ARRL Laboratory
Expanded Test-Result Report

Yaesu FT-897

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Model Information:
FT-897 Serial #: 2N120204
QST "Product Review" May, 2003

Manufacturer:
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Cypress, CA 90630
Telephone: 714-827-7600
http://www.vxstdusa.com/

Contents:

Introduction

This document summarizes the extensive battery of tests performed by the ARRL Laboratory for each unit that is featured in *QST* "Product Review." For all tests, there is a discussion of the test and test method used in ARRL Laboratory testing. For most tests, critical conditions are listed to enable other engineers to duplicate our methods. For some of the tests, a block diagram of the test setup is included. The ARRL Laboratory has a document, the *ARRL Laboratory Test Procedures Manual,* that explains our specific test methods in detail. This manual includes test descriptions similar to the ones in this report, block diagrams showing the specific equipment currently in use for each test, along with all equipment settings and specific step by step procedures used in the ARRL Laboratory. While this is not available as a regular ARRL publication, the ARRL Technical Department Secretary can supply a copy at a cost of $20.00 for ARRL Members, $25.00 for non-Members, postpaid.

Most of the tests used in ARRL product testing are derived from recognized standards and test methods. Other tests have been developed by the ARRL Lab. The ARRL Laboratory test equipment is calibrated annually, with traceability to National Institute of Standards and Technology (NIST). Most of the equipment is calibrated by a contracted calibration laboratory. Other equipment, especially the custom test fixtures, is calibrated by the ARRL Laboratory Engineers, using calibrated equipment and standard techniques.

The units being tested are operated as specified by the equipment manufacturer. Mobile and portable equipment is operated at the voltage specified by the manufacturer. Units are tested at room temperature and humidity as determined by the ARRL HVAC system. Units that are capable of mobile or portable operation are also tested for functionality over their rated temperature range in a commercial temperature chamber.

ARRL Product Review testing typically represents a sample of only one unit (although we sometimes obtain an extra unit or two for comparison purposes). This is not necessarily representative of all units of the same model number. It is not uncommon that some parameters will vary significantly from unit to unit. The ARRL Laboratory and Product Review editor work with manufacturers to resolve any deviation from specifications or other problems encountered in the review process. These problems are documented in the Product Review.

Units used in Product Review testing are purchased off the shelf from major distributors. We take all necessary steps to ensure that we do not use units that have been specially selected by the manufacturer. When the review is complete, the unit is offered for sale in an open mail bid, announced regularly in *QST*.

Transmitter Output Power

Test description: One of the first things an amateur wants to know about a transmitter or transceiver is its RF output power. The ARRL Lab measures the CW output power for every band on which a transmitter can operate. The equipment is also tested on one or more bands for any other mode of operation for which the transmitter is capable. For example, on an HF transmitter, the SSB tests are done on 75 meters for lower sideband, 20 meters for upper sideband, and AM tests are done on 75 meters, FM tests are done on 10 meters, etc. This test also compares the accuracy of the unit's internal output-power metering against the ARRL Laboratory's calibrated test equipment.

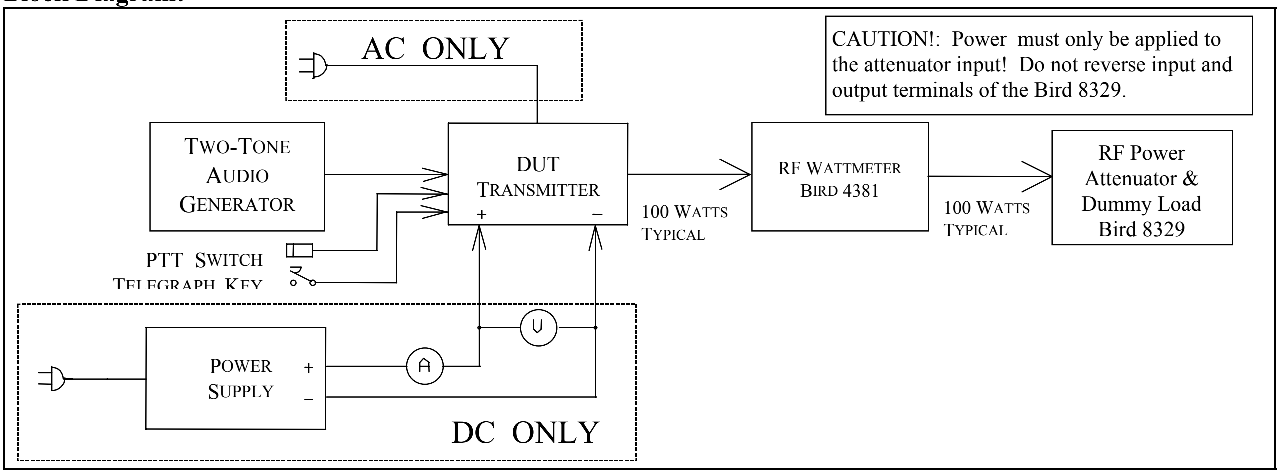
The purpose of the Transmitter Output-Power Test is to measure the dc current consumption at the manufacturer's specified dc-supply voltage, if applicable, and the RF output power of the unit under test across each band in each of its available modes. A two-tone audio input, at a level within the manufacturer's microphone-input specifications, is used for the SSB mode. No modulation is used in the AM and FM modes.

Many transmitters are de-rated from maximum output power on full-carrier AM. In most cases, a 100-watt CW/SSB transmitter may be rated at 25 watts carrier power on AM. The radio may actually deliver 100 watts PEP in AM but is not specified to deliver that power level for any period of time.

In almost all cases, the linearity of a transmitter decreases as output power increases. A transmitter rated at 100 watts PEP on single sideband may actually be able to deliver more power, but as the power is increased beyond the rated RF output power, adjacent channel splatter (IMD) usually increases dramatically.

Key Test Conditions:
Termination: 50 ohms resistive, or as specified by the manufacturer.

Block Diagram:



Transmitter Output Power Test Results

Frequency Band	Mode	Unit Minimum Power (W)	Measured Minimum Power (W)	Unit Maximum Power (W)	Measured Maximum Power (W)	Notes
1.8 MHz	CW	"5"	N/A	"100"	96.9	1, 2, 3
3.5 MHz	CW	–	N/A	–	97.2	
3.5 MHz	AM	–	N/A	–	20.3 carrier	
7.0 MHz	CW	–	N/A	–	99.5	
10.1 MHz	CW	–	N/A	–	100.3	
14 MHz	CW	–	2.7 W	–	101.4	
14 MHz	USB	–	N/A	–	100.0	
18 MHz	CW	–	N/A	–	101.8	
21 MHz	CW	–	N/A	–	102.7	
24 MHz	CW	–	N/A	–	103.5	
28 MHz	CW	–	N/A	–	104.4	
28 MHz	FM	–	N/A	–	104.2	
50 MHz	CW	–	N/A	–	97.7	
50 MHz	FM	–	N/A	–	98.8	
50 MHz	AM	–	N/A	–	20.5 carrier	
50 MHz	SSB	–	N/A	–	99.0	
144 MHz	CW	–	N/A	"50"	49.5	
144 MHz	FM	–	N/A	–	48.6	
144 MHz	AM	–	N/A	–	12.6 carrier	
144 MHz	SSB	–	N/A	–	50.0	
432 MHz	CW	–	N/A	"20"	18.8	
432 MHz	FM	–	N/A	–	18.7	
432 MHz	AM	–	N/A	–	4.8 carrier	
432 MHz	SSB	–	N/A	–	20.0	

Notes:
1. Unit's power meter consists of LCD segments; minimum power showed 0 segments lit.
2. The unit showed LED segments reaching a fixed display label reading 100 at full power.
3. Power level on DUT is set by a menu entry.

Current Consumption

(DC-powered units only)
Test Description: Current consumption can be an important to the success of mobile and portable operation. While it is most important for QRP rigs, the ARRL Lab tests the current consumption of all equipment that can be operated from a battery or 12-14 Vdc source. The equipment is tested in transmit at maximum output power. On receive, it is tested at maximum volume, with no input signal, using the receiver's broadband noise. Any display lights are turned on to maximum brightness, if applicable. This test is not performed on equipment that can be powered only from the ac mains.

Current Consumption:

Voltage	Transmit Current	Output Power	Receive Current	Lights?	Notes
13.8 V	15.1 A	100.0 W	1.0 A	ON	

Transmit Frequency Range

Test Description: Many transmitters can transmit outside the amateur bands, either intentionally, to accommodate MARS operation, for example, or unintentionally as the result of the design and internal software. The ARRL Lab tests the transmit frequency range inside the screen room. The purpose of the Transmit Frequency Range Test is to determine the range of frequencies, including those outside amateur bands, for which the transmitter may be used. The key test conditions are to test it at rated power, using nominal supply voltages. Frequencies are as indicated on the transmitter frequency indicator or display. Most modern synthesized transmitters are capable of operation outside the ham bands. However, spectral purity is not always legal outside the hams bands, so caution must be used. In addition, most other radio services require that transmitting equipment be type accepted for that service. Amateur equipment is not legal for use on other than amateur and MARS frequencies.

Test Results:

Frequency	Low-Frequency Limit	High-Frequency Limit	Notes
160 M	1.800 00 MHz	2.000 00 MHz	
80 M	3.500 00 MHz	4.000 00 MHz	
40 M	7.000 00 MHz	7.300 00 MHz	
30 M	10.100 00 MHz	10.150 00 MHz	
20 M	14.000 00 MHz	14.350 00 MHz	
17 M	18.068 00 MHz	18.168 00 MHz	
15 M	21.000 00 MHz	21.450 00 MHz	
12 M	24.890 00 MHz	25.990 00 MHz	
10 M	28.000 00 MHz	29.700 00 MHz	
6 M	50.000 00 MHz	54.000 00 MHz	
2 M	144.000 00 MHz	148.000 00 MHz	
70 CM	430.000 00 MHz	450.000 00 MHz	

CW Transmit Frequency Accuracy

Test Description: Most modern amateur equipment is surprisingly accurate in frequency. It is not uncommon to find equipment operating within a few Hz of the frequency indicated on the frequency display. This test measures the output frequency. Unit is operated into a 50-ohm resistive load at nominal temperature and supply voltage.

Test Results:

Unit Frequency	Supply Voltage	Temperature	Measured Frequency Full Output Power	Notes
14.000 00 MHz	13.8 V	25 C	14.000 013 MHz	
50.000 00 MHz	13.8 V	25 C	50.000 046 MHz	
144.000 00 MHz	13.8 V	25 C	144.000 127 MHz	
430.000 00 MHz	13.8 V	25 C	430.000 390 MHz	

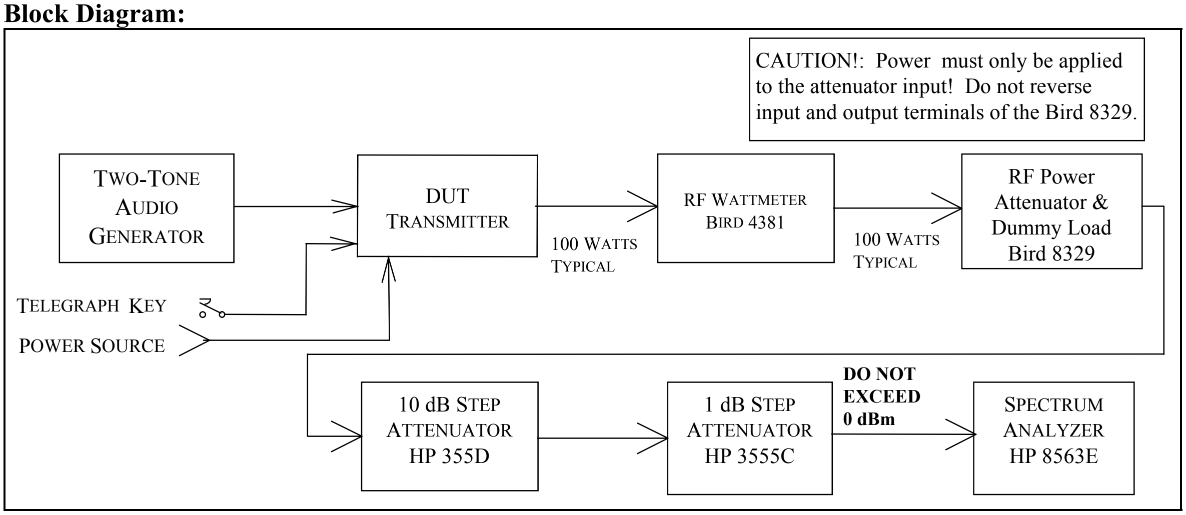
Spectral Purity

Test Description: All transmitters emit some signals outside their assigned frequency or frequency range. These signals are known as spurious emissions or "spurs." Part 97 of the FCC rules and regulations specify the amount of spurious emissions that can be emitted by a transmitter operating in the Amateur Radio Service. The ARRL Laboratory uses a spectrum analyzer to measure the spurious emission on each band on which a transmitter can operate. The transmitter is tested across the band and the worst-case spectral purity on each band is captured from the spectrum analyzer and stored on disk. Spectral purity is reported in dBc, meaning dB relative to the transmitted carrier.

The graphs and tables indicate the relative level of any spurious emissions from the transmitter. The lower that level, expressed in dB relative to the output carrier, the better the transmitter is. So a transmitter whose spurious emissions are –60 dBc is spectrally cleaner than one whose spurious emissions are –30 dBc. FCC Part 97 regulations governing spectral purity are contained in 97.307 of the FCC rules. Information about all amateur rules and regulations is found in the *ARRL FCC Rule Book.* Additional information about the decibel is found in the *ARRL Handbook.*

Key Test Conditions:
Output power is adjusted to full power on each amateur band.
The resolution bandwidth of the spectrum analyzer is 10 kHz on HF, 100 kHz on VHF, 1 MHz on UHF.

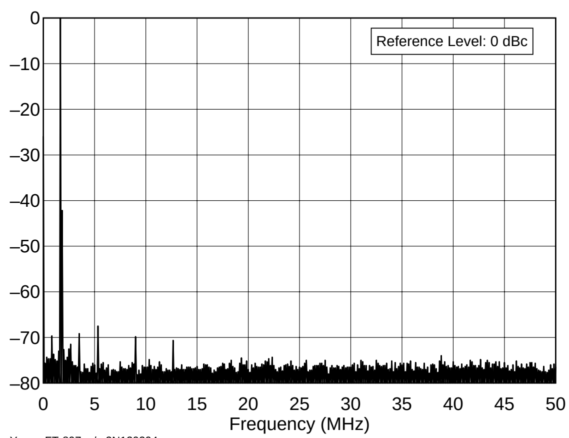
Block Diagram:



Test Results:

Frequency	Spurs (dBc)	Notes
1.8 MHz	–67 dBc	
3.5 MHz	–63	
7 MHz	–65	
10.1 MHz	–54	
14 MHz	–53	
18 MHz	–63	
21 MHz	–59	
24 MHz	–60	
28 MHz	–54	
50 MHz	–63	
144 MHz	–64	
430 MHz	–61	

Spectral-Purity Graphs:



Yaesu FT-897, s/n 2N120204
1.8 MHz Band, Spectral Purity, 100 W
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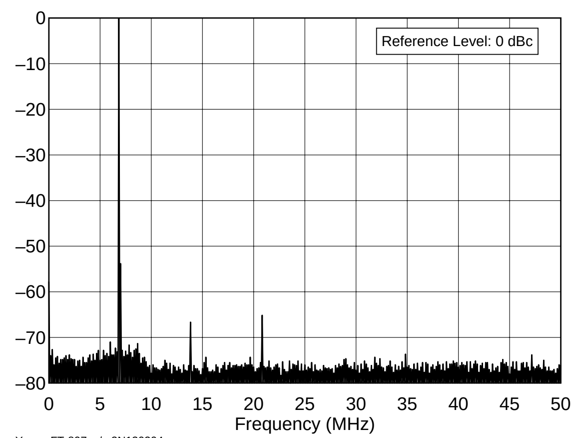

Yaesu FT-897, s/n 2N120204
7.0 MHz Band, Spectral Purity, 100 W
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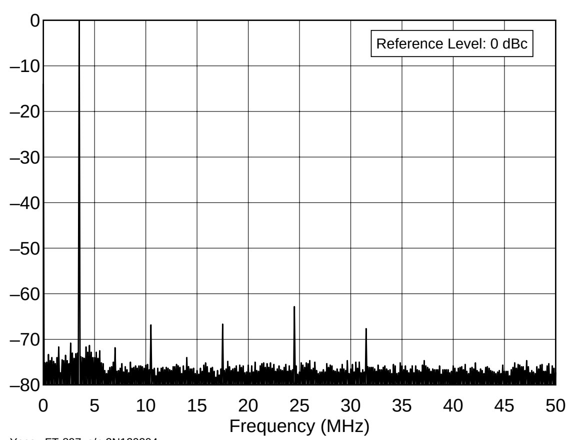

Yaesu FT-897, s/n 2N120204
3.5 MHz Band, Spectral Purity, 100 W
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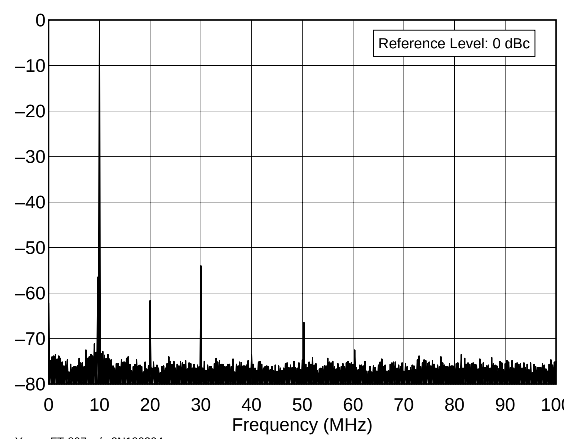

Yaesu FT-897, s/n 2N120204
10.1 MHz Band, Spectral Purity, 100 W
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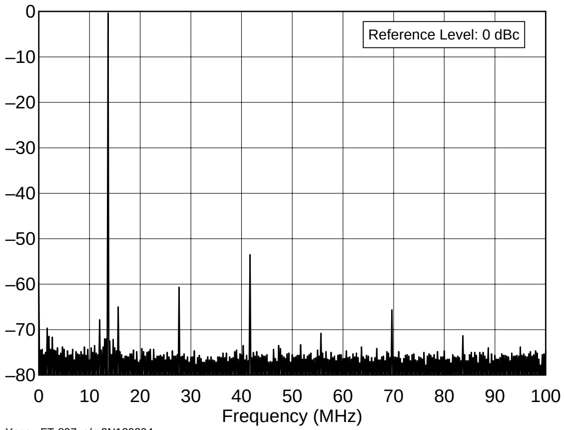

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14.0 MHz Band, Spectral Purity, 100 W
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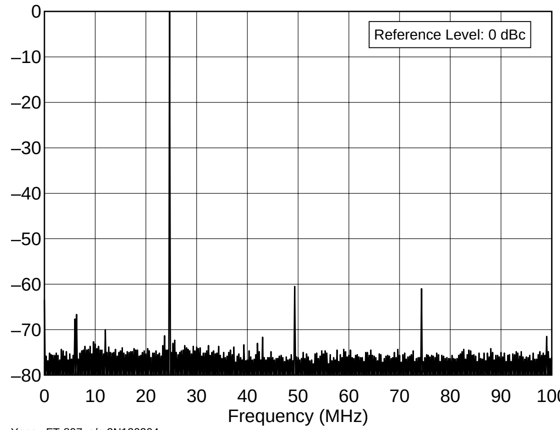

Yaesu FT-897, s/n 2N120204
24.9 MHz Band, Spectral Purity, 100 W
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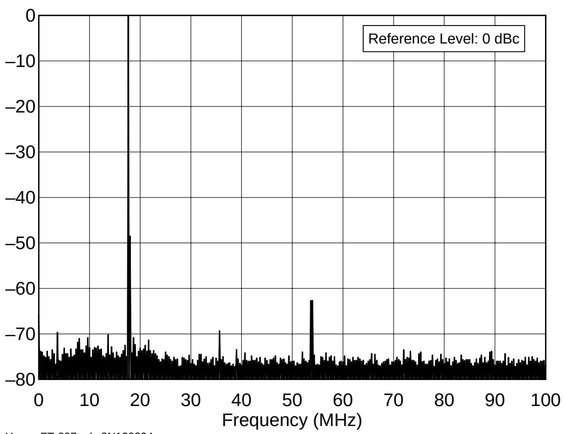

Yaesu FT-897, s/n 2N120204
18.1 MHz Band, Spectral Purity, 100 W
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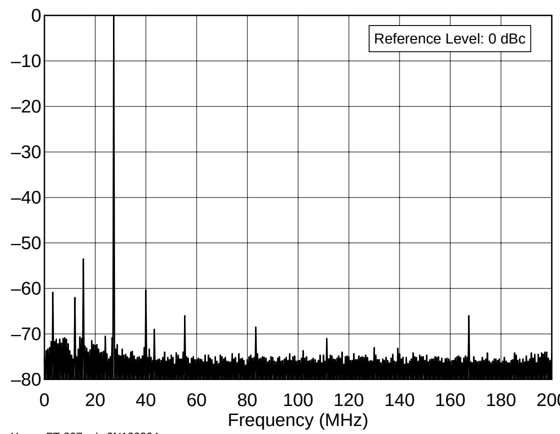

Yaesu FT-897, s/n 2N120204
28.0 MHz Band, Spectral Purity, 100 W
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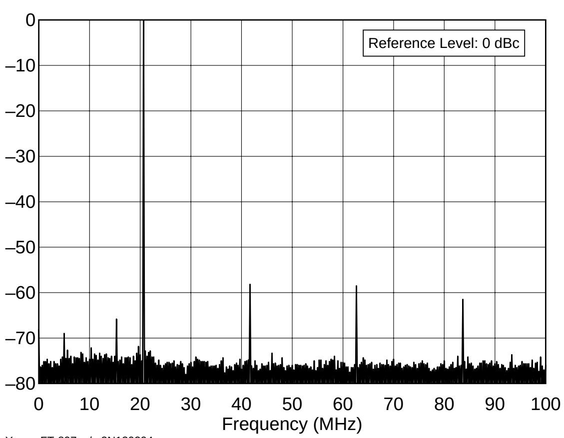

Yaesu FT-897, s/n 2N120204
21.0 MHz Band, Spectral Purity, 100 W
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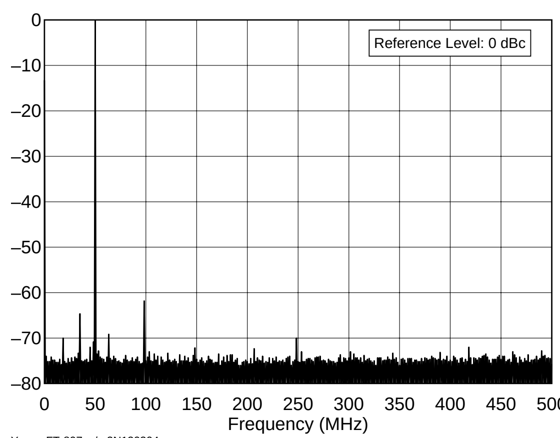

Yaesu FT-897, s/n 2N120204
50.0 MHz Band, Spectral Purity, 100 W
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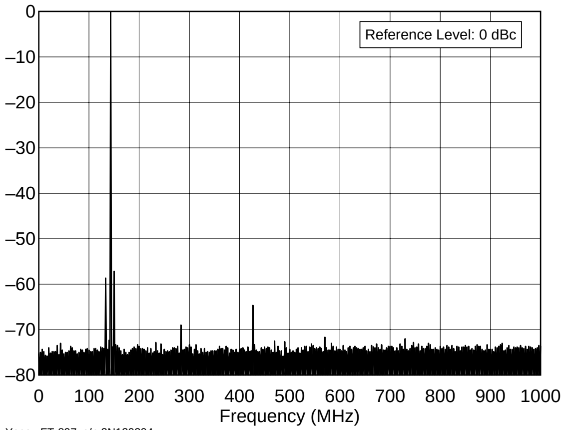

Yaesu FT-897, s/n 2N120204
144.0 MHz Band, Spectral Purity, 50 W
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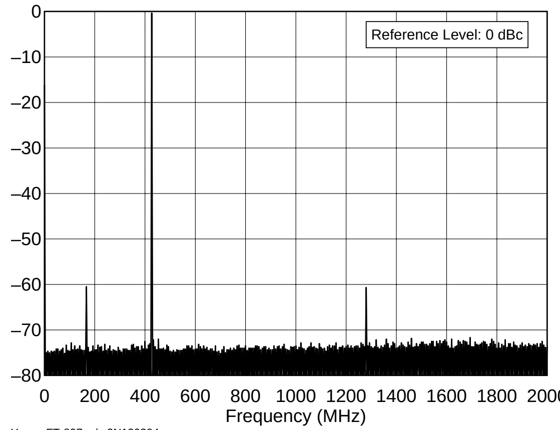


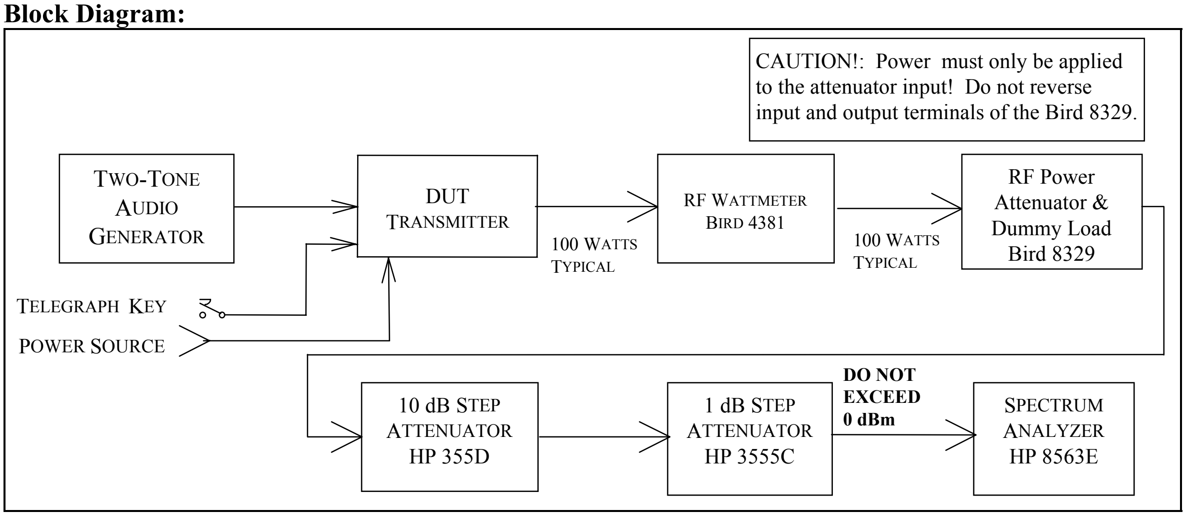
Yaesu FT-897, s/n 2N120204
420.0 MHz Band, Spectral Purity, 20 W
I:\PRODREV\TESTS\FT897REV\FT897S70.TXT

Transmit Two-Tone IMD

Test Description: Investigating the sidebands from a modulated transmitter requires a narrow-band spectrum analysis. The display shows the two test tones plus some of the IMD products produced by the SSB transmitter. A test signal with frequencies of 700 and 1900 Hz is used to modulate the transmitter. The intermodulation products appear on the spectral plot above and below the two tones. The lower the intermodulation products, the better the transmitter. In general, it is the products that are farthest removed from the two tones (typically > 3 kHz away) that cause the most problems. These can cause splatter up and down the band from strong signals.

Key Test Conditions:
Transmitter operated at rated output power (PEP). Audio tone level and mic gain adjusted for best performance. Level to spectrum analyzer, –10 dBm maximum. Resolution bandwidth, 10 Hz

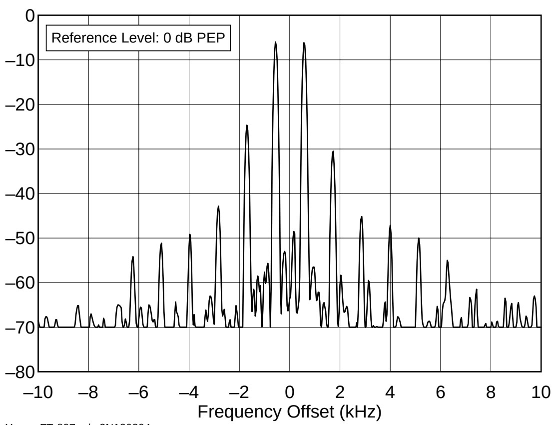
Block Diagram:



Test Result Summary:

Frequency	Worst-case 3rd-order dB PEP	Worst-case 5th-order dB PEP	Notes
1.85 MHz	–25	–43	
3.9 MHz	–29	–44	
7.25 MHz	–29	–43	
10.12 MHz	–32	–43	
14.25 MHz	–30	–39	
18.12 MHz	–30	–38	
21.25 MHz	–28	–41	
24.95 MHz	–31	–42	
28.35 MHz	–23	–37	
50.2 MHz	–27	–39	
144.2 MHz	–24	–39	
432.2 MHz	–32	–40	

Transmit IMD Graphs



Yaesu FT-897, s/n 2N120204
1.850 MHz, Transmit IMD, 100 W
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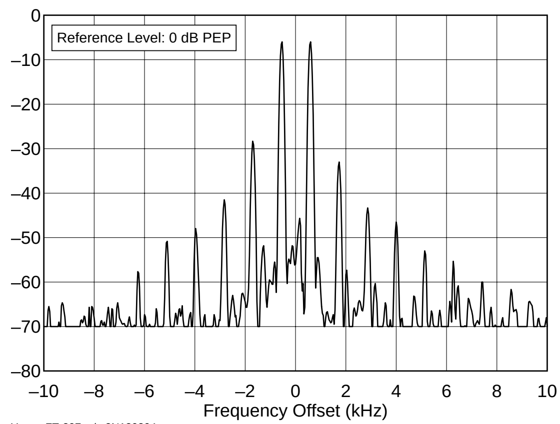

Yaesu FT-897, s/n 2N120204
7.250 MHz, Transmit IMD, 100 W
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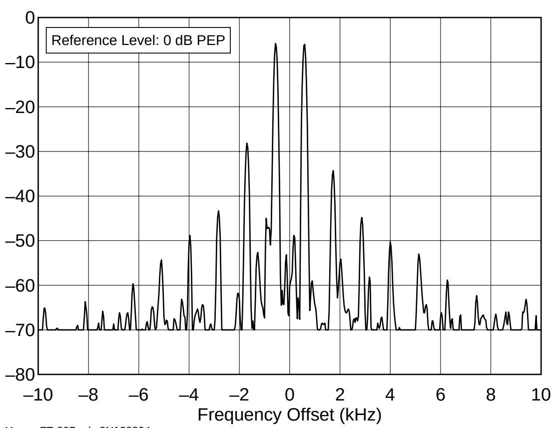

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3.900 MHz, Transmit IMD, 100 W
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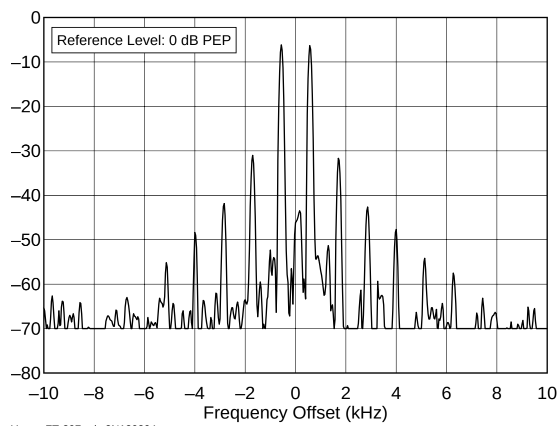

Yaesu FT-897, s/n 2N120204
10.120 MHz, Transmit IMD, 100 W
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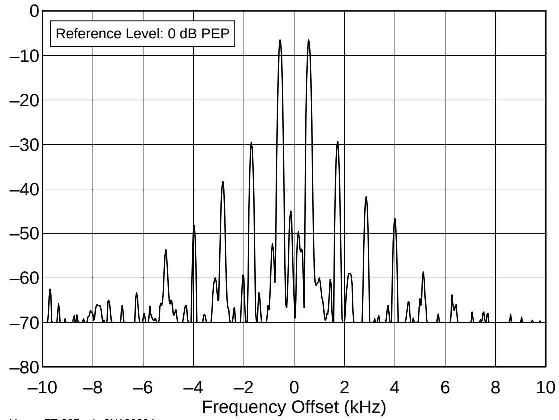

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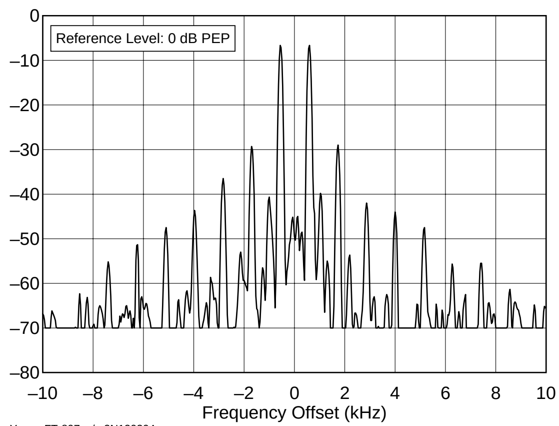

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18.120 MHz, Transmit IMD, 100 W
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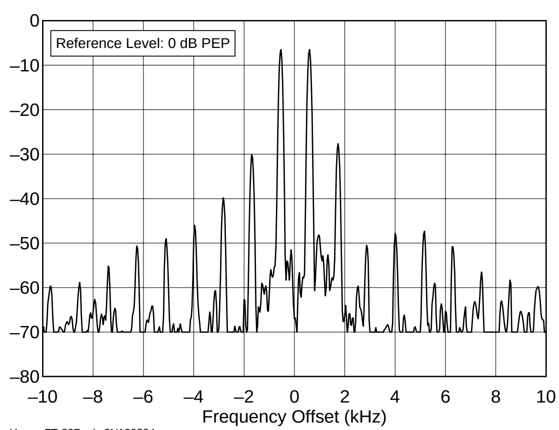

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21.250 MHz, Transmit IMD, 100 W
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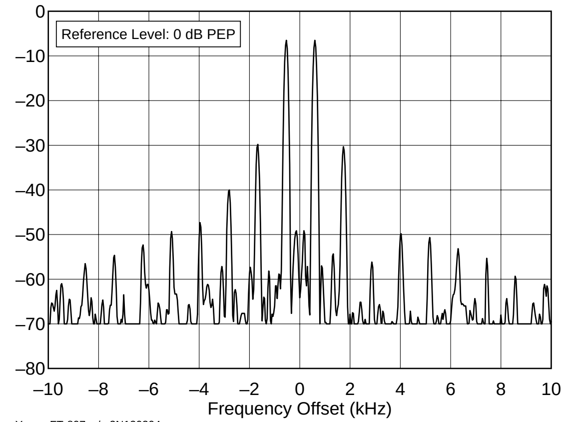

Yaesu FT-897, s/n 2N120204
24.950 MHz, Transmit IMD, 100 W
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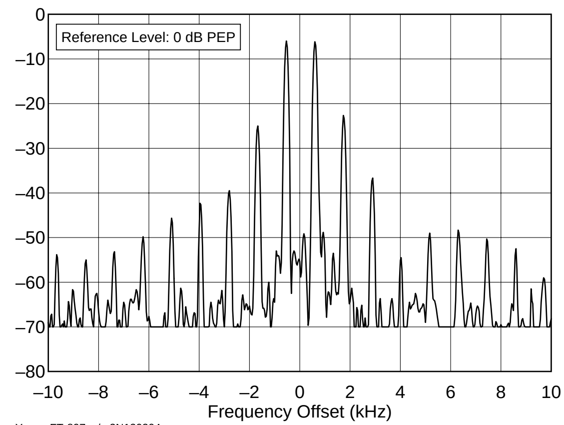

Yaesu FT-897, s/n 2N120204
28.350 MHz, Transmit IMD, 100 W
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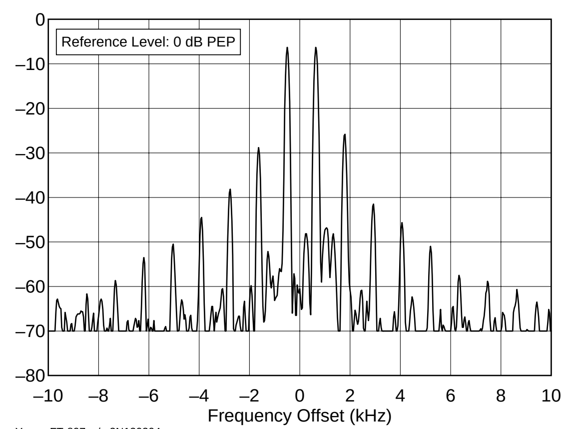

Yaesu FT-897, s/n 2N120204
50.200 MHz, Transmit IMD, 100 W
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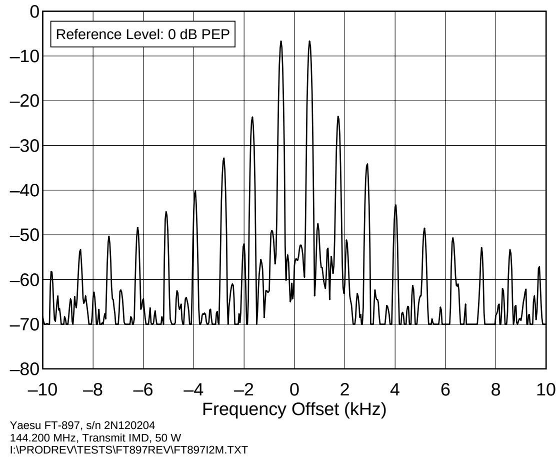
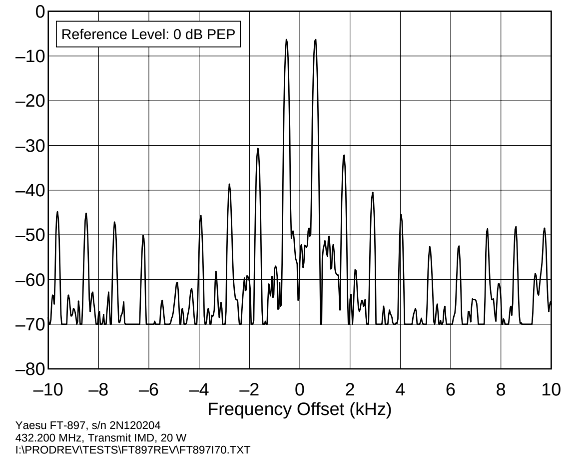




SSB Carrier and Unwanted Sideband Suppression

Test Description: The purpose of the SSB Carrier and opposite-sideband Suppression test is to determine the level of carrier and unwanted sideband suppression relative to Peak Envelope Power (PEP). The transmitter output is observed on the spectrum analyzer and the unwanted components are compared to the desired sideband. The level to the spectrum analyzer is -10 dBm nominal. The measurement bandwidth is 100 Hz. The greater the amount of suppression, the better the transmitter. For example, opposite sideband suppression of 60 dB is better than suppression of 50 dB.

Test Results:

Frequency	Carrier Suppression USB/LSB (PEP)	Opposite Sideband Suppression USB/LSB (PEP)	Notes
14.2 MHz	< –60/–60 dB	< –53/–56 dB	
50.2 MHz	< –60/–62 dB	< –58/–55 dB	
144.2 MHz	< –45/–60 dB	< –60/–57 dB	
432.2 MHz	< –60/–60 dB	< –56/–54 dB	

CW Keying Waveform

Test Description: The purpose of this test is to determine the shape of the RF output envelope of the transmitter in the CW mode. A picture of the oscilloscope screen is taken of the results. Some transmitters exhibit a first dit that is shorter than subsequent dits. Other transmitters can show significant shortening of all dits when used in the QSK mode. The latter will cause keying to sound choppy.

If the risetime or falltime become too short, the transmitter will generate key clicks. Most click-free transmitters have a rise and fall time between 1 ms and 5 ms. However, key clicks are most often generated by sudden transitions in the keying envelope (e.g., "square corners"), so a short rise or fall time is not a guarantee of clicks.

This test also measures the sidebands generated by the transceiver on high speed CW. This is an indication of the degree to which a transmitter may exhibit 'key clicks'. The transmitter is keyed at 60-wpm by an external circuit. The sidebands are measured on the spectrum analyzer using a resolution bandwidth of 10 Hz, and a long sweep time (30 seconds) so the worst-case spectrum is captured. Note that in a receiver with a bandwidth of 500 Hz, the sidebands would be heard at a level 17 dB higher than the graph indicates (10*LOG(500/10)=17).

Key Test Conditions:
The transmitter is operated at room temperature at rated output power into a 50-ohm resistive load. The power supply voltage is nominal. Attenuators are adjusted to obtain 3 volts RMS to the oscilloscope.

Test Result Summary:

Figure 1 This shows the first and second dits in Full QSK mode.

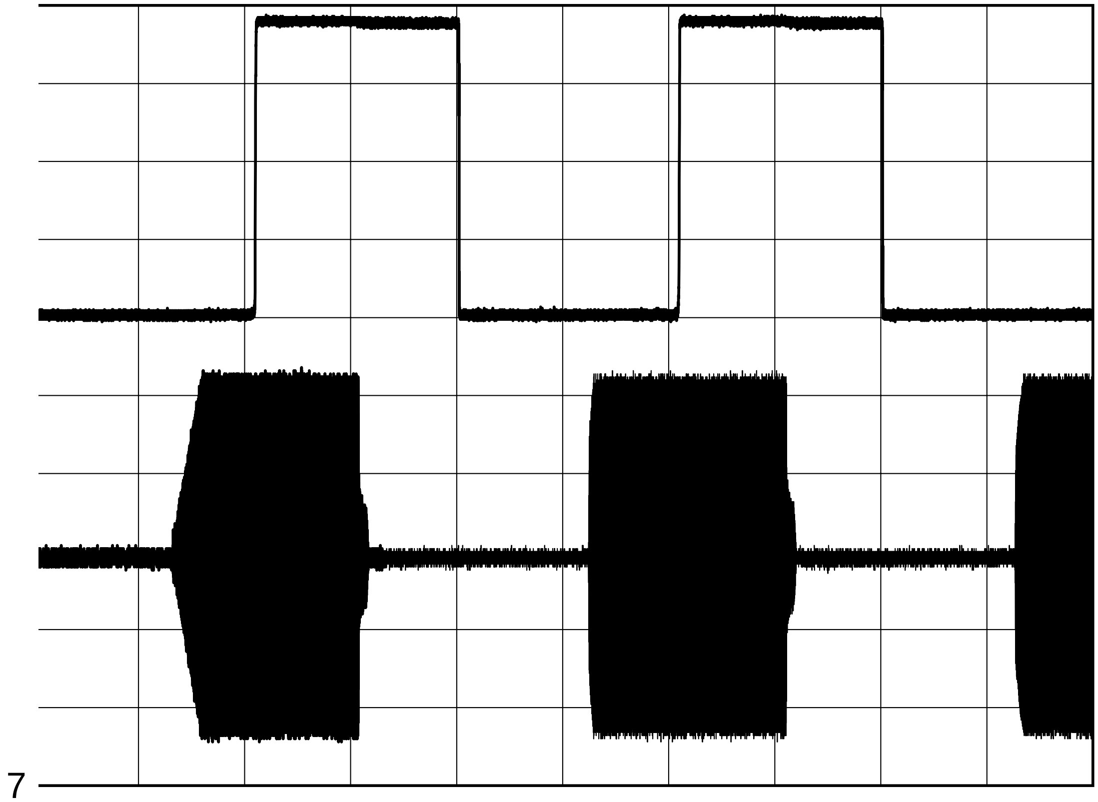
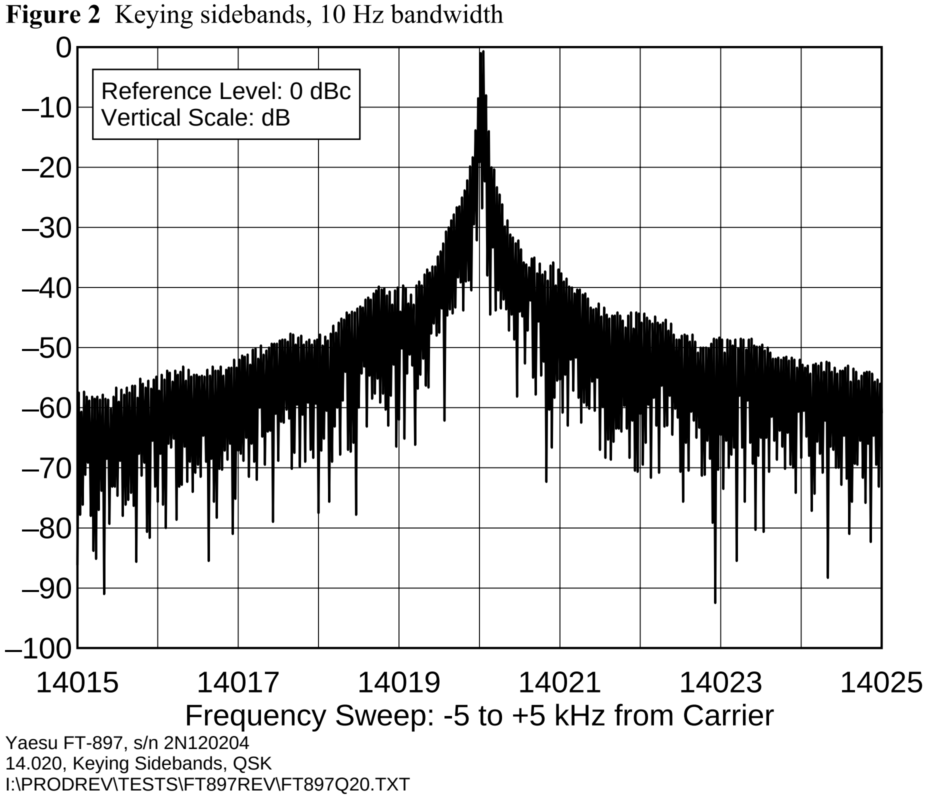


Figure 2 Keying sidebands, 10 Hz bandwidth



Transmit Keyer Speed

Test Description: This test measures the speed of the internal keyer on transmitters so equipped. The keyer is tests at minimum, midrange and maximum speeds and the time from dit to dit is measured using an oscilloscope and used to calculate the speed using the "Paris" method of code speed calculation. (In the Paris method, the word "Paris" is used as the standard word to calculate words per minute.)

Test Results:

Minimum	Maximum	Default	Notes
4 wpm	57 wpm	12 wpm	

Keying Sidetone

Test Description: This test measures the audio frequency of the keyer sidetone.

Test Result:

Default pitch	Minimum	Maximum	Notes
703 Hz	400 Hz	800 Hz	

Transmit/Receive Turnaround

Test Description: The purpose of this test is to measure the delay required to switch from transmit to receive on a transceiver.

Test Results:

Frequency	Conditions	T/R Delay AGC Fast	T/R Delay AGC Slow	Notes
14.2 MHz	50% audio	6 ms	6 ms	1

Notes:
1. T/R delay less than or equal to 35 ms is suitable for use on AMTOR.

Transmit Delay

Test Description: The purpose of this test is to measure the time between PTT closure and 50% RF output. It is measured on SSB, modulated with a single tone and on FM, unmodulated.

Test Results:

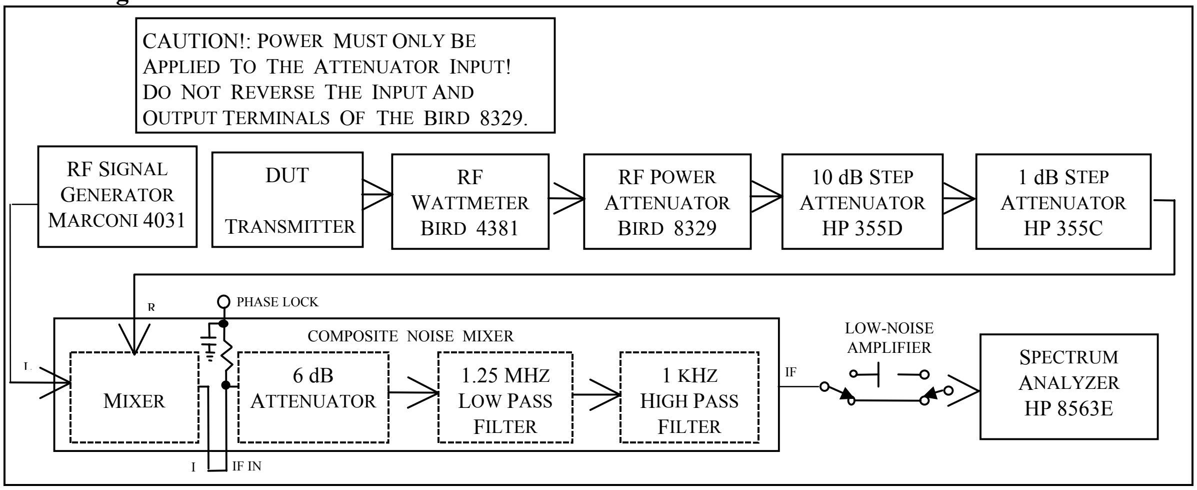
Frequency	Mode	On delay	Notes
14.2 MHz	SSB	21 ms	
29 MHz	FM	15 ms	
52 MHz	FM	15 ms	
146 MHz	FM	15 ms	
440 MHz	FM	14.5 ms	

Transmit Composite Noise

Test Description: The purpose of this test is to observe and measure the phase and amplitude noise, as well as any spurious signals generated by the transmitter under test. Since phase noise is the primary noise component in any well-designed transmitter, it can be assumed, therefore, that almost all the noise observed during this test is phase noise. This measurement is accomplished by converting the output of the transmitter down to a frequency about 10 or 20 Hz above baseband. A mixer and a signal generator used as a local oscillator are used to perform this conversion. Filters remove the low frequency components as well as the unwanted heterodyne components. The remaining noise and spurious signals are then observed on the spectrum analyzer. The lower the noise as seen on the plot, the better the transmitter.

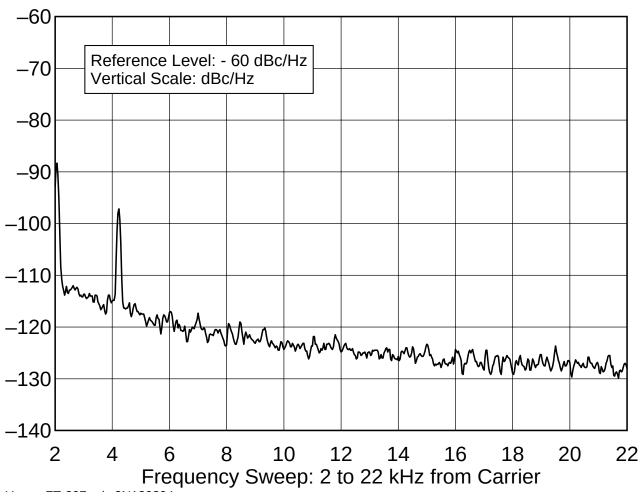
Key Test Conditions: Frequencies from 2 to 22 kHz from the carrier are measured. Ten sweeps are averaged on the spectrum analyzer to reduce noise.

Block Diagram:

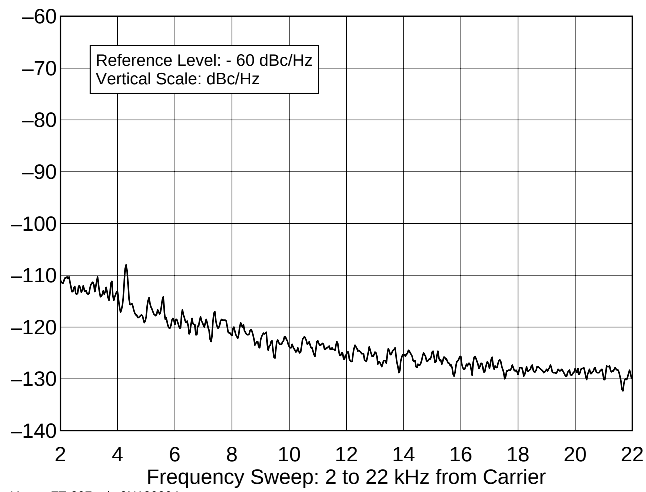


Test Result Summary:

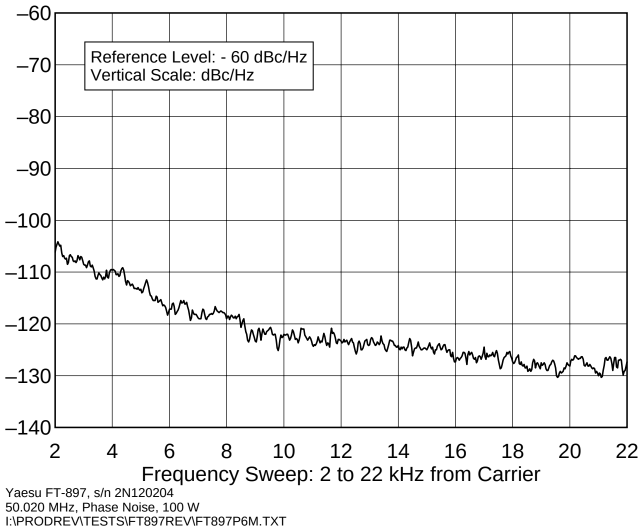
Frequency	2 kHz offset (dBc/Hz)	20 kHz offset (dBc/Hz)	Notes
3.520 MHz	–112	–129	
14.02 MHz	–112	–128	
50.2 MHz	–107	–128	
144.2 MHz	–100	–126	
432.2 MHz	–97	–123	

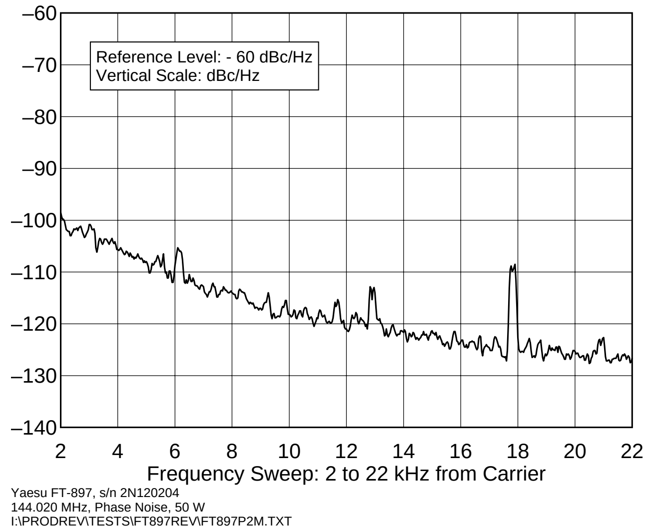


Yaesu FT-897, s/n 2N120204
3.520 MHz, Phase Noise, 100 W
I:\PRODREV\TESTS\FT897REV\FT897P80.TXT



Yaesu FT-897, s/n 2N120204
14.020 MHz, Phase Noise, 100 W
I:\PRODREV\TESTS\FT897REV\FT897P20.TXT





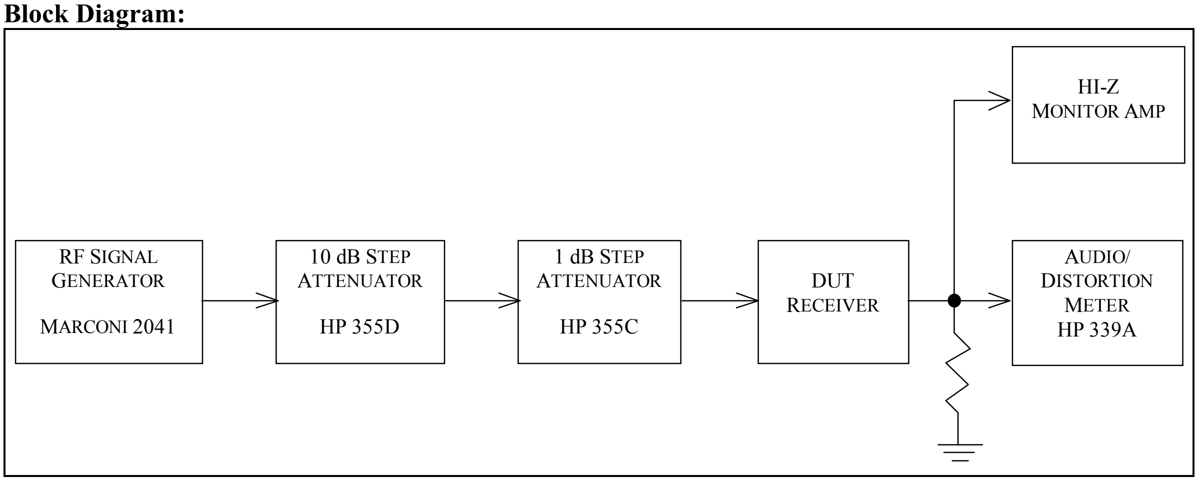
Receiver Noise Floor

(Minimum Discernible Signal)

Test Description: The noise floor of a receiver is the level of input signal that gives a desired audio output level that is equal to the noise output level. This is sometimes called "minimum discernible signal " (MDS), although a skilled operator can detect a signal up to 10 dB or so below the noise floor. Most modern receivers have a noise floor within a few dB of "perfect." A perfect receiver would hear only the noise of a resistor at room temperature. However, especially on HF, the system noise is rarely determined by the receiver circuitry. In most cases, external noise is many dB higher than the receiver's internal noise. In this case, it is the external factors that determine the system noise performance. Making the receiver more sensitive will only allow it to hear more noise. It will also be more prone to overload. In many cases, especially in the lower HF bands, receiver performance can be improved by sacrificing unneeded sensitivity by placing an attenuator in front of the receiver. The more negative the sensitivity number expressed in dBm, or the smaller the number expressed in voltage, the better the receiver.

Key Test Conditions:
Receiver is tested using 500 Hz bandwidth, or closest available bandwidth to 500 Hz.

Block Diagram:



Noise Floor:

Frequency	Preamp OFF (dBm)	Preamp ON (dBm)	Notes
1.02 MHz	–128.6	–134.0	
1.82 MHz	–130.0	–136.4	
3.52 MHz	–131.7	–136.5	
7.02 MHz	–131.3	–135.8	
10.12 MHz	–130.8	–135.3	
14.02 MHz	–132.6	–137.2	
18.1 MHz	–132.0	–136.5	
21.02 MHz	–131.3	–135.2	
24.91 MHz	–131.1	–136.0	
28.02 MHz	–131.5	–136.9	
50.02 MHz	–137.6	–141.6	
144.02 MHz	N/A	–140.3	
430.02 MHz	N/A	–139.4	

Receive Frequency Range

Test Description: This test measures the tuning range of the receiver. The figures given represent the range over which the receiver can be tuned. Most receivers exhibit some degradation of sensitivity near the limits of their tuning range. In cases where this degradation renders the receiver unusable, we report both the actual and useful tuning range.

Test Results:

Minimum Frequency	Minimum Frequency Noise Floor	Maximum Frequency	Maximum Frequency Noise Floor	Notes
100 kHz	–76.4 dBm	56.0 MHz	–138.2 dBm	
76 MHz	N/A	108 MHz	N/A	WFM only
118 MHz	–141.1 dBm	164 MHz	–139.6 dBm	
420 MHz	–131.4 dBm	470 MHz	–125.5 dBm	

AM Sensitivity

Test Description: The purpose of the AM receive Sensitivity Test is to determine the level of an AM signal, 30% modulated at 1 kHz, that results in a tone 10 dB above the noise level (MDS) of the receiver. Two frequencies, 1.020 MHz and 3.800 MHz are used for this test. The more negative the number, expressed in dBm, or the smaller the number expressed in voltage, the better the sensitivity.

Test Results:

Frequency	Preamplifier	µV	Notes
1.02 MHz	OFF	1.78	
1.02 MHz	ON	0.86	
3.9 MHz	OFF	1.26	
3.9 MHz	ON	0.691	
53 MHz	OFF	0.831	
53 MHz	ON	0.431	
120 MHz (aircraft)	ON	0.402	
146 MHz	ON	0.457	
440 MHz	ON	0.473	

FM SINAD

Test Description: The purpose of this test is to determine the 12 dB SINAD value at appropriate test frequencies. SINAD is an acronym for "SIgnal plus Noise And Distortion" and is calculated via the formula:

$$SINAD = \frac{Signal + Noise + Distortion}{Noise + Distortion}$$

Since distortion can be considered as merely another form of noise, this can be reduced to:

$$SINAD = \frac{Signal + Noise}{Noise}$$

When the level of signal is much greater than the noise, the value of the SIGNAL + NOISE can be approximated by the level of the SIGNAL alone. The SINAD equation then becomes just Signal/Noise. A 12 dB SINAD level is thereby equal to 25 percent distortion: SINAD = 20 log (100%/25%) = 20 log 4 = 12 dB.

The smaller the figure, expressed as a voltage, the better the sensitivity.

Test Results:

Frequency	Preamplifier	μV	Notes
29.0 MHz	OFF	0.433	
29.0 MHz	ON	0.255	
52.0 MHz	OFF	0.279	
52.0 MHz	ON	0.166	
100.0 MHz	ON	3.81	WFM
146.0 MHz	ON	0.195	
164.2 MHz	ON	0.202	
440.0 MHz	ON	0.205	

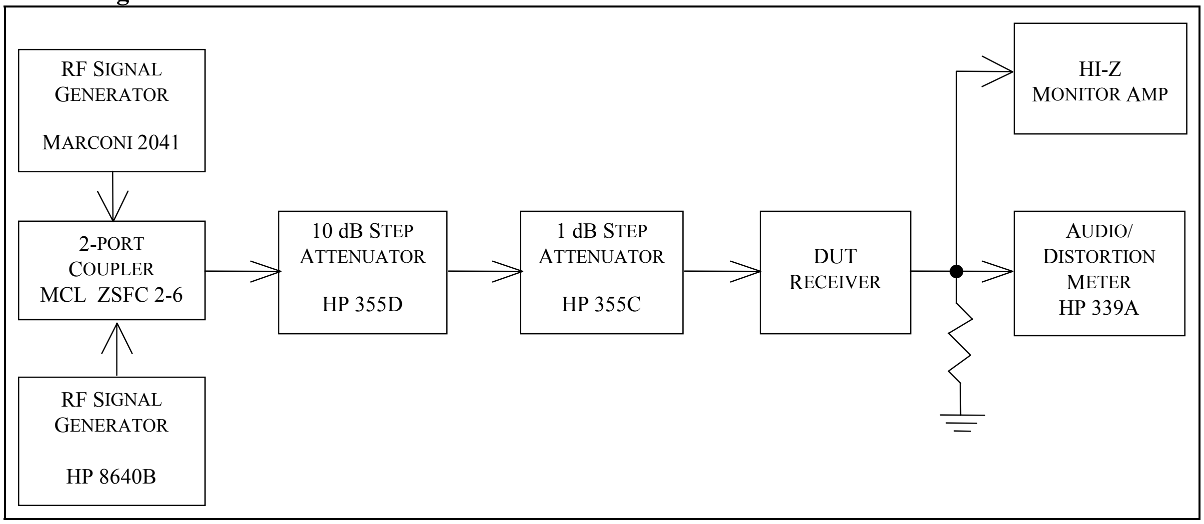
Blocking Dynamic Range

Test Description: Dynamic range is a measurement of a receiver's ability to function well on one frequency in the presence of one or more unwanted signals on other frequency. It is essentially a measurement of the difference between a receiver's noise floor and the loudest off-channel signal that can be accommodated without measurable degradation of the receiver's response to a relatively weak signal to which it is tuned. This difference is usually expressed in dB. Thus, a receiver with a dynamic range of 100 dB would be able to tolerate an off-channel signal 100 dB stronger than the receiver's noise floor.

In the case of blocking dynamic range, the degradation criterion is receiver desense. Blocking dynamic range (BDR) is the difference, in dB, between the noise floor and a off-channel signal that causes 1 dB of gain compression in the receiver. It indicates the signal level, above the noise floor, that begins to cause desensitization. BDR is calculated by subtracting the noise floor from the level of undesired signal that produces a 1-dB decrease in a weak desired signal. It is expressed in dB. The greater the dynamic range, expressed in dB, the better the receiver performance. It is usual for the dynamic range to vary with frequency spacing.

Key Test Conditions:
AGC is normally turned off; the receiver is operated in its linear region. Desired signal set to 10 dB below the 1-dB compression point, or 20 dB above the noise floor in receivers whose AGC cannot be disabled. The receiver bandwidth is set as close as possible to 500 Hz.

Block Diagram:



Test Result Summary:

Band	Preamp	Spacing	BDR (dB)	Notes
1.82 MHz	ON	50 kHz	136.4	1
3.52 MHz	OFF	20 kHz	111.4	
3.52 MHz	OFF	5 kHz	98.7	
3.52 MHz	ON	50 kHz	138.2	
3.52 MHz	ON	20 kHz	109.4	
3.52 MHz	ON	5 kHz	102.2	
14.02 MHz	OFF	100 kHz	136.3	
14.02 MHz	OFF	20 kHz	108.5	
14.02 MHz	OFF	5 kHz	96.1*	
14.02 MHz	ON	100 kHz	117.0	
14.02 MHz	ON	50 kHz	116.2	
14.02 MHz	ON	20 kHz	106.3	
14.02 MHz	ON	5 kHz	88.8*	
21.02 MHz	ON	50 kHz	127.2*	
28.02 MHz	ON	50 kHz	123.3*	
50.02 MHz	OFF	20 kHz	113.6*	
50.02 MHz	OFF	5 kHz	92.2*	
50.02 MHz	ON	50 kHz	115.5*	
50.02 MHz	ON	20 kHz	104.1	
50.02 MHz	ON	5 kHz	84.3*	
144.02 MHz	ON	50 kHz	109.7*	
144.02 MHz	ON	20 kHz	102.4*	
144.02 MHz	ON	5 kHz	81.3*	
430.02 MHz	ON	50 kHz	108.5*	
430.02 MHz	ON	20 kHz	98.7*	
430.02 MHz	ON	5 kHz	79.3*	

Notes:

1. 500 Hz receiver bandwidth for all tests.

* Indicates that measurement was noise limited at values shown

Third-Order Intercept

Test Description: Third-order intercept (IP3) is not actually a separate test, but is part of the IMD Dynamic Range test. The third-order response of the receiver can be characterized (ideally) as a straight line with a 3:1 slope. The "on-channel" response of the receiver would be a line with a 1:1 slope. Any two lines of differing slope will have a point at which they intersect. However, the "intercept" of the third-order and on-channel responses is at a level far higher than the strength of signals receivers can normally handle. Thus, it has to be calculated rather than measured.

The IP3 calculation can be based on a variety of signal levels. One common level is the noise floor (aka "mds") - however, at this level, noise can cause a non-linear response in the real-world circuits of the receiver. Also, it should be noted that IP3 is generally considered to be a measure of a receiver's strong-signal handling ability, thus it is most appropriate to calculate this with signal levels well above the noise floor. In the ARRL Lab, signal levels of S5 are used for the IP3 calculation.

Third-Order Intercept Summary: (All figures in dBm)

Band	Spacing	IP3 Preamp Off	IP3 Preamp On	Notes
3.52 MHz	20 kHz	+5.65	–1.85	1
3.52 MHz	5 kHz	–21.35	–28.85	
14.02 MHz	20 kHz	+1.25	–6.7	
14.02 MHz	5 kHz	–24.25	–32.2	
50.02 MHz	20 kHz	–3.45	–11.7	
50.02 MHz	5 kHz	–28.95	–38.7	
144.02 MHz	20 kHz	N/A	–11.8	
144.02 MHz	5 kHz	N/A	–40.3	
430.02 MHz	20 kHz	N/A	–10.65	
430.02 MHz	5 kHz	N/A	–38.17	

Notes:
1. Receiver bandwidth set to 500 Hz for all tests.

Two-Tone 3rd-Order Dynamic Range

Test Description: Intermodulation distortion dynamic range (IMD DR) measures the impact of two-tone IMD on a receiver. IMD is the production of spurious responses resulting from the mixing of desired and undesired signals in a receiver. IMD occurs in any receiver when signals of sufficient magnitude are present. IMD DR is the difference, in dB, between the noise floor and the strength of two equal off-channel signals that produce a third-order product equal to the noise floor.

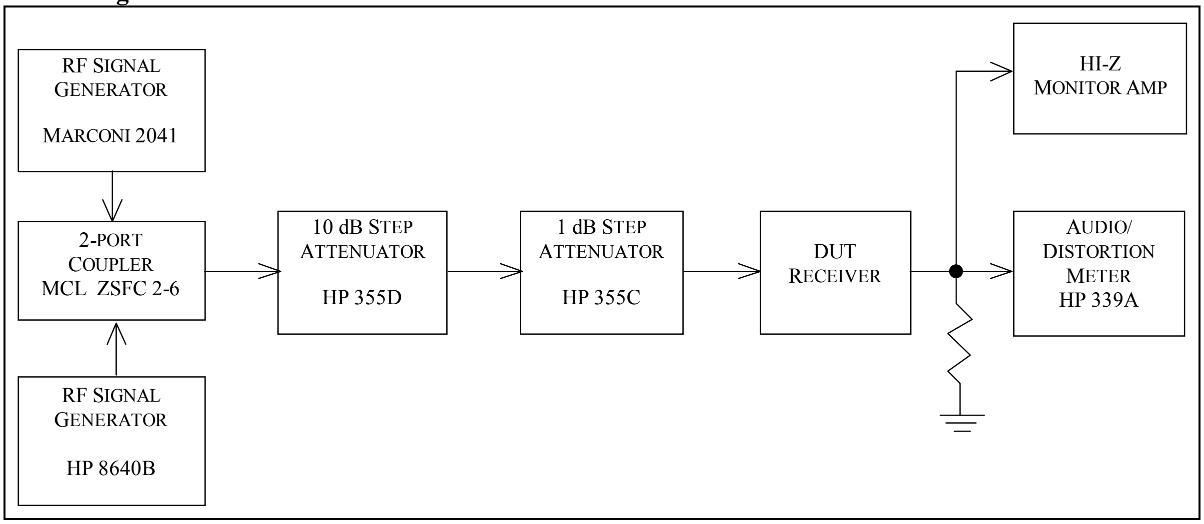
In the case of two-tone, third-order dynamic range, the degradation criterion is a receiver spurious response. If the receiver generates a third-order response equal to the receiver's noise floor to two off-channel signals, the difference between the noise floor and the level of one of the off-channel signals is the blocking dynamic range.

This test determines the range of signals that can be tolerated by the device under test while producing essentially no undesired spurious responses. To perform the 3rd Order test, two signals of equal amplitude and spaced 20 kHz apart, are injected into the input of the receiver. If we call these frequencies f_1 and f_2, the third-order products will appear at frequencies of ($2f_1$-f_2) and ($2f_2$-f_1).

The greater the dynamic range, expressed in dB, or the higher the intercept point, the better the performance.

Key Test Conditions:
Sufficient attenuation and isolation must exist between the two signal generators. The two-port coupler must be terminated in a 20-dB return loss load. The receiver is set as close as possible to a 500-Hz bandwidth.

Block Diagram:



Two-Tone Receiver IMD Dynamic Range Test Results:

Band	Spacing	Preamp OFF IMD DR (dB)	Preamp ON IMD DR (dB)	Notes
1.82 MHz	50 kHz	N/A	90.4	1
3.52 MHz	50 kHz	N/A	90.2	
3.52 MHz	20 kHz	90.7	89.5	
3.52 MHz	5 kHz	67.7	66.5	
7.02 MHz	50 kHz	N/A	89.8	
14.02 MHz	100 kHz	99.3	93.2	
14.02 MHz	50 kHz	N/A	93.2	
14.02 MHz	20 kHz	88.6	86.2	
14.02 MHz	5 kHz	66.6	65.2	
21.02 MHz	50 kHz	N/A	92.2	
28.02 MHz	50 kHz	N/A	93.4	
50.02 MHz	50 kHz	N/A	90.7	
50.02 MHz	20 kHz	88.6	84.6	
50.02 MHz	5 kHz	67.6	64.6	
144.02 MHz	10 MHz	N/A	101.6	
144.02 MHz	50 kHz	N/A	91.6	
144.02 MHz	20 kHz	N/A	85.3	
144.02 MHz	5 kHz	N/A	63.8	
430.02 MHz	10 MHz	N/A	94.5	
430.02 MHz	50 kHz	N/A	93.0	
430.02 MHz	20 kHz	N/A	82.4	
430.02 MHz	5 kHz	N/A	63.4	

Notes: 1. Unit tested at 500 Hz bandwidth.

Dynamic Range Graphs:
The following page shows one of the highlights of ARRL test result reports -- swept graphs on receiver two-tone, third-order IMD dynamic range and blocking dynamic range.

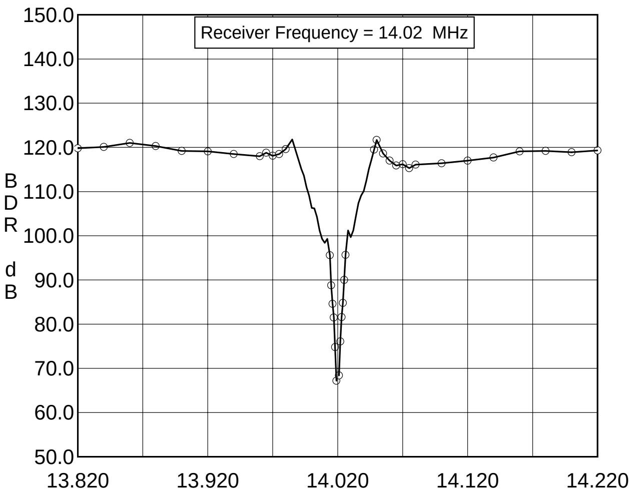
Dynamic range measures the difference between a receiver's noise floor and the receiver's degradation in the presence of strong signals. In some cases, the receiver's noise performance causes receiver degradation before blocking or a spurious response is seen. In either case, if the noise floor is degraded by 1 dB due to the presence of receiver noise during the test, the dynamic range is said to be noise limited by the level of signal that caused the receiver noise response.

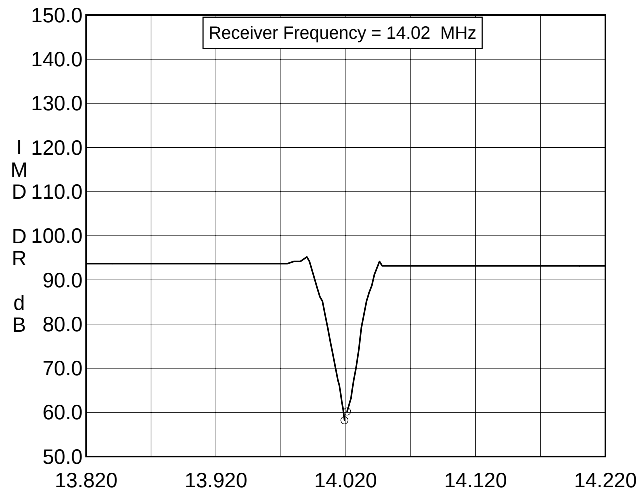
Being "noise limited" is not necessarily a bad thing. A receiver noise limited at a high level is better than a receiver whose dynamic range is lower than the noise-limited level. In essence, a receiver that is noise limited has a dynamic range that is better than its local-oscillator noise.

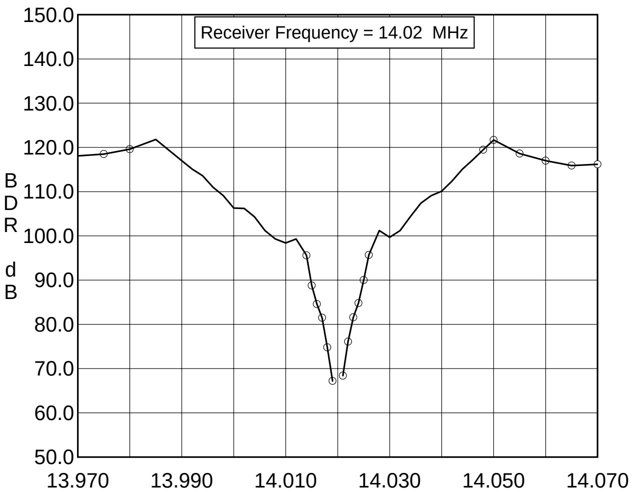
The ARRL Laboratory has traditionally used off-channel signals spaced 20 kHz from the desired signal. This does allow easy comparisons between different receivers. There is nothing magical about the 20-kHz spacing, however. In nearly all receivers, the dynamic range varies with signal spacing, due to the specific design of the receiver. Most receivers have filter combinations that do some coarse filtering at RF and in the first IF, with additional filtering taking place in later IF or AF stages. As the signals get "inside" different filters in the receiver, the dynamic range decreases as the attenuation of the filter is no longer applied to the signal. Interestingly, the different filter shapes can sometimes be seen in the graphs of dynamic range of different receivers. In the case of the ARRL graphs, one can often see that the 20-kHz spacing falls on the slope of the curve. Many manufacturers specify dynamic range at 50 or 100 kHz.

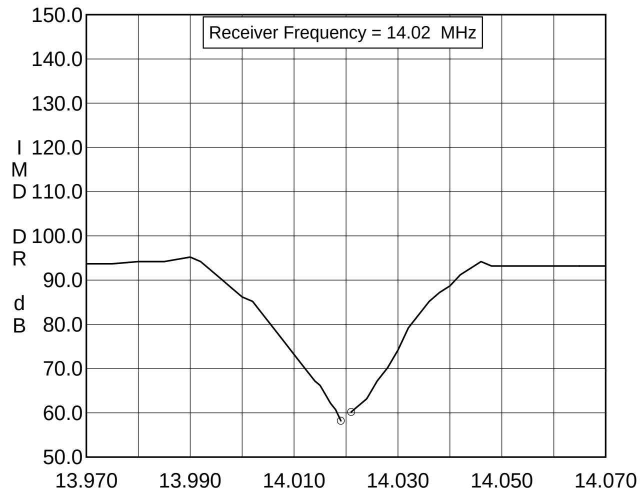
The graphs that follow show swept blocking and two-tone dynamic range. In the blocking test, the receiver is tuned to a signal on 14.020 MHz, the center of the graph. The X axis is the frequency (MHz) of the undesired, off-channel signal. In the two-tone test, the receiver is tuned to a signal on 14.020 MHz, the center of the graph. The X axis is the frequency of the closer of the two tones that are creating intermodulation.

Dynamic-Range Graphs:









Second-Order IMD

Test Description: This test measures the amount of 2nd-order mixing that takes place in the receiver. Signals at 6 and 8 MHz are presented to the receiver and the resultant output at 14 MHz is measured.

Test Results:

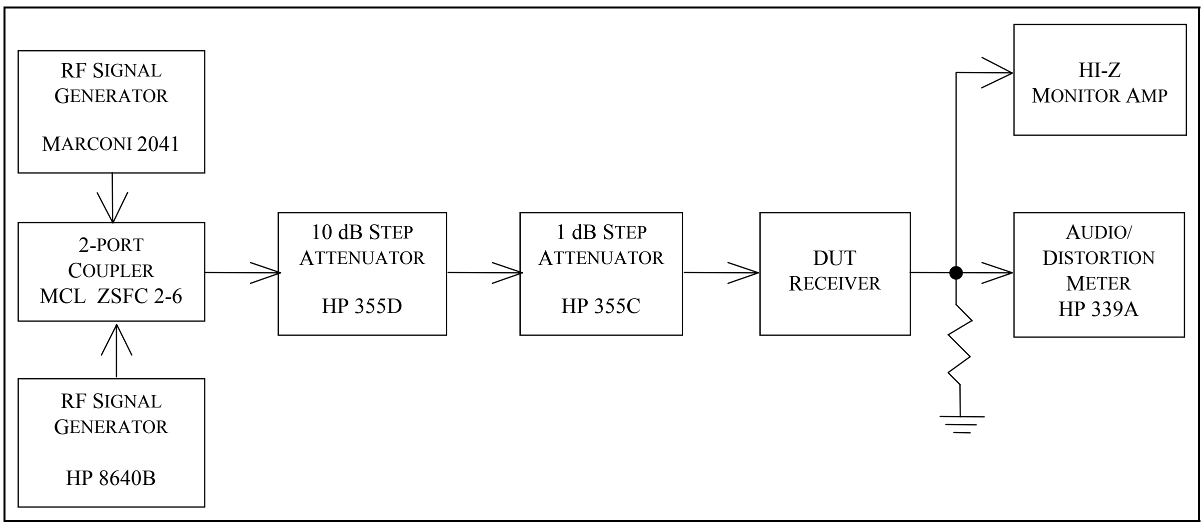
Frequency	Preamplifier	Mode	Dynamic Range (dB)	IP2	Notes
14.02 MHz	OFF	CW	104.6 dB	+67.5 dBm	
14.02 MHz	ON	CW	99.2 dB	+61.6 dBm	

In-Band Receiver IMD

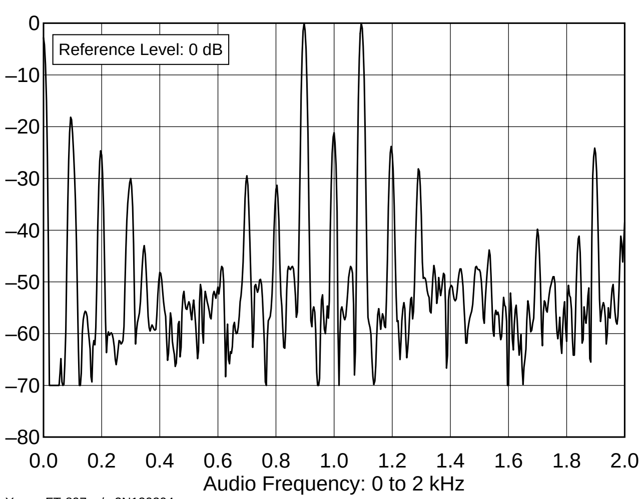
Test Description: This test measures the intermodulation that occurs between two signals that are simultaneously present in the passband of a receiver. Two signals, at levels of 50 µV (nominally S9), spaced 100 Hz are used. The receiver AGC is set to FAST. The receiver is tuned so the two signals appear at 900 Hz and 1100 Hz in the receiver audio. The output of the receiver is viewed on a spectrum analyzer and the 3rd- and 5th order products are measured directly from the screen. The smaller the products as seen on the graph, the better the receiver. Generally, products that are less than 30 dB below the desired tones will not be cause objectionable receiver intermodulation distortion.

Key Test Conditions:
S9 or S9 + 40 dB signals
Receiver set to SSB normal mode, nominal 2 - 3 kHz bandwidth

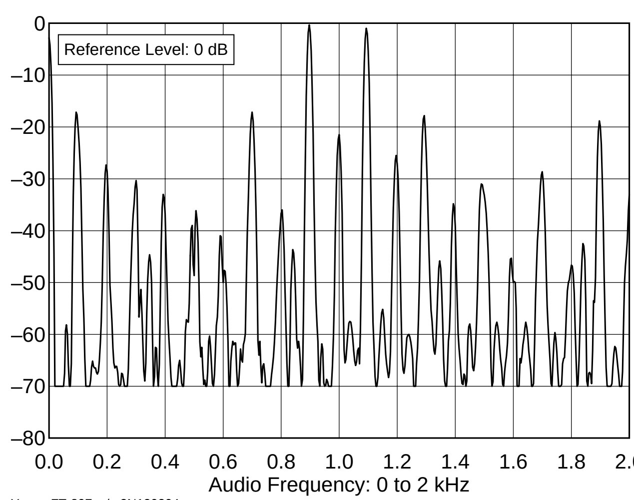
Block Diagram:



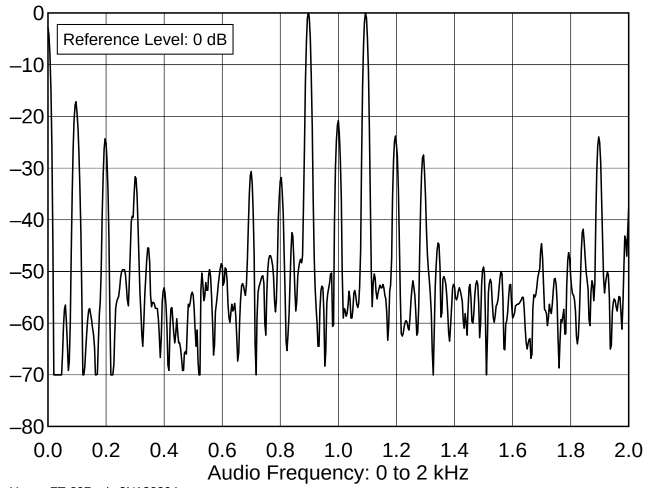
In-Band Receiver IMD Graphs



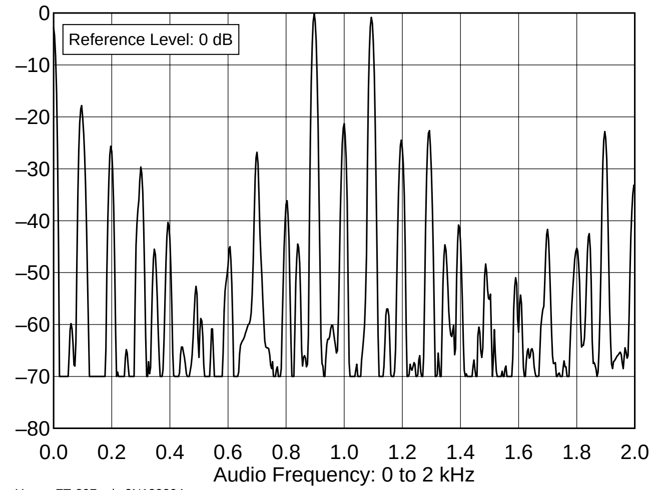
Yaesu FT-897, s/n 2N120204
14.020 MHz, AGC Fast, S9 In-Band Receiver IMD
I:\PRODREV\TESTS\FT897REV\FT897IBF.TXT



Yaesu FT-897, s/n 2N120204
14.020 MHz, AGC Fast, S++ In-Band Receiver IMD
I:\PRODREV\TESTS\FT897REV\FT897IF6.TXT



Yaesu FT-897, s/n 2N120204
14.020 MHz, AGC Slow, S9 In-Band Receiver IMD
I:\PRODREV\TESTS\FT897REV\FT897IBS.TXT



Yaesu FT-897, s/n 2N120204
14.020 MHz, AGC Slow, S++ In-Band Receiver IMD
I:\PRODREV\TESTS\FT897REV\FT897IS6.TXT

FM Adjacent Channel Selectivity

Test Description: The purpose of the FM Adjacent Channel Selectivity Test is to measure the ability of the device under test receiver to reject interference from individual undesired signals while receiving various levels of desired signal. The desired carrier signal will be at 29.000 MHz, modulated at 1000 Hz, and the offending signal will be located at adjacent nearby frequencies with 400 Hz modulation. (NOTE: The SINAD Test in 5.3 must be performed before this test can be completed.) The greater the number in dB, the better the rejection.

Test Results:

Frequency	Preamplifier	Frequency Spacing	Adjacent-channel Rejection	Notes
29.0 MHz	ON	20 kHz	65.6 dB	
52 MHz	ON	20 kHz	65.3 dB	
146 MHz	ON	20 kHz	65.1 dB	
440 MHz	ON	20 kHz	67.7 dB	

FM Two-Tone 3rd-Order Dynamic Range

Test Description: The purpose of this test is to determine the range of signals that can be tolerated by the receiver in the FM mode while producing no spurious responses greater than the 12-dB SINAD level. To perform this test, two signals, f_1 and f_2, of equal amplitude and spaced 20 kHz apart, are injected into the input of the receiver. The signal located 40 kHz from the distortion product being measured is modulated at 1,000 Hz with a deviation of 3 kHz. The receiver is tuned to the Third Order IMD frequencies as determined by $(2f_1-f_2)$ and $(2f_2-f_1)$. The input signals are then raised simultaneously by equal amounts until 25 % distortion, or the 12 dB SINAD point, is obtained. Frequencies 10 MHz outside the amateur band are used to test the wide-band dynamic range. The greater the dynamic range, the better the receiver performance.

Test Results:

Frequency	Preamplifier	Frequency Spacing	Dynamic Range	Notes
29 MHz	ON	20 kHz	65.4 dB	
52 MHz	ON	20 kHz	62.6 dB	
146 MHz	ON	20 kHz	62.2 dB	
146 MHz	ON	10 MHz	89.7 dB	
440 MHz	ON	20 kHz	62.4 dB	
440 MHz	ON	10 MHz	98.9 dB	

IF and Image Rejection

Test Description: This test measures the amount of IF and image rejection for superheterodyne receivers by determining the level of signal input to the receiver at the first IF and image frequencies that will produce an audio output equal to the MDS level. The test is conducted with the receiver in the CW mode with the receiver's preamplifier on, using the 500 Hz, or closest available, IF filters. AGC is turned OFF, if possible. The greater the number in dB, the better the image rejection.

Test Results:

Frequency	1st IF Rejection	Calculated Image Frequency	Image Rejection	Notes
14.02 MHz	123.7 dB	150.68 MHz	90.2 dB	
50.02 MHz	95.5 dB	186.68 MHz	85.5 dB	
144.02 MHz	121.8 dB	280.68 MHz	95.6 dB	
430.02 MHz	122.9 dB	568.68 MHz	76.7 dB	

Audio Output Power

Test Description: This test measures the audio power delivered by the receiver. The manufacturer's specification for load and distortion are used. For units not specified, an 8-ohm load and 10% harmonic distortion are used.

Test Results:

Specified Distortion	Specified Load Impedance	Audio Output Power	Notes
10% T.H.D.	4 ohms	4.2 W	

IF and Audio Frequency Response

Test Description: The purpose of this test is to measure the audio frequencies at which the receiver audio drops 6 dB from the peak signal response. The frequency-response bandwidth is then calculated by taking the difference between the lower and upper frequency.

Test Results:

IF Filter Use/Unit Mode	Nominal Bandwidth Hz	Low Freq (Hz)	High Freq (Hz)	Difference (bandwidth)	Notes
CW	500	385 Hz	971 Hz	586 Hz	
USB	WIDE	250 Hz	2563 Hz	2313 Hz	
LSB	WIDE	420 Hz	2588 Hz	2168 Hz	
AM	NARROW	124 Hz	2379 Hz	2255 Hz	

Squelch Sensitivity

Test Description: The purpose of the Squelch Sensitivity Test is to determine the level of the input signal required to break the squelch at the threshold and at the point of maximum squelch. This number is not usually critical. A result anywhere between 0.05 and 0.5 µV is usually useful. The maximum can range to infinity.

Test Results:

Frequency	Preamplifier	Mode	Threshold	Notes
29 MHz	ON	FM	0.16 µV	
52 MHz	ON	FM	0.10 µV	
146 MHz	ON	FM	0.087 µV	
440 MHz	ON	FM	0.12 µV	
14.2 MHz	ON	SSB	1.55 µV	

S-Meter Sensitivity

Test Description: The purpose of this test is to determine the level of RF input signal required to produce an S9 and S9+20 dB indication on the receiver S meter. This test is performed with the receiver in the CW mode at a frequency of 14.200 MHz. The IF filter is set to 500 Hz, nominal. A traditional S9 signal is a level of 50 µV (an old Collins receiver standard).

Test Results:

Frequency	Preamplifier	S Units	µV	Notes
14.2 MHz	OFF	S9	16.0	
14.2 MHz	ON	S9	5.68	
52 MHz	OFF	S9	7.07	
52 MHz	ON	S9	2.54	
146 MHz	ON	S9	2.19	
440 MHz	ON	S9	2.26	