# The SHoW DMX Test

By: John Huntington

## Inside the development of City Theatrical's new, and most controversial, product


Above: SHoW DMX.

As part of the development process for its trademarked SHoW DMX wireless DMX transmission system, City Theatrical (CTI) caused a stir in the industry after it hired an independent testing lab to test not only its products, but those of its chief competitors. *LSA* sent John Huntington out to City Theatrical's headquarters in New Jersey to discuss development, testing, and the resulting controversy about the product, which received a U.S. patent in October, itself a source of further controversy. (In his capacity as professor at City Tech, Huntington participated in the first set of tests of WDS, the predecessor of SHoW DMX.)

Huntington spoke with Larry Dunn, head of engineering at City Theatrical; Gary Fails, the company's president, and Paul Kleissler, its senior engineer. You can read the lab report at www.citytheatrical.com/labreport.htm.

**John Huntington:** Can you talk about the first round of wireless DMX tests, and how that led to the development of SHoW DMX?

**Gary Fails:** We first met in 2005 at City Tech, mostly with the objective of having a real theatrical space to work in. We set up a number of wireless systems to understand how they worked in that environment, and how they worked in the face of interference. There was a broad range of frequency hoppers and Wi-Fi-based systems. We wanted to test systems in a real-world setting, and to judge their performance.

**Paul Kleissler:** I remember we tested Strand's Wi-Fi system, our system, and a DMX frequency-hopping system. We tested the movement of moving lights—one moving wired and one moving wireless side by side in the face of increasing interference. We also used a bit error rate tester to evaluate the Wi-Fi-based system.

**GF:** We also had our LED visualizer. We had learned that LED panels were effective evaluators of DMX quality, both wired and wireless. We had four Color Kinetics panels that we had built into a universe of DMX, so we could see how DMX quality was affected by interference and range. That was the first time we'd ever done that type of testing in the real world, studying interference and performance. We were interested in visualizing this thing that you couldn't see. There was no testing gear that we could use that would work for frequency hoppers. Our ad-hoc test was as good as we could get at the point.

**JH:** What did you learn, big picture, from those tests?

**GF:** The Wi-Fi based systems had incredibly good performance in the absence of interference—but, as soon as there was any interference, the quality declined very rapidly. We'd always assumed that Wi-Fi was unusable for wireless DMX, but we learned that, under certain circumstances, it is an excellent system. Unfortunately, the user rarely can control the environment well enough to insure good performance.

**PK:** The other big thing we learned had to do with the hopping frequency versus the DMX refresh rate, and how that misalignment affected the output. Many systems chop the DMX packets into smaller packets as they hop, send them through the air, then try to reassemble the packets on the other end. This inevitably leads to some lost data that gets replaced with older data from the buffer. On our visualizer, we could see what we called "smearing," with some data lagging behind by a packet or two, which is the older data that has been substituted for the portions of the packet that were lost. The visualizer showed it very well. No one had ever seen this before, and all the frequency hoppers showed the same basic problem of smearing. We've since come to refer to that as "fragmentation." Fragmentation is a valid strategy but there are penalties in using it.

> “We wanted a test engine that could make absolutely predictable data that we could send through a wireless system, and look at it and see how it compared with what was received. It's a simple concept, really, but no one had ever done it.” —Kleissler


SHoW DMX's RDM monitor allows system settings to be changed, and system performance to be monitored, from a laptop connected to the SHoW DMX transmitter

**JH:** When DMX fragments, what kind of problems does that cause? Can the packets just go back together in the receiver?
**PK:** You need to transmit these smaller packets at a sufficient speed to allow redundancy or fail/retry operations to occur to prevent fragmentation. The faster you transmit, the more bandwidth you use. You run out of time. DMX spews out constantly, and you have to abandon repairs. The idea with DMX is, you're spewing out so many refreshes a second that, if one gets lost, who's going to care? In modern lighting, this becomes more and more of a problem that can easily be seen with LEDs. Prior to this, wireless DMX was pretty forgiving—with incandescent loads, for example. If it's a table lamp that's rarely moving, it's not going to make a noticeable difference to anyone. Most wireless DMX manufacturers utilize a strategy of fragmentation, including CTI, in our WDS product.

**JH:** After that time, you developed your new product [SHoW DMX]. I assume you did lots of tests yourself. What spurred you to hire an independent lab?
**GF:** We felt early on that we were developing a system that was superior in several ways. First off, we synchronized the radio hop with the DMX packet to insure that fragmenting and smearing would be eliminated, since we only would broadcast full packets. We designed and developed our own radio for this because none existed. We filed patents for it, because it was unique new technology. Wireless DMX broadcast takes place in the air, and the primary focus of all our research was that we wanted to prove our claims and quantify wireless DMX in a way that had never been done before by anyone, anywhere. We felt we could make a large advancement in the technology by being able to prove our claims with data.

**JH:** What's the lab you used? How did you find it, and what does it do that's different from what you are able to do in-house?
**LD:** Intertek Testing Services is one of the three biggest safety and compliance organizations in the country. They're certified in North America by the U.S. and Canadian governments. They are commonly used for electrical and product safety and emissions screening.

**JH:** Does the lab work with the FCC?
**PK:** Intertek is the parent company of ETL. They have a complete FCC-certified semi-anechoic chamber for testing.

**JH:** Why is it "semi-anechoic"?
**PK:** Because it has a hard floor that's technically not absorbent, so there's some possibility of RF interaction with the floor. It meets the FCC requirements for intentional and unintentional radiation testing, which means you can use the lab to license the radio. They can do FCC Part 15 unintentional radiation, which means they're held to a very high standard. We knew the lab was pristine and beyond any question of impropriety, which is why manufacturers use a lab of that type. We did it there, because they're a disinterested third party, and they're professional testers held to a high standard by many government agencies. Their lab is probably the most beautiful, interference-free environment you could ever test a wireless product in. All other variables caused by interference, reflection, and range were eliminated. Every unit that was tested there got the best results they could ever achieve.

**JH:** How did you develop the testing specification? One criticism I've heard about this is, you wrote the specs; of course your product is going to do best.
**LD:** The ultimate goal was to see if it performs like wired DMX. We didn't steer the specs toward any one system. We steered the specs to what a wire would act like. We wanted to compare wired DMX, which is perfect, to wireless DMX, under very controlled circumstances, and for the first time to create data to show wireless DMX fidelity.

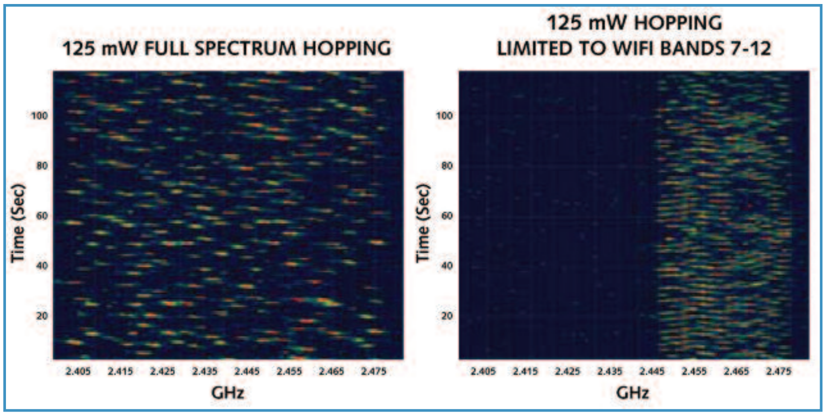
**JH:** I didn't see this in the testing, but I know that, in the earlier testing, there seemed to be a trade-off between latency [delay] and data fidelity. If the data throughput is slower, it can be bulletproof. I didn't see any specs on propagation delay in the testing. Did they have a means to test for that?
**PK:** As you said, there's a tradeoff between fidelity and latency. SHoW DMX gathers one packet before sending it on, whereas fragmenters don't, so we have a built-in latency of a minimum of one packet plus a bit more for radio housekeeping issues. Our sys-

tem has an average latency of 60 milliseconds, which is not noticeable, and in fact is comparable to WDS [City Theatrical's previous product], which has been used on Broadway for six years, and we've never gotten a negative comment about its latency. All electronic devices introduce some latency into the DMX stream.

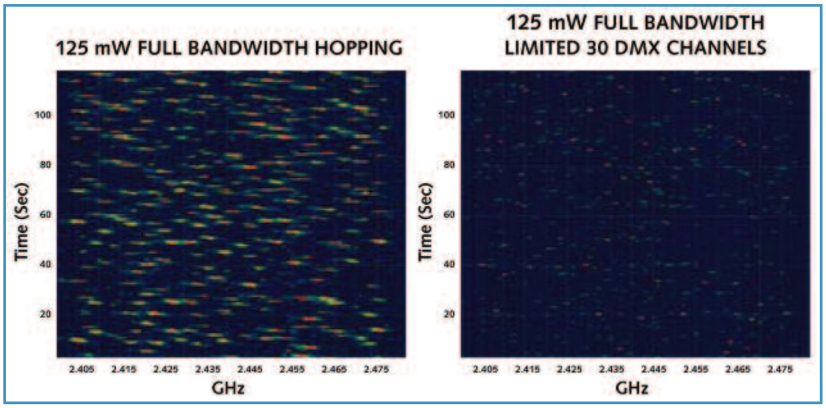
**JH:** This is really interesting to me, because this is the type of thing that no one in our busines really knows: What's perceptible to the eye? In a rock concert, the lighting guy is 125' from the stage, meaning he is hearing the sound about 100ms after it leaves the stage. Is he hitting the button 150 milliseconds early to sync things up, or is it that we can't perceive that kind of sync offset?

**GF:** We wondered about that, and put a lot of thought into it. Our LED visualizer, or any LED screen, reveals everything, really, but in a visual way. After a while, we realized we needed more than the visualizer could provide, since there was no way to interpret it or quantify it, and we said, "This has to be shown in numbers."

**PK:** Our goal for SHoW DMX was to try to replicate the function of the wire, and remove all of the subtle performance issues that we first identified at City Tech and which had growing significance to LED targets. We said, "These are all the best qualities of wire data. Let's get as close to that as we can."




Top: This screen shot of a WiSpy spectrum analyzer shows SHoW DMX's ability to decrease its radio footprint. The left image shows broadcast at high power over the full 2.4Ghz spectrum; the right image shows broadcast limited to the upper end of the spectrum only, permitting other radio devices to operate in the lower portion of the spectrum unimpeded. (Color denotes radio activity; less color equals less radio activity.) Below: These WiSpy screen shots compare SHoW DMX broadcasting over the full spectrum in full power. The left screen shows all 512 DMX channels being broadcast, and the right screen shows only 30 DMX channels being broadcast in limited-burst mode.




**JH:** Can you describe the tests that the lab performed?

**PK:** We provided the SHoW DMX manual and the wireless DMX tester manual to [the testing lab] ETL as a part of the test. There are three basic tests.

The first test, which is called the Integrity Test, tested if the DMX packets, which are generated from the wireless DMX tester [CTI patent-pending], were transmitted and received correctly.

The wireless DMX tester generates a known unique set of packets, and then outputs them on a five-pin XLR as DMX data. That goes out to any wireless DMX transmitter, and the companion receiver's output goes back to the wireless DMX tester. The tester then counts to see if any packets didn't arrive, and reports the results. The wireless DMX tester outputs a known unique stream of 512 data packets, where the first 510 contains data, and the final two contain a sum-check value. Each packet is labeled with a unique number that corresponds to its content. The system outputs the packets, then checks the sum-check values and counts valid packets, and displays that result in a variety of ways—packet errors, maximum percentage, minimum percentage. During that test, it also outputs the refresh rate, so you can say, "Okay, this console is outputting at 42; what's the receiver putting back?" A wire would have no errors and no change in the refresh rate.

The second test is the Fragment Test, which measures the number of slots that come back differently from how they were originally transmitted. It outputs 10 packets, containing all 0s. This is to clear the buffers of the system under testing. Then it outputs one packet to contain all Fs, and then it checks the contents of the received packet to make sure it's all Fs. If any of those are fragmented, it tells you if any slots were stitched or patched in from previous packets.

**JH:** With that test, because every packet is changing, are you effectively fading every channel with every update?

**GF:** Every level changes in every packet; therefore, any error is easily spotted.

**PK:** The third test is the Account Test. It looks for lost packets. It begins by priming the system by outputting 10 packets, containing all 0s, just to wash all the buffers, and 256 packets where each packet has a unique identifying number in the first byte. One is labeled 1, 2 is 2, and so forth, through 256. Then the unit looks back at what's coming from the receiver to see if they all came back, and looks to see if any were lost. In any case, the results are displayed in a range, and you can get max and min.

There are some other test tools. You can send packets from the unit and can configure it, so that you can change the packet length, you can adjust the refresh rate, you can adjust the interbyte time, and those tests could be used to determine, for example, if your wireless system did anything to maintain the source's refresh rate.

We wanted a test engine that could make absolutely predictable data that we could send through a wireless system, and look at it and see how it compares with what was received. It's a simple concept, really, but no one had ever done it.

**GF:** We wanted to be able to compare wired to wireless DMX on a byte-by-byte basis. It had never been done by anyone in the world that we know of. We felt this was vital to being able to prove that we had superior technology and to separate fact from marketing hype.

**LD:** Our goal was to establish a perfect radio-testing environment, then send a lot of DMX data that was known in every parameter, and then study it and see how it compared to wired data. This was part of our original concept when we started product development, but the actual method was not developed until quite late in the process, since it required an additional invention, our wireless DMX tester.

> **"If we had access to a testing lab and an anechoic chamber, we could have done the tests ourselves, but then everyone would have said, 'Well, they did the tests.' So we took it to a nationally recognized testing lab, who would conduct it and certify it. I don't know that anyone doubts UL or ETL certification, and that's a similar process. We did create the testing gear and the test, but there is no testing gear or test for wireless DMX, so we *had* to invent it."** —Dunn

**JH:** What was the testing lab's input to the process? Was it mostly advising in terms of the RF issues?

**LD:** They conducted the tests and collected the data.

**PK:** We gave them the gear. We asked them to do the tests, we explained the wireless DMX tester and the way we initiated the tests. They asked to see the specs and the owner's manual, and asked us to explain how it works.

**LD:** If we had access to a testing lab and an anechoic chamber, we could have done the tests ourselves, but then everyone would have said, "Well, they did the tests." So we took it to a nationally recognized testing lab, who would conduct it and certify it. I don't know that anyone doubts UL or ETL certification, and that's a similar process. We did create the testing gear and the test, but there is no testing gear or test for wireless DMX, so we *had* to invent it. We brought data to an area where none had ever existed. I think the test accurately represents what we did, and what the world wants to know.

**PK:** We now use this data and tester regularly in our testing and development to see how things are working, like if we want to try a new antenna. It's a tool for us.

**JH:** Since you released the report, have your competitors challenged the test methodology?

**GF:** Wireless DMX is a small but very competitive niche. We were spurred by competition to improve our technology and we have raised the technology bar in this field. Any wireless DMX manufacturer has the duty to prove their claims. We've proven our claims.

**JH:** Are the competitors you used in the tests your chief competitors? Was anyone left out?

**GF:** The market is always changing; there must be dozens around the world who compete in the field now. The group we chose was a cross-section. We thought that our data would get away from rough, seat-of-the-pants, subjective tests. It's really hard to test that way and get any meaningful results.

**PK:** I'll give you one example; one of the tests that was done in Eastbourne [a test conducted by *Lighting&Sound International* on the street in Eastbourne, England] was looking at the DMX refresh rate coming out of the receiver. It wasn't understood that a fragmenter has nothing to do with a refresh rate through air. A system whose transmission strategy is to take the DMX, chop it up into little packets, and then reassemble them into a frame—if those systems don't successfully receive one of those slices, they fill in with one from past history. They might put things in a complete refresh rate, but it might not be a com-

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plete transmission. The fragmentation strategy is to run at a constant stream, and fill in missing bytes on the theory that, on sending 44 refreshes to this dimmer, it's not going to care if it gets only 42 refreshes. We wanted to look at refresh rate in to refresh rate out, because that would tell us if the system was accurately modeling the refresh rate at the source. There is some gear that is refresh-rate-sensitive, such as LEDs. Let's say your console has an adjustable refresh rate, like some of ETC's consoles. It would be really great if your wireless system could support that adjustment. We designed our system to do that. No one else does.

**JH:** So testing in a clean RF environment is the way to insure an equitable test?
**PK:** Each system was allowed to test at its absolute best. Each system will never produce better results than it did in this environment.

**JH:** I noticed that when you did the Wi-Fi interference testing, it looked like you tested several power modes in your system, but only one mode in each other system.
**GF:** In the [competitors'] systems we bought, there weren't any other power options offered. If there were, they were not available to the general public. We used what was available to the public at the time.

**JH:** So you tested what was available to you at the time of the tests in late 2007.
**LD:** That was actually one of the things James Eade [of *Lighting&Sound International*] did in Eastbourne, which I thought was good. He limited the test to what was on the market. You couldn't bring in special gear.

When WDS was on sale, we often did Broadway shows with custom-crafted firmware. We'd put a chip in and make custom designs, but it wasn't listed on our website or available to the general public. SHoW DMX is user-changeable for everyone, and has many built-in user selectable options.

**JH:** The most controversial thing I saw in the test results was the 99% average error rate for one of the systems tested. It seems like that system must work to some extent, or it wouldn't still be on the market.
**GF:** We divide the lighting world into three segments: incandescent, moving lights, and LEDs. You can have a huge amount of data loss with incandescent lights and not notice it; you can have as much as 20% data loss with moving lights and not notice it, but not with LEDs. Data loss there is nearly always visible. There is a place in the market for wireless DMX with large data loss, as long as the user is willing to accept its limitations. Even a system with a 99% error rate will work fine for a table lamp that fades up in a few seconds, stays on for the scene, and blacks out at the end. The wireless DMX market is pretty well segmented, with various levels of price and performance.

**JH:** You don't have a test for only one channel changing. Were you asking some systems to do things they weren't designed to do, such as moving all 512 channels at once?
**LD:** Although we didn't have a test for only one channel, the tests on that product showed that 99% of all packets transmitted had an error of some amount in it. To contrast that with our system, ours had zero errors. Not one packet wrong. Of all the significant things that come from the lab, the biggest one is that we set out to invent something that had perfect data transmission. In perfect conditions, we were perfect. In the real world, with interference and unpredictable conditions, we're not always perfect, but we start out at a much higher level than our competitors, and stay that way longer.

**JH:** Do you guys have any sense of what an acceptable error rate is?
**PK:** It depends on the targets and what you're trying to do with them. If you're doing flash-and-trash moving lights at a rock-'n'-roll concert, or you're doing incans on a table, you could get away with a tremendous amount of packet loss.
**GF:** It just depends on your show and what's acceptable to you. We said, “Let's not break up the packet, since if we commit to breaking up the packet, we're committing to data loss; let's create a different system that doesn't do that.”

**JH:** You're not breaking up packets for transmission, and you have a lot more control over the radio transmission. Is it all integrated?
**LD:** Yes, we set out to create an integrated system, with both full-packet synchronized-hopping transmission and wide control of all of the broad-

cast parameters. It's custom-built and radio-specific. We designed and built the radio from scratch. We used a purchased radio with WDS, but, with SHoW DMX, we designed a radio from scratch that would provide the unique features we wanted, starting from that philosophy where we don't throw data away, and keeping the DMX packet intact always.

We wanted to make a friendly, clean radio system, with a small footprint. We wanted to set out to have as little negative impact as possible. To evaluate SHoW DMX fairly, you have to see that it has two big missions: high fidelity and low impact.

**JH:** You had had experiences before, where your systems caused interference with other systems.
**GF:** Between 2002 and 2006, the growth of Wi-Fi was enormous, and suddenly Wi-Fi was in every theatre, running mission-critical information. WDS was powerful and easily obliterated Wi-Fi, since it was fighting for the same bandwidth. That conflict forced us into this development, and it became our philosophy. We faced it really big on a tour of *The Lion King*. Their automation department was running the Pride Rock turntable on a Wi-Fi-based wireless control system, and WDS knocked it out. Every time they turned on the WDS system, the turntable stopped working. We saw we couldn't be a steamroller anymore, and needed a system with much more finesse. We set out to design and build what would become SHoW DMX.

**JH:** Are you happy with the sales?
**GF:** Sales are strong. SHoW DMX is the standard of Broadway and the West End, just as WDS was. People see it as the leading edge of wireless technology. We think they realize it gives them lots of user options. We opened an office in Europe to help meet demand over there, and just announced our first eight OEM manufacturing partners.

**JH:** I think you're using RDM to configure these new products?
**PK:** Most of the interface configurations are available through RDM, such as changing the DMX address, changing the radio power, the battery voltage, or checking the received signal strength. People will find this really useful on shows. This is one of the early big RDM applications, with a remote monitor that users can plug into.
**LD:** The system has three roles for RDM. One is as a remote way of configuring RDM equipment in the system; two, as an RDM proxy for use with other RDM controllers; and three, as a way of monitoring the wireless system performance directly.

All the radios are transceivers and the transmitters actually receive. Also, we have a nice RDM controller built right into the transmitter to control all RDM responders. It's being used on a show right now that uses other brands of RDM—the *Mary Poppins* tour in the U.K.

**JH:** I read that in a separate test, you tested your system with 16 universes at one time?
**GF:** This was the first verifiable 16-universe test with data, although it was not a lab test. We did it outdoors in a field in the New Jersey Meadowlands, within sight of New York City. We used our wireless DMX tester over a 730' length, and we were able to test the data fidelity over all 16 universes. No one had ever done this before and proven it. This is in the theme of data gathering and proving our claims. We didn't want to say we could do 16 universes without proof.

**JH:** Was there data loss in the 16-universe test?
**LD:** Data loss over the 16 universes varied from 4% to 20%. We found those within usable limits for a typical show with moving lights. LEDs would have shown steppiness. This was a very demanding test, and there are physical limits to radio fidelity, due to factors like interference, reflection, and range.

**JH:** Anything else you want to add?
**LD:** The whole thing is built in our factory. We make the circuit boards and radio, design the extrusion parts, and fabricate all the metalwork and do the assembly here. We have an incredible group of dedicated people who designed SHoW DMX and who now manufacture it. We really enjoy being on the leading edge of this technology.

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