Dan Mattson, EMF Technician
360 Grand Ave. #292
Oakland, CA 94610
510-658-2819 voice/fax
www.danmattson.com
danmattson@sunset.net

The Landis + Gyr Smart Meter: An Inside View

November 8, 2015

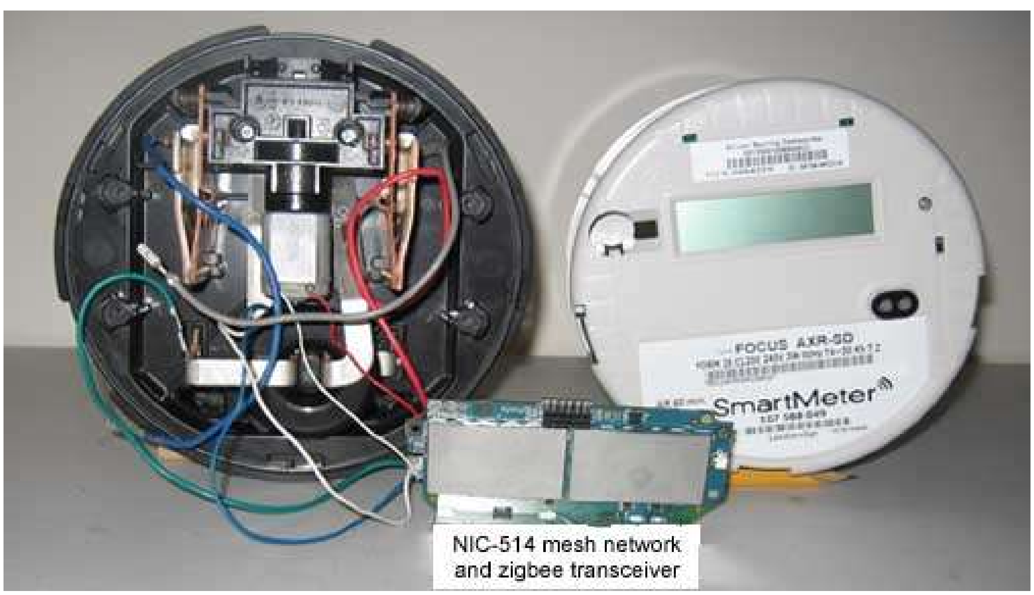
This is a report on the Landis Gyr Focus AXR-SD smart meter. This is one of two smart meters in regular use for single phase 120/240 volts AC in Pacific Gas and Electric's (PG&E) service territory. The report is based on **visual examination of a disassembled meter** and **non-invasive measurement of an operating meter**. Privacy is a major concern with smart meters. The measurements done for this report reveal a way that consumer equipment can be identified. This will be discussed

This report is made possible by partial funding for a more detailed report I wanted to do. As such, it does not cover everything that could be covered.

Known types of electromagnetic emissions from this smart meter are:
- ELF magnetic fields
- The pulsed microwave radiation (902-928 MHz)
- The switch mode power supply switching frequency radiation (130 kHz)
- There is also a zigbee transceiver (2.5 GHz) for the home area network. At the time of this writing, I know of no implementation of this feature.

There are two parts to this report (plus a conclusion on p. 11).

Part one looks inside the smartmeter, identifying the parts associated with the emissions.
Part two documents measurements of the switch mode power supply and discusses the privacy issue.



A safe smart meter. This was left, partially disassembled, in a box on my doorstep. It has been valuable and interesting to get an inside view of this thing that is making so many people sick, but I have not gone so far as to connect power to it.

Part One: Examining a Landis + Gyr Smart meter
This examination covers some of the components in the Silver Spring Networks NIC-514 transceiver module, the current transformer that is the source of the ELF magnetic fields, and the switch mode power supply (SMPS) that powers the whole meter.

The NIC-514 Transceiver
A number of names are interchangeable for this module. NIC is an acronym for network interface card. That is, in generic usage, it is has a similar function to an Ethernet card that plugs into a PCI slot or a USB dongle that is an Ethernet port. The NIC-514 as whole unit can be properly referred to as radio and a transceiver. Within it there are two distinct transceivers, the mesh network and the zigbee (HAN) transceivers. In the ES world people seem to often think of it simply as a transmitter. The chip I reference next is specifically called a transceiver. This mesh network transceiver is a commercially available chip, a RF3858. A primary application for this chip is smart grid wireless networks.

This is a portion of the NIC-514 circuit board. (1.) is the RF3858 mesh network transceiver chip. (2.) is the circuit board trace to the feed point on the antenna. A 3.3-volt regulator on the main circuit board powers this chip. The source for this is the 12volt DC SMPS.

The NIC-514 antenna is a small piece of sheet metal.

This antenna is visually very simple, and, I expect, electrically quite complex. It has two sections. One is for the mesh network transceiver the other for the zigbee transceiver.

1. Feed point for the 915 MHz mesh network transceiver.
2. Electrical separation point between the mesh network section and the Zigbee section.
3. Feed point for the 2.5 GHz Zigbee transceiver.

If I were to name the 915 MHz section of this antenna, I would call it a 1/10-wavelength dipole with a complex radiation pattern, perhaps something like a horizontal tornado. I won't hazard a guess about the Zigbee section.

The Landis+ Gyr SMPS

This shows the section of the circuit board that holds the power supply and surge protection components. The SMPS seems to be a fairly ordinary 12-volt DC one-amp power supply. The current waveform shown on page five indicates little was done to address power factor (discussed on p. 4).

1. The oscillator chip, a [TNY277GN](), is directly on the other side of the circuit board from the chip I labeled (1.) It produces a switching frequency of about 130 kHz. It works with external circuitry to convert 240 volts AC to 12 volts DC.
2. This is a proprietary 130 kHz transformer that is part of the above-mentioned external circuitry.

The data sheet linked to above says the oscillator chip is used for "… Chargers/adapters for cell/cordless phones, PDAs, digital cameras, MP3/portable audio, shavers, etc."and that "The oscillator incorporates circuitry that introduces a small amount of frequency jitter, typically 8 kHz peak-to-peak, to minimize

Dan Mattson, EMF Technician • danmattson@sunset.net • 510-658-2819

EMI emission." I take this latter statement at face value and note that the components on the NIC-514 radio board are totally covered with shielding.

Industry and the FCC on EMI and harmonic distortion

Just to say it, when it comes to biological effects of EMF's, industry and FCC interest seems to begin and end with thermal effect maximum permissible exposure. Together they are dismissive of the idea that any emissions from smart meters can present a health hazard. For other reasons, they go into a great deal of detail as to what emissions are permissible. Broadly these are in two categories, intentional and unintentional emissions. Their main concern is that licensed users of the RF/MW spectrum don't interfere with each other. This applies to both intentional and unintentional emissions.

Within industry a great deal of attention is given to problems associated with high-speed switching circuits. SMPS are an example, but there are many others as well. There are switching circuits in computers that are above one gigahertz. Creating chips that work in the presence of transients created by high-speed switching circuits is one of many ways the electronics and telecommunications industries are constantly challenging themselves.

Harmonic distortion is of primary concern to the electrical utilities, and is inclusive of the issue of power factor. This is a complex subject and beyond the scope of this paper. At the end of this paper are links to papers on reactive power and power factor correction in SMPS. Below are current waveforms for a Landis + Gyr smart meter and a LCD monitor. I cannot measure the power factor of the smart meter. I can of the monitor. It measured 0.5, which is a low power factor. The similarity of the waveforms strongly suggests the smart meter is also low power factor. For this reason I state the power consumed in volt-amps (VA) rather than watts. When low power factor is involved, the watts are less than the VA. I will say a little about the difference between non-linear and linear reactive loads.

Linear reactive loads do not cause distortion to the sinewave power waveform. Non-linear loads do. The SMPS is such a load. What makes a SMPS a nonlinear reactive load is a circuit combination of a diode and capacitor together.

Transformers, motors and capacitors are all linear reactive loads. They do not cause harmonic distortion. A capacitor can have a power factor of zero and will appear as zero watts consumed. Its VA is not zero and it draws real amps. It is the VA that has to be generated by the utility to supply that low power factor load.

Power factor correction is possible with both linear and non-linear loads. Electric utilities have requested of industry that power factor be increased. I have done field measurements of refrigerators that show this happening. A new refrigerator that would have likely been around 0.7 a few years ago will now measure about 0.95. A refrigerator that draws 5 amps will have a VA of 600. With a power factor of 0.7 you would be billed for 420 watts. With a power factor of 0.95 the same refrigerator would have you billed for 570 watts. Increasing the power factor may in some ways be a good thing, but it will cost us more on our electricity bills.

Pages six and seven show current measurements of two switching power supplies. To set the context, I show first a linear reactive load. The image below is the measured current drawn by an older Stetzer filter that someone gave me. I show the current waveform below. This capacitor filter has a power factor of 0.0.

Current measurement of a Stetzer Filter, a linear reactive load

This measurement of a Stetzer filter was done with same equipment used for the smart meter measurements below. This is a near sinusoidal 60Hz waveform with bit of noise on it. This is a measurement of zero power factor reactive current. Your utility sees it as zero watts. The volt-amps can be calculated by multiplying volts and amps. 607 mA ≈ 0.61 amps x 120 volts = 73 VA. This is the actual power consumed by this capacitive filter. This is about the same as the volt-amps consumed by a 75-watt incandescent light bulb. An incandescent light bulb has a power factor of one, so volt-amps and watts are the same.

Smart meter examination continued

The surge protector components in the smart meter are very ordinary and protect only the circuit board. I found no evidence of surge protection that protects the electrical system the meter is connected to.

240 volts AC powers the electronics in this meter. Within the meter there is no connection to the neutral. The electronics are not grounded.

The current transformer

The metal pieces that plug into the meter socket go through this current transformer.

An electricity meter, either analog or digital, produces an ELF magnetic field proportional to the current being drawn through the meter by end user loads. In the case of an analog meter the motor that spins the familiar disc produces this field. In the digital meter, such as this smart meter, a current transformer produces the field. This is the same technology as the clamp-on current clamps used in Part Two.

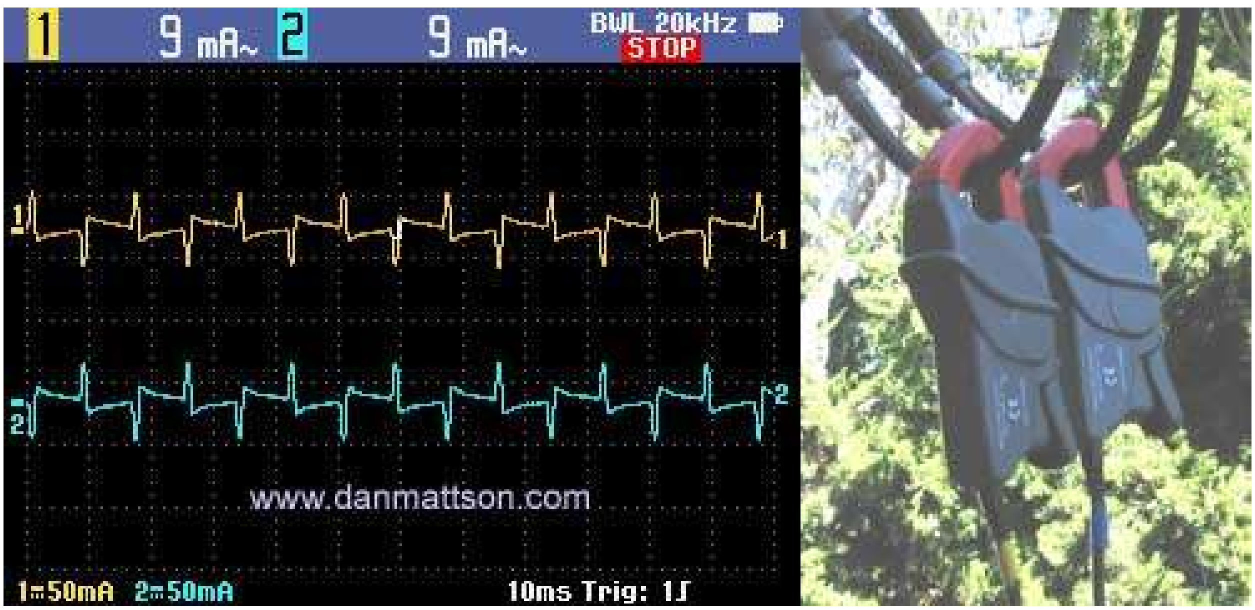
Part Two: Measurements of a working smart meter

What follows are two sets of measurements on an installed and operating Landis + Gyr Focus AXR-SD smart meter. It is installed on a residential 100-amp service entrance. I personally installed this service entrance on my home in 1987. PG&E installed this smart meter in 2010.

These are non-invasive measurements. That is, they are done with external sensors rather than direct contact with wiring or circuit board traces. I used current clamps and antennas for making the two sets of measurements of the smart meter SMPS.

> Note: While I have been measuring the pulsed microwave emitted by the NIC-514 radio and the very similar NIC-507 for five years, measurements of the pulsed microwave are not included in this report. For a pulsed microwave report done by Bob Metzinger, president of Safe Living Technologies in Toronto click here.

Current measurements of a working smart meter



This is an oscilloscope image of the current at the service entrance of my home electrical system with the main breaker turned off. The only known load is the Landis + Gyr smart meter PG&E installed in 2010. This current waveform is typical of a switch mode power supply (SMPS). The frequency of this waveform is 60Hz. This is measurement of the current on the 120-volt hot legs at the masthead. This shows this smart meter is consuming about two VA (24/7) that is not charged to my account. In the upper right corner it says BWL 20kHz. This tells us I chose a 20 kHz low pass filter option in the oscilloscope for each of these channels. Without this filter the display would be so noisy the 60 Hz waveforms would be largely obscured. I used Fluke i-200s clamp-on current clamps for this. Their rated sensitivity is 100ma. What they are measuring here is less than 1/10 of this.

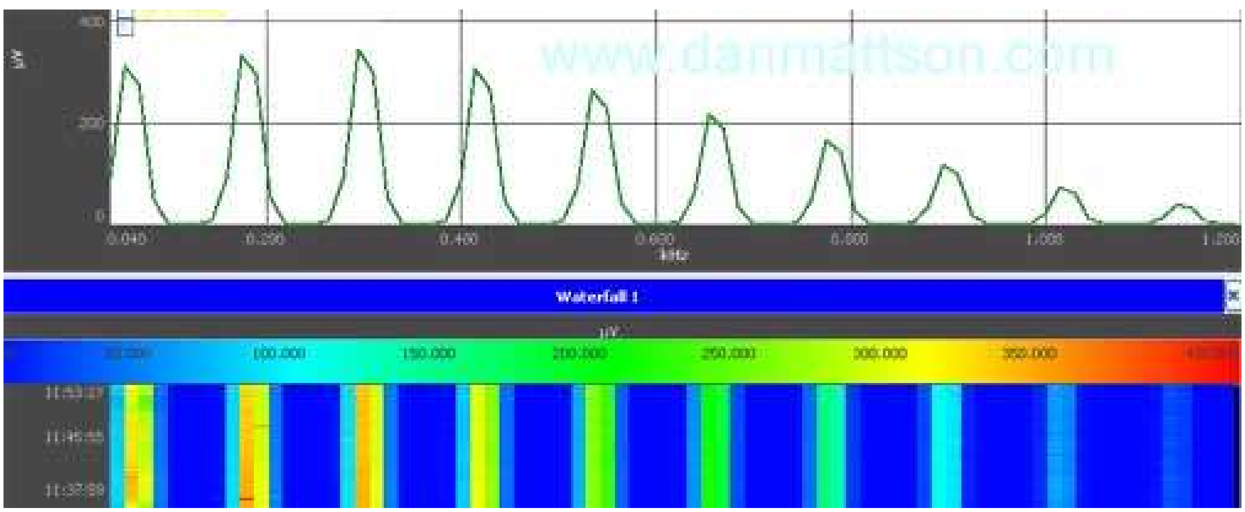
The privacy issue

Much has been said about using electrical signatures as a way of identifying electrical devices and appliances since the advent of smart meters. Use of simple power data as a signature has risen to the level of congressional and FBI papers. Such data is now available from utilities to customers who have smart meters. While this is clearly useful information to someone who bothers to log into his or her utility account and look it up, it is limited information.

From knowledge of your personal habits you will be able to say, “Oh, that is when I ran my electric dryer, that’s my oven, and that’s my kiln.” However, you won’t be able to tell the difference between them in any objective way. In other words, your utility won’t be able to tell the difference between the oven and the kiln, let alone identify either by brand and model number. A manufacturer could imbed such a signature in an appliance. The smart meter would then transmit it to the utility. I believe this to be the case for any linear load.

This is not the case with nonlinear loads. Nonlinear loads do create a signature. The waveform above shows harmonic distortion. This is a first step but not the whole story. To reveal the signature, this must be analyzed for the harmonic content. This signature will be unique to individual devices.

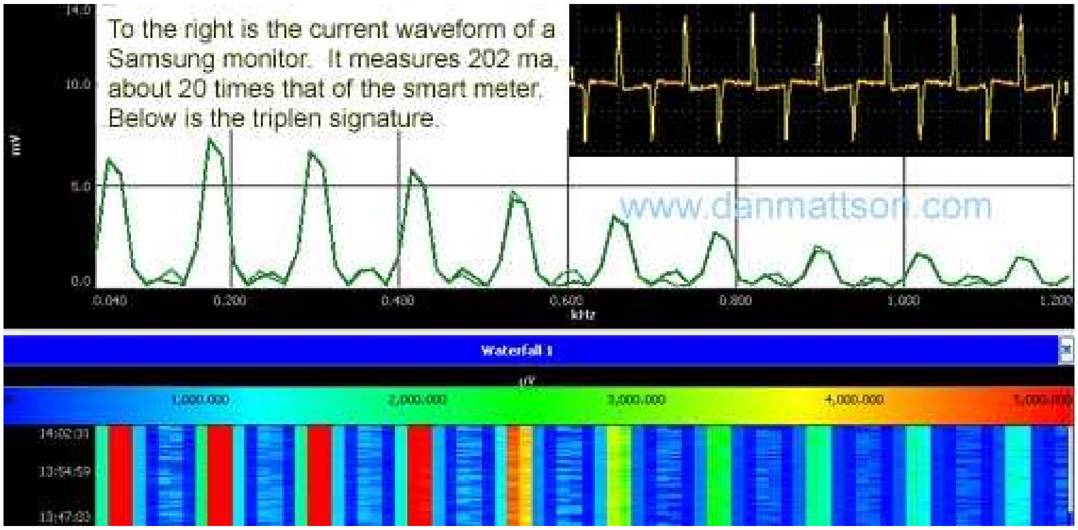
SMPS harmonic distortion signatures



Landis + Gyr smart meter signature

This is a spectrum analyzer view of the harmonic distortion in the smart meter current waveform shown above. All non-linear loads, such as switching power supplies, produce such an image and all of them are unique. What is shown are known as third order harmonics (triplens). Starting from the left we have: 60Hz, 180Hz, 300Hz, 420Hz, and so on with the 19th harmonic (1140Hz) being the last one shown. A spectrogram like this can be used as an identifying signature. This kind of identification has it roots in ELF acoustic signatures of Soviet submarines starting in the 1950's.

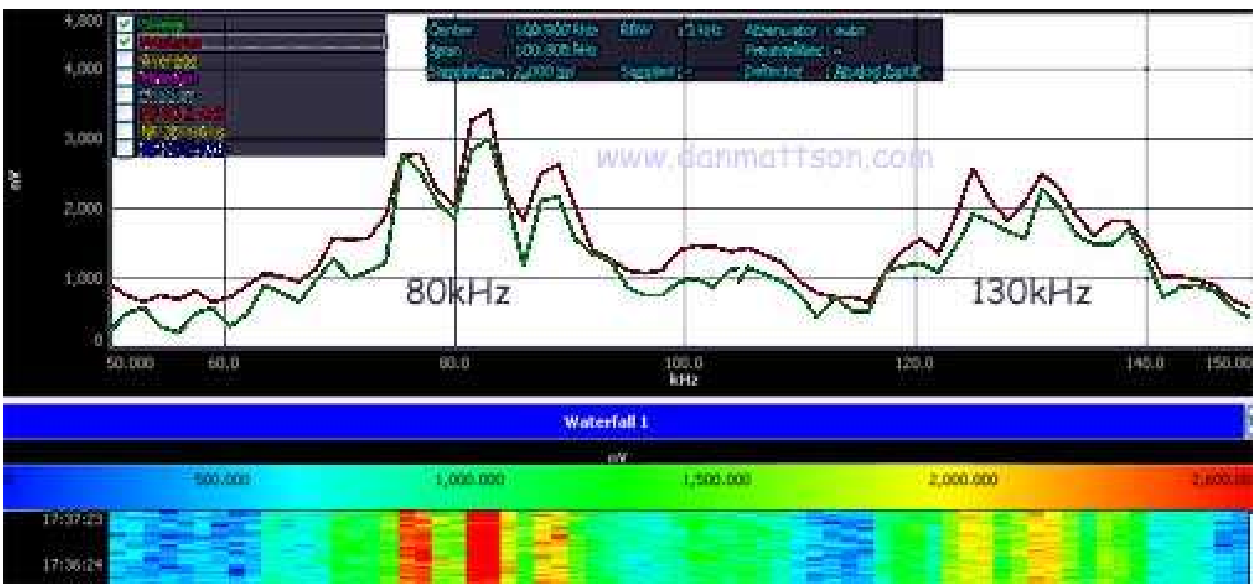
For comparison I did similar measurements on a Samsung 21-inch LCD monitor with an analog (VGA) input. The differences may seem subtle, but on close examination they are clear.



Samsung LCD monitor signature

This was done with the monitor displaying graphics. The signature is very different when the monitor is in standby.

Measurement of the SMPS switching frequency as induced current



This is the smart meter SMPS switching frequency as induced current on one of the hot legs. This was done with a Fluke 80i-1000s clamp-on current clamp. It has a bandwidth of 100 kHz. The 130 kHz switching frequency is right at the edge of its capability. It needs to be adjusted up by about 10 dB for amplitude accuracy. That would make the 2µv signal about 16µv. The current clamp is set for 100mv/amp. The sensitivity of this clamp is also100ma. This 130kHz signal is more than 100 times smaller than this. I computed it at 625 micro amps. This 625µa has to be considered a very approximate number as there are a number of calibration problems with this measurement. It does however show that the smart meter SMPS switching frequency is easily induced into the 120/240 volt wiring, even if at a fairly low level. The 80 kHz signal must be, I think, associated with the SMPS and that it appeared as induced current must be taken at face value. It was not expected. Nor was it a surprise. (As will be seen below this 80kHz does not appear as radiated noise.) While it is more in the bandwidth of the current clamp, with corrections, it is less than half the amplitude of the known switching frequency (130kHz).

These signal levels are less than an oscilloscope can display. I used a spectrum analyzer to do these measurements. It is capable of measuring much smaller signals than those shown here.

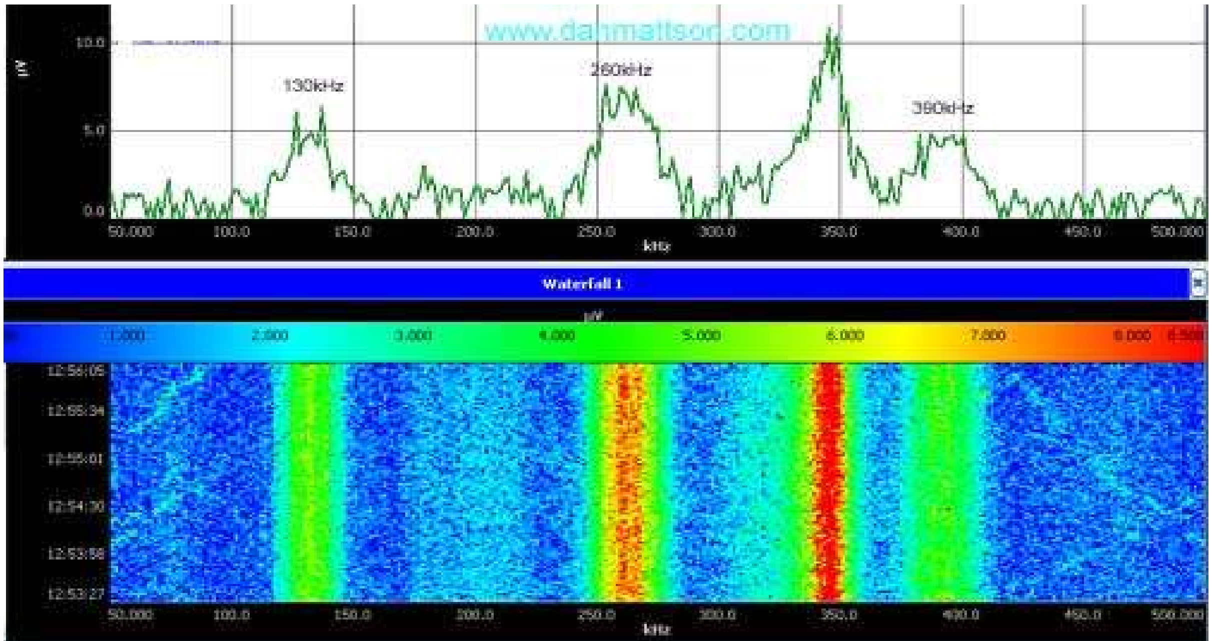
Measurement of Smart Meter SMPS switching frequency as radiated energy
I used three measurement techniques for comparison measurements of radiated energy from this smart meter. The frequency range of interest was 50kHz to 500kHz. This covers the range of the fundamental frequency (130kHz) and several harmonics while avoiding getting into the signal clutter of the AM radio band starting at 540kHz. This is not to say that harmonics cannot be heard on an AM radio. They can, typically at close range, within 3 feet of the meter, with a few inches giving the best results. Knowing the layout of the components and where I measure the 130kHz the strongest, I can say the source is most likely the transformer pictured on page 3. Experimenting with the location of the radio will give the best results. This frequency range will also show the presence or absence of unexpected SMPS noise, such as the 80kHz in the current image above. For these measurements I used:

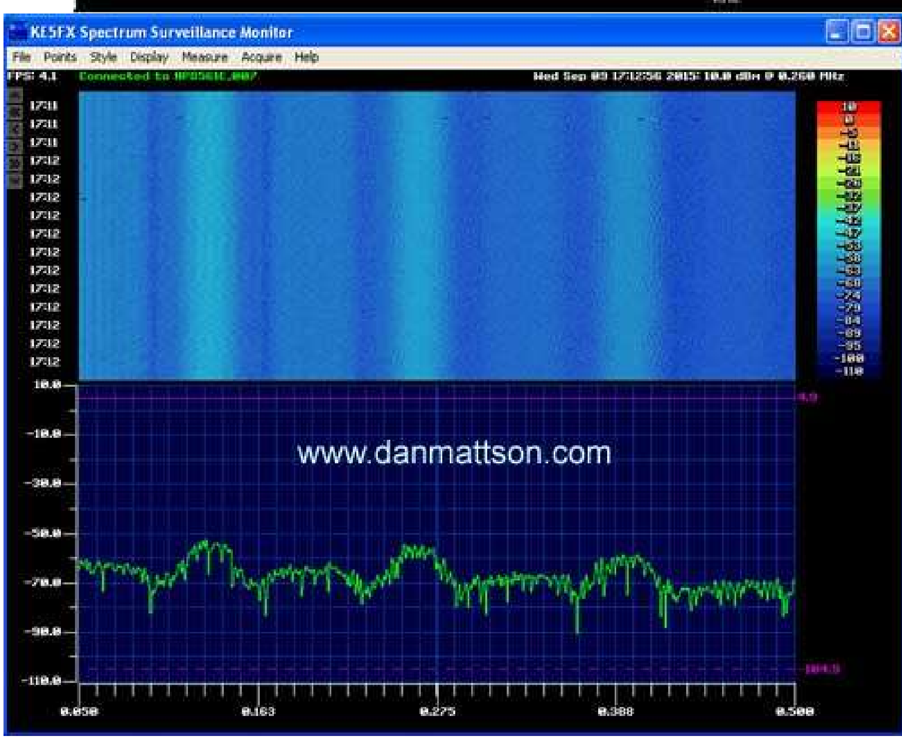
1. A Tecsun PL-660 portable radio. This tunes down to 100 kHz using an internal antenna.
2. An Aaronia NF-5035 spectrum analyzer with a commercially available antenna, 10kHz-2000kHz. For the images (current and radiated) this analyzer was connected by USB to a laptop. I used manufacturer-supplied software.
3. A HP 8561E spectrum analyzer with a custom made loop antenna. For the images I connected the spectrum analyzer to a laptop computer with a 1970's vintage interface called GPIB. The software is open source.

These are the two antennas I used for the measurement of the radiated emissions from the SMPS. I made the loop antenna about five years ago. It is about 12 inches in diameter and has about 120 feet of 18-gauge wire wrapped in a single layer. I had the opportunity to compare it to a high-end loop antenna. It compared well. I have no calibration data on it, but it works best as a 50-ohm antenna. It is usable from ELF to about one GHz. It is best from about 1MHz to 30 MHz.

Note: Smart meters are not the only source of 130 kHz dirty electricity. Not long ago I found, with my radio, 130 kHz in the air in a empty apartment. It was coming from the wiring of a specific circuit. Out of simple curiosity I did some tracing of that noise. I found it was coming from a bundle of phone and cable TV wires on the outside of the building. It was being induced into the power wiring where they ran in parallel for a number of feet a few inches apart. It was also induced into the cast iron drain system. I further traced the source of the noise to an underground AT&T wiring vault. This was a dramatic example of how such noise can travel more than 300 feet from an identifiable source, be induced into electrical wiring and plumbing, and then transmitted into the apartment with enough intensity to be heard on my radio throughout the apartment.

Measurement of 130kHz SMPS emissions radiated from a Landis + Gyr smart meter





These two images are of the radiated emissions from the switching power supply. We now have three images showing the 130kHz. Two of the three have "horns" on the 130 kHz spectrogram image. These may correspond to the jitter mentioned in the data sheet. The images on this page also clearly show harmonics at 260kHz and 390kHz. One shows a signal at 340kHz. With the radio I can associate this with the smart meter. It is also easy to associate this frequency with other sources, which I have not specifically identified. What is clear is that they all sound different. There is, in fact, a cacophony of sound from these switching frequencies and their harmonics. Tuning from 100kHz to 500kHz, near SMPS, near some phone and cable TV lines, near some ground wires and powerlines, can be an overwhelming experience. For that reason, it requires some patience and careful measurement to find the harmonic relationship between these signals that contributes to the signature, in this case, for a Landis + Gyr smart meter.

Of course, the sound is valuable in and of itself for initially discovering the existence of this dirty electricity and how far it extends from the source. This is made easy because these harmonics go into the AM radio band. An ordinary AM radio is very good for informing you about the existence of this biologically intrusive dirty electricity noise in your environment.

Conclusion

This paper intends to demystify some components of the Landis + Gyr Focus AXR-SD. This meter and other smart meters have triggered electrical sensitivity in people who did not know it had been introduced into their environment. It is presented with the belief that good technical information is essential to countering the rush into a poorly conceived "upgrade" to a smart grid. That our electrical infrastructure needs upgrading is not in question. However, layering high-tech components on top of aging much lower tech components while largely ignoring the issue of electrical sensitivity even as the evidence is coming in that smart meters are aggravating the problem is not in the public interest.

This paper presents evidence based on manufacturer specifications and field measurement that the switching frequency of a Landis + Gyr smart meter SMPS is about 130 kHz. Further, that this creates a harmonic rich signal that is readily induced in the hot legs of a 100-amp residential service entrance. Evidence from field measurement is also presented showing that this harmonic-rich switching frequency is radiated from the meter.

Studies are coming out that show these frequencies, sometimes called intermediate frequencies, from common devices can do biological harm, especially if there is direct contact between ones body and the device.

This paper also shows the current waveforms of two switching power supplies. We see harmonic distortion indicating a low power factor and a spectrum analysis of this harmonic distortion. The paper explains how these images can be used for product identification. Power factor correction of a SMPS will change any such signature and quite possibly reduce the likelihood of making a positive identification of the associated device. Power factor correction has no effect on the switching frequency or its harmonics.

Reactive power and power factor correction links:

http://www.aptsources.com/resources/pdf/True%20vs.%20Apparent%20Power.pdf

http://www.electronics-tutorials.ws/accircuits/reactive-power.html

https://www.fairchildsemi.com/application-notes/an/an-42047.Pdf
This one is on power factor correction in SMPS.

Dan Mattson works at the grass roots as a self-employed EMF technician and consultant.