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Enhanced UTP PMD for IEEE 1394b

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Abstract

This specification defines a PMD sublayer for IEEE 1394b that supports operation over UTP cable at speeds of S200 and S400.

Keywords

IEEE 1394, Serial Bus, enhanced UTP PMD; E-UTP PMD

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Contents

Annexes

Foreword (This foreword is not part of 1394 Trade Association Specification 2006001)

This specification defines a new PMD sublayer for IEEE 1394 that supports operation over UTP cable at speeds of S200 and S400.

This specification contains one Annex which is informative and is not considered part of this specification.

After 1394 TA balloting, this material will be incorporated into Clause 12 of IEEE P1394r prior to its first ballot.

This specification was accepted by the Board of Directors of the 1394 Trade Association. Board of Directors acceptance of this specification does not necessarily imply that all board members voted for acceptance. At the time it accepted this specification, the 1394 Trade Association. Board of Directors had the following members:

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Revision history

Revision D1.0 (July 26, 2006) – initial draft distributed to the SI WG reflector.

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Revision D3.0 (Nov. 28, 2006) – submitted for SI working group ballot

Revision D4.0 (Dec. 17, 2006) – submitted for TA ballot after incorporating comments from SI WG ballot

Enhanced UTP PMD for IEEE 1394b

1 Scope and purpose

1.1 Scope

This document specifies a PMD sublayer for IEEE 1394b that supports operation over UTP cable at speeds of S200 and S400. Operation at S800 is for future study.

1.2 Purpose

IEEE 1394-1995 and IEEE 1394a-2000 support operation only in localized clusters with a maximum cable length of 4.5m. IEEE 1394b-2002 extends the maximum transmission distance to 100m over either optical fiber or UTP cable. However, the 1394b UTP interface is limited to S100 and has not been widely implemented.

IEEE 1394c-2006 defines a specification for S800 over 100m of UTP cable using a modified version of the 1000BASE-T PHY. While IEEE 1394c is ideally suited for high-performance interfaces, it is much more complex than a 1394 β-mode interface and may not be suitable for low-cost equipment.

This document defines an enhanced UTP PMD sublayer which supports S200 and S400 data rates over UTP cabling. This PMD will be referred to as the E-UTP PMD.

The E-UTP PMD sublayer is architecturally similar to the other six PMD's which have previously been defined in IEEE 1394b, as illustrated in Figure 1[1]. This PMD can also be used to make a simple adapter which can be used to extend the transmission distance for existing equipment, as illustrated in Figure 2.

[1] Figure 1 is the same as Figure 14-1 in IEEE 1394c-2006.

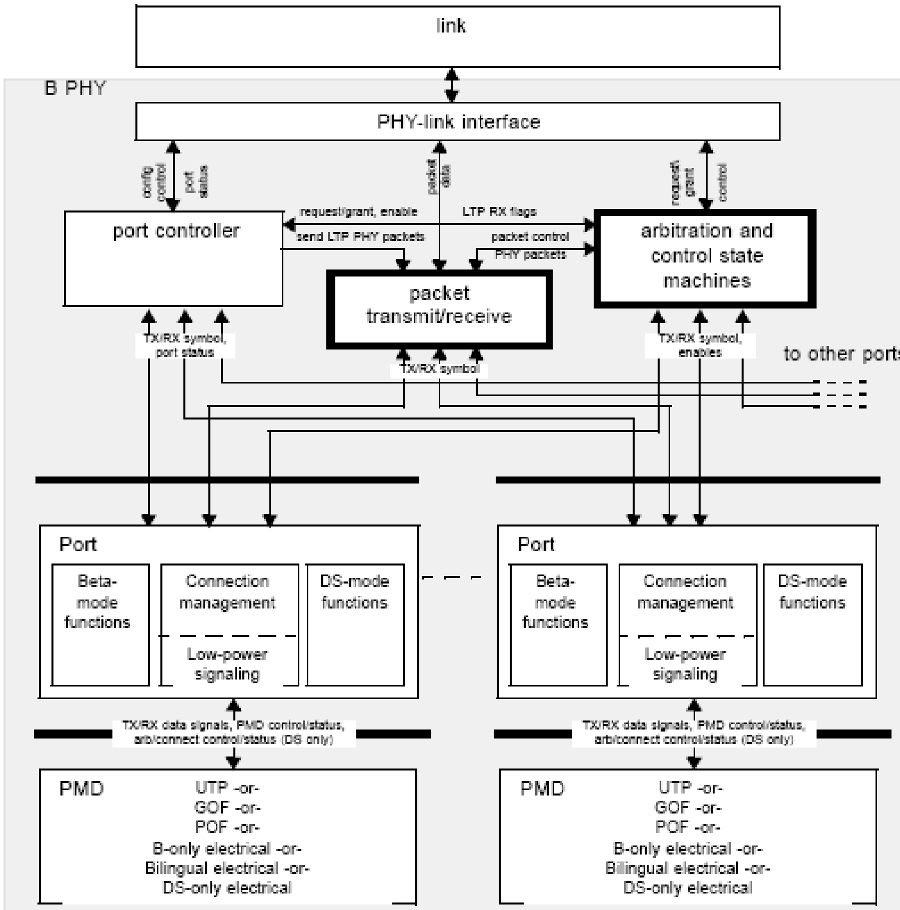

Figure 1 -- PMD sublayer architecture

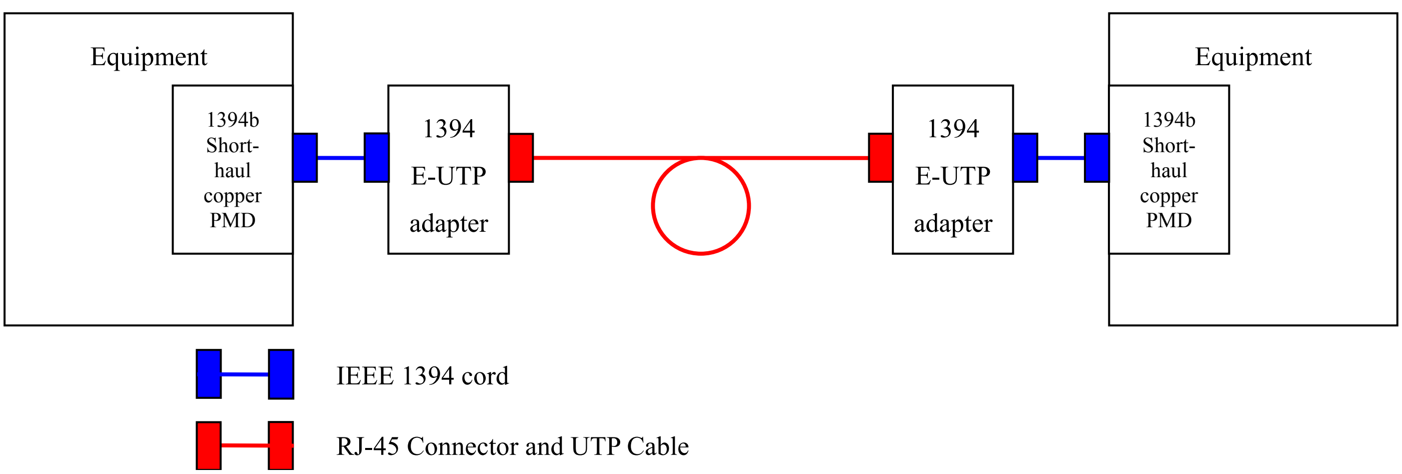

Figure 2 -- E-UTP adapter

2 Normative references

2.1 Reference scope

The specifications and standards named in this section contain provisions, which, through reference in this text, constitute provisions of this 1394 Trade Association Specification. At the time of publication, the editions indicated were valid. All specifications and standards are subject to revision; parties to agreements based on this 1394 Trade Association Specification are encouraged to investigate the possibility of applying the most recent editions of the specifications and standards indicated below.

2.2 Approved references

The following approved specifications and standards may be obtained from the organizations that control them.

IEEE Std 1394-1995, Standard for a High Performance Serial Bus

IEEE Std 1394a-2000, Standard for a High Performance Serial Bus—Amendment 1

IEEE Std 1394b-2002, Standard for a High Performance Serial Bus—Amendment 2

IEEE Std. 1394c-2006, Standard for a High Performance Serial Bus – Amendment 3

Throughout this document, the term “IEEE 1394" shall be understood to refer to IEEE Std 1394-1995 as amended by IEEE Std 1394a-2000, IEEE Std 1394b-2002, and IEEE Std 1394c-2006.

2.3 Reference acquisition

The references cited may be obtained from the organizations that control them:

1394 Trade Association, 1560 East Southlake Blvd, Suite 242, Southlake, TX 76092 USA; (817) 416-2200 / (817) 416-2256 (FAX); http://www.1394ta.org/

American National Standards Institute (ANSI), 11 West 42nd Street, New York, NY 10036, USA; (212) 642-4900 / (212) 398-0023 (FAX); http://www.ansi.org/

Institute of Electrical and Electronic Engineers (IEEE), 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331, USA; (732) 981-0060 / (732) 981-1721 (FAX); http://www.ieee.org/

In addition, many of the documents controlled by the above organizations may also be ordered through a third party:

Global Engineering Documents, 15 Inverness Way, Englewood, CO 80112-5776; (800) 624-3974 / (303) 792-2192; http://www.global.ihs.com/

3 Definitions and notation

3.1 Definitions

3.1.1 Conformance

Several keywords are used to differentiate levels of requirements and optionality, as follows:

3.1.1.1 expected: A keyword used to describe the behavior of the hardware or software in the design models assumed by this specification. Other hardware and software design models may also be implemented.

3.1.1.2 ignored: A keyword that describes bits, bytes, quadlets, octlets or fields whose values are not checked by the recipient.

3.1.1.3 may: A keyword that indicates flexibility of choice with no implied preference.

3.1.1.4 reserved: A keyword used to describe objects (bits, bytes, quadlets, octlets and fields) or the code values assigned to these objects in cases where either the object or the code value is set aside for future standardization. Usage and interpretation may be specified by future extensions to this or other specifications. A reserved object shall be zeroed or, upon development of a future specification, set to a value specified by such a specification. The recipient of a reserved object shall ignore its value. The recipient of an object defined by this specification as other than reserved shall inspect its value and reject reserved code values.

3.1.1.5 shall: A keyword that indicates a mandatory requirement. Designers are required to implement all such mandatory requirements to assure interoperability with other products conforming to this specification.

3.1.1.6 should: A keyword that denotes flexibility of choice with a strongly preferred alternative. Equivalent to the phrase “is recommended.”

3.1.2 Glossary

The following terms are used in this specification:

3.1.2.1 E-mode: The operating mode of a port using the Enhanced UTP PMD as described in this document.

3.1.2.2 Category 5e UTP cabling: Unshielded twisted pair cabling which meets or exceeds the ISO/IEC 11801:2002 specifications for Class D balanced twisted pair cabling (which is equivalent to Category 5e cabling as specified in ANSI/TIA/EIA-568-B.2.)

3.1.2.3 Category 6 UTP cabling: Unshielded twisted pair cabling which meets or exceeds the ISO/IEC 11801:2002 specifications for Class E balanced twisted pair cabling (which is equivalent to Category 6 cabling as specified in ANSI/TIA/EIA-568-B.2-1.)

3.1.3 Abbreviations

The following are abbreviations that are used in this specification:

E-UTP PMD	Enhanced UTP PMD
FFS	For future study
PMD	Physical Medium Dependent
UTP	Unshielded Twisted Pair

4 Overview (informative) – Rationale for long-haul (100m) high-speed UTP operation

Although S100 operation over 100m of UTP cable was specified in IEEE 1394b-2002, it has not been widely accepted in the market. There are two main reasons for this. First, some of the early UTP hardware did not work very well. Second, the S100 speed is not enough for many applications. The availability of a robust, reliable, low-cost interface which can transmit S400 signals over 100m of UTP will facilitate applications in many areas, including the following:

- Home networking – IEEE 1394 is an ideal backbone protocol for home networks because of its capability to support isochronous streams for audio and video. Since UTP is widely deployed in homes, a low-cost, high-bandwidth UTP solution would facilitate the use of IEEE 1394 in residential backbone networks.

- Pro Audio – The isochronous capabilities of IEEE 1394 are also well suited to the professional audio market. Low cost, robustness, and ease of installation make UTP a very attractive transmission medium for audio equipment, especially for installations which must be frequently moved or reconfigured.

- Industrial – IEEE 1394 is often used in industrial applications for transmitting video or other time-critical information, such as the position of a moving device.

5 E-UTP PMD Specification

In general, the E-UTP PMD shall meet all requirements of the UTP PMD which is defined in Clause 12 of IEEE 1394b-2002 (as modified by IEEE 1394c-2006), with exceptions and additions as noted in this document. To facilitate comparison with IEEE 1394b clause 12, this clause has an identical subclause structure.

5.1 Overview

This clause specifies the electrical signaling properties for the long-haul Enhanced UTP PHY operating at speeds of S200 and S400. To distinguish E-UTP transmission speeds from standard IEEE 1394b speeds, the E-UTP speeds are denoted by an "e" suffix, e.g., S200e and S400e. S800e operation is for further study.

E-mode ports shall meet or exceed the maximum transmission distances for UTP media (Category 5e and 6) and speeds (S200e and S400e) as specified in Table 1. The use of Category 6A cabling is for further study. Note that screened or shielded cabling meeting the Category 5e or Category 6 specifications may also be used.

Table 1 - E-mode maximum transmission distances

Speed	Distance (m)	
	Cat 6 UTP	Cat 5e UTP
S200e	100	75
S400e	75	50
S800e	FFS	FFS

Because S400e signals contain frequency components above the maximum frequency specified for Category 5e cabling, Category 6 cabling is recommended for S400e operation.

5.2 PMD block diagram

As in IEEE 1394b, interface specifications apply at the points of entry and exit from the equipment (TP2 and TP3.) In the case of the E-UTP interface, these reference points are at the modular connectors. Figure 3 illustrates the TP2 and TP3 reference points for the E-UTP PMD. Note that Figure 3 shows only one direction of transmission of a full-duplex connection.

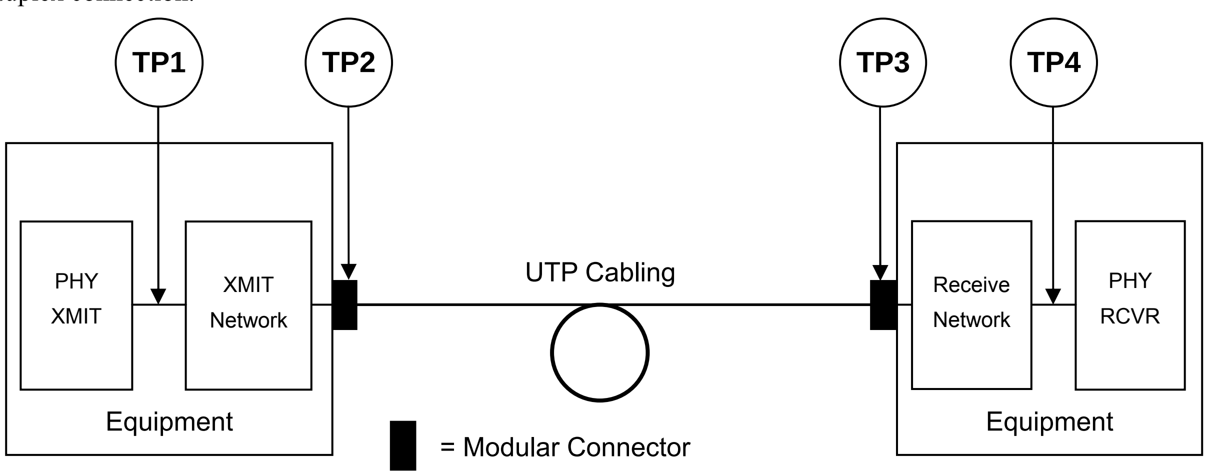

Figure 3 -- Measurement test points

5.3 Operation of UTP connections

The E-UTP connections employ full-duplex baseband transmissions over two pairs of Category 6 unshielded twisted-pair. Shorter distances may also be supported on Category 5e UTP, as per Table 1.

5.4 Media Specification

5.4.1 100Ω UTP connection segment specification

The cabling media shall meet the requirements of IEEE 1394b, clause 12, with the exception that Category 6 UTP cabling must meet the specifications previously mentioned in clause 3.1.2 of this document.

5.4.2 100Ω UTP cable specification

The transmission medium for an E-UTP connection shall be four-pair 100Ω balanced UTP cable meeting the transmission requirements for Category 6 cabling in ISO/IEC 11801. Category 5e cabling may also be used with reduced distances as specified in Table 1.

5.4.3 Connecting hardware

All connecting hardware used within an E-UTP connection shall meet the requirements for Category 6 connecting hardware in ISO/IEC 11801. Category 5e connecting hardware may also be used with reduced distances as specified in Table 1.

5.4.4 Media Interface Connector

Modular connector pin assignments shall be the same as in IEEE 1394c, as specified in Table 2.

Table 2 - Standard E-UTP modular connector pinouts

Pin	Circuit
1	TPB
2	TPB*
3	TPA
4	Note 1
5	Note 1
6	TPA*
7	Note 1
8	Note 1

Note 1: Pins 4, 5, 7, and 8 are reserved for transmission of DC power as per IEEE 802.3-2005, clause 30.

When the autocrossover function is not implemented (see clause 5.4.5), the modular jacks may be configured as in Table 2 and connected with cross-over cabling. Alternatively, some of the modular jacks may be configured with the alternate pinout of Table 3 which reverses the TPA and TPB pairs so that they may be connected with straight-through cabling to a jack using the standard pinouts of Table 2. Modular jacks which use the alternate pinout of Table 3 shall be clearly labeled.

Table 3 - Alternate E-UTP modular connector pinouts

Pin	Circuit
1	TPA
2	TPA*
3	TPB
4	Note 1
5	Note 1
6	TPB*
7	Note 1
8	Note 1

Note 1: Pins 4, 5, 7, and 8 are reserved for transmission of DC power as per IEEE 802.3-2005, clause 30.

5.4.5 Autocrossover

It is strongly recommended that E-UTP PMDs should support the autocrossover functionality as per IEEE 1394c clause 12.4.5.

5.5 PMD Electrical Specifications

5.5.1 Galvanic isolation

E-UTP PMD ports shall meet the requirements of IEEE 1394b clause 12.5.1.

5.5.2 Transmitter Specifications

For E-mode operation, the transmitter shall meet the specifications of Table 4.

Table 4 - E-UTP transmitter characteristics

Parameter	S200e	S400e	Units
Signaling	8B/10B		
Nominal data rate	196.61	393.22	Mb/s
Nominal baud rate	245.76	491.52	MBd
Tolerance	±100		ppm
Differential amplitude (pk-pk)			
Maximum	800		mV
Minimum	475		mV
Maximum (off)	20		mV
Rise and fall time (20-80%)			
Maximum	2.2	1.2	ns
Minimum	80		ps
Differential skew	50		ps

The output driver in 8B/10B signaling shall have output levels at TP2 which meet the normalized eye diagram mask of Figure 4 and the absolute eye diagram mask of Figure 5. Normalized time intervals are defined in Table 5.

Table 5 -- Normalized time intervals for TP2

Symbol	Value	Units
X1	0.14	Unit intervals
X2	0.44	Unit intervals

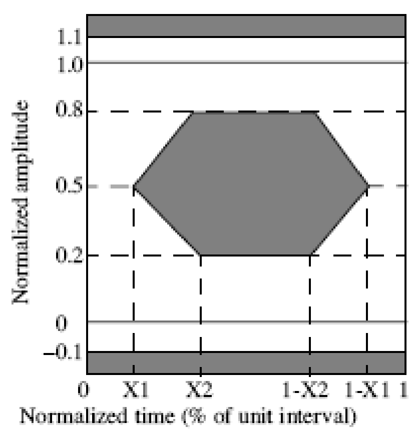

Figure 4 -- Normalized eye diagram mask at TP2

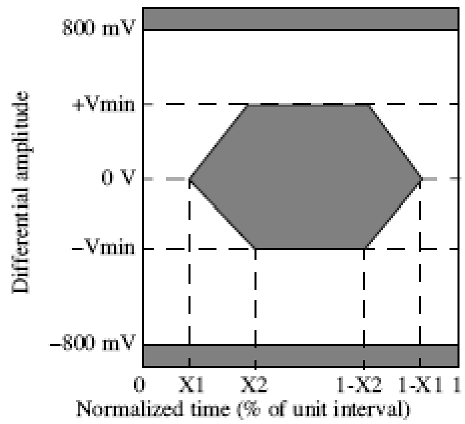

Figure 5 -- Absolute eye diagram mask at TP2

5.5.3 Receiver Specifications

5.5.3.1 Receiver input signals

A received BER of 10^{-12} shall be maintained over either a Class D (Category 5e) or Class E channel (Category 6). The E-mode receiver shall comply with the requirements of Table 6.

Table 6 – E-UTP receiver electrical specifications

Parameter	Requirement	Units
Minimum sensitivity (peak-peak)	100	mV
Minimum sensitivity (differential amplitude)	50	mV
Input impedance	100 ± 15	Ω
Return loss		
2 ≤ f < 30 MHz	>16	dB
30 ≤ f < 60 MHz	>16-20log(f/30)	dB
60 ≤ f < 100 MHz	>10	dB
100 ≤ f < 250 MHz	>6	dB

5.5.3.2 PMD signal detect function

All E-mode ports shall provide a signal_detect variable which indicates whether a valid input signal is being received. The signal_detect variable shall be compliant with IEEE 1394b Clause 12.5.3.2. However, if the receiver sensitivity exceeds the minimum requirements of Table 6, then the threshold voltages in Table 12-5 of IEEE 1394b may be adjusted accordingly.

5.6 PMD implementation (informative)

Although this specification does not impose a particular implementation, the use of an adaptive equalizer is recommended to extend the transmission distance of IEEE 1394b signals. This section gives a brief review of equalizer technology. Advances in both equalizer and UTP cable technology have made it possible to support higher transmission rates than the S100 rate specified in IEEE 1394b.

As signals propagate along a UTP cable, the high frequency components are attenuated more than the low frequency components. Table 7, for example, shows attenuation at several frequencies for 100m of Category 6 UTP cable.

Table 7 - Attenuation of 100m of Category 6 UTP cable

Frequency (MHz)	Attenuation (dB)
1	2.0
10	6.0
100	19.8
200	29.0
250	32.8

At 250 MHz, the attenuation is 30.8 dB more than at 1 MHz, which represents a factor of more than 1200. This attenuation of high frequencies causes pulses to be “rounded off” as they propagate along the cable. An equalizer

provides gain that is proportional to the attenuation of the cable, i.e., large at high frequencies and low at low frequencies. This compensates for the cable characteristics and allows for longer transmission distances.

Figure 6 shows the attenuation vs. frequency plot (blue) of Category 6 UTP cable and an associated equalizer curve (red). Note that, at every frequency, the value of gain in the equalizer exactly compensates for the attenuation in the cable.

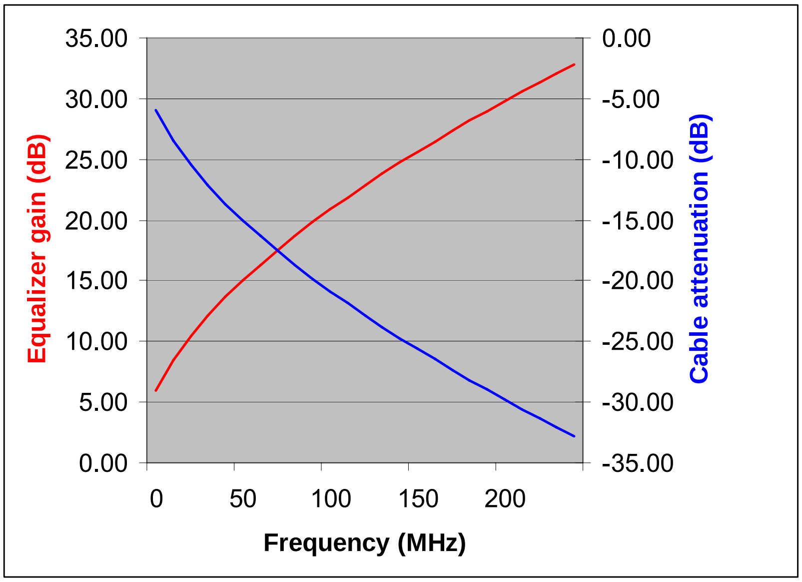

Figure 6 - Equalizer gain and cable attenuation curves

In a real cabling channel, the attenuation vs. frequency curve would be more complex than the simple curve shown in Figure 6, so the equalizer curve would have to be more complex also to properly compensate for the effects of the attenuation.

Adaptive equalizers automatically adjust their gain at various frequencies to compensate for the characteristics of the particular channel they are connected to.

One of the major advantages of equalizers is that they do not require any changes to the transmitter. This makes them very easy to add to legacy equipment.

Annex A
(informative)

Bibliography

[B1] IEEE Std 1212-2001, Standard for a Control and Status Registers (CSR) Architecture for microcomputer buses

[B2] IEEE Std 1394-1995, Standard for a High Performance Serial Bus

[B3] IEEE Std 1394a-2000, Standard for a High Performance Serial Bus—Amendment 1

[B4] IEEE Std 1394b-2002, Standard for a High Performance Serial Bus—Amendment 2

[B5] IEEE Std. 1394c-2006, Standard for a High Performance Serial Bus – Amendment 3

[B6] ISO/IEC 9899:1990, Programming Languages—C