QUIETING THE RFI HASH FROM INVERTER GENERATORS

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October 17 2019

While storage batteries produce zero noise, and ordinary gasoline-powered alternators produce only modest ignition noise, plus possibly some noise from a feed-back control to the field current, , the **newer fuel-sipping inverter generators are a real problem for emergency communications power**. The extremely fast switching times of their internal semiconductors, designed to increase efficiency by decreasing semiconductor pass transistor heat dissipation in the "linear" portion of the operating curve, can function as very efficient wide-band modern spark-gap transmitters! These inverters tend to use insulated gate bipolar transistors (IGBT)[1] which have much lower saturation voltages (and hence losses) at higher currents, and can be switched at 20kHz, with the switching modulated with a pulse-width modulation to create a near-perfect sine wave output and efficiencies in the 97% or higher range.[2] Yet sometimes, users prefer to take advantage of the reduced weight, increased quietness and fuel-conservation of these newer generators.

Wide-band noise produced by these devices comes in two flavors: RADIATED and CONDUCTED. Radiated can be reduced by physically increasing the separation between the antenna and generator, as well as using shielded transmission line and reducing outer-shield conduction with a unun and balun. Additionally one can construct a crude form of faraday shielding with some wire wrapped around the generator and connected to the frame of the generator and to a good earth ground.

Conducted seems to be much more of a problem. In my experience, this wideband noise comes to the AC power supply of the HF transceiver and jumps quite easily through it into the receiver, and can create astonishing amounts of apparent signal --- 10 dB over S9 or approximately -60dBm equivalent RF signal. When a standard HF dipole might have an galactic and lightning background floor of -95 dBm, this is a HUGE problem, overwhelming anything but the very strongest of received signls on a band. .

I have detailed some efforts previously to deal with the conducted noise, but was unable to provide satisfactory results on an ongoing basis.

This report details the results of various filtering techniques applied to a Champion 3400 watt inverter generator, and on a 2 kw AI Power inverter genereator, in both cases using an ICOM 718 transceiver as the test receiver.

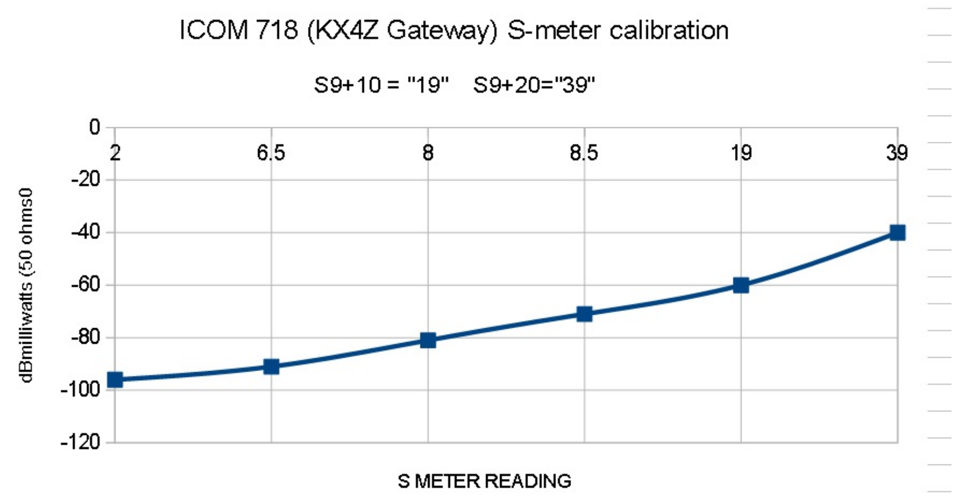
RFI MEASUREMENT SYSTEM

A ham-sticks compact 40 meter horizontal dipole was set up at a height of about 3 feet, near the transceiver. The ICOM 718 S-Meter was used as the measurement device. The ICOM 718 S-meter is

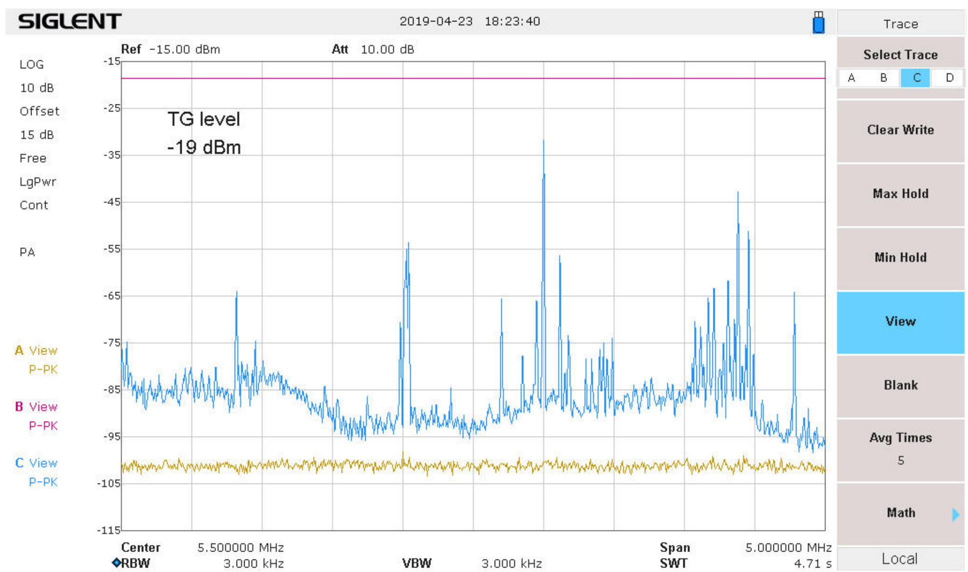
1 Wikipedia: https://en.wikipedia.org/wiki/Insulated-gate_bipolar_transistor

2 Wibawa T. Chou, Electronic Design 2009 https://www.electronicdesign.com/energy/build-efficient-500-w-solar-power-inverter-using-igbts

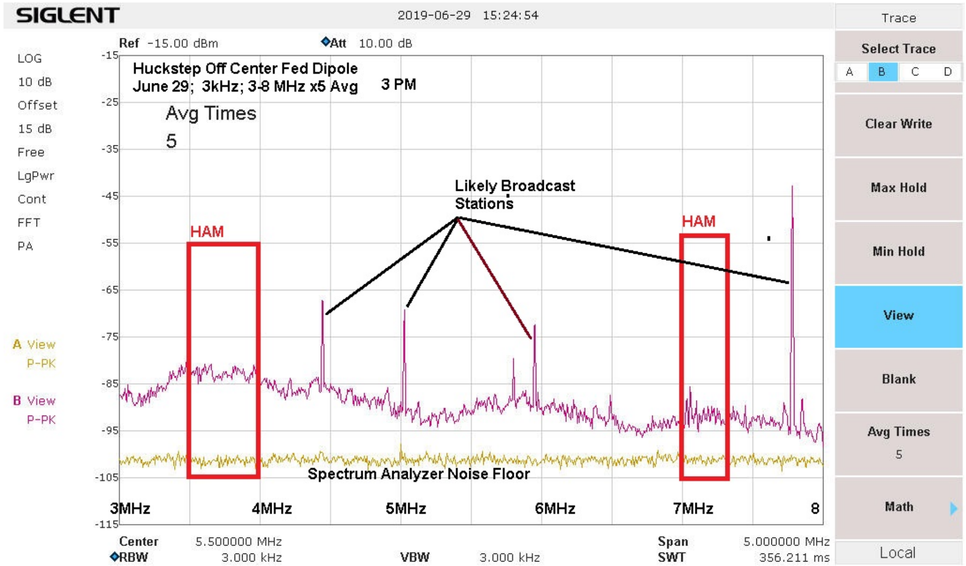
not linear, and most S-units are NOT 6dB. The following graph is a representative S-meter calibration based on previous experiments carried out with calibrated power signals from a Siglent Spectrum Analyzer.



Represenative background noise in a residential environment (in dBm) can be viewed here:



and compared to this similar measurement at another residential location:



TAKE HOME: **Background HF 2.8 kHz noise is in the range of -85 to -95 dBm** in the lower HF ham bands, corresponding to S2 to S7 on the Icom 718. Generator noise ideally should be reduced below those levels.

COMMON/DIFFERENTIAL MODE FILTER

After burning out a simple 20-amp commercial line filter that had the approximate volume of a pack of cigarettes, by running a single RV travel trailer air conditioner through it (esimated 14A AC), I decided to switch to a larger, more heavy duty AC line filter. The unit chosen waas the Rosburg MIF23 EMI input filter. This is a hefty unit intended for indoor intallation inside a closed box. It will require some improved mounting to be longer-term usable and provide protection for its semi-exposed terminals, but for the purposes of these tests, connections were protected with electrical tape. The unit is not inexpensive, retailing around $130 --- but still far cheaper than the price differential of lesser-expensive inverter genreators from "gold standard" inverter generators (which still produce noticeable RFI hash)

This MIF23 is rated at 1-phase, wither 120VAC or 240VAC, and at 23 amps. This is plenty to operate the major functions of my 21-foot travel trailer inclluding the AC and the amateur radio station.

RFI specfications include

Mode	Specified Reduction (likely 50 ohm environment)
Different mode rejection	70-80 dB in the HF spectrum
Common mode rejction	70-95 dB in the HF spectrum

Typically these type specifications are made in a 50-ohm test envronment. They are unlikely to represent the actual common mode impedance presetned by the line end of a 100-foot extension cord and thus the commmon mode rejection obtained, particularly if the extension cord has an apparent higher impedance at the desired frequency, will be considerably less in actual practice.

Ref: https://about.automationdirect.com/contact-us/index.html MIF-23, $128.

MIF23 = Roxburgh EMI input filter, heavy duty commercial filter, 120/240 VAC, 1-phase, 23Ampere rating, panel mount, EMI/RFI filtering, multi-stage, drive rated, very high performance, screw terminals. For use with 1-phase AC drives . Specs: 23 Amp current rating, voltage up to 240 VAC: https://cdn.automationdirect.com/static/specs/mifseries.pdf
Specs: https://cdn.automationdirect.com/static/manuals/emifilters/MIF23.pdf Common mode rejection in the range of 70-95 dB (likely 50 ohm environment) and differential mode rejection 70-80 dB at HF)

DATA CAPTURE RESULTS

ALL TESTING:
100 feet extension cord to Icom 718.
Ham Sticks 40 meter antenna at Icom 718, tuned with ICOM Intellituner (cw transmission to tune)
40 Meters

CHAMPION 3400 WATT INVERTER GENERATOR

CONDITION	S-Meter	Approximate dBm
Baseline generator AC power to Icom	S9+10 dB	-60 dBm
4 turn FT-240-43 ferrite at generator end		-60 dBm
MIF-23 + 4 turn FT-240-43 ferrite at generator end	S5 to S6	-90 dBm
MIF-23 + 4 turn FT-240-43 ferrite at generator end, running linear battery charger on group 24 battery powering transceiver	S3 to S5	-95 dBm
MIF-23 + 4tur FT-240-43 at generator end, 9 turn FT-240-43 at transceiver end, powering analog charger to group 24 battery	S0 (NOTHING)	well below -95 dBm
MIF-23 + 4turn FT-240-43 at generator end, 9 turn FT-240-43 at transceiver end, AC power to transceiver	S0 (NOTHING)	well below -95 dBm

AI POWER 2kw Inverter generator

CONDITION	S-Meter	Approximate dBm
Baseline generator AC power to Icom	not measured	not measured
4 turn FT-240-43 ferrite at generator end, power analog battery charger, group 24 battery	S 8-1/2	-70 dBm

4 turn FT-240-43 ferrite at generator end	S8	-60 dBm
MIF-23 + 4 turn FT-240-43 ferrite at generator end	S0 to S1	below -95 dBm
MIF-23 + 4 turn FT-240-43 ferrite at generator end, running linear battery charger on group 24 battery powering transceiver	S0 to S1	below -95 dBm
MIF-23 + 4tur FT-240-43 at generator end, 9 turn FT-240-43 at transceiver end, powering analog charger to group 24 battery	S0 (NOTHING)	well below -95 dBm
MIF-23 + 4turn FT-240-43 at generator end, 9 turn FT-240-43 at transceiver end, AC power to transceiver	S0 (NOTHING)	well beow -95 dBm

DISCUSSION

DIFFERENTIAL MODE NOISE = opposite polarity currents on different wires of the 120V extension cord. Quench using series inductors in each line, and capacitors shunting. MIF23 provides different mode rejection.

COMMON MODE NOISE appears more prevalent. In this case, the RF voltage/current is similar or the same on 2 or more of the conductors in the 120V extension. The extension cord is acting either as an antenna wire, or as one conductor in an unbalanced transmission line (the other conductor being the ground beneath the extension cord). Solution is to add inductive reactance in series by wrapping the entire extension cord seveal turns around FT-240-43 ferrite. This resists the flow of the RF energy down the extension cord. Then lay the line on the ground to increase its capacitive shunting to the earth, and absorb any radiated energy in lossy Florida sand. Reduce radiation by placing significant common mode inductive reactance as close to the start (at the generator) as possible (short line between initial MIF23 filter and generator.

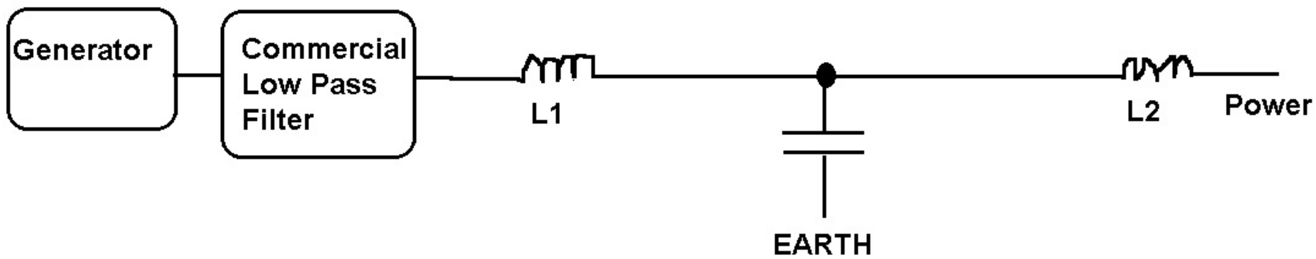
The 4turn coil was created ad-hoc by merely threading the male plug as many times possible through the FT-240-43 core. The 9turn coil was created by cutting into a 16-gauge short extension cord, and then 9 turns were able to be created, and the wires soldered to reconnect.

The extension cord presents a varying impedance along its transmission line with distance. It essentially traces out a curve on a Smith Chart with distance. The series common mode inductance is a fixed reactance, so it will be more effective if placed at a point of lower impedance on the line, than if place at a point of higher impedance. The impedance peaks and troughs are different for every frequency and difficult to predict... Therefore it may be advantagoues to have 2 or 3 interspersed series common mode chokes, at different distances, and even some trial and error may be required.

Number of common mode turns around FT-240-43 core	Inductance	Inductive Reactance at 7 MHz
4 turns	30 uH	1300 ohms inductive
9 turns	120 uH	5300 ohms inductive

The basic idea of any filter to reject a signal is

- provide series impedance to obstruct its flow
- provide shunt susceptive to short out its potential



Model of Generator RFI Filtering

In this case, the series common mode inductive chokes impede the flow of the undesired RF energy. The capacitance between the extension cord and "ground" helpfully shorts it out (forming a lowpass filter) --- but the "ground" is poorly conductive and at an unknown "effective depth". An improvement might be to add one or more ground rods, even if of short length, and connect to the GREEN (ground) wire of the extension cord; then the inter-wire capacitance of the cable begins to work in your favor. Additional lumped physical capacitors to actual ground rods from the hot and neutral wires might be added in fixed installations.

The $128 commercial filter clearly added a huge amount of filtering -- 30 dB effective.

The battery charger/battery added a variable amount of "filtering" -- sometimes up to 10dB and other times ineffective.

The additional 9 turn filter (at the particuar location chosen) took the signal down to un-discernible, with an estimated reduction of 10 dB; the additional 4 turn filter right at the start of the 100 foot extension cord was somewhat less effective, estimate in single digits dB; a 9 turn at that locaion might be more effective simply due to the higher impedance.