EMC Performance
For 10GBASE-T over Category 6A Cabling

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1. Introduction

The next generation of Ethernet will provide a capacity of 10 Gigabits per second over 4 twisted pairs of copper for a distance of 100 meters. This represents a thousand-fold increase in capacity compared to the first generation of Ethernet which was introduced in the early nineties. The ability to do this comes from advances in both copper cabling and digital signal processing technology. 10 Gigabit Ethernet will employ sophisticated noise cancellation and coding algorithms to reduce the probability of errors to less than 1 error in 1,000,000,000,000 bits of information.

The transmission at high frequencies up to 500 MHz for 10 Gigabit Ethernet, compared to 100MHz for 1 Gigabit Ethernet, presents some new challenges in the design of the structured cabling systems. The two major challenges are:

a) The existence of noise signal generated by one channel to its neighbors, such noise is called alien crosstalk.

b) The control of the channel performance up to very high frequencies.

Augmented Category 6 (Cat 6A) components are required in order to overcome these challenges for channels up to 100-meters. Different manufacturers have employed different techniques to optimize their products to achieve Cat 6A performance. Belden CDT developed a 10GX product line based on (4) revolutionary enabling technologies. These technologies are described in a white paper at http://www.nordx.com/public/htmen/pdf/10GX_WP.pdf

The deployment of these (4) technologies involved a complete redesign of the module and the cable, using some quite innovative concepts to extend the high frequency performance and to cancel out the alien noise.

Also, Belden CDT took advantage of a patented* technology to achieve its objective, in redesigning the 10GX patch cords. The essential elements of the design include a dual jacketed construction with a screen interposed between the two jackets. This design is very compact and flexible and effectively eliminates the alien crosstalk between cords in a bundle. The stable position of the screen and the bonded twisted pair core construction ensure a very well electrically-balanced design. This "electrically-balanced design" is the key to ensuring exceptional EMC performance.

2. Cabling Balance and EMI

Belden CDT Modular Cords are constructed using bonded 23 AWG twisted pairs. The bonded construction ensures that the two conductors of a twisted pair are in continuous contact, concentric and equidistantly spaced along the length of the pair. Also, the two conductors are exactly the same length and are unaffected by manipulating the cable. This ensures a precise balance between the position of the conductors and the internal screen, which is sandwiched between the two jackets and held firmly in place.

The balance of Category 6 components is specified in TIA standard 568-B.2-9 "Additional Category 6 Balance Requirements and Measurement Procedures". Balance is also called the Transverse Conversion Loss (TCL). If a balanced (transverse) signal is applied to a pair of conductors, a portion of the signal is converted into a longitudinal signal, also called a common mode signal. The common mode signal is proportional to the balance of any pair with respect to the other pairs and to the surrounding screen if any. It is the resultant common mode signal on the cable pairs including the screen that gives rise to an electromagnetic field which radiates from the cabling.

We measured the pair balance of a 10GX mated connection and a 10GX patch cord link including a 10GX connector. The balance measurements are illustrated in Figure 1 and Figure 2 respectively.

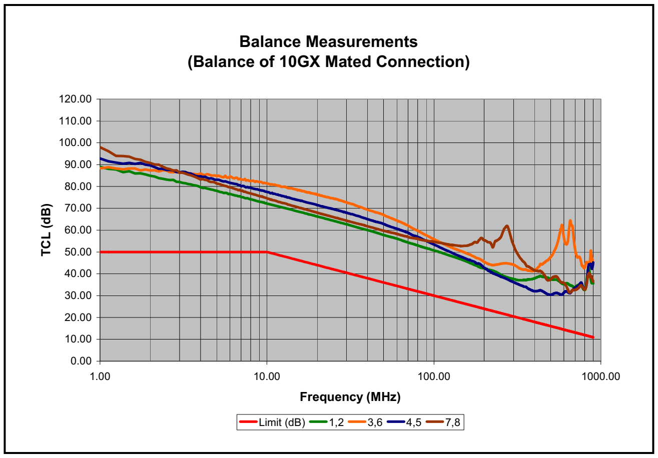

Figure 1 – TCL of 10GX mated connection

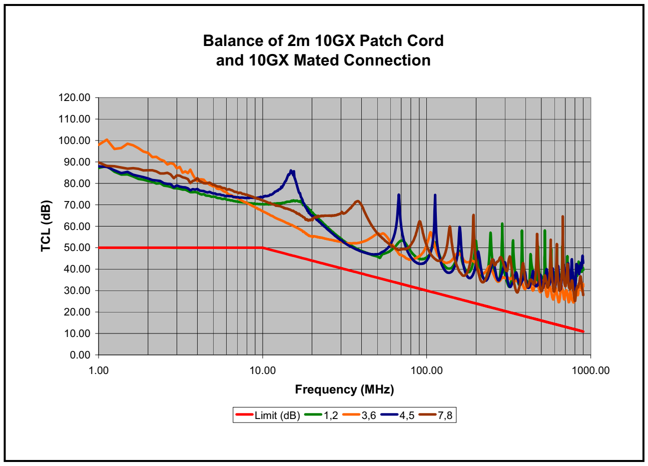

Figure 2 – TCL of 10GX Patch Cord and 10GX mated connection

The balance measurements indicate ~10 dB headroom compared to the proposed TCL limits for an augmented Category 6 (Class E_A), Type E2 Channel in ISO 11801 Amend. 1.1 © ISO/IEC:2005(d2.0).

3. FCC and CISPR Requirements

The FCC Rules and Regulations, Title 47, Part 15, Subpart B regulates any unintentional radiator (device or system) that generates and uses timing pulses at a rate in excess of 9000 pulses (cycles) per second and uses digital techniques. Most products regulated by Part 15, Subpart B fall into one of two categories. Class A devices are those that are marketed for use in a commercial, industrial or business environment. Class B devices are those that are marketed for use in the home. Currently there are no FCC regulations pertaining to product immunity to electromagnetic fields.

Countries in the European Economic Community (EEC) and many other countries have adopted radiated emissions standards based on CISPR 22. The CISPR 22 standard categorizes products as Class A or Class B and specifies a test procedure and emission limits that are similar to the FCC Part 15, Subpart B requirements. The FCC and CISPR Class A requirements are shown in Figure 3.

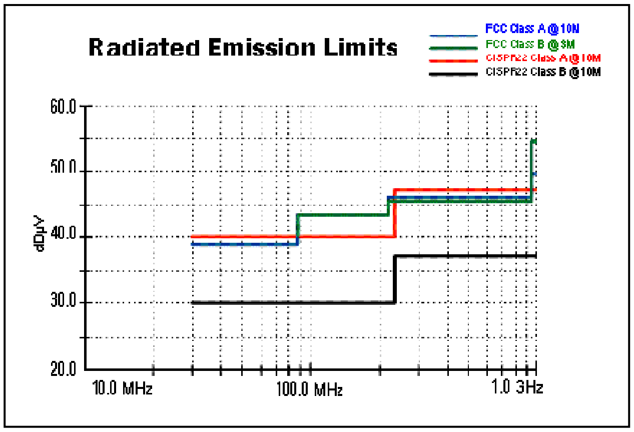

Figure 3 – Comparative FCC and CISPR22 Requirements

Note: For measurements performed in an anechoic chamber at a distance 3 meters the requirements shown in Figure 3 are adjusted upwards using a scale factor of 20log(10/3) or 10.5 dB.

4. EMI Test Setup

The EMC performance of the Belden IBDN 10GX cabling system was tested in an anechoic chamber at the "Centre de Recherhe Industrielle Quebec" (CRIQ) in Montreal. The tests at CRIQ are conducted in an environment certified by the Standards Council of Canada or recognized by the appropriate American, Canadian and European authorities (FCC, FDA, CCMC, UTAC, LNE, TNO, etc.).

The test configuration is illustrated in Figure 4 and Figure 5. A first series of tests was performed using a Gaussian white noise generator that has a uniform power spectrum extending up to 500 MHz. The noise signal is applied on all 4 pairs through a power splitter and a prototype Media Independent Interface (MDI), see Figure 4. This gives a worst case result since the signal is the same on all 4 pairs and the peak noise is correlated.

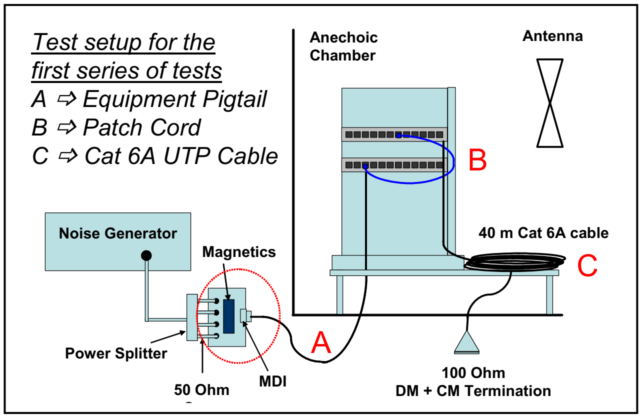

Figure 4 – EMI test setup using MDI

A second series of tests was performed using a 4-balun interface instead of the MDI interface to apply the signal over the channel, as shown in Figure 5.

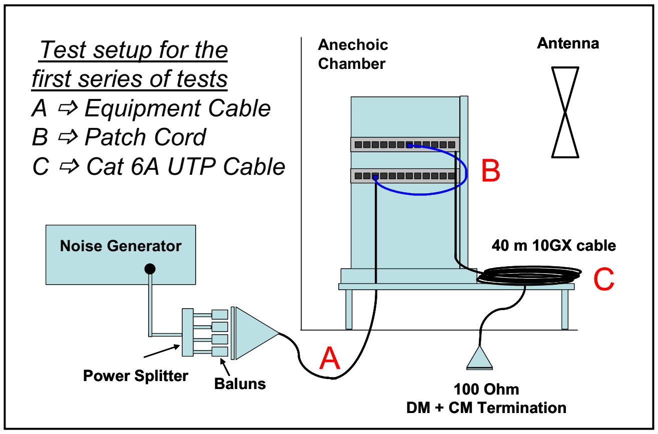

Figure 5 – EMI test setup using baluns

The channel configuration is comprised of 4 m equipment cable, a cross-connection and 40 meters of horizontal 10GX cable that is coiled inside the chamber. The configuration is kept constant for both series of tests. The effect on radiated emissions is observed as a function of the launch condition, the type of equipment cable and the patch cord.

A photo of the test facility at CRIQ is shown in Figure 6.

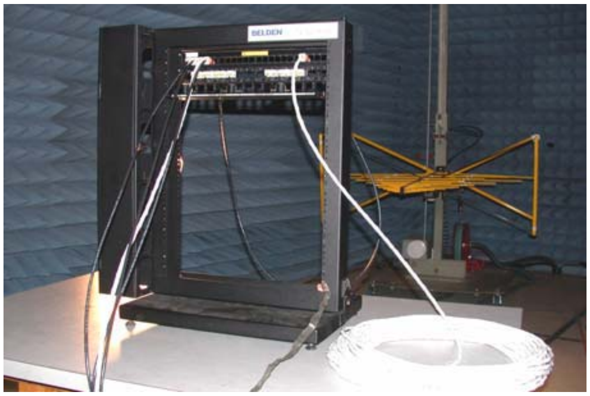

Figure 6 – Test setup in anechoic chamber at CRIQ

5. EMI Test Results

Two series of tests were performed. In the first series of tests using the MDI launch condition, the equipment pigtail was a 10GX patch cable with a floating screen for Case i) and Case iii) and a grounded screen for Case ii). In the second series of tests using the Balun launch condition, the equipment cable was a 10GX patch cable with a floating screen for Case iv) and a 10GX (Cat 6A) horizontal cable without a screen for Case v) and Case vi).

Two types of patch cords were evaluated for the different test cases listed in Table 1. These cords were a 10GX modular cord with a floating screen, labeled as Cat 6A FS, and a Cat 6A modular cord from another vendor.

Series #1	***Launch Condition***	***Equipment Cable***	***Patch Cord***
i	***MDI***	***4m Cat 6A FS***	***2m Cat 6A FS***
ii	*MDI*	*4m Cat 6A GS*	*2m Cat 6A FS*
iii	*MDI*	*4m Cat 6A FS*	*2m Cat 6A*
Series #2			
iv	***Balun***	***4m Cat 6A FS***	***2m Cat 6A FS***
v	*Balun*	*4m Cat 6A*	*2m Cat 6A FS*
vi	*Balun*	*4m Cat 6A*	*2m Cat 6A*
---	*Noise floor measurement*		

Table 1 – Test Configurations

The radiated emissions measurements for the different test cases are presented in graphical format in Figures 7 to Figure 12 inclusive compared to the FCC and CISPR limits. The light green trace is the noise floor measurement with no signal on the cabling.

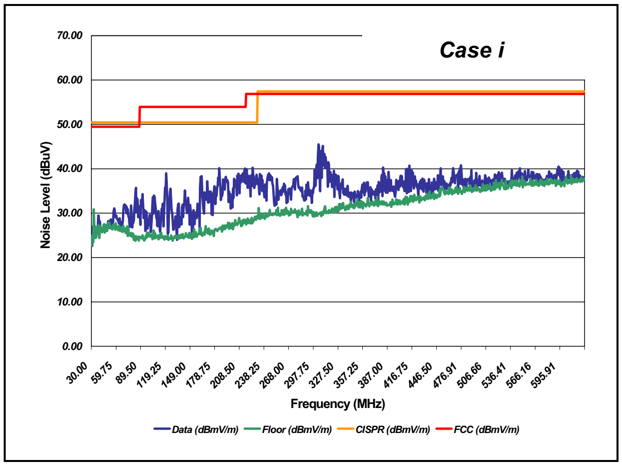

Figure 7 – Radiated emissions MDI, C6A FS EQ, C6A FS PC

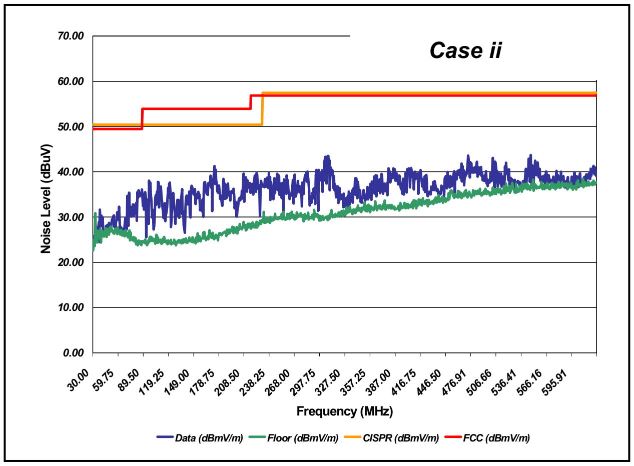

Figure 8 – Radiated emissions MDI, C6A GS EQ, C6A FS PC

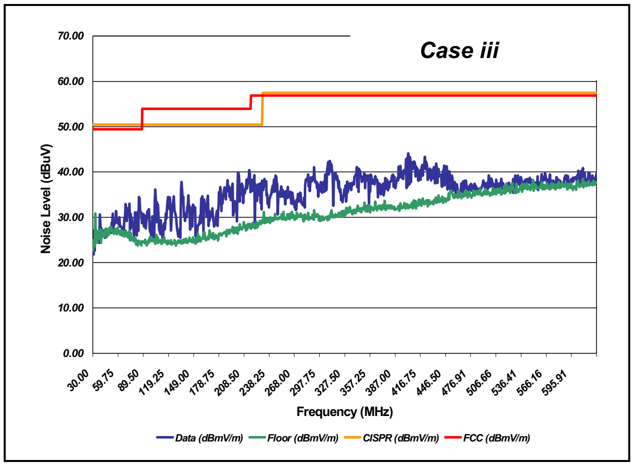

Figure 9 – Radiated emissions MDI, C6A FS EQ, C6A PC

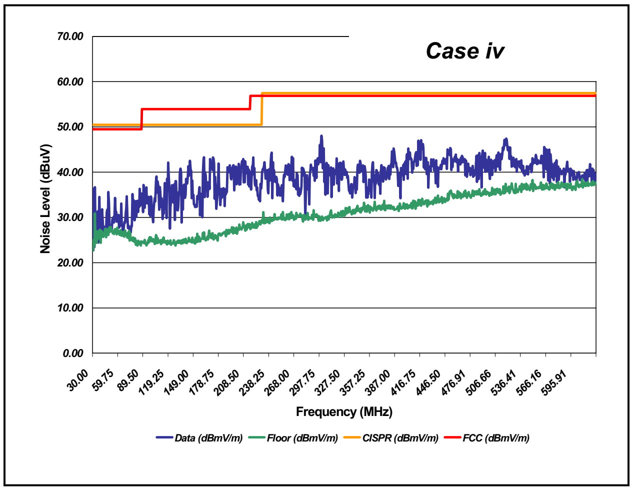

Figure 10 – Radiated emissions Balun, C6A FS EQ, C6A FS PC

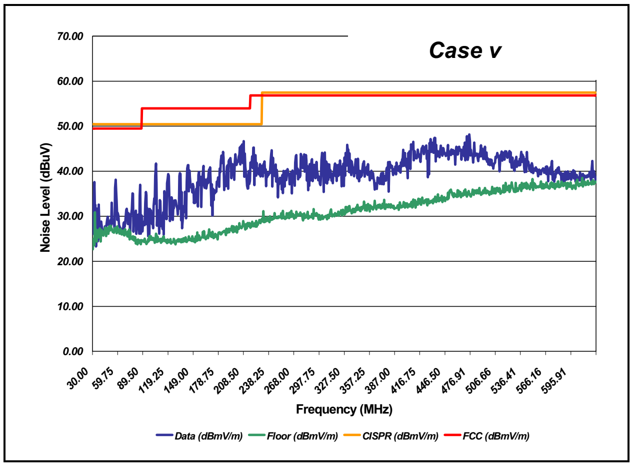

Figure 11 – Radiated emissions Balun, C6A EQ, C6A FS PC

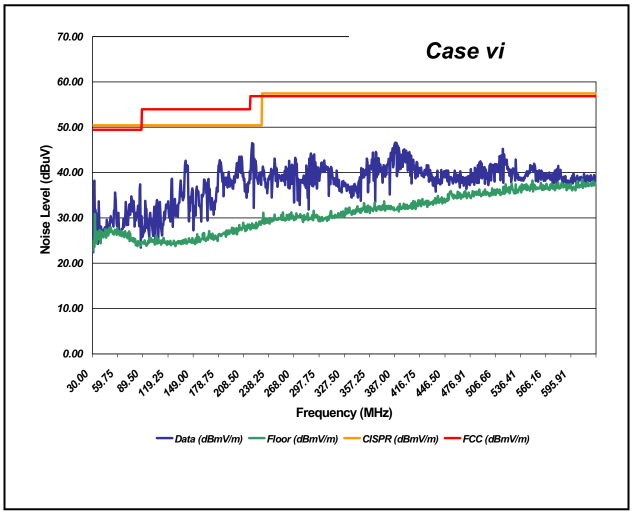

Figure 12 – Radiated emissions Balun, C6A EQ, C6A PC

6. Discussion of EMI Results

6.1 Results Comparison

It is instructive to compare the EMI results for the different cases tested. Case i) and Case ii) look at the effect of grounding the screen at the equipment connector. The difference in results on a point-by-point basis is shown in Figure 13. Grounding the screen of the equipment pigtail tends to increase the radiated emissions by approximately 1 dB worse on average. In comparing results for the different test cases, the difference between peak measurements can vary by as much as 15 dB at individual frequencies. The reason for this needs further investigation. The randomness of the cabling balance contribution and the orientation of the test sample is likely a factor. The most significant result to observe is the worst case peak measurement relative to the FCC and CISPR limits. These results are presented in Table 2.

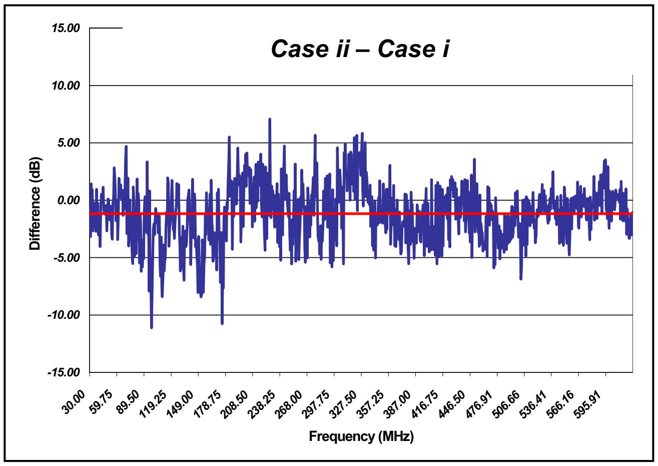

Figure 13 – The effect of grounding the screen at equipment

Another interesting comparison is the difference in radiated emissions when launching the signal through the MDI connector or by connecting the pairs directly to the baluns, as is typical for network analyzer measurements in the laboratory. The difference in results is shown in Figure 14.

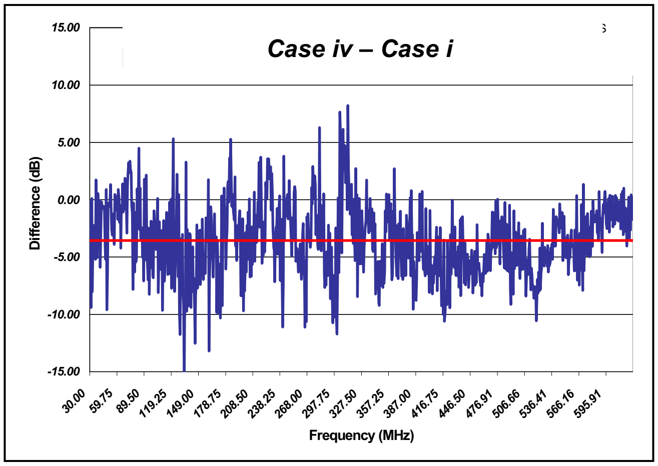

Figure 14 – The effect of Balun vs. MDI launch conditions

From the results of Figure 14, it is noted that the radiated emissions for the same channel configuration Case i) and Case iv) are about 4 dB worse on average using the balun setup. In comparing the results for all the cases tested, it is observed that the launch condition has the greatest impact on the EMI performance. This is likely because the prototype MDI provides a better termination and a better balanced signal output compared to the balun setup.

6.2 Results Summary

It is important to understand the way that the EMI measurements are performed. The device under test is located on a table top that is sitting on a rotating turntable. The receiving antenna is positioned 3 meters away from the test device, in this case a rack which contains the connectivity components and the cable interconnections. When a test is in process, the antenna moves up and down in a horizontal and vertical alignment for different rotations of the turntable. A total of 16 tests are performed for different orientations over the specified frequency range. The worst case result is recorded at each frequency point. As a final test a noise floor measurement is performed with no signal applied to the cabling.

The bottom line EMI performance is the worst case measurement peak compared to the FCC or CISPR22 Class A limits. The worst case margins are summarized in Table 2. There is a significant difference between the FCC Margin and the CISPR Margin in some cases. This is due to the fact that the FCC limits are less restrictive than CISPR22 limits in the frequency range from 88 MHz to 216 MHz. Any measurement peaks in this frequency range have a large effect on the available margin vs. CISPR requirements.

This leads to an interesting observation that the measurement peaks for a test configuration using Cat 6A UTP equipment cable and patch cords without a screen (case vi) can be worse than the reference condition (case iv) using equipment cable and cords with a floating screen. This is because of a measurement peak in the critical region between 200 MHz and 230 MHz (see figure 12) where the CISPR emission requirements are the most restrictive.

		Launch Condition	Equipment Cable	Patch Cord	FCC Margin	CISPR Margin
#1	**i**	**MDI**	**4m Cat 6A FS**	**2m Cat 6A FS**	**11.4 dB**	**10.2 dB**
	ii	MDI	4m Cat 6A GS	2m Cat 6A FS	12.7 dB	9.2 dB
	iii	MDI	4m Cat 6A FS	2m Cat 6A	12.7 dB	10.0 dB
#2	**iv**	**Balun**	**4m Cat 6A FS**	**2m Cat 6A FS**	**8.8 dB**	**7.2 dB**
	v	Balun	4m Cat 6A	2m Cat 6A FS	7.2 dB	3.7 dB
	vi	Balun	4m Cat 6A	2m Cat 6A	10.3 dB	3.9 dB
	---	Noise floor measurement				

Table 2 – Worst case margin vs. FCC and CISPR22 Class A

7. Conclusions

This study, was performed under controlled conditions at the CRIQ (Centre de Recherche Industrielle Quebec / Quebec Industrial Research Center). This center is recognized by the Standards Council of Canada as well as most of American and European authorities.

The objective of the study was to compare the relative EMI performance of various channel configurations using a Gaussian white noise source with a uniform power spectral density extending to 500 MHz. Three general cross-connect configurations were studied:

a) Cat 6A modular equipment cable with a floating screen and patch cord with a floating screen, based on the 10GX modular cord design (reference configuration)

b) Cat 6A modular equipment cable with a grounded screen and patch cord with a floating screen

c) Cat 6A equipment cable without a screen and modular patch cord with and without a floating screen

Under the conditions described in this paper, all these configurations studied passed FCC and CISPR22 Class A requirements.

Measurements have shown that the reference configuration using 10GX equipment cable and patch cord - based on an “electrically-balanced” design with a floating screen - exhibited better EMI performance than unscreened Cat 6A equipment cable and unscreened patch cord in the critical region between 200 MHz and 230 MHz where the CISPR emission requirements are the most restrictive. Therefore, it is concluded that a structured cabling system using 10GX modular cords will exhibit an EMI performance at least as good as the ones using unscreened Cat 6A patch cords.

Measurements have shown that grounding the screen at equipment is slightly worse than floating the screen (about 1 dB on average).

We also observed that the launch condition has the largest effect on EMI performance. The media dependent interface (MDI) provides a minimum of 3 dB improvement in EMI performance compared to a laboratory test setup using a balun interface. This reinforces the importance of the equipment interface and is recognized in the MDI impedance balance specifications of the IEEE 802.3an draft standard.

8. About the author

Paul Kish is Director, IBDN Systems and Standards with Belden CDT. He has been active in the development of cabling standards with TIA and also with IEEE. Paul has authored many technical papers in various industry magazines and conferences. He has presented seminars at BICSI and other industry forums to promote cabling standards and the need for higher performance cabling.

9. Acknowledgements

The author would like to thank Francois Beauregard and Antoine Pelletier for their assistance in developing the test setup and in coordinating the measurements at CRIQ.

10. References

[1] Code of Federal Regulations, Title 47, Volume 1, Revised as of October 1, 2004, From the U.S. Government Printing Office via GPO Access, CITE: 47CFR15.109, Page 773-775

[2] Electromagnetic compatibility, The role and contribution of IEC standards