Larry D. Wolfgang, WR1B, tc@arrl.org

ARRL Laboratory Handheld Transceiver Testing

Those who have attended Hamvention in Dayton, Ohio or several other conventions over the last 3 years may recall seeing a team of ARRL Laboratory Engineers and volunteers performing spectral output tests of VHF/UHF handheld transceivers. This testing was performed as a service for attendees who wished to know the spectral quality of the output from their handheld transceiver.[1]

Most readers are familiar with ARRL Product Reviews, and the laboratory testing that we conduct for those reviews. How was the convention testing different? In the case of Product Review testing, we have new radios, in previously unopened boxes. We conduct extensive testing, and compare a radio's receive and transmit test results with the manufacturer's claimed specifications as well as the FCC spectral requirements, specifically FCC Rule, Part 97.307(e).

**FCC Part 97.307(e) The mean power of any spurious emission from a station transmitter or external RF power amplifier transmitting on a frequency between 30 – 225 MHz must be at least 60 dB below the mean power of the fundamental. For a transmitter having a mean power of 25 W or less, the mean power of any spurious emission supplied to the antenna transmission line must not exceed 25 μW and must be at least 40 dB below the mean power of the fundamental emission, but need not be reduced below the power of 10 μW. A transmitter built before April 15, 1977, or first marketed before January 1, 1978, is exempt from this requirement.*

For example, a typical 5 W handheld transceiver transmitting at 146 MHz would need a minimum of 53 dB of harmonic and spurious suppression. For a 4 W transmitter, a minimum of 52 dB is required; 3 W = 50.8 dB, 2 W = 49 dB, 1 W = 46 dB, and 100 mW = 40 dB.

A spurious emission is RF energy that is unintentionally generated by a transmitter at any frequency other than the desired (fundamental) transmit frequency. Harmonics are spurious emissions that are unintentionally generated by a transmitter and are easy to spot on a spectrum analyzer or panoramic receiver, being two times, three times, four times, and so on, the fundamental frequency. Other spurious emissions ("spurs") can sometimes be unintentionally generated above or below the fundamental frequency.

It is important to note that the data gathered at the convention measurement tables represents the emissions from *used* equipment, unlike the data that is gathered during testing of new equipment for *QST* Product Reviews. Handheld transceivers that have been dropped, damaged by moisture, or modified by their owners in any way may become noncompliant.

A total of 919 handheld radios were tested, to date. After five major conventions, some interesting trends began to appear. Certain radios tend to comply, or not, with FCC emission requirements regarding spurious emissions. Table 1 summarizes the data collected over the years. Table 2 breaks down the data by manufacturer, although no attempt was made to list the specific models of radios being tested. In Table 2, the manufacturers are listed in order, according to the number of radios tested.

[1]Handheld testing was performed at 2012 Pacificon, 2013 – 2015 Dayton Hamvention® and in the ARRL Laboratory during the 2014 ARRL Centennial Convention.

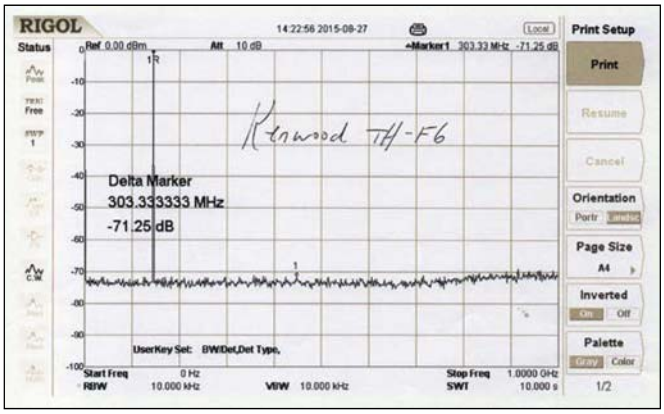

Figure 1 — This Kenwood TH-F6 handheld transceiver has a very clean spectral output, with only a single signal at the intended fundamental frequency, and all of the remaining spectrum being more than 70 dB below the intended output, out to 1.0 GHz. This spectral output is typical of most of the compliant radios.

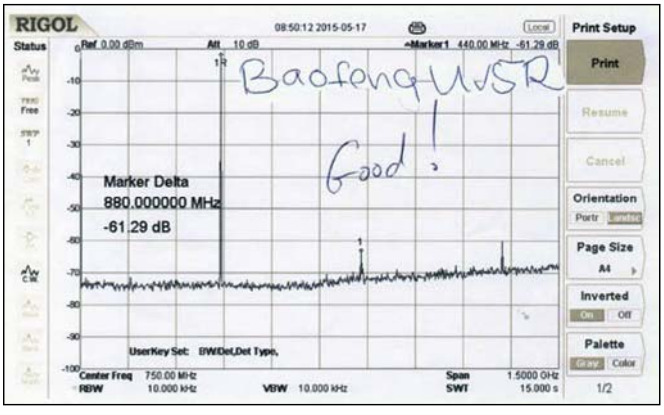

Figure 2 — Many of the handheld radios that are not compliant on the 2 meter band show good engineering practice when operating on the 70 centimeter band. Here you can see a Baofeng UV5R operating on 70 centimeters, and the second and third harmonics are 60 dB or more below the fundamental output.

Table 1
ARRL Laboratory Testing of Handheld Transceivers at Conventions

Year	Units Tested	Compliant	Borderline	Noncompliant
2012	129	91%	3%	6%
2013	244	87%	4%	9%
2014	282	76%	8%	16%
2015	264	80%	7%	14%

Table 2
ARRL Laboratory Testing of Handheld Transceivers by Manufacturer

2012

Manufacturer	Units Tested	Compliant	Borderline	Noncompliant
Yaesu	54	100%	0%	0%
Wouxun	16	100%	0%	0%
Kenwood	15	100%	0%	0%
Icom	14	100%	0%	0%
Baofeng	13	31%	15%	54%
TYT	6	50%	17%	33%
Other	11			

2013

Manufacturer	Units Tested	Compliant	Borderline	Noncompliant
Yaesu	67	99%	0%	1%
Icom	47	100%	0%	0%
Baofeng	41	49%	15%	36%
Kenwood	40	100%	0%	0%
Wouxun	26	77%	4%	19%
Motorola	6	100%	0%	0%
RadioShack	5	100%	0%	0%
Other	12			

2014

Manufacturer	Units Tested	Compliant	Borderline	Noncompliant
Yaesu	90	100%	0%	0%
Baofeng	67	10%	33%	57%
Kenwood	47	98%	0%	2%
Icom	37	100%	0%	0%
Wouxun	15	67%	0%	33%
RadioShack	6	100%	0%	0%
Motorola	5	100%	0%	0%
Connect Systems	5	100%	0%	0%
Other	10			

2015

Manufacturer	Units Tested	Compliant	Borderline	Noncompliant
Yaesu	69	100%	0%	0%
Baofeng	65	25%	21%	54%
Icom	53	100%	0%	0%
Kenwood	27	100%	0%	0%
Wouxun	22	86%	0%	14%
Connect Systems	8	100%	0%	0%
Other	20			

Specific makes and models in which the majority of the units tested were noncompliant:
Baofeng, UV5R, UV5R+, UV5RA, UV5RE, UV5RT, UVB5, UV82X, UV-B6, BF-F8HP, GT3; F-11, E-5 MKII, UV-3R (older units, pre 2013)
Wouxun, KG-UVD1P (2 m / 220 MHz), KGUV3D (2 m / 220 MHz)
TYT, TH-UV3R (2 m / 220 MHz), TH-UVF9 (2 m / 220 MHz)
Handhelds of "Other" Manufacturers numbered less than 5 units of each model and therefore, a reasonable sample of each model was not available.

One reason for carrying out this testing was to help Amateur Radio operators understand the spectral output of their handheld radios. Many radios produce very clean transmitted signals, while some produce strong harmonic content or other spurious emissions, which may or may not comply with the FCC requirements.

Our convention tests measured the levels of spurious emissions using a test fixture consisting of a Bird Model 43 RF Power Meter, a Bird Model 8322 30 dB power attenuator, a Hewlett-Packard HP-355C 0 to 12 dB step attenuator, and a Rigol DSA-815TG spectrum analyzer. All test equipment was calibrated by Essco Calibration Laboratory of Chelmsford, Massachusetts prior to each convention.

The test procedure was fairly simple. First, the power output of the handheld under test was measured using the Bird Model 43 meter. For a given power output, the minimum level of the required harmonic suppression, in dB, was known. For example, the minimum required suppression level for a 5 W transceiver is 53 dB; ≥53 dB is compliant; 50 to 53 dB is considered borderline; 50 to 0 dB is noncompliant.

Next, with the radio push-to-talk (PTT) button pressed and held, the Rigol DSA-815TG spectrum analyzer was used to perform a sweep from 0 to 1000 MHz. After about 10 seconds, a completed spectral plot appeared on the spectrum analyzer screen, showing the transmitted fundamental signal, plus any harmonics and spurs. Viewing the completed sweep, the test engineer noted the difference, in dB, between the level of the fundamental and the level of each harmonic and any other spurious emission. The spurious emission with the least difference from the fundamental, in dB, was the level of suppression.

Spurious emission suppression levels were documented in our test notes. Noncompliant handheld spectral plots were printed directly from the Rigol spectrum analyzer for later analysis. The brand name and model number were hand-written on the printed spectral plots. Each owner of a tested handheld was given a paper copy of the test results, if he or she wanted it.

There are three basic categories of test results; compliant, borderline, and noncompliant.

Figure 3 — Here is the spectral output for another Baofeng UV5R, which is borderline compliant with the FCC spectral requirements. Note that there are several signals that are approximately 50 dB below the strength of the fundamental output.

Figure 4 — This Baofeng UV82X does not comply with the FCC spectral requirements of Part 97.307e. The second harmonic of the fundamental signal is only 15.8 dB below the strength of the desired output signal.

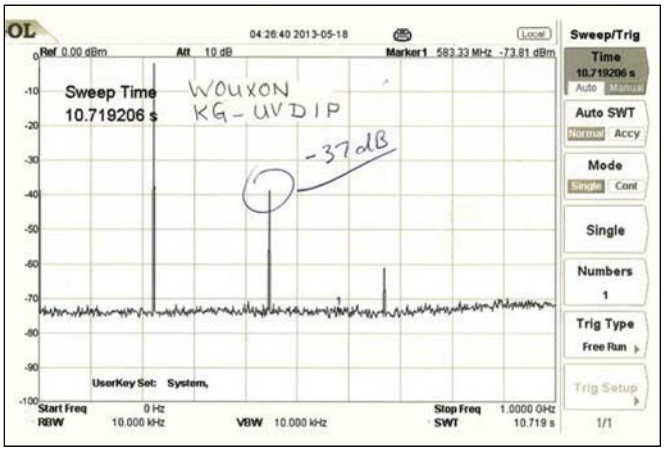

Figure 5 — This Wouxun KG-UVD1P does not comply with the requirements of FCC Part 97.303e, with a second harmonic signal that is only down 37 dB.

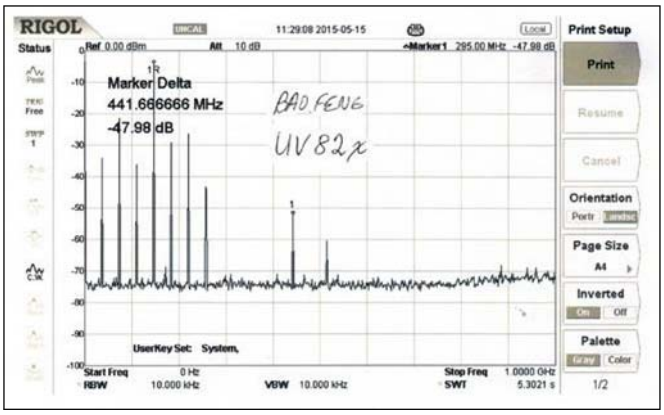

Figure 6 — This Baofeng UV82X does not comply with the FCC requirements. Notice that there are three strong signals at frequencies less than the fundamental and three more signals higher in frequency than the fundamental, all of which are less than 40 dB below the strength of the fundamental. All of these signals are strong enough to cause interference to communications on other radio services.

Compliant transceivers had spurious emission suppression that exceeded FCC requirements. Figure 1 shows one of the compliant spectral plots. Figure 2 shows a Baofeng UV5R transceiver that was operating on the 70 centimeter band. While many of these radios were not compliant on the 2 meter band, they show good engineering practice on the 70 centimeter band. Here you can see some noticeable second and third harmonic radiation. Please note that FCC Rule 97.307(e) does not apply to radios operating above 225 MHz.

Borderline transceivers had spurious suppression that was 3 dB less than or equal to FCC requirements. Figure 3 is an example of a borderline handheld radio. There are three spurious signals that are only a little more than 50 dB below the strength of the fundamental signal. The borderline category was necessary to accommodate measurement tolerances and uncertainty.

Noncompliant transceivers had spurious emission suppression that was more than 3 dB less than FCC requirements. Figure 4 is the spectral plot of a radio that had a second harmonic signal that was only 15.8 dB below the strength of the fundamental! Figure 5 is the plot for a radio that has a second harmonic signal that is only down 37 dB.

Figure 6 shows the plot of another noncompliant radio. In this case you can see that there are multiple spurious signals that are less than 50 dB below the fundamental, including one that is less than 20 dB down. As you can see, this radio is transmitting many fairly strong spurious signals, starting much lower in frequency than the fundamental signal.

A word of caution to those who wish to modify their handheld so it can operate on additional amateur bands (or other frequencies). One gentleman who had his handheld transceiver tested was pleased as punch to tell the ARRL Laboratory booth that he had successfully modified his 2 meter / 70 centimeter handheld radio so it could also transmit on the 1¼ meter amateur band. When measured with a spectrum analyzer, the second harmonic was 14 dB *greater* than the intended fundamental! — *73, Bob Allison, WB1GCM, ARRL Senior Test Engineer*; **ballison@arrl.org**