**James N Lester Ballasting**
83 Wood Drive
Essex, Massachusetts USA 01929
Cell: 978-768-3278
EMAIL: j.lester@ieee.org

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## EXECUTIVE SUMMARY

This author has no objection to testing MOSFET based lighting products to 1000 MHz. Most high volume bipolar transistor based lighting products generate little measurable radiated noise and testing them for radiated EMI will un-necessarily increase test costs and time. Part 15 and 18 should not have conflicting test range statements compared to this reference document discussed here.

# RECENT LIGHTING EVOLUTION

In the 1970s and early 1980s, bipolar power transistors were mainly used in lighting ballasts and their slow speed limited radiated noise to low frequencies. MOSFET transistors began being used in the 1980s onward because of their higher efficiency and easier ability to be controlled. But the MOSFET's fast switching speed can generate radiated EMI to above 500 MHz easily. At first they were used primarily in non-consumer ballasts but as their costs came down they started to show up in consumer lighting products also. Today's dim-able lighting consumer products usually use MOSFETs while non-dimmable consumer fluorescent lamps usually use bipolar transistors. Non-consumer products use mostly MOSFETs today.

This author has been testing MOSFET based lighting products, during development, to 500 MHz since about 1990 to be sure no unexpected interference results from the MOSFETs use.

## UPDATE PART 15 AND 18

Although this document has reached many in the lighting industry, many smaller lighting companies are used to obtaining their lighting compliance information from FCC Part 2, 15, and 18. In addition, EMI test houses look to Part 15 and 18 for testing information such as limits and test ranges. Having this document in a knowledge database is not a consistent way to inform the people. To be more confusing, the required radiated test ranges in Part 15 and 18 do not agree with this document. All should agree so that everyone uses the same set of rules. The normal rule making/change process should be used to update Part 15 and 18 to maximize the distribution of this change.

## INTERFERENCE RESOLUTION

Both Part 15.15 and 18.115 already require that interference problems, caused by lighting, be resolved. This is commonly done and many times this author has seen a lighting product removed from an installation and another lower EMI product substituted.

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Non-consumer lighting products are typically built to comply with assorted industry voluntary standards, for example ANSI C78.5 for fluorescent ballasts. Section 4.4 (2003 issue) specifies that all the ANSI qualified ballasts must pass radiated testing to 200 MHz, no matter what the FCC Part 18.309 test range requirement specifies. This author routinely saw this testing performed. Some lighting products even included filters to minimize radiation in the FM radio band, thereby reducing the chance for interference further.

Compact electronic lighting is slowly replacing incandescent lighting, largely to lower power consumption. Federal laws are forcing this change. The sales rate of these electronic lamps exceeds 100 million a month. It's not uncommon for 50,000 light sources to be in a multi floor building. The interference potential is considerable. Companies that sell lamps that generate unacceptable EMI don't survive. There is a lot of competition and profit margins are small. It is common to test and design lamps beyond FCC requirements if the market for that lamp requires it.

The FCC does not hear of many lighting interference problems, as stated in the document, because lighting works to avoid or resolve most of them first.

## TEST TIME AND COST

EMI test houses typically charge by the day and half-day. It takes about 30 minutes to perform a conducted test but up to 4 hours to perform a radiated test on a lighting product. In the past, with limited required radiated testing, multiple test samples were usually conducted tested during a half-day test period. Now with a required radiated test, only one test sample can be evaluated during a half-day. To test the same number of samples, many days of testing may be required which will increase the test time and cost. Alternately, fewer or one sample can be tested during the half-day test period to keep the test time and cost the same as before. This author suspects that the second case will prevail and fewer lighting samples will be tested in the future.

## RF LIGHTING DEVICES

LED compact light sources often have substantial RF frequency energy applied to the LED light source along with or without a DC component. These lamps often are considered Part 18 devices because RF is delivered to the load to produce light. RF has also been delivered to incandescent lamps to produce light, which allows for small power supplies. HID gas lamps are often operated from below-RF frequency square waves, which is more suitable for Part 15 testing. There are many different types of lighting products that use RF energy either for power conversion or to deliver power to the lamp load. The capability to generate radiated EMI varies greatly and types that are unlikely to generate radiated EMI will be un-necessarily radiated tested increasing test time and costs.

## PART 15 UNINTENTIONAL RADIATORS

Part 15.109a requires (all) unintentional radiators to comply with Class B requirements. Part 15.109b refers to Class A "Digital" devices and a few special devices but not unintentional devices in general. Part 15.3k defines a Digital device. But this document refers to Class A and Class B lighting devices. Part 15.109b should be updated to allow for Class A

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unintentional radiating devices in general unless lighting is to be considered a Digital Device which should be clarified in Part 15.3k.

Both this document and Part 15 should clearly agree to maximize the distribution of this document change and avoid confusion of Class A lighting requirements.

# RADIATED MEASUREMENT ISSUES

One concern is the ability to measure low radiated EMI signals at assorted EMI formal and pre-compliance test labs. The FCC limits being measured against are shown in Table 1 at different test distances assuming a 1/r field variation with distance for Part 15 and 18.

**Part 15 Class A Digital only, RADIATED LIMITS (15.109b)**

| Frequency Range (MHz) | QP Limit (dBuV/m) 30 m Test Distance | QP Limit (dBuV/m) 10 m Test Distance | QP Limit (dBuV/m) 3 m Test Distance | QP Limit (dBuV/m) 1 m Test Distance |
|---|---|---|---|---|
| 30 to 88 | 29.6 | 39.1 | 49.6 | 59.1 |
| 88 to 216 | 34 | 43.5 | 54 | 63.5 |
| 216 to 960 | 36.9 | 46.4 | 56.9 | 66.4 |
| > 960 | 40 | 49.5 | 60 | 69.5 |

**Part 15 Class B Digital and all Non-Digital, RADIATED LIMITS (15.109a)**

| Frequency Range (MHz) | QP Limit (dBuV/m) 30 m Test Distance | QP Limit (dBuV/m) 10 m Test Distance | QP Limit (dBuV/m) 3 m Test Distance | QP Limit (dBuV/m) 1 m Test Distance |
|---|---|---|---|---|
| 30 to 88 | 20 | 30.5 | 40 | 50.5 |
| 88 to 216 | 23.5 | 34 | 43.5 | 54 |
| 216 to 960 | 26 | 36.5 | 46 | 56.5 |
| > 960 | 34 | 44.5 | 54 | 64.5 |

**Part 18 NON-CONSUMER RADIATED LIMITS (18.303c)**

| Frequency Range (MHz) | QP Limit (dBuV/m) 30 m Test Distance | QP Limit (dBuV/m) 10 m Test Distance | QP Limit (dBuV/m) 3 m Test Distance | QP Limit (dBuV/m) 1 m Test Distance |
|---|---|---|---|---|
| 30 to 88 | 29.5 | 39.0 | 49.5 | 59.0 |
| 88 to 216 | 34.0 | 43.5 | 54.0 | 63.5 |
| 216 to 1000 | 36.9 | 46.4 | 56.9 | 66.4 |

**Part 18 CONSUMER RADIATED LIMITS (18.303c)**

| Frequency Range (MHz) | QP Limit (dBuV/m) 30 m Test Distance | QP Limit (dBuV/m) 10 m Test Distance | QP Limit (dBuV/m) 3 m Test Distance | QP Limit (dBuV/m) 1 m Test Distance |
|---|---|---|---|---|
| 30 to 88 | 20.0 | 29.5 | 40.0 | 49.5 |
| 88 to 216 | 23.5 | 33.1 | 43.5 | 53.1 |
| 216 to 1000 | 26.0 | 35.6 | 46.5 | 55.6 |

**Note:** The Class A Part 15 specified test distance is 10 meters. The Class B Part 15 specified test distance is 3 meters. The Part 18 specified test distance is 30 meters. The lower limit applies at boundaries. A 1/r field drop off is assumed. See 15.109 for alternate radiated limit possibilities.

**Table 1 Radiated emission limits at different test distances**

James N Lester Ballasting
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The lowest system measurement level or system sensitivity is given in Equation 1 below. This has to be lower that values in Table 1 in order for measurements to be made.

S=NF+AF+CL+M Equation 1

Where:
S= lowest system measurement capability, dBuV
NF= Analyzer noise floor, dBuV
AF= Antenna Factor, converts antenna dBuV/m to dBuV
CL= Cable loss, dB
M= Measurement margin, signal above noise floor, typically 3 dBuV

Looking at each term:

NF- The modern analyzer noise floor, NF, is fairly constant from 30 to 1000 MHz. Table 2 gives some typical analyzer noise floors from manufacturer's specifications converted to a 120 kHz detection bandwidth and converted to dBuV, with no input attenuation, with and without a low noise input preamp turned on if available.

| **ANALYZER** | **60 MHZ NOISE** | **1000 MHZ NOISE** | **60 MHZ NOISE** | **1000 MHZ NOISE** | **COMMENT** |
|---|---|---|---|---|---|
| | PREAMP OFF | PREAMP OFF | PREAMP ON | PREAMP ON | |
| | dBuV, 120 kHz | dBuV, 120 kHz | dBuV, 120 kHz | dBuV, 120 kHz | |
| | | | | | |
| Advantest R3265A 100-8000MHz | +9 | +9 | +4 | +4 | old |
| HP 8568B | +12 | +12 | ? | ? | Very old Was popular |
| HP 8546A | +9 | +9 | +4 | +4 | old |
| R&S FSL | +18 | +18 | +6 | +6 | $10,000 pre-compliance |
| R&S ESU | +4 | +4 | -7 | -7 | New FFT type |
| Agilent N9038A | +8 | +8 | -5 | -5 | New $90,000 |

**Note:** The noise floor can't go below around -17 dBuV due to the Earth's noise temperature. Values above are converted from manufacturer specifications. 60 MHz noise is about where the antenna AF is at it's lowest value and is used in the text discussion.

## Table 2 Old and new analyzer noise floors

AF- EMI antennas have measurement conversion factors that have to be added to the measured signal to convert field strength to a terminal voltage that the analyzer can measure. At low frequencies (30 to 200 MHz), a bi-conical antenna has been used for years and for upper frequencies (200 to 1000 MHz), a log-periodic antenna has been used. Many test houses today use one complex antenna that combines the two types into one assembly. Typical antenna factors, whether or not one or two antennas are used to cover the frequency range, are 8, 15, and 25 dB for 60, 200, and 1000 MHz. The higher the antenna factor, AF, the worse the system measurement sensitivity discussed below. System sensitivity decreases as frequency goes up. The lowest AF occurs around 60 MHz and it increases simply as the frequency increases. The highest is at 1000 MHz.

CL- The coax cable, connecting the antenna to the analyzer, also has loss, which also has to be added to the measured signal. For a good cable, it will vary from less than 1 dB at 30 MHz to near 7 dB at 1 GHz per 100 meters. Depending on the layout, the cable may typically be 20 meters long so cable loss is of small importance but it also lowers system sensitivity, S, as frequency goes up by a few dB.

M- When measuring noise on top of a system noise floor, the measured value needs to be greater than the noise floor to be confident that a signal has been detected. A good EMI tester can be confident with a 3 dB margin while someone less experienced may need a 20 dB margin. Here, 3 dB is used.

S- The only parameter in the equation that is very frequency sensitive, is the antenna factor, AF. The AF raises the measurement noise floor voltage by nearly a factor of 10 as the measurement frequency goes from low to higher radiated frequencies. For example, a system using the modern low cost pre-compliance analyzer, FSL, can have a noise floor as high as 26 increasing to 46 dBuV from 60 to 1000 MHz. From Table 1, a Part 18 consumer test distance of 3 m or closer would need to be used to be able to measure signals near the limit line at high frequencies. This is far from the specified 30 m test distance. With the pre-amp turned on, the system noise floor drops to 14 to 34 dBuV over the frequency range, and testing to 10 m would be marginal but possible.

A top analyzer, like the HP N9038A, used in a system can have a noise floor as low as 16 to 36 dBuV from 60 to 1000 MHz. From Table 1, a Part 18 consumer test distance of 10 m or closer would need to be used to be able to measure signals near the limit line. This makes the specified 30 m test distance data not too useful. With the pre-amp turned on, the system noise floor drops to 3 to 23 dBuV over the frequency range, and testing to 30 m would be marginally possible.

At lower radiated frequencies (30 to 300 MHz) modern systems can measure EMI that is just above the Part 15 and Part 18 limits because the AF is so low. As the test frequency is increased (500 to 1000 MHz), the measurement noise floor of all EMI systems increases due to the increasing antenna AF, and measuring EMI that is just above the Part 15 and Part 18 limit can become difficult. The effect is that the measured EMI appears to disappear into the noise floor as the test frequency increases. This can lead to false passing reports. A measurement procedure like MP5 could address this potential problem. Alternately, testing can all be done at 3 m or closer and limits and test distances could be specified. Testing in the near field raises many other technical questions which your audience could help answer. A study of EMI labs and their ability to measure low level lighting EMI in the 500 to 1000 MHz range should be done before testing requirements are increased substantially.

In the past, lighting interference at these high frequencies wasn't a problem, so the ability to measure low signals correctly there for lighting wasn't important to most test houses. There is a chance that even modern pre-compliance EMI receivers and spectrum analyzers can have problems measuring low noise in the 500 to 1000 MHz range.

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## EMI ABOVE 1000 MHZ

In the referenced document, it is stated that interference was measured from lighting ballasts in the 300 to 3000 MHz range. Why is radiated testing still limited to 1000 MHz? In the future, more use will be made of frequencies above 1000 MHz. Should the limit line below 1000 MHz be extended to 3000 MHz or some other frequency?

## THE FUTURE

As incandescent lamps are replaced by electronic light sources, the ambient EMI noise level in the USA and the world will increase. The numbers of newly installed electronic light sources will be staggering, exceeding perhaps 100 million a month from multiple manufacturers for many years. A tall building or display can contain 50,000 electronic light sources or more. What will be the resulting EMI? Recent market studies show that there are a couple of billion incandescent lamps in the USA. Many of these will be replaced by electronic lighting. Presently lighting is responsible for interference to licensed services (15.15 and 18.115). Managing EMI from billions of electronic light sources from many manufacturers all mixed in different locations will be a challenge. Licensed technologies are always advancing and finding ways to increase receiver sensitivity to lower needed transmitter power and extend portable battery life. EMI noise levels that are acceptable today may become unacceptable in the distant future but replacing millions of noisy and therefore unacceptable electronic light sources may become an unrealistic task. Will it be possible to protect all future cell technology deployments against lighting EMI?

Licensed technologies exist today that didn’t exist in the 1980s when the FCC established their limits for Part 18 RF lighting products. Are these limits still acceptable? The Part 18 measurement procedures, MP5, developed in 1986 are still in use by lighting. Part 15 and 18 lighting regulations may be due for a formal update, which should involve many industries.