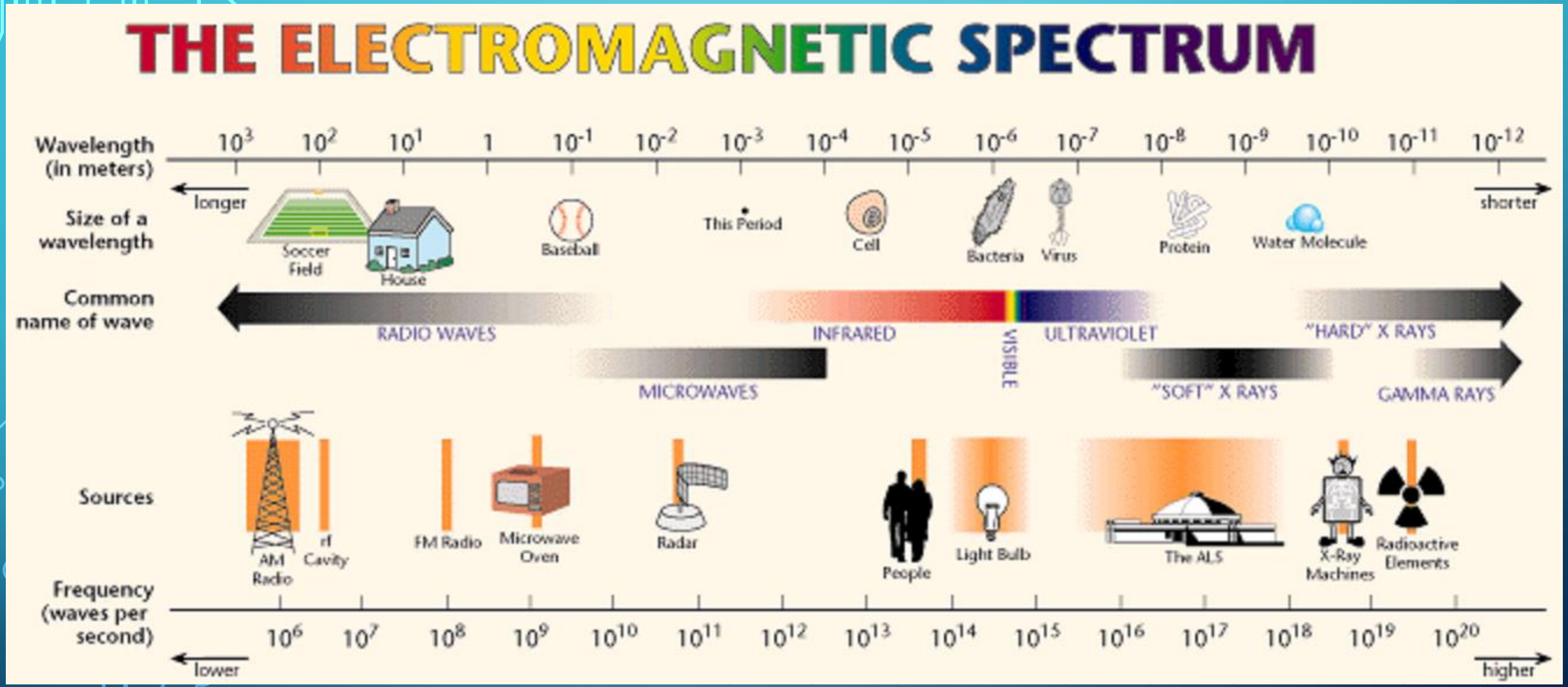
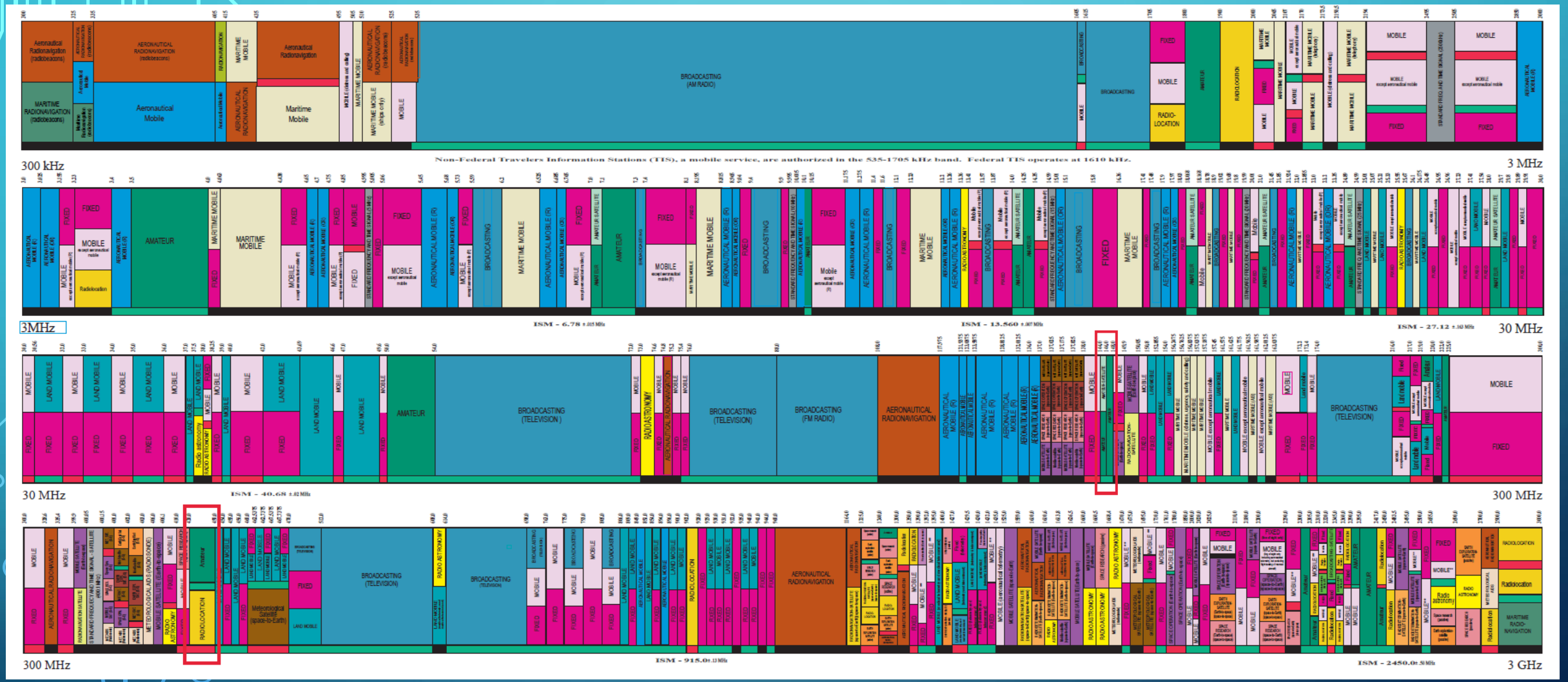
RADIO TEST

November 11, 2021

Rick Nungester, WA6NDR



Big Picture #1: Frequency and Wavelength. Ham radio is in 29 frequency bands from 136 kHz ($10^{5.1}$ Hz, 1.4 miles) to 250 GHz ($10^{11.4}$ Hz, 1.2 mm) and all above 275 GHz.



Big Picture #2: The Federal Communications Commission (FCC) has rules for all these radios. They all need testing and FCC approval. Only 300 kHz to 3 GHz is shown here. The amateur 2m and 70 cm bands are in red boxes.

Mark J. Wilson, K1RO, k1ro@arrl.org

Product Review

Alinco DJ-VX50T VHF/UHF Hand-held Transceiver

Reviewed by Steve Ford, WB8IMY
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The Alinco DJ-VX50T is a dual-band (2-meter and 70-centimeter) FM transceiver that is designed to be a serious contender in the lower-cost handheld market. It sets itself apart from the competition in several ways, beginning with its rugged construction. The radio is housed in a dense ABS plastic case with a textured surface to minimize slippage. With the 1,800 mAh Li-ion battery attached, the DJ-VX50T has a hefty, almost heavy feel.

As I examined the exterior, I noticed the external microphone and speaker ports were covered by a shield that you can only open by removing a screw. The robust shield is sealed with a gasket and present because the DJ-VX50T is water- and dustproof, carrying an Ingress Protection (IP) rating of 67. The first number designates protection against solid objects, such as dust and sand. This number can range from 0, meaning no protection, to 6, meaning 100% protection. The second number rates protection against liquids. It ranges from 0 to 8. So, the DJ-VX50T is 100% protected against solid objects, and it has been tested to work after being immersed under a

A typical 2m/70cm radio review in QST magazine (September 2021, p39)

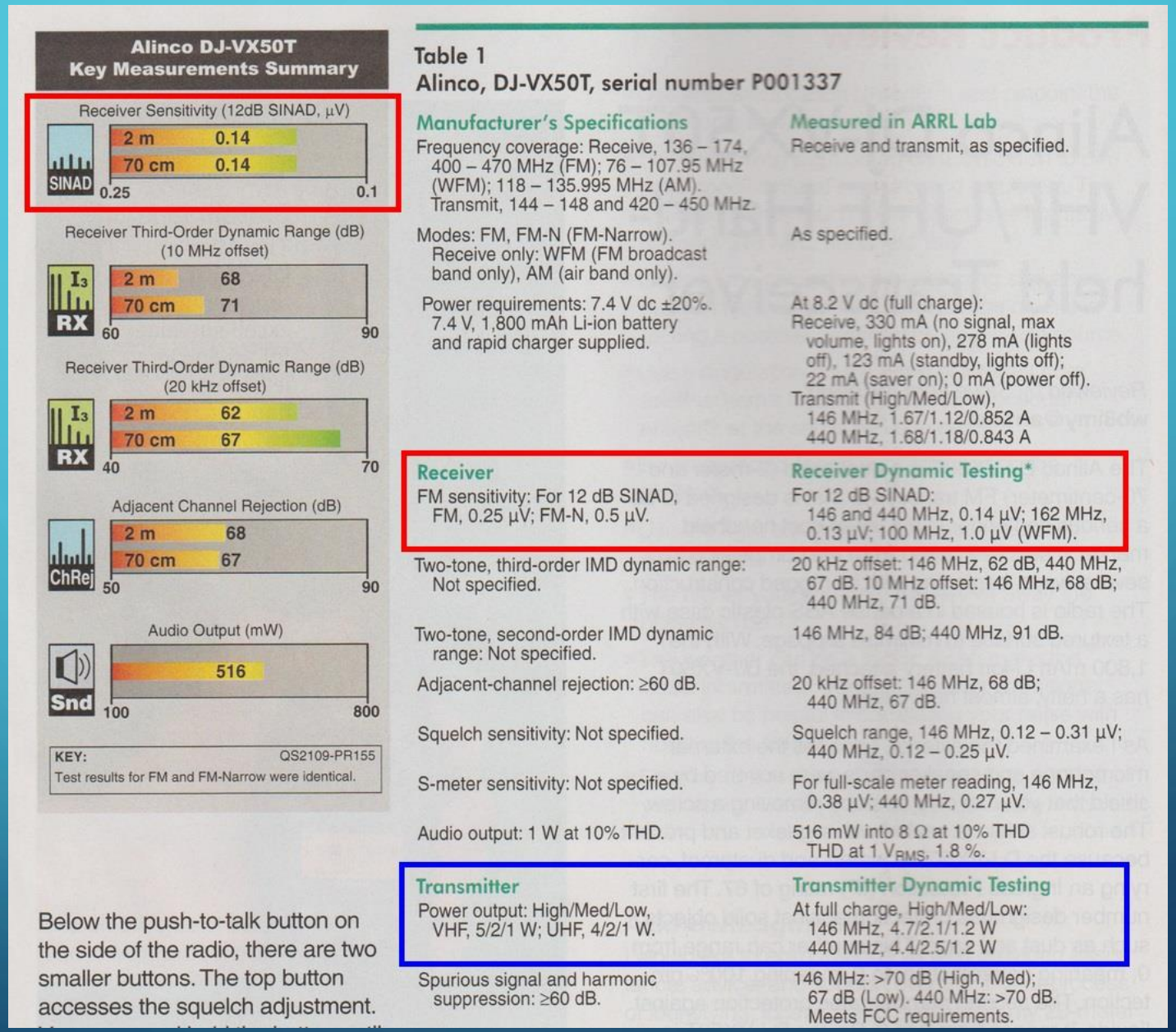


Table 1
Alinco, DJ-VX50T, serial number P001337

Manufacturer's Specifications	Measured in ARRL Lab
Frequency coverage: Receive, 136 – 174, 400 – 470 MHz (FM); 76 – 107.95 MHz (WFM); 118 – 135.995 MHz (AM). Transmit, 144 – 148 and 420 – 450 MHz.	Receive and transmit, as specified.
Modes: FM, FM-N (FM-Narrow). Receive only: WFM (FM broadcast band only), AM (air band only).	As specified.
Power requirements: 7.4 V dc ±20%. 7.4 V, 1,800 mAh Li-ion battery and rapid charger supplied.	At 8.2 V dc (full charge): Receive, 330 mA (no signal, max volume, lights on), 278 mA (lights off), 123 mA (standby, lights off); 22 mA (saver on); 0 mA (power off). Transmit (High/Med/Low), 146 MHz, 1.67/1.12/0.852 A 440 MHz, 1.68/1.18/0.843 A
Receiver	**Receiver Dynamic Testing***
FM sensitivity: For 12 dB SINAD, FM, 0.25 µV; FM-N, 0.5 µV.	For 12 dB SINAD: 146 and 440 MHz, 0.14 µV; 162 MHz, 0.13 µV; 100 MHz, 1.0 µV (WFM).
Two-tone, third-order IMD dynamic range: Not specified.	20 kHz offset: 146 MHz, 62 dB, 440 MHz, 67 dB. 10 MHz offset: 146 MHz, 68 dB; 440 MHz, 71 dB.
Two-tone, second-order IMD dynamic range: Not specified.	146 MHz, 84 dB; 440 MHz, 91 dB.
Adjacent-channel rejection: ≥60 dB.	20 kHz offset: 146 MHz, 68 dB; 440 MHz, 67 dB.
Squelch sensitivity: Not specified.	Squelch range, 146 MHz, 0.12 – 0.31 µV; 440 MHz, 0.12 – 0.25 µV.
S-meter sensitivity: Not specified.	For full-scale meter reading, 146 MHz, 0.38 µV; 440 MHz, 0.27 µV.
Audio output: 1 W at 10% THD.	516 mW into 8 Ω at 10% THD THD at 1 V_{RMS}, 1.8 %.
Transmitter	**Transmitter Dynamic Testing**
Power output: High/Med/Low, VHF, 5/2/1 W; UHF, 4/2/1 W.	At full charge, High/Med/Low: 146 MHz, 4.7/2.1/1.2 W 440 MHz, 4.4/2.5/1.2 W
Spurious signal and harmonic suppression: ≥60 dB.	146 MHz: >70 dB (High, Med); 67 dB (Low). 440 MHz: >70 dB. Meets FCC requirements.

Below the push-to-talk button on the side of the radio, there are two smaller buttons. The top button accesses the squelch adjustment.

"Specifications" and "Measured in ARRL Lab". What does it all mean? How is it measured?

Common Radio Test Instruments

Radio Frequency Analysis

Frequency Counter
Power Meter
Spectrum Analyzer with
    Storage/Normalizer
Demodulator (AM/FM/SSB)

DC/Audio Frequency Analysis

Frequency Counter
Voltmeter (DC, peak, true RMS)
Oscilloscope
SINAD/Distortion Meter with
    Filters, De-Emphasis, Notch…
Signaling Analyzer (DTMF, Paging…)
DC Current Meter

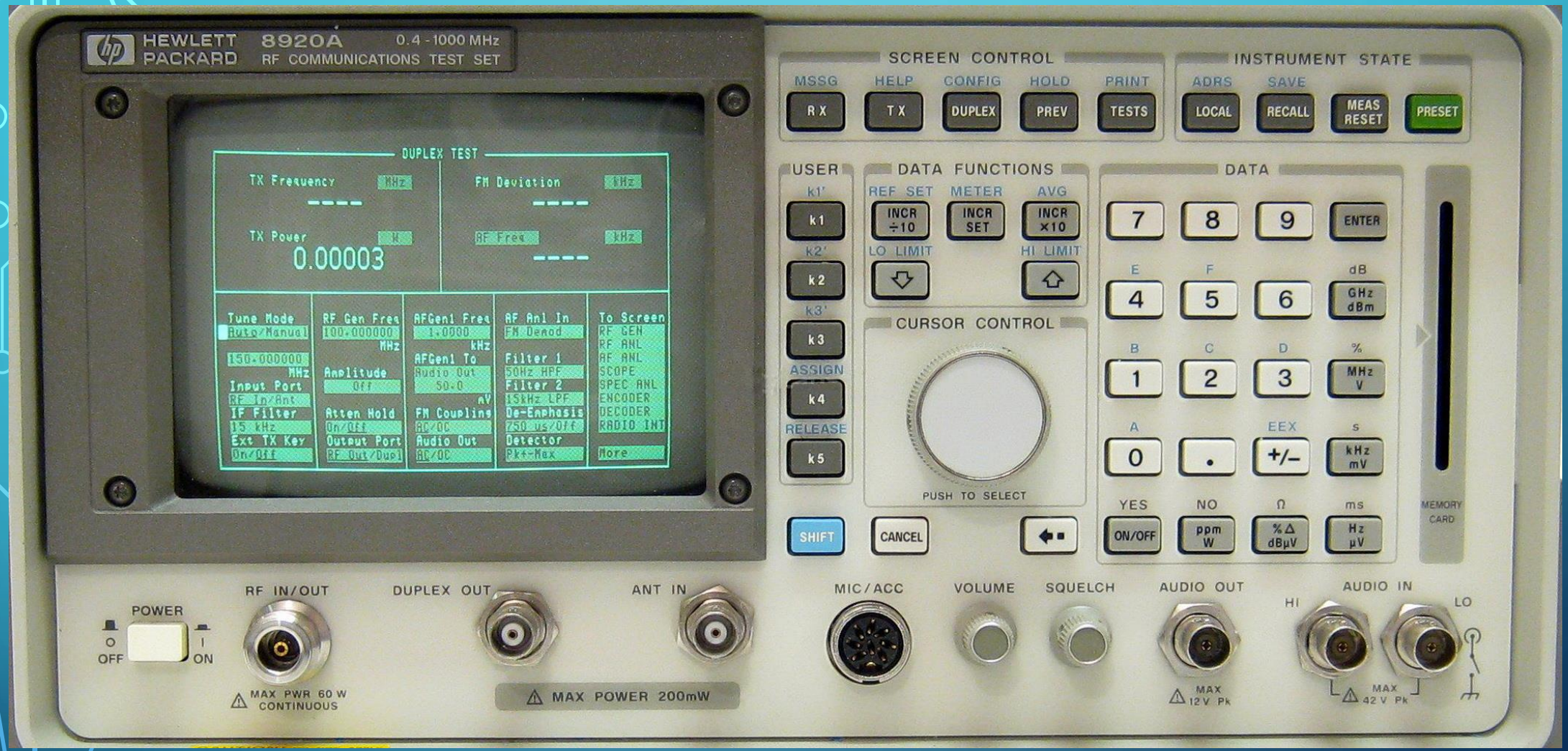
DC/Audio Frequency Generation

Function Generator (Sine, Square…)
Signaling Generator (DTMF, Paging…)

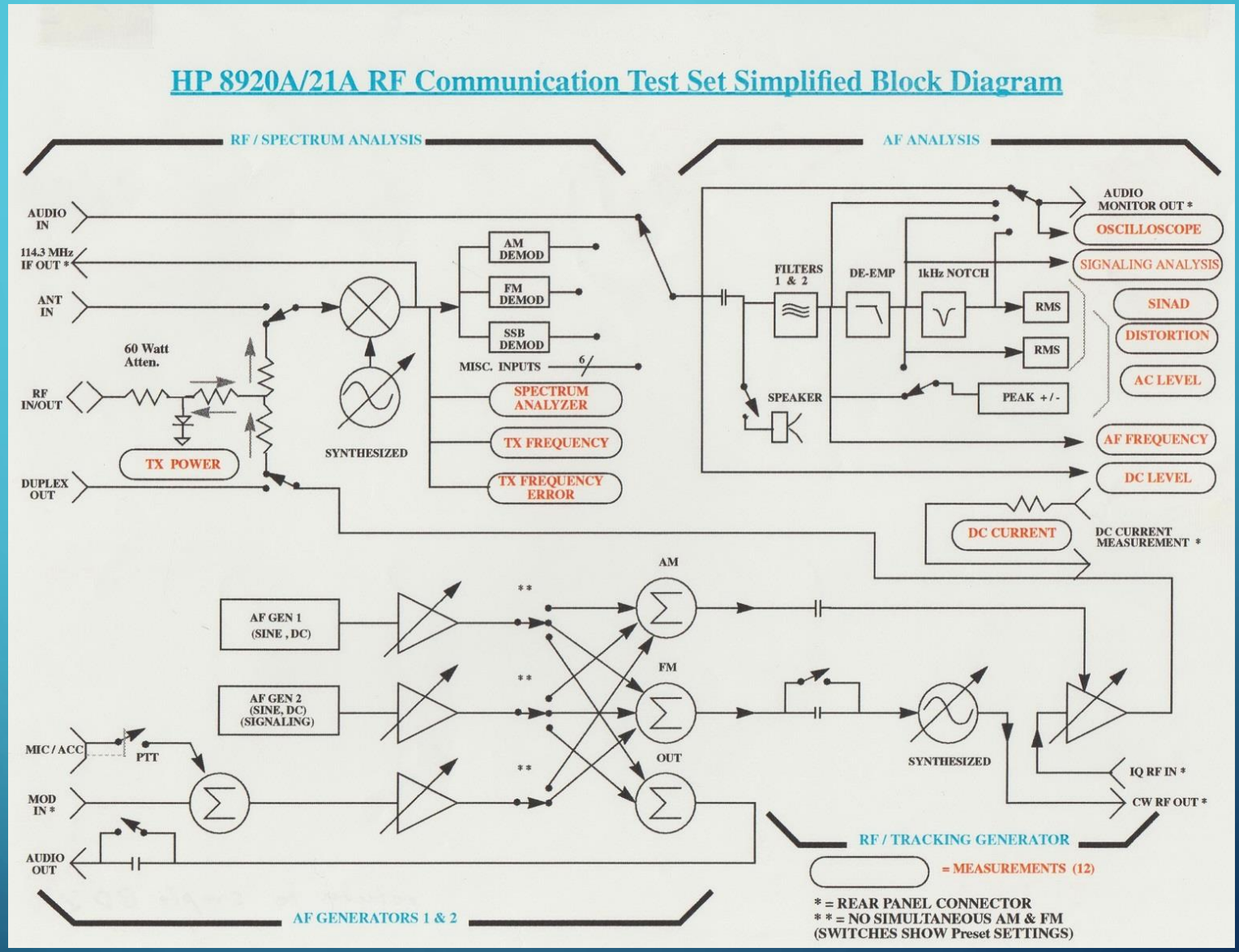
Radio Frequency Generation

Signal Generator with AM/FM
    and Spectrum Analyzer Tracking

What's missing?

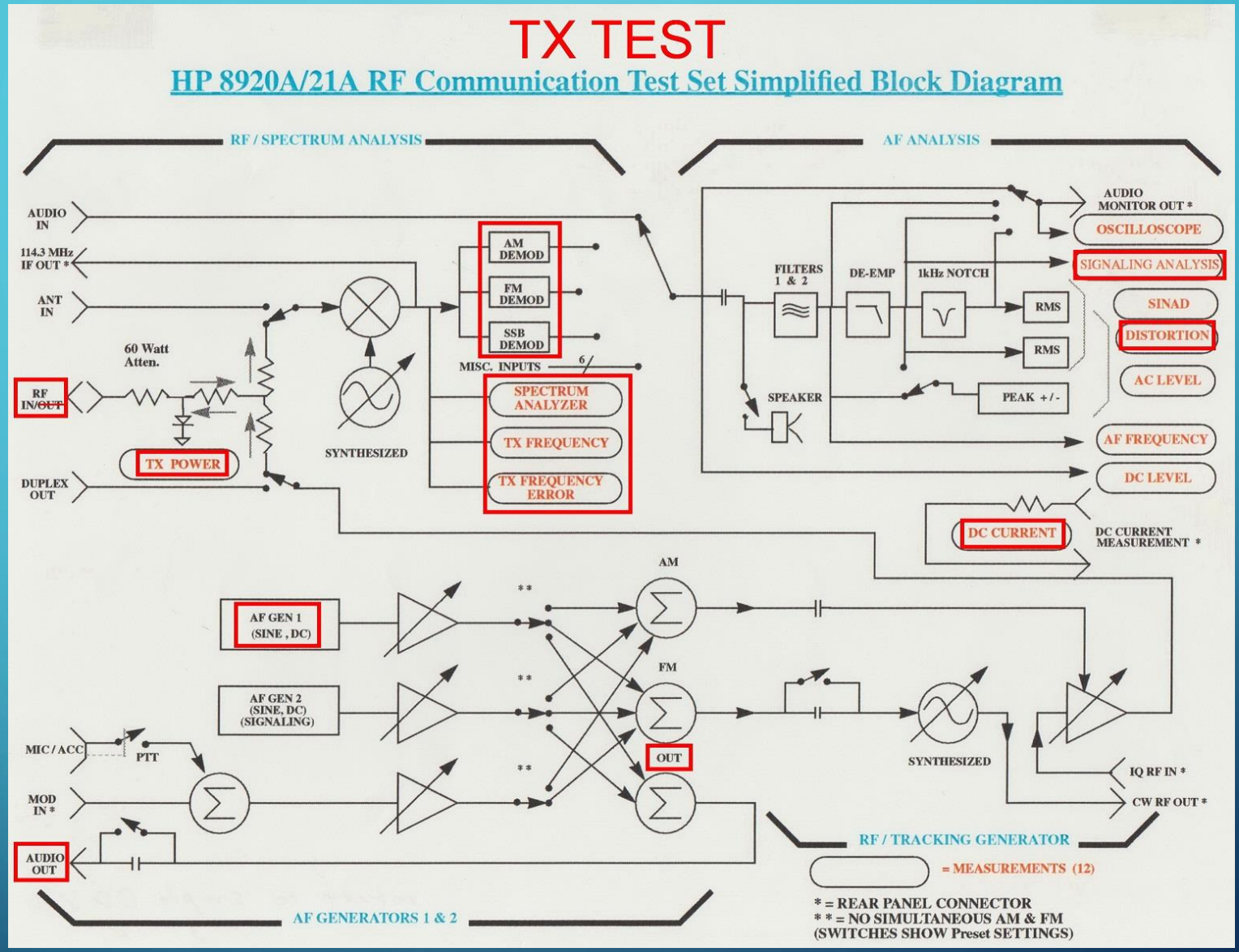


Hewlett-Packard 8920A RF Test Set; 1984-1991 development; $20,000 with all options; RF/AF generators; RF/AF analyzers (0.4-1000 MHz); AM/FM/SSB; $50,000 in today's dollars; now obsolete; ~$2,000 used on eBay. An RF test set is just a very good general-purpose transceiver with various detectors throughout its block diagram.



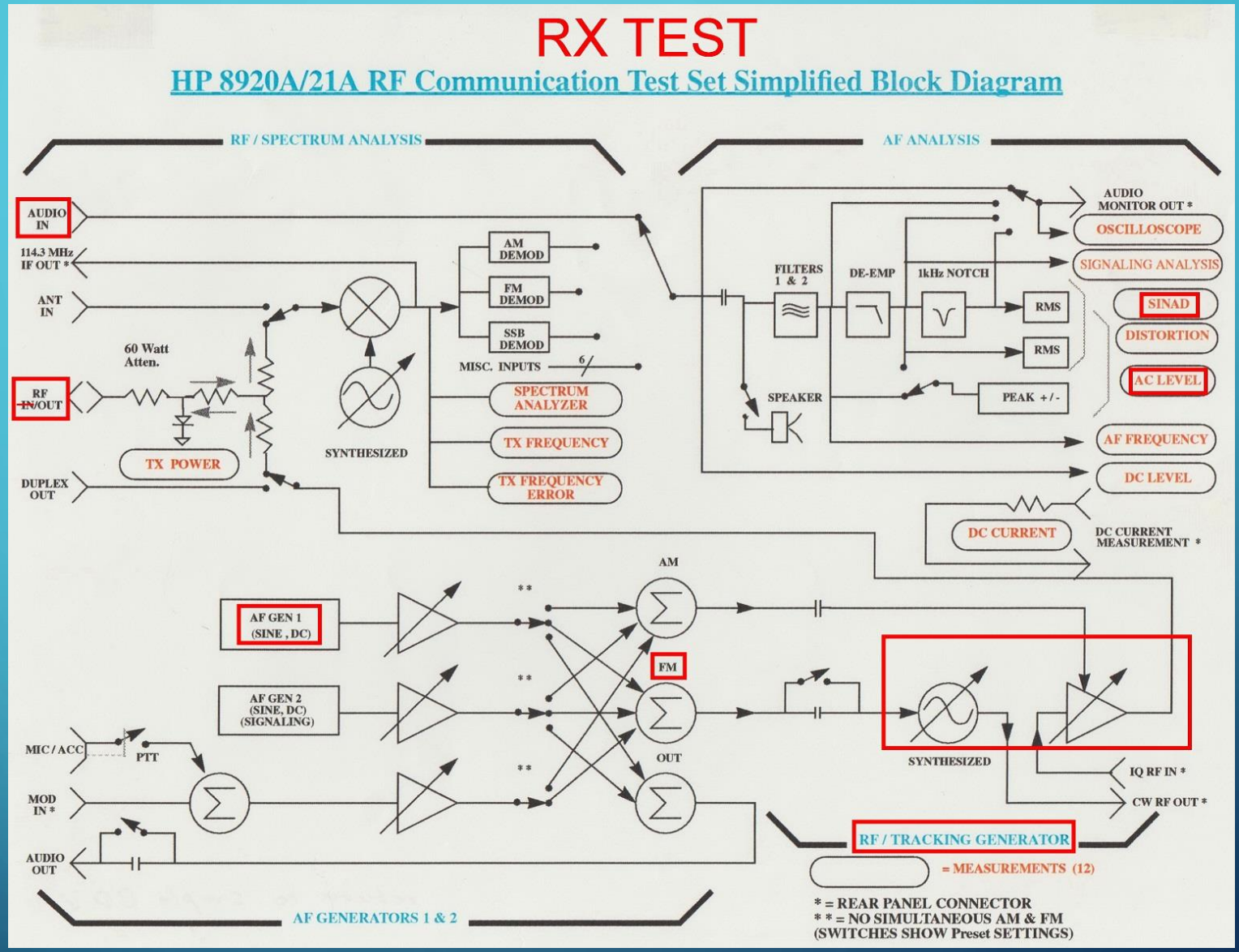
Notice the same 4 sections as 2 slides back. A test set generates and analyzes radio and audio frequencies, connecting key signals in useful ways, with very good specifications.

TX TEST

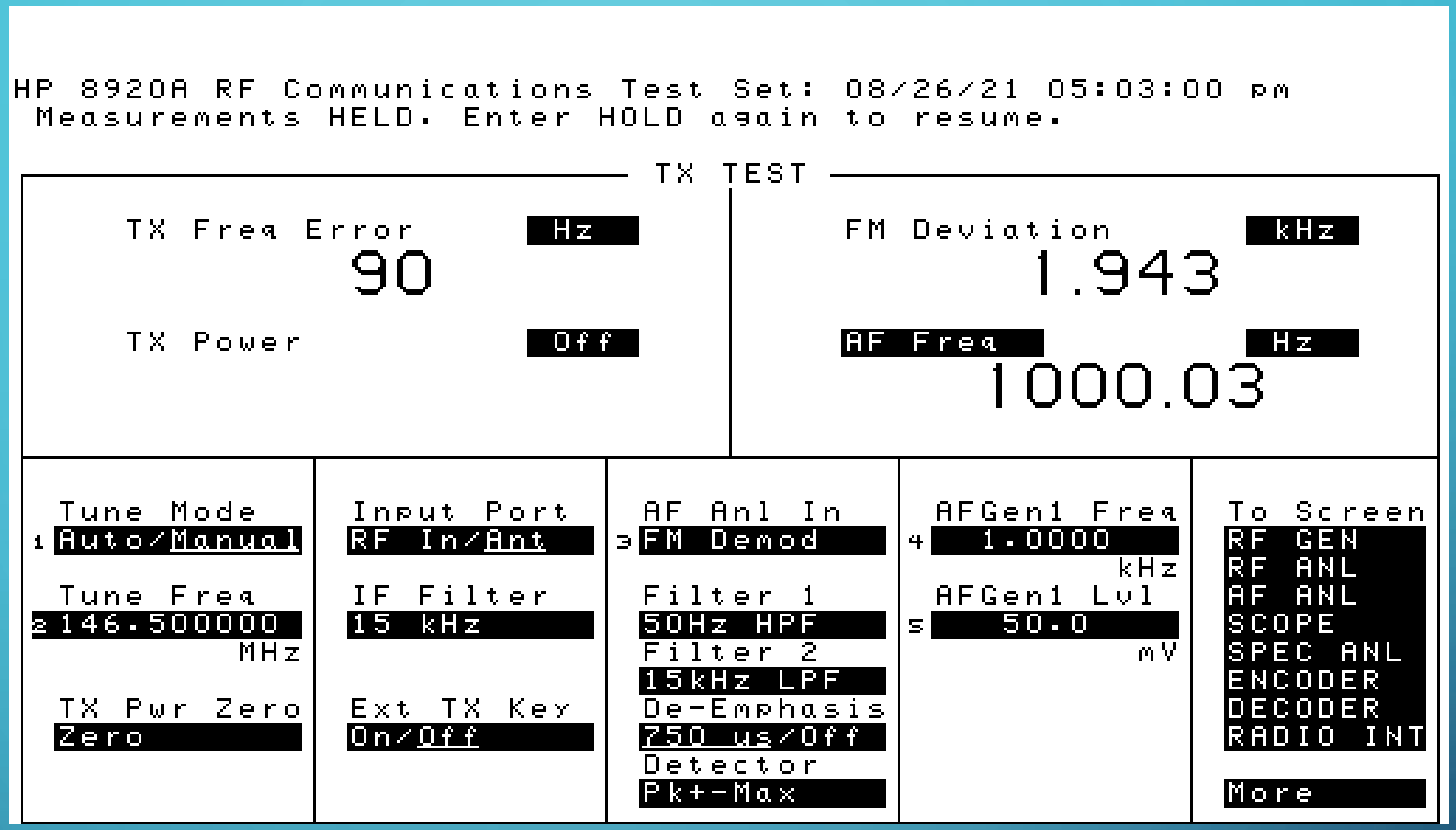


Test set Audio Out to the radio Mic Input. Radio RF output to the test set RF Input. Measure all the red boxes in the RF/Spectrum/AF Analyzer sections. RF Generator is unused.

RX TEST

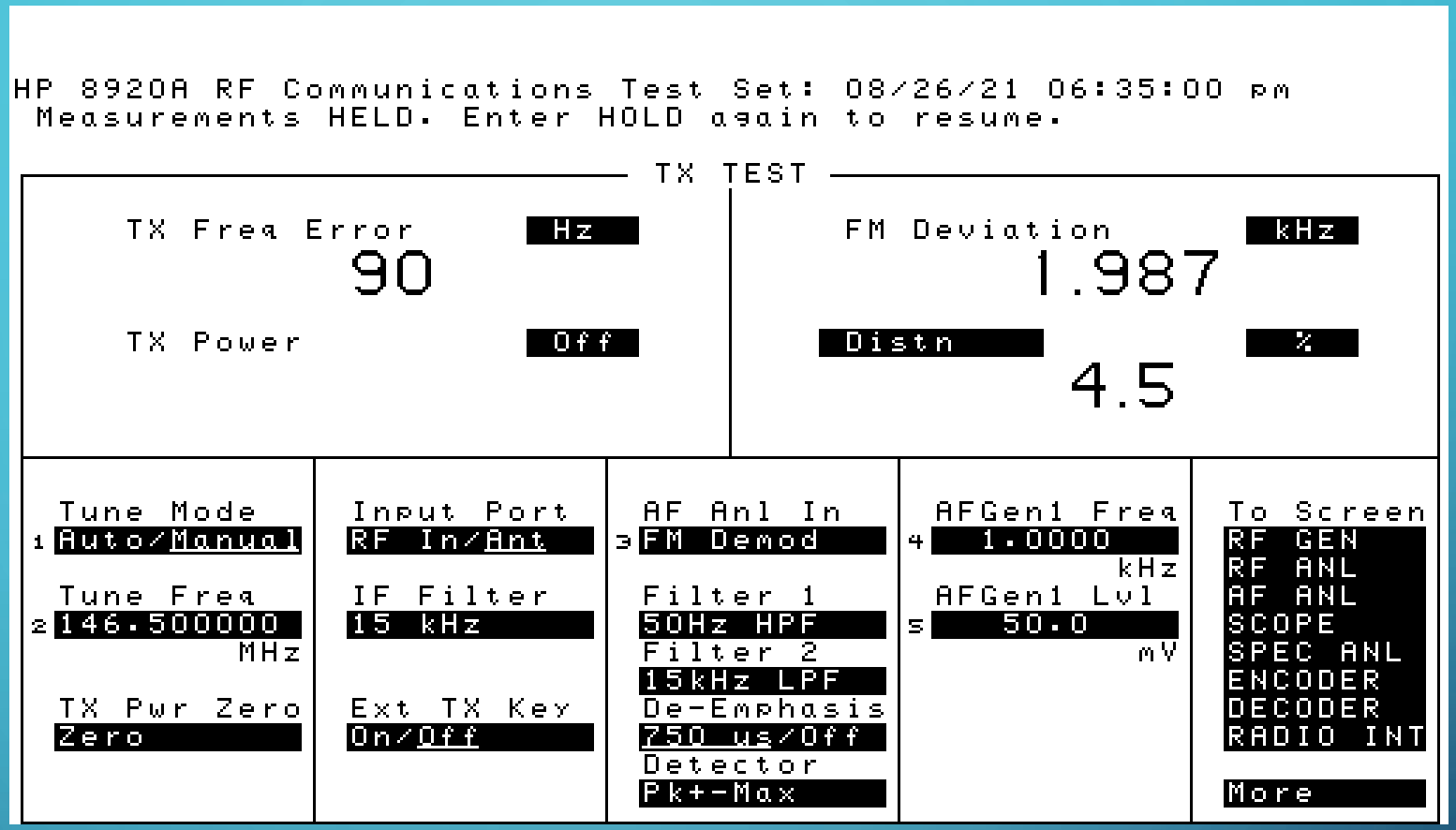


Test set audio modulates its RF Generator that goes to the Radio antenna. The Radio speaker output goes to the test set Audio Input. Measure Receiver Sensitivity (audio AC Level and SINAD).



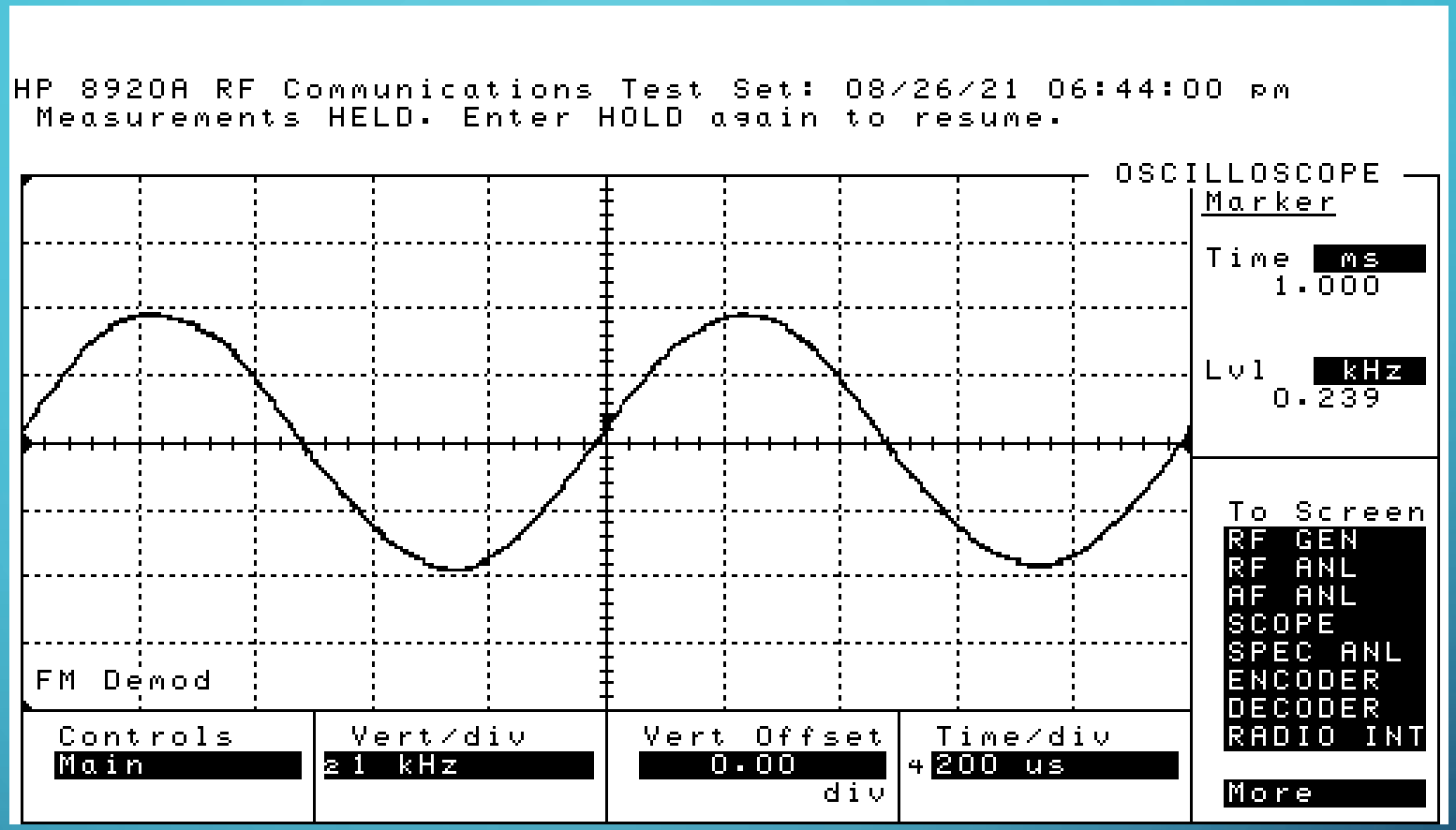
3 radio connection scenarios: Over The Air (OTA, 0 cables); antenna only (1 cable); antenna + mic + speaker (3 cables). Each scenario can test more than the previous one.

Baofeng UV-5R OTA TX Test. The radio CALL button generates a 1 kHz tone.
Measurements: Frequency Error, FM Deviation, Tone Frequency.



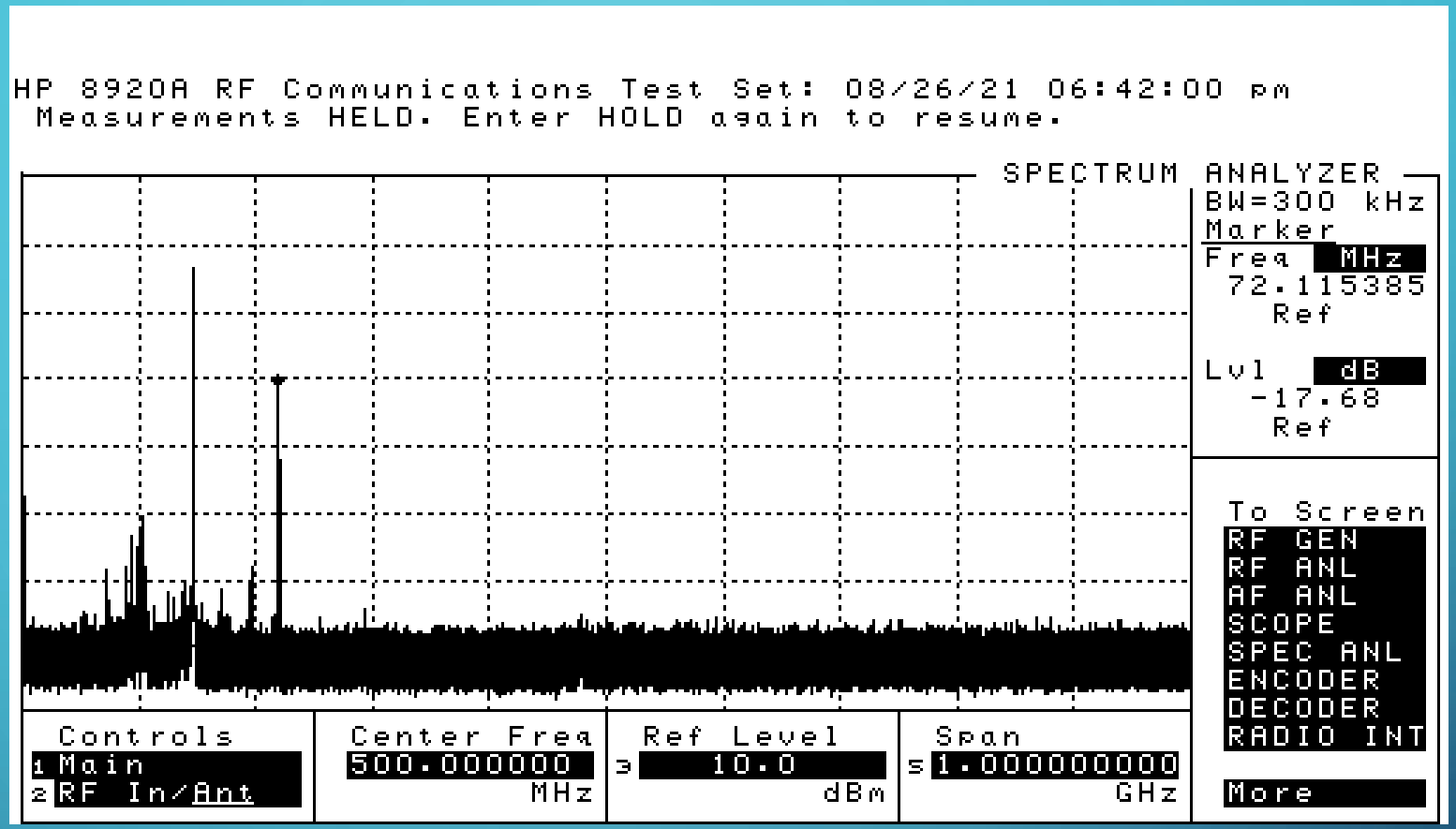
Baofeng UV-5R OTA TX Test. The radio CALL button generates a 1 kHz tone.

Measurements: Audio Distortion of the demodulated 1 kHz tone.

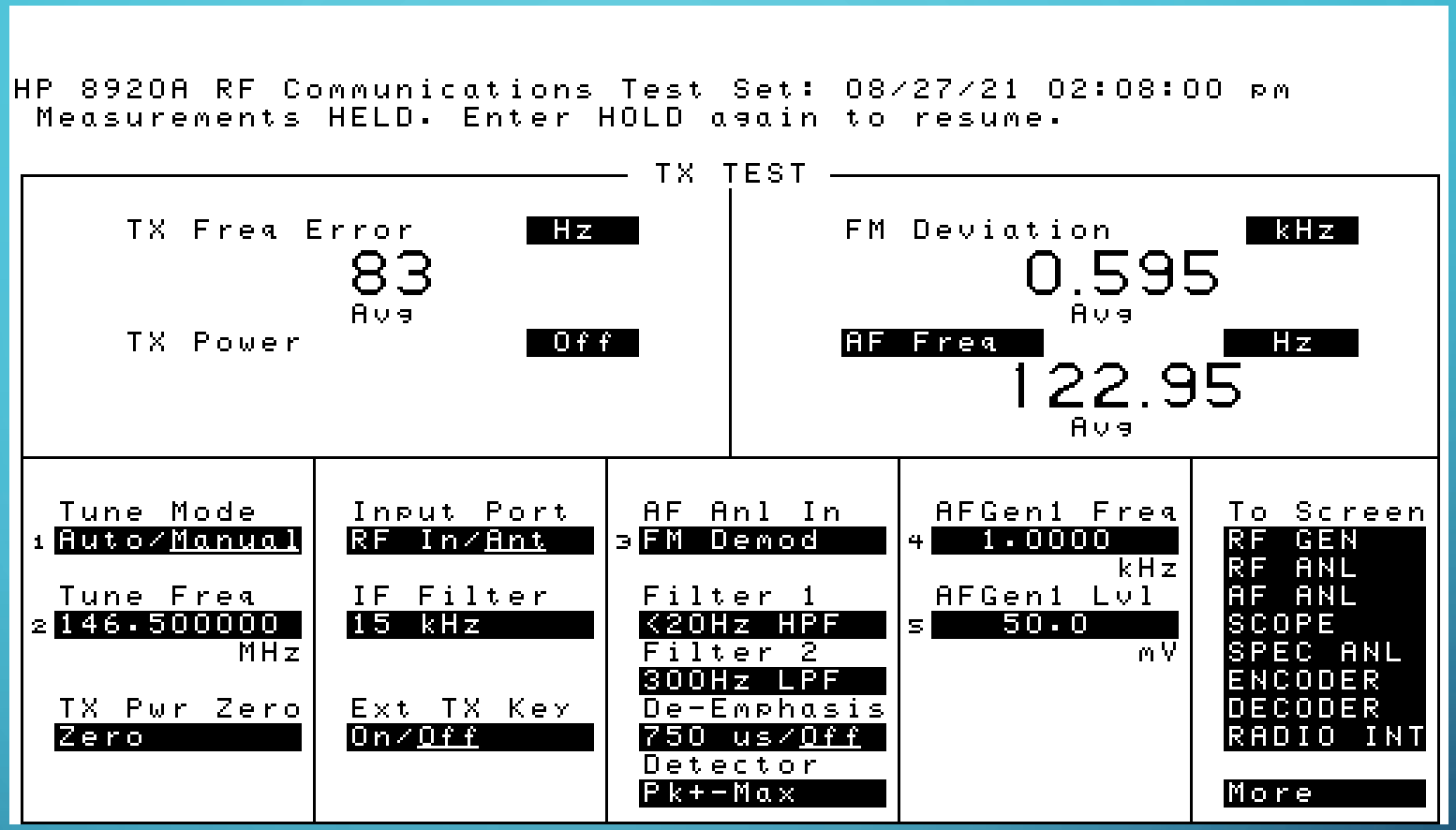


Baofeng UV-5R OTA TX Test. The radio CALL button generates a 1 kHz tone.

Measurements: Demodulated 1 kHz tone on an oscilloscope, 200 µs/div, 1 kHz/div. The 'scope also has markers and marker-delta functions for waveform measurements.

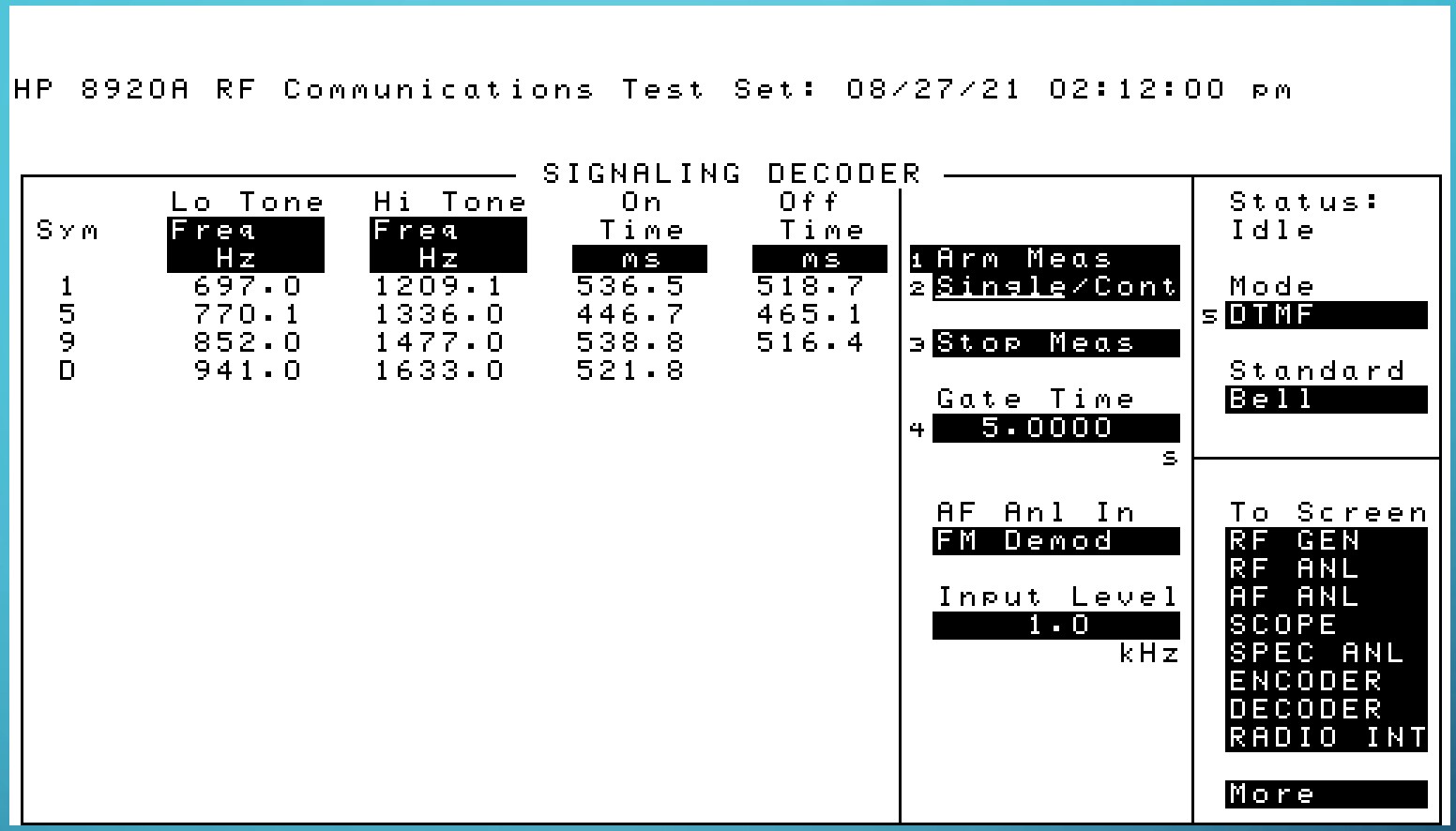


Baofeng UV-5R OTA TX Test. This shows a 0-1000 MHz spectrum analyzer scan, 10 dB/div, 100 MHz/div, carrier at 146.5 MHz, unwanted signal 72 MHz higher, 18 dB down. The spectrum analyzer has markers, an RF tracking generator, a storage-normalizer (for return loss measurements), and more.



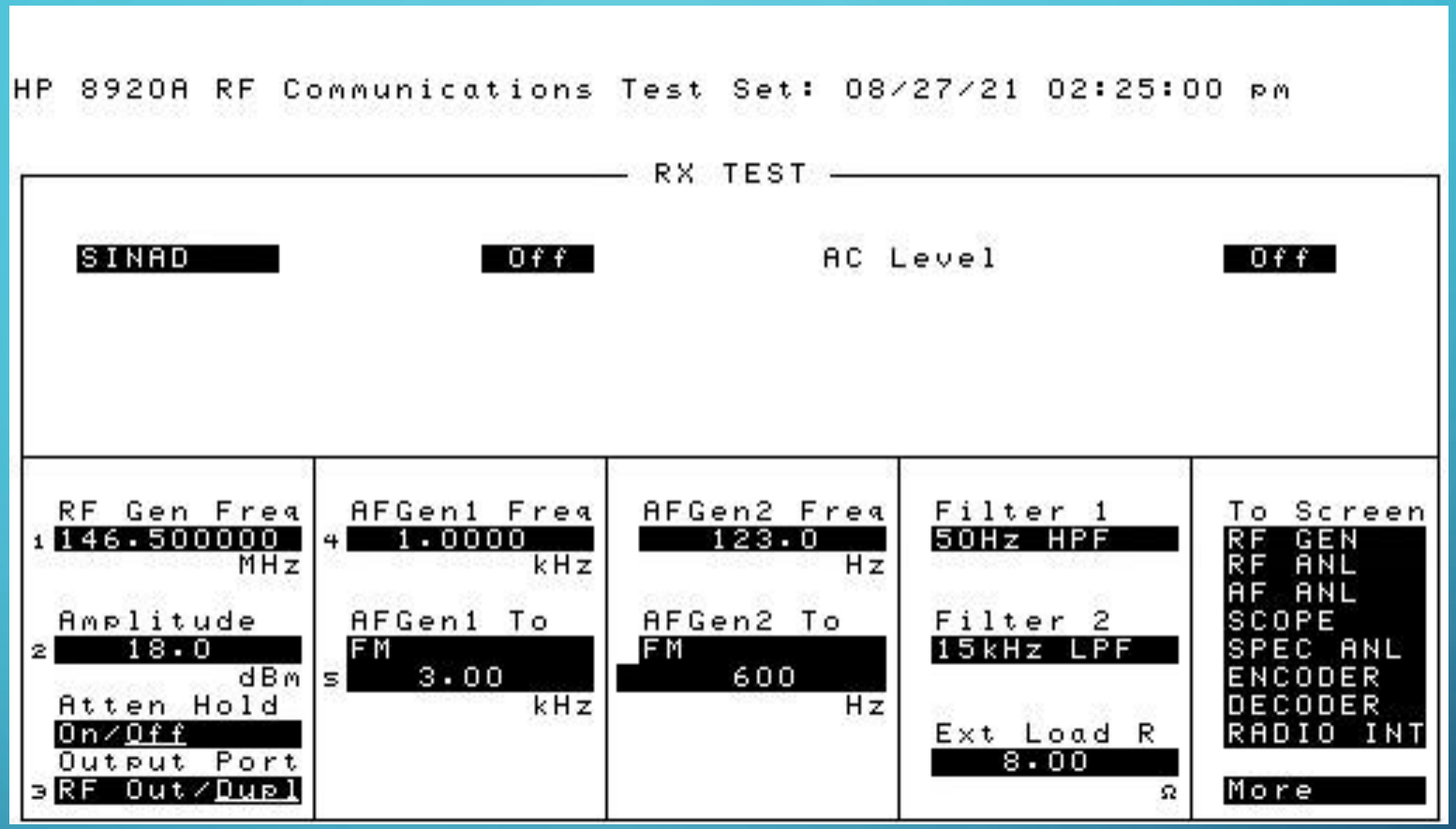
Baofeng UV-5R OTA TX Test, sending a 123.0 Hz tone.

Measurements: FM deviation and audio frequency. Notice 20 to 300 Hz filtering and measurement averaging to reduce noisy displays.

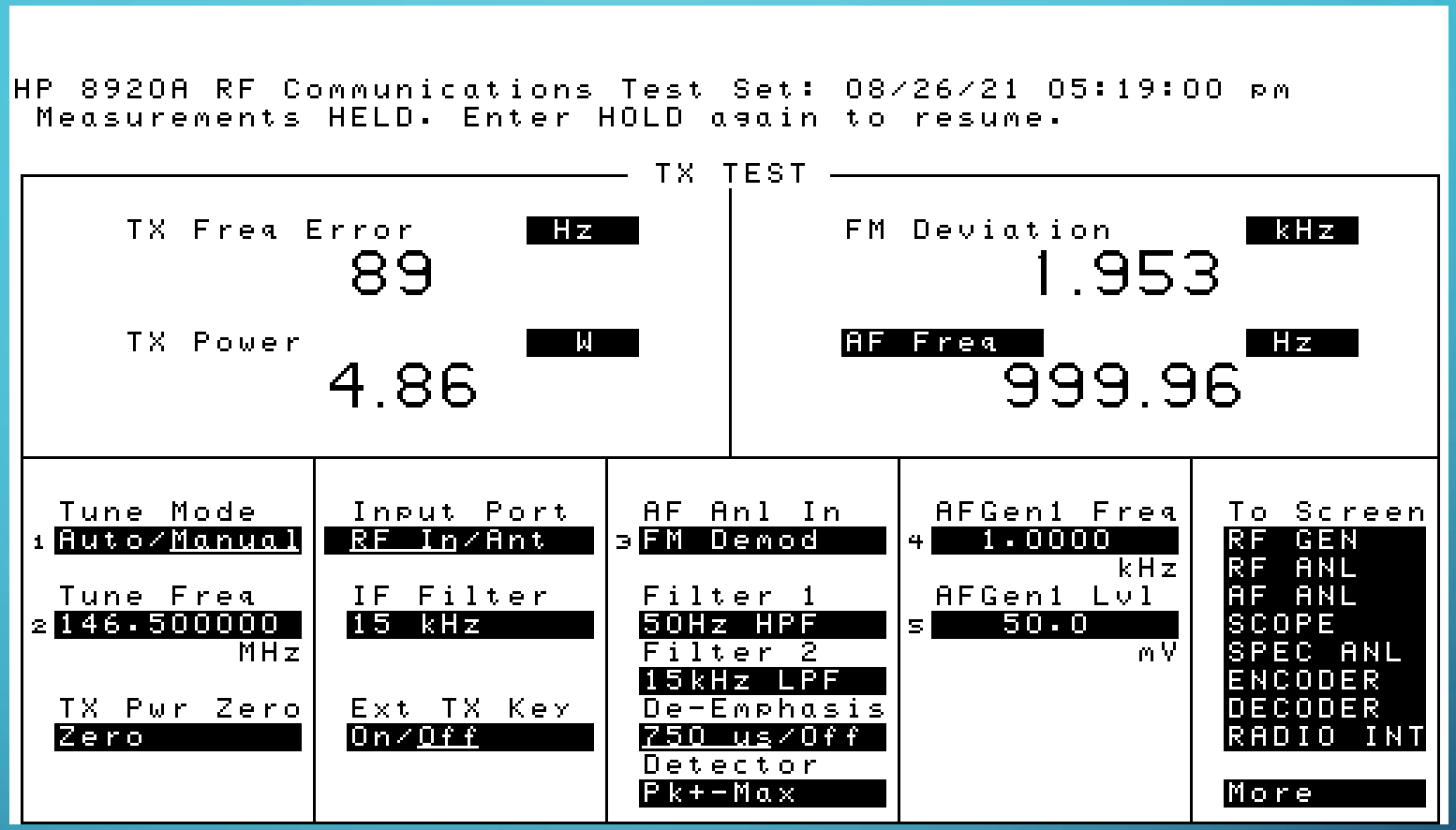


Baofeng UV-5R OTA TX Test, sending 159D DTMF tones (all 4 high and low tones).

Measurements: DTMF tone frequencies and on/off times. Test set AF Signaling Analysis also includes Tone Sequential, RPC1, POCSAG, EIA, CCITT, CCIR, ZVEI, DZVEI, GOLAY, EEA, AMPS/EAMPS/NAMPS, TACS/ETACS, JTACS/NTACS, NMT-450, NMT-900, LTR1, EDACS, MPT 1327, and TDMA dual-mode.

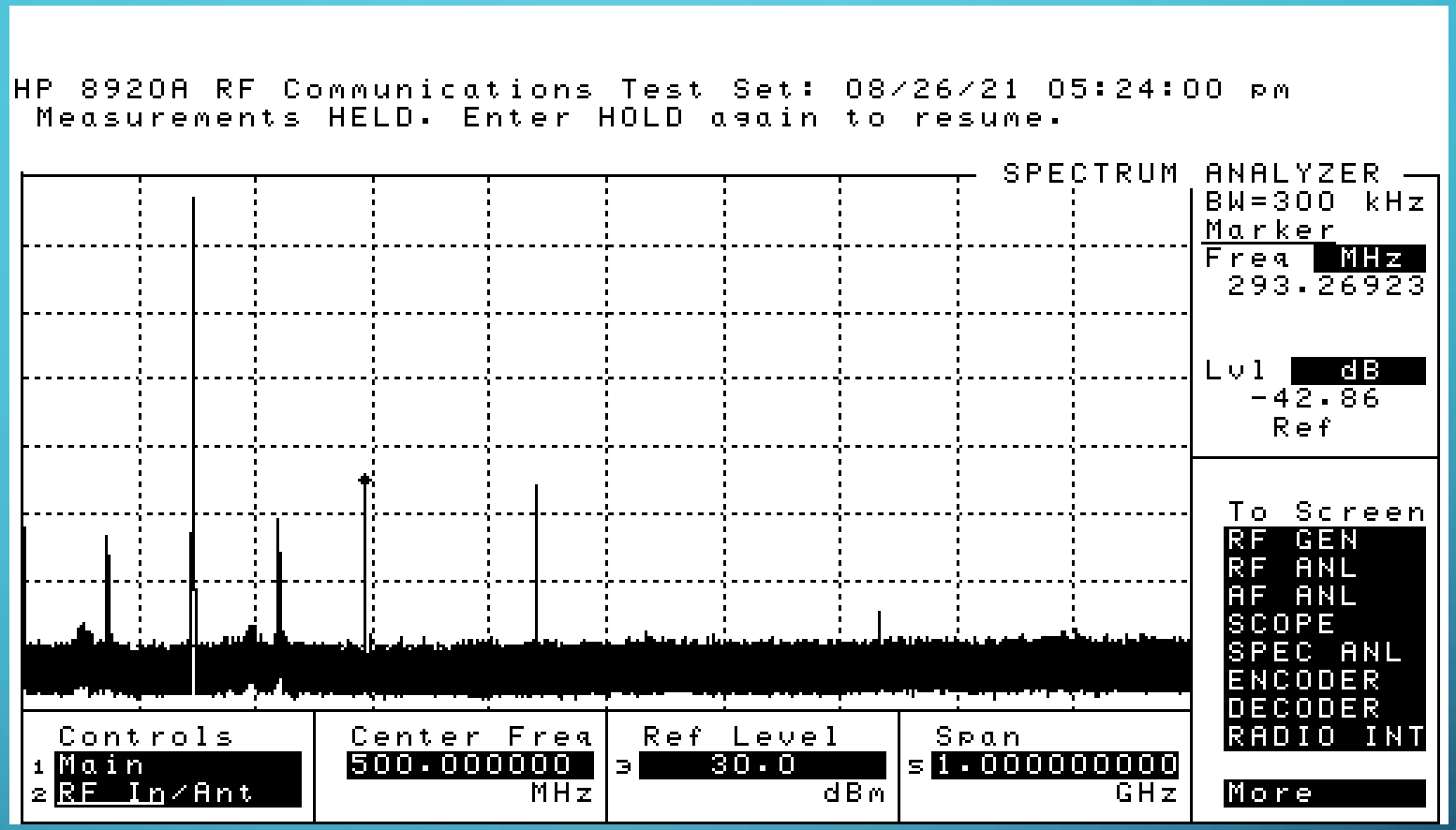


Baofeng UV-5R OTA RX Test. Hear a tone in the radio and the receiver works! Turn on RX CTCSS in the radio (uncommon) and check that a 123.0 Hz tone is required from the test set for the radio to de-squelch. For all slides to this point we haven't yet connected the radio to the test set!



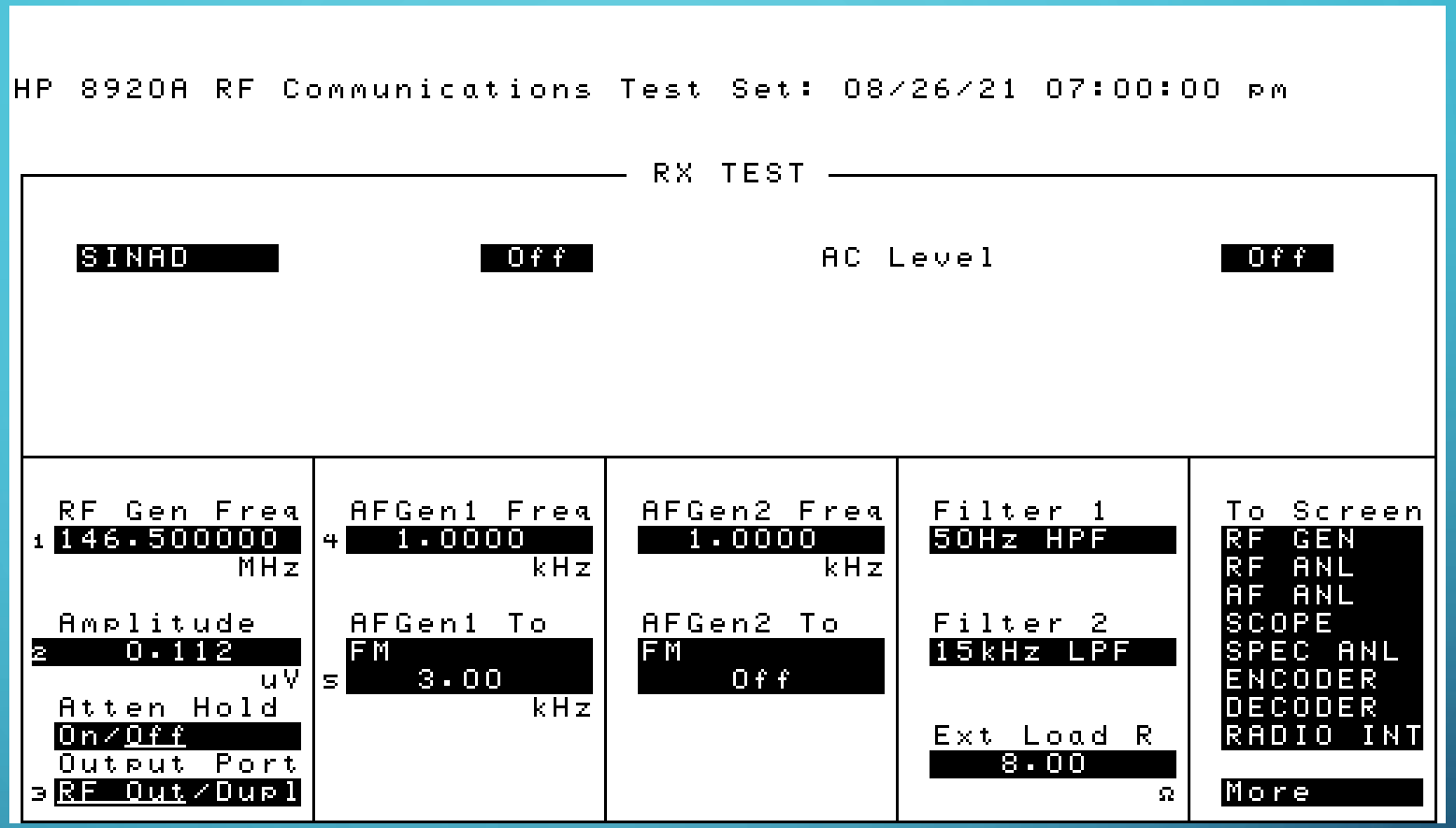
Baofeng UV-5R 1-cable TX Test, High Power, using the CALL key to transmit a 1 kHz tone.

Measurements: The same as the OTA scenario, but now TX Power can be measured.



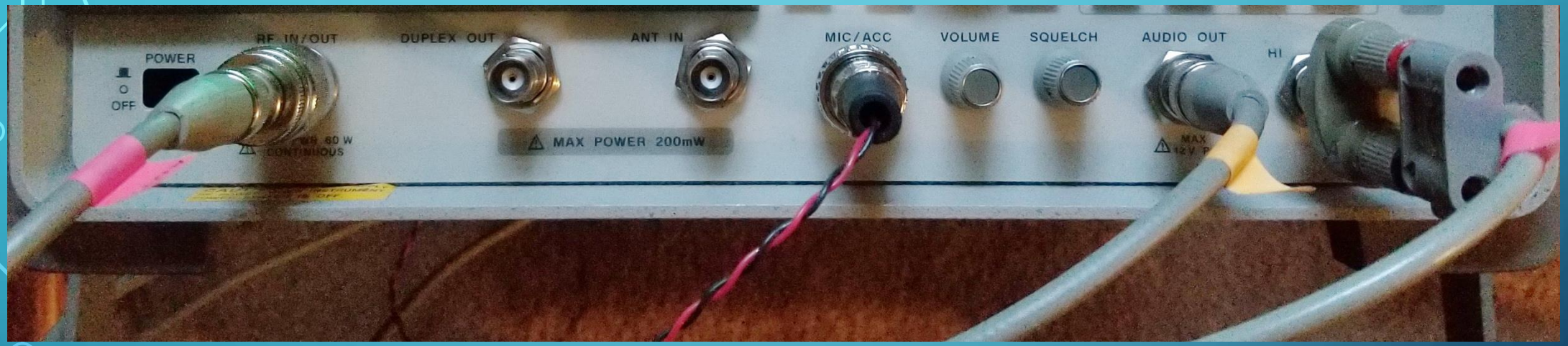
Baofeng UV-5R 1-cable TX Test.

The spectrum analyzer shows the 2nd harmonic 43 dB down, and the 3rd harmonic at about the same level. Tests need to verify that the radio does what it's supposed to do, and that it doesn't do what it isn't supposed to.



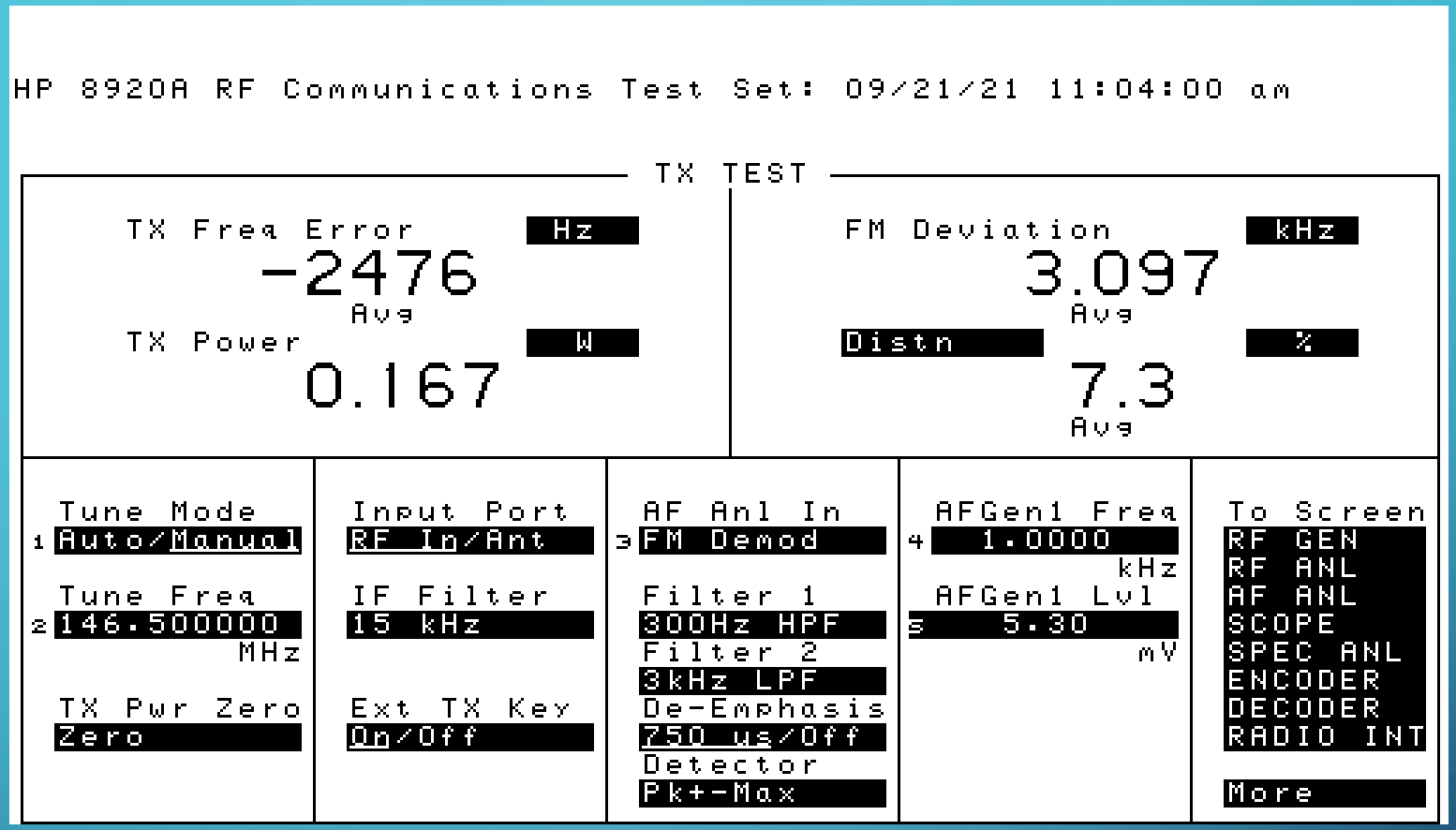
Baofeng UV-5R 1-cable RX Test. Measure Receiver Sensitivity (important!) by knowing what 12 dB SINAD sounds like in the radio speaker. RX Sensitivity ~= 0.112 µV (good).

3 cable connections to a Kenwood TR-2500 HT: Antenna, Mic, Speaker.



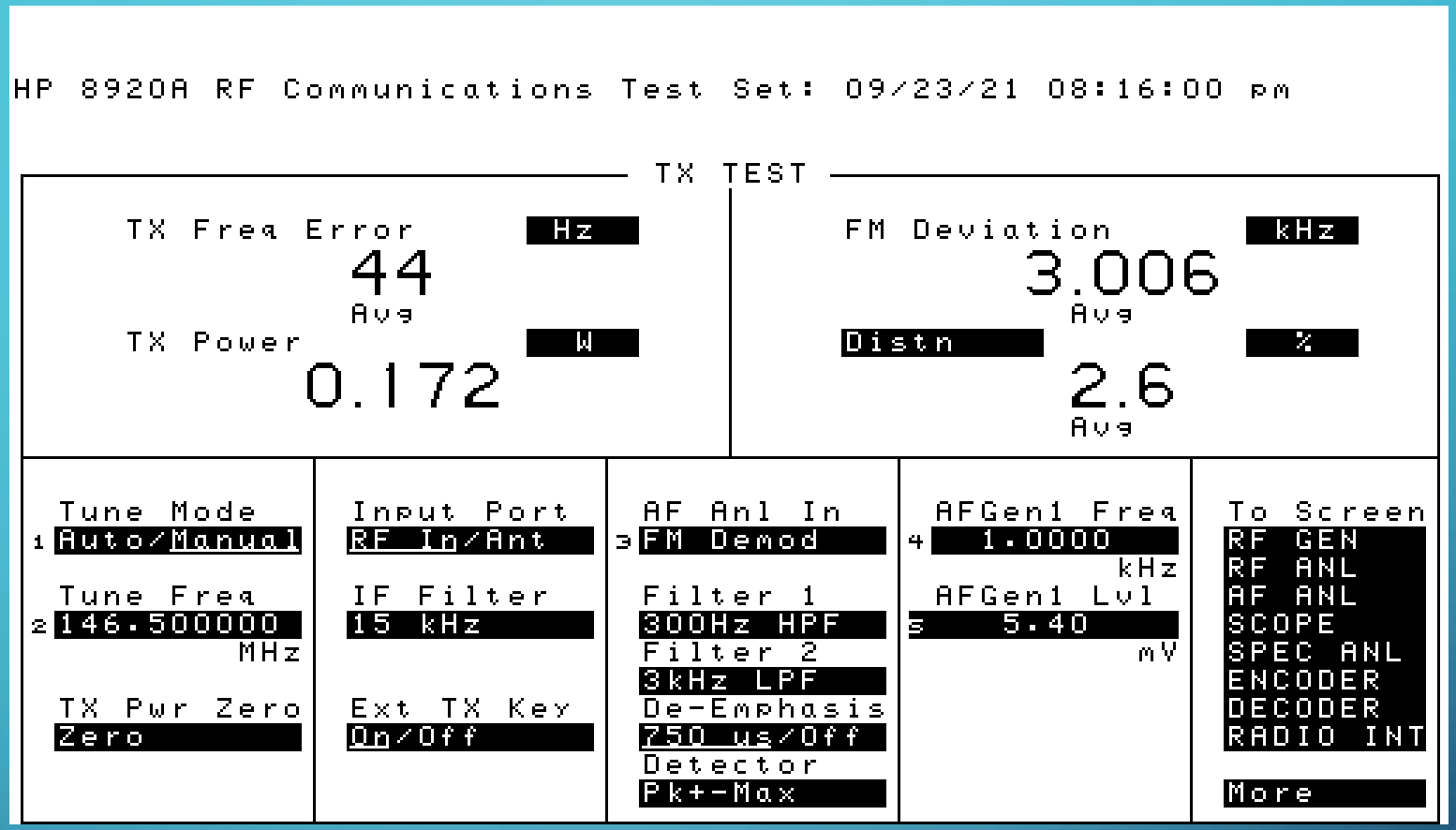
4 cable connections to the test set: RF In/Out (to the radio antenna), Mic/Acc (a radio-specific RX/TX switch), Audio Out (to the radio Mic input), Audio In (from the radio speaker output). The Mic/Acc connector will also accept a PTT Mic to operate the test set as a transceiver.

Me demonstrating the HP 8920A to Bill Hewlett in 1990, testing my Kenwood TR-2500 2m HT.

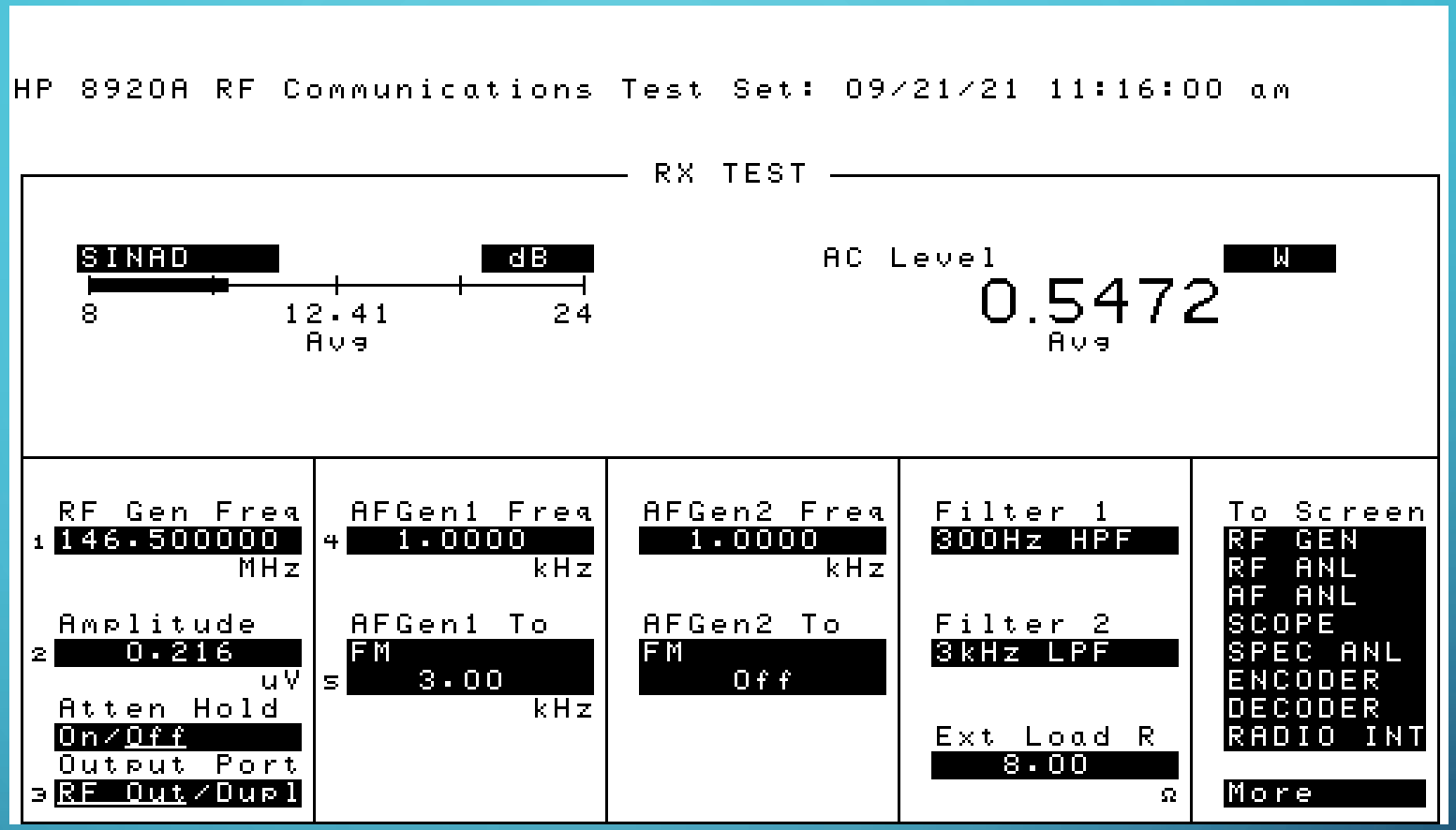


Kenwood TR-2500 3-cable TX test. Test set audio output goes to the radio mic input. RF output from the radio antenna goes to the test set RF input.

-2.5 kHz TX Frequency Error is bad! Microphone Sensitivity: It takes 5.3 mV mic drive for the radio to generate 3 kHz deviation. With a good 1 kHz sine wave into the radio mic, the radio adds 7.3% distortion (bad).

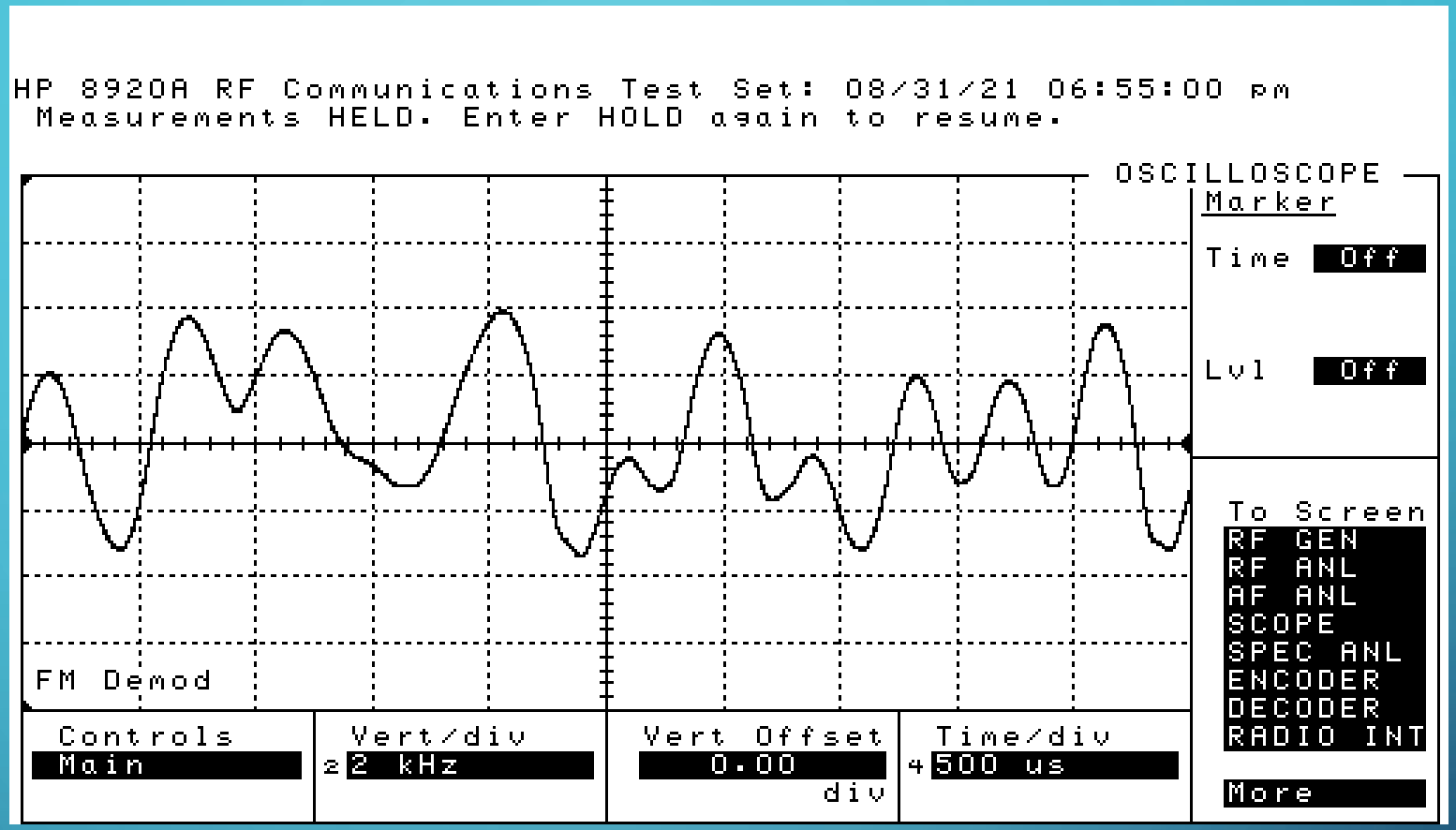


Kenwood TR-2500 3-cable TX test. Two days later I downloaded the rig Service Manual, took apart the HT, and adjusted an inductor to improve TX Frequency Error (-2476 Hz to 44 Hz). This also improved Distortion from 7.3% to 2.6%.

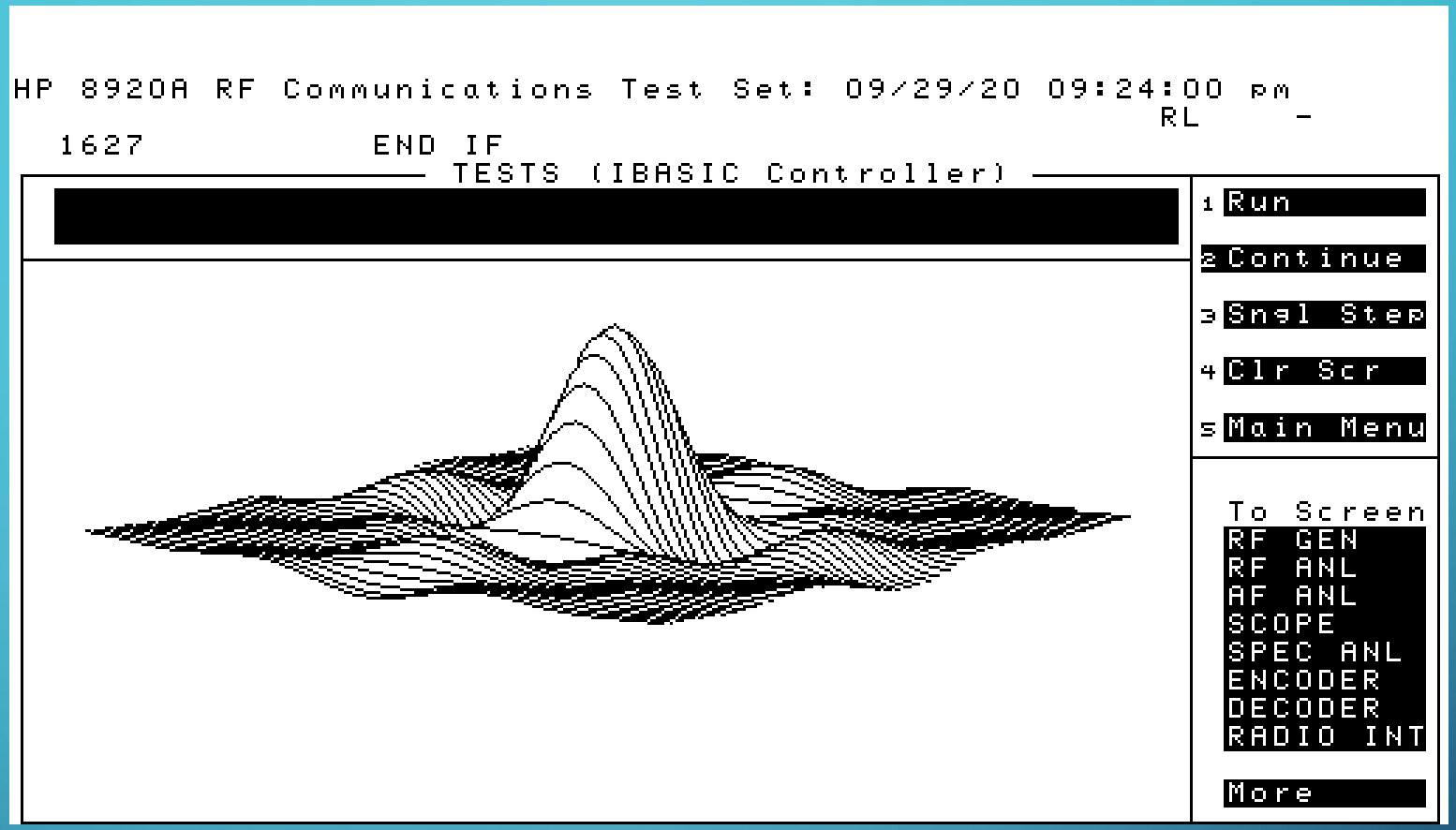


Kenwood TR-2500 3-cable RX test. The test set audio generator adds FM to the test set RF generator, that goes to the radio antenna. The radio speaker output goes to the test set Audio Input for analysis.

Accurate receiver sensitivity: 0.216 µV for 12 dB SINAD and 0.5W speaker output power (when loaded with an 8Ω resistor).



Yaesu System Fusion FT-70DR transmitting C4FM, demodulated by the test set and viewed on its 'scope. This shows the 4800 symbols/s baud rate (1/4800 = 208 us = 0.42 div) and 2 bits per baud (4 deviation states, the "4" in C4FM, 2 above the axis and 2 below), or 9600 bps.



Test set miscellany: SAVE/RECALL registers hold complete instrument states. An Instrument BASIC (IBASIC) controller lets users write their own radio test software, with other devices (printer, disk drive, 2nd signal generator…). Industry-standard IBASIC test software suites test a particular family of radios. Self-tests and diagnostics help troubleshooting. IBASIC allows 3D graphics fun (a 1980s hobby of mine).

Review of Key Concepts

- 3 hardware scenarios: OTA (0-cable), 1-cable, 3-cable.
- TX Test
  - RF Frequency Error
  - TX Power
  - Spectrum Analysis
  - FM Deviation
  - Audio Frequency
  - Audio Distortion
  - Oscilloscope
  - Mic Sensitivity
  - PL tones (frequency and FM deviation)
  - DTMF tones (frequency and FM deviation)
- RX Test
  - Receiver Sensitivity
  - SINAD
  - Audio AC Level

Questions or Comments?