Entertainment Services and Technology Association

DMX512 Over Category 5 Cable

Task Group Report

Part One
Un-Shielded Twisted Pair Category 5 (UTP) Cable vs. EIA-422 Rated Cable
Radiated and Induced Signal Immunity

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Introduction
In response to a perceived industry requirement for lower cost DMX512 cable installations, the DMX-over-Category 5 Cable Task Group was formed by ESTA’s Control Protocols Working Group (CPWG) at the January 1998 TSP meetings in Dallas. The Task Group’s mission was to employ an independent laboratory to carry out a series of comparison tests between a typical cable presently used for hardwired DMX512 installations, and conventional Category 5 data cable. The goal of this testing was to establish whether Category 5 cable, or “generic premises cable” as it has become known, could be used as a low cost substitute in permanently wired DMX512 installations.

Two series of lab tests were conducted in July and November of 1998 at MPB Technologies in Airdrie, Alberta. Additional tests were conducted in December of 1999

This section (Part 1 - CP/2000-1024.1) of the report describes the first series of tests which compared the DMX512 handling characteristics of a typical EIA-422 rated data cable with those of a standard Category 5 unshielded twisted pair (UTP) cable. Radiated emissions tests were also done. Results of these tests indicated that Category 5 UTP cable performed as well as conventional DMX512 cable.

Part 2 of this report (CP/2000-1024.2) describes the second series of tests which were carried out with Category 5 shielded twisted pair (STP) cable, and also included radiated and induced signal immunity tests to current IEC standards on all cable types.

Part 3 of this report (CP/2000-1024.3) describes the third series of tests which were conducted to determine the effect of combining different types of cable (i.e., Category 5 and EIA-485) on the same wire run. At this time, tests were also done with Rosco/ET IPS equipment to determine whether the use of Category 5 cable caused any timing problems with their talkback data.

Test Conditions & Equipment
MPB Technologies supplied a HP54510A 250MHz Digital Storage Oscilloscope and HP7475 pen plotter to generate the attached oscillograph plots. Radiated emissions and immunity tests were carried out in one of the largest of their five anechoic chambers, and data was acquired by a HP8566B Spectrum Analyzer with HP85685A pre-selector. To generate the required sweep frequencies, a HP8340A Synthesized Sweep Generator was used; this was driven by a HP43314A Function Generator. MPB used a custom software interface to format the output of the Spectrum Analyzer for laser printing. For induced immunity testing, a Velonex V-3300 fast transient burst generator, in conjunction with an MPB-constructed induction clamp conforming to IEC1000-4-4, was employed.

Gray Interfaces supplied the following equipment to facilitate the various tests:
- Goddard Design Li’l DMX’ter (used for DMX512 source and error checking)
- Gray DMX Repeater (isolated 1-in, 6-out buffer unit)
- Tektronix TDS 220 Oscilloscope
- Fluke DSP-100 LANMeter c/w smart remote
- Custom-wired transceiver unit with various EIA-485 transceiver types and switchable termination values
- Custom pulse generator

300 meters (1000 feet) of each of the following cable types was purchased for testing:
- EIA-422 (100 ohm) cable (2-pair with overall shield): Belden 9829
- Category 5 unshielded twisted pair (UTP) cable: Prestolite D0424 COU BL R-2
- Category 5 unshielded twisted pair (UTP) cable: Alpha 9504C
Investigation - Signal Characteristics
The purpose of this investigation was to compare the characteristics of EIA-422 rated Belden 9829 shielded twisted pair cable to that of standard Category 5 unshielded twisted pair cable (UTP).

We used the facilities of MPB Technologies in Airdrie, Alberta to obtain the results documented below. We were able to test both the Belden and Category 5 UTP for similarities in transmission characteristics and radiation.

As mentioned in Dave Higgins' February 16 memo to the “DMX-over-Category 5 Task Group” the electrical similarities between Category 5 cable and Belden 9829 or 9842 are quite apparent. In particular the similar 100 ohm characteristic cable impedance, the resistance per 1,000 feet (29 ohms for Category 5 vs. 24 ohms for the 9829), and capacitance, 14 pF per foot for Category 5 vs. 15.5 pF per foot for 9829 (note that the 9829 may exhibit a capacitance of up to 22 pF per foot when the effect of the shield is factored in).

Our tests have borne out the advertised similarities in the two types of cable, and the preliminary conclusion is that the Category 5 UTP cable is a functional equivalent to Belden 9829 shielded paired cable in permanent installations. As the measurements below will demonstrate, in some circumstances Category 5 UTP will slightly outperform the Belden shielded cable. This will be noticed most clearly in the oscillographs #4 and #9 where the waveform distortion is much less in the Category 5 cable due to the lower overall cable capacitance after 300 meters.

Slew Rate Limited Transmitters
One byproduct of this Category 5 UTP investigation is data obtained on the behavior of slew rate limited (SRL) EIA-485 transceivers. A number of factors have come to light that would indicate that these devices should be preferred over conventional EIA-485 transceivers with the usual fast rise time characteristic of their output wave form.

Due to the slower rise time, the effect of cable capacitance in deforming the waveshape is much less pronounced as are reduced reflections on unterminated cable.

These two benefits when coupled with the apparent reduced harmonic radiation from the cable would make them preferred line drivers in most DMX512 applications. Note that these devices are limited to 250 kbps.

The SRL devices used in these tests were a Sipex SP483ES. The non-SRL devices used were a T.I. SN75176BP.
Oscillograph Plot Description

#1 – The top and bottom trace display the standard 250 khz square wave signal used in the following tests. The top signal is the standard signal and the bottom trace is the same signal 90 degrees out of phase. This out of phase signal is used in some of the following tests where it is sent along an adjacent pair to induce crosstalk.
#2 – 1 meter of Belden 9829 terminated into 100 ohms, driven by the non-SRL transmitter, measured at the termination resistor with both halves of the wave form shown.
#3 – 1 meter of Belden 9829 terminated into 100 ohms, driven by the SRL transmitter, measured at the termination resistor with both halves of the waveform shown.
#4 – 300 meters of Belden 9829 terminated into 100 ohms, driven by the non-SRL transmitter, measured at the termination resistor with both halves of the waveform shown.

Note the severe rise time limiting due to the resistance and capacitance of the cable.
#5 – 300 meters of Belden 9829 terminated into 100 ohms, driven by the SRL transmitter, measured at the termination resistor with both halves of the waveform shown.

Note the rise time limiting due to the resistance and capacitance of the cable is much less severe than in the case with the non-SRL driver.
#6 – 300 meters of the Belden 9829 unterminated, driven by the SRL transmitter. Top waveform is the recovered waveform at the output of the non-SRL line receiver. Bottom is the signal on the cable measured at the (+) input to the receiver.

Note the rise time limiting due to the resistance and capacitance of the cable is much less severe than was the case with the non-SRL driver.
#7 – 300 meters of Belden 9829 unterminated, driven by the non-SRL transmitter. Top waveform is the recovered signal at the output of the non-SRL receiver. At bottom is the signal on the cable measured at the (+) input of the receiver.

Note the rise time limiting due to the resistance and capacitance of the cable as compared with slew rate limited driver.
#8 – 300 meters of Belden 9829 terminated with 100 ohms, driven by the SRL transmitter. Top waveform is the recovered signal at the output of the non-SRL receiver. At bottom is the signal on the cable measured at the (+) input to the receiver.

Note the rise time limiting due to the resistance and capacitance of the cable is much less severe than is the case with the non-SRL limited driver. ** The small "glitches" on the bottom waveform were likely caused by insufficient decoupling on the receiver chip.
#9 – 300 meters of Category 5 UTP, driven by the non-SRL transmitter with 100 ohm termination. Top waveform is the recovered signal. The bottom trace is the signal on the cable at the (+) input to the non-SRL receiver.

Note that the rise time is much shorter than with the Belden 9829 cable leading to much less distortion, also that the overall amplitude is slightly greater than with the 9829.
#10 – 300 meters of Category 5 UTP, driven by the SRL transmitter with no termination. Top waveform is the recovered signal. The bottom trace is the signal on the cable at the (+) input to the non-SRL receiver.

Note that even without a terminator the distortion of the waveform is minimized and no corruption of the recovered signal is evident.
#11 – 300 meters of Category 5 UTP, driven by the non-SRL transmitter with no termination. Top waveform is the recovered signal. The bottom trace is the signal on the cable at the (+) input to the the non-SRL receiver.

Note the gross distortion of the waveform in particular the large peak at the trailing edge of the positive excursion and the long decay of the trailing slope. Also notice that in spite of this distortion no corruption of the received signal is observed.
#12 – 100 meters of the Category 5 UTP driven by the non-SRL transmitter with 100 ohm termination. Top waveform is the recovered signal. The bottom trace is the signal on the cable at the (+) input to the non-SRL receiver.

Note the short rise time and minimal distortion.
#13 – 100 meters of Category 5 UTP driven by the SRL transmitter with 100 ohm termination. Top waveform is the recovered signal. The bottom trace is the signal on the cable at the (+) input to the non-SRL receiver chip.

Note that the distortion is minimal as compared to the 1 meter 9829 example (plots 2 & 3).
#14 – 300 meters of Category 5 UTP, driven by the non-SRL transmitter with 100 ohm termination. The signals are measured at a receiving unit placed 150 meters along the cable (the mid-point between the transmitter and the terminated end), with the signal “looped through” the unit and sampled using the non-SRL receiver. The top waveform is the recovered signal and the bottom waveform is the cable signal.

Note that the waveshape remains consistent with the signal noted in the 300 meter terminated example and the rise time is similar. However, notice that the overall signal level is slightly less than in the single receiver, terminated line example.
#15 – 300 meters of Category 5 UTP, driven by the SRL transmitter with 100 ohm termination. The signals are measured at a receiving unit placed 150 meters along the cable (the mid-point between the transmitter and the terminated end), with the signal “looped through” the unit and sampled using the non-SRL receiver. The top waveform is the recovered signal and the bottom waveform is the cable signal.

Notice the similarity in all points with the 100 meter single receiver, terminated version of this test (plots 12 & 13).
#16 – 300 meters of Category 5 UTP driven by the non-SRL transmitter with no termination. The signals are measured at a receiving unit placed 150 meters along the cable (the mid-point between the transmitter and the unterminated end), with the signal “looped through” the unit and sampled using the non-SRL receiver. The top waveform is the recovered signal and the bottom waveform is the cable signal.

This is truly a “worst case” test. Note the reflections on the cable from the unterminated end. Also note the corrupted recovered signal.
#17 – 300 meters of Category 5 UTP, driven by the SRL transmitter with no termination. The signals are measured at a receiving unit placed 150 meters along the cable (the mid-point between the transmitter and the unterminated end), with the signal “looped through” the unit and sampled using the non-SRL receiver. The top waveform is the recovered signal and the bottom waveform is the cable signal.

Contrast this with the previous test. While there is some deformation of the signal due to reflections from the unterminated end, it is much less pronounced than with the fast rise time characteristic of the non-SRL 75176. This translated into a recoverable signal in the output of the non-SRL receiver.
#18 – 300 meters of Category 5 UTP driven by the non-SRL transmitter with 100 ohm termination. The signals are measured at a receiving unit placed 150 meters along the cable (the mid-point between the transmitter and the terminated end), with the signal “looped through” the unit and sampled using the SRL receiver. The top waveform is the recovered signal and the bottom waveform is the cable signal.

This test was included to show the response of the SRL receiver as opposed to the standard non-SRL 75176 receiver. The recovered signal is approximately 90 degrees out of phase with the signal on the cable.
Investigation - Radiated Signal Tests
The radiated signal tests are intended only to show a comparison between the Belden 9829 and Category 5 UTP cable. The radiated signal tests were conducted in the following manner:

300 meters of the cable under test (either Category 5 UTP or Belden 9829) was placed in the shielded anechoic chamber. In both cases the cable was placed on a table in a loose pile approximately 1 meter square. The test signal was DMX512 generated from a Goddard Design “li’l dmx’ter”, then buffered through a Gray Interfaces opto-splitter.

The signal consisted of 512 channels, all at a value of A5 hex. The tests were conducted with the cable terminated and unterminated and with both standard and slew rate limited transmitters.

The one area where the 9829 cable had a clearly superior performance to Category 5 UTP cable was in the area of radiated signal. This was to be expected in that the Belden cable has an overall foil and braid shield which would clearly serve to minimize radiation. The cable radiation tests were conducted in MPB Technologies’ anechoic chamber and were intended only to show the relative radiation characteristics of the two types of cable.

With the above limitations in mind the results seem to demonstrate that the lowest overall level of radiation is achieved with Belden shielded cable, terminated with 100 ohms and driven with a slew rate limited (SRL) transmitter. In fact, in all cases the SRL driven line showed a measurable decrease in radiated noise when compared with a non-SRL transmitter.

MPB Technologies recommends that for an absolute (as opposed to relative) evaluation of the radiated noise it would be necessary to conduct outdoor free field measurements to obtain absolute radiated noise figures which could then be compared to Canadian Industry Ministry, American FCC and European CE specified limits.

It could be concluded from our measurements that the Category 5 UTP cable, when driven by a SRL transmitter and properly terminated compares favorably with a shielded Belden cable driven by a non-SRL transmitter and properly terminated. The only areas where the Category 5 cable demonstrates a disadvantage in this scenario is in the area of 30 MHz, and presumably below, where the radiated signal appears to be as much as 15 dBµV greater than the 9829.

Until we are able to perform free field radiation measurements to ascertain conformity with the various national standards regarding acceptable levels of radiation it would be best to limit the use of Category 5 UTP for DMX distribution to “in conduit” only installations and avoid the use of Category 5 for free air interconnections.
Radiated Signal Plot Description

Only representative (the best and worst) plots are included here for both Belden #9829 and Category 5 UTP cables.

**Figure E1** - Belden #9829, non-Slew Rate Limited Line Driver, Terminated
Figure E2 - Belden #9829, Slew Rate Limited Line Driver, unterminated
Figure E3 - Category 5 UTP, non-Slew Rate Limited Line Driver, Terminated
Figure E4 - Category 5 UTP, Slew Rate Limited Line Driver, unterminated
Investigation - Induced Immunity Tests

Pulses were induced on the cables both inductively and capacitively. No plots were made. The performance of DMX equipment was observed, and no adverse results were noted.

– End Part One –