On Multiverse: How Advances in Wireless DMX Will Change the Way We Do Lighting
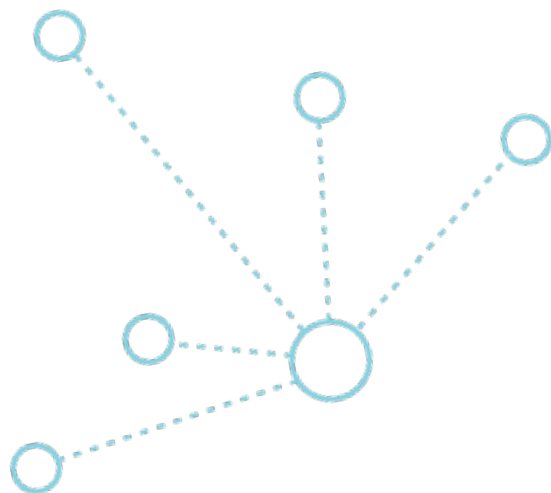
A White Paper
By Gary Fails
Founder, City Theatrical

On Multiverse: How Advances in Wireless DMX Will Change the Way We Do Lighting

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I. Introduction

City Theatrical envisions a future of wireless lighting control in which every DMX controlled lighting fixture contains a tiny, inexpensive, Multiverse® Module, leading to wireless control of systems containing hundreds of fixtures and dozens of universes, and making lighting control easier for everyone.

Multiverse wireless DMX/RDM is the culmination of three years of research, engineering, and development and utilizes innovative technology that for the first time allows large scale multi-universe wireless lighting systems to be used effectively and reliably.

This white paper will take a look at the underlying technology which enables this breakthrough performance along with the many features built into Multiverse that can make lighting control easier for everyone.

II. A Brief History of DMX

To more fully understand how Multiverse works, let's briefly review the history of DMX and the evolution of its wireless counterpart.

DMX 512 (ANSI E1.11 - 2008 (R2018)) is the protocol used in entertainment lighting that standardized the communication between a lighting controller and a lighting device regardless of product manufacturer or brand. Prior to the use of DMX, manufacturers created proprietary communication protocols and systems were incompatible between manufacturers. This prevented lighting users from creating systems with products from various manufacturers of their choice, such as a console from one company, and dimmers from a second company. Market demand drove the development of a communication protocol that would allow products from all manufacturers to interoperate. It was developed in 1986 and became an ANSI standard in 2004.

III. A Brief History of Wireless DMX

In the early 2000s, wireless DMX systems were developed with the aim of eliminating the cables needed for lighting control, which were expensive to purchase and install. In addition, wireless control allowed designers the freedom to accomplish lighting effects that would have been impossible otherwise such as in moving scenery or in places that cables can't reach, such as across a river or highway or to the top of the exterior of a tall building.

IV. Restraints to the Growth of Wireless DMX

While wireless DMX use has increased over time in all areas, and has become common in the film and video world, widespread acceptance has been limited. There are several interrelated reasons for this including:

• *Inefficient wireless DMX systems with high radio energy to data ratios*

• *Crowded radio spectrum*

• *Limitations of the DMX512 standard*

• *Cost*

Let's look deeper into each of these reasons.

• *Inefficient Wireless DMX Systems with High Radio Energy to Data Ratios*

Until Multiverse, it has taken a large amount of radio energy to broadcast one universe (512 DMX slots of data) of wireless DMX. This single universe could be quickly consumed by only a handful of modern lighting fixtures. Lighting users requiring larger wireless installations used several single universe systems at the same time to increase capacity.   This approach generates a proportionately larger amount of radio energy, and like a house of cards, the broadcast soon collapses because it produces so much radio interference that the wireless system will no longer operate reliably. This has been a limiting factor to the growth of wireless DMX. Even when the motivation by users was there, it was not possible to scale up reliably beyond a few universes.

• *Crowded Radio Spectrum*

The electromagnetic spectrum is a valuable commodity and is highly regulated by governments around the world. The radio portion of the electromagnetic spectrum includes frequencies from 30 hertz to 300 GHz.
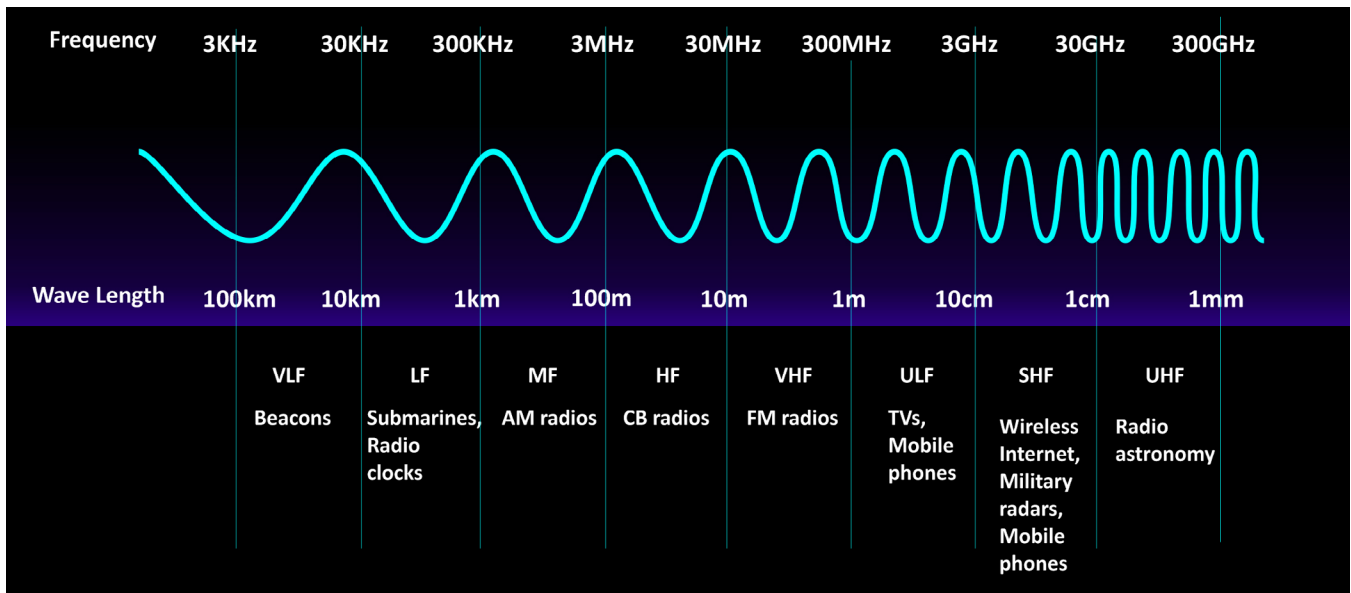

Figure 1: Radio Frequencies, and some common uses

Different parts of the radio spectrum are carefully allocated for different radio transmission technologies and applications to prevent interference between users.
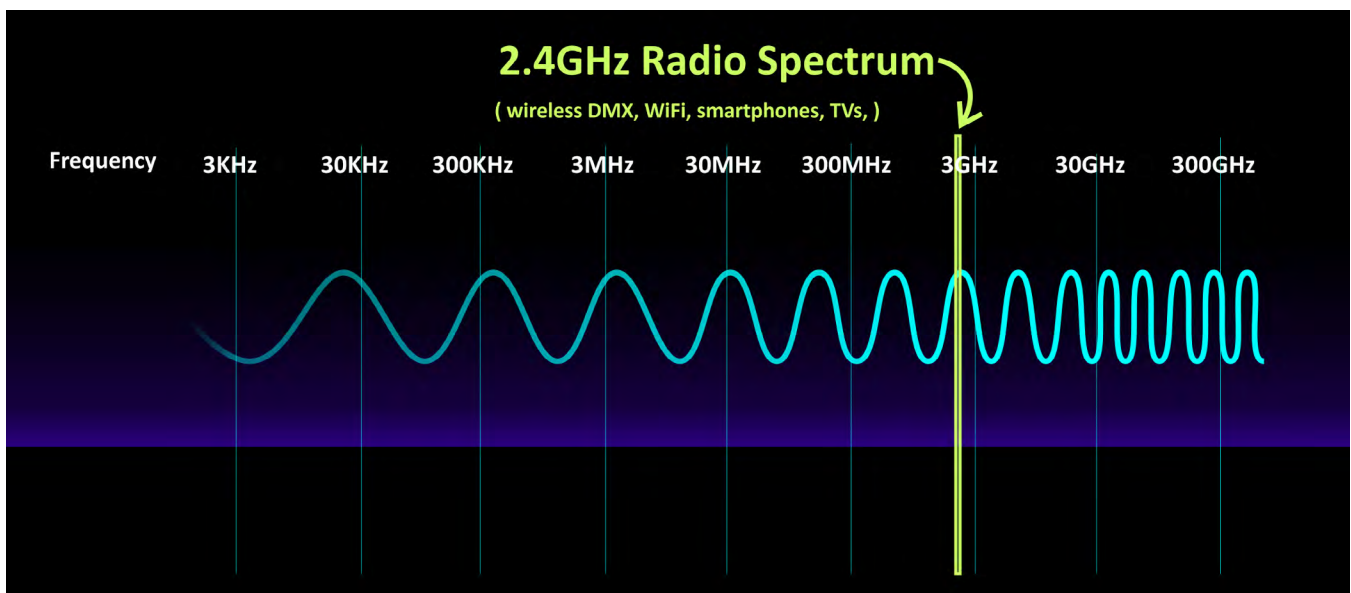

Figure 2: 2.4GHz RF Spectrum includes: wireless DMX, Wi-FI, smartphones, television

Wireless DMX, along with Wi-Fi and other technologies, has occupied a small portion of the spectrum in the 2.4GHz Industrial, Scientific, and Medical (ISM) band. As popular wireless technologies have expanded globally, this region has become more crowded.
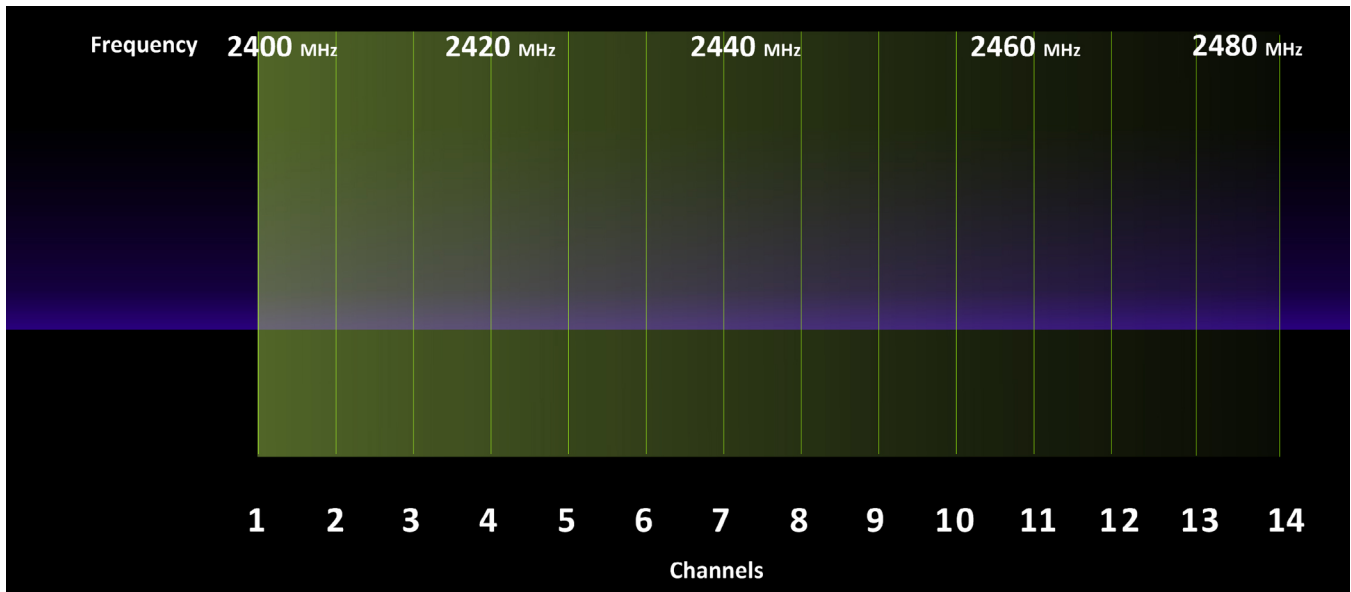
Figure 3: The 2.4GHz RF Spectrum is the most widely used band for Wi-Fi operation of: smartphones, laptops, plus many more devices. It is divided into 14 channels.

Wireless DMX manufacturers have developed specialized techniques for operating within this crowded environment, but there are limitations that have prevented larger systems from being scaled up.
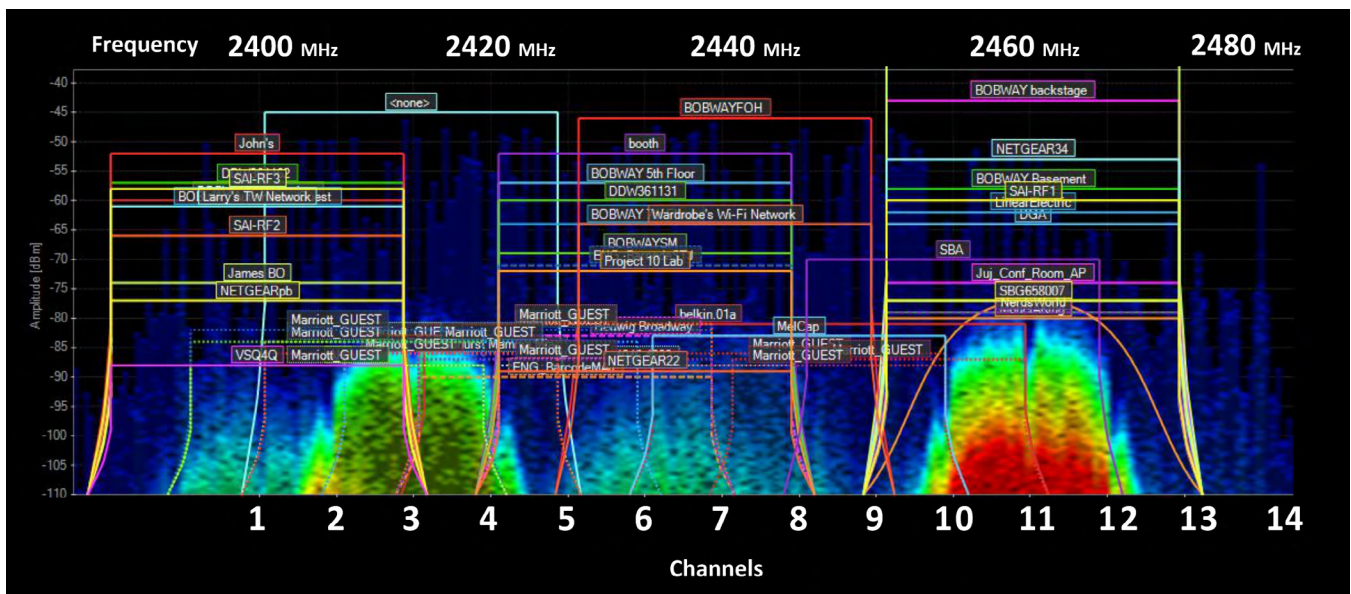

Figure 4: Crowded 2.4GHz RF Spectrum
(Spectrum analysis of a theatre with 40+ different wireless spectrums in use)

• Limitations in the DMX512 Standard Causing Excessive Radio Energy to be Transmitted

The DMX512 standard requires commands to be sent from the lighting controller to each fixture as many as 44 times per second. This redundancy ensures that the control commands reach their destination even if a transmission error occurs. There is no downside to using this method in a wired system, but in a wireless DMX system the redundant commands create vast amounts of unneeded radio energy. In a crowded radio environment this negatively impacts the DMX system's fidelity and that of other wireless systems in the area.

• Cost

Each professional quality wireless DMX transceiver (a device that can be made to either be a transmitter or a receiver) costs between approximately $350 and $2,000 and many productions require multiple transceivers.   Later dongle style systems and "wireless module on a circuit board" systems reduced this cost but remain expensive. Even if scaling up a large show was technically feasible, it remains prohibitively expensive in most markets.

V. The Development of Multiverse

Faced with the great potential of wireless DMX contrasted with the inability of any available system to meet the growing demands of wireless users, City Theatrical began to design what we envisioned as a system that could be scaled up to meet the needs of future lighting users.

Many new breakthrough technologies needed to be invented to overcome the drawbacks that had impeded all wireless DMX systems, including:

1. New radios that can transmit five times more data than ever before, while producing 80% less radio energy per universe than a typical single universe transmitter
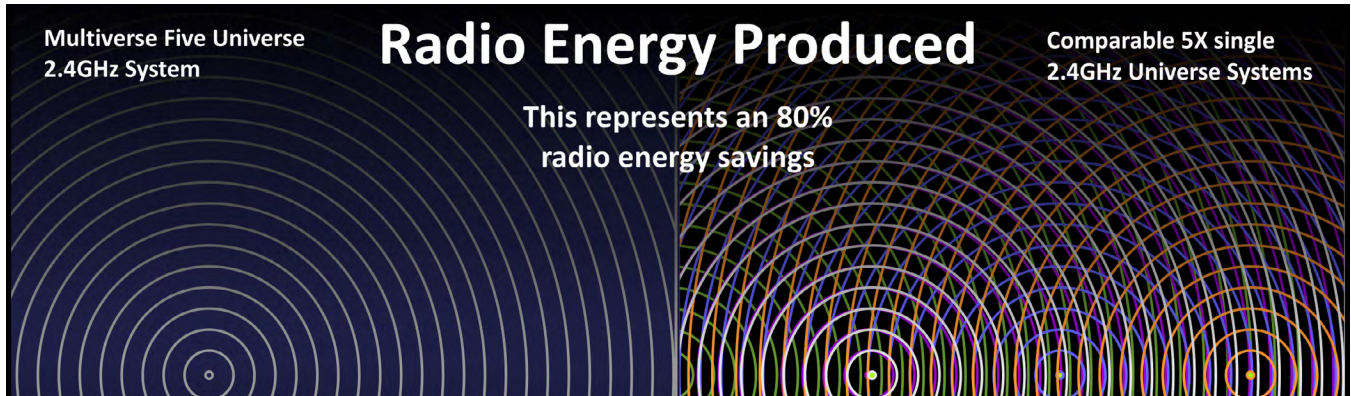

Figure 5: Radio Energy Produced: Multiverse five-universe 2.4GHz system vs.
Comparable five single universes system

2. Ability to transmit in either the 2.4GHz or 900MHz bands, or in both simultaneously

Figure 6: Simultaneous Dual Band Operation, Nine Universe Capable

3. mDMX (Multiverse DMX), an encapsulation of the DMX512 standard for wireless transmission that produces an additional dramatic reduction in radio energy used

4. mRDM (Multiverse RDM), an encapsulation of the RDM (ANSI E1.20-2010) standard for wireless transmission that improves wireless RDM performance

5. Forward Error Correction to detect and repair missing data

6. Show Key Security to prevent interference from other Multiverse systems in the area

7. Smartphone and tablet lighting control built into Multiverse Transmitters

8. Lock PIN: Locks unauthorized users out of the system

9. Backwards compatibility with SHoW DMX Neo wireless DMX products (operates Multiverse in Neo Mode)

10. RDM integration of entities: Radio and fixture appear as one device when Multiverse Module is installed in lighting fixtures

11. Low cost technology

VI. Deeper Look into these Breakthrough Technologies

1. New radios that can transmit five times more data than ever before, while producing 80% less radio energy per universe than a typical single universe transmitter

The Multiverse radio's ability to broadcast much more data while using much less radio energy is only the first step in building larger, more reliable DMX/RDM systems.

With conventional wireless systems, DMX instructions are coded and separated into data packets of varying capacity, as seen in Figure 7.

With Multiverse, however, data packets can contain up to 5X more data, as illustrated in Figure 8.
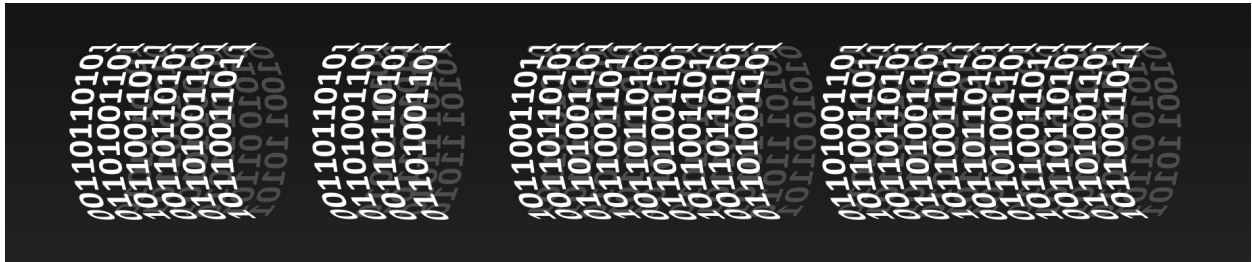

Figure 7: Illustration of DMX Instructions in Conventional Wireless DMX System
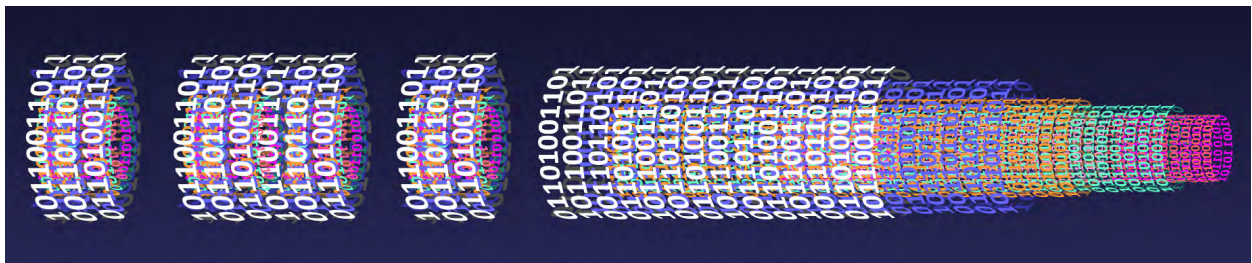

Figure 8: Illustration of Data Packets in Multiverse Wireless DMX System

In conventional wireless systems, 512 DMX slots is the maximum amount of data that can be attached and broadcast, and data packets are attached to carrier waved, as illustrated in Figure 9.

With Multiverse, 2560 DMX slots can be attached to the same carrier wave and transmitted, as illustrated in Figure 10.
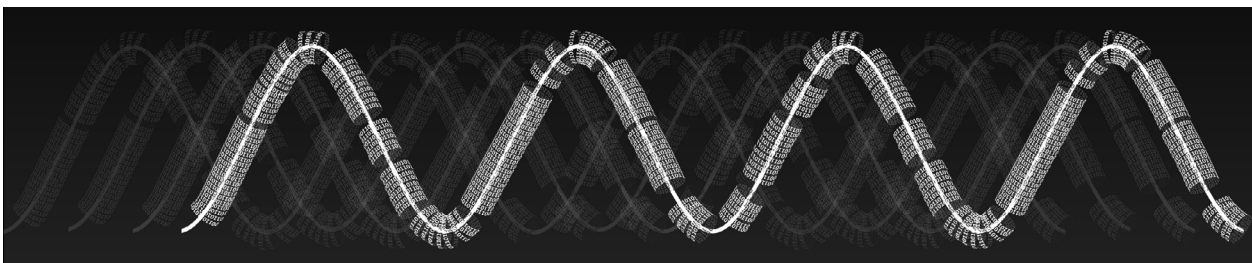

Figure 9: Illustration of Data Packets Attached to Carrier Waves in Conventional Wireless DMX System
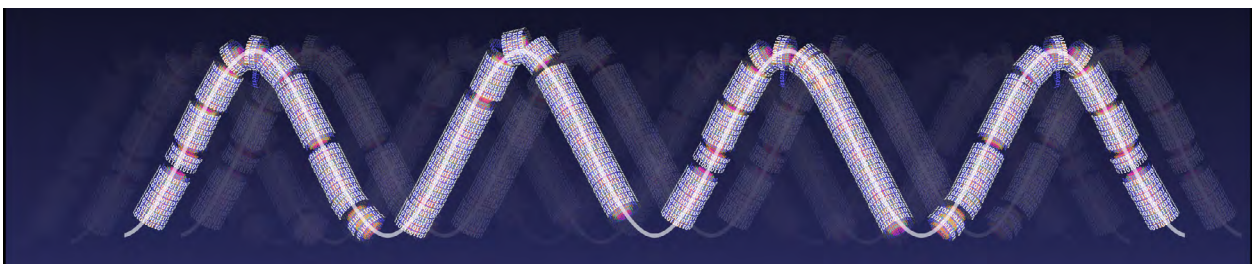

Figure 10: Illustration of 2560 DMX Slots Attached to the Same Carrier Wave with Multiverse

2. Ability to transmit in either the 2.4GHz or 900MHz band, or in both simultaneously

While most wireless DMX systems operate in the 2.4GHz radio spectrum, Multiverse systems are capable of also operating in the 900MHz ISM band, which is licensed for use in North America.

Users can broadcast on both frequencies separately or simultaneously (depending on the Multiverse product) and configure their systems for optimal performance.

The 2.4GHz band has always been the area of choice for wireless DMX due to its ability to carry larger amounts of data.

Figure 11: Benefits of the 2.4GHz RF Band

The 900MHz has become a good choice for extended working range, ability to pass through objects, and a less crowding environment, among other reasons.

Figure 12: Benefits of the 900MHz RF Band

Here is a comparison of the two bands:

Table 1: Stregnths and Weaknesses of the 2.4GHz and 900MHz Bands

Band	Strengths	Weaknesses
2.4GHz	Available nearly everywhere around the world Passes through objects well Good broadcast distance Multiverse can carry five universes of data	Crowded band
900MHz	Less crowded band Passes through objects better than 2.4GHz Broadcasts farther than 2.4GHz Multiverse can carry four universes of data	Available only in North America

Some U.S. theme parks do not allow wireless DMX broadcast in the 2.4GHz band to ensure that there is no possible conflict with cash transaction devices operating on 2.4GHz. 900MHz is a good option to overcome that restriction. Other users choose to split their broadcast over both bands to spread their radio energy over a wider area. Outside of North America, users must broadcast only in the 2.4GHz band.

3.   mDMX (Multiverse DMX) An encapsulation of the DMX512 standard for wireless transmission that produces an additional dramatic reduction in radio energy used

mDMX is the heart of Multiverse's ability to reduce radio energy used far beyond the 80% baseline reduction achieved with Multiverse radios. The DMX-512 ANSI standard specifies data redundancy, requiring data to be sent as many as 44 times per second whether a DMX slot is moving or not.

Picture an extreme example of someone giving a one hour speech at a podium with some lighting directed toward him or her. The lights are brought up to full in five seconds, stay there for an hour, and are brought back down to zero in five seconds.

Let's do the math:

60 seconds x 60 minutes = 3,600 seconds x 44 DMX packets per second

= 158,400 DMX packets in an hour

During that hour, the lights actually changed for a total of 10 seconds (five seconds up, and five seconds down) and were static for the remainder of the time. 10 seconds out of 3,600 seconds is 0.28% and therefore the lights were static for 99.72% of the time but receiving commands constantly.

In a wired system where bandwidth is not a concern, this is not a problem and we think nothing of it. But in a wireless system, the penalty is severe since we are sending radio energy into the spectrum that serves no purpose, and in fact causes interference with all other systems in our area of the spectrum.

City Theatrical's research into cue movements on large musical productions showed that even on the largest and busiest shows, the majority of DMX slots are static in any cue, and many DMX slots such as unused parameters on moving lights, never move the entire show.
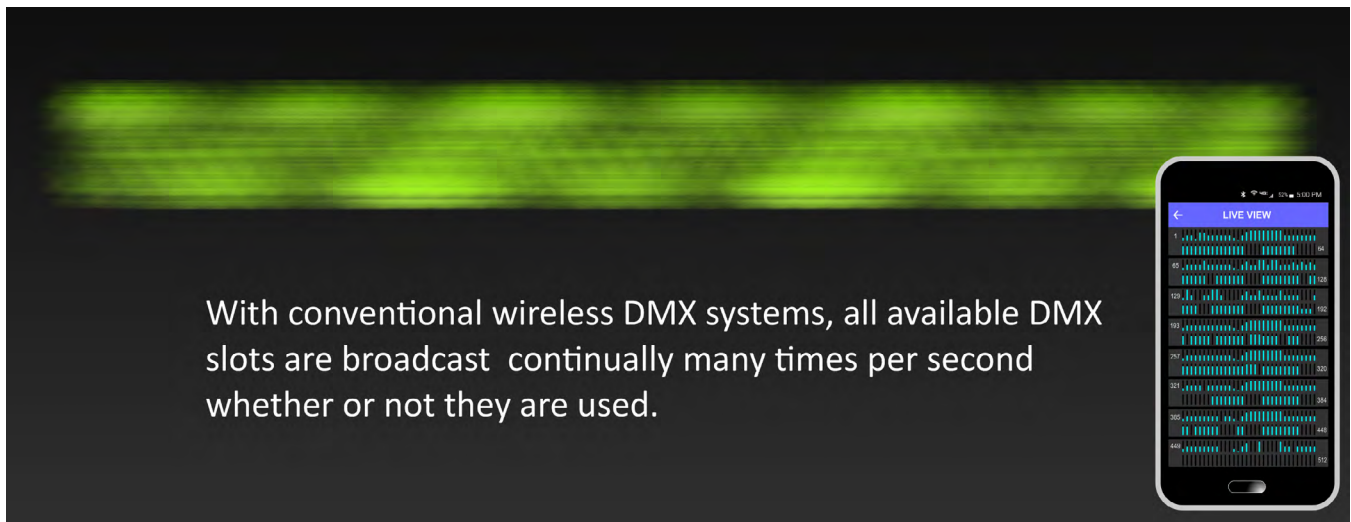

Figure 13: DMX Slots in Conventional wireless DMX systems

Since the link from Transmitter to Receiver is proprietary in a Multiverse system (no other lighting fixture or device is affected by it), we realized that it was not mandatory to follow the DMX512 ANSI standard and we created an encapsulation of the standard optimized for wireless use, and called it mDMX. This is a true technology breakthrough that changes everything in wireless DMX.
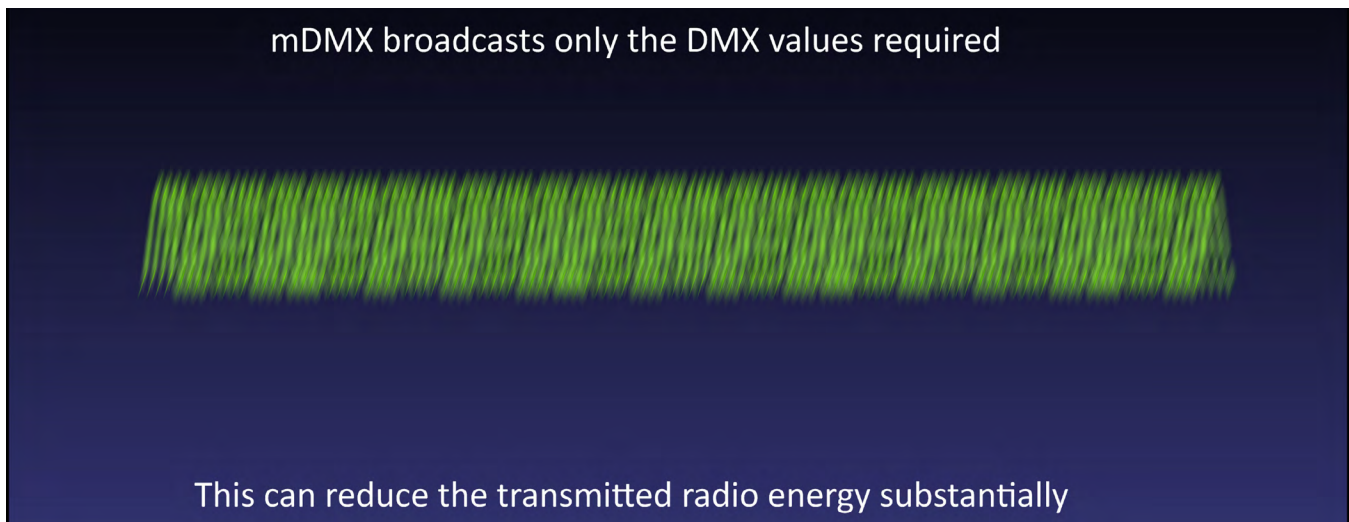
Figure 14: mDMX Broadcasts only the DMX Values Required

mDMX uses its radio energy extremely wisely, conservatively sending all of the data needed, refreshing it regularly and always retaining the ability to transmit entire universes with every slot moving. This allows larger and larger systems to be scaled up with careful stewardship of radio energy created, and with no reduction in performance of the lighting system.
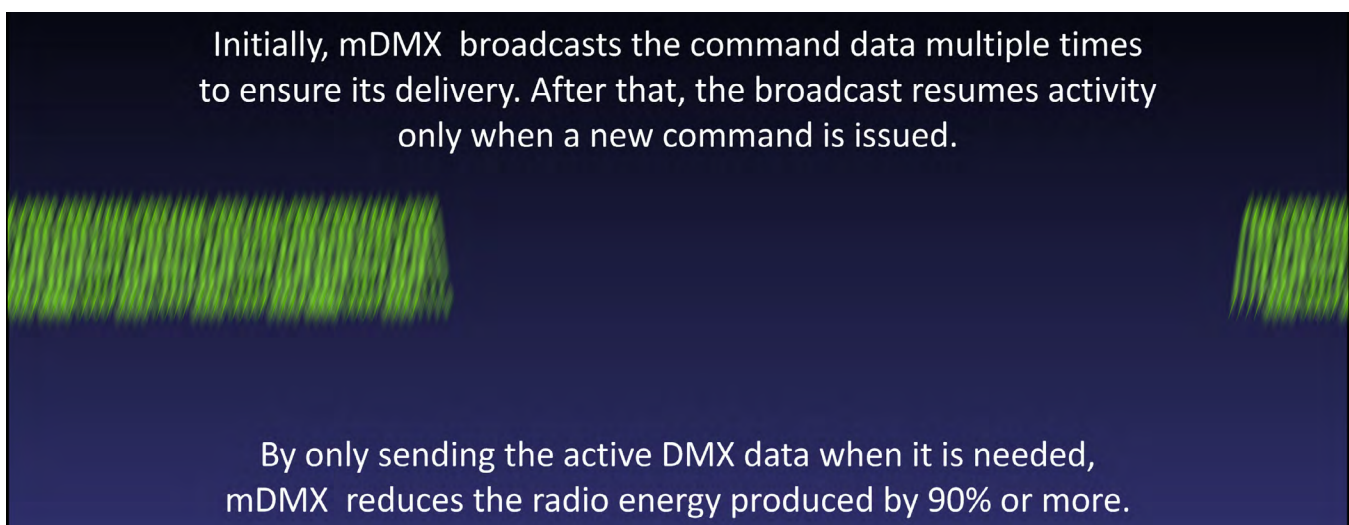

Figure 15: mDMX Reduces Radio Energy Produced by 90% or more

4. mRDM (Multiverse RDM) An encapsulation of the RDM (ANSI E1.20-2010) standard for wireless transmission that improves wireless RDM performance

DMX is a uni-directional protocol with data flowing only from the lighting controller to the end device. RDM (Remote Device Management) is an enhancement to DMX which allows users to communicate bi-directionally with their lighting gear. That means lighting users can utilize RDM to change a DMX addresses or the personality of a lighting fixture without climbing a ladder, and can get status data such as fixture hours or circuit board temperatures remotely. The RDM ANSI standard requires DMX to briefly stop broadcasting when RDM is being used since in a wired system DMX and RDM share the same pair of wires. This degrades DMX performance and for that reason, many lighting users have avoided using RDM, and RDM has never achieved its full potential as a technology.

Multiverse's mRDM radio technology allows RDM to report back without disrupting DMX or interfering with DMX at all, and this feature is unique to wireless mRDM, as seen in Figure 7. Better RDM performance opens new worlds of easier setup and troubleshooting for wireless lighting users. City Theatrical was the innovator of wireless RDM technology and holds the U.S. patent for the technology.
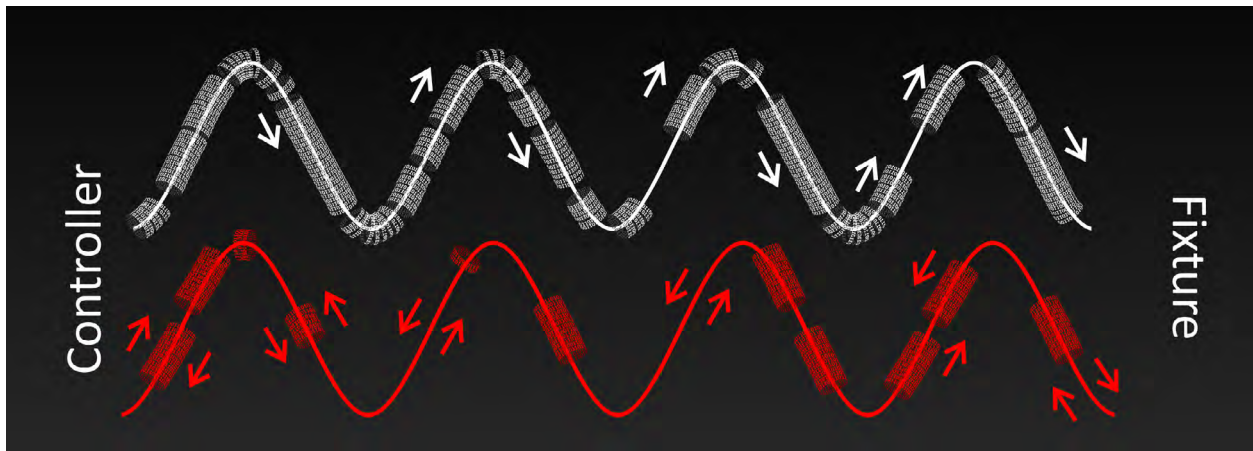
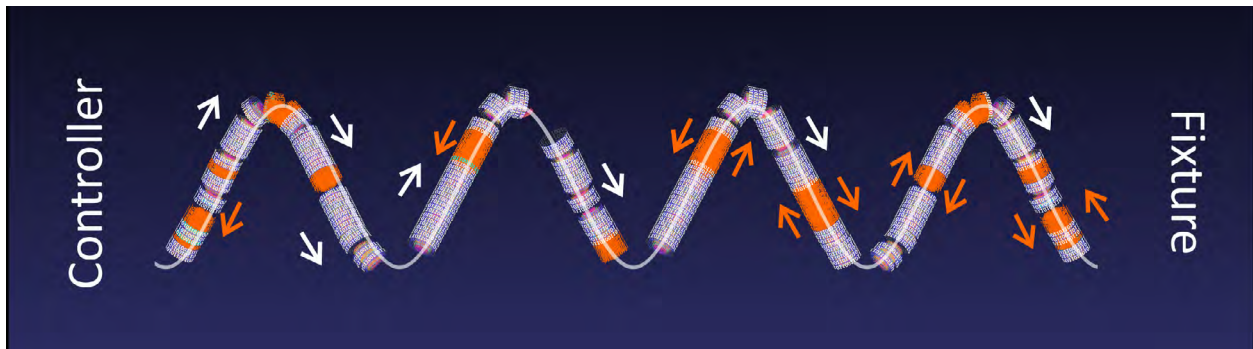Figure 16: Illustration of DMX and RDM Travel in a Conventional Wireless System

Figure 17: Illustration of DMX and mRDM Simultaneous Travel in a Multiverse Wireless System

5. Forward error correction to detect and repair missing data

Data can be corrupted during transmission, especially in an overcrowded radio environment. Forward error correction detects and corrects errors in transmitted data. This helps to maintain data fidelity when mission critical data is imperative.

### 6. Show Key Security to prevent interference from other Multiverse systems in the area

Multiverse wireless DMX systems employ SHoW IDs (unique combinations of broadcast parameters such as radio frequency, data rate, band location, and hopping pattern) to ensure optimal performance and fidelity within the environment in which they are operating. When setting up a Multiverse system, all components (transmitter and receivers) are set to the same SHoW ID. If two separate Multiverse systems with identical SHoW IDs are in use in close proximity (such as adjacent theatres or studios) there is the chance that one system could inadvertently control the other. To eliminate this possibility, a three digit SHoW Key may be added to lock down the system from any outside control.

7. Smartphone and tablet lighting control

Smartphone control of lighting for setup and troubleshooting removes the need to have a skilled lighting programmer on hand at all times.   All models of Multiverse Transmitter include both Bluetooth and Wi-Fi radio receivers for input control. Through the use of City Theatrical's free DMXcat® smartphone app, users can set up and configure the wireless system as well as control any lighting fixture that is part of the Multiverse setup, whether it is a fixture with a built in Multiverse module, a fixture receiving its data from a Multiverse Node, or any connected (wired) fixture downstream of those devices. For tablet users, Wi-Fi lighting controllers like Luminair are supported as well.

8. Lock PIN: Locks unauthorized users out of the system

Since Multiverse systems can be modified and or controlled using RDM controllers such as DMXcat, for added security Lock PINs (four digit codes) can be assigned to each transmitter to prevent unauthorized or malicious use. When using Wi-Fi
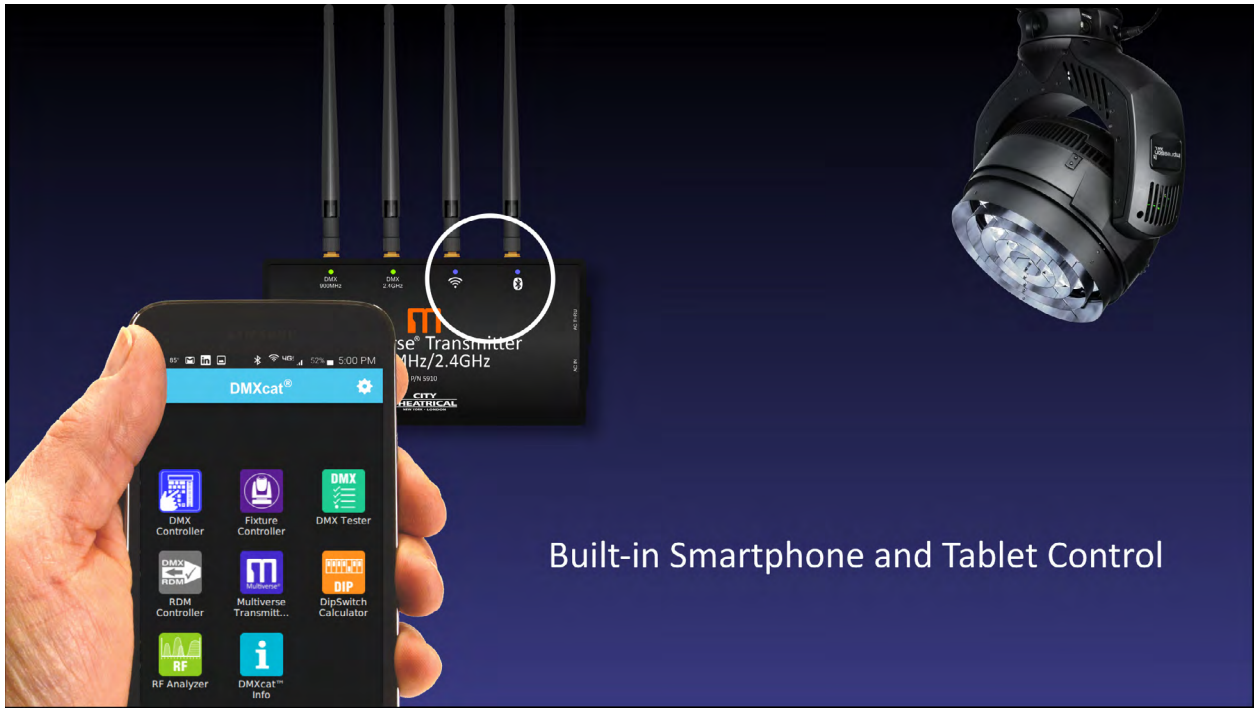
Figure 18: Smartphone and Tablet Lighting Control is Built In

controllers to control Multiverse Transmitters, a Wi-Fi password can be utilized for the same purpose.

9. Backwards compatibility with SHoW DMX Neo wireless DMX products

Multiverse SHoW Babys, Multiverse Nodes, and Multiverse 2.4GHz radio modules are fully compatible with City Theatrical's Legacy SHoW DMX products and may be used to expand these existing systems' capabilities.

Figure 19: Multiverse SHoW Baby, Multiverse Node, and Multiverse Transmitter
radios and universes

10. RDM integration of entities: Radio and fixture appear as one device when Multiverse Module is installed in lighting fixtures

When Multiverse Modules are implemented into a lighting fixture, they become an integrated part of the device. Lighting users simply look for the fixture they want to communicate with, not the radio module in addition to the fixture. This simplifies the setup process, particularly on large shows.

11. Low Cost Technology

The Multiverse Modules used in every Multiverse product are the lowest cost full featured DMX/RDM devices ever introduced. They are perfect for direct integration into all types of lighting fixtures.

VII. How Multiverse Will Affect the Future of Lighting

Multiverse, for the first time, allows lighting users to scale up larger systems of hundreds of fixtures and dozens of universes, leading to a future of wireless lighting control. As more and more manufacturers implement the Multiverse Module into their fixtures, lighting systems will include Multiverse compatible consoles, lighting fixtures, gateways, fog machines, dimmers, and any other imaginable DMX device.

We live in a wireless world. Sometimes we plug in our laptops and sometimes we run them wirelessly, and the future of lighting control will be similar. Our lighting fixtures will have the capability to be run wired or wirelessly, and lighting users will make that choice depending on their needs, lowering costs, saving time, and adding flexibility to lighting setups.

Multiverse products are covered by U.S. Patents #7,432,803 B2, #10,129,964 B1, and other patents pending. Designed and manufactured in the USA.

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