Shielded or foiled again!

BY **JAVID BUTLER**

Cable infrastructure, Part 1

MANY DIFFERENT TYPES OF CABLE have been used for DMX512, with different levels of success. It has been said that DMX512 will run over barbed wire if you do not need it to go very far, and that is true. Barbed wire aside, the way the cable is constructed and how it is installed can determine whether a system works flawlessly or whether it has problems. In this installment of this article we will look at how cable construction affects DMX512 signals. With the next installment, we will look at how installation of that cable can affect the signal quality in a system.

Cable construction

Construction of a cable determines its performance, and that performance depends on the application. We all know that microphone cable does not work well for DMX512, although some have used it. The problem is that microphone cable will work some times in some applications, but not all the time in all applications. Where it works and where it does not is based on the construction of the cable.

DMX512 uses EIA-485 for the physical layer. EIA-485 is a differential voltage signal or balanced signal. A differential signal transmitted over a twisted pair cable can have significant noise immunity, even over long distances, which is what makes it so well suited to DMX512. The reason for this is that one wire of the pair carries the signal while the other wire carries the inversion or complement of the signal. We call it Data (+) and Data (-). At the receiver the signal is measured as the difference of the two wires, not the absolute value. Over a pair of parallel wires stretched out flat that would have some noise immunity, but the real noise immunity come when the pair is twisted together. When this is done the individual wires see any external noise at the same level—both halves of the signal are affected the same way. Since the receiver only measures the difference between the signals, any noise common to both wires is ignored. The extent to which noise is ignored is called the Common Mode Rejection Ratio, or CMRR, and it describes the ratio of desired signal to and Common Mode signal. A high CMRR means a clean signal at the receiver.

One way to improve the CMRR of a system is to increase the number of twists in the cable, which would give it a shorter lay length. The shorter the lay length is, the higher the noise immunity of the cable. The closer the wires in the pairs are together, the more they respond in common to any external noise. Bonded pairs, where the wires are physically bonded together, can retain a high noise immunity even under conditions that would decrease the noise immunity of unbonded pairs. Unbonded pairs, which are typical of most of the cables used for DMX512, can be stretched through use of excessive pulling force which makes the lay length of the cable longer and the noise immunity lower. Microphone cables often have a very long lay length compared to high speed data cables, which is one thing that limits their usefulness for long runs of DMX512. Category 5 (or 5e, 6, and 6a) cable has a much shorter lay length than most EIA-485 cables, giving the Category cable a higher noise immunity. Take a look at the twist of a Category cable compared to a DMX512 cable. You might also notice that the twist of the different pairs in the Category cable is different, which limits the crosstalk between the pairs in the Category cable. Also look at the drain wire of the DMX512 cable, and notice how it can (in some cases) distort the symmetry of the twist of the pairs. This reduces the noise immunity of the cable because asymmetry allows noise to affect the wires differently rather than commonly.

Another way the construction of a cable affects its performance is through the capacitance and impedance of the cable. For maximum energy transfer from the cable to the receiver, the impedance should be matched. For DMX512 this means a 120 ohm cable per EIA-485. Take a look at **Table 1** and see how the different cables match up. Microphone cable is clearly not suitable for DMX512, but Category cable is pretty close. In fact, Category cable is specified at the data rate it is designed to be used with, and at DMX512 speeds its impedance is about 115 Ohms—almost a perfect match.

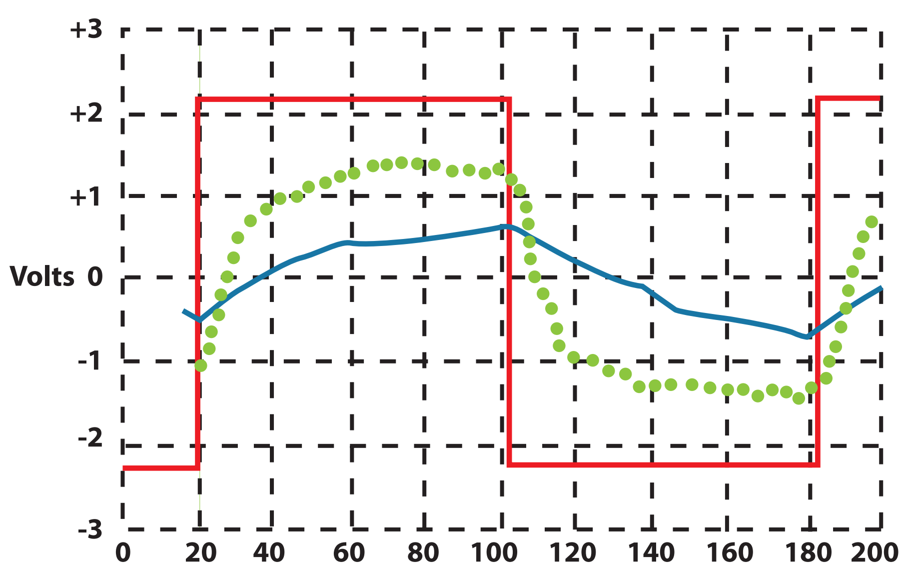
To see how capacitance affects a signal look at **Table 2**. It shows a square wave, along with a low capacitance digital cable and an analog cable with higher capacitance. At 300 feet the low capacitance digital cable (dashed line) still has a recognizable digital signal while the analog cable is severely distorted.

This describes the construction of the cable conductors, but there is another important part to the cable—the shield.

Table 1 | Courtesy Steve Lampen/Belden, used with permission

Cable Type	Format	Impedance	Capacitance	Bandwidth
EIA-485	Shielded Twisted Pair	120Ω	12.8pF/Ft	10 MHz
Analog Mic	Braid Shield Twisted Pair	30-70Ω	30-50pF/Ft	20 MHz
Analog Line	Foil-Shield Twisted Pair	30-70Ω	30-50pF/Ft	20 MHz
Analog Snake	Foil/Braid Shield Twisted Pair	30-70Ω	30-50pF/Ft	20 MHz
Digital Patch	Braid Shield Twisted Pair	110Ω	13pF/Ft	25 MHz
Digital Install	Foil-Shield Twisted Pair	110Ω	13pF/Ft	25 MHz
Digital Snake	Foil-Shield Twisted Pair	110Ω	13pF/Ft	25 MHz
Category 5/5e	Unshielded Twisted Pair	110Ω	15pF/Ft	100 MHz
Category 6	Unshielded Twisted Pair	110Ω	15pF/Ft	250 MHz
Category 6a	Unshielded Twisted Pair	110Ω	15pF/Ft	500 MHz

Table 2 | Courtesy Steve Lampen/Belden, used with permission



Shielding

Shielding and grounding in the world of DMX512 are intertwined, but for the moment we need to look at them separately. In this installment we will look at shielding as part of the cable, and in Part 2 in the next issue, we will review grounding as part of the system. There is no way to entirely separate them, but in this issue we can ask how much shielding is enough, and is that shielding actually doing what you think it is?

Allow me to digress for a moment. Sensitive instruments often use what is called a driven shield (also called a driven guard). A circuit is added that, rather than draining the shield to earth ground or circuit common, drives the shield at a voltage. Sometimes the voltage is one that is approximately one half the peak-to-peak voltage of the signal being measured, other times the voltage is an in-phase copy of the signal being measured. What this does is reduce the effect of the conductor-to-shield capacitance. Since the shield voltage is close to the conductor voltage the cable capacitance creates less distortion than if the shield were referenced to a voltage outside the envelope of the signal. As mentioned before, capacitance is one of the major limiting factors in the maximum run of a DMX512 cable. Reducing the effect of that capacitance would make for more reliable signal transmission and allow longer runs. So why don't we do it? It is not worth the cost. A driven shield used for the probe leads of a high end measurement instrument makes sense, but not in a DMX512 network.

The extent to which noise is ignored is called the Common Mode Rejection Ratio . . .

What we are doing now works pretty well, and it is just not worth changing the DMX512-A standard to allow for a driven shield that would be extremely difficult and expensive to implement—not to mention having to change the wiring of most DMX512 installations around the world to make it work.

Why bring up driven shields if I am not going to suggest using them? Because it shows that anything we are currently doing with shielding can be improved upon. There is always a better way to shield, or a way to add more shielding, but it will not always be cost- or performance-effective. A driven shield reduces the effect of capacitance, but does not add enough benefit to justify the cost. A foil shield is effective in shielding out RF frequencies, but at DMX512 speeds is essentially transparent. Foil is less expensive than braid, but does not even begin to become effective until over 5 MHz. Braid shields are effective at lower frequencies. Earth grounded conduit that is properly installed has some shielding effect at lower frequencies. However, no shield will keep the harmonics generated by dimming from disrupting a signal. In one case in my own experience even seemingly impervious coax fell victim to the infamous "dimmer at 50%" noise. A piece of coax on a road show had to be run near the front-of-house loads for a road show. In one particular cue many of the lights were at 50%, which generated enough EMI to interrupt the Ethernet communication on the coax. It only happened during that cue, and could be readily duplicated. The fix was not shielding, but distance—at other stops on the tour it had been possible to run the coax further away from the front-of-house loads.

At the same time, anyone who has played an electric musical instrument has learned about ground loops—sometimes painfully. Ground loops are caused when two different potentials exist in the grounding of a system, causing current to flow through the grounded shields connecting them. Preventing ground loops is a major reason for the preferred topology of DMX512-A with its central-point grounding at the transmitter with floating receivers. Ground loops are the reason that sound techs carry ground lifting plugs.

In European countries there are laws limiting the amount of interference that can be emitted from a cable, and a shield is required. This is a good time to point out that the emissions do not just disappear, but that some of the signal is reflected back from the shield into the conductors. With DMX512 the resulting slight increase in crosstalk is minor even when both pairs are used, and Ethernet rules account for allowable crosstalk at high speeds so the use of shields to limit emissions does not generally cause a problem.

So the question to address with shielding is, What you are trying to shield against? If the primary concern is RF, whether from commercial sources such as radio and television transmitters or portable sources such as cell phones, then a foil shield that is properly grounded will do quite well. A braid shield will cost more but will work even better at lower frequencies. If the concern is emissions then a braid shield will work well, and earth grounded conduit will help even more. If the concern is ground loops, then it might work to eliminate the shield altogether and avoid any risk of the shield accidentally grounding. Answers to the question of what shield to use run from no shield at all to double shielding—a shielded cable and grounded metallic conduit. The needs of the system determine the shielding strategy. A system designer should be aware of all the concerns and be able to address them effectively for each system they design. The needs of a rural church project in the US will be quite different than the needs of a project in a professional theatre in Europe.

In Part 2 to appear in the Summer issue of *Protocol*, we will look at installation of DMX512 cables and the grounding strategies used with the shielding. Just using a shielded cable does not mean much if it is not grounded using a strategy appropriate to the frequencies that are to be screened out. So grab your fish tape and we will go pull some cable! ■

Javid Butler is a member of the ESTA Control Protocols Working Group and Chair of the E1.27 Cabling Task Group. He is in charge of product development for Integrated Theatre Inc., a custom products and product development company. Javid can be reached at javidbutler@cox.net.