Taming a Small Generator/Inverter with RFI Noise for Field Day

A number of small generator/inverters are available that weigh only 20 to 30 lbs and are rated at 700 to 1000 Watts continuous duty. There are also a number of units rated around 2000 Watts typically weighing 35 to 50 lbs. The units considered here have 4-cycle engines and will run for 24 hours on only several gallons of gas at an average load of 50%, partly due to the efficiency of a generator/inverter design. Some can be purchased for less than $300. So they appear to be very attractive for ARRL Field Day, emergency communications and portable operations since they are so light in weight, sip gas very meagerly, and are fairly low cost.

The solution described in this article was first used for Field Day 2023 by the Antietam Radio Association with a noisy Sportsman GEN1000i powering the CW rig. It produced excellent results with no detected interference at the CW setup and no noticeable interference at the 20 meters phone rig powered by a separate generator. Previous years showed significant interference on 80 meters CW during receive mode and on 20 meters phone during receive mode and when CW was transmitted. It appears that substantial interference was previously coupled out of the Sportsman generator and then radiated by the 200 feet of power cable connecting power to the CW rig.

A serious downside of generator/inverters is the inverter which uses high power switching circuits and is likely to generate significant RFI, especially for lower frequencies of operations such as 160 and 80 meters. This problem is readily addressed with RFI filtering of differential and common mode noise combined with good grounding and bonding. However, a simple and high performance solution may not be entirely obvious. This article presents receiver noise measurements with and without RFI suppression and conducted emissions test results, and a simple effective solution is discussed for generator/inverters. This article adds to earlier work on generator/inverter RFI found here: http://www.ka2c.com/wp-content/uploads/2020/04/RFI-Management-for-Field-Day.pdf . By minimizing grounding impedance at the generator combined with an appropriate external RFI filter and common mode choke, common mode RFI noise and differential RFI noise are strongly attenuated resulting in elimination of measurable or noticeable generator noise at the HF rig. Placement of the generator and power cable away from antennas and perpendicular to antennas for cross-polarization isolation also is helpful.

Previous Work on Generator/Inverters and EMI/RFI

The June 2012 QST edition contains a review of 4 generator/inverters that were available at that time. They weighed 40 to 50 lbs and provided 1600 to 2000 Watts of continuous power, so about 2x the weight and 2x the output power of the light weight units considered in this article. RF noise was also found to be a major issue with generator/inverters in the 2012 QST article, especially on 160 and 80 meters, and using RFI filters was discussed. General EMI/RFI problems and solutions are discussed in the ARRL Handbook and in the ARRL book “Grounding and Bonding for the Radio Amateur”. K9YC, Jim Brown, and others have addressed this problem. An in depth practical discussion of grounding and EMI problems can be found in a presentation by Prof. John McNeill: https://users.wpi.edu/~mcneill/papers/cpe/Lecture_1_(offering_4)_annotated_mod_1_day_2.pdf .

The discussion there on grounding impedance; differential and common mode noise; and low frequency versus high frequency ground and noise issues is useful to understand and address generator/inverter noise and grounding/bonding. Some other work on generator/inverter noise can be found here: https://www.n1kdo.com/inverter-generator-filter/index.html and https://qsl.net/nf4rc/2019/InverterGeneratorSolutions.pdf .

Small Generator/Inverter Units

The first unit that was used for testing and RFI fixes in this article is the Sportsman Gen1000i. It is rated at 1000 Watts surge power and 800 Watts continuous duty. It is 16 x 15 x 9 inches in size and weighs only 21 lbs without fuel. It is rated to run for 6.3 hours at 50% loading with a 0.55 gallon gas tank. Its price range is about $300. A second similar unit is the Powersmart PS55. It is slightly larger and can output a bit more power than the Gen1000i. A third unit is the AIMS GEN800W unit. It weighs 25 lbs and is rated at 800 Watts surge power and 700 Watts continuous duty. Another unit is the Honda EU1000i which weighs about 29 lb and is rated at 1000W surge and 900 W continuous power (however it is priced at about $950). Other similar units are available that can power 1 to 3 radios capable of 100W of RF output on the HF bands while weighing only about 20 to 30 lbs and use small amounts of gas. While the RFI issue with various units is expected to vary, it is likely that almost all, if not all, of these small units will have some level of RFI problems for HF operations. Some previous articles gave high marks for Honda generators, although they come with a price premium and are likely to have at least some residual RFI issues, especially on 160 and 80 meters.

We also looked at larger units and with the help of Jeff Addleman, W3ADD, a Generac GP2500i was obtained and tested and a Honda EU2000i was obtained and tested. The Honda EU2000i was tested in the June 2012 QST article, so it is useful to compare the results.

Generac, Sportsman and Honda generators that were tested

The Gen1000i was used for ARRL Field Day for CW operations the last few years by the Antietam Radio Association, W3CWC, with good results and without any RFI filtering except that generator hash noise on 80 meters was substantial. Noise on 40 meters through 10 meters was not significant for us. However, we were able to live with the noise, and still made many contacts on 80 meters. But during Winter Field Day 2023, we also used the Gen1000i to power 2 radios with operations on 160 meters added as well as phone operations (we did not include the RFI filtering from our earlier work on this problem). We soon realized that 160 meters was unusable due to hash noise and that 80 meters phone was also very difficult. So a decision was taken to revisit this problem and focus on a good solution to the RFI problems caused by the inverter in the small generator/inverter for the future, and for Winter Field Day 2023 we switched to a conventional higher power generator with no inverter for nighttime operations on 160 and 80 meters.

Three types of tests were conducted for 3 generators, the Sportsman Gen1000i, the Generac GP2500i and the Honda EU2000i. They are in price classes of $300, $650 and $1200. A Honda EU1000i generator is also available at price class $950. The first set of measurements was to measure RFI noise using the S-meter on the FTDX101D used in KA2C's radio shack, and also using the nearby antennas on 80, 40 and 20 meters with various configurations for the generators The second set of measurements was to measure the acoustical noise of the generators using an application on an Android smartphone. The third test was to measure the conducted emissions of the generators using a TinySA Ultra spectrum analyzer..

RFI Noise Measurements using an FTDX101D and KA2C's antennas

Generator test May 10, 2023

Generators under test:

- Sportsman Gen1000i – 800 Watts running - 22 lbs
- Honda EU2000i - 1800 Watts running – 47 lbs
- Generac GP2500i - 2000 Watts running - 48 lbs

Test 80/40/20 meters (80/40 inverted vees and tribander on 20 meters pointed south) – KA2C QTH

Test 2 generator locations: - 80 and 40 meter inverted vees share an apex support tower and are approximately at 90 degrees

1) Power cable parallel to a 40 meters inverted vee leg with 100 feet extension cord
2) Power cable parallel to an 80 meters inverted vee leg with 100 feet extension cord, but the other 40 meters leg not widely separated

test with these conditions

1) Commercial mains – generator OFF – baseline noise levels – ck for any local noise sources
2) Generator running with power cable – rig on commercial mains – no filters
3) Generator running and powering the rig - no filters
4) Generator running and powering the rig - no filters – generator NOT grounded
5) Generator running and powering the rig – commercial EMI filter
6) Generator running and powering the rig – common mode choke
7) Generator running and powering the rig – commercial EMI filter & common mode choke
8) Generator running and powering the rig – commercial EMI filter & common mode choke with added 500 Watt load
9) Generator running with ground but no filters and loaded at about 400 Watts - rig running from the commercial mains - No wired connections from generator to the rig

All Cases except 4) are with the generator grounded to a local earth ground rod

Receiver is FTDX101D set to SSB mode, preamp set to 1, and no front end attenuation – Samlex 1235 switching power supply – S units on the FTDX101D correspond to 3 dB which is normal for Yaesu rigs

Turn OFF noise sources: shack PC, shack lights, shack Mr Cool, electric farm fencer, electric farm fencer meters, power switching well - check for any thunderstorms within 500 miles +-

Location 1 - Measured S levels

Sportsman

Case #	3.530	7.030	14.030
1	2.5	5	0
2	7.5	5	0+
3	9+5dB	9+5dB	3.5
4	3	9	3.5
5	3.5	5.5	0+
6	9+5dB	9+5dB	0
7	2.5	5	0
8	2.5	5	0
9	9+5dB	9+2dB	3.5

Honda

Case #	3.530	7.030	14.030
1	2.5	5	0
2	2.5	5	0
3	2.5	5	0
4	2.5	5	0
5			
6			
7			
8			

Generac

Case #	3.530	7.030	14.030
1	2	4.5	0
2	2	4.5	0
3	3	5	0
4	2.5	5	0
5	2	5	0
6	3	5	0
7	2	5	0
8	2	5	0
9	3	4.75	0

Location 2 - Measured S levels

Sportsman

Case #	3.530	7.030	14.030
1	2	4.5	0
2	9+5dB	4.5	0+
3	9+15dB	9	2
4	9+10dB	9	3
5	6	5	0+
6	9+10dB	9	1
7	2	4.5	0
8	2	4.5	0

Honda

Case #	3.530	7.030	14.030
1	2	4.5	0
2	2	4.5	0
3	2.5	5	0
4	2.5	5	0
5	2	5	0
6	2.5	5	0
7	2	5	0
8	2	5	0

Generac

Case #	3.530	7.030	14.030
1	2	4.5	0
2	2.5	4.5	0
3	4	5	0
4	3	5	0
5	2	5	0
6	3	5	0
7	2	5	0
8	2	5	0

Several very weak birdies in the noise heard on 20 meters with the Sportsman generator – even with filters – about 30 KHz spacing - 0+ indicates weak buzz heard but overall noise level is S0

Acoustical Noise Measurements – Location 1

Test acoustical noise level with Moto G6 Pro Android phone running Sound Meter App at 7 meters (about 23 feet) or standard test distance, 50 feet and 100 feet

Sportsman - spec is 56 dBA – no load

Case #	level
7 meters (23 feet)	60
50 feet	50
100 feet	42

Honda - spec is 53 dBA – ¼ load

Case #	level
7 meters (23 feet)	58
50 feet	48
100 feet	40

Generac - review is 60 dBA – ¼ load

Case #	level
7 meters (23 feet)	62
50 feet	52
100 feet	44

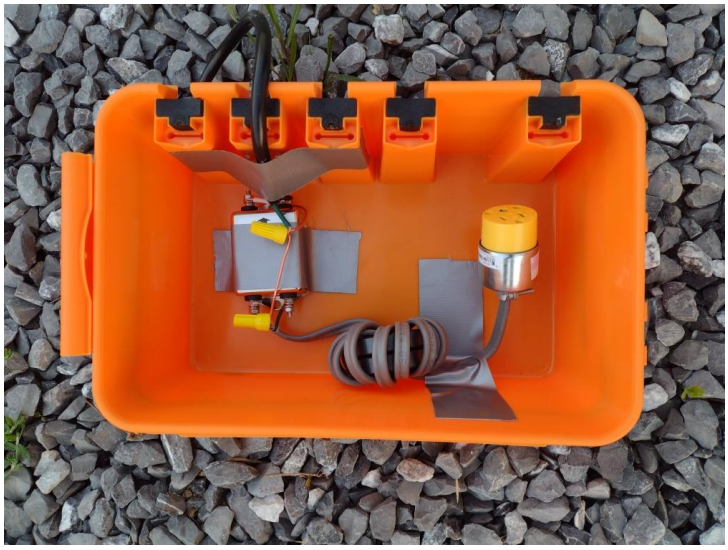
Conducted Emissions Tests

Using a TinySA Ultra, conducted emissions tests were performed on the 3 generators under 4 conditions for each generator. Conducted Emissions testing is specified by the CISPR 25 standard. For testing a generator, the setup turns out to essentially be capacitive coupling the hot wire of the generator to a spectrum analyzer to measure 150 KHz to 30 MHz. For other types of tests such as a switching power supply, a LISN (Line Impedance Stabilization Network) is needed to isolate the AC power line from the power supply and properly couple the emissions from the power supply to the spectrum analyzer. For accurate results down to 150 KHz, a capacitor of 0.1 uF is appropriate, but I used a 0.01 uF capacitor which is OK for 1 MHz and higher frequencies.

Key settings for the spectrum analyzer are 150 KHz to 30 MHz range with a filter bandwidth of 9 KHz (I used 10 KHz with the TinySA Ultra). The units are set to dBuV with a reference level of 100 dBuV (top of screen). And the mode is set to Quasi-Peak. The TinySA Ultra does not support the 9 KHz filter bandwidth, so this is not consistent with the test specifications, but it should actually cause the results to be slightly higher (order of 1 dB) than results fully consistent with the specifications.

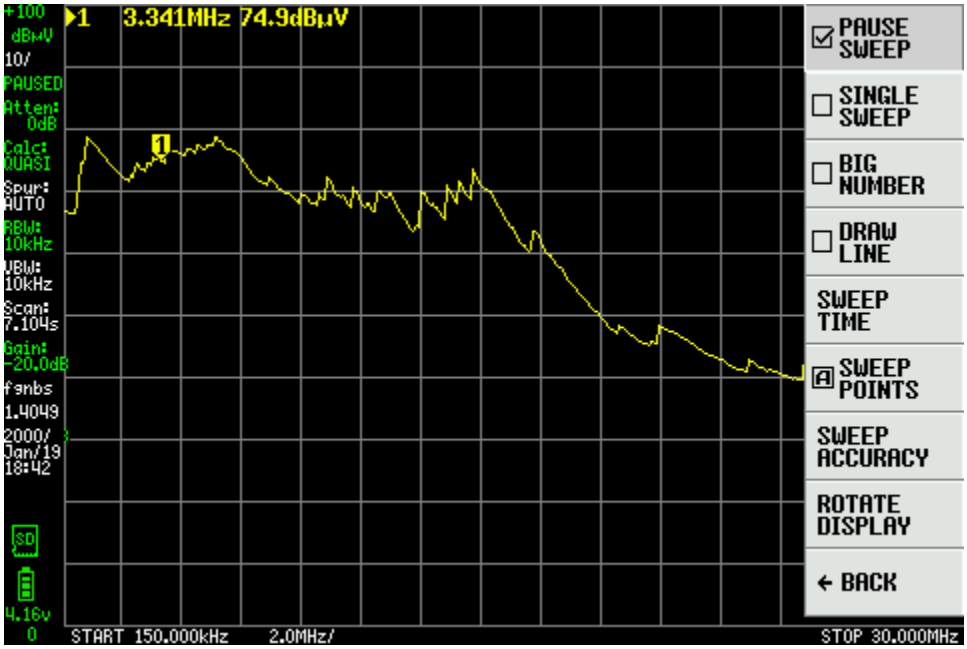
I found that the USB interface with a cable connected to a PC laptop injected some noise into the TinySA Ultra. So, the traces were captured with the USB cable disconnected and then "paused". Then after connecting the USB cable, each capture was downloaded to a laptop.

For these tests, a dual filter was used to obtain results with and without RFI filtering. The filter is shown in the picture below with the waterproof container's lid removed. It consists of a commercial EMI/RFI filter, a CW4L2-20A-S, which is available on Amazon for only $16. It has 2 common mode filter inductors in series on the hot and neutral wires with bypass caps at the input, between the inductors and at the output to ground and between hot and neutral to suppress both common mode and differential mode noise. It is rated at 50 to 65 dB of suppression for both noise modes. However, it is important to remember that it does not suppress any RF currents on the ground wire itself, but it does strongly suppress RF on the hot and neutral wires. This filter was followed by an RF choke implemented by using a pair of FT240-43 toroid cores (FT240-31 cores can provide higher inductance) with a power cable wrapped with 9 turns on the toroid cores. These filters are placed in an outdoor waterproof container. An outlet is inside the container, so that in the field, a long extension cord can connect inside the container and then go to the operating position, and a short 1 feet cable with a plug goes to the generator placed next to the RFI filter. This arrangement minimizes RF current from reaching the long power cable where it would be partly radiated and partly conducted to the rig at the other end of the power cable. Notice the connecting ground wire across the RFI filter, but the hot and neutral wires go through the filtering circuits. The RFI filter must be closest to the generator to have a low impedance ground connection to the inverter in the generator/inverter, and the RF choke immediately follows it prior to the long power cable to the operating position to impede RF current on all wires.

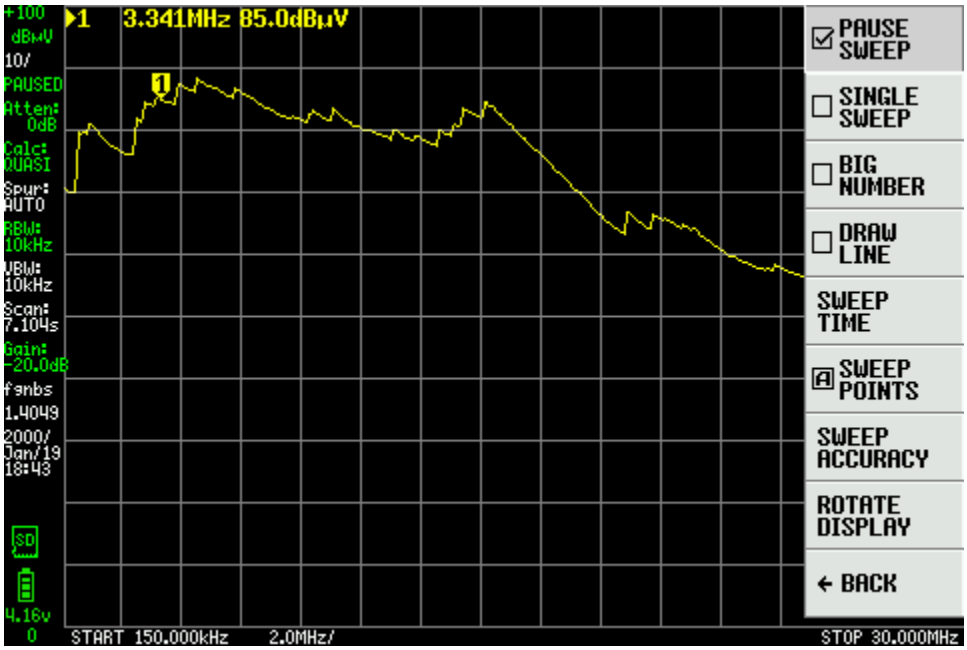


The 4 conducted emissions tests for each generator were as follows:

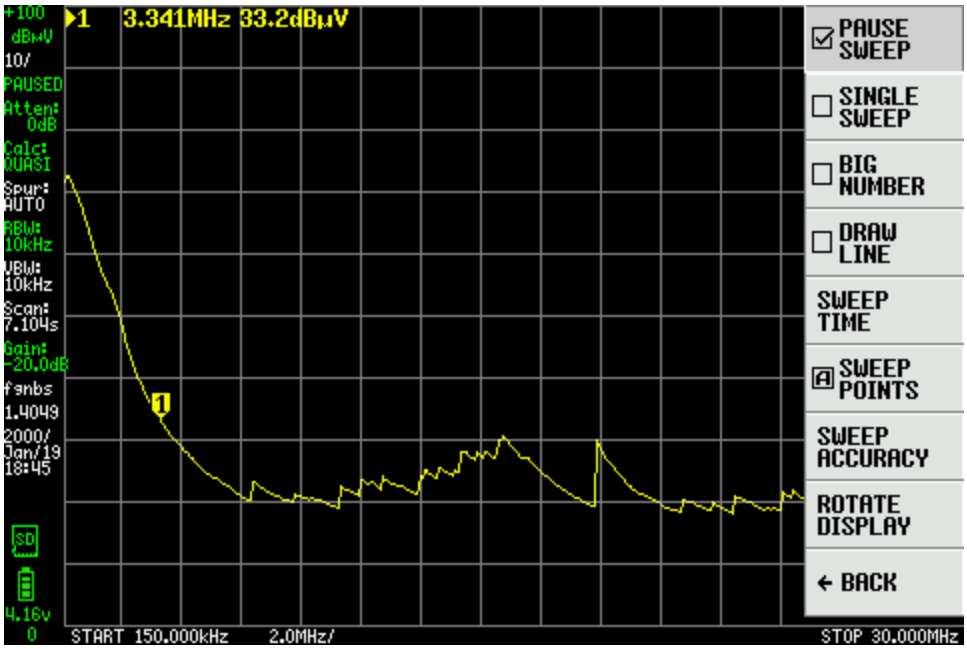
1) Generator with no load
2) Generator with a 400 Watt load
3) Generator with a dual filter with no load
4) Generator with a dual filter with a 400 Watt load



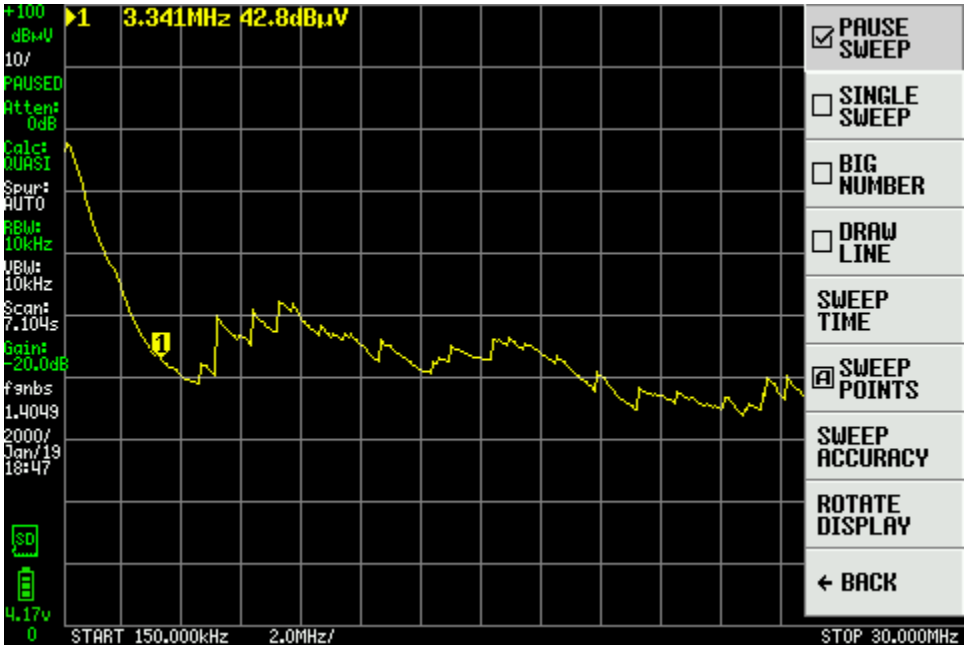
Sportsman with no load



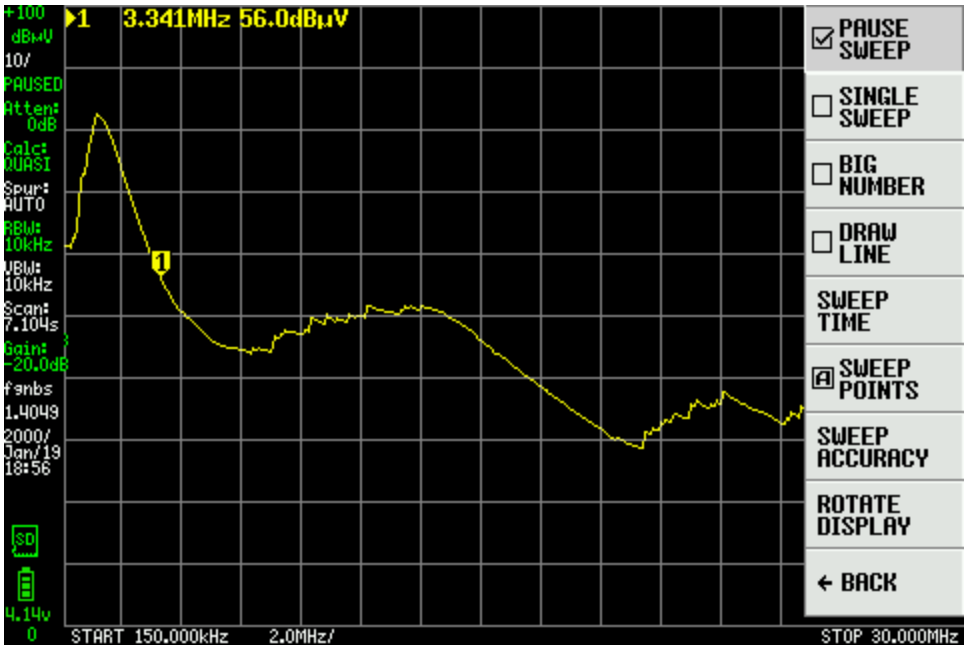
Sportsman with 400 Watt load



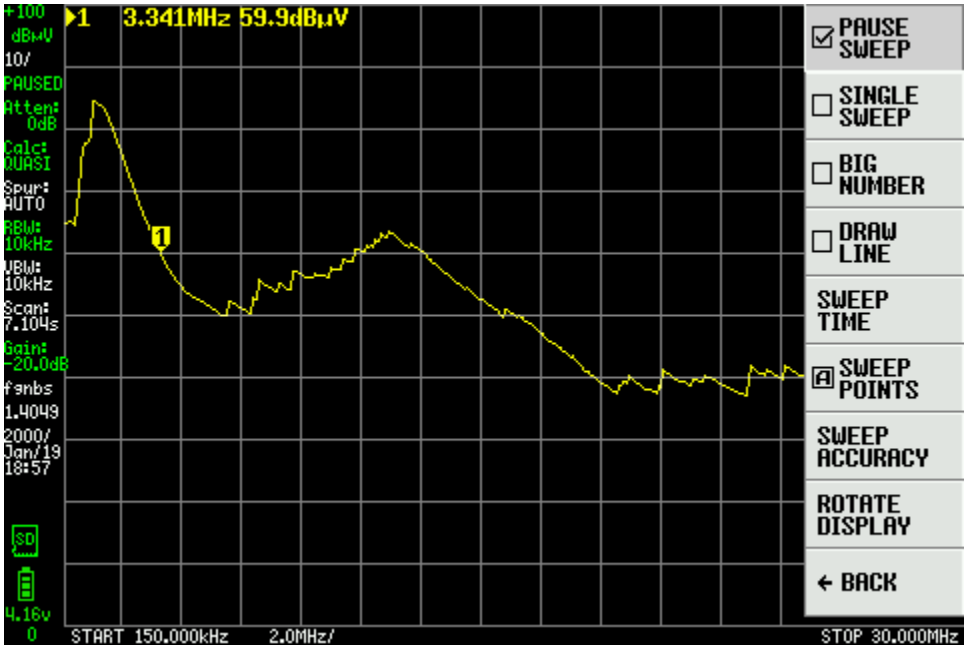
Sportsman with no load and the dual filter



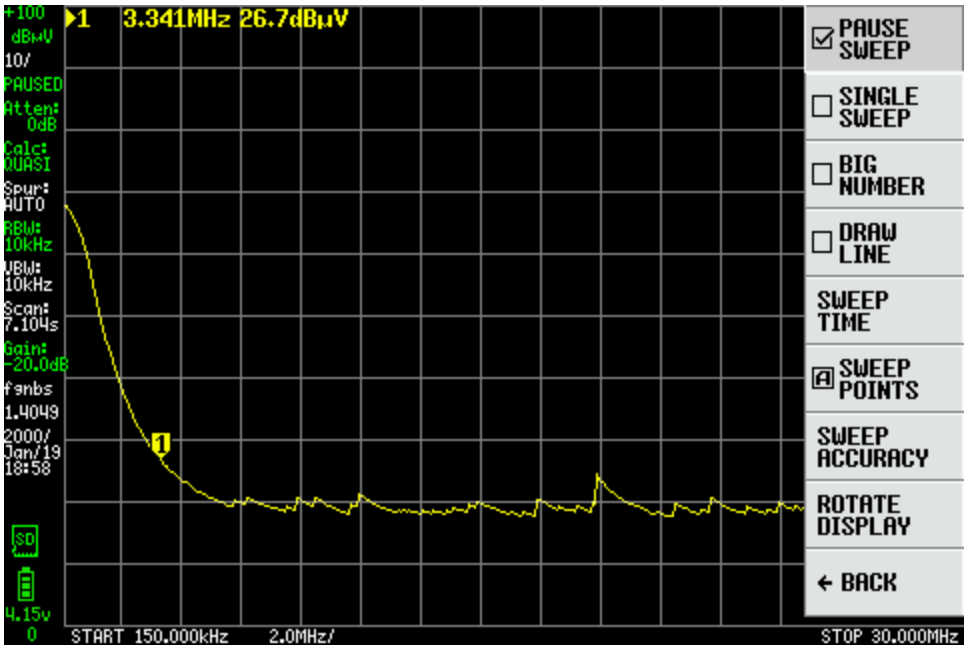
Sportsman with a 400 Watt load and the dual filter



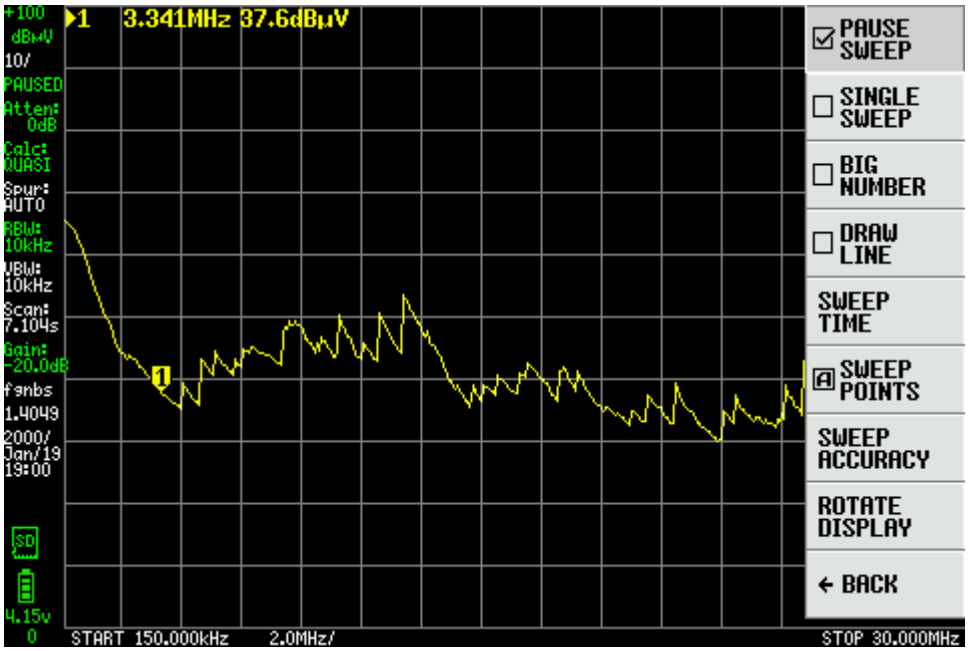
Honda with no load



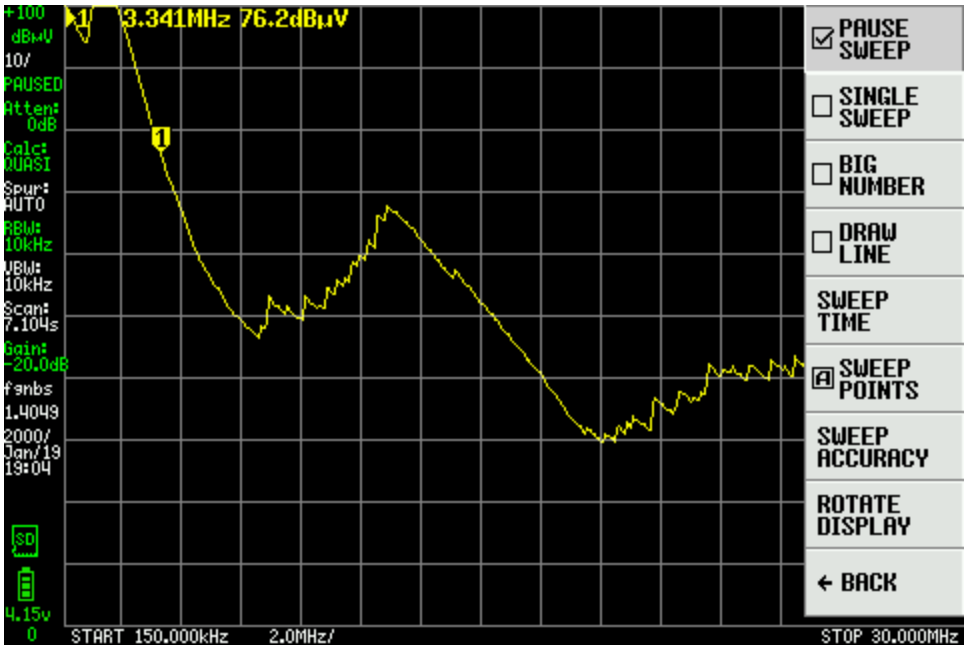
Honda with 400 Watt load



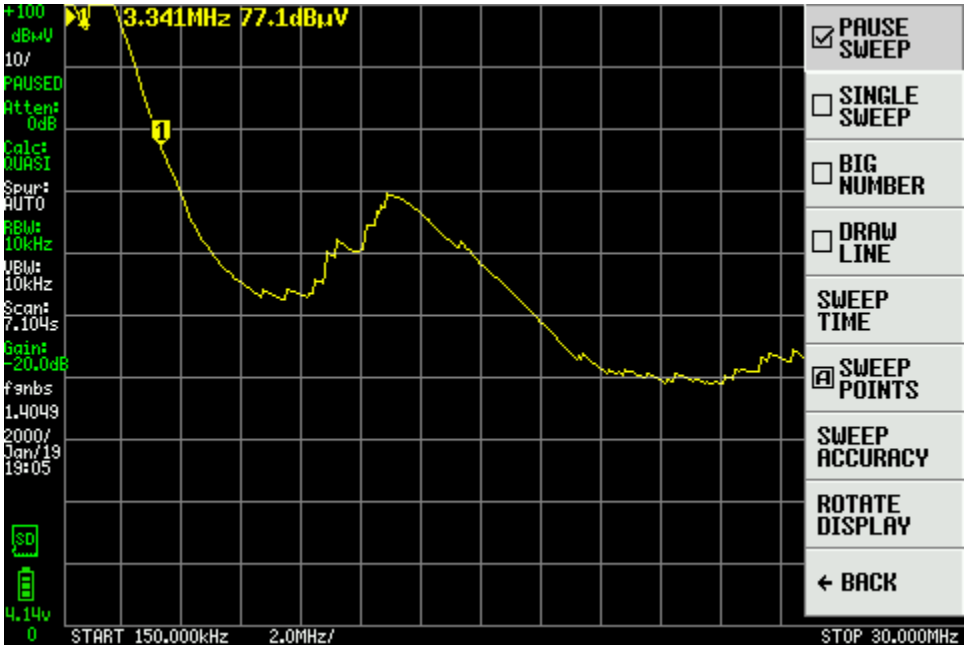
Honda with no load and the dual filter



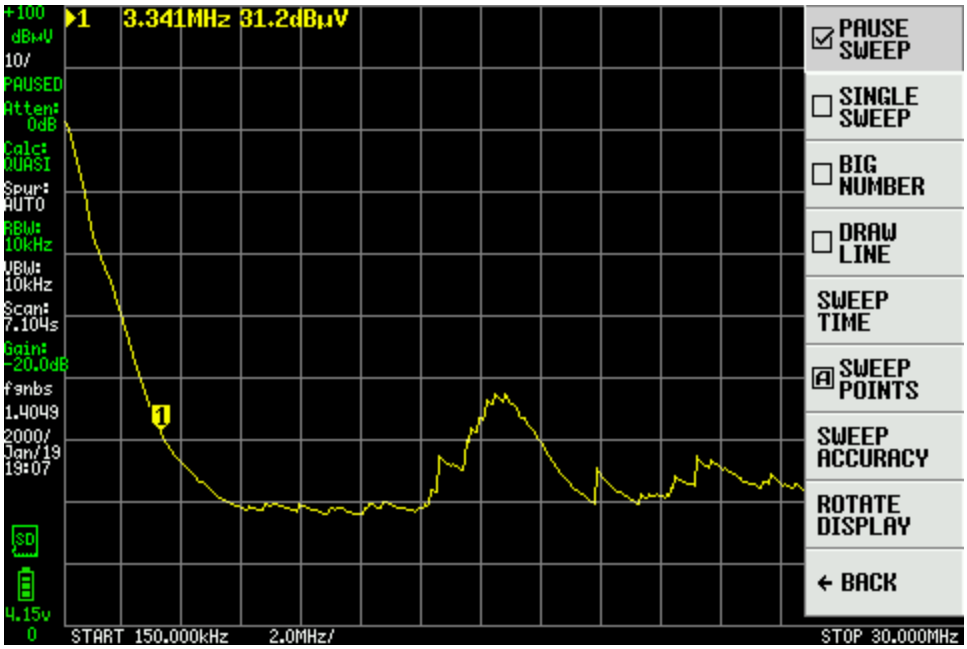
Honda with a 400 Watt load and the dual filter



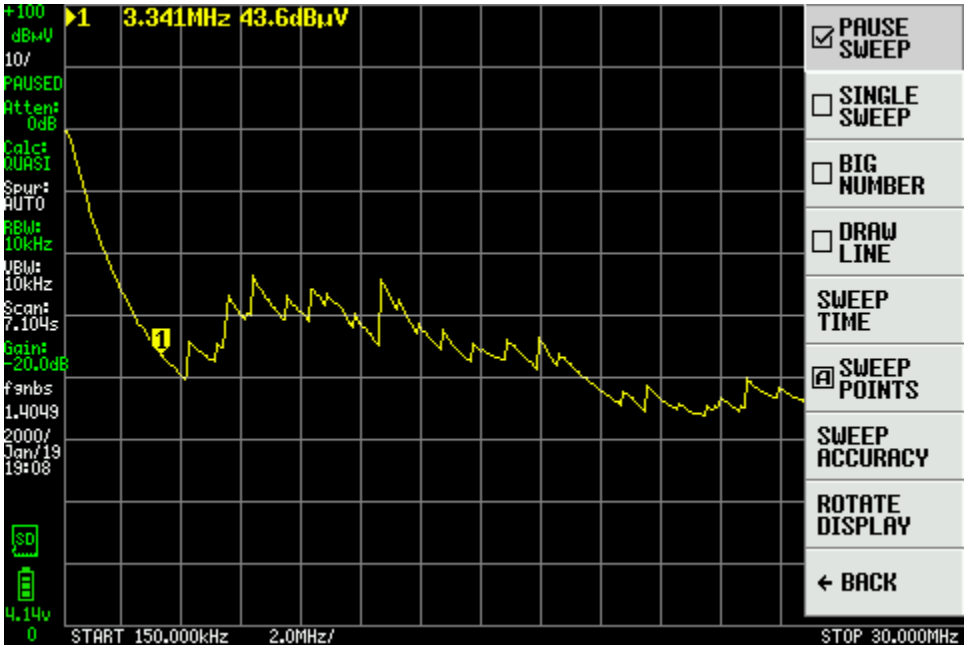
Generac with no load



Generac with 400 Watt load



Generac with no load and the dual filter



Generac with a 400 Watt load and the dual filter

Discussion

The Honda conducted emissions tests with no external filtering appear very similar to the results in the June 2012 QST article on generator/inverters assuming light loading. The QST article does not specify the loading on the generator during conducted emissions test, but the results here show higher emissions for 400 Watts of loading and lower emissions for no loading with a very similar curve, so assuming a loading of 100 to 200 Watts, it appears the results would be very similar.

The Honda generator gave the best results in all 3 tests, and there was no detected interference for location 1 for the interference test into an FTDX101D using nearby antennas as described and just perceptible interference for location 2 on 80 and 40 meters where the power cable from the generator was fairly close to one leg of both the 80 meter and 40 meter inverted vees. The Generac was pretty good, but not as good as the Honda, but the interference from the Sportsman was quite severe, especially on 80 meters, with some interference on 40 meters and a bit of interference on 20 meters. With the dual filtering, all 3 generators gave very good results for both locations. Only for the Sportsman in location 2, which is poor for coupling, was weak birdies detected.

These results show that even with a fairly dirty generator/inverter, the RFI can be well addressed with a few inexpensive items. There are some key issues for a good solution: 1) very close after the output of the generator/inverter add a high performance EMI/RFI filter such as the CW4L2-20A-S with a short ground connection as well as hot and neutral connections; 2) follow the EMI/RFI filter immediately with an RF choke of several hundred uH such as 9 turns or so of cable on 2 stacked FT240-43 or FT240-31 toroid cores; 3) attach an earth ground rod close to the generator at about 1 foot; and 4) keep the long power cable to the rig away from your antennas and preferably at a 90 degree angle to provide polarization isolation. The CW4L2-20A-S filter costs only about $16. A pair of FT240-43 cores cost less than $20. A waterproof box for these items may cost about $25, and a power plug and power outlet are needed. So the entire device is less than $75. This suggests that while the Honda generator is very quiet for RFI out-of-the-box, the much higher price is a significant question since a very cheap generator/inverter can be easily corrected for RFI at low cost.

Operating on 160 meters with these generators is a concern. Even the Honda shows quite high levels in the conducted emissions test at 1.8 to 2 MHz, and the Generac is quite severe for 160 meters. The levels for the Honda on 160 meters are 25 to 30 dB higher than for 80 meters. The Sportsman also has high levels on 160 meters, but they appear similar to 80 meters (both are high though). In a separate test, only the Sportsman was tested on 160 meters with the FTDXD101D and a nearby 160 meters inverted vee with the power cable going perpendicular to the antenna for low coupling. With no filtering, the interference on 160 meters was severe at S9 + 5 dB, but with the dual filtering, the interference noise fell below the background noise at S 6. Probably all 3 of these generator/inverters should have strong dual-filters for operations on 160 meters, but with an appropriate filter and other precautions, operations should be fine on 160 meters.

In a separate test, a Tripp Lite Isobar was used with only the Sportsman GEN1000i. That test included a situation of a very good EMI filter (Tripp Lite Isobar) but WITHOUT a short 1 foot ground connection, but with a 6 foot ground connection to the EMI filter in the connecting power cable. This setup showed significant residual RFI.

This picture shows the addition of a very short bonding ground wire from the Tripp Lite Isobar to the generator/inverter. This was added following observations of intermittent noise results that appeared to be associated with the Tripp Lite Isobar shorting to the ground rod. Once this ground wire was added, the RFI suppression improved significantly. Measurements of the inductance of the ground wire in the 6 feet of the Isobar power cable were about 3.3 uH. It seemed in the earlier work that the 6 feet of power cable including the ground wire should not be a problem to filter out RFI on 80/40/20 meters since it is much smaller than a ¼ wavelength, which is often cited as a target for bonding ground wires (less than ¼ wavelength). However, when actually looking closely at the inductance of even a 6 feet power cable ground wire, it became clear that it can be a problem, and that for good RFI filtering, the target for bonding ground wires should be much much less than ¼ wavelength and as close to zero as is practical. When 30 to 50 dB of noise suppression is needed, then even small inductances in the ground connections matter. This is a completely unsurprising result in retrospect, and some articles caution to make ground connections for EMI/RFI filters very short. Nevertheless it was interesting to see the actual results with the included ground wires of commercial EMI/RFI filters. Ground inductance from the inverter to the EMI/RFI filter reduces the achieved noise suppression.

The Tripp Lite Isobar does not include a proper ground terminal as it probably was not considered for operation in this close filtering situation directly at a strong RFI noise source such as an inverter, but you can easily connect to the Isobar's ground by backing out one of the case's screws and connecting a ground wire there. Note that a very similar situation would occur with a switching power supply.

Significant reduction of RFI would probably occur with Tripp Lite Isobar using only the ground in the 6 feet power cable, but RFI reduction would be increased significantly by adding a short 1 foot or less dedicated ground wire from the switching power supply to the Isobar.

This picture shows a high performance but inexpensive commercial EMI/RFI filter wired with electrical 3-wire plug and socket and connected to the generator with about a 1 foot wire to the plug and generator/inverter and a 6 inch connector to the socket. Very similar and good results for RFI were obtained with this setup as were obtained with the Tripp Lite Isobar with an added short ground wire. The EMI/RFI filter used here is a CW4L2-20A-S which is available on Amazon for only $16. It has 2 common mode filter inductors in series on the hot and neutral wires with bypass caps at the input, between the inductors and at the output to ground and between hot and neutral to suppress both common mode and differential mode noise. It is rated at 50 to 65 dB of suppression for both noise modes. However, it is important to remember that it does not suppress any RF currents on the ground wire itself, but it does strongly suppress RF on the hot and neutral wires, and stray coupling in this setup will limit the suppression significantly.

N1KDO, Jeff Otterson, built a nice EMI/RFI filter here: https://www.n1kdo.com/inverter-generator-filter/index.html . However, the power cable to the generator/inverter is 2 to 3 feet in length (shorter than the 6 feet cable I had with a Tripp Lite Isobar) but longer than the 1 foot I used for ground connections. Good results were obtained by N1KDO, but perhaps the results would improve with a shorter ground connection.

*Champion inverter generator and test-filter...**note that this is NOT the final planned implementation**! For safety and weather protection, the sys-*

https://archive.arrl-nfl.org/wp-content/uploads/2019/11/00-QST-NFL-November-2019.pdf

KX4Z, Gordon L. Gibby, added a high performance and high power commercial filter (MIF23) to a Champion 3400 generator/inverter capable of 3.4 kW of power as shown in the picture. Also see this information: https://qsl.net/nf4rc/2019/InverterGeneratorSolutions.pdf . The picture shows a power cable of about 1 foot connecting the filter to the generator/inverter, which is fairly good. About 30 dB of effective noise rejection by the filter was obtained, which is much less than the ratings of the filter at 70 to 95 dB of common mode and differential mode rejection, but the lab results are no doubt obtained with shielded cables and a specially prepared test setup to eliminate almost all stray coupling outside of the device under test. KX4Z added additional filtering with an RF choke after the high performance high power commercial filter to achieve full noise quieting of the RFI at the rig, similar to what was done here, except not placed immediately after the EMI/RFI filter.

The June 2012 QST article found that the radiated emissions from the generators were fairly small. In those tests, no power cable was connected to the generator. And the generator was moved away from a victim antenna until no interference noise was detected. Moving the generators about 50 feet away from antennas eliminated radiated emissions issues and that problem actually appeared to primarily be

the ignition system in the generator motors. We did not do any such tests since that problem appears to be secondary and is normally not an issue with generators placed 100 to 200 feet from operating tables and rigs to eliminate acoustical noise. So the dominate issue then for RFI appears to be conducted RF currents from the generator that get into the connecting power cable to the rigs and are partly radiated there and partly conducted to the rigs. Such conducted emissions can be addressed with the dual filtering approach with a high performance conventional EMI/RFI filter followed by an RF choke.

Field Day 2023

This picture shows the Sportsman Gen1000i under a small weather protection cover with the RFI filter in the orange weatherproof box and a ground rod both tightly bonded to the generator's ground. The power cable to the right ran 200 feet to the CW rig, so the generator audio noise could not be heard at the CW setup. This setup for Field Day 2023 produced excellent results with no noticeable or measurable RFI noise from the generator on the CW rig or on 6 other rigs used in the contest running on a different generator.

Conclusion

The small light-weight 4-cycle generator/inverters now available that weigh as little as 21 lbs and sip gasoline during operations are very attractive for Field Day and emergency operations. They output 700 to 1000 Watts continuously, enough for 2 or 3 HF rigs. They cost as little as about $300. However, the inverters in these generator/inverters may output severe RFI noise on HF frequencies. This is easily and simply solved at low cost with a high performance EMI/RFI filter rated for about 60 dB or more of

suppression of common mode and differential mode noise. However, the achieved noise suppression is much less in practical setups, but still quite significant. To achieve best results, the ground of the EMI/RFI filter should be bonded to the generator/inverter ground with a wire or ground strap of only about 1 foot maximum, and a ground rod should be bonded to the generator/inverter also with a very short wire. The EMI/RFI filter should be immediately followed by a strong RF choke such as 9 to 10 turns of power cable on 2 stacked FT240-43 or FT240-31 toroids to impede any residual RF currents including especially any RF currents on the ground wire. These measures together strongly suppress any RF currents on the long power cable from the generator to the operating table and rig. Any residual RF currents might partly radiate from the power cable and might partly conduct over the power cable to the rig. Being able to use gas efficient and light weight generator/inverters for Field Day and emergency communications without impairing the radios is an excellent capability for those events. Even the low-cost and RFI dirty generators work well when used with low-cost and simple filtering with appropriate implementation. This approach was used for Field Day 2023 by the Antietam Radio Association allowing the usage of a very RFI dirty but lightweight and inexpensive generator, a Sportsman GEN1000i, with no noticeable/measurable interference to any of the rigs.