Clear Connect RF Technology

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Forward thinking

In 1991, Lutron identified the need for a completely retrofit light control system. The retrofit requirement meant the device communications needed to be wireless. We knew that light control in a home or business was operationally essential, therefore ultimate reliability was vital. These systems can never stop working; in fact, they can’t even tolerate latency issues. The required performance standard for a light control system is much higher than for many other systems.

We began analyzing the needs in the global marketplace, investigating possible communication topologies, observing and predicting changes and trends in RF technology and usage, and working through the various frequency bands and their regulatory requirements.

We determined that designing a groundbreaking retrofit control system would require new communications technology. The mission was defined: design an ultra-reliable RF communications system that works to specification every time — in every installation — today and well into the future.

The result? RadioRA became the first easy-to-install, versatile and reliable RF light control system. Moving forward, we developed many diverse product lines using this patented technology: HomeWorks, RadioTouch, AuroRa, and Sivoia QED electronic shading systems.

In 2008, after more than a decade of experience and refinement with the system, and with over a million RF devices installed globally, we introduced Clear Connect RF Technology — our latest advancement in reliable RF communication. Clear Connect has since been deployed in Lutron’s next generation RF systems including Maestro Wireless, Radio Powr Savr sensors, GRAFIK Eye QS Wireless, Sivoia QS Wireless, and Caséta Wireless.

This paper will describe the Lutron requirements, investigations and decisions regarding best methods for RF communications in a light control system. Other available frequencies, system topologies, industry standards for RF products, and practical field issues will also 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 present the Lutron perspective on the science of RF light control. We hope that you will find this information useful in determining the RF system parameters that meet the unique needs of your clients.
The requirements

When investigating RF communications, ultimate reliability was key due to the operationally essential nature of our systems. Beyond ultimate reliability, the system had to be completely “retrofittable” and easy to install, without requiring special tools. It had to replace existing switches and dimmers using the existing wiring — calling for dimmers that operate without a neutral wire, which takes significantly more engineering effort and skill. 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 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. Having the ability to control table lamps, or provide control from your car, phone, or voice is the difference between ordinary and extraordinary control.
The investigation

We investigated many different frequency bands, such as 400 MHz, 900 MHz, and 2.4 GHz. We also considered numerous regulatory requirements from a global perspective. We conducted RF emission surveys in the field to assess the best bands for operation. We took measurements in major cities and around major RF transmission sites (antenna farms), and put existing RF products (like cordless phones) to the test, all in an effort to understand real-world issues and activity.

This FCC chart shows the complexity of spectrum allocation in the United States. The operating rules (power, maximum on-time, bandwidth...) in each band can be dramatically different.

RF competition is everywhere.
Considering FCC 15.231

Our analysis of the frequency bands and their rules, combined with our field studies of real-world activity led us to FCC 15.231. The benefits of operation in this band, listed below, were a good match for our requirements.

- Band is essentially silent.
- Plenty of frequency room available, ~170 MHz; overcrowding 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.

FCC 15.231: An overview

- Devices are relatively low power (fractions of a watt). This reduces the possibility of interference between adjacent systems and eases a product’s power supply requirements.
- Devices may not transmit continuously. Generally speaking, all activity is driven by user action (like pressing a button), which further reduces the likelihood of interference.
- 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.

Typical devices found in FCC 15.231.
The decision

We decided that operation under the 15.231 regulations would provide the best overall system performance. This decision was key in the development of the initial RadioRA system, as well as all domestic Lutron RF systems, including those with Clear Connect. After reviewing the devices currently operating in this band (public domain information on the FCC website), we then chose frequencies that did not line up with other popular devices, such as garage door openers.

The result was an ultra-reliable system that has been all but free of in-band interference. This band has proven to be great for high-density installations like multi-dwelling units, urban areas, and dense single-family developments. The proliferation of wireless devices in the global market has had minimal impact on this band.

15.231

In 2002 we 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).
RF communication architecture

Choosing FCC 15.231 was an important decision. Now we needed to design the best method to move the messages around large spaces quickly and reliably and also define the command content so that it was both effective and efficient.

Message delivery: Fixed and mesh network

In applications where the network of devices covers a large area and point-to-point direct communication among all devices is not possible, messages must somehow be relayed through the system.

There are two primary methods for delivering messages around an extended whole home automation network. One calls for dedicated sending, receiving, and computing stations in predetermined locations—providing RF coverage to all system devices.

This message delivery scheme is called a “fixed network,” meaning the coverage area and message route are constant. The stations in a fixed network are commonly known today as Wireless Access Points, or WAPs. We 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.

It is fairly simple to create fixed network coverage for homes 10,000 square feet or larger. Messages are moved up and down the fixed network quickly and in a predetermined manner. Lutron RF systems use this delivery mechanism.

Another common method for message delivery is called a “mesh network.” In this topology, messages can be relayed from a source device through other system 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 circulate how to get the message delivered by way of hops through other system devices. If there are enough repeating devices in the network, no dedicated signal relay stations are required. If a preferred route is unavailable, another route can be identified.

These descriptions are brief, conceptual overviews. While we could provide pages of detail, it is widely accepted that both methods will work for home automation systems.

The advantages of Lutron’s 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 a predictable, fast reaction time to a button press, regardless of that button’s location within the system. The network is not shared with, or doing work for, any task other than home control.
A mesh network can use any participating devices for message relay. This diagram shows delivery of four directed commands.

In addition, we have designed our repeaters to be ultra-reliable. 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. And because repeaters are installed in hidden locations — and are not interacted with during normal operation — they are less susceptible to electrostatic discharge failure through touching and are less likely to be moved, replaced (as is a TV that may get upgraded regularly), or unplugged. These are important factors when considering the long-term stability of the communication network.

**Group commands vs. directed commands**

Unrelated to how the messages move around the system is the issue of the message content and how the system design reacts to that content. Lutron systems, including those with Clear Connect, use “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.

While these systems can be expanded with no degradation in performance, most system designs 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 systems comprised of devices from a disparate group of manufacturers, commands must be issued to each device sequentially. These commands are called “directed commands.” To turn on 10 different devices requires 10 unique commands. This can create 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

Industry standards are valuable tools. However, they are generally designed to solve as large a problem as possible and therefore result in less than optimum performance for a given specific application. Built on over a decade of experience, Lutron’s Clear Connect RF communication technology was designed specifically for the needs of a light control system.

Low-cost, plug-in power-line-carrier devices are fine for the hobbyist turning on Christmas lights. Likewise, RF standards will probably provide the do-it-yourself amateur good performance for his various home automation projects. However, Lutron asserts that the RF standards can fall short on their promises and that they do not provide professional grade products for light control systems. Here are four reasons why:

Point 1—Control system is still required
The promise of RF standards is that all devices can talk to one another seamlessly – just start buying devices and they all interoperate.

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 your audio amplifier going to have buttons to arm your security system? How will you program these buttons, since this could get somewhat complex? Is the thermostat manufacturer going to develop a PC utility for programming the system?

Clearly, having all devices able to talk to one another is much different than coordinating them to all talk to one another. The point is that we will always have the need for a “parent” or “control” system or device to program and control all these devices. That requirement doesn’t go away with an RF standard.

Point 2—Quality and experience
The existence of RF standards greatly lowers the barriers of entry into the RF market. RF chip manufacturers would lead you to believe that all you have to do is plunk down their chip, and presto, it works! Device manufacturers who do 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 inherently 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—Accountability
Imagine an RF network comprised of equipment from three different manufacturers utilizing an RF standard. During the set up 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—Compatibility
When revisions to the standards, device profiles, and application layer 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. Many of them write specs stating “works up to 100 feet.” Does that mean it will work at 50 feet? What is the minimum working distance? How does one design a system using this ambiguous specification?

Still others specify ranges based on results in flat, unobstructed outdoor environments. This specification is appropriate for devices operated outside, like a remote controlled toy or a car visor transmitter, but it is not appropriate for a device operating within a home or commercial building. Devices boasting an operating range of 300 feet in ideal outdoor conditions may not work 30 feet inside a building. Dense construction materials attenuate RF signals quickly. A number of RF reflective materials such as metal, cause multi-path fading and shadowing. Grounded metal wallboxes, metal wallplates, large sections of metal ductwork, refrigerators, and more can cause problems.

We publish definitive specs based on the real-world conditions that the product was designed to operate in. Very often our products will exceed our worst-case spec, but the spec is one that you can design to in the planning phase and then depend on at installation time (and for years thereafter). When we state our indoor ranges of 60 feet from repeater to repeater — which translates to a sphere of 2,500 square feet of coverage per repeater; or 30 feet from a repeater to another device — we are accounting for the worst-case conditions so that you don’t have to.

To provide installers the maximum utilization of their equipment, we also provide some unobstructed or line-of-sight range values for certain indoor products (like an occupancy sensor). These values are not the misleading “outdoor” specs because they are still accounting for real indoor conditions, like multi-path fading, but they are logical specs for the line-of-sight type applications they cover. For outdoor products (like a car visor transmitter) we provide outdoor specs.

Don’t be mislead by various “specmanship” techniques used by other manufacturers. While the range spec is the most visible and touted, other specs such as power output or data rate are similarly used as misleading selling points. These specs taken in isolation of the total system design are meaningless. Customers don’t need 10dBm more power — they need the command to get through. Specs with bigger numbers aren’t better — specs that are accurate, real-world, reliable, and meaningful are better.

The best specification point of all is a system that works — it’s a one-name spec — Lutron’s Clear Connect RF Technology.
Lutron integration

Lutron systems can operate independently of equipment from other manufacturers or the home’s network. We design our systems to allow you to isolate and troubleshoot them on a stand-alone basis. Integration is relatively simple since most control systems meet at the home’s data network or in the cloud and integrate seamlessly.

Lutron systems using Clear Connect RF Technology 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 evolution of our patented RF technology stands as testimony:

1997
Lutron launches RadioRA, the first two-way, radio frequency, whole-home lighting control system. RadioRA opens new doors for homeowners looking to add a lighting control system to existing homes.

1998
Lutron introduces HomeWorks Interactive. Building on HomeWorks, this system includes additional aesthetics and load controllers for a more expansive solution. HomeWorks Interactive is configured using a drag and drop PC configuration tool that allows for easier design and programming.

1999
RadioTouch, the first commercial radio frequency controller allowing the adjustment of different lighting zones, is introduced.

2003
Lutron introduces the ultra-quiet Sivoia QED system, which automatically controls roller shades, Roman shades, and draperies.

2006
Total light management comes to fruition with Quantum, which puts complete control of all lighting in a building or campus in one location. By maximizing the use of daylight and minimizing waste, Quantum delivers dramatic energy savings.

2008
Lutron introduces Clear Connect RF Technology, its latest advancement in reliable radio frequency technology.
Lutron enters the sensor market with **Radio Powr Savr wireless occupancy/vacancy sensors** and controls.

Lutron also launches the **Radio Powr Savr daylight sensor**, which automatically dims lights when there’s sufficient daylight in a space.

Lutron introduces **RadioRA 2**, a state-of-the-art PC programmable wireless lighting control system that provides convenient and intuitive control of lights, shades, audio-visual devices, and temperature all at the touch of a button.

**2009**

**HomeWorks QS**, a powerful wireless home system that offers control of lights, shades, temperature, and small appliances, is launched.

**2010**

Lutron introduces **Triathlon** remote controlled insulating honeycomb shades. These wireless shades are battery-powered and easy to install.

**2011**

**Caséta Wireles**, which controls lights, shades, and temperature from anywhere with a mobile device, is introduced.

**2014**

Lutron launches **Sivioa QS Wireless shades**, roller shades that feature industry-leading battery performance for easy installation and maintenance—perfect for retrofit applications.

**2016**

Lutron introduces **Vive**, a simple, scalable, modular wireless lighting control for new and existing commercial buildings.

**2017**

**RA2 Select** expands the market for professional whole home lighting control that’s simple, fast, and flexible for any installer, any home, and any budget.

**2018**

Lutron acquires **Ketra**, maker of natural light and tunable white solutions, which seamlessly emulate daylight in residential and commercial environments.
Which RF technology offers the most for your customers?
The answer is Clear Connect.

**The leader in light control**
- In business over 55 years
- Global organization
- 24/7 technical support
- Focus on light, shade, temperature and energy 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 automation category
- Over 2 million devices sold
- More than a decade of production, sales, and installation
- Many diverse product lines

**RF Technology**
- Seven RF-specific patents
- Fixed network message delivery topology
- Fast group or preset commands
- Unique house codes, device addresses, serial numbers
- Easy and reliable integration (mobile apps, Ethernet, cloud services, RS232, IR, CCI’s, CCO’s)

**Depth**
- Load types: LED, ELV, MLV, FL, halogen, incandescent
- World’s most advanced shading and temperature solutions
- 2-wire, neutral-wire
- Dimming and switching
- Wall-mounted and tabletop dimmers and keypads
- Aesthetic styling, colors, and finishes

**Quality**
- Recognized industry leader
- ISO 9001:2015 certified
- 100% end-of-line testing

**In conclusion**
This document detailed Lutron’s RF design philosophy and methodology which has led to the development of the company’s Clear Connect RF Technology. What is unwritten, but obvious, is Lutron’s steadfast commitment to designing and manufacturing the world’s premier RF control systems.

We hope that the information presented will be of value to you when making your critical business decisions. There are a number of things to consider when deciding what manufacturer will supply your business with products — choose the one who will supply your business with success.

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