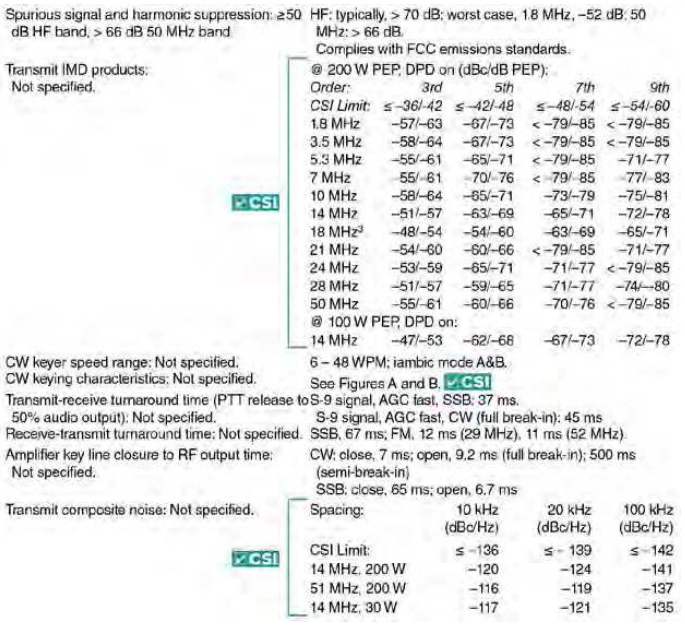
The Launch of the Clean Signal Initiative

The work toward clean HF transmit signals starts now.

George Spatta, W1GKS
ARRL Laboratory Manager

This month marks the official launch of ARRL's Clean Signal Initiative (CSI) and its integration with *QST* Product Review. For decades, HF receiver performance has steadily improved, while transmitter cleanliness has not kept pace. The result has been a long period of CW key clicks, SSB splatter, and excessive composite noise on the HF bands.

The CSI program, conceived by Mike Ritz, W7VO, and Ward Silver, NØAX, was developed by ARRL Lab staff, respected RF experts, and engineers from several manufacturers. All worked to agree on a set of transmitter performance benchmarks that we hope will encourage HF radio manufacturers to improve their designs, thereby closing the performance gap. By introducing clear standards for transmitter signal purity and focused efforts to better educate operators, ARRL is working toward ensuring that modern amateur transmissions occupy no more bandwidth than necessary, improving the experience for everyone on the air. For more information on the origins of CSI and the formation of its Working Group, see "The ARRL Clean Signal Initiative" by Ritz in the June 2023 issue, and "ARRL's Clean Signal Initiative Adopts Metrics for Transmitter Performance" by the CSI Working Group in the May 2024 issue.



Spurious signal and harmonic suppression: Not specified.	HF: typically, > 70 dB; worst case, 1.8 MHz, –52 dB; 50 MHz: > 66 dB. Complies with FCC emissions standards.				
Transmit IMD products: Not specified.	@ 200 W PEP, DPD on (dBc/dB PEP):				
CSI	*Order:*	*3rd*	*5th*	*7th*	*9th*
	CSI Limit:	*≤ –36/–42*	*≤ –42/–48*	*≤ –48/–54*	*≤ –54/–60*
	1.8 MHz	–57/–63	–67/–73	< –79/–85	< –79/–85
	3.5 MHz	–58/–64	–67/–73	< –79/–85	< –79/–85
	5.3 MHz	–55/–61	–65/–71	< –79/–85	–71/–77
	7 MHz	–55/–61	–70/–76	< –79/–85	–77/–83
	10 MHz	–58/–64	–65/–71	–73/–79	–75/–81
	14 MHz	–51/–57	–63/–69	–65/–71	–72/–78
	18 MHz[3]	–48/–54	–54/–60	–63/–69	–65/–71
	21 MHz	–54/–60	–60/–66	< –79/–85	–71/–77
	24 MHz	–53/–59	–65/–71	–71/–77	< –79/–85
	28 MHz	–51/–57	–59/–65	–71/–77	–74/–80
	50 MHz	–55/–61	–60/–66	–70/–76	< –79/–85
	@ 100 W PEP, DPD on:				
	14 MHz	–47/–53	–62/–68	–67/–73	–72/–78
CW keyer speed range: Not specified.	6 – 48 WPM; iambic mode A&B.				
CW keying characteristics: Not specified.	See Figures A and B. CSI				
Transmit-receive turnaround time (PTT release to 50% audio output): Not specified.	S-9 signal, AGC fast, SSB: 37 ms. S-9 signal, AGC fast, CW (full break-in): 45 ms				
Receive-transmit turnaround time: Not specified.	SSB, 67 ms; FM, 12 ms (29 MHz), 11 ms (52 MHz).				
Amplifier key line closure to RF output time: Not specified.	CW: close, 7 ms; open, 9.2 ms (full break-in); 500 ms (semi-break-in) SSB: close, 65 ms; open, 6.7 ms				
Transmit composite noise: Not specified.	Spacing:	10 kHz (dBc/Hz)	20 kHz (dBc/Hz)	100 kHz (dBc/Hz)	
CSI	CSI Limit:	≤ –136	≤ – 139	≤ –142	
	14 MHz, 200 W	–120	–124	–141	
	51 MHz, 200 W	–116	–119	–137	
	14 MHz, 30 W	–117	–121	–135	

Figure 1 — An example of a *QST* Product Review's Table 1 showing CSI badges. These are not actual results; they are for demonstration purposes only.

Overview

The ARRL Lab is central to the CSI program; it will be the *only* lab that can certify a device as being CSI compliant. Devices will need to meet three benchmarks. CSI *badges*, or emblems displayed next to the pertinent test results in each relevant review's Table 1 (see Figure 1), will indicate which devices have met CSI criteria. The overall rating is as follows: gold for meeting all three benchmarks, silver for meeting any two, or bronze for meeting one. Badges (see Figure 2) will appear near the title of the review. If a transmitter does not comply with any of the three CSI benchmarks, no reference to CSI will be made in the review, though the maximum acceptable levels (masks) will still be visible in the relevant graphs. The exception is if a device fails a benchmark by a small enough margin. For example, if there is a difference of 1 dB on one band, it will technically not achieve CSI compliance, but we will point this out in the review's "Lab Notes" sidebar. A device that is that close to earning a badge will still be considered a good performer deserving of a mention. Manufacturers of CSI-certified devices may use the associated graphics on their website, promotional materials, and packaging of the compliant device.

Starting with this issue of *QST*, you will notice some changes and additions to what the Lab reports in Product Review. These changes are discussed in the following sections and summarized in the sidebar, "*QST* Product Review Changes."

Figure 2 — Overall rating designations for a CSI-compliant transmitter meeting three, two, or one of the benchmarks.

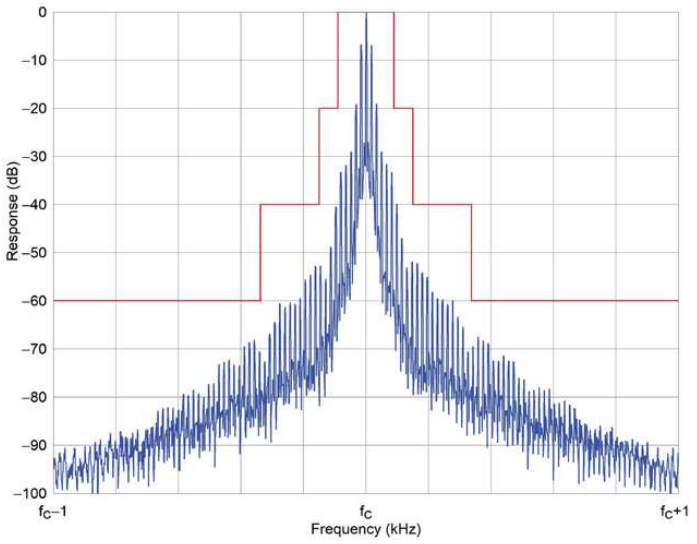


Figure 3 — Spectral plot of a CSI-compliant CW signal. All components of the signal (blue trace) do not exceed the mask (red trace).

CSI Eligibility

For a radio to be considered for any CSI badge, there are two prerequisite provisions. First, the unit must comply with FCC rules for spurious emissions on every band on which it can transmit. Second, the amplifier key-line times (both key down and key up) must prevent the radio from *hot switching* an external power amplifier. Hot switching is when the transmit or receive state of the amplifier changes while RF is still being transmitted. When this happens, the amplified signal occupies a significantly larger bandwidth than it should, causing interference to other users of the band.

The Benchmarks

As determined by the CSI Working Group, three key technical specifications serve as the foundation of CSI's transmitter performance benchmarks: CW bandwidth, two-tone transmit intermodulation distortion (IMD), and composite noise. These metrics were chosen and the benchmarks were formed based on practical on-air observations and rigorous laboratory analysis of modern HF transceivers.

For a radio to be CSI compliant for CW bandwidth and two-tone transmit IMD, it must achieve compliance on every band on which it can transmit. Composite noise must achieve compliance on 20 meters at full power and 30 W (if applicable), as well as 6 meters (if applicable) at full power. Compliance on 20 meters at 30 W describes the typical level required to drive a power amplifier.

Until now, the Lab has graphed certain measurement results on the same band every month to allow for easy product comparisons. Starting with this issue, we

QST Product Review Changes

Starting with this issue of QST*, the ARRL Lab will make the following changes to reported data in* QST *Product Review:*

- A newly added Figure A: a transmit two-tone IMD graph of the worst-performing band referenced to dBc.
- In the transmit "Two-Tone Intermodulation Distortion (IMD)" section of the "Key Measurements Summary," the unit of measurement will be changed to dBc.
- A Figure C CW bandwidth graph will be of the worst-performing band.
- The "Transmit Keying Sidebands" section of the "Key Measurements Summary" will show the maximum and minimum values for the power of keying sidebands in each of the three CSI mask bandwidths for the worst-performing band.
- A "Transmit Composite Noise" section will replace the "Transmit Phase Noise" section in the "Key Measurements Summary." It will show the maximum and minimum values for the composite noise power in the two CSI mask bands for the transmitter at full power on 20 meters.
- Figure D will display composite noise, and phase noise and amplitude noise graphs will be available at **www.arrl.org/qst-in-depth**.
- The "Audio Output" section of the "Key Measurements Summary" will be removed. Audio level comparisons are subjective, so we feel this is no longer needed. We will continue to verify the manufacturer's specifications in Table 1.
- When testing a direct-sampling software-defined radio, where there is no observed blocking, an ADC overload level will be reported in its place.

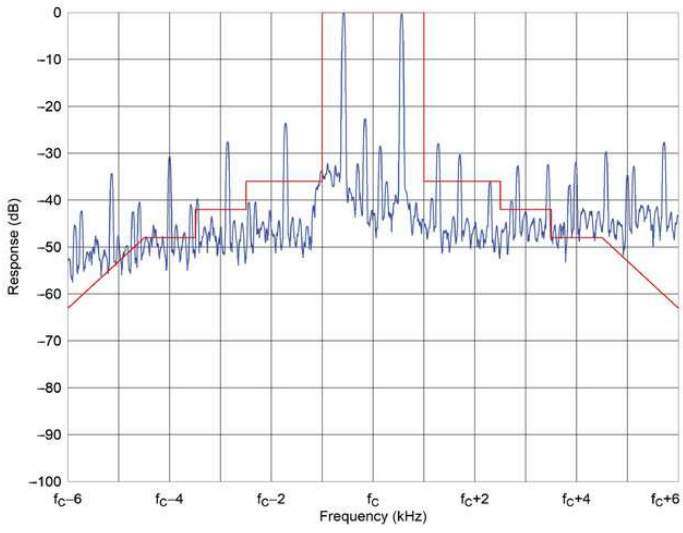


Figure 4 — Spectral plot of a non-CSI-compliant transmit IMD signal. Many components of the signal up to the 11th-order product (blue trace) exceed the mask (red trace).

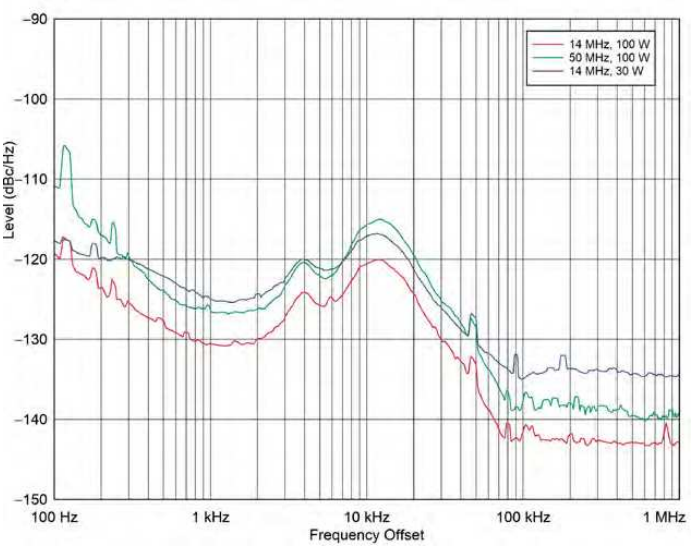


Figure 5 — Example results using data from Table 1 in this article, showing a non-CSI-compliant composite noise graph. All results are higher than the acceptable CSI levels listed in Table 1. These results are for demonstration purposes only.

Table 1 — Example Transmit Composite Noise Results

	10 kHz	*20 kHz*	*100 kHz*
Spacing:	(dBc/Hz)	(dBc/Hz)	(dBc/Hz)
CSI Level:	*≤ –136*	*≤ – 139*	*≤ –142*
14 MHz, 100 W	–120	–124	–141
51 MHz, 100 W	–116	–119	–137
14 MHz, 30 W	–117	–121	–135

will instead publish a graph of the data from the band displaying the worst-case CW bandwidth and transmit IMD measurements. We will still report data for applicable bands in numerical form in the review's Table 1. We will also provide graphs of the data for all bands at **www.arrl.org/qst-in-depth**.

CW Bandwidth

Figure 3 is an example of a CSI-compliant CW bandwidth graph displaying the transmitter output (blue trace) ± 1 kHz from the carrier. The red trace represents the mask for any signal relative to the carrier for CSI compliance. A CSI-compliant CW signal must fall entirely beneath the masks at all frequency offsets and at full output power, while keyed at 40 WPM and with QSK enabled at every available rise-time setting. These thresholds (–20 dBc at 180 Hz, –40 dBc at 300 Hz, and –60 dBc at 675 Hz) ensure that key clicks are significantly attenuated and do not interfere with nearby spectrum, even during contests or crowded band conditions.

Two-Tone Transmit IMD

The IMD mask in the newly added two-tone transmit IMD graph (see Figure 4) limits third-, fifth-, and seventh-order distortion products to –36 dBc, –42 dBc, and –48 dBc, respectively. Higher-order products must exhibit a 6 dB slope, with no product down to the 11th order being worse than that by more than 4 dB. Transmitters that produce IMD products below these limits will generate SSB signals that are much narrower and cleaner than what many transceivers have produced over the past decades. Some recent designs implementing varieties of predistortion have been effective at reducing transmitted IMD.

Composite Noise

Composite noise, comprising phase and amplitude noise components, is the third benchmark adopted by CSI. Composite noise will be measured and graphed on 20 meters at both full power and 30 W, as well as on 6 meters at full power (if applicable). To be CSI compliant, the measured values at specific spacings from the carrier must be less than –136 dBc/Hz at 10 kHz, –139 dBc/Hz at 20 kHz, and –142 dBc/Hz at 100 kHz. Table 1 in this article and Figure 5 show an example of a transmitter that does not achieve CSI compliance; all results are higher than the acceptable CSI limits. Due to the X-axis log scaling of the composite noise graph, a mask trace between 10 and 100 kHz will not be easy to see. So, we will be reporting the actual composite noise numerical data in the review's Table 1 in addition to graphing out to 1 MHz from the carrier. For anyone who wishes to see only the phase noise component for historical comparison, we will provide graphs at **www.arrl.org/qst-in-depth** displaying the phase, amplitude, and composite noise data for both bands.

Currently Available Products

Starting with this issue, every HF transceiver tested in *QST* Product Review will be evaluated for CSI compliance. There are many products on the market that we have already tested, so under certain conditions and at their expense, manufacturers may provide us with a previously reviewed device for CSI compliance testing. Manufacturers will need to contact the Lab to initiate this process, as we will not be looking at past reviews for devices that may be candidates for CSI compliance. We will re-test only for the CSI benchmarks and link any badges/rating to the original review. The Lab's priority will be testing new transceivers, so we will accommodate requests on a first-come, first-served basis and fit them into our schedule as time allows.

Looking Ahead

The standards that the CSI Working Group has developed, coupled with ARRL's testing and badge program, provide guidelines and incentive for transceiver manufacturers to design their equipment to transmit cleaner signals. The ARRL Lab remains committed to providing support to manufacturers and operators to help create a cleaner, more enjoyable HF spectrum. See future issues of *QST* for more technical articles and videos from the Lab in support of the Clean Signal Initiative.