Abstract
In this paper, we will provide information on the application of broadband video over high performance Category 6 UTP cabling. We will describe the implementation of a broadband video distribution system over twisted pair cabling and some applications where it might be used. We will look at the advantages of running broadband video transmission over a parallel network (RF highway) compared to running video over the corporate LAN highway. We have recently completed a series of comprehensive tests to demonstrate the technical feasibility of running broadband video (CATV) over a high-end Category 6 cabling system up to a frequency of 550 MHz (78 channels of NTSC video). This paper will show the results of these tests in a real-time environment including signal level measurements, alien noise measurements, and the effect of simultaneous LAN and video transmission in the same cable.

Keywords
Category 6; Broadband video; UTP; CATV; IP video; RF transmission, NTSC; video distribution; twisted-pair; balun.

1. Introduction
The recent publication of the Category 6 standard by TIA marks an important milestone in the evolution of network cabling. Category 6 provides a significant improvement in transmission performance compared with Category 5/5e cabling with a specified frequency range of 250 MHz and a capability extending much higher in practice. What applications can take full advantage of the higher bandwidth and improved performance of Category 6 cabling? One of the most demanding applications on the market today is broadband video, commonly known as CATV or cable television. It carries a broad range of signals extending to 650 MHz and beyond. Coaxial cable (RG-59 or RG-6) is commonly used for these applications, primarily for home networks. Most people are not aware that high performance twisted pair cabling can also support broadband video.

To simulate a worst-case scenario, we tested 100-meter channels that were representative of typical Category 5e, Category 6 as well as a low loss Category 6 cable with improved crosstalk performance. We tested each of the three channels under two different configurations. The first configuration evaluated the picture quality using a modulated signal carrier at 547 MHz (Channel 78). The second configuration evaluated the picture quality using a modulated signal carrier at 55 MHz (Channel 2) while simultaneously applying a 100BASE-TX Ethernet signal on the same cabling.

An appreciable difference in picture quality was observed for the three different channels that were tested, due to the effect of signal interference or due to the signal losses in the cabling. It is not sufficient to demonstrate qualitative differences in picture quality. It is also necessary to verify that the UTP cabling complies with the stringent requirements of CATV distribution systems. To this end all the parameters required for satisfactory video performance were determined and independently verified by an independent laboratory. These tests include signal level measurements and tilt adjustment for the video and audio carrier levels across the frequency band up to 550 MHz, noise ingress measurements due to different noise sources and signal leakage measurements to establish compliance with regulatory emissions requirements.

2. Broadband video distribution
Figure 1 illustrates how broadband video can be distributed in a business environment. Potential applications would include Cable TV/Satellite newscasts, stored or live video broadcast, distance learning, security monitoring and video conferencing.
A big advantage of broadband video over twisted pair is that it has the capability to transmit many channels simultaneously using only a single pair in a 4-pair cable for broadcast video distribution or two pairs for bi-directional interactive video transmission.

What is the composition of a broadband video signal? A standard-definition composite video signal is composed of the video information (luminance and chroma) and the audio information. The composite video signal is then modulated on a carrier as shown in Figure 2. Different channels are spaced at 6 MHz intervals. Therefore, depending on the bandwidth of the cabling, many channels can be carried at the same time. A typical allocation would carry from channel 2 to channel 78 using a frequency band from 54 MHz to 550 MHz.

The broadband video systems on the market today are designed to be used with 75 Ohm coaxial cables. To transmit these signals over 100 Ohm balanced twisted pair cabling requires a high quality broadband balun (Balanced to unbalanced transformer) at either end of the channel to adapt a 75 Ohm coaxial input using an F-connector to a 100 Ohm balanced output using a modular 8-position connector.

How far can you transmit video signals over Category 5e and Category 6 cabling? Most video receivers (e.g. TV sets) are designed to accommodate a wide dynamic range of signals. The minimum signal level at the remote television receiver is around 1 mV pk-pk (-10 dBmV). With weaker signals, the picture is snowy and also much more susceptible to external noise. The maximum output level from the local amplifier is around 1 V pk-pk (50 dBmV), giving a dynamic range of up to 60 dB for the cabling. It should be noted that the signal level may need to be reduced below 50 dBmV because of radiated emission requirements that can further limit the dynamic range for the application.

Figure 3 is a graph of the frequency range that can be accommodated for a 100-meter Category 5e, Category 6 and a high-end Category 6 channel based on a 60 dB Insertion Loss limit. The frequency range is 400 MHz for a Category 5e, 500 MHz for Category 6 and 650 MHz for a high-end Category 6 channel, such as the NORDX/CDT 4800LX System, which has a very low Insertion Loss and about 10 dB improved SNR beyond the Category 6 standard. This is the theoretical upper limit based on signal quality. For this graph, it is assumed that the transmission characteristics of the cabling are well behaved beyond the maximum frequency specified for Category 5e (100 MHz) and Category 6 (250 MHz). Other transmission impairments can further restrict either the maximum reach (100 meters) or the maximum number of channels supported.

What are the different options for delivering video to the desktop and what are some of the advantages of a broadband video (CATV) distribution network? One option is Video over IP using the corporate LAN. To some extent this option is already in use today with video clips, newscasts and web camera images available through the Internet. The video images tend to be of a lower resolution than broadcast quality video, e.g. a DVD movie requires a transmission capacity of 6 – 8 Mb/s using MPEG-2 video compression. A major deterrent for implementing Video over IP over the corporate LAN is that real time video imposes severe demands on bandwidth and Quality of Service (QoS) for your network.

QoS is extremely important when implementing a converged network in which video, voice and data share the same IP circuit. Without effective QoS, bursty data traffic can disrupt video traffic, causing glitches, cutouts, frame loss, and other consequences. This results in severe quality degradation and user dissatisfaction. It can be an expensive proposition to upgrade an existing LAN to support high quality video. That is why it makes sense to consider a parallel broadband network, to deliver video to those locations that need it, conference rooms, class rooms, bulletin boards, select users. Another advantage of doing it over high performance UTP cabling is that the Category 5e and higher cabling is already...
installed in commercial buildings, is easy to administer and does not require the disruption of installing new coaxial cabling.

Figure 4 illustrates conceptually the advantages of a parallel RF highway, analogous to a high speed train that is called the Broadband Express, which can deliver up to 3.4 Gb/s of dedicated transmission capacity for broadcast quality video and audio.

How do you implement a broadband video distribution system to support streaming video applications under IP control, to deliver satellite feeds and for security monitoring? Without getting into too many details as to the type of equipment required, Figure 5, 6 and 7 illustrate a block diagram of how the system is implemented for different applications.

3. Performance evaluation

3.1 Test configuration and results - Video
To evaluate the performance of broadband video distribution over Category 6 UTP cabling, we used the test configuration and the components shown in Figure 8. The broadband video distribution hub (16-port) and the balun adapter at the work area location are manufactured by Z-Band Corporation. We installed seven IBDN 4800LX cables in a 1-inch conduit to simulate a worst-case installation with 90 meters of cable and 10 meters of patch cords. This allowed us to perform the testing in a worst-case scenario while simultaneously loading all the cables with video and or LAN signals to take into account the effect of alien crosstalk between cables.
Figure 8 – Setup for signal level and alien crosstalk measurements

The first series of tests performed included measuring the signal level at the input of the distribution hub and at the output of the balun in the work area over the frequency range from 50 MHz to 550 MHz. The alien crosstalk was measured by applying a signal on channel B through G respectively and measuring the noise coupled on channel A. The results are shown in Figure 9. After completion of these tests quality of the picture from a DVD player modulated on channel 2 (55.25 MHz) and channel 78 (547.25 MHz) was observed and noted with and without alien noise present.

Figure 9 – Signal level and alien noise measurements

The main effect of the alien noise was changing the level of the signal slightly, either higher or lower compared to the receive signal without alien noise present mainly at the higher frequencies. There was no significant effect on picture quality that was noticeable.

3.2 Test configuration and results - LAN and Video

To evaluate the performance of broadband video distribution and LAN over the same cabling or over separate cabling, we used the test configuration and the components shown in Figure 10. For this test, the 100BASE-TX signal was injected into the auxiliary ports of the Broadband video distribution hub using a crossover patch cord (pairs 2, 3 → pairs 1,2). The other two pairs, pair 4 and pair 3 are used for outgoing and incoming video respectively.

Figure 10 – Setup for signal level and ingress measurements

When the broadband video and LAN signal are present simultaneously in the same cable, we observed that measured ingress generated by the 100BASE-TX signal was limited to a frequency range under 200 MHz, and therefore, the main effect was at lower channels (NTSC channel 2 – 6). The ingress from LAN signal on adjacent cables (Alien NEXT) is insignificant.

The ingress measurements are shown in Figure 11 and 12 respectively, for 100BASE-TX signals in the same cables and in adjacent cables, respectively.

Figure 11 – Ingress from LAN and Video in same cable

Figure 12 – Ingress from LAN and Video in separate cables

What is the effect on picture quality of running LAN and video in the same cable? First of all, it requires a cabling
3.3 Additional testing

This paper presents some of the main parameters that were tested in a real-time environment to evaluate the technical feasibility of broadband video transmission over high-end UTP cabling. The authors would like to mention the results of other independent tests that were performed in our laboratory that are provided in an independent third-party test report (see reference 1). These additional tests include leakage measurements in compliance with FCC part 15 – Radio Frequency devices, subpart B, unintentional radiators. This report is available on our web site at www.nordx.com.

At the time of this writing, a more comprehensive series of emissions test is in progress at an independent test laboratory and will be reported during the IWCS proceedings.

4. Conclusions

Broadband video is definitely one application that can take full advantage of the improved transmission performance offered by Category 6 cabling and beyond. A low Insertion Loss and a high Signal-to-Noise Ratio are the most important cabling parameters for the broadband video application. Although the composite video signal is an analog signal today, future digital television signals will use the same broadband frequency spectrum and channel allocation but a different digital modulation scheme (MPEG-2 / 8-VSB or 256-QAM). Digital television offers the potential to carry up to 500 standard definition channels using the frequency range from 50 MHz to 550 MHz bandwidth.

Broadband video can find all kinds of applications in a business environment including specialty news channels, video conferencing, distance learning and security monitoring. There is an advantage to having the video application running on a separate broadband network to prevent network congestion and bottlenecks. High quality video will be the next wave of applications that will have a dramatic impact on your network. High performance Category 6 cabling is well positioned to meet the bandwidth requirements for these applications.

4.1 Authors
Paul Kish is Director, IBDN Systems and Standards with NORDX/CDT. He is the current vice-chairman of the TIA TR-42 engineering committee responsible for telecommunications cabling standards for commercial and residential installations. He has been active in the development of cabling standards since 1989 with TIA. He has also participated in standards development at CSA, ISO/IEC and IEEE. He initiated the work that led to the publication of additional specifications for Category 3, 4 & 5 cables, which have had a major impact in the cabling industry. Paul Kish is also a member of the BICSI TIM Committee that is responsible for the Chapters on Cable Transmission and Electromagnetic Compatibility.

Paul Kish graduated with an M.A.Sc. Degree in electrical engineering from the University of Waterloo, Ontario, Canada in 1972. He started to work as a cable design engineer with Bell Northern Research in 1972. He joined Northern Electric a year later to work on cable development projects. He has held a number of positions at Northern Telecom including Manager of the Cable Development Laboratories, Manager of Cable Design and Product Manager for IBDN Cabling. Paul Kish is recognized in the industry as an expert in “cable transmission”. He has authored many technical papers that have been published in various industry magazines and technical conferences. He has presented seminars at BICSI and other industry forums to promote cabling standards and the need for higher performance cabling.

Michel Bohbot graduated in electrical engineering from the University of Montreal, Quebec, Canada in 1985. He also graduated in Nuclear engineering from Geneva Engineering School, Switzerland in 1982. He started to work as a design engineer in the development of passive and active networking product in 1985. He joined Northern Telecom in 1989 to work on cabling system testing. He has held a number of positions at Northern Telecom including Product Manager for Networking Equipment and Manager for the IBDN Systems and Applications Laboratories.

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DVD movie entitled “Back to the Future”, ©2002 Copyright, Universal Studios.

6. References