

Light Bulbs and RFI – A Closer Look

New high efficiency light bulbs put out plenty of light, but hams wonder what else.

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Since its invention by Thomas Edison in 1879, the light bulb has had a truly dramatic and profound impact on modern society. Despite its effect on our daily lives, most of us probably take the light bulb for granted. But as many of us already know, Mr. Edison's incandescent light bulb is now being phased out in favor of more energy efficient alternatives, in part driven by new government requirements. These changes have sparked particular interest among some amateurs who are concerned about the potential for interference that the new bulbs may cause.

The US government's new energy efficiency standards, which were implemented in 2012, require a lighting technology that is roughly 30% more efficient than the incandescent light bulb. Modern energy saving bulbs, however, typically contain electronic circuitry. This circuitry has the potential to generate RF, and with it, the possibility of interference to nearby radio receivers, including amateur receivers.

So far, most energy saving *drop-in replacement* bulbs have been one of two types — compact fluorescent lights (CFLs) and light emitting diode (LED) bulbs. While the newer LED bulbs seem to be gaining in market popularity, both types of bulbs can contain electronics capable of causing RFI.

What The FCC Says

Two sets of rules apply for these new bulbs in a residential environment. LED bulbs operate under Part 15 of the FCC rules. Typically, they are classified as an *unintentional radiator*, if their internal circuitry is operating at greater than 9 kHz. See Table 1A for the specified FCC limits. If at less than 9 kHz, the bulb would still operate under Part 15 but as an *incidental radiator*. In this case, there would be no specified emissions limits, just a requirement not to cause harmful interference. Since incandescent bulbs do not intentionally generate RF, they are also classified as incidental radiators.

Rules of Many Parts

Many people are surprised to learn that CFL bulbs, and electronic ballasts for fluorescent light ballasts for that matter, do not operate under Part 15. Rather, these devices typically operate under Part 18, which addresses



Industrial, Scientific and Medical (ISM) devices. Some household and consumer devices, however, also fall under Part 18. These devices convert RF energy above 9 kHz directly into some other form of energy such as light, heat or ultrasonic sound. While CFL bulbs and electronic fluorescent light ballasts are two common examples, there are others, including microwave ovens and some ultrasonic jewelry cleaners.

Part 18 has two sets of limits for bulbs — consumer and non-consumer RF lighting devices. The emissions limits are considerably lower for consumer rated bulbs. Consumer rated bulbs are the only bulbs that should be used for residential applications. See Tables 1B and 2B as well as the sidebar "Part 18 Consumer versus Non Consumer Ballasts" for the applicable Part 18 limits.

While manufacturers are required to meet the applicable limits for a bulb, it's important to understand that these limits are high enough that interference can still occur to nearby receivers in some cases. Should this occur, however, both Parts 15 and 18 have an addi-

tional provision against harmful interference. The burden in this case then falls on the operator of the device, in this case the light fixture *operator* — not the manufacturer — to correct the problem.

What the Rules Mean

In a nutshell, manufacturers of these new bulbs are required to meet certain specified emissions limits. Bulb *operators* must correct any interference that the device might cause, including a provision to cease using the device upon notification by an agent of the FCC. Typically, this means the ham who uses these bulbs, or a nearby neighbor with a noisy bulb, is ultimately responsible for fixing any interference problems caused by the bulb. The applicable rules are perhaps best summarized by the ubiquitous Part 15 label that comes with all unintentional radiators, including LED bulbs. Part 18 also has a requirement for similar labeling:

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this de-

The FCC Conducted Emissions Limits

Radio frequency voltage conducted back onto the ac power line (on any frequency or frequencies) by lighting equipment designed to be connected to the public utility (ac) power line shall not exceed the limits in the following tables.

These limits are based on the measurement of the radio frequency voltage between each power line and ground at the power terminal using a $50\ \mu\text{H}/50\ \Omega$ line impedance stabilization network (LISN).

Table 1A

Part 15B Conducted Emissions Limits (For Unintentional Radiators, such as LED Lighting)

Frequency of emission (MHz)	Conducted limit (dB _μ V)	
	Quasi-peak	Average
0.15-0.5	66 to 56*	56 to 46*
0.5-5	56	46
5-30	60	50

*Decreases with the logarithm of the frequency.

Table 1B

Part 18 Conducted Emissions Limits (For RF Lighting Devices, such as CFLs and Electronic Fluorescent Light Ballasts)

Frequency (MHz)	Maximum RF line voltage measured with a 50 uH/50 ohm LISN (μV)	Conducted limit (dB _μ V)
Consumer Equipment		
0.45 to 2.51	250	48
2.51 to 3.0	3000	70
3.0 to 30	250	48
Nonconsumer Equipment		
0.45-1.6	1000	60
1.6-30	3000	70

vice must accept any interference received, including interference that may cause undesired operation.

One notable exception to this rule involves interference from a Part 18 device (such as a CFL) in an ISM band. When amateur spectrum falls in an ISM band, such as the entire 902 MHz band, and parts of the 2.4 GHz band, interference from a Part 18 device must be tolerated. Amateur Radio is not protected under the rules in this case. Fortunately, in the case of light bulbs, this has not been an issue, at least not one that has so far been reported to the ARRL.

Conducted Emissions Testing

Both Part 15 and 18 specify two types of emissions limits. Above 30 MHz, they specify a field strength limit for direct radiation from the bulb itself. Below 30 MHz, however, they only specify conducted emissions limits. At HF and lower frequencies, bulbs (and most consumer devices) are simply too small to act as an efficient antenna. In this case, the device generates the RF, which is

then conducted by the power cord, or the connection to the house wiring. The house wiring then acts as an antenna to radiate the RF. The RF can also be conducted by power lines out to the street, resulting in the power distribution wires also radiating the unwanted noise. Based on practical real world experience, most HF interference problems to Amateur Radio are caused by conducted emissions.

As shown by Table 1A, the Part 15 limits for conducted emissions are expressed in dB_μV, or dB relative to 1 μV. The FCC also specifies that these measurements be made between each power line and ground at the power terminal using a $50\ \mu\text{H}/50\ \Omega$ line impedance stabilization network, commonly referred to as a LISN. A LISN is essentially a filter that separates the RF voltage to be measured from the 60 Hz power frequency. The FCC also specifies that measurements be made using quasi-peak detection.¹ See the

¹Notes appear on page 45.

April 2009 issue of *QST*, page 48 for additional discussion concerning Part 15 conducted emission level limits.

The ARRL Lab Test Facility

Several years ago, the ARRL Lab constructed a room for conducted emissions testing per ANSI Standard C63.4-2003. In order to make such measurements to ANSI standard specifications, a LISN and special receiver are required and, in addition, a ground plane on the floor and back wall of specified dimensions are required. The standard also specifies dimensions for a non-conducting test bench, plus detail on product configuration, test layout and so forth. This level of detail ensures test repeatability with uniform and universal results. It was a lot of work, but it gave the ARRL Lab the ability to reasonably measure some consumer products, including light bulbs, for conducted emissions compliance.

Gathering the Samples

Our objective was to select a wide variety of bulbs, including CFL and LED products from a number of manufacturers. In the end, we tested 40 different bulbs from many different sources, including local retail outlets, online sources and hamfests. If applicable, we also tested each bulb in an insulated porcelain fixture and a grounded recessed metal fixture, for comparison.

As part of this program, we tested 7 CFL bulbs, 30 LED bulbs, a self-contained outdoor light — LED lantern fixture and two traffic lights that we purchased at the Dayton Hamvention® flea market.

Test Results

We found that most brand name bulbs substantially met their limits within our measurement uncertainty. Most of the issues that we found were below 500 kHz, and most of them were probably within our measurement uncertainty. We did see obvious problems associated with those bulbs purchased online directly from an overseas source. These bulbs clearly did not meet FCC specifications, and did not have the proper FCC labeling. See the test data on the *QST* in Depth web page for all of our results.² Figures 1-4 show representative samples of LED and CFL bulbs tested that both passed and failed.

What About the Real World?

We tested a random sample of the bulbs in a variety of fixtures in the home and shack of Senior ARRL Lab Engineer Bob Allison, WB1GCM. These tests included the fixtures we used for conducted emissions testing. In each case, we listened for noise with the station's ham receiver and a portable battery powered Sony ICF-2010 shortwave receiver. The portable radio allowed us to listen

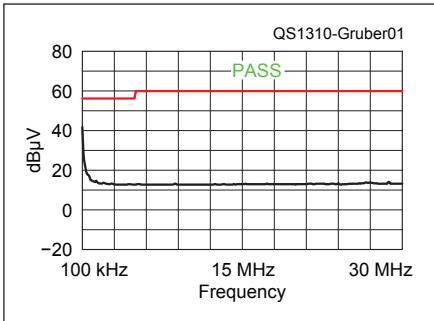


Figure 1 — Conducted emission spectrum from 0 to 30 MHz of an LED night light bulb of unknown manufacture purchased from an Internet auction site. This bulb passed nicely.

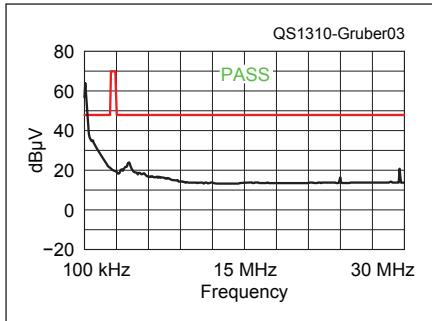


Figure 3 — Conducted emission spectrum from 0 to 30 MHz of an Ecosmart 41314 14/60 W pear shaped CFL light bulb purchased from a home supply store. This bulb passed nicely.

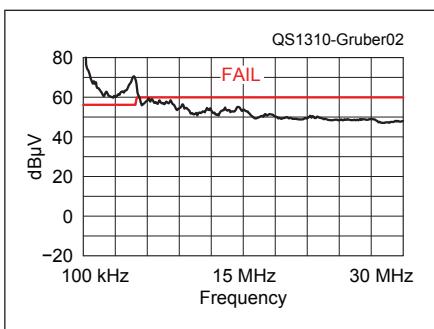


Figure 2 — Conducted emission spectrum of an LED flood light bulb of unknown manufacture purchased from an Internet auction site. Note the difference from Figure 1 for this failed bulb.

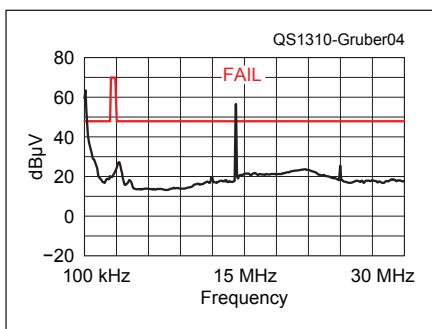


Figure 4 — Conducted emission spectrum from 0 to 30 MHz of a Phillips 13/60 W "twist" CFL light bulb purchased from a home supply store. This test, measured on the neutral wire had a nasty spike near 20 meters and failed. If only the line lead were measured, it would have looked as if this bulb had passed.

throughout the house, yard, adjacent properties and other neighborhood areas.

We also looked at interference from a number of these bulbs at frequencies below 500 kHz. Specifically, we looked for interference in the areas of the proposed new amateur bands at 137 kHz and 472-479 kHz. In addition, we looked in the area of 160-190 kHz, a popular band for Part 15 experimenters. In each case, we tuned considerably above and below the band limits looking for noise peaks. These peaks may vary with a particular bulb sample, or potentially drift into a ham band over time.

The antenna that we used for this testing was an 88 foot inverted L operated against a ground system. Bob reports that he's been using this setup for LF and MF reception with adequate results for a number of years. It consists of a homebrew loading coil 10 inches in diameter, and nearly two feet long, located in the shack. Bob made it by wrapping an old roll of insulated doorbell wire around a "concrete form" cardboard tube. It has a number of taps for tuning.

Simply select the tap that provides the loudest signal. Bob also placed it in line with clip leads for the coil taps and a knife switch at the window sill.

What We Found

In most cases we found that there is minimal noise potential from these bulbs. Noise issues are possible in some cases, however, especially from nearby bulbs. The 160 meter band was the most likely of our current bands to receive noticeable interference, followed by 80 meters. In some cases, it may be possible to hear bulbs from a nearby residence, depending on neighborhood density, wiring and other factors.

Special mention should be made about LED light dimmers. Some LED bulbs are capable of being used with a special dimmer, and the dimmer itself can create noise. While our LED dimmer represented only a sample of one, the noise could be severe with every bulb we tried. In some cases, it was S-9 throughout the house. No bulb we tested with a dimmer had a completely acceptable noise level. The noise level did, however,

Part 18 Consumer versus Nonconsumer Ballasts

As the tables show, the emissions limits for consumer RF lighting devices are considerably lower than for non-consumer devices. In fact, the range for both conducted and radiated emissions varies by $10 \text{ dB} \pm 1 \text{ dB}$. Only consumer rated CFLs and fluorescent light ballasts should be used in a home or residence. We have noticed, however, that nonconsumer devices, particularly ballasts, are being marketed and sold at many home and hardware stores. In some cases, these may be labeled as Part 18A devices. Whenever purchasing an electronic ballast, or a fluorescent light with an electronic ballast, it is important to verify that it is rated as a *consumer* device. In some cases, the label may indicate that it is a *Part 18B* device. If the label is not on the outside of the box, you may need to open it. The Part 18 rating must either appear on the ballast or the documentation inside the box. *Verify before you buy.* Any device marketed or being sold as *heavy duty* or *industrial grade* is particularly suspect, be sure to go by the FCC label.

vary with the dimmer level and band of interest. Although not all LED dimmers may be this noisy, it's important to at least be aware of this interference potential.

For light fixtures, we again used the hanging fixture in the shack. This fixture is within several feet of the loading coil and the antenna wire. We also used the two conductor porcelain fixture and a grounded metal fixture in an adjacent room. For bulb tests, we selected a sample of several bulbs including some of the best and worst bulbs based on our test data.

The results generally were pretty much as expected. With some power line noise in the area, the noise increased by several S-units in some cases when in the shack fixture.

The interference from the worst bulbs would clearly be considered harmful. Some of the better bulbs tested in this configuration were far less problematic. Some produced minimal interference. Others were inaudible or almost inaudible. In all cases, however, interference from even the worst bulbs was dramatically reduced when operated from either fixture in the adjacent room. I was also a bit surprised to see that there often seemed little difference between the metal and porcelain fixture in this configuration.

The FCC Radiated Emissions Limits

(a) Except for Class A digital devices, the field strength of radiated emissions from unintentional radiators at a distance of 3 meters shall not exceed the following values:

Table 2A — § 15.109 Radiated Emission Limits

Frequency of Emission (MHz)	Field Strength (μV/meter)
30-88	100
88-216	150
216-960	200
Above 960	500

(b) In the emission tables above, the tighter limit applies at the band edges. Sections 15.33 and 15.35 which specify the frequency range over which radiated emissions are to be measured and the detector functions and other measurement standards apply.

Table 2B — Part 18 Radiated Emissions Limits for RF Lighting Devices

Frequency of Emission (MHz)	Field Strength Limit (μV/meter)
Nonconsumer Equipment:	
30-88	30
88-216	50
216-1000	70
Consumer Equipment:	
30-88	10
88-216	15
216-1000	20

As a final check, I took the ICF-2010 receiver outside the house. Although this radio only goes down to 150 kHz, I listened across the spectrum up to about 500 kHz. Not surprisingly, the noise was very strong in proximity to the power meter. The worst case name brand bulbs, however, quickly became inaudible as I walked along the power lines coming in from the street.

Obviously I was using a compromise antenna, but the noise diminished dramatically with distance by the time I reached the street. I continued walking along the lines toward the transformer located several poles from the house. The noise was weak enough that it simply dropped down to the level of normal background noise. With some power line noise in the neighborhood, I could no longer accurately assess the noise level beyond 25 feet or so from the power meter.

Conclusion

Based on the number of interference reports that we've received so far, bulbs have generally not proven to be a significant source of RFI. Based on our testing, however, it pays to be cautious and informed. Remember that

bulbs can meet the regulatory limits and still cause RFI. Should this happen, the bulb operator is responsible for fixing the problem. In many cases, this is the ham dealing with a bulb in the house, but it could also come from a neighbor. There are simply no guarantees with any bulb, regardless of the FCC limits!

Summary and Some Additional Guidelines

Some bulbs are better than others. Generally look for recognizable brand name products.

Avoid bulbs without proper FCC labeling, such as those from direct overseas sources.

Based on our testing, the 160 meter band is the most likely to be affected. Next is the 80 meter band. Operators in these bands should wish to exercise extra caution when purchasing bulbs. The proposed amateur bands at 137 kHz and 472-479 kHz may also be problematic.

Consumer type CFL bulbs operating under Part 18 have significantly lower FCC emissions limits than LED Part 15 bulbs. Any LED bulb when used with a dimmer can cre-

ate problems — regardless of how quiet that same bulb is without the dimmer.

It's important to understand that we really can't tell you what kind of bulbs to buy. Even if our test data shows a low potential for RFI, bulbs can vary. Bulbs that look similar and are labeled in the same way may not actually be the same. Even if a particular bulb purchased today doesn't cause RFI, the same brand and bulb type may cause interference if purchased 6 months later.

Your mileage may also vary based on such factors as the configuration of your home's wiring. Remember — these are conducted emissions that are being radiated by the wires powering the bulb. The interference can also be conducted to other wires both inside and outside your home. Obviously, your antenna and its proximity to these wires can be a significant factor toward the impact and level of the noise at your station.

Our best recommendation, therefore, is to *try before you buy*. Start with a sample or purchase one bulb. If you observe no RFI, buy a suitable quantity of that same bulb, preferably from the same store.

For the most part, based on noise reports received at the ARRL, these new energy saving bulbs have not proven to be a widespread epidemic of RFI. Nonetheless, it pays to be cautious and informed. I hope this article has helped in that regard.

Notes

¹Quasi-peak detection is a measurement technique specified by the FCC for its conducted emissions limits. CISPR quasi-peak measurements are made using AM and a 9 kHz bandwidth. The tests are designed to assess the effect of interference of a received signal to the human ear. CISPR is the International Special Committee on Radio Interference of the International Electrotechnical Commission.

²www.arrl.org/qst-in-depth

Before joining the ARRL, EMC Engineer Mike Gruber was an electrical engineer in the aerospace industry. He holds a B.S.E.E. degree from the University of Bridgeport and an A.S.E.T. from Hartford State Technical Institute. First licensed in 1974 as WN1SVF, Mike now holds an Amateur Extra class license and enjoys ragchewing, portable operation and project building. While at the ARRL, Mike served as the Product Review Test Engineer for seven years. He's been at the ARRL RFI desk since 2002, primarily assisting in power line noise and other Part 15 interference cases, writing articles and editing ARRL books pertaining to RFI. He can be reached at w1mg@arrl.org.

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