Isotrope WIRELESS

Thinking outside the sphere

Report on Examination of Selected Sources of Electromagnetic Fields at Selected Residences in Hastings-on-Hudson

November 23, 2013

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1. Introduction

Isotrope, LLC was engaged by a group to evaluate the electromagnetic environment at several residences in Hastings-on-Hudson, New York. The clients expressed concern about human exposure to certain specific sources of electromagnetic fields. Of primary interest were the automatic meter reader (AMR) electric meters installed on local residences by Consolidated Edison. Also of interest were an electronic water meter equipped with a transmitter and cordless telephones operating with the DECT protocol. The general concerns expressed by the clients prior to the examination related to the various modes of propagation: radiated fields, conducted fields and re-radiated fields.

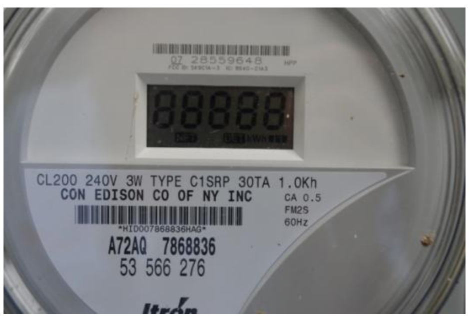
The clients sought an evaluation of the radiated and conducted emissions characteristics of these devices beyond merely comparing the emissions to applicable health and safety guidelines. The clients hypothesize that the emissions of some or all of the types of subject devices interact with human physiology in a manner that is not captured by conventional emissions safety guidelines. The clients' concerns relate primarily to the possible impact of these pulsed radio frequency emissions on humans in the residential environment. The examination was performed solely to characterize the nature and intensity of the emissions of concern. While the measured emissions are compared to the FCC exposure limitations, among other things, for reference, this report draws no conclusions about the risks of human exposure to these emissions.

To evaluate the devices in situ, Isotrope made a field survey of the various emissions of concern, employing an array of electronic test equipment. Conclusions in this report include the observation that Part 15 radiated- and conducted-emissions testing of electrical meters does not replicate actual conditions because a power cord is attached to the meter socket in the test chamber rather than simulating the installation of the meter on a meter socket connected to both the power grid secondary and the residence distribution panel. Moreover, while the conducted emissions from the meter at 915 MHz ISM frequencies in a residence was observed to be substantial, FCC Part 15 regulations limit conducted emissions testing to 30 MHz, ignoring the conducted emissions of the AMR radio signal.

2. Devices Under Test

Residential AMR Electric Meters

The AMR electric energy meters of interest are manufactured by iTron. As an intentional emitter of RF energy in the industrial, scientific and medical (ISM) band at 902-928 MHz, the model of meter has been factory tested to verify conformity with Part 15 regulations of the FCC (Title 47 of the US Code of Federal Regulations). Its test information is available from the FCC. Isotrope reviewed the test filings by referencing the FCC ID number posted on the meters.



The AMR meters were originally designed to transmit a 7 millisecond pulse of data about once every two seconds. (The meters we tested ran at about two pulses per minute.) A revision of the design is reported with a 45 ms pulse of data. The unit is designed to transmit one pulse on one radio channel and then change to another channel. This is called "frequency hopping." The hopping stays within the 915 MHz ISM radio band and is designed to minimize interference to other users of the band. The FCC reports say that radiated power levels are stated to conform to the FCC Section 15.247 interference limit for the band, which requires 1 watt or less power to the antenna.

Water Meter Transmitter

The water meter transmitter is manufactured by Neptune. Under its FCC ID number, the unit's certification filings describe a pulse is transmitted approximately once every 13 seconds. The device uses frequency hopping (see sidebar above). It is designed and tested under the same Part 15 interference regulations as the AMR meters.

DECT Phone

The cordless phone employs the DECT standard and operates in the unlicensed PCS band. DECT phones are required to comply with Part 15 interference regulations.

3. Test Methodology

Isotrope brought an array of equipment to the site in anticipation of a variety of possible measurement needs.

Equipment	Bandwidth	Antenna Pattern	Exposure Range
Anritsu MT8222A Spectrum Analyzer with ETS model 905 probe **("Anritsu")**	1 MHz to 1 GHz probe range	Dipole-like omnidirectional	Wide dynamic range, equivalent to a minimum of less than 1 picowatt per cm^2 depending on settings (<<-90 dB mW/cm^2)
Advantest Spectrum Analyzer **("Advantest")** used with Isotrope Line Impedance Stabilization Network **("LISN")**	LISN nominally 10 kHz to 30 MHz	Conducted measurement; Not Applicable	Not an exposure measuring setup
Tektronix Oscilloscope **("Oscilloscope")**	500 MHz	Conducted measurement; Not Applicable	Not an exposure measuring setup
Gigahertz Solutions HF35-C field intensity meter (provided by others) **("HF35-C")**	800 MHz to 2.5 GHz	Log Periodic directional	Wide dynamic range, equivalent to a minimum of 10 picowatts per square centimeter (-80 dB mW/cm^2)
NARDA 8718 Meter with 8722-D Conformal Probe **("NARDA")**	300 kHz-40 GHz	3D omnidirectional	2% to 1500% of the FCC limit for general population/uncontrolled areas; equivalent to a minimum of about 10 $\mu W/cm^2$ at 1 GHz (-20 dB mW/cm^2)[1]

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[1] Although the emissions under observation are at levels that are lower than the FCC safety limits, the FCC is presently inquiring "whether there is a need for reassessment of the Commission radiofrequency (RF) exposure limits and policies." (FCC 13-39). Ultimately, all radiated power densities observed were substantially below the sensitivity of the Isotrope NARDA human exposure compliance meter.

To measure radiated emissions in relative proximity to the respective sources, including in the near field and at distances typically of no more than 40 feet radially from any particular source, Isotrope employed radio frequency spectrum analyzers and a reference electric field probe commonly used in close-in electromagnetic interference (EMI) testing. The relative insensitivity of the probe was not a constraint on the measurements due to the proximity of the probe to the sources of interest. The probe was also used in close proximity to power wiring and conductive surfaces to sense any localized fields.

To examine conducted energy on the power lines, Isotrope used a line impedance stabilization network (LISN). The LISN was used to feed a spectrum analyzer, and also to feed an oscilloscope.

Finally, the client provided a Gigahertz Solutions HF35-C field intensity meter. This device employs an attached log-periodic antenna to sample the electric field between 800 MHz and 2.5 GHz. This frequency span encompasses the most common wireless telephone bands (Cellular, SMR, PCS, AWS, BRS) as well as 915 MHz ISM and 2.4 GHz WiFi, among others. The HF35-C is a relatively sensitive instrument that has plenty of dynamic range to explore the residential wireless signal environment.

> The Gigahertz Solutions HF35-C measures the electric field and converts to equivalent plane wave free space power density (reported in microwatts per square meter - µW/m^2). The unit is highly sensitive, capable of reading on the more sensitive scale to values as low as 0.1 µW/m^2 or -80 dBmW/cm^2. This is comparable to the received signal strength of an FM radio station broadcasting from about 10 miles away.

4. AMR Electric Meter

HF-35C Equivalent Power Density

At three residences AMR electric meters were observed. They consistently emitted short pulses once every thirty seconds. The HF35-C instrument was set to peak reading mode to capture as much of the pulse peak power as possible. With the HF35-C meter within about 1.5 to 2 feet of the AMR meters, the pulse would register on the high scale at levels typically between -43 and -37 dBmW/cm^2 (500 to 2000 µW/m^2), depending on the orientation of the instrument's antenna.

Closer to the AMR meter, the HF35-C would regularly blank the display on receiving a pulse, indicating an over-range condition.[2] Note that the instantaneous power density (the pulse power density) is reported. FCC exposure specifications base public exposure on a 30 minute averaging time. In 30 minutes there would be about 60 pulses of about 50 ms duration. This totals to about 3 seconds of emissions to be averaged over 30 minutes. This way of calculating exposure reduces the FCC interpretation of average exposure level to 2 tenths of a percent of the measured peak level.

Whether or not the pulse was over-range, the pulse energy would be retained by the instrument's averaging circuits and the subsequent readings would steadily decay back to the background level over the course of five seconds or so. It is important to note that only the first reading captures emitted RF energy. The subsequent readings as the meter reading decays to a baseline level are artifacts of the way the meter handles pulsed emissions and do not indicate emissions are present. The instrument manual explains this phenomenon as "charging and drooping", acknowledging that a peak reading may be "even up to a factor of ten too low." The graphic below illustrates how the instrument may capture some of the energy of the pulse and then show a decaying level after the pulse has ended.

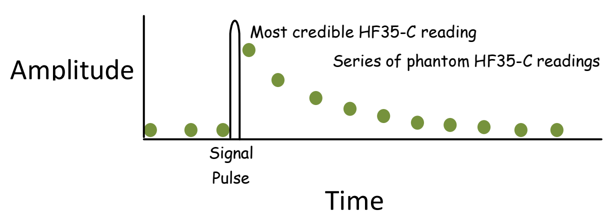

Figure 1 - Illustration of HF35-C Meter Readings over Time, in the Presence of a Single Signal Pulse

Spectrum Analysis

Using a spectrum analyzer, the AMR meter pulses were also captured in both the frequency domain and the time domain.

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The pulse power levels obtained by the spectrum analyzer at the second residence were on the order of -20 dBm with the sensor approximately 6 inches from the meter's internal antenna. Recall that dBm are units of power measurement. To translate to human exposure terminology, the power received by the instrument through its antenna has to be translated to units of power per unit area, such as milliwatts per square centimeter (mW/cm^2). Based on the instrumentation characteristics, this translates to an equivalent of -20 $dBmW/cm^2$ free space pulse power density at 6 inches from the meter.

The result on the spectrum analyzer is as much as 20 dB higher than on the HF35-C meter. This higher reading is due to two probable differences. First, the spectrum analyzer was substantially closer to the signal source than the HF35-C. Second, even if the instruments were at the same distance, it is expected that the HF35-C response to pulse inputs would artificially diminish its reading. Overall, there is enough consistency between the results of the two measurement methods to confirm the more precise measurements of the spectrum analyzer.

Away from the AMR Meter

Inside the residences, the received power levels from the AMR meters were consistent with the weakening of the signal that would be expected with increasing distance from the meter and signal absorption of residential construction. On the second floor at the opposite side of the house from the meter (in two residences tested) the AMR meter pulses were extremely diminished to the point of not being measurable on the HF35-C meter, and the pulse's clicking sound produced by the HF35-C AM detector would diminish and recede into the background noise. Similarly, attempts to capture occasional pulses on the spectrum analyzer in rooms distant from the AMR meter were often not fruitful. Measured pulse levels tended to range between -60 $dBmW/cm^2$ indoors nearest the meters to levels less than the sensitivity of the HF35-C instrument (< -80 $dBmW/cm^2$) in opposite ends of the residences. With a sensitivity of less than -90 $dBmW/cm^2$, the spectrum analyzer confirmed the unmeasurable levels of the AMR meter emissions were less than -90 $dBmW/cm^2$ in more distant parts of the houses tested.

In the basement of one residence, directly behind the cement block wall with the AMR meter on the outside, the combination of the meter's metal enclosure and the cement block construction reduced the AMR meter's signal level to -63 $dBmW/cm^2$ (5 $\mu W/m^2$). Outside, in front of the meter, the signal level was consistent with the power density observed near the other AMR meters (-20 to -40 $dBmW/cm^2$). The signal loss into the basement was about a 30 dB reduction over the free space loss that would occur outside the meter. In other words, the strength of the signal just behind the basement wall was about a thousand times weaker than the strength of the signal outside in front of the meter.

Conducted Emissions

Within the electric meter enclosure, the 915 MHz emission of the AMR meter is radiated within several inches of the power lines that pass through the meter enclosure on the way to the main service panel. Consequently, it is likely that the house electrical system conducts some of the 915 MHz signal into the residence. In the basement described above, the power cable penetrates the cement block wall, going from the meter outside to the main circuit panel mounted inside near the penetration. The nearest electrical outlet in the basement is on an interior wall approximately 12 feet away (perhaps 20 feet by wire).

A line impedance stabilization network was connected to the outlet, treating the meter/electrical panel as the device under test. A spectrum analyzer was connected and the spectrum was monitored. With the FCC regulated range below 30 MHz, the conducted emissions appeared to be compliant with the regulations. Above 30 MHz, there was a substantial conducted 915 MHz component on the power line.

The conducted 915 MHz signal level was approximately -55 dBm (about 52 dBµV RMS). The LISN is not calibrated for 915 MHz measurements; however it is reasonable to assume that if there is any error in reading a 915 MHz signal from the power line, the error is likely to cause the reading to be lower than the actual condition, due to impedance mismatch and UHF losses in the LISN. The 52 dBµV measurement is therefore conservative, erring on the side of understating the conducted 915 MHz energy.

If the 915 MHz conducted energy were held to the same standard as 30 MHz, the level of the 915 MHz conducted energy from the AMR meter would fail. FCC Part 15 conducted emissions regulations do not specify conducted emissions limits above 30 MHz. The 30 MHz limit for an appliance injecting noise into the power line is 50 dBµV at 10 ft (cable distance from the device under test).

Conducted-then-Radiated Emissions?

Emissions that are captured by house wiring and conducted around the house may ultimately be radiated from outlets and along the house wiring. When in close proximity to conductive objects (house wiring, outlets, metal lamp) the measured levels increased. This is consistent with the known behavior of objects that "re-radiate" RF energy. The apparent re-radiation of these objects created elevated fields concentrated close to the objects.

The general ambient field levels in the houses followed the basic pattern of being weaker as the distance from the source (at the meter) increased. This is known in the literature as presenting elevated "hot spots" of energy concentrated near the conductive objects.

For example, in one house, the ambient levels of the AMR signal (and a DECT phone signal emitted from the first floor) were observed to have a spatial peak value in proximity to house wiring in the wall of a second floor bedroom by a bed as well as in proximity to a metal bed-side table lamp in another bedroom, among other locations. The spatial peaks near the electrical wire and table lamp were, on one hand, several orders of magnitude lower than the measured radiated signals found near the electric meters and the DECT phones, yet, on the other hand, these conducted/reradiated signals were still substantially greater than the ambient emissions found generally in the same rooms as the conductive objects.

The spatial peaks that occur near conductive objects connected to the house electrical wiring could be the result of two factors. First, there could be resonant re-radiation of the over-the-air signal and/or, second, radiation of emissions conducted from the source. Resonant re-radiation occurs when a conductor is of such electrical dimensions that it acts as a passive antenna, receiving a signal from the air, resonating and reradiating the signal. Such an object may or may not be connected to a wiring network like the house electrical system. Radiation of conducted emissions occurs when conducted energy (from the house wiring) reaches conditions that cause the conductive object to radiate like an antenna.

5. Water Meter

The water meter of interest is located in a public park containing a tennis court. The park is approximately the size of one house lot, and is surrounded by houses on approximately ¼ acre lots. The meter is mounted on an in-ground water pipe. The water pipe is exposed below grade and is marked by a wooden post. Mounted on the wooden post is a weather-tight electronics package with a label revealing information including an FCC ID number. One low-voltage cable connects the analog meter to the electronics. There is no power connection.

Researching the FCC ID number, the unit is a transmitter that operates in the 911-924 MHz band. Like the AMR electric meters, the water meter AMR transmitter on the post is designed to transmit a burst of data at regular intervals. Operation is designed to be compliant with the Part 15 emission limit (less than 1 watt).

The HF-35C instrument detected a pulse emitted every 13 seconds, which was most apparent as an audible click on the audio detector. As is sometimes the case with direction-finding in the near field, the pulses were strongest within a 10 foot radius of the transmitter, but within that radius the signal level varied with position and sensor antenna orientation. The pulses registered on the most sensitive range of the HF-35C. It is not known what the pulse response of the instrument is, however the unit was kept on peak detection mode, which is intended to capture more realistic measurements of peaky signals. In close proximity to the water AMR transmitter power was similar to that of the electric AMR meters.

There was plenty of background noise near the water meter. Various kinds of cell site emissions appeared to be the dominant components, based on the detected audio provided by the HF35-C, in addition to the short bursts from the Neptune transmitter which were audible approximately every 13 seconds.

A scan of the radio spectrum with a spectrum analyzer resulted in an array of wireless signals and other similar signals at levels that are typical of a residential area. Because the water meter transmitter frequency hops like the AMR electric meter transmitter does, its emissions were not captured on the spectrum analyzer during the short visit at the water meter. The radio frequency power of the water meter transmitter is comparable to that of the AMR meters, according to the FCC test data. The behavior of the unit observed in the park was consistent with this information.

6. DECT Telephone Set

Some of the residences included in the survey had cordless telephone base units and one or more cordless phones associated with them. Operating in the unlicensed PCS band at 1920-1930 MHz, these units are designed to share the spectrum with other DECT phone sets in the same neighborhood without mutually interfering and without intercepting the communications of the others. They operate by monitoring the band and selecting an available channel. Once on a channel, the base units send short bursts of data, enabling the handheld units to share the channel using time division duplexing. The base units were observed on the spectrum analyzer to be transmitting their signals at levels consistent with their unlicensed use, which are substantially below the applicable RF exposure limits.

7. Summary Conclusions

The following observations result from the survey.

- **Interference Compliant.** The radio transmitters of interest appeared to be functioning within the FCC radiated interference limits imposed in Part 15.
- **Interference Specifications are Not Exposure Specifications.** Part 15 exists to enable compatible use of the radio spectrum by myriad devices that use radio frequencies without requiring licensing of the use. It is not a safety specification.
- **Strongest Fields are Found Near the Sources.** The greatest potential whole body exposure to the AMR meter energy would occur near the meter and would be no greater than 1 mW/m^2 (-40 $dBmW/cm^2$) per pulse. However, the spatial peak ("hot spot") exposure within 6 inches of the meter was as high as -20 $dBmW/cm^2$ per pulse.
- **Range of In-Home Exposure to EMR Meter Emissions:** Regardless of the previous conclusion, the emissions of the AMR meters are well above ambient RF levels and measured in occupied space from below -90 $dBmW/cm^2$ at more distant rooms to about -60 $dBmW/cm^2$ inside the exterior walls nearest the meters.
- **AMR Conducted Emissions Are Strong, but Not Regulated.** The conducted emissions of the AMR electric meters at the 915 MHz band are substantial, but are not regulated by Part 15 (which cuts off above 30 MHz). If the 30 MHz limit were applied to 915 MHz, it is probable that the meter would fail a lab test, subject to the following observation.
- **AMR Meter Lab Testing Fails to Simulate in Situ Wiring.** The lab testing of the AMR meters employed a simple power cord temporarily attached to the meter mounted in a panel. The meter does not normally employ a power cord. This approach does not simulate the manner in which the house wiring feeds through the electric meter. The meter has two power connections: one entering the meter typically from the top to deliver power to the meter and another exiting the bottom of rear of the meter panel to supply power to the main breaker panel. Using a power cord instead of setting up the power wiring the way the device is actually used may not reveal how the house circuit wiring through the meter may act. The actual in situ wiring may be more like an antenna that may pick up unwanted RF energy and noise within the meter and conduct it into the residence. See photo appended to this report.
- **Distinction between Peak and Average Exposure.** Using the electric AMR meter transmissions as an example, the pulses are 50 millisecond duration, once every 30 seconds, representing a duty cycle of less than two-tenths of one percent. Using the averaging method on this pulse train, the averaging method yields an exposure level that is 28 dB lower than the peak pulse power.

- **Reradiation and Incidental Radiation Exists as Expected.** House wiring (and other metallic objects and cables) act as concentrators or reradiators of RF energy that produce spatial peaks of RF energy near the conductors. This is a well-known phenomenon (particularly at AM broadcast frequencies, where the effect near high power AM stations is substantial – the effect exists on all frequencies to some degree, depending on the frequency and radiated power level and dimensions of the conductor); the appearance of conducted RF energy and localized RF fields around conducting objects at AMR and DECT frequencies is consistent with experience.
- **Reradiation and Incidental Radiation Appears Near Conductive Objects.** Reradiated energy from in-house conductors (such as electrical wiring) is lower than the emissions in the vicinity of the radiating antenna. The nature of passive reradiation is that the reradiating object or material cannot increase the power it receives. Therefore, the amount of energy emitted by the reradiator cannot be greater than that which is emitted by the source that excites the reradiator. Also, as the distance from the source to the reradiator increases, the field intercepted by the reradiator diminishes.
- **Table 1, below, Summarizes Ambient Levels of the AMR Meters Tested.**

Table 1 - Comparison of Exposure Levels from Emissions of the AMR Meter under Test

Location of Measurement	Equivalent Plan Wave Free Space Power Density†	Device
Approximately 6 inches away	-20 dBmW/cm^2 *	Spectrum Analyzer
1 – 2 feet away	-37 to -43	HF35-C ††
Inside occupied spaces	-60 to less than -90**	Spectrum Analyzer
Inside occupied spaces	-60 to less than -80**	HF35-C

†The general practice is to convert measured field (volts per meter) to power density assuming the measurement was of a signal radiating in free space. In proximity to objects or to the radiating element, this conversion may overstate the actual power density.

††Note that HF35-C readings may be artificially low due to meter design with respect to short pulses.

*The use of decibels makes it easier to present data over a wide numerical range. The more negative the number of dB, the weaker the signal.

-20 dBmW/cm^2 is one one-hundredth of a milliwatt per square centimeter (0.01).
-60 dBmW/cm^2 is one millionth of a milliwatt per square centimeter (0.000001).
-90 dBmW/cm^2 is one billionth of a milliwatt per square centimeter (0.000000001).

** The lower figures (-90 and -80) represent the approximate sensitivity of the instruments. When signals are not measured, it is because they are below the sensitivity of the instrument.

8. Remediation

Removal

If the AMR meter emissions at a particular residence are to be minimized, the most effective method is to remove the meter. Of course, this must be done in coordination with the electric power supplier.

Reduce Duty Cycle (to about once a month)

If the meter can be replaced with one that only responds when polled, then there would only be a brief emission during monthly meter readings when a meter reader passes the location of the meter with a radio that interrogates the meter and receives its reply. However, as AMR meters give way to so-called smart meters that communicate with devices in the house, the rate of transmissions will increase to provide data communication between the meter and smart appliances.

Retrofit with Protection

If neither of the above can be accomplished to eliminate or minimize the meter emissions, shielding the meter so that its emissions are diminished or are focused away from the residence could be considered. One vendor of a meter shield product made a demonstration that obtained what was apparently about 40 dB of attenuation of the meter's radiated emission (a reduction to one ten thousandth of the power density without the shield.)

Also, based on our conducted emission test, if shielding is employed, then it may be desirable to place filtration on the power lines entering/exiting the meter panel to reduce conducted emissions. A search for "power line EMI filter" will yield a variety of sources. A party experienced in EMI suppression should be involved in working with the electrician.

9. Conclusion

This report summarizes the results of a field survey of the ambient emissions of AMR meters at three residences in Hastings on Hudson, New York. Measurements were taken near the outdoor meters and within the residences to which they are attached, including radiated emissions testing in three homes and conducted emissions testing on the electrical wiring in one home. Radiated emissions measurements were compared between two primary measuring devices. Measurements were also compared to applicable interference and exposure standards for reference.

10. Appendix 1 – Photograph of Test Configuration of AMR Meter

with substitute power cord installed in lieu of typical house mains wiring configuration

Source:

FCC Part 15.247 Certification
Test Report

FCC ID: SK9C1A-3

FCC Rule Part: 15.247

ACS Report Number: 05-0122-15C

Manufacturer: Itron Electricity Metering, Inc.
Equipment Type: Electricity Meter With FHSS Transmitter
Trade Name: CENTRON ™ ICARe
Model: C1A-3

Test Setup Photographs

Isotrope Note:

Power cord installed for testing. Not consistent with field applications of device.

No House Mains wiring installed for simulation (on radiated and conducted emissions tests).

Figure 3: Conducted Emissions – Front View