ARRL Laboratory
Expanded Test-Result Report

Yaesu FT-100

Prepared by:
American Radio Relay League, Inc.
Technical Department Laboratory
225 Main St.
Newington, CT 06111
Telephone: (860) 594-0214
Internet: mtracy@arrl.org

Order From:
American Radio Relay League, Inc.
Technical Department Secretary
225 Main St.
Newington, CT 06111
Telephone: (860) 594-0278
Internet: reprints@arrl.org

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Model Information:
FT-100 Serial #: 9D021081
QST "Product Review" June, 1999

Manufacturer:
Yaesu U.S.A.
17210 Edwards Rd
Cerritos, CA 90703
Telephone: 562-404-2700
http://www.yaesu.com/

List of Tests:

(Page numbers are omitted because the length of the report varies from unit to unit.)

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. The ARRL screen room has an ac supply that is regulated to 117 or 234 volts. If possible, the equipment under test is operated from the ac supply. Mobile and portable equipment is operated at the voltage specified by the manufacturer, at 13.8 volts if not specified, or from a fully charged internal battery. Equipment that can be operated from 13.8 volts (nominal) is also tested for function, output power and frequency accuracy at the minimum specified voltage, or 11.5 volts if not specified. Units are tested at room temperature and humidity as determined by the ARRL HVAC system. Also, units that are capable of mobile or portable operation are tested at their rated temperature range, or at –10 to +60 degrees Celsius 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* .

Related ARRL Publications and Products:

The *1999 ARRL Handbook for Radio Amateurs* has a chapter on test equipment and measurements. The book is available for $32.00 plus $6 shipping and handling. The *Handbook* is also now available in a convenient, easy to use CD-ROM format. In addition to the complete *Handbook* text and graphics, the CD-ROM includes a search engine, audio clips, zooming controls, bookmarks and clipboard support. The cost is $49.95 plus $4.00 shipping and handling. You can order both versions of the *Handbook* from our web page at http://www.arrl.org, or contact the ARRL Publications Sales Department at 888-277-289 (toll free). It is also widely stocked by radio and electronic dealers and a few large bookstores.

The ARRL Technical Information Service has prepared an information package that discusses Product Review testing and the features of various types of equipment. Request the "What is the Best Rig To Buy" package from the ARRL Technical Department Secretary. The cost is $2.00 for ARRL Members, $4.00 for non-Members, postpaid.

Many *QST* "Product Reviews" have been reprinted in three ARRL publications: The *ARRL Radio Buyers Sourcebook* (order #3452) covers selected Product Reviews from 1970 to 1990. The cost is $15.00 plus $4.00 shipping and handling. The *ARRL Radio Buyers Sourcebook Volume II* (order #4211) contains reprints of all of the Product Reviews from 1991 and 1992. The cost is $15.00 plus $4.00 shipping and handling. The *VHF/UHF Radio Buyer's Sourcebook* (order #6184) contains nearly 100 reviews of transceivers, antennas, amplifiers and accessories for VHF and above. You can order these books from our Web page or contact the ARRL Publications Sales Department to order a copy.

QST is also available on CD ROM! The *ARRL Periodicals CD ROMs* (*1998*, order #7377; *1997*, order #6729; *1996*, order #6109 and *1995*, order #5579) each contain a complete copy of all articles from a year's worth of *QST*, the *National Contest Journal* and *QEX* (ARRL's experimenter's magazine). Each CD is available for $19.95 plus $4.00 for shipping and handling. Contact the ARRL Publications Sales Department to order a copy.

Older issues of *QST* are also available: *QST View CD-ROMs* come in sets covering either five years each (*1960-1964 through 1990-1994)*, ten years each (*1930-1939, 1940-1949* and *1950-59*) or more (*1915-1929)*. The price for each set is $39.95. Shipping and handling for all ARRL CD ROM products is $4.00 for the first one ordered, $1.00 for each additional set ordered at the same time.

Additional test result reports are available for:

Manufacturer	Model	Issue
Alpha Power	91ß	Sep 97
Ameritron	AL-800H	Sep 97
ICOM	IC-706	Mar 96
	IC-706 MkII	Jan 98
	IC-756	May 97
	IC-775DSP	Jan 96
	IC-821H	Mar 97
JRC	NRD-535	May 97
Kenwood	TS-570D	Jan 97
	TS-870S	Feb96
QRO	HF-2500DX	Sep 97
Ten-Tec	Centaur	Jun 97
	Omni VI +	Nov 97
Yaesu	FT-100	Jun 99
	FT-847	Jul 98
	FT-920	Oct 97
	FT-1000MP	Apr 96

The cost is $7.50 for ARRL Members, $12.50 for non-Members for each report, postpaid. ARRL Members can obtain any three reports for $20.00, postpaid.

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 unit is tested across the entire amateur band and the worst-case number for each band is reported. The equipment is also tested on one or more bands for any other mode of operation for which the transmitter is capable. Typically, the most popular band of operation for each mode is selected. Thus, 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.

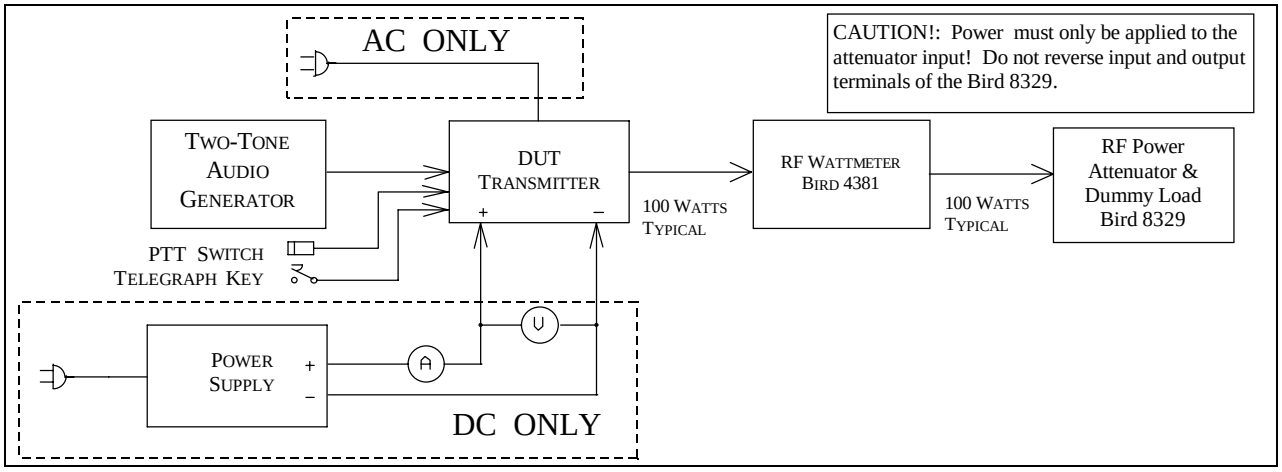
The purpose of the Transmitter Output-Power Test is to measure the dc current consumption at the manufacturer's specified dc-supply voltage, if applicable, and the RF output power of the unit under test across each band in each of its available modes. A two-tone audio input, at a level within the manufacturer's 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 and FM modes. 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 or FM but is not specified to deliver that power level for any period of time. In these cases, the published test-result table will list the AM or FM power as being "as specified."

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. If the ARRL Lab determines that a transmitter is capable of delivering its rated PEP SSB output, the test-result table lists the power as being "as specified."

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	0	0.3 W	"100"	88.5 W	1, 2
3.5 MHz	CW	0	N/A	–	93.3	
3.5 MHz	AM	0	N/A	–	N/A	3
7.0 MHz	CW	0	N/A	–	94.9	
10.1 MHz	CW	0	N/A	–	95.3	
14 MHz	CW	0	N/A	–	95.9	
14 MHz	USB	0	N/A	–	97.0	
14 MHz	CW	0	N/A	–	22.6	4, 10, 99
14 MHz	CW	0	N/A	–	94.3	11, 99
14 MHz	CW	0	N/A	–	95.7	12, 99
18 MHz	CW	0	N/A	–	95.6	
21 MHz	CW	0	N/A	–	95.6	
24 MHz	CW	0	N/A	–	95.1	
28 MHz	CW	0	N/A	–	96.0	
28 MHz	FM	0	N/A	–	96.7	
50 MHz	CW	0	N/A	–	98.9	
50 MHz	FM	0	N/A	–	99.5	
50 MHz	AM	0	N/A	–	N/A	3
50 MHz	SSB	0	N/A	–	98.5	
144 MHz	CW	0	N/A	"50"	53.4	
144 MHz	FM	0	N/A	–	52.7	
144 MHz	AM	0	N/A	–	N/A	3
144 MHz	SSB	0	N/A	–	53.3	
432 MHz	CW	0	N/A	"20"	19.9	
432 MHz	FM	0	N/A	–	20.2	
432 MHz	AM	0	N/A	–	N/A	3
432 MHz	SSB	0	N/A	–	20.0	

Notes:

1. Unit's power meter consists of LED segments; minimum power showed 0 segments lit.
2. The unit showed LED segments reaching a fixed display label reading 100 at full power.
3. Due to a problem with this unit, AM carrier power could not be measured in a meaningful way. See text of QST's Product Review for details.
4. Initial power output upon applying power after "soaking" at -10 deg for an hour. After each subsequent transmission, the power output increased with rise in rig's internal temperature (three very short transmissions brought the output up to about 50W).

10. Temperature chamber test at -10 degrees Celsius.
11. Temperature chamber test at +60 degrees Celsius.
12. Output power test at 11.5 volts dc power supply (if applicable).

99. Temperature chamber tests and 11.5 volt tests are performed *only* for portable and mobile equipment.

Current Consumption Test: (DC-powered units only)

Test Description: Current consumption can be a 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	17 A	97.0 W	1.3 A	ON	

Transmit Frequency Range Test:

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	420.000 00 MHz	450.000 00 MHz	

CW Transmit Frequency Accuracy Test:

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. However, some units, notably "analog" units, not using a phase-lock loop in the VFO design, can be off by a considerable amount. This test measures the output frequency. Unit is operated into a 50-ohm resistive load at nominal temperature and supply voltage. Frequency is also measured at minimum output power, low supply voltage (12 volt units only) and over the operating temperature range (mobile and portable units only). Non-portable equipment is not tested in the temperature chamber.

Test Results:

Unit Frequency	Supply Voltage	Temperature	Measured Frequency Full Output Power	Notes
14.000 00 MHz	13.8 V	25 C	14.000 011 MHz	
14.000 00 MHz	12.5 V	25C	14.000 011 MHz	
14.000 00 MHz	13.8 V	-10C	13.999 949 MHz	
14.000 00 MHz	13.8 V	+60C	14.000 043 MHz	
50.000 00 MHz	13.8 V	25 C	50.000 037 MHz	
144.000 00 MHz	13.8 V	25 C	144.000 106 MHz	
430.000 00 MHz	13.8 V	25 C	430.000 315 MHz	
430.000 00 MHz	13.8 V	-10C	429.998 297 MHz	
430.000 00 MHz	13.8 V	+60C	430.001 271 MHz	

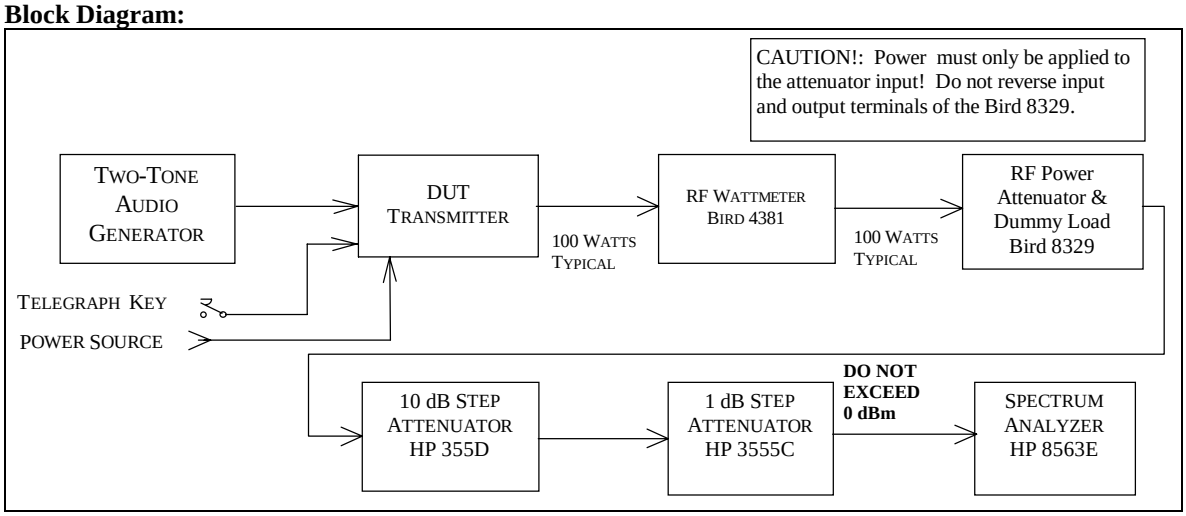
Spectral Purity Test:

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 is 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:
Unit is operated at nominal supply voltage and temperature.
Output power is adjusted to full power on each amateur band.
A second measurement is taken at minimum power to ensure that the spectral output is still legal at low power.
The level to the spectrum analyzer is –10 dBm maximum.
The resolution bandwidth of the spectrum analyzer is 10 kHz on HF, 100 kHz on VHF, 1 MHz on UHF.

Block Diagram:



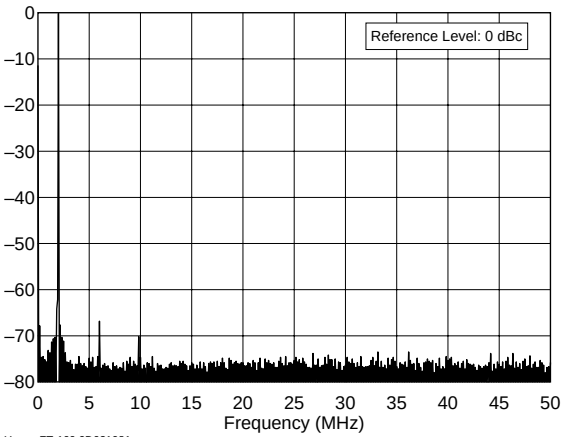
Test Results - summary:

Frequency	Spurs (dBc)	Notes
1.8 MHz	–68 dBc	
3.5 MHz	–40	1
7 MHz	–55	
10.1 MHz	–54	
14 MHz	–55	
18 MHz	–59	
21 MHz	–53	
24 MHz	–60	
28 MHz	–50	
50 MHz	–60	
144 MHz	–60	
430 MHz	–68	

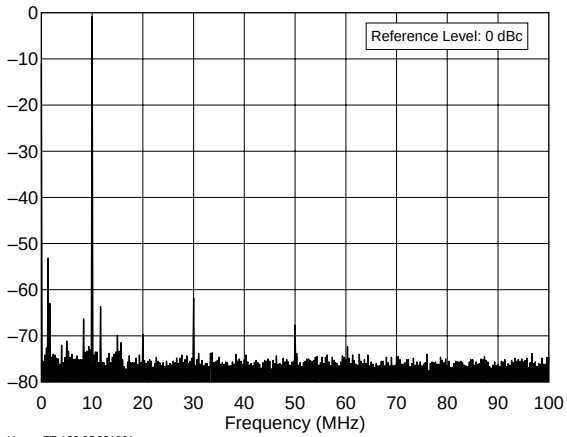
Notes:

1. A second unit tested showed a spur of –50 dBc on this band.

Spectral-Purity Graphs:



Yaesu FT-100 9D021081
1.8 MHz Band, Spectral Purity, 100 W
F:\SHARED\PROD_REV\TESTS\FT100.2ND\FT100SLO.TXT



Yaesu FT-100 9D021081
10.1 MHz Band, Spectral Purity, 100 W
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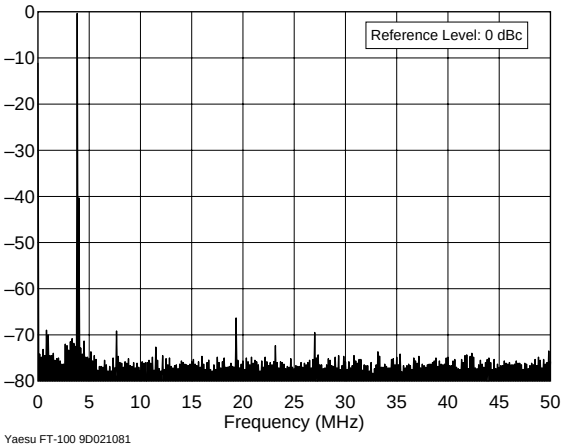

Yaesu FT-100 9D021081
3.5 MHz Band, Spectral Purity, 100 W
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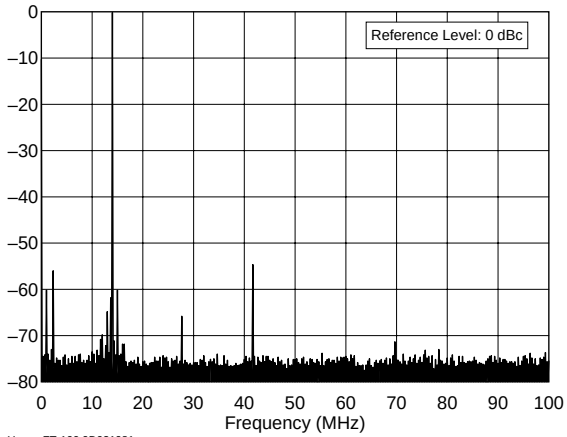

Yaesu FT-100 9D021081
14.0 MHz Band, Spectral Purity, 100 W
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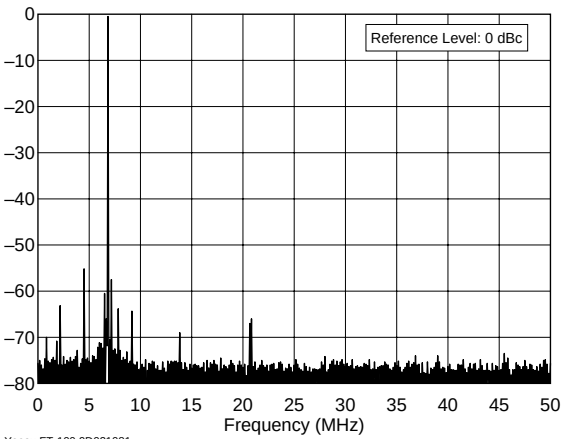

Yaesu FT-100 9D021081
7.0 MHz Band, Spectral Purity, 100 W
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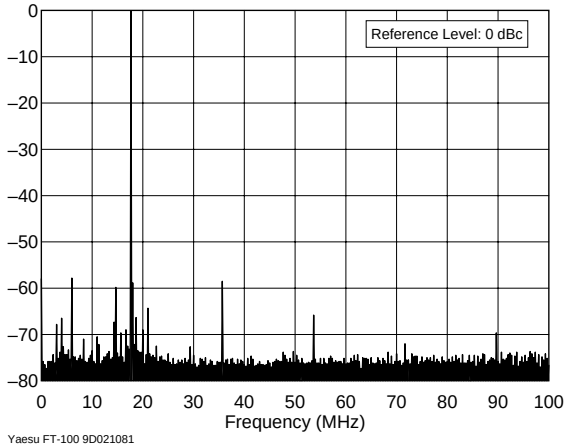

Yaesu FT-100 9D021081
18.1 MHz Band, Spectral Purity, 100 W
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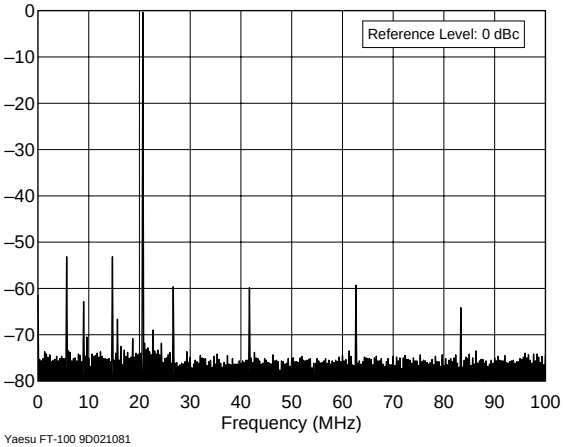

Yaesu FT-100 9D021081
21.0 MHz Band, Spectral Purity, 100 W
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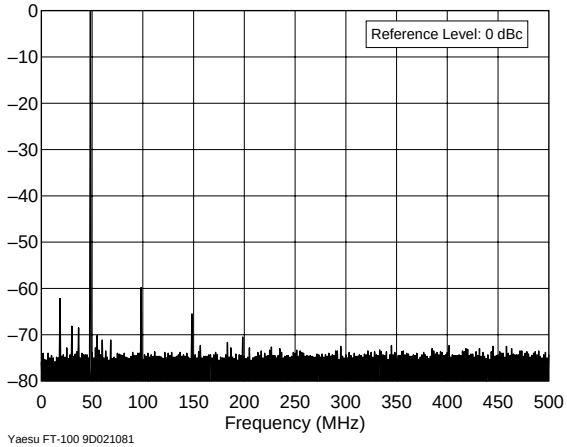

Yaesu FT-100 9D021081
50.0 MHz Band, Spectral Purity, 100 W
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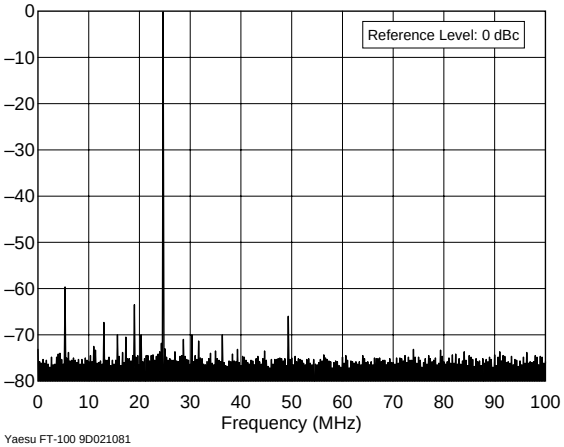

Yaesu FT-100 9D021081
24.9 MHz Band, Spectral Purity, 100 W
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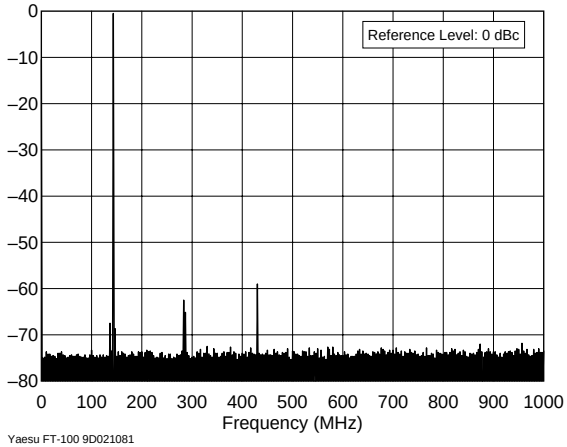

Yaesu FT-100 9D021081
144.0 MHz Band, Spectral Purity, 50 W
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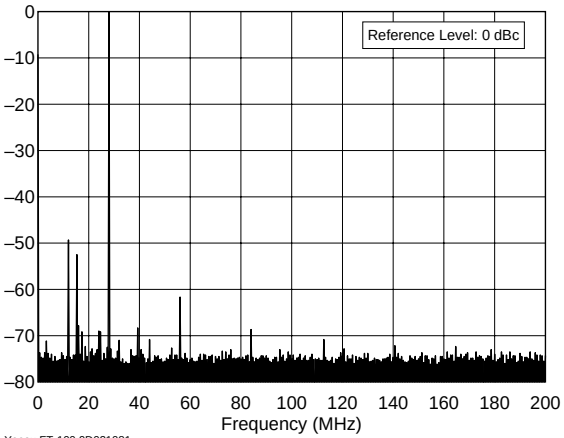

Yaesu FT-100 9D021081
28.0 MHz Band, Spectral Purity, 100 W
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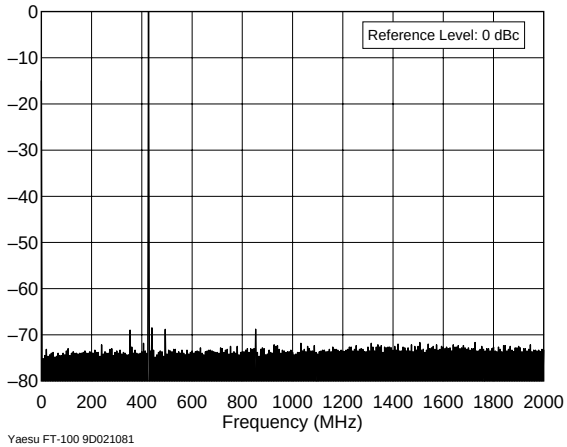


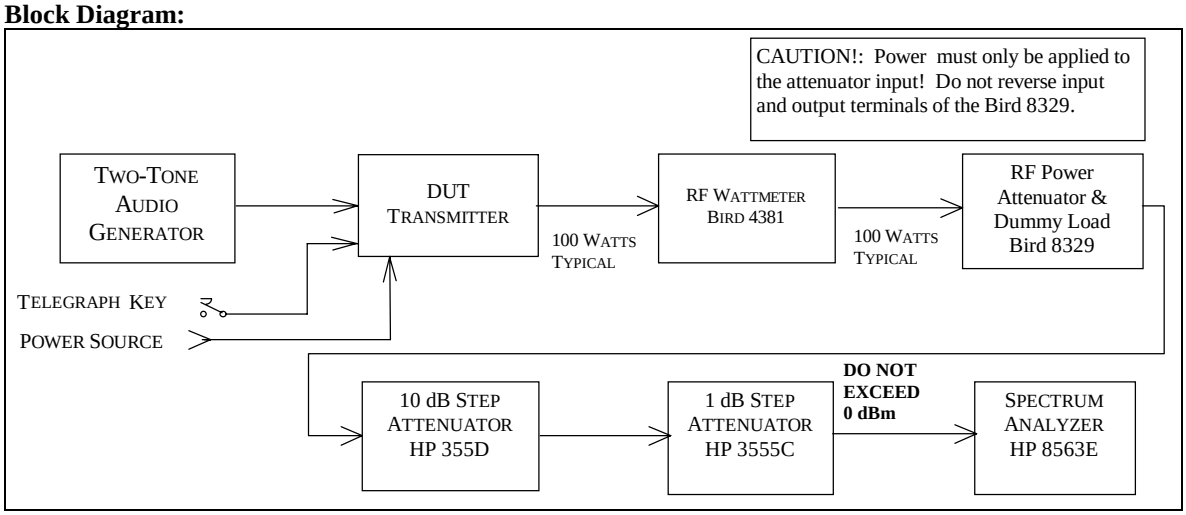
Yaesu FT-100 9D021081
420.0 MHz Band, Spectral Purity, 20 W
F:\SHARED\PROD_REV\TESTS\FT100.2ND\FT100S70.TXT

Transmit Two-Tone IMD Test:

Test Description: Investigating the sidebands from a modulated transmitter requires a narrow-band spectrum analysis. In this test, a two-tone test signal is used to modulate the transmitter. The display shows the two test tones plus some of the IMD products produced by the SSB transmitter. In the ARRL Lab, a two-tone test signal with frequencies of 700 and 1900 Hz is used to modulate the transmitter. These frequencies were selected to be within the audio passband of the typical transmitter, resulting in a meaningful display of transmitter IMD. 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. Audio tones and drive level adjusted for best performance. Audio tones 700 and 1900 Hz. Both audio tones adjusted for equal RF output. Level to spectrum analyzer, - 10 dBm nominal, -10 dBm maximum. Resolution bandwidth, 10 Hz

Block Diagram:

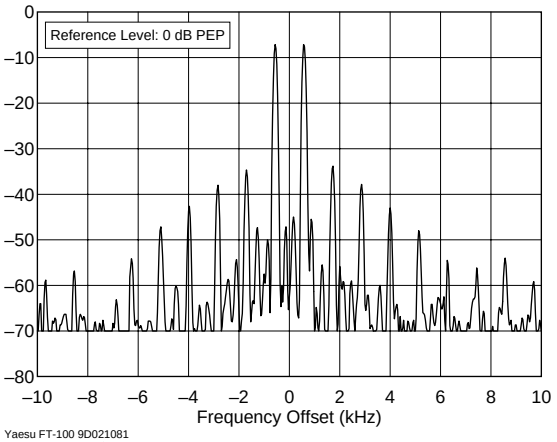


Test Result Summary:

Frequency	Worst-case 3rd-order dB PEP	Worst-case 5th-order dB PEP	Notes
1.85 MHz	–35	–39	
3.9 MHz	–30	–48	
7.25 MHz	–29	–47	
10.12 MHz	–32	–36	
14.25 MHz	–30	–53	
18.12 MHz	–30	–43	
21.25 MHz	–30	–37	1
24.95 MHz	–30	–40	
28.35 MHz	–32	–39	1
50.2 MHz	–25	–40	1
144.2 MHz	–22	–43	
432.2 MHz	–26	–42	

Notes:
1. Tested at 80W; at higher power levels, additional spurious mixing products obscured the IMD products. This did not occur with a single tone input, however.

Transmit IMD Graphs



Yaesu FT-100 9D021081
1.850 MHz, Transmit IMD, 100 W
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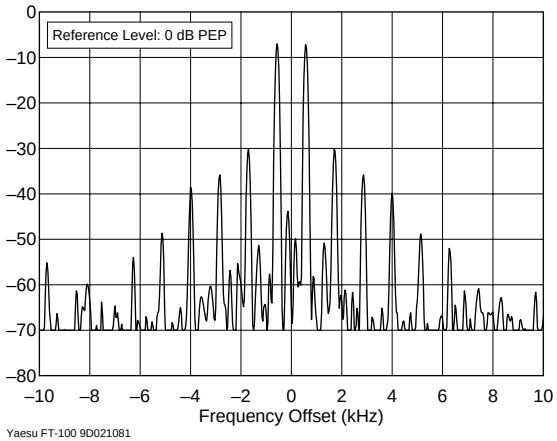

Yaesu FT-100 9D021081
10.120 MHz, Transmit IMD, 100 W
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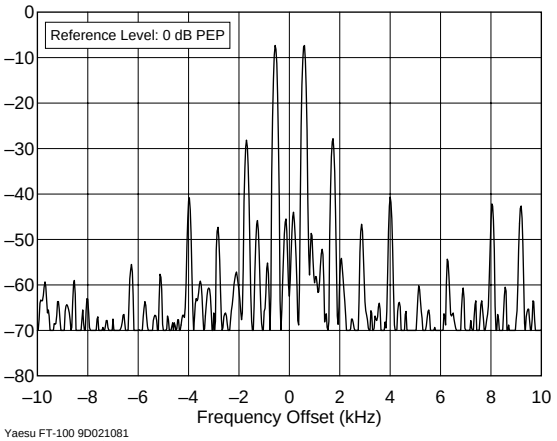

Yaesu FT-100 9D021081
3.900 MHz, Transmit IMD, 100 W
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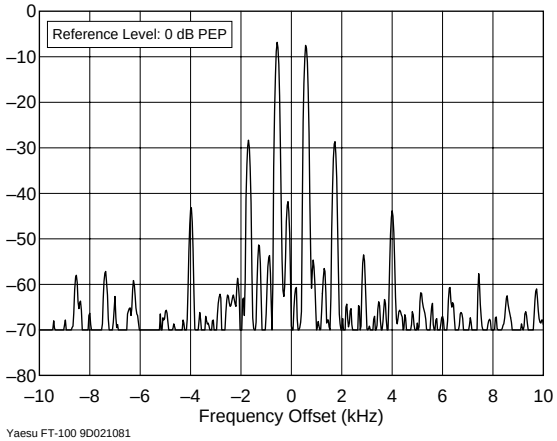

Yaesu FT-100 9D021081
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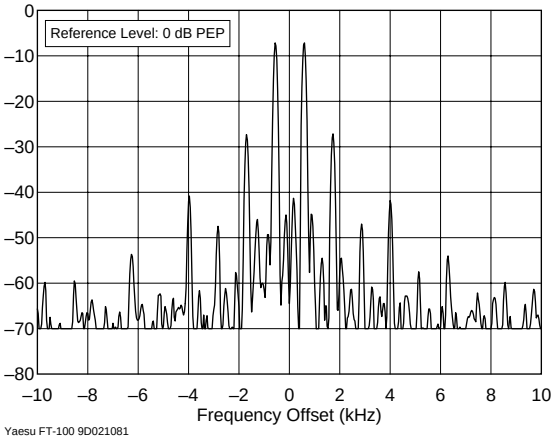

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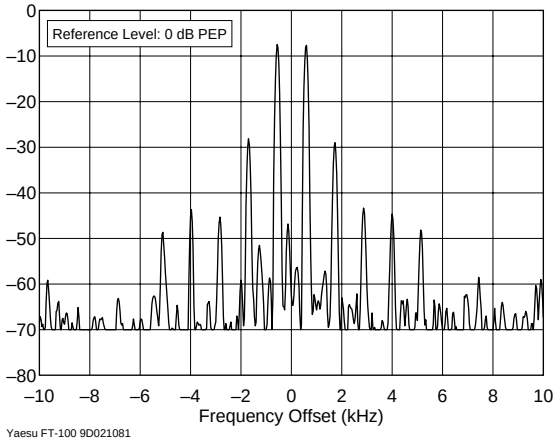

Yaesu FT-100 9D021081
18.120 MHz, Transmit IMD, 100 W
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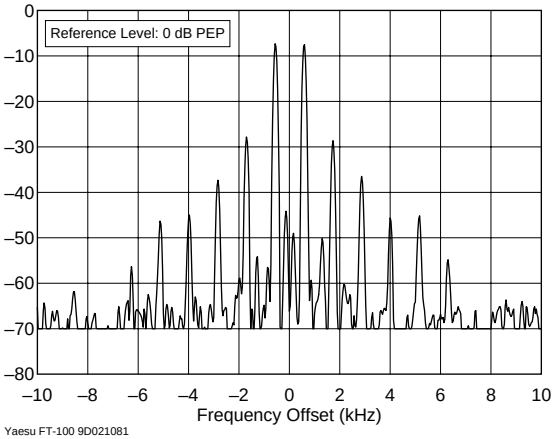

Yaesu FT-100 9D021081
21.250 MHz, Transmit IMD, 100 W
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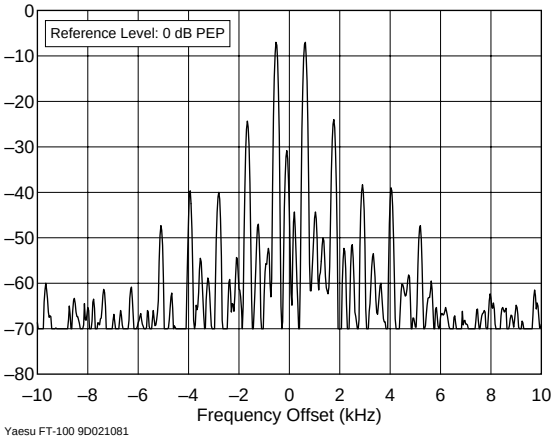

Yaesu FT-100 9D021081
50.200 MHz, Transmit IMD, 100 W
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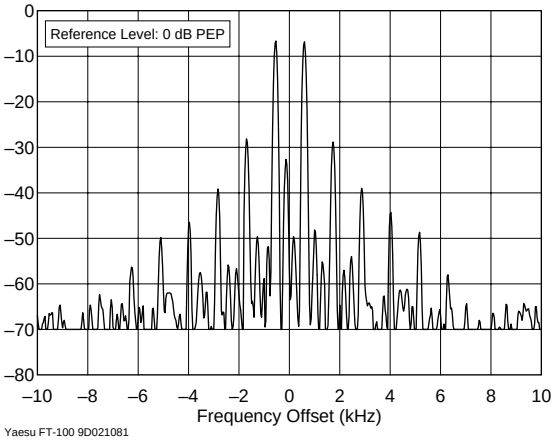

Yaesu FT-100 9D021081
24.950 MHz, Transmit IMD, 100 W
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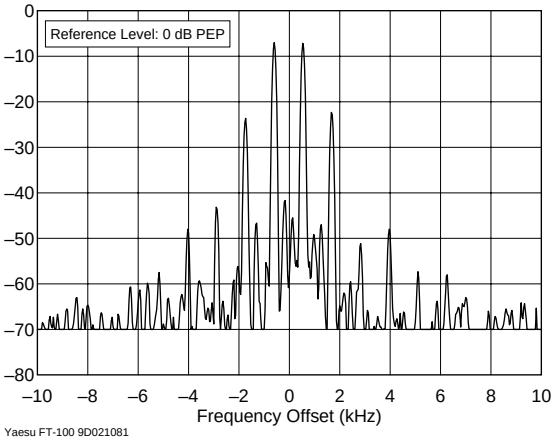

Yaesu FT-100 9D021081
144.200 MHz, Transmit IMD, 50 W
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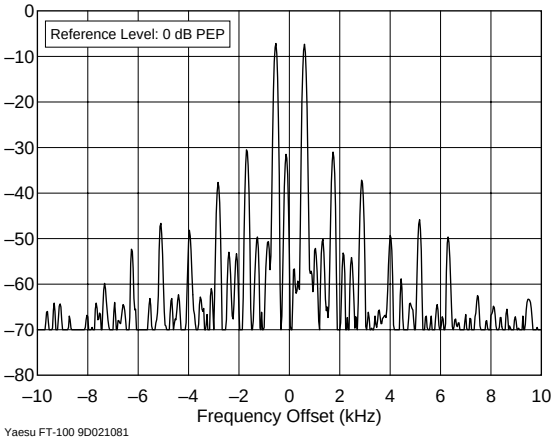

Yaesu FT-100 9D021081
28.350 MHz, Transmit IMD, 100 W
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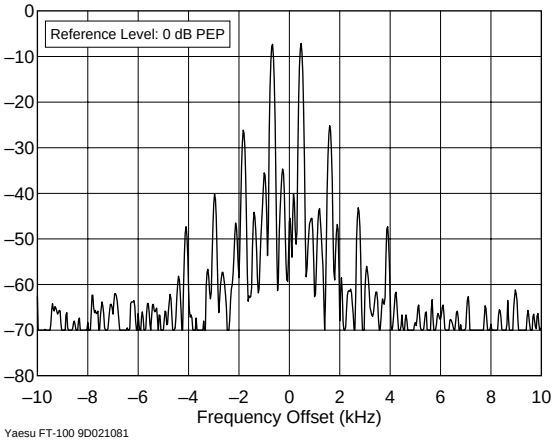

Yaesu FT-100 9D021081
432.200 MHz, Transmit IMD, 20 W
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SSB Carrier and Unwanted Sideband Suppression Test:

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	< –52/–53 dB	< –68/–67 dB	
50.2 MHz	< –53/–53 dB	< –66/–66 dB	
144.2 MHz	< –54/–53 dB	< –67/–69 dB	
432.2 MHz	< –51/–52 dB	< –64/–63 dB	

CW Keying Waveform Test:

Test Description: The purpose of the CW Keying Waveform Test is to determine the rise and fall times for the 10% to the 90% point of the device under test's RF output envelope in the CW mode. The on and off delay times from key closure to RF output are also measured. If the transmitter under test has several CW modes, (i.e. VOX, QSK) these measurements is made at rated output power for each mode. A picture of the oscilloscope screen is taken of the results with the QSK off, and in the VOX mode showing the first dit, and any other test conditions that result in a waveshape that is significantly different from the others (more than 10% difference, spikes, etc.). The first and second dits are shown in all modes.

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. The absolute value of the on delay and off delay are not critical, but it is important that they be approximately the same so that CW weighting will not be affected.

Some transmitters used in the VOX mode 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.

The first dit foreshortening is expressed as a "weighting" number. In perfect keying, the weighting is 50%, meaning that the carrier is ON for 50% of the time.

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:

Captions (Figures on next pages): All Figures are 10 ms/division., unless otherwise noted.
Figure 1. This shows the first and second dits in Full QSK mode.
Figure 2. This shows the first and second dits in Semi QSK mode.
Figure 3. This shows the first and second dits in Full QSK mode, 35 watts output.

CW Keying Waveforms:

Figure 1

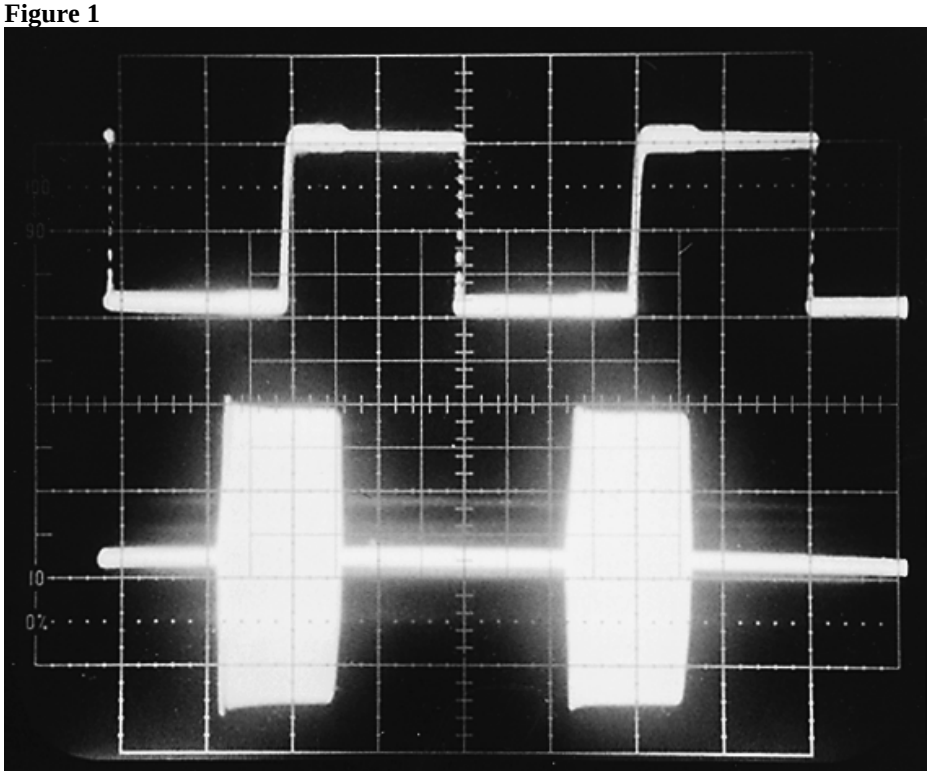

Figure 2