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To: Federal Communications Division, Office of Engineering and Technology, Laboratory Division

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Subject: Document 640677 D01 LED LIGHTING v01

INTRODUCTION

Draft Document 640677 D01 RF LIGHTING v01 was initially circulated for comments August 27, 2014. It covered Part 15 and Part 18 RF lighting devices including LED lighting devices. A revised draft was released on October 22, 2015, which now limits its coverage to LED Lighting. The comments that follow, apply to the second draft released in October 22, 2015. Comments supplied by this commenter to the FCC on the initial release of this Draft, still apply and are not repeated here.

EXECUTIVE SUMMARY

This author has no objection to limiting this Draft to LED devices. However there are many traditional lighting devices still on the market and there is a replacement market that will be served for years to come. Part 15, 18, and this Draft should not have conflicting Lighting technical and Compliance requirements. Combining them to one location may be due.

FCC Part 15.107 and 15.109 allow for Class A testing only for “digital devices.” Consumer and non-consumer LED lighting, as a non-digital device per 15.3k is to be tested to Class B limits only. This differs from the Draft’s discussions.

Electronic lighting has been transitioning from nearly a novelty in the Consumer market to a necessity over the past few years due to the government’s action toward banning of inefficient incandescent lighting. The days of electronic lighting being a minor RF noise source are gone.

Many LED lamps are small relative to a wavelength, and do not radiate well. Often radiation comes from the power line connected to the LED lamp. The line length and orientation controls the measured radiated signals and weather or not the product passes compliance testing at different test houses.

LIGHTING PRODUCTS

Lighting circuits have evolved over the past decades. In the 1970s and earlier, slow-switching bipolar transistors were used to generate RF frequencies of 20 to 40 kHz and lower. Many large fluorescent lamp ballasts and compact-screw-in fluorescents lights in the 1980s were made like this when the FCC first looked at Lighting. Faster MOSFETs were arriving but expensive to use. Seldom did EMI appear above 30 MHz then so the 1.705 MHz test was useful. As technology advanced, fast-switching MOSFET transistors took over and operating RF frequencies moved above 40 kHz and by the 1990s, lighting products reached

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2.65 MHz and higher. Measureable EMI over 500 MHz became common so the 1.705 MHz test became less useful. Today, 99% of LED lamps use fast-switching MOSFET transistors. Many products today, still use slow switching bipolar transistors and generate no EMI above 30 MHz. The circuit technology used in lighting products today controls the radiated EMI generated and the 1.705 MHz test is not capable of discovering the circuit technology used. The 1.705 MHz test is becoming obsolete.

It is becoming more important than ever, to understand how a lighting product works, to optimize the compliance test time and costs. Verification Compliance testing is a good match for today's evolving lighting products.

LED circuits often have shunt capacitance in their output circuitry that reduces the magnitude of higher RF frequencies. While, traditional lighting circuits often have series capacitance in their output circuits that can enhance the amplitude of higher RF frequencies. In addition, LED lamp circuits generate narrow PWM power pulses at 150 kHz that step 160 VDC down to about 12 Vp pulses that are filtered and fed to the LEDs. These narrow pulses are rich in harmonics. Traditional lighting circuits typically generate square-waves at, perhaps, 40 kHz. Their square-wave is fed through a filter that mainly lets the fundamental sine-wave through to the lamp. Their square-wave generates a smaller amount of harmonics than the LED lamp pulse wave shape. So the different technologies can generate different amounts of EMI. Testing all lighting products to 1000 MHz using the Verification Procedure to minimize Compliance testing costs should be considered.

Cost dominates the purchase of consumer lighting products in the USA. Not all the World bases their purchase on cost. So the technology available in the USA is changing due to many worldwide factors. Presently USA LED lamp prices are low due to a 2015 over production in China. Production corrections may drive LED lamp costs up again and low cost compact fluorescent lamps may come back in 2016. Mature, low cost compact fluorescent lamps still sell strongly in other parts of the world. Deleting traditional lighting concern from this Draft may be premature.

Below is a partial list of modern electronic lighting products and the FCC Parts often used for compliance testing prior to the release of this Draft.

INCANDESCANT
- Electronic transformer (ET) with or without an integral lamp delivering RF frequencies above 9 kHz to the lamp load, MR16 types – Part 18, consumer or non-consumer
- Electronic transformer (ET) with or without an integral lamp delivering DC to the lamp but using internal power converter frequencies above 9 kHz – Part 15, unintentional radiator, Class B only
- Incandescent with system frequencies below 9 kHz – Part 15, incidental radiator, (phase controlled or series diodes are examples), only requirement is to use good engineering practice and interference cannot be caused.

HID
- Lamp operated above 9 kHz, integrally ballasted – Part 18, consumer or non-consumer

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- Lamp operated with a low frequency (<< 9 kHz) square or sine wave of current with an internal inverter operating above 9 kHz with or without a buried microcontroller – Part 15, unintentional radiator, consumer only (Class B), Note that ANSI C82.14 presently specifies a Part 18 compliance requirement. Their requirement does not agree with OET discussions.
- Lamp with no system inverters operating above 9 kHz, magnetic ballast - Part 15, incidental radiator, only requirement is to use good engineering practice.

FLUORESCENT

- Self ballasted compact fluorescent with Lamp frequency above 9 kHz, CFLi, Induction lamps – Part 18, consumer or non-consumer.
- Separate RF fluorescent Lamp and ballast with PFC and/or inverter frequencies above 9 kHz with or without a buried microcontroller – Part 18, consumer or non-consumer.
- Fluorescent Lamp with no system frequencies above 9 kHz, magnetic ballast - Part 15, incidental radiator, only requirement is to use good engineering practice.
- RF Lamp and Ballast with digital DALI control interface or similar, The system must meet both Part 18, consumer or non-consumer and Part 15, Class A or B, digital device, unintentional radiator.
- RF Lamp and Ballast with DC control interface using no integral RF circuitry, Part 18, consumer or non-consumer.
- RF Lamp and Ballast with DC control interface using integral RF circuitry, The system must meet both Part 18, consumer or non-consumer and Part 15, Class A or B, digital device, unintentional radiator.
- RF Lamp / Ballast and a carrier current control interface, The system must meet both Part 18, consumer or non-consumer and Part 15 (carrier current system), Class B.

LED

- Integrally ballasted screw-in with internal inverter operating above 9 kHz with DC power to LEDs – Part 15, Class B only, unintentional radiator.
- Integrally ballasted screw-in with internal inverter operating above 9 kHz with DC and RF modulation (>10%) to LEDs – Part 18, consumer or non-consumer.
- Separate dedicated LED power supply, internally operating above 9 kHz, with DC to a passive LED array load or a load with internal frequencies operating below 9 kHz – Part 15, Class B only, unintentional radiator.
- Separate dedicated LED power supply, internally operating above 9 kHz, with DC and RF modulation (>10%) to a passive LED array load or a load with internal frequencies operating above and below 9 kHz – Part 18, consumer or non-consumer.
- Generic Part 15 DC-output power supply containing no RF circuitry with a passive LED array load, delivering only DC current to the LEDs – Part 15, incidental radiator, only requirement is to use good engineering practice.
- Generic Part 15 DC-output power supply with integral circuitry generating frequencies above 9 kHz with an LED array load with DC only delivered to the LEDs – Part 15, Class B only.
- Generic Part 15 DC-output power supply with integral circuitry generating frequencies above 9 kHz with an LED array load with DC and significant RF delivered to the LEDs – Part 18, consumer or non-consumer. The power supply will have to meet the Part 18 requirements in this case as a composite device. Whoever combines these products is responsible for system FCC compliance to Part 18.

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AUTOMOTIVE, AVIATION, MARINE, BATTERY POWERED LIGHTING

- Same as in the other categories but no conducted EMI technical requirements. Radiated, documentation, and labeling requirements still apply.
- Digital automotive devices (communicates with other devices) are exempt from Part 15 compliance (15.103-a) unless it is a composite device (15.103i). See COMPOSIT DEVICES below.

CONTROLS

- Controls (dimmers, occupancy detectors, sequence controllers) that have internal PFC, inverter, or clock frequencies above 9 kHz.
  - Special DC control lines to ballast – Part 15 unintentional radiator, Class B only.
  - Inject RF control signals greater than 9 kHz into power line – Part 15 carrier current device, Class B only.
  - Wireless remote controls or ballast controls – Part 15, Class B only, intentional radiator
  - Digital controller like DALI – Part 15, Class A or B, digital device unless operating frequencies are below 1.705 MHz, in which case they are exempt from FCC compliance (15.103h).
- Phase control incandescent dimmers, with no internal operating frequencies above 9 kHz, – Part 15, incidental radiator, no FCC compliance requirements but can not cause interference.

COMPOSIT DEVICES (15.31k)

- If there is one resulting primary function then one FCC Part will apply. A soda machine with an internal fluorescent lamp is still primarily a soda machine and must meet only Part 15. A laptop computer with fluorescent backlighting is still primarily a computer and is a Part 15 device. A RF fluorescent ballast, with an integral microcontroller, that does not interface with the outside world is still a Part 18 fluorescent ballast.
- If there are two distinct resulting functions then both FCC Parts will apply. For example a RF fluorescent lamp ballast and a digital communications interface like DALI in one package must meet both Part 15 and Part 18 compliance requirements. The more stringent of the two technical requirements and all of the documentation and labeling requirements must be met. They can be blended together.
- When the compliance requirements are not clear, contact the FCC who can make a formal determination.

Some traditional lighting sources may eventually be replaced with LED lighting. A quick review of lighting manufacturer's catalogs and distributors product listings shows all the above products to still be available. Over time, new manufacturers may begin to produce traditional lighting products that major lighting manufacturers drop from their product lines. The replacement market will exist for years to come. Having two FCC Parts to select from can be confusing as the above list shows. Combining Part 15 and 18 lighting devices into one Part would shorten the above list and minimize potential errors.

RF TO THE LED-LOAD

Some LED lamps deliver DC voltage plus a substantial amount of RF to the LED load. That amount can vary from a fraction of a percent to a significant amount of the delivered power, for example 50%. This is done to minimize the size and cost of the filter electrolytic capacitor

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across the LED on the output of the ballast circuit. This capacitor limits the life of the product and eliminating it is desirable. In discussions with OET Engineering in the past, this commenter was advised that if any RF was delivered to the load (LED), the lighting product was to be tested as a Part 18 device. This Draft appears to change that test.

COMPOSIT LED DEVICES (15.31k)

Many LED lamps are used in backlighting applications in TVs, cell phones, electronic Pads, etc. This Draft should not apply to those applications as the primary product may not be considered LED lighting.

LED lamps are also, presently, combined with IoT technology containing WiFi or Blue Tooth circuitry making them intentional radiators. This Draft should clarify that the compliance requirements for those lamps are exempt from this Draft.

Lighting, like many technologies, is becoming more complex. LED lamps are becoming a part of a distributed network of smaller lamps or different color lamps. Ten years ago, a lamp was either on or off but today intensity, color, and direction are being controlled in LED lighting, which interface easily to sensing, network, and control circuitry. Although simple ON-OFF LED lighting still exists, LED lighting technology is rapidly changing and involving networks and the use of this Draft will become increasingly questionable.

In 2011, a new data network referred to as Li-Fi, was proposed where LED lamps in a building would also be data nodes for an optical data network. Optical data speeds exceed 100 times present WiFi/Blue Tooth speeds. Video is being modulated on modified LED ceiling lamps. In late 2015 a complete movie was sent optically from an LED lamp in under one second. By 2018 this network is expected to be in wide use. Even cell phones, will communicate with Li-Fi with their built in cameras.

LED Street lights will send traffic information on their light to traffic. Car's headlights and taillights will communicate to reduce crashes. Traffic lights will send optical signal signals to headlights and cars will know when to stop.

An LED lighting network is more secure than a radio network, which pushes the use of an LED lighting data network sooner. So in the very near future, LED lighting will become a complex, and necessary part of society with much interest. LED lighting may need it's own FCC Part in the very near future.

UPDATE PART 15 AND 18

Presently FCC limits for lighting products in Part 15 and 18 allow for a measurable amount of interference at close distances. In the past, the use of electronic lighting was limited and if interference occurred, the lighting was turned off, moved further away, or replaced with lighting that didn't generate RF energy. Today the options are becoming more limited as traditional lighting use is disappearing by government mandates and public interest in more efficient lighting products. There are an increasing number of applications where reduced RF from lighting products would be desirable. Part 15 and 18 list fairly high, radiated RF noise limits at 10 and 30 meters, which protects neighbors but not users. And, without much

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guidance, the FCC Parts also say that it is lighting's responsibility to insure no interference to licensed devices occurs. For many applications, this is acceptable but for other applications, an additional set of lower limits would be useful to identify needed low RF interference limits. Part 18 lighting has not been updated since the 1980s. Part 15 has been updated for reasons mainly unrelated to lighting. But the use of RF lighting is increasing dramatically.

Lighting technology has changed rapidly over the last 10 years with the advancement of LED lighting. It may be time for an FCC standard just for lighting that would offer guidance in limits for acceptable RF noise levels for most applications and acceptable noise levels for applications that require low noise.

Acceptable noise levels are polarity sensitive as well. A lamp injecting RF noise into a horizontal power line may not interfere with a cell phone with a vertically orientated antenna, for example.

In the late 1980s and early 1990, Part 15 and 18 lighting devices had the same compliance limits. So if a lighting device was tested to the wrong FCC Part, the same limits were used. Part 15 has been updated so that the two Parts now use different limits, especially the conducted limits. It may be time to update the Parts to be similar to keep all lighting limits similar. Then possibly, in a future update, all lighting products can be merged into Part 15 into a lighting product category eliminating a lot of confusion on Part selection as lighting technologies are developed.

Also the different Part 15 and 18 Compliance requirements generate unnecessary confusion.

Class A or B

Certain LED lighting products are clearly aimed at the industrial market and clearly can comply with Class A requirements while other lighting devices can be sold into either the residential or industrial market. Often the industrial products are bulk packed at discount prices. These lower cost products can end up selling on the internet to who ever will purchase them. This leads to the chance of industrial products being purchased by the residential market. It should be made clear in this Draft that if an LED lamp can easily be used as a class A or B device, it should be tested for compliance as a Class B device. A screw-in 60 watt incandescent replacement lamp would be a typical example.

The Draft refers to Class A and B LED lighting devices however Parts 15.107b and 15.109b which cover Class A unintentional radiators only cover "computing devices." Parts 15.107a and 15.109a cover non-Class A unintentional radiators which implies Class B devices. Part 15.3k defines a "computing device" and most LED lamps would fail to meet this description. The way Part 15 is presently written, most LED lamps, as unintentional radiators for the consumer and non-consumer markets, are to be tested to Class B only while the Draft discusses Class A and Class B LED lamp testing. There is a disagreement here.

RADIATED FIELD MEASUREMENT

Compact-screw-in LED lamps are small relative to a wavelength in the 30 to 1000 MHz range. So they don't radiate well. RF noise in the LED lamp couples into the power line and

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the power line becomes the radiating antenna. The line length controls what frequencies radiate well. Each test house uses a different power line length so radiation peaks are at different frequencies at different test houses. One house may fail a product while another may pass it.

Sometimes a pre-scan is done in a shielded room with a very short power line and the final scan is done at an open field test site with a longer power line. Then, often only the pre-scan peaks are examined. But they are not peaks in the open field test site so the product, unintentionally, passes easily.

To further complicate radiated measurements, different-length-sections of the power line will be horizontal and different-length-sections will be vertical. This changes the strength and polarity of the measured field strength. Additionally, a horizontal section of the power line will be on the test table, a vertical section will drop to the grounded floor, and another horizontal section will lie upon the grounded floor. All these power line sections can be oriented in line with the test antenna or at some odd angle relative to the antenna.

The power line is uncontrolled making radiated measurements often questionable.

THE FUTURE (edited from my response to the August 27, 2014 Draft)

As incandescent lamps are replaced by electronic light sources, the ambient EMI noise level in the USA and the world is increasing. The numbers of newly installed electronic light sources are staggering, exceeding 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 combined EMI? Recent market studies show that there are a couple of billion incandescent lamps in the USA to be replaced. Many of these will be replaced by electronic lighting. Presently, lighting is considered 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. In the past, lighting using non-RF technology could be substituted for noisy RF lighting products to solve interference problems. But in the future, those solutions will no longer be available. Only lighting products using RF will be available. New standards and low-EMI generating products will be needed. Perhaps a third, low EMI Part 15 Class, Class C is needed.

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 future but replacing billions of noisy and therefore unacceptable electronic light sources may become an unrealistic task, especially considering the expected long lives of LED lighting. Will it be possible to protect all future licensed technology deployments against existing lighting EMI levels?

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.