Clear Connect RF Technology

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LUTRON

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 — the next evolution in Lutron's 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.

In 2014, the maturity of 2.4 GHz technology and the family of protocols built on IEEE 802.15.4 prompted a new look from Lutron. Five years of research and development culminated in the 2019 introduction of Clear Connect Type X; an extension within the Clear Connect family of wireless protocols. Offering more aesthetic options and flexible deployments, Type X is a complementary implementation that expands Lutron's ultra-reliable and ultra-responsive Clear Connect wireless solutions. Highly optimized for advanced lighting and shade control, Type X launched alongside all-new intelligent light sources by Ketra.

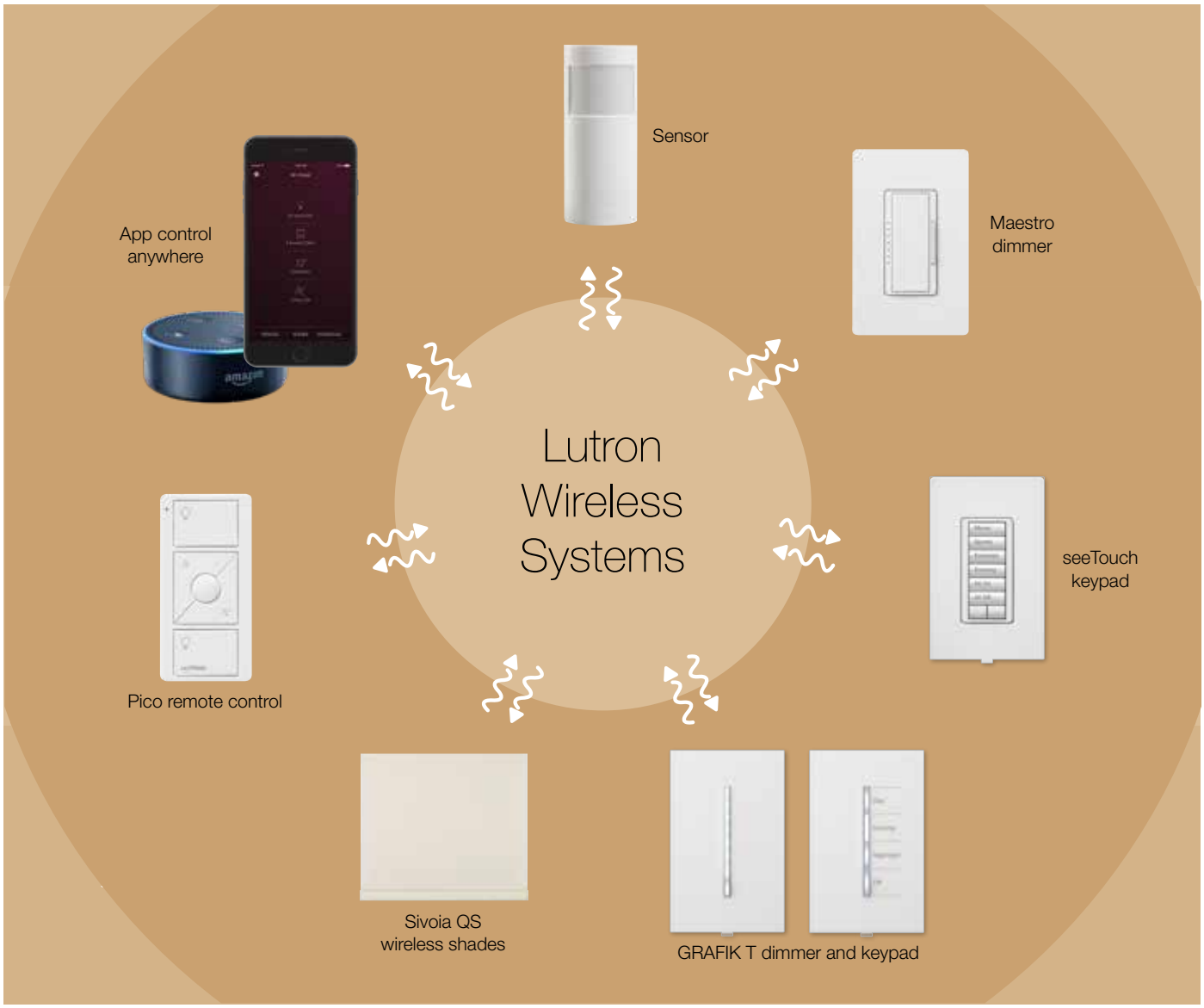
This paper will describe the Lutron requirements, investigations and decisions regarding best methods for RF communications in a light control system. Considerations of available frequencies, system topologies, industry standards for wireless products, and practical field issues will also be discussed.

The company's exhaustive research and unwillingness to compromise on performance led to our leadership in the wireless lighting control market. The following pages present the Lutron perspective on the science of wireless light control. We hope that you will find this information useful in determining the wireless 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.

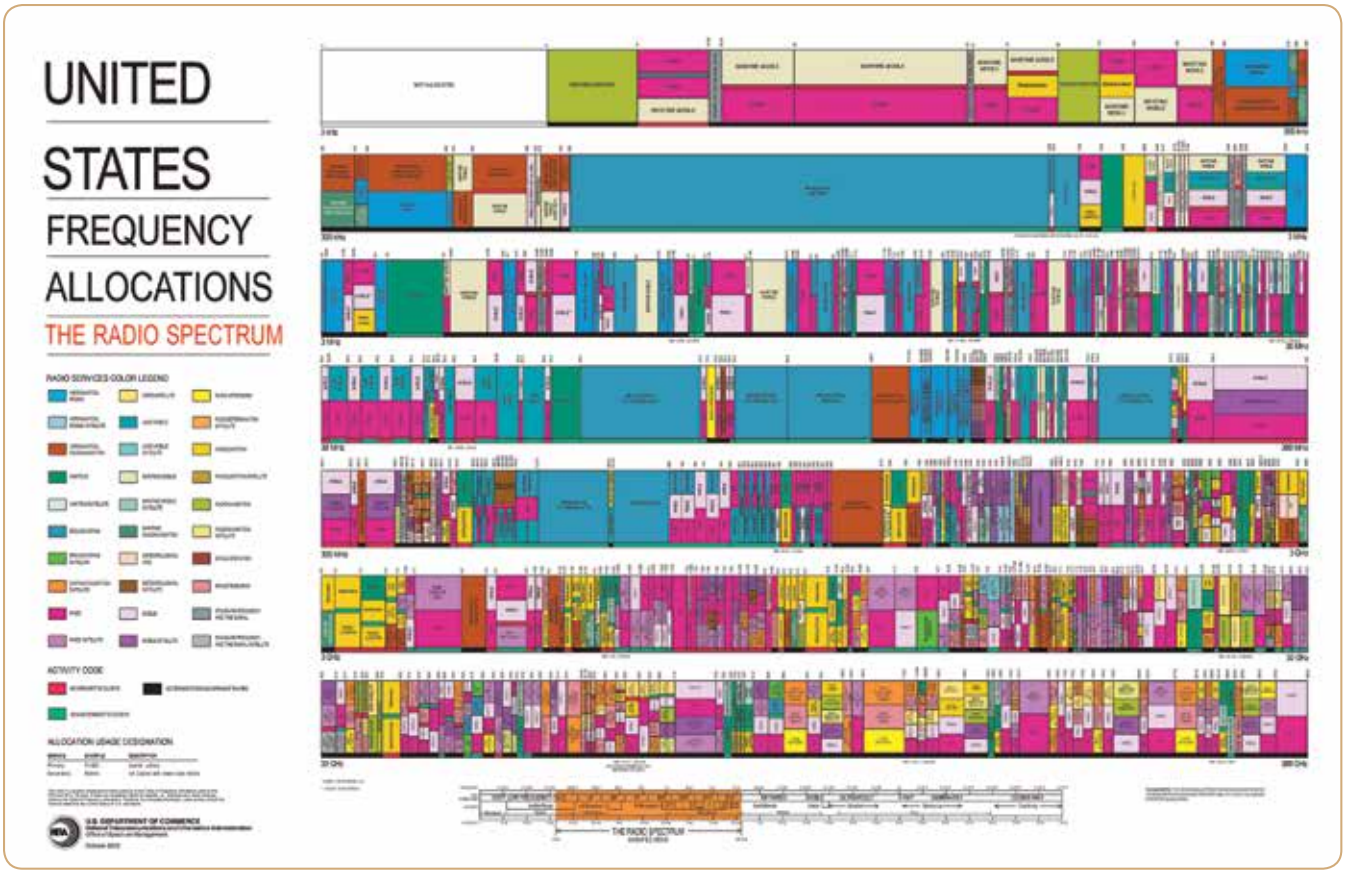


Lutron wireless systems bring the connected home to your fingertips.

The investigation

We investigated many different frequency bands, from 400 MHz to 3.6GHz. 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 used existing RF products (like wireless access points, cell phones, and security cameras) to the test, all in an effort to better 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.



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

In 2008 our analysis of the frequency bands and their rules, combined with our field studies of real-world activity initially 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

Typical devices found in FCC 15.231.

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.

Considering 2.4 GHz and IEEE 802.15.4

One popular frequency for wireless communication is 2.4 GHz. This frequency has fewer regulatory constraints, leading to significantly more competition for airtime. There are many established standards for 2.4 GHz communication, including IEEE 802.15.4.

First released in 2003, IEEE 802.15.4 was promising for lighting control applications, but at the time did not meet Lutron's customers' expectations for reliability and performance. However, technological advances over 15 years, has now enabled IEEE 802.15.4 as a viable option for investigating. These advancements include:

- Higher frequency radios permit smaller antenna design
- 2.4 GHz radios are now designed to coexist in the presence of Wi-Fi and other 2.4 GHz equipment
- New mesh networking implementations have become more reliable in dense environments such as in smart light fixtures
- 2.4 GHz is a globally available frequency
- Maturing industry expertise and development tools for various IEEE 802.15.4 implementations

Lutron's Clear Connect Technology is ultra-reliable and performs flawlessly even in high-density installations.

The decision

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. We decided that operation under the 15.231 regulations would provide excellent overall system performance and reliability. 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.

IEEE 802.15.4

As technology and customer needs change, we're constantly exploring new tools for delivering a high standard of quality and performance. After 5 years of rigorous engineering research, we concluded that recent improvements in radio technology and processing power made it possible to deliver the performance of Clear Connect in the 2.4 GHz band. In 2019, backed by over 25 years of wireless lighting experience, we introduced Clear Connect Type X as the first native 2.4GHz Clear Connect product from Lutron.

Rather than cast our network decision as a binary choice, we built Clear Connect Type X to be a complementary solution to our 15.231-based platform. Our engineers worked tirelessly to understand the strengths and weaknesses of previous mesh efforts. Type X utilizes the properties of industry leading mesh solutions augmented by Lutron enhancements, providing a robust lighting control solution. This new wireless solution allows us to meet our high standards for quality, state of the art aesthetics, and serve new applications such as individual fixture controlers

Clear Connect

Clear Connect is Lutron's overall standard for ultra-reliable wireless devices, with different sub types for different application-specific implementations. To meet the Clear Connect standard our products go through rigorous testing and certification. Our 15.231 based solution remains an excellent solution for low-density, non-uniform networks with both powered and battery-operated devices. Complementing this is Type X, designed for dense deployments of small form factor, high-performance lighting.

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 decades of experience, Lutron's Clear Connect RF communication technology was designed specifically for the needs of a light control system. essential to a home or building.

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.

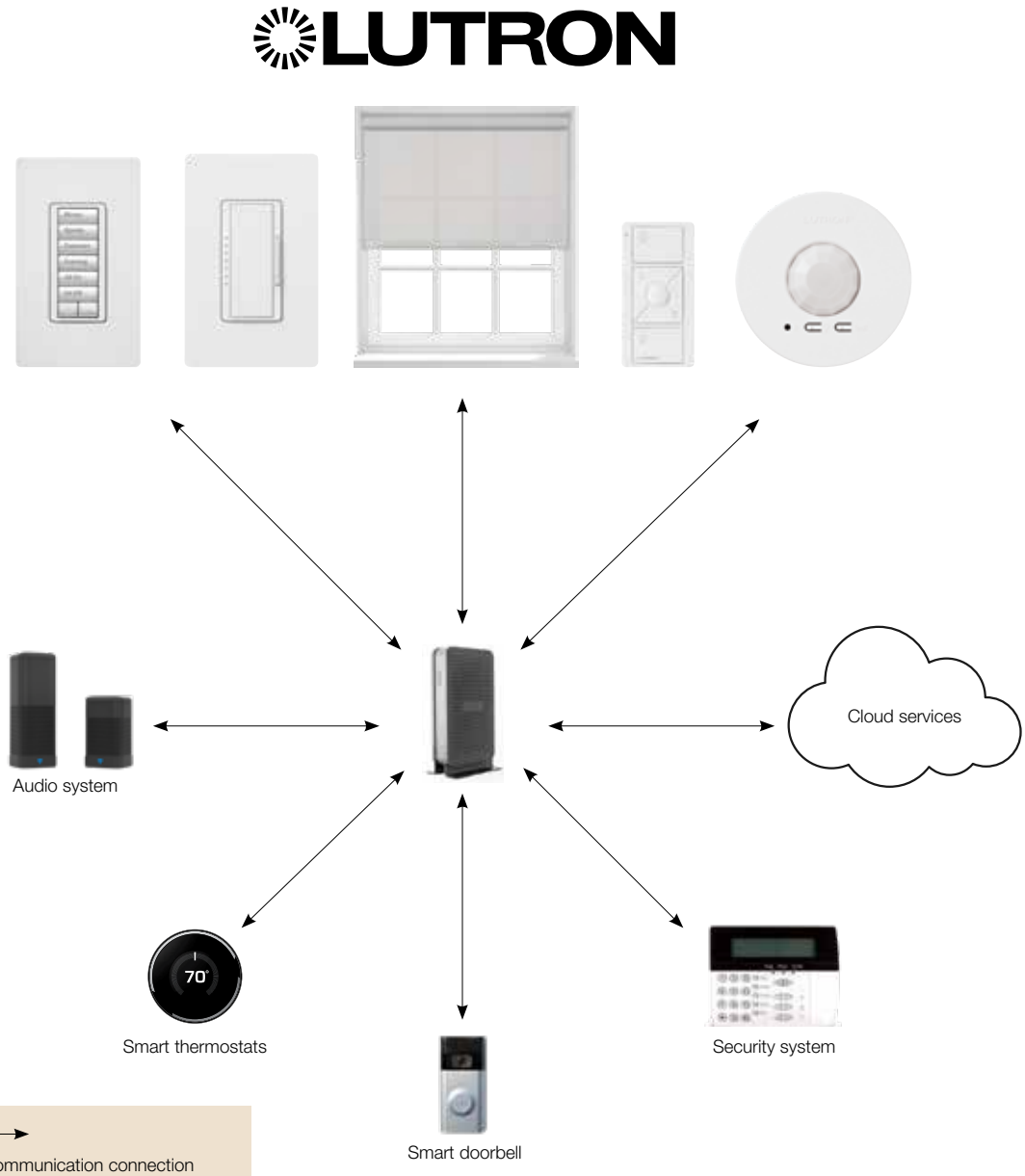
To provide installers the maximum utilization of their equipment, we also provide some unobstructed or line-of-sight range values for certain indoor products (like an occupancy sensor). These values are not the misleading "outdoor" specs because they are still accounting for real indoor conditions, like 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. Lutron launches **HomeWorks Illumination**, a total home solution combining a full line of wired and wireless devices with an enhanced processor platform and seamless shade integration.
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.

2009

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.

2010

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

2011

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

2014

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

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.

2019

Lutron launches **Clear Connect Type X**, compatible with all new **Homeworks QSX processor** and new **Ketra** hardware.

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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