Multimedia Shared Sheath Applications

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ABSTRACT: This papers explorers the potential of four-pair UTP cable for use in non-data, or mixes data/non-data applications. In order to simplify this analysis, only Category 5, Level 6, and Level 7 UTP are compared.

What is SHARED SHEATH?

Shared sheath can be multiple signals on one four-pair cable, such as two 10baseT signals on a four-pair cable, or four audio channels on a four-pair cable

Shared-sheath can also be multiple *systems* on one four-pair cable, such as audio and video on one cable, or 100baseT and broadband/CATV on one cable. Shared sheath can often involve combining data with non-data applications.

Because it is application non-specific, shared sheath is often described as being "Open Architecture". That means that the cable may be installed in such a manner that you can change your mind what the cable is for after installation.

What are "Non-data" Applications?

Below is a list of "Non-data" applications. To be more correct, one might say these are "non-premise" applications, because many of these applications are digital. These digital applications often exhibit the same requirements, and limitations of traditional premise applications such as 10baseT, 100baseT Ethernet™, or Token Ring.

Telephone

This includes common carrier systems, ranging from the analog phone, to digital phones, FAX, modems of varying speeds to 57.6 kbps. It also included dedicated or dial-up service for high data rate transfer down standard phone company cable such as ASDL, xSDL, Switched 56, ISDN, up to T-1 (1.544 Mbps)

Audio

Audio application can encompass consumer audio systems (which are generally unbalanced systems based on the RCA or "phono" connectors, and professional audio systems (generally balanced systems, most commonly based on the XLR connector).

Audio also falls into two categories in both consumer and professional systems, analog audio and digital audio. Surprisingly, when converting to digital, the connectors remain the same (RCA for consumer, XLR for professional) but the cables specified change. Digital audio runs at a much higher frequency than analog, which requires such a change. There is also a coaxial-based professional digital audio standard.

Baseband Video

Baseband video consists of one video picture being sent point-to-point, such as the video output of a VCR to the video input of a monitor. As before, there is consumer analog video (based on the RCA connector) and professional analog video, (based on the BNC connector.)

While the bandwidths are similar between broadcast studio and home installations, signal integrity and performance is much more critical with broadcast studio baseband video.

Professional digital baseband video systems, also based on the BNC connector, run at various data rates depending on the quality desired. Digital consumer systems are only just emerging (such as DVD). These employ much lower data rates.

Machine Control

Machine control is used in various industries as a simple network protocol to control various machine functions. In television broadcast, for instance, machine control allows the engineers to network all the video machines so that start-stop-play-record-fast forward-rewind are addressable from the network, greatly simplifying remote or semi-automatic control of large number of machines. These fall under a number of common standards such as RS-422, RS-423, and RS-485.

Broadband/CATV

In the ever-growing demand for more channels, broadband/CATV is definitely the bandwidth 'king'. Up to 158 channels are delivered to the home, with a bandwidth of 1 GHz, on a single specialized coax cable. As many as 500 channels are promised in future applications.

Plug'n'Play Architecture

"Plug'n'Play" describes a number of cutting-edge systems which are emerging for consumer, and even some professional, applications. They go under various titles such as IEEE 1394 "FireWire™", Universal Serial Buss, and home automation systems such as AMX™, or LonWorks™.

These systems either work with one master computer as a central hub, or they use smart devices, each of which has a small computer built-in. These can be wired up in any order, as long as basic requirements for the system are met, making it as simple as possible for the consumer.

Standards

Most systems have standards. That is, they have a basic list of requirements which must be met to allow the system to work. For wire and cable, these standards can be divided into two groups: physical standards, and performance standards

Physical Standards

Physical standards for wire and cable are those which outline how a specific construction will be built, what components may be used, and how it will look when it is manufactured. Controlling the physical construction will dictate what performance will be realized from such a construction. If such specifications say, for instance, that "shielded" cable must be used, *and if you are required to adhere to that specification*, then unshielded cable will not be an option.

The question is, what if you can meet the performance specifications without the physical specification? Isn't that the purpose of the physical specification: to assure the performance of the system? For instance, in our example, what if you could meet the noise ingress-egress requirements of a system without using shielded cable? Couldn't you use the unshielded cable?

Physical specifications may include gage size, insulation material, shielding, and jacketing. It can also include installation requirements such as minimum bend radius, or maximum pulling tension.

So How Do You Compare?

If you have two different types of cable, how can you compare them for a given application? You really have only two ways. First, if you *must* meet the standard to the letter, if you are required by your customer, a designer or architect, or other specifying party to meet a specific standard, then you'll have to meet it. This probably means you will have to use the cable specified even if there is one with better performance, easier installation, or cheaper. You haven't been given the choice.

On the other hand, if you're the "Keeper of the Spec", if you are the one who establishes the specification, and if there is a new or different cable which meets the performance specifications, and it has been proved to you that it works in that application, then use it!

It's DISTANCE & BANDWIDTH

One key factor in comparing cables is distance (attenuation) and frequencies (bandwidth). For instance, if you can identify what system(s) you want to use, and how far you want to go, and what cable you want to use, you can quite accurately predict the bandwidth you will have.

Likewise, if you know what system(s) you want to use, and the bandwidth you require, and what cable you want to use, you can quite accurately predict you how far you can go.

The word "predict" means that, using performance data on cable and hardware supplied by manufacturers, you can correlate the general limitations of a system. Where either cable or hardware performance data is missing, no prediction is then possible. In those cases, extrapolation can sometimes be applied from known performance to unknown areas. The accuracy of such extrapolated prediction becomes less and less accurate the farther you get away from the actual published performance data.

So let's "lock" the DISTANCE...

Since the purpose of this paper is to determine the performance of premise cables for non premise applications, we can help simplify this analysis by choosing one distance. We have chosen the distance of 100 meters (328 ft.) as this standard length, since all premise cables are well documented at that distance.

It is then just a matter of whether you can get the cable to theoretically perform at that distance, almost a "Yes" or "No" proposition.

Some Things We Can Agree On...

A cable could handle a signal on one pair but fail in a multi-***signal*** application. In this case, such as, for instance, two 100baseT signals (at two pairs each) or four baseband video signals (at one pair each), there could be various kinds of interference between signals which could render all signals unusable. This is analogous to "power-sum crosstalk" in premise data, where three pairs are driven and the interference read on the one undriven pair. For instance, in video, sync signals (different for each video) could easily interfere with each other rendering all resulting videos unwatchable.

A cable could handle a signal on one pair but fail in a multi-***system*** application. There is evidence that in multi-system applications the requirements are worse than the worst requirement alone.

You'll need all the cable performance you can get! In fact, there is evidence that that cable most exceed the most critical factor among the applications running on the cable. How much? 3 dB? 5 dB? We don't know yet. But this is a good reason to be conservative and underrate your cable, or buy cable which outperforms the system specs by a good margin.

OK, so LET'S GO!

Telephone

Bandwidth	Crosstalk
3.5 kHz	20 dB(?)
Category 5	100m+
DataTwist®350	100m+
MediaTwist®	100m+
12,000 ft. on Category 0	

Note that the bandwidth is very low and the crosstalk requirements are not even called out (but we've put a reasonable number there as a starting place.) Be aware that, when you hear your neighbor order pizza, crosstalk can be 6 dB or less.

Since the phone company routinely runs phone calls on very low quality twisted pairs, up to 12,000 ft. between your home and the Central Office, it seems ridiculous to ask if Cat 5, Level 6, or Level 7 will run for 328 ft. Of course they will.

Analog Audio

Bandwidth Crosstalk
20 kHz 90 dB

Category 5 ? (64 dB at 772 kHz)
Level 6 ? (69 dB at 772 kHz)
Level 7 ? (74 dB at 772 kHz)

In the recent past, the crosstalk would have been listed as 60 dB. That is the noise floor for FM broadcasts, and most LP's. But the advent of digital systems, such as CD's. has made many consumers aware of just how quiet quiet can be. In those instances, a noise floor of 90 dB is not uncommon. So that is why such a number is listed above. The problem lies in the fact that none of the cables were interested in show crosstalk at those low frequencies.

In the real world, we have tested Level 7 for crosstalk at 20 kHz. The results were so good that we could not read them. They were in the "noise floor" of the test equipment (i.e. >100 dB). While no testing has been done on Level 6 or Cat 5, it is believed that they too meet this specification. We urge other cable manufacturers to test their cables at audio frequencies for those applications.

Digital Audio

Bandwidth	Crosstalk
3.072 MHz	30 dB

Category 5	55.2 dB
Level 6	60.2 dB
Level 7	65.2 dB
AES/EBU Standard	

Digital audio jumps up to a serious bandwidth (3 MHz) with an identical data rate. Being a digital system, digital audio requires very little in terms of crosstalk. All cables above easily meet these requirements.

Analog Video

Bandwidth	Crosstalk
4.2 MHz	60 dB

Category 5	53 dB
Level 6	58 dB
Level 7	63 dB

Slightly higher bandwidth than digital audio, analog video requires much greater crosstalk protection (because we are back to analog). However, the new era of quiet sound has not yet found its way into pictures. Our eyes are much less sensitive to noise than our ears are. So 60 dB is a reasonable number. (There are some that will even say 50 dB is a reasonable number. Since there are no standards for picture quality, it's up to the user/installer to decide what number is acceptable.

And when HDTV comes into the home, what will be the number then? The bandwidth will increase to 6 MHz, but, being a digital system, the crosstalk will most likely come down to the 30 dB range.

Digital Video

Bandwidth	Crosstalk
135 MHz	35 dB

Category 5	30.6 dB
Level 6	35.6 dB

Level 7 40.6 dB
SMPTE 259M Serial Digital

Digital video, as outlined here, is the kind you would find in a broadcast facility. The top-of-the-line ("component serial digital") is 270 Mbps data rate at a bandwidth of 135 MHz. This is the standard both domestically and in Europe. Since it is a digital system, it doesn't require much crosstalk. Note, however, that the Category 5 standard spec does not offer enough crosstalk at 325 ft. In digital systems, one of the problems is that you can build up bit errors (flaws) until the system fails and you could be unaware that you are even close to that "cliff".

Plug'n'Play Architecture

IEEE 1394 "FireWire"
Bandwidth Crosstalk
400 MHz 35 dB

Category 5 (??)
Level 6 (??)
Level 7 (??)
4.5 m max per segment
73 m max total

"FireWire" is a trademark of Apple Corp. It is a "plug-n-play" architecture. That is, you simply plug all the boxes together, without regard to their purpose or application. Each device is "smart" and knows what it is and when it should do what it's designed for. Most of the applications out there are in the low-data rate to 16 MHz range. However, future applications are designed to run up to 400 MHz bandwidth.

The problem, again, is that we don't have any specifications for Cat 5, Level 6, or Level 7 up that high. On the other hand, the "standard" cable for Fire Wire is two stranded, shielded, twisted-pairs, inferior to Cat 5, much less Level 6 or 7. So will the cables work? For the present day low bandwidth applications, that should be no problem. For future, high data rate application, more work, more testing, on these cables needs to be done.

Universal Serial Buss

16 MHz
5 m (16 ft.) at 20 AWG
2 m (6 ½ ft.)

This plug-and-play architecture has a much lower bandwidth, so it can easily be carried by any of the cables considered. And they can go much farther than the 6 ft. or 16 ft. called out in that standard.

Home Automation

AMX ™

LonWorks™
78 kHz typical
1 MHz max.

Most home or small-business automation protocols are relatively slow speed standards. Any of the cables mentioned can easily carry them for 328 ft., and no doubt much greater lengths also. The standard cables called out in their specs are much larger gage (i.e. 18 AWG, 16 AWG, 14 AWG) generic twisted shielded pairs. Experiments need to be done with Cat 5, Level 6 and Level 7 to determine just how far they can go.

Machine Control

Bandwidth Crosstalk
10 MHz 35 dB

Category 5 47.3 dB
Level 6 52.3 dB
Level 7 57.3 dB
RS-422, RS-423, RS-485

These are common standards in many industries for machine control. For instance, broadcasters commonly use RS-422 to control tape machines (stop-start-fast forward-rewind-play-record) in a networked format..

Broadband Video

Bandwidth Crosstalk
160 MHz 35 dB
The highest frequency Cat 5, Level 6 and Level 7 show

Category 5 29.3 dB
Level 6 34.3 dB
Level 7 39.3 dB
160 MHz = Cable Channel 20

Broadband/CATV is the bandwidth "king". Systems are currently running up to 158 channels (1 GHz total bandwidth) with rumors of 500-channel systems in the works. In many instance, such as hotels or hospitals, systems of only a few channels (usually less than 30) are common.

The problem with comparing Cat 5, Level 6, and Level 7 (again) is that these cables are not spec'd past 160 MHz. The data above shows that Cat 5 probably won't meet the crosstalk required. Level 6 may squeak by and Level 7 passes with room to spare.

In fact, the key factor for this application may be attenuation. While attenuation specs for these cables are good, they are nowhere near coax performance. This is due mostly because there is more copper, simply more conductor, in coax than in a twisted pair.

Even given a 10 dB head start, the twisted pairs, do not do well, as can be seen on the next chart:

Attenuation (-10 dB) Crosses at:
Category 5 55 MHz (Ch. 2)
Level 6 55 MHz (Ch. 2)
Level 7 100 MHz (Ch. 6+)
SCTE RG - 59 (Series 59) attenuation

What this indicates is that the attenuation of UTP, even Level 7, is immediately worse than coax. On the other hand, TV receivers all have a built-in compensation for signal loss. After all, when picking up signals from a roof antenna, for examples, some signals can be strong and some signals can be weak. Most TV have a wide range of signals which result in good picture quality. So what can we expect from, say Level 7, in the real world. Currently, the winner is KDTV, San Francisco, using Level 7 up to 806 MHz (Ch. 126 on cable, Ch. 69 off air) at a distance in excess of 200 ft.

However, no twisted pair cable has been tested at those frequencies, so even though it works, we really don't know what it can do. And one of the key questions regarding UTP at high frequencies, is emission, or RF energy coming off the cable.

Ingress/Egress/Emission

I would strongly urge all cable manufacturers to test their Cat 5, Level 6 and Level 7 cables for emission. Most test labs (such as Underwriter's Laboratories) have test facilities already established for such testing.

We have tested our Level 7 cable for emission with the professional digital video system outlined above (270 Mbps/135 MHz serial digital video) and were awarded a certificate for Class A -- Digital Devices. While that might be of interest to a TV broadcaster, it says nothing of broadband/CATV or any other application.

Since emission is linear with frequency...the higher the frequency, the harder it is to keep a cable from radiating...we might assume that lower frequencies (such as 10 MHz machine control, for instance) produce cable emissions of even lower intensity.

And, like anything else, the emission is only as good as the weakest link in the chain. Since baluns are required to convert from coax to twisted pairs, very high-bandwidth broadband baluns would be required for such a test. And they would play a significant role in the passing or failing of the test by any cable.

The reverse also holds true. If noise can't leave the cable, the outside noise can't get into the cable. So the protection from emission afforded by these new designs also means that these cables will not pick up noise or RFI (radio frequency interference).

Why Should I Do This?

I would think the question should be, "Can You Avoid This?" Because, as soon as an end-user knows something is possible, he will eventually ask for it. If you are a designer or installer, and a customer of yours knows that there are these "super" twisted pairs which can give him an open architecture, so he can make up his mind, or change his mind, at any time in the future, of course he will ask for it. And the more the end-user doesn't know what he wants, the more likely he is to ask for an open architecture system.

In commercial and professional installations, it may take a little more time. We don't see TV stations rushing to throw out their coax cables. But, if in their next data install, they knew that the cable they install has a myriad other uses they would probably (1) extend that network to places it might not otherwise go and (2) use it in an emergency.

For instance, the CEO says he was to record a videotape in his office, but there's no coax run in there for a camera. The engineer doesn't want to lug a camera and crew up there just for this one shot. Wait! You put in that Level 7 cable. Two baluns and a patch cord later and that video is running from his office on twisted pairs. And how many times must a broadcast engineer do this, with results imperceptibly different from his standard coax, before he begins to see that maybe he should expand his network everywhere...just in case?