Lutron RF Technology…

Reliable. **F**irst. *Forward Thinking*.

By Rich Black
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Lutron Electronics Co., Inc.

Forward thinking

In 1991, Lutron® identified the need for reliable retrofit home light control systems. The company began analyzing the global market, investigating communications and working through the various frequency bands and regulatory requirements. The mission: design an ultra-reliable communications system that works to specification every time—in every installation—well into the future.

The result? RadioRA® became the first, easy to install, versatile and reliable RF home light control system (LCS). Today, after more than a decade of refinement, line extensions and unparalleled success, Lutron solutions are recognized as the benchmark for RF light control.

In addition to RadioRA, five diverse product lines have been developed using this patented technology: HomeWorks®, RadioTouch®, AuroRa®, Milenyia™ (European RF) and Sivoia QED™ electronic shading systems.

This paper will describe the Lutron requirements, investigations and decisions regarding best methods for RF communications in an LCS. Other available frequencies, system topologies, industry standards for RF products and practical field issues will be discussed.

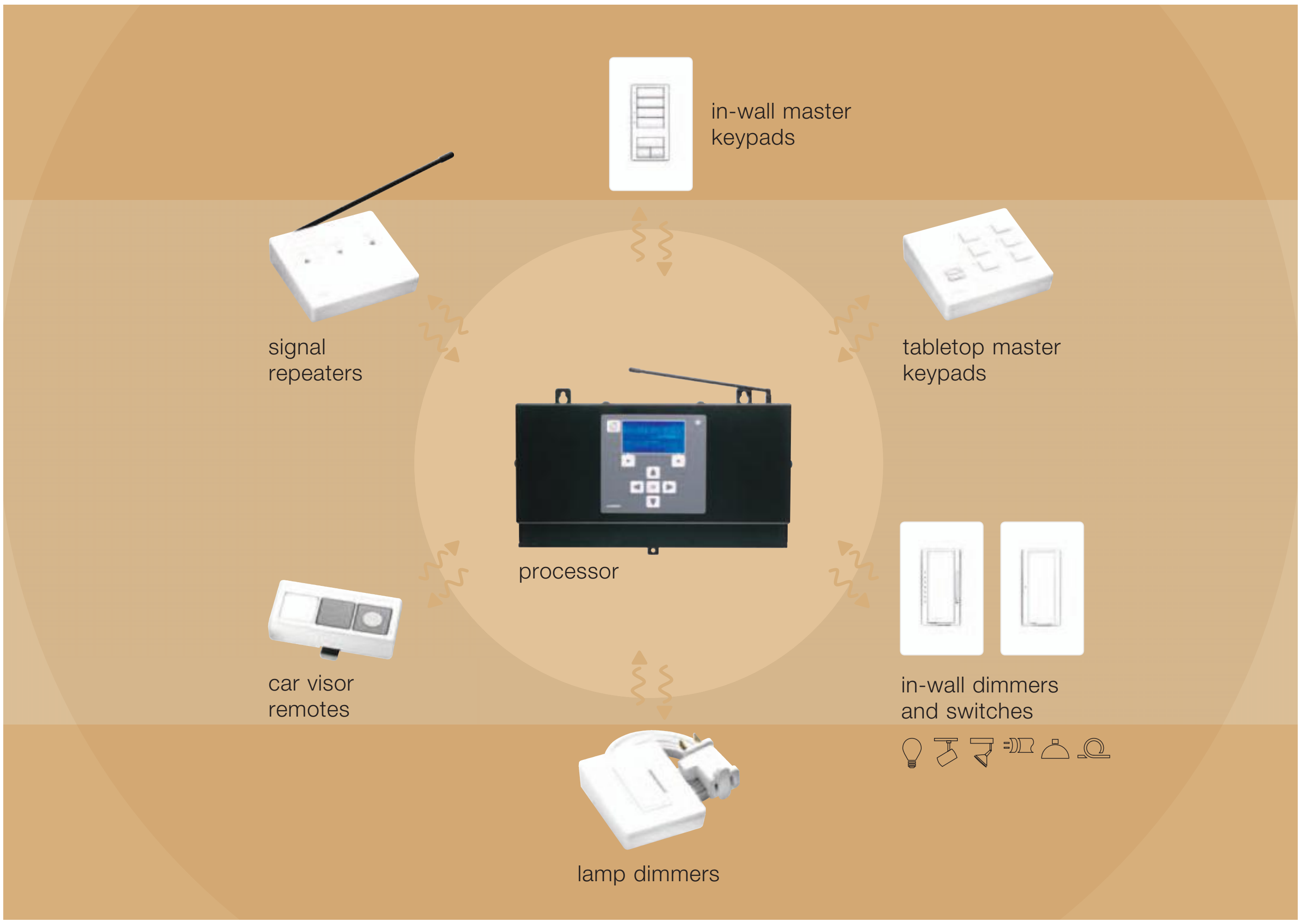
The company's exhaustive research and unwillingness to compromise on performance, led to its leadership in the RF lighting control market. The following pages have been written to present the Lutron perspective on the science of RF light control. We hope that you will find this information useful in determining the parameters for RF systems that meet the unique needs of your clients.

The requirements

When investigating RF communications, ultimate **reliability** was obviously key for Lutron. Beyond ultimate reliability, the system had to be completely **"retrofittable"** and easy to install. No special tools or workmanship would be required. It had to replace existing switches and dimmers using the existing wiring—calling for dimmers that operate without a neutral wire.

Two-way communications were essential. The system would confirm that all messages sent were received, and, thereby, provide confirmed status feedback on the keypads. The complete solution would control all load types, have wall-mounted and tabletop keypads and dimmers, controls for the car, and integration devices. Components would have elegant aesthetics and be easy to use and understand—something Lutron has always required of its products.

Many new entrants to the RF light control market miss several of these key elements. A system that provides the ability to control "most" of the lights from "most" locations loses "most" of its value. Designing non-neutral-based products takes significantly more engineering effort and skill, but many wall boxes do not have a neutral. Having the ability to control table lamps, or control lights and shades from your car, is the difference between ordinary control…and extraordinary convenience.



Lutron RF Systems are reliable, "retrofittable" and complete solutions.

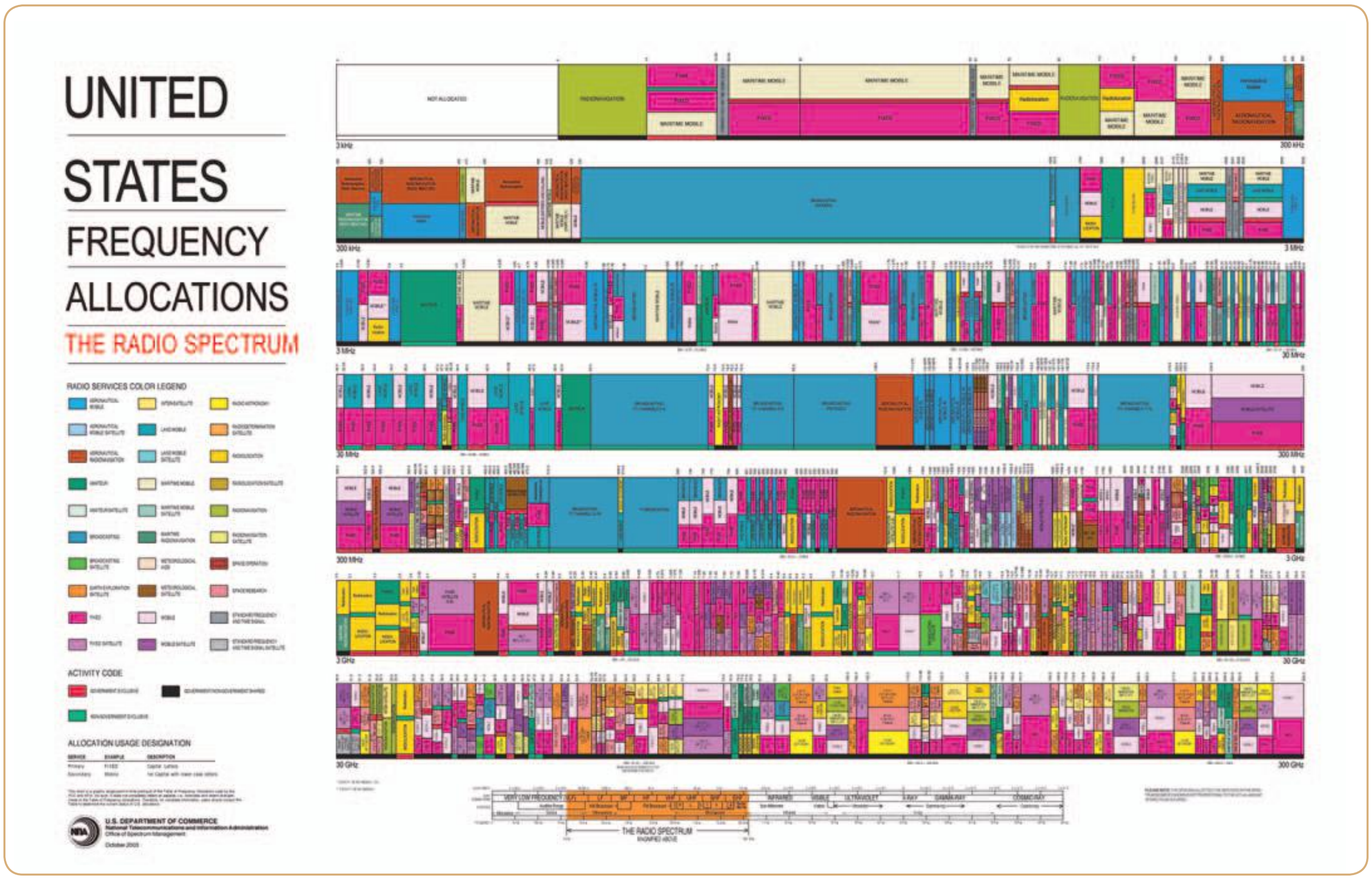
The investigation

Lutron investigated many different frequency bands (e.g. 400 MHz, 900 MHz, and 2.4 GHz). The company also considered numerous regulatory requirements from a global perspective. RF emission surveys were conducted in the field to assess the best bands for operation. Measurements were taken in major cities, and around major RF transmission sites (antenna farms), all in an effort to understand real-world issues and activity. Existing RF products (like cordless phones) were also put to the test.

What did Lutron learn?

- Every tested system was subject to interference and could be compromised—regardless of sophisticated modulation, hopping or coding schemes.
- While higher RF power would extend range under "quiet" conditions, it did not ensure **reliability**. Since all devices in a given operating band can radiate at the same power level, the risk of in-band interference greatly outweighs the benefit of additional power.
- Bands allowing "continuous" transmissions (like those from cordless phones and wireless routers) would always be problematic (too many devices with too much "on" time). These bands must be avoided.
- Lower frequencies experience less attenuation through—and reflection from—construction materials than higher frequencies (analogous to low frequency audio signals).

Testing and analysis concluded that operating in "quiet" bands—allowing only very brief, low-power transmissions—optimized overall system performance. The ideal band was defined by FCC regulations Part 15.231.



This FCC chart shows the complexity of spectrum allocation in the United States.

RF competition is everywhere.

FCC 15.231: A brief description

- Devices are relatively "low power' (fractions of a watt). This reduces the possibility of interference between adjacent systems, and eases the power supply requirements of a product.
- Devices may not transmit continuously. Generally speaking, all activity is driven by user action (like pressing a button).
- Devices may not poll or generate periodic transmissions. There is a 5-second maximum event time after pressing a button.
- Devices in this band include garage door openers, security sensors and car key fobs.

Benefits of 15.231

- Band is essentially silent
- Plenty of frequency room available, ~170 MHz; overcrowding is not foreseeable
- The band has a long and stable history with respect to regulatory changes
- No proposed rule changes
- Bands with similar definitions were available globally by other governments' telecommunications authorities

Typical devices found in FCC Part 15.231.

Imagine how many 900 MHz or 2.4 GHz devices could exist in a building like this.

The decision

Lutron decided that operation under the 15.231 regulations would provide the best overall system performance. This decision was key in the development of the RadioRA system. We reviewed the devices currently operating in this band (public domain information on FCC website). We then chose frequencies that did not line up with other popular devices—such as garage door openers.

The result was a system that has been virtually free of in-band interference. The band has proven great for high-density installations like multi-dwelling units (MDU), urban areas, and dense single-family developments. The proliferation of wireless devices in the global market has had minimal impact on this band.

In 2002, Lutron began work on RF HomeWorks®—our second major RF product line. Its system size and feature set mandated changes to the communications system. Ultimately, the data protocol was modified. However, after careful re-evaluation, we agreed that we were operating with the correct frequency band and rules (15.231).

How many of these popular devices do you own?

Why not 900 MHz or 2.4 GHz?
These bands allow for continuous-on, high-power transmitters such as telephones, Wi-Fi routers and Bluetooth® devices. This puts customers at high risk for interference, which can result in performance issues.

Complex radio techniques such as Direct Sequence Spread Spectrum (DSSS), Frequency Hopping Spread Spectrum (FHSS) and Orthogonal Frequency Division Multiplexing (OFDM) are used in these bands.

These techniques are required for several reasons: First, due to the fierce competition for bandwidth, they are required just for basic operation of several co-located devices. Next, personal voice and data require the highest level of security provided by these techniques. Finally, many of the intended applications require very high data rates (e.g., Wi-Fi router).

The extra hardware, processing power and software required to operate in these bands, adds no value to light control applications. These applications prefer not to compete with co-located devices. Security concerns are more than adequately addressed with several basic, low overhead techniques. The data payloads required for normal operations are relatively small; the key is to have them travel through the system quickly. There will be more about that later.

Both the industry and public equate higher frequency and power levels to higher product performance levels. While all of this makes for great marketing—admittedly important to selling products—the "benefits" are mostly just trade-offs. Our design decisions have always been based on superior, total system performance—*not great advertising*.

Clearly many 900 MHz and 2.4 GHz projects will install flawlessly and operate successfully for years. The knowledgeable integrator (hopefully you, or others you are working with) will identify potential risks—and mitigate them.

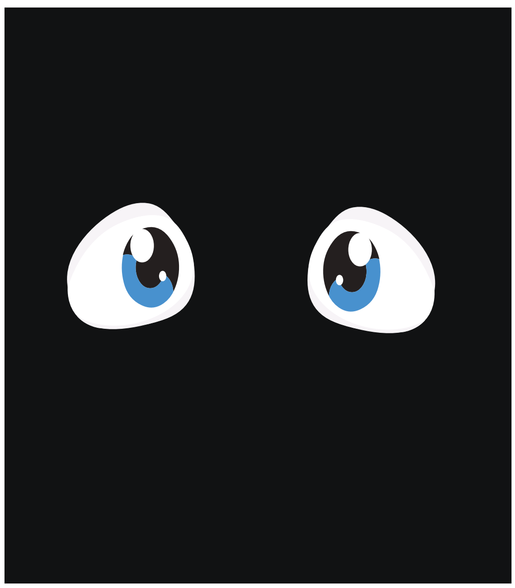
Let's assume that you make the right decision and install a 5.6 GHz phone system in a 2.4 GHz-based home automation system. What happens when the occupant buys a new 2.4 GHz phone to pick up an extra location? What if he installs a 2.4 GHz wireless camera to monitor the new baby? What happens after the building, development or community is built out? How many service calls can your business provide before your reputation and profits begin to suffer?

Interference may not be a problem in your cozy little duplex…

What happens when that duplex becomes a community?

Electronic devices are going "wireless" at a breakneck pace. All of us have experienced dropped cell phone calls, or a lost Bluetooth connection. It's something we've learned to expect and to live with. When an AV system goes down, it's inconvenient. When a light control system goes down, it's unacceptable. It means that you must roll a truck to that location immediately.

Losing a cell phone call is really frustrating…

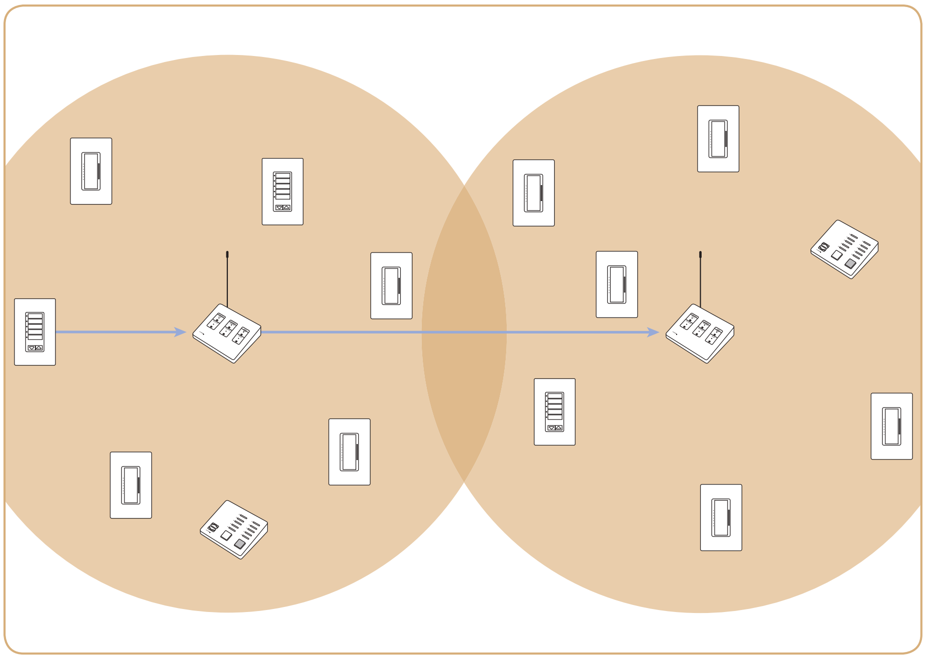


When a light control system fails, it's unacceptable.

Message delivery:
Fixed or mesh network?

There are two primary methods for delivering messages around an extended home automation network. One calls for dedicated sending, receiving and computing stations in predetermined locations—providing RF coverage to all system devices. These stations are commonly known today as WAP's or Wireless Access Points. Lutron began calling these devices "repeaters" over a decade ago. Through years of development, their functionality now extends well beyond the usual definition of the word. This is called a "fixed network," meaning the coverage area and message route are constant. It is fairly simple to create this coverage for homes 10,000 sq. ft. or larger. Messages are moved up and down the fixed network quickly, in a predetermined manner.

The other common method for message delivery used by most RF standards, is called a "mesh network". In this topology, messages can be relayed from a source device through any other device(s) to reach their destination. The devices in the network form a "matrix" of possible message delivery routes. When a source device needs to send a message to a destination device, it uses a routing table to figure out how to get the message delivered—by way of hops through other system devices (if required). This is reasonably analogous to how the Internet moves messages. If there are enough devices in the network, no signal relay stations are required. If a preferred route is unavailable, another route could presumably be identified.

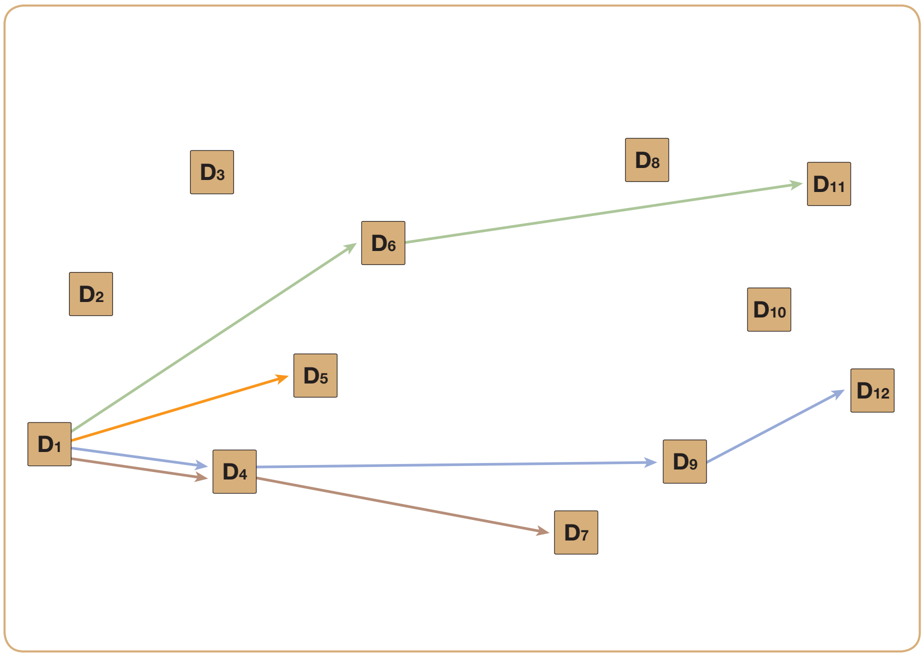


Fixed network
Lutron utilizes a fixed network to quickly transmit group commands—to the entire LCS.

These descriptions are brief, conceptual overviews. While pages of detail could be provided, it is widely accepted that both methods will work for home automation systems. Each has its advantages and disadvantages. The advantages of the fixed network are revealed when we think specifically about light control applications—as opposed to general home automation applications.

The predetermined route in the fixed network provides predictable, fast reaction time to a button press, regardless of that button's location within the system—always. The network is not shared with, or doing work for, any task other than lighting control. Lutron has designed its repeaters to be ultra-reliable. The failure rate is incredibly low. The vast majority of returns are due to product abuse, not electrical failure.

Because repeaters are installed in hidden locations—and are not interacted with during normal operation—they are less likely to be unplugged, and less susceptible to electrostatic discharge through touching. They are separated from the line voltage by a robust low voltage transformer that suppresses any damaging line phenomenon. Their solid state design generates very little heat.



Mesh Network
A mesh network can use any participating devices for message relay. This diagram shows delivery of four directed commands.

Depending on the locations of the source and destination devices in a mesh network, system reaction time may vary from imperceptibly fast—to unacceptably slow. When a device that was part of the normal route is unplugged, switched off or fails, a new route must be identified. This will take time. Hopefully, there is another route.

Mesh network troubleshooting can also be challenging, since the number of possible message routes is large and dynamic. Also, there is no mandatory requirement that a device (using a given RF standard) must participate in the relay of messages—from other system devices. While it may be good citizenship to participate, will all manufacturers take on the additional workload (e.g. processing resources, battery life, timing issues)?

It might go unnoticed if it takes a few extra seconds to turn on the coffee maker from a bedroom control, or for the lawn sensor to report a "dry" condition. However, if you are standing at the door at night holding a bag of groceries, and the lights take a few seconds to come on—you will notice that. These realities have a serious impact on perceived system quality. Erratic performance issues can lead to service calls, even though the overall system is operating fine.

Group Commands vs. Directed Commands
Unrelated to how the messages move around the system, is the issue of the content of the message, and how the system design reacts to that content. Lutron uses "Group" or "Preset" commands. In this scheme, a button press sends out a generic command like "Preset 01".
The devices have distributed intelligence (e.g. devices have non-volatile memory and a database, and know how to react to this command). When a button is pressed, the system transmits "Preset 01" down the fixed network one time. All devices "hear" and respond simultaneously. These systems can be expanded with no degradation in performance.

Most standards do not have this mechanism and are unable to provide it. The reason is that it requires ownership, coordination, and hardware (memory) of all the devices in the network. In the typical standards-based system, the devices are from a disparate group of manufacturers.
Commands must be issued to each device sequentially. These are called "directed commands".
To turn on 10 different devices requires 10 unique commands.
This creates the "popcorn effect."
One light turns on; there is a pause, the next turns on, and so on. To see it in the application is a real letdown. Customers may be happy with the initial installation, add more devices, and become dissatisfied at a later date.

Practical field issues

While it is not the goal of this paper to denigrate the RF standards, it is important to discuss the issues that prevent them from being the best choice for light control. It is my belief that RF standards are a good thing in general. They add value to society and to our industry as a whole. However, they are not the “end-all” solution.

Low-cost, plug-in power line carrier devices are fine for the hobbyist turning on Christmas lights. Likewise, RF standards will probably provide the amateur good performance for his various home automation projects. Lutron believes that current RF standards fall short of providing professional grade products for light control systems. Here are four reasons why:

Point 1
The promise of RF standards is that all devices can talk to one another seamlessly. Let’s think about that in practical terms—within the context of complete home automation. Is someone going to make a thermostat that has a user interface to control your audio amplifier? Is my audio amplifier going to have buttons to arm my security system? How will I program these buttons, since this is going to get quite complex? Is the thermostat manufacturer going to develop a GUI for programming the system? Clearly having all devices able to talk to one another is much different than making them all talk to one another. The point is that we will always have the need for a “parent” or “control” system—to program and control all these devices. That requirement doesn’t go away with an RF standard.

Point 2
The existence of the RF standards greatly lowers the barriers of entry into the RF market. RF chip manufacturers would lead us to believe that all you have to do is plunk down their chip, and presto, it works! Device manufacturers who would not have the engineering resources, expertise and commitment to develop RF technology on their own, can now jump right in.

Let’s assume that the standards are absolutely flawless—perfect hardware, software stack, and protocol. Each manufacturer still has to execute that perfect standard correctly. Mistakes and oversights can be made in the implementation (such as not meeting timing requirements to turn around a message).

It is particularly difficult to design an RF dimmer. Placing sensitive radio receivers in an electrically challenging environment, is a difficult task. Understanding all the possible states, conditions and tolerances is not an easy feat. Newcomers—and their customers—will likely endure the pain of this learning curve.

Point 3
Imagine an RF network comprised of equipment from three different manufacturers utilizing an RF standard. During the setup process, you’re experiencing some difficulty getting the handheld remote to hop through the security sensor, to talk to the dimmer. Who do you call? Which company will stand behind the system if it fails to operate as specified, even though they are only one element of it? Who will be sending field service out to help you? Which manufacturer even has a field service department?

Point 4
When revisions to the standards and application firmware occur, how do you ensure compatibility? Will you be stuck with all the old features even when you add new devices—because you have to operate under the old rules? As an example, the way 802.11g operates with 802.11b is by slowing all the “g” devices down to “b” speeds. Therefore, one “b” device holds back your entire network.

Published specs: Don't just read them. Read into them.

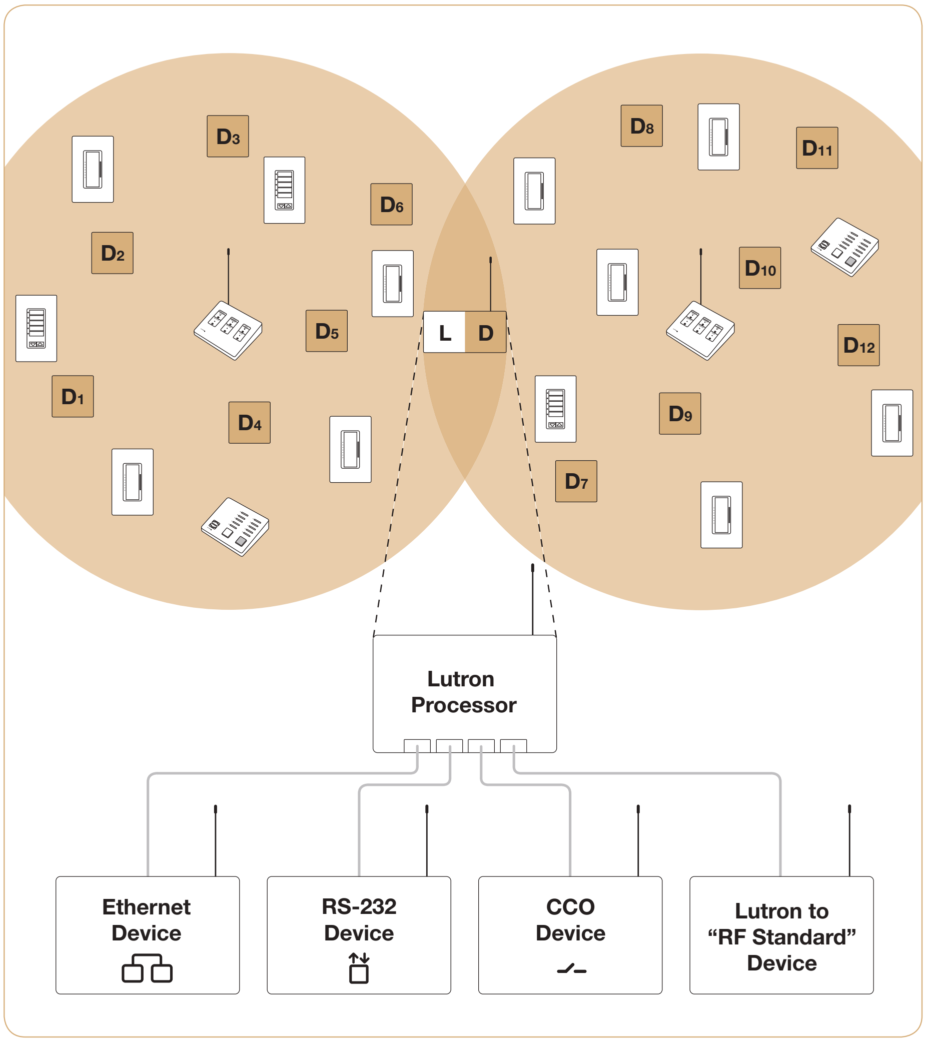
A number of RF equipment manufacturers appear to be eternal optimists—with a belief that their customers are a bit naive. Many of them write specs stating "works up to 100 feet." Does that mean it will work at 50 feet? How does one design a system using this specification? Still others specify ranges based on results in flat, unobstructed outdoor environments.

Devices boasting an operating range of 300 feet in those ideal conditions, may not work 30 feet inside a home or building. Dense construction materials attenuate RF signals quickly. A number of RF reflective materials such as metal, cause multi-path fading and shadowing. Consider grounded metal wall boxes, metal wall plates, large sections of metal duct work, refrigerators and more.

Lutron bases its specs on these (and other) real world conditions. When we state a range of 60 feet from repeater to repeater—which translates to two spheres of 2,500 square feet each; or 30 feet from a repeater to any device. They are specifications you can design to, and depend on.

The Lutron approach

Lutron Systems can operate independently of equipment from other manufacturers. Our systems are designed to allow you to isolate and troubleshoot them on a stand-alone basis. We make integration with third-party equipment simple, seamless and cost-effective. If needed, we could even make a direct Lutron-to-RF standard interface someday. There is minimal inefficiency in mixing a Lutron light control system (LCS) and any other subsystem together. The payback is an ultra-reliable LCS. We have the service organization, decades of experience and unflinching commitment to stand behind our systems and products—RF or otherwise.



Lutron can co-exist seamlessly with other subsystems. Integration between Lutron light control systems and any other subsystem is simple and reliable.

Always evaluating and anticipating

Lutron has always evaluated new technologies and anticipated customer needs. It is a practice we live by today, and one we will always embrace. The following details on the evolution of our patented RF technology, stand as testimony:

1997	**RadioRA 418 MHz – one channel (AM)** World's first RF professional-grade two-way LCS. Today it's the "gold standard" to which all LCSs are compared.
1998	
1999	**RadioRA "B" Frequency 434 MHz – one channel (AM)** In nearly a decade—and with over 1 million devices sold—only one isolated area in North America has interfered with our one channel RadioRA system—New York City. The "B" frequency was developed to address this situation. More proof of the Lutron commitment to our customers, and the light control business. This empirical evidence speaks volumes about the appropriateness of operating in FCC 15.231.
2000	
2001	
2002	
2003	**HomeWorks – 434 MHz – 60 channels (FM)** When Lutron decided to design RF products for the HomeWorks product line, the system size and feature set required a multi-channel transceiver (allows multiple subsystems to communicate simultaneously). This was a complete redesign of the radio transceiver, and we reevaluated all the decision points that were discussed in this paper. Ultimately, we came to the same conclusions: FCC 15.231 was still the best band of operation, and our fixed network topology yielded superior results.
2004	
2005	
2006	**RF Sivoia QED electronic shading systems are introduced** to the HomeWorks product family **AuroRa is introduced** as the world's simplest RF light control system
Coming Soon	**Milenyia** (RF products for Europe)

When you question which RF technology offers the most for your customers, the answer is Lutron.

Lutron pioneered the radio-frequency light control category. We continue that legacy with our electronic shading systems (wired and RF).

The leader in light control

- 45-year company history
- Global organization
- 24/7 technical support
- Sole focus on light control
- Industry leader expanding the market with trade and consumer campaigns
- Industry leader who is providing programs to develop your business

RF Experience

- Pioneered RF LCS category
- Over 1 million devices sold
- More than a decade of production, sales and installation
- Five diverse product lines

RF Technology

- Seven RF-specific patents
- Fixed network message delivery topology
- Fast group or preset commands (not directed commands)
- Unique house codes, device addresses, serial numbers
- Easy and reliable integration (Ethernet, RS232, IR, CCIs, CCOs and telephone interfaces)

Quality

- Recognized industry leader
- ISO 9001:2000 certified
- 100% end-of-line testing

Depth

- Load types: Incandescent, ELV, MLV, FL, LED
- World's most advanced shading solutions
- 2-wire, neutral wire
- Dimming and switching
- Wall-mounted and tabletop dimmers and keypads
- Aesthetic styling, colors and finishes

In closing…

This document details the Lutron commitment to designing and manufacturing the world's premier RF light control systems. It is our sincere hope that the information we have presented will be of value to you. We understand that there are a number of things to consider, and that no two projects are exactly alike. We also hope that you will consider the facts. When specifying your next light control system, remember:
Lutron **RF** Technology…
Reliable. **F**irst. *Forward Thinking.*

This publication has been written and produced by Lutron Electronics Co., Inc., as a technical and professional trade document. It presents views, findings and facts gathered through extensive field and analytical research. The contents of this document are intended for use by certified, professional electronics dealers and installers.

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