The Great Wireless

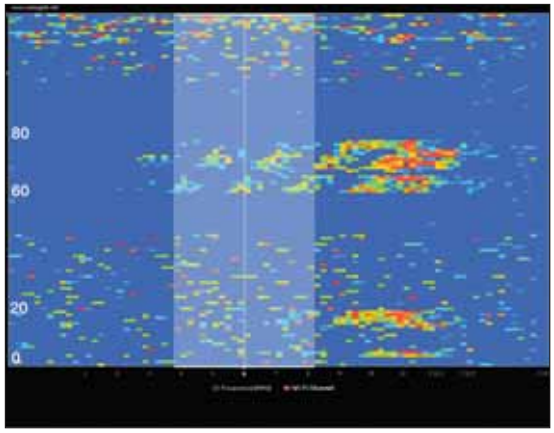

Figure 1: Wi-Spy screen grab showing the microwave cooker turned on between bands nine and 12 between 60-80 seconds, turned off and then on again at 20 seconds. Blue colour shows minimum signal strength (the noise floor) with red being maximum peaks.

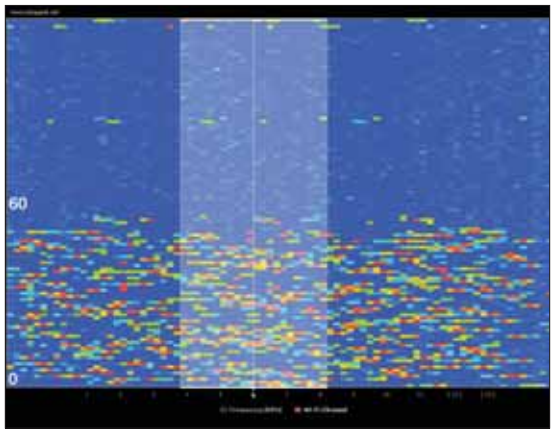

Figure 2: The City Theatrical unit demonstrating the wide band nature of FHSS between 0 and 60 seconds. Note the actual quietness of the band locally above the 60 second point.

In an industry well-accustomed to wireless technology, lighting has perhaps been the poor relation, having only embraced the copperless void in the last few years. Not, however, for lack of trying: the principle reason why it has taken so long is that it is actually quite hard to send raw DMX data through the air.

A DMX stream sends data bits at a rate of around 23kHz and to modulate a higher frequency RF carrier with that information would not only need a much higher frequency to operate but also a chunky allocation of bandwidth to get all the data in. As such, the lack of available licence-free bands, coupled with the expense of developing something that would be robust enough in normal operation, has hitherto hampered the best engineers and designers.

However, it isn't as hard to convert DMX data into something suitable for sending over an Ethernet network running at 100Mb/second, and several manufacturers now avail of this in various forms, such as ETC, Strand and the widely adopted Art-Net from Artistic Licence. It doesn't take a great leap to realise that you can send Ethernet wirelessly in the short range - just pop down to the local PC World, buy a Wireless Access Point (WAP) and off you go. So, there we have it: the means to send DMX over the air.

But is it any good? Does it work reliably? Should you keep all fingers and toes crossed during a show in the hope that the link will hold up? Will interference cause it to fall over? It was this last point that caused two manufacturers of wireless products to enter into a debate over the use of the phrase 'interference free' - and thus caused L&SI to step into the breech and draw its own conclusions. So read on to find out . . .

Look, no copper!

Of course, nothing is truly interference-free - any wireless signals can be blocked if you try hard enough - just ask MI5, who can quite happily (and sometimes do) block the airwaves, principally to prevent terrorists from remotely detonating devices or communicating with each other. There are tales of such things happening at public events where high profile guests appear, upsetting everything from radio mics to (of course) wireless DMX.

Such widespread blocking, however, is thankfully rare, and in many instances wireless DMX can be an ideal solution - but not if cables can be installed! All the manufacturers who were present at the following tests were in agreement with what Ric Salzedo of Avolites was at pains to point out: "I'm often having to tell people that wired is far more reliable than wireless - if it is at all possible to run a cable, then do it." Indeed, saving a few pounds on an awkward cable installation may be nothing to the potential costs of the system failing during a crucial moment. While the systems tested were pretty reliable, they (mostly) did succumb to interference - which just goes to illustrate the point.

DMX Shoot-Out

The technology

All the systems tested use the licence-free Industrial, Scientific and Medical (ISM) band of 2.4GHz, which is split up into several channels - actually 14, but Europe and North America can only use up to channel 11, with the Japanese having access to channels 12-14 as well. These channels actually overlap so, for example, a transmitter on channel 6 may spread over into channels 4 and 8. It's not really a problem, save for the fact that one ends up with fewer available channels than might be expected - really there are only three - 1, 6 and 11, but depending on the local RF environment it might be better to settle for something in the middle of these.

There are two main methods (or protocols) for transmitting data that are commonly used. All work using some form of spread spectrum which is essentially a noise-like signal transmitted over a defined wide bandwidth - much wider than would be required for the actual data alone. There are two types, Direct Sequence Spread Spectrum (DSSS) and Frequency Hopping Spread Spectrum (FHSS). DSSS (figure 3) basically works by modulating a sinewave carrier frequency with pseudo-random noise, which is a sequence of 1 and -1 values, at a frequency much higher than that of the carrier, thereby spreading the information wider over the band. At the other end, the receiver again multiplies the incoming signal with the same pseudo-random sequence and thus gets the original information back - as 1x1=1, and -1x-1=1. Transmitters using different phase noise sequences will therefore be ignored, and on this basis transmissions can share the same channel of operation - up to a limit!

However, for this de-spreading to work correctly, the transmitter and receiver sequences must be synchronised and this is achieved by a timing search process. Incidentally, if the sequences of multiple transmitters are synchronised using this method, the relative synchronisations a receiver must make between them can be used to determine the time difference between them, and if the transmitter positions are known this can be used to determine the receiver position, a process which is the basis for satellite navigation systems.

FHSS (figure 2) works by continuously and rapidly switching the actual carrier frequency across a defined band, using a pseudo-random sequence known to both the transmitter and receiver. A variant on this is Adaptive Frequency Hopping Spread Spectrum (AFHSS) (figure 4) which intelligently looks for busy sections of the band in question and avoids them, to further reduce interference. While all the products on test use either FHSS or DSSS, Wireless Solutions is the only one to use AFHSS with a custom encryption sequence.

In all, while such systems are apparently quite robust, proper frequency and coverage planning is actually quite crucial to setting them up, particularly those operating using DSSS where interference is potentially more likely to occur. Because the energy is distributed across a wide

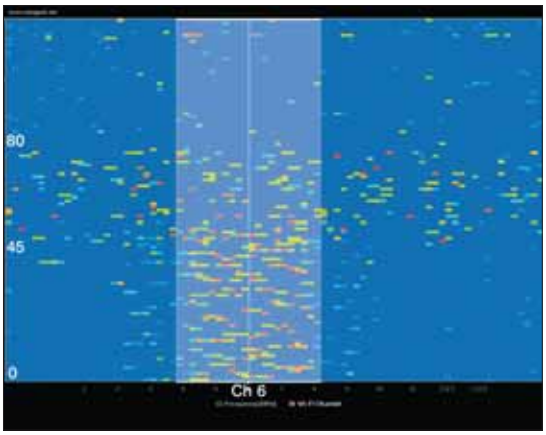

Figure 3: The wideband signals between 45 and 80 seconds are the Avolites eDMX Tube looking for its WAP, and 0-45 seconds shows that it has locked on to the WAP on channel 6. This gives a good example of DSSS operation.

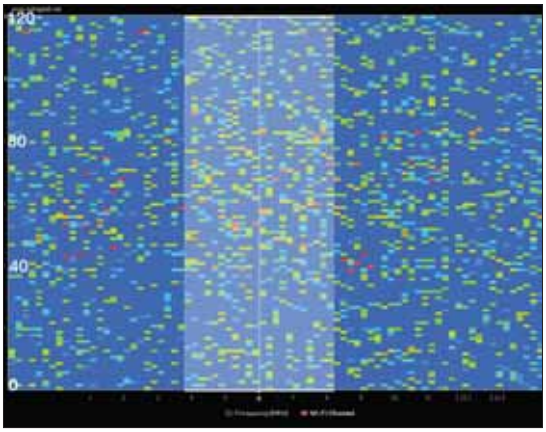

Figure 4: An example of AFHSS - the W-DMX transmitter is turned on between 80-120 seconds, but the receiver is off. The receiver is turned on at around 80 seconds, and a faint increase in general signals can be seen between 40 and 80 seconds while the units converse. As things settle down (no data was being transmitted) below 40 seconds, the signal levels return to their previous state.

General Product Round-up							
	Artistic Licence NetLynx + Lancom L54G WAP	Avolites eDMX	City Theatrical WDS	Goddard Design DMX-Link + Cirronet SEM2411	Luminex Ethernet-DMX8	Wireless Solutions W-DMX	Max Score*
What's in the box?	2 Lancom WAPs; Net-Lynx Input; Net-Lynx output; four PSUs and 2 antennas, two network cables, manuals.	2 eDMX tubes; two mains leads; WAP with PSU, network lead, software and antennas, manuals, Wendi House software, RS232 and network cables.	WDS 5501 transmitter; 5510 receiver; 2 power supplies, 2 antennas, manuals.	DMX-Link Encode2 and a Decode2; 2 x PSUs; 2 normal and 2 crosswired ethernet cables; 2 x Cirronet SEM2411 with antenna, RS232 cable, software, PSUs, and quick start guide.	Ethernet-DMX8, mains lead, 2 antennas, manual.	Transmitter, Receiver, 2 x mains leads, set-up guide.	
Were the instructions required?	No	No	No	No	Yes	No	-
Supplied parts	4	3	4	4	3	3	5
Ease of setup	4	4	5	2	5	5	5
Ease of configuration	4	5	4	4	3	5	5
Local 20m range test	Pass	Adjusted[3]	Adjusted[3]	Pass	Pass	Pass	-
Recovery time[1]	4s	4s	3s	18s	22s	1s	-
Microwave	Pass	Pass	Pass	Pass	Glitched[a]	Pass	-
Bluetooth	Pass	Fail	Fail	Pass	Fail	Pass	-
Battery-operated receiver[2]	Yes (9-48V)	Yes (12V)	Yes (9-12V)	Yes (12-48V)	No	No	-
Frequency	2.4	2.4/5.8	2.4	2.4	2.4	2.4	-
Protocol	Not specified	DSSS	FHSS	FHSS	DSSS	AFHSS	-
Power	17dBm	100mW	10mW	18dBm	75mW	80-100mW	-
Cost SRP for TX and RX system	£1,620	£1,600	US$ 2,600 (£1,690)	US$ 3,920 (£2,550)	€5,920 (£4,100)	€1,200 (£840)	-

Note 1: Power removed and reconnected after 5 seconds, and the figures quoted are the time taken for the unit to recommence data flow.
Note 2: If possible, can the receiving unit be operated from batteries?
Note 3: Orientation of receiver antenna adjusted to correct polarisation.
Note A: Glitched while receiving antennas touching microwave case underneath - recovered exceptionally quickly.
Note*: Scores are totally subjective and the Technical Editors decision.

Transmitter Data: Avolites Pearl running latest operating system, sending a full 512 channels of DMX ramping channels 1-512 up and down simultaneously.
Transmitter Measurements: Average break length - 324: Make after break - 55: Bytes per packet - 512: Break to break average - 25.3: Refresh rate average 39Hz.
(All in microseconds unless stated.)

Table 1: The results of the range testing.

bandwidth, the systems (more so FHSS) actually operate close to the noise floor, so high levels of interference can be a problem.

Range

Range depends on several variables, some within and some outside the scope of user adjustment. Factors such as transmitter power are fixed, and most manufacturers operate their systems as close as possible to the legal limit - it's also worth noting that these limits are different in Europe and the US (where it is higher). Often manufacturers will quote 100mW ERP, which stands for Effective Radiated Power. The actual transmitter power may be much lower than this, as the difference is made up using the gain of the antenna. As a rule of thumb, the more directional an antenna the more gain it has - a typical Yagi antenna (the same or similar to a typical TV antenna) has several dB of gain, but only in the direction in which it points. Accordingly, reception can be greatly increased by using different antennas and all the manufacturers have various antenna options over the standard ones supplied. It's worth remembering that antenna orientation can also affect reception - both the transmit and receive antenna need to have the same polarisation - vertical, horizontal or somewhere in-between. The difference in signal strength caused by antennas being in opposite polarisation is -3dB - i.e. half the power.

Other factors that affect range include data rates, bandwidth and physical terrain and surroundings, such as buildings, car parks (very reflective at RF!), trees (particularly in the summer) and even the weather. This latter point has two main affecting factors - more obvious is rain, snow or similar ground level effects but perhaps less obvious are the effects of the sun and the higher atmospheres - sunspots and solar flares (which manifest themselves as magnetic disturbances) have a big effect on radio communications causing different effects at different frequencies. For example, many readers may have come across foreign radio stations suddenly popping up on the FM broadcast bands as a result of Tropospheric lift conditions, typically when there is a high pressure (cyclone) over the UK. If a system is set up and works well one day, unexplained failure the next could have an answer millions of miles away!

The Brief

The aim of the shoot-out was to basically test the transmit and receive (TX/RX) quality and its ability to reliably send DMX information over a wireless link in a typical environment over a measured distance.

The tests were conducted at the offices of L&SI and PLASA in Eastbourne, East Sussex, which is a typical urban environment with accordant electrical noise. This was chosen to represent a situation where a wireless link may be deployed to transmit DMX between buildings, for example. Notably, the East Sussex Fire and Rescue Service HQ is within a few hundred yards as the crow flies; this is their main communications centre, making the environment heavy with out of band (but in some instances close) interference. While this should not ostensibly affect the tests, it may have the result of de-sensitising some receiver topologies, making reception more unreliable. There is also an electric mainline railway across the road which would be likely to give rise to wideband spurious interference.

The manufacturers were required to supply the basic product of the model chosen for the tests - no optional high gain antennas or similar enhancements were allowed. Equally, they were asked to supply the goods as they would be when purchased a general user - i.e. not ready configured for the application. Also, only one universe of DMX was used for the tests - while some are capable of sending two or more (Luminex, Goddard and Artistic Licence) others were limited to the one.

Methodology

Other aims of the tests were to see how easy it was to set the system up and get it working from the box, how they performed with interference and finally how far would they go.

Table 1 lists the actual results of how each product fared, as well as giving general information. Table 2 gives the results of the distance testing. The tests, as well as the location, were all chosen to represent typical situations and natural, rather than contrived, interference - it's ultimately not helpful to the potential purchaser of such equipment to know that a particular product failed when jammed with 200mW ERP at 2m by a home-made 2.4GHz transmitter, but it is nice to know that if you start cooking your lunch in the microwave nearby, that it will still work.

So, firstly we took a look at the parts supplied. While not too critical, it does help if the box contains the relevant leads to get the system up and running. All of the units tested had power and Ethernet cables where necessary, but you're expected to provide your own DMX cables - hence most only scored 4/5 for this point. Next we looked at the ease of set-up and how easy it was to plug things together, and then the actual configuration of the units - did

The distance results in full!

		Eastings	Northings	dE	dN	Distance (Metres)	Notes
Transmitter Location		*561097*	*099420*	*0*	*0*	*0*	*On wall outside PLASA office*
Avolites	Intervention	560980	099526	117	-106	158	WAP located with transmitter
Avolites	Lost	560956	099546	141	-126	189	WAP located with transmitter
Avolites	Intervention	560898	099587	199	-167	260	WAP moved to midpoint
Avolites	Lost	560809	099648	288	-228	367	WAP moved to midpoint
Artistic Licence	Intervention	561035	099482	62	-62	88	
Artistic Licence	Lost	560965	099534	132	-114	174	
City Theatrical	Intervention	560981	099525	116	-105	156	
City Theatrical	Lost	560901	099584	196	-164	256	
Goddard Designs	Intervention	561000	099503	97	-83	128	
Goddard Designs	Lost	560917	099570	180	-150	234	
Luminex	Intervention	561065	099549	32	-129	133	
Luminex	Lost	560960	099539	137	-119	181	
Wireless Solutions	Lost	560763	099686	334	-266	427	No intervention required

1. All figures from Garmin eTrex GPS with 5 satellite reception and accuracy better than 11m.
2. Intervention - The first point where some effort was required to increase reception signal strength such as by raising the antenna/receiver.
3. Lost - The point where reasonable efforts to increase reception signal strength no longer effective.

Table 2: The product comparison table and results of the tests.

addresses have to be set? Was software required to configure them? Or did they work straight away?

When all was set up, each unit underwent a series of tests within the building. Firstly, the receivers were taken to the far end of the building (about 20m away) which required the signal to pass through several prefabricated walls, a test which they all passed. At this point, a mobile phone was used to perform a Bluetooth device discovery within 1m of the receiver. The reason why a discovery was performed rather than just using a Bluetooth headset to make a call is that the discovery process searches all the band in question looking for a companion device: if a call had been made to an already paired device then this would only use a section of the band in which the DMX unit may not be operating. As such, it gives a better idea of what would happen if one's phone/headset combination was operating at close range with the DMX receiver in the same section of the band.

We then tested the recovery time of the system from power failure and measured how long it took the units under test to recover from such a situation. We also checked the recovery time from interference, but as the systems operate pretty fast, as soon as the interference was removed the data started flowing - faster at least than we could operate a stopwatch! Finally, we tested how well the units worked next to a microwave oven, which emits a heavy band of noise around channel 10 (figure 1).

Throughout the tests the data was provided by an Avolites Pearl console, which was running a chase of channels 1 thru' 512 inclusive, continuously ramping up and down. This ensured a full duty cycle of DMX and made the systems work hardest. The receivers were all tested for data integrity when they were receiving data, and refresh rate.

The range tests were quite simple - set the transmitter up, and walk away with the receiver (running off batteries or an inverter) and see when the received data begins to falter. All the units, as one would expect, hold the last valid state when reception is lost, so using the view channel function on the Lil' DMXter, it was easy to see when reception failed. At this point, efforts were made to regain the reception, either by raising the antenna or moving location.

The range was increased until the point where reasonable efforts to regain reception failed - it should be pointed out, however, that this is not a definitive guide to maximum range - it was typical of the situation. There is no doubt that if we moved the receivers (or transmitters) up a few metres, as you would be able to do on a PA or lighting tower, for example, then it's likely that a few extra tens of metres distance could be achieved. We had planned to operate the transmitters from the third floor window in the L&SI office, until Larry Dunn of City Theatrical, who had travelled from New York to take part in the tests, gently pointed out that the tinted office windows were made such by introducing metal into the glass, and perhaps, therefore, it wasn't such a great idea - plus there was a big tree in full leaf in the way anyway . . .

Product Overview

And so how did each manufacturer fare?

Artistic Licence - Net-Lynx

While Artistic Licence doesn't make a specific wireless DMX product, by using the Net-Lynx DMX to Art-Net (Ethernet) converters and simple WAPs, a wireless system can be set up. Artistic specify the Lancom L54G as the preferred WAP, and the company has done extensive testing of its own and the Lancom products together. The Lancom can be powered either using the supplied adaptor or via Power over Ethernet (PoE), while the Net-Lynx requires a 24Vdc supply using the supplied adaptor. While not impossible, such an arrangement doesn't lend itself readily to battery operation.

In terms of setting up, the system plugged together and worked out of the box, which was a plus point, although as the Net-Lynx is capable of sending two universes of DMX over Art-Net, some background knowledge of universes and sub-nets would help - or failing that, one could read the instructions as a last resort. Usefully, the two outputs could be set either as separate universes or the second configured as a buffered output on the same DMX universe. The only minor downside is that as four boxes are required (see figure 13) to make a send/receive system, it's not exactly 'plug and play'. Surprisingly, while the data integrity was good, the measured refresh rate was only in the region of 25Hz, compared to the transmitted 39Hz. While this would not really be noticeable in most situations, it would be interesting to note where the lost data ends up.

Avolites - eDMX

The Avolites eDMX is a robust, touring-grade system built into the same plastic 'drain pipe' housings as its truss buffers, and also come with the same Velcro mounting straps. The units can be readily configured as either transmitters or receivers and only need a single WAP to operate (figure 13). As the units have universal power supplies and can run on either 12V batteries (there is a standard coaxial DC input connector for this, and it will last 48 hours on a 1.8AH battery) or a range of mains voltages, they are

Figure 5: A view of the street along which the tests were conducted, from the control position.

quite flexible in terms of location. The only drawback is that Avolites supply the mains lead without a plug, as they can be shipped to a variety of countries. Arguably a minor frustration, but it did result in a '3' for supplied parts.

While it worked straight out of the box, there are various means of easily configuring the system. The WAP comes with its own software, whereas the tubes can be configured either using Telnet, Hyper Terminal or the supplied Wendi House software from the system's developers, DaftData. This also allows the user to set up virtual receivers or transmitters, and there is also a simple console to allow the user to send DMX data from the PC - ideal for checking fixtures. With the range tests, the system was originally set up with the WAP located next to the transmitter. When the reception eventually died, the WAP was moved to a point about 120m from the transmitter allowing the system a far greater range. This is one advantage of the Avolites system over some of the others in that the WAP is not connected to the transmitters or receivers, and thus no interconnecting network cables are required.

Avolites also supplied its latest DMX system - the P2P, a 'point to point' transmitter receiver operating in the 5.8GHz band. While it was a prototype and not part of the tests, the system easily outshone the others in the range testing, and distances of over a mile were discussed. Plans are afoot for a more detailed analysis of this product in L&SI in the near future . . .

City Theatrical - WDS

Next up was City Theatrical, with its WDS system. It was the first tested that was truly 'plug and play' - connect DMX, power, and off it goes. The WDS had the lowest power output of any of the devices on test - a tiny 10mW compared to the others operating at around 100mW, and taking that into account, the range test results are quite impressive, beating some of the other higher-powered devices.

While the system worked out of the box, it was necessary resort to the manual to work out what the DIP switch settings were for - which transpired to be the radio hopping pattern selection. The only confusing aspect was the multi-coloured LED indicators on each unit - green, one would expect, indicates all is well, but that's not the case. If there is no DMX, or the RF link is lost, then this is flagged up by the green colour, whereas a happy and healthy system is indicated by amber for both. Once you've got your head around that, they're really straightforward and easy units to use.

City Theatrical also has a higher-powered (200mW) version, which is above the legal limit for operation in the UK. It also manufactures

Figure 6: The transmitter position in true festival-style set-up!

a range of accessories including mains-powered receivers for truss-mounting, a single-channel 15A low voltage dimmer, adaptors for converting Color Kinetics ColorBlast 12 to WDS wireless control and power, amongst others.

Goddard Design - DMX-Link

US-based Goddard Design also joined the party, sending in a DMX-Link Encode2 and a Decode2, coupled with Cirronet industrial WAPs. While the DMX-Link is remarkably similar to one of the other manufacturers on test (see figures 11 and 12 - while the cases differ, the guts were even more similar!) the results were different in the range tests because of the different access points used. The Goddard system again supports two universes of DMX over Art-Net (there's a clue) although it was the only one that didn't work straight away - save for the Luminex unit, of which more later. The WAPs were configured for transmit and receive, and as they were not marked there was a 50% chance of getting it wrong - which, of course, we did. At least with DMX the cable connector sex dictates which is send and receive, with RJ45s you don't get such luxury!

Once the system was up and running though, it performed well, except, like the Artistic Licence unit, the refresh rate was low. The WAPs took longer to recover from a power failure than the Artistic Licence-supplied Lancom units, although the RF link was better, taking longer to initially drop out and working the greater distance. While it is theoretically possible to use other WAPs with these products, the ones supplied by the manufacturers have been tested and are known to work well, which is some advantage. The only drawback with such office technology is that it is not exactly built for the road, although the Cirronet units were by far the most industrial and robust-looking and would probably survive for a while. It comes at a price premium though - each WAP costs around US$1,400 compared to US$560 for the DMX-Link. While both the Artisitic Licence and Goddard systems can run on batteries (the Art-Net boxes require 9-48V) the WAPs would require special connectors, unless one wanted to adapt the moulded cables that come with the power supplies.

Luminex - Ethernet-DMX8

Belgian company Luminex made the trip over armed with a selection of Ethernet-DMX8's. With the Luminex system, the user isn't just purchasing a wireless link, but a complete eight-universe DMX processing box. As with the other products tested, there are more features than can be listed in this review, but here's a potted highlight of some of the more pertinent ones: Eight DMX connectors on the back can be configured for any combination of input/output or buffered outputs across eight universes; unit can be configured as a merger, backup or splitter; DMX-Ethernet (Art-Net) conversion; 40 user-programmable configurations and 10 preset ones; WYSIWYG compatible (DMX inputs can be viewed in WYSIWYG); and on top of that the wireless link allows it to be used in either single or multiple bridged with up to eight units to allow for redundancy. Oh, and it also has an internal network switch.

With all this stuffed in a 1U rack case, it's understandable that a bit of configuration was required to make it do what we wanted it to, and hence we had to resort to the manual to set it up. Once we had understood the menu structure and softkey operation, configuring the units was very straightforward and took a matter of seconds. It's also possible to use the system's built-in webserver for configuration if the laptop is to hand. The low score for supplied parts is caused by the lack of DMX gender changers - all the connections on the unit are female XLRs, whether configured as input or output. Accordingly, if used as an input, then a male-to-male gender changer is needed.

As for performance, the two little antennas struggled a bit and didn't do as well as some of the other systems, although the range did increase when we tried them with a set of optional 5dB versions - but these results were disallowed as the antennas are not supplied as standard. It also glitched during the microwave test - whether this was because the antenna were stuck parallel to the bottom of the cooker, or the interference upset the internals, we will never know, but in fairness we did try quite hard to stop it working, and it recovered data output very quickly. Otherwise, they worked well and given the functionality would be a great asset on larger shows. L&SI is informed that there will be a host of developments including software to be unveiled at the PLASA Show (Earls Court, 10-13 September), so watch this space.

Wireless Solutions - W-DMX

The final contender was from Swedish company Wireless Solutions, who sent through their W-DMX system. This system, like the City Theatrical units, was really plug-and-play, and in that respect there is nothing much to report on! The manual was required to decipher the status LED colour codes, but it turned out the green lights meant that all was well. With a combination of flashing red and

Figure 7: Wireless Solutions W-DMX.

Figure 8: Avolites eDMX tubes.

Figure 9: City Theatrical WDS.

Figure 10: Luminex Ethernet-DMX8.

Figure 11: Artistic Licence NetLynx and WAP.

Figure 12: Goddard Designs DMX-Link.

green indications the unit can indicate whether the signal is lost, or the signal is good but there is no DMX, or whether the receivers are logging on to the transmitter.

In terms of performance, the W-DMX system outshone the rest. Despite trying, we could not get it to fall over using the interference tests, and it performed the best in the range tests. If used with optional higher gain antennas, these little boxes should be able to send a signal quite some distance. The units supplied were not capable of being operated on a battery supply (although the mains inputs are universal) but there are outdoor and Pro versions that can be - the outdoor version being an IP-rated Pro unit. The two also have a built-in UPS to allow for 8 hours of operation should the mains fail - for more information on these (and other wireless DMX products) visit the company's website.

And finally . . .

Well, there ought to be a disclaimer, so here's two. The Technical Editor's decision is final, and no discussions will be entered into! Seriously though, there is one, and that is more advice than a disclaimer - the interference and range tests published are a true account of what was achieved over the two days, but are specific to the conditions in which the products were evaluated. The figures given in the range test should only be used as a guide - one may find that these figures could be higher or lower than can be achieved in other locations.

Also for those who may be interested, the Wi-Spy software and USB dongle used in the tests is a really useful little gadget and well worth getting if you work with equipment in the 2.4GHz band. It's available from various suppliers at a cost of around £100 including VAT - see www.wi-spy.co.uk for details of the product and a list of stockists.

Finally, thanks to Chris Crockford (dAFTdATA), Ric Salzedo (Avolites), Larry Dunn (City Theatrical) and Fabrice Gosnet (Luminex) for taking the time to witness the tests and offer their support, and generally for helping to make it a fun couple of days. Also thanks again to Ric for the loan of the Pearl lighting desk used as the main DMX source for all the tests, the Wi-Spy screen grabs, and to Bob Goddard for the loan of the Lil' DMXter (via Chris Cook of XTBA) which was used for all the data integrity monitoring. Oh, and to this organ's esteemed editor Lee, for buying lunch.

For more information, visit the following websites:

>>> www.artisticlicence.com
>>> www.avolites.org.uk
>>> www.citytheatrical.com
>>> www.daftdata.com
>>> www.goddarddesign.com
>>> www.luminex.be
>>> www.wirelessdmx.com

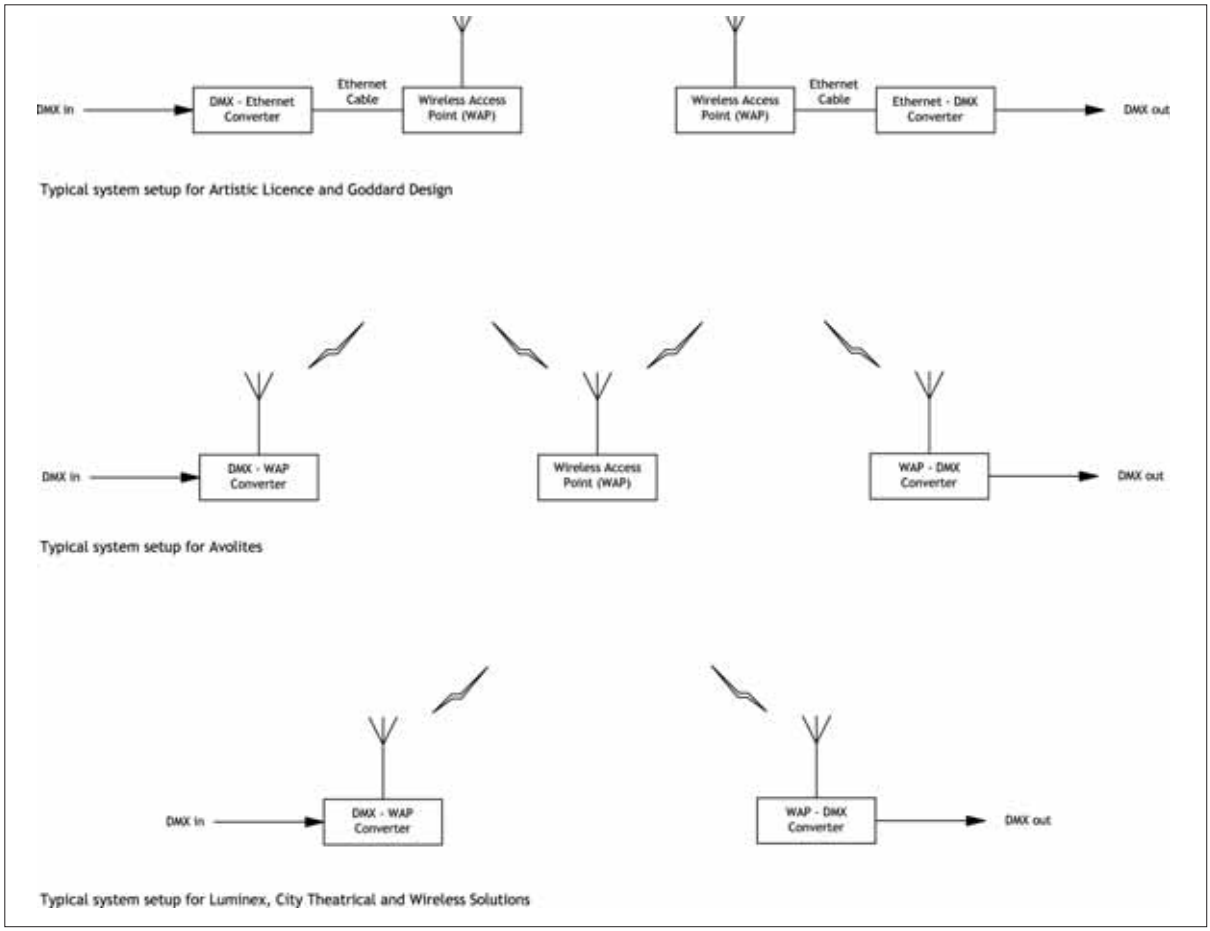

Figure 13: Schematic showing typical set-ups of the systems tested.