PSC Motion #1 (FINAL)

Moved: Mr. Ritz
Seconded: Mr. Vallio
Mr. Lippert
Ms. McIntyre
Mr. Norris
Dr. Zygielbaum
Mr. Grady

Motion to Adopt the ARRL "Clean Signal Initiative"

Whereas: ARRL denotes itself as "The National Association for Amateur Radio", and,

Whereas: ARRL has an obligation to our members and the amateur radio community at large to ensure the technical advancement and enjoyment of Amateur Radio, as outlined in the ARRL Strategic Plan, and,

Whereas: The ability of amateurs to meet the intent of FCC regulations commensurate with long-standing self-policing by the amateur community would be enhanced by formally addressing transmitted signal purity. Without such guidance, and with the current lack of adequate training materials, the inadvertent emission of poor quality signals can cause interference within the radio amateur service, as well as possibly to other radio services, and,

Whereas: The ARRL Lab, along with experts within the Amateur Radio community, have established formalized testing methodologies and defined practical limits for amateur radio equipment to ensure transmitted signal purity beyond FCC requirements, and,

Whereas: The proposed *ARRL Clean Signal Initiative* seeks to engage ARRL technical staff and volunteer subject matter experts to enhance technical standards for transmitted signal purity of amateur radio equipment, certify new equipment to these standards, and work with manufacturers to ensure compliance with these standards for the good of Amateur Radio worldwide. It also requires that the ARRL address the educational aspect of transmitted signal purity by developing materials to train amateurs in the proper operation of amateur radio transmitting equipment.

Therefore, be it resolved that ARRL formally adopt and promote the concepts and goals of the *ARRL Clean Signal Initiative* as fully outlined in Attachment 1.

Cost; (As outlined in Attachment 1: "**What are the costs of the Clean Signal Initiative**?")

ATTACHMENT 1 – PSC Motion 1   January 2022

An Opportunity Presented: The ARRL Clean Signal Initiative (CSI)

Final REV C- 28 DEC 2021

Submitted to the ARRL Programs and Services Committee, on behalf of the Working Group for Transmitter Cleanliness:

Mike Ritz, W7VO, ARRL Northwestern Division Director, (Chair, Pro Tem)
Kristen McIntyre, K6WX, ARRL Pacific Division Director
Carl Luetzelschwab, K9LA, ARRL Central Division Director
Ed Hare, W1RFI, Manager, ARRL Lab, and Staff Liaison
Ward Silver, N0AX, Lead Editor, ARRL Handbook and Antenna Book
Rob Sherwood, NC0B, Owner, Sherwood Engineering

Abstract:

Observation of the HF bands suggests that many signals exhibit poor signal quality with spurious emissions from distortion of both the RF and information signals that modulate them. This problem exists independently of band congestion and is present for all modes. Initially, it was suggested that sanctioning the transmitting station in some way, through regulation or other operating rules, would provide the incentive to improve signal quality.

After some discussion, however, it was recognized that very few amateurs actually *intend* to transmit poor quality signals, so punitive rules would in reality be ineffective. There has to be a better way to attack the problem. After additional discussion it was decided that the best solution for everyone is to go after the *sources* or root causes of “poor quality signals”: fairly lax FCC rules that lead to compromised commercial transmitter/amplifier design standards for signal purity, lack of education about the technical causes of spurious emissions, and a lack of adequate training regarding how to actually adjust a transmitter and/or amplifier properly.

The proposed **Clean Signal Initiative** (CSI) is a project to clearly define the signal quality problem and present it to the amateur community, along with mechanisms to address and correct the problem. This presents a unique opportunity for the ARRL, the “National Association for Amateur Radio”, to be the definitive technical leader in this regard.

What Are the Root Causes of the Problem?

- Over the years, transmitter signal purity has lagged behind receiver performance (see examples at the end of this document). (Rob, NC0B notes that "*Transmitters have actually gotten worse while RX performance has improved 30 dB or more*".)
- Solid-state amplifiers use MOSFETs with compromised linearity compared to vacuum tubes
- Transmitted composite noise levels are too high
- IMD from misadjusted speech and data modulation in transmitters can be too high
- Keying artifacts (clicks) are a problem in some transceivers (Reference APPENDIX 1)
- The FCC has set maximum values of spurious emissions as outlined in Part 97: §97.307, however, as amateur radio is for the most part self-policing we can do more to address signal purity. (Reference APPENDIX 2, which shows a comparison of FCC Part 97: §97.307 versus current ARRL lab tests)

And importantly, amateurs new to HF operating are less aware of how to properly adjust the transmitter for the cleanest signal on any mode. More experienced amateurs may be unfamiliar with and mis-use the latest technology, particularly solid-state amplifiers.

While a generally cleaner tube linear amplifier can certainly be misadjusted, the only "adjustment" for solid-state amps is drive level. Some solid-state amps rely on an ALC connection which is problematic at best. The I/O curve linearity of LDMOS amps is from mediocre to poor.

Should FCC RM-11828, the "Technician Enhancement" petition be adopted, potentially there could be thousands of new hams on the HF bands with very little training in adjusting their transceivers to optimize signal quality. As a result, education is both key and vitally necessary for amateurs to make the best use of current technology. At the same time, manufacturers need to understand performance expectations of amateurs and deliver equipment that meets those expectations.

Competition forced significant receiver performance improvement by hams voting with their pocketbook. So far this has not happened on the transmit side. "Pre-distortion", a design technique which is known to help with signal purity, is currently a niche feature available from only a few select manufacturers.

What Should Be ARRL's Role in Addressing the Problem?

The CSI is envisioned to be an extension of the ARRL, who has traditionally established performance expectations and educate amateurs on how to meet them. The ARRL has also historically worked with manufacturers to correct design shortcomings and provide validated test metrics and procedures. This strategy has contributed to exceptional receiver performance over the years, now it's time to work on transmitters and amplifiers.

The ARRL must be seen as a credible and responsible institution in defining and correcting problems. Historically, the ARRL Lab and Technical Advisers have taken the lead in addressing these types of performance issues. (A recent example of this is shown in APPENDIX 1) This serves as a tangible benefit for ARRL's membership and raises the profile of the organization as a whole. As our CEO, David Minster, NA2AA, mused: "*If not the ARRL, then who?*"

<u>What Is the Role of the ARRL Lab?</u>

The CSI's associated standards and educational elements must be established as a core HQ function, funded and staffed appropriately within an ARRL Technical Standards Committee.

Creating a package of industry specifications that will affect manufacturers is an open-ended process and will affect product design and development for many years, extending the impact that discussing performance deficiencies in *QST* "Product Review" and other articles has done. The ARRL Lab has established a cadre of volunteers (the Test Review team), advising ARRL on various test methodologies, procedures and upcoming developments that necessitate changes in the testing and reporting that ARRL does. Manufacturers need credible, ongoing contacts and liaisons. As such, the CSI will build on the work of the ARRL Lab and its full-time staff and volunteers. The Test Review Team will provide substantial and expert input on the best ways to test equipment and provide its recommendations on benchmark levels that could be used by the CSI program. The Lab staff will thus provide a stable home in the organization, volunteers and elected officials will come and go but to maintain credibility and adapt to technology changes, it must be a staff function.

Similarly, educating amateurs will be an on-going program to generate publications in various formats. The ARRL Lab staff will work with the ARRL Editorial Team and ARRL Learning Network to help educate amateurs about the CSI program and about the best ways to use their equipment to obtain the maximum performance and on-the-air cleanliness. The ARRL Lab should also work with the National Conference of Volunteer Examiners Coordinators (NCVEC) Question Pool Committee to ensure that appropriate topics are included in the three levels of license exams. The ARRL Lab will be called on to act as a trusted party to resolve disagreements about performance issues.

It is suggested that the ARRL work with IEEE, a well-known and recognized technical standards organization, to form a consensus IEEE Working Group Committee to develop an IEEE Recommended Practice, to formalizing the test methodology that ARRL already does and to document future changes in test methodology that CSI program will help create. The ARRL Lab has an established relationship with IEEE, as Ed Hare, the ARRL Lab Manager, is a member of the IEEE EMC Society Board of Directors, as the elected Vice President for Standards. Ed has indicated that formal documentation through IEEE will be at a minimal cost. The Lab has already had experience with this process, having brought an IEEE Recommended Practice on the resolution of power-line noise to the point at which balloting is imminent. The Working Group for this standard met 100% on webinar meetings, eliminating all travel and most administrative costs. The members of the CSI/Test-Review team will be good candidates for this Working Group.

It is recommended that any IEEE Technical Standards related to amateur radio that are produced by the CSI effort be also branded as "*ARRL Technical Standards*" as to not diminish the fact that these standards are driven by the ARRL for the good of Amateur Radio worldwide.

<u>What Are the Five-Year Goals of CSI?</u>

- Re-purpose the existing ARRL Test Review Team into an ARRL Technical Standards Committee as an extension of the ARRL Lab, including the necessary staff and outside consultants to maintain and represent CSI materials and programs.
- Create core technical performance benchmark standards on a per-parameter basis, maintained by the ARRL Lab, defining metrics and terminology.
- Agree on test procedures and publication of results with major transceiver manufacturers. Add transmitter tests and results to Product Review publications.
- Create a program to certify equipment that passes standards evaluation tests, either as a whole, or by individual parameters.
- Look at the feasibility and desirability of working with the IARU to develop these standards into international standards.
- Create a program within the amateur community for assessing signal purity, including rationale stated in terms of on-the-air effects. Assess whether an organized monitoring function is warranted and/or practical.
- Develop educational materials to explain and instruct on how to meet primary expectations, both technically and operationally, by using their radio controls effectively.
- Report to the ARRL Board bi-yearly on status in conjunction with ARRL Board meetings, outlining on-the-air results, standards and educational deliverables, and resource needs.

<u>Is the CSI supported by the ARRL Strategic Plan?</u>

The Clean Signal Initiative, as an ARRL program, fully supports applicable parts of the ARRL Vision statement, Values, and Strategic Goals as outlined in the 2016-2020 ARRL Strategic Plan. (The most current version of the ARRL Strategic Plan):

ARRL Vision Statement:

> "… *advances radio technology and education*; …"

ARRL's Values:

> Of, by, and for the radio amateur: "*…We are committed to using our skills, experience and resources for the benefit of our members and the worldwide Amateur Radio Community now, and for future generations…"*
>
> Excellence: "*We encourage and support high standards in all aspects of Amateur Radio, including technological innovation, operating practice and etiquette, signal quality…."*

Strategic Goals:

Initiative 2.2: *"Sustain ARRL's status as the most trusted, respected, impartial, and enduring source of information about amateur radio.*

Initiative 3.4: "*Reduce spectrum pollution*."

Initiative 4.1: *"Cultivate a climate of innovation that advances the art, science, and practice of Amateur Radio."*

Initiative 4.3: *"Provide technical information and operating guidance that contributes to more skillful, active members."*

<u>What are the Costs of CSI Program?</u>

It is believed that the first several years of the program should not exceed $50,000 total in additional recurring and non-recurring costs, (including capital equipment), and very likely much less. Ed Hare believes most of the work can be handled with a combination of subject matter expert volunteers and existing staff, at minimal additional costs. Ed believes their current inventory of test equipment required to perform any additional parametric tests set in upcoming standards is adequate for the foreseeable future. Along with defining CSI's necessary structures and tasks, one of the start-up deliverables will be a cost estimate for sustaining the program once mature.

At the front end, some of the standards research and development efforts can be performed by volunteer ARRL Technical Standards Committee members. Most of the tests performed by the ARRL Lab that measure amateur radio equipment performance for technical specifications, (such as signal purity under a variety of conditions), are already very well defined and documented. That said, exact pass/fail benchmarks are not well established.

At this time, it is impossible to determine if any additional Lab technical personnel or administrators will be needed to complete the tasks to meet the CSI Five-Year Goals outlined above, and that is where the majority of the expected additional costs will be found. There will most likely be costs associated with developing educational materials through the ARRL Lifelong Learning Program as well, but those numbers are not known at this time.

In any case, these costs can be somewhat offset by an increase in membership revenues brought in by amateurs that believe the ARRL is "doing right by Amateur Radio" by providing this service as a member benefit. The tangential benefits gained by the ARRL by demonstrating leadership in the area of technical standards and education cannot be understated.

Transmitter Signal Purity References

Transmitter Phase Noise Comparison: **http://k9yc.com/TXNoise.pdf.** This is a very well-done analysis of current transceivers, including test methodology, and using data from the ARRL Lab's Bob Allison who was doing all of the Product Review testing. ARRL Lab staff is currently performing these tests and storing the measured data. Pages 8 and 9 are particularly germane to CSI, including a how-to-test summary and the use of pink noise or band-limited white noise, (as the ARRL Lab decides is most suitable), in addition to a two-tone test for IMD measurements. The ARRL Lab staff should investigate this test methodology and determine how to incorporate it into the transmitter test battery that is currently performed.

Clean Transmitting: **http://k9yc.com/K6XXAmpTalk.pdf.** This is a presentation on clean transmitting by Elecraft design engineer Bob Wolpert, K6XX.

Amplifier IMD Comparison, (APPENDIX 3 of this document): This table and chart was developed based on test results by the ARRL Lab (Bob Allison, WB1GCM). The chart illustrates a way to show how on-the-air performance is affected by amplifier linearity. (Red-yellow-green levels were selected with the advice of the ARRL Lab's Test-Review team and Lab staff to represent the general level of the best equipment tested to date and what was deemed to be a minimal usable level of performance and to illustrate the idea of creating performance thresholds.)

Addendum insert by Rob Sherwood, NC0B

In the case of key clicks, many modern transceivers have a menu for rise time adjustment. Whether the CW envelope is created using a raised cosine or a sigmoid doesn't change the bandwidth much. At least the amateur has the option to select 6ms instead of 1, 2 or 3ms. Education of the transceiver owner is key to making a reasonable menu selection, as is convincing the OEMs to stop offering menu selections that are unreasonable choices.

As to IMD splatter, I don't see "transmitter adjustment" as much of a solution. While one may argue that the 5th order product is more significant to excessive bandwidth, most hams currently focus on the third-order value. Let's make a few general observations.

If we look at tube or hybrid transmitters/transceivers (hybrid = a tube driver and tube PA in an otherwise solid-state rig), the third-order IMD variation from the best to the worst is about 10 dB. What is significant is how much faster odd-order IMD products fall off compared to a solid-state PA.

If we look at current 13.8 volt solid-state rigs, the third-order IMD variation from best to worst is again about 10 dB. What is stunning is a legacy tube PA has about half the splatter bandwidth of a solid-state PA. At -60 dB below the PEP level, a legacy rig is about 20 kHz wide while a modern solid-state PA is about 40 kHz wide. While we would rarely have a 60 dB S/N ratio for splatter comparisons, the 2:1

bandwidth difference between legacy tube PAs and 13.8 volt solid-state PAs still exists at -30 dB for example.

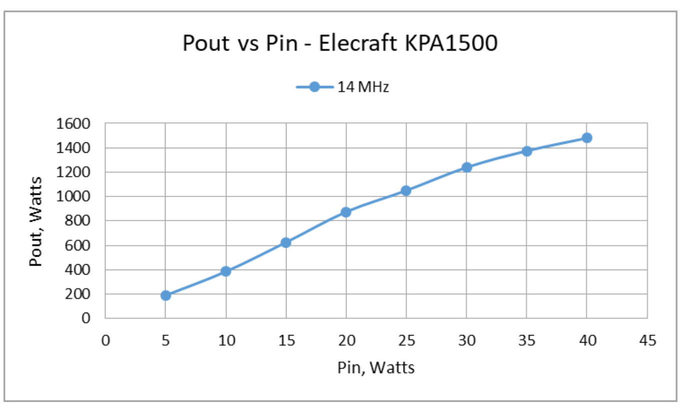
There isn't much to adjust other than in some cases the level of ALC. If the ALC time constant is too fast the ALC does increase transmit bandwidth. In other cases the amount of ALC has minimal effect. Adjusting knobs full clockwise may make the in-band signal of poor quality, but bandwidth may not change much. Likewise, excessive speech processing may ruin the in-band signal quality; it rarely significantly affects transmit splatter.

Comparing IMD of a tube linear amp to an LDMOS "linear amp" is at least 10 dB if not 20 dB worse by ARRL published data. Other than adjusting drive level, there isn't much the amateur can do reduce the splatter from an LDMOS amp. In the case of the Acom 600S and 1200S, the I/O curve at rated SSB output produces an unacceptably wide signal.

Pre-distortion right now is a one-OEM offering though both Flex and Elecraft keep promising to provide this feature. The two splatter solutions appear to only be providing a better way to monitor amp overdrive, plus the longer-term promise of pre-distortion.

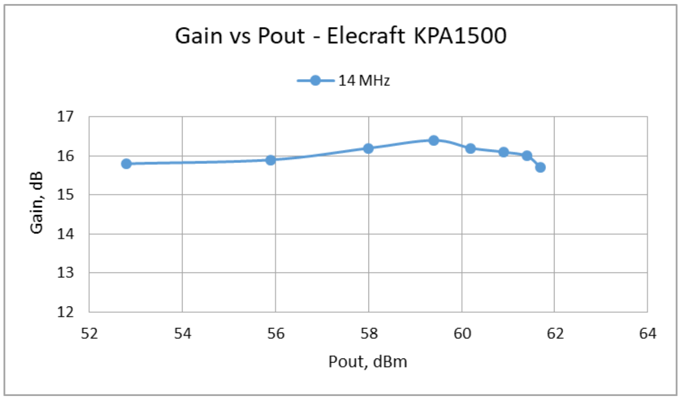
Addendum Insert by Carl Luetzelschwab, K9LA

The characterization of an RF power amplifier (PA for short) is usually plotted in terms of the output power (Pout) n Watts versus the input power (Pin) in Watts. The straighter the Pout vs Pin line, the better the linearity of the PA (in terms of intermodulation distortion – *see note 1*). But it can be tough to judge how straight the Pout vs Pin line is since it's generally at an approximate 45° angle. Here's Pout vs Pin on 14 MHz for the Elecraft KPA1500 amplifier from data in the March 2019 Product Review in QST:



You can eyeball a straight line on this plot, and you'll conclude that the Pout vs Pin data does deviate from the straight line. But what does that mean?

To answer this question, a better way to characterize a PA is to use the same data from the Pout vs Pin plot, but plot Gain in dB vs Pout in dBm. Here's that plot for the KPA1500 on 14 MHz:



Now the determining factor for linearity is how flat the gain is until compression begins (when the Gain rapidly decreases). A Class A PA will have extremely flat gain until compression begins and this results in excellent linearity. The KPA1500 exhibits about a half dB of gain expansion just before compression begins, and this tells us this is a Class AB PA. This small amount of gain expansion should still result in good linearity, and this is confirmed by the 2-tone measurements in the Product Review.

A final comment is in order. Amplifiers are usually evaluated into a 50 ohm load. In the real world at your station, your antenna may not be 50 + j0 ohms. Under this condition, the linearity may be a bit better or it may be a bit worse.

Note 1 – A common linearity test is a 2-tone test. A better measurement is a Noise Power Ratio test, or equivalent.

APPENDIX 1- AN EXAMPLE OF THE ARRL LAB WORKING WITH A MANUFACTURER TO MITIGATE AN EMISSION ISSUE FOUND DURING TESTING

(QST Sidebar by Bob Allison, WB1GCM, June 2021 QST /ARRL Lab Review of Yaesu FTdx-10)

Below is an example where the ARRL Lab found an issue with transceiver settings that could potentially cause CW "key-clicks", (ie: wide sidebands), due to excessively fast rise time settings with a new product (Yaesu FTdx-10) under review. The Lab worked with the manufacturer to resolve the issue. (Note that there are currently no FCC specifications for CW rise times, however excessively fast CW rise times are known to be a major cause of key-clicks):

Transmitter performance is very good. Transmit phase noise is low, especially at the 30 W level, an RF output level typically used for driving a linear amplifier. Transmit IMD products are reasonably low, too.

As with many of today's transceivers, CW bandwidth varies with the **CW RISE TIME** menu setting, where the user can select the rise/fall time of the CW waveform. With the original firmware, the FTDX10 menu offered choices of 1, 2, 4, and 6 milliseconds rise time, as found on other current Yaesu models. After reviewing data and comments from the ARRL Lab that showed wide keying sidebands with the 1- and 2-millisecond settings, Yaesu modified the firmware (Main V01-05) to eliminate the 1- and 2-millisecond settings, add an 8-millisecond setting, and change the default to 6 milliseconds. (The Lab measured the actual rise/fall times for these settings to be 2.7/3.9, 4.2/4.6 and 5.4/6.6 milliseconds for the 4-, 6-, and 8-millisecond menu settings.)

Figures A and B elsewhere in this review show the CW waveform and bandwidth using the default setting of 6 milliseconds. A document comparing the FTDX10's CW keying waveform and bandwidth at all three current settings is available from **www.arrl.org/qst-in-depth**. You can see that the transmitted bandwidth is good at all three settings and that the transmitted signal narrows as the rise time setting increases. We are very pleased that Yaesu made these changes.

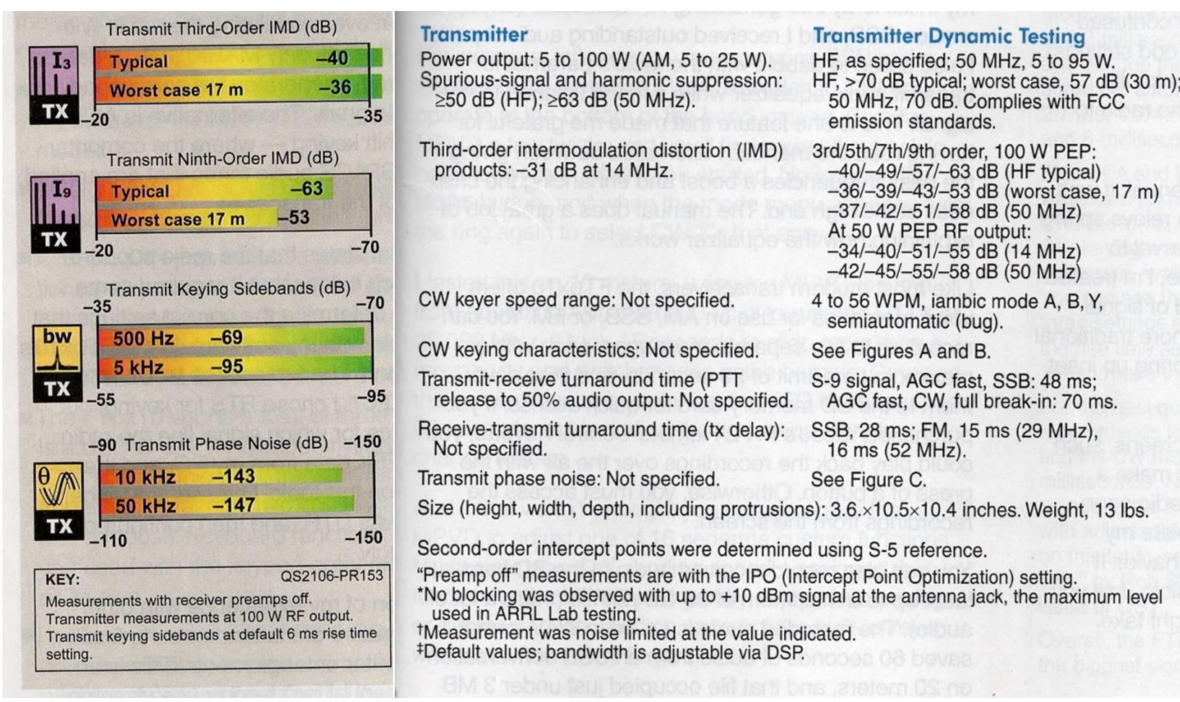
For the best quality transmitted signal, the ARRL Lab recommends loading the Main V01-05 firmware and setting the **CW RISE TIME** in the **MODE CW** menu to 6 or 8 milliseconds. Note that this recommendation is not unique to the FTDX10 and applies to any transceiver with adjustable rise time settings. For more information on this topic, see "It's Time to Clean Up our Transmitters," by Rob Sherwood, NCØB, in the November 2019 issue of *QST*.

APPENDIX 2 – Comparison of FCC Part 97: §97.307 verses Current ARRL Lab Tests

Here is what FCC Part 97:§97.307 has to say about amateur radio spurious emissions for current products:

> **d) For transmitters installed after January 1, 2003, the mean power of any spurious emission from a station transmitter or external RF power amplifier transmitting on a frequency below 30 MHz must be at least 43 dB below the mean power of the fundamental emission.**
>
> **(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.**

On the other hand, below is an example of published results of ARRL Lab testing preformed on a Yaesu FTdx-10, extracted from the June 2021 issue of QST magazine. Note that there are no hard benchmarks indicated, just relative “red (bad) to green (good)” areas on the graphs. As a part of CSI, the new ARRL Technical Standards Committee will be tasked with establishing appropriate benchmarks for each parameter as appropriate, and possibly adding new test parameters;



Transmitter	Transmitter Dynamic Testing
Power output: 5 to 100 W (AM, 5 to 25 W).	HF, as specified; 50 MHz, 5 to 95 W.
Spurious-signal and harmonic suppression: ≥50 dB (HF); ≥63 dB (50 MHz).	HF, >70 dB typical; worst case, 57 dB (30 m); 50 MHz, 70 dB. Complies with FCC emission standards.
Third-order intermodulation distortion (IMD) products: –31 dB at 14 MHz.	3rd/5th/7th/9th order, 100 W PEP: –40/–49/–57/–63 dB (HF typical) –36/–39/–43/–53 dB (worst case, 17 m) –37/–42/–51/–58 dB (50 MHz) At 50 W PEP RF output: –34/–40/–51/–55 dB (14 MHz) –42/–45/–55/–58 dB (50 MHz)
CW keyer speed range: Not specified.	4 to 56 WPM, iambic mode A, B, Y, semiautomatic (bug).
CW keying characteristics: Not specified.	See Figures A and B.
Transmit-receive turnaround time (PTT release to 50% audio output: Not specified.	S-9 signal, AGC fast, SSB: 48 ms; AGC fast, CW, full break-in: 70 ms.
Receive-transmit turnaround time (tx delay): Not specified.	SSB, 28 ms; FM, 15 ms (29 MHz), 16 ms (52 MHz).
Transmit phase noise: Not specified.	See Figure C.

Size (height, width, depth, including protrusions): 3.6×10.5×10.4 inches. Weight, 13 lbs.

Second-order intercept points were determined using S-5 reference.
“Preamp off” measurements are with the IPO (Intercept Point Optimization) setting.
*No blocking was observed with up to +10 dBm signal at the antenna jack, the maximum level used in ARRL Lab testing.
†Measurement was noise limited at the value indicated.
‡Default values; bandwidth is adjustable via DSP.

APPENDIX 3

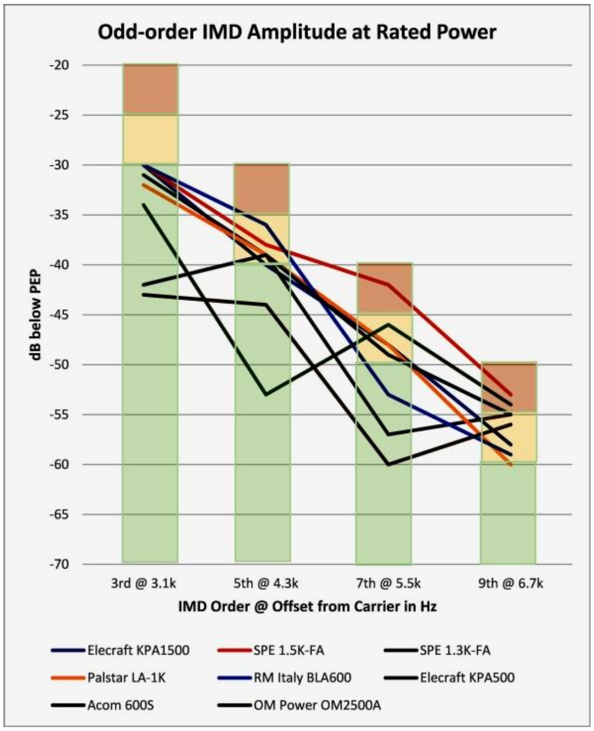
Amplifier IMD Comparison Chart

7/7/2020 Ward Silver, N0AX

Based on ARRL Lab measurements

Product	3rd @ 3.1k	5th @ 4.3k	7th @ 5.5k	9th @ 6.7k	Power Out (W)	Notes
Acom 1200S	-34	-33	-47	-64	1000	
Elecraft KPA1500	-30	-40	-48	-58	1500	
SPE 1.5K-FA	-30	-38	-42	-53	1500	
SPE 1.3K-FA	-31	-39	-57	-55	1200	
Palstar LA-1K	-32	-39	-48	-60	1000	
RM Italy BLA600	-30	-36	-53	-59	500	
Elecraft KPA500	-34	-53	-46	-54	500	
Acom 600S	-42	-39	-49	-55	600	
OM Power OM2500A	-43	-44	-60	-56	2500	Tube amp

	3rd	5th	7th	9th
Solid state average	-32.875	-39.625	-48.75	-57.25
Difference from tube	10.125	4.375	11.25	-1.25



Current Transceiver Performance Measurements: two graphs from a complete set of transmitter noise measurements published in Jan 2021 by a group of Slovenian contest operators and station owners:

http://lea.hamradio.si/~s53ww/TX%20noise/TX_noise.html?fbclid=IwAR0iwTRMPVobIHPqY9YJDMISdLN5j872ujhvrf_AtVogXHrz2U19Jv4OV2Y