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IEEE 1394 Baseband Coax PMD Specification

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Abstract

This specification defines the requirements for a PMD sublayer for IEEE 1394 that supports baseband operation over coaxial cable.

Keywords

IEEE 1394, Serial Bus, baseband coax PMD; BBC PMD, coaxial cable

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Annexes

Foreword (This foreword is not part of 1394 Trade Association Specification TS2007005)

This specification defines a new PMD sublayer for IEEE 1394 that supports baseband operation over coaxial cable.

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

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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2/23/2009 – Draft 1.9, distributed for SIG ballot

5/5/2009 – Version 1.0, incorporated resolution of SIG ballot comments

Baseband Coax PMD Specification

1 Scope and purpose

1.1 Scope

This document specifies an IEEE 1394 PMD sublayer that supports full duplex baseband operation over a single coaxial cable. Only beta mode is supported.

1.2 Purpose

IEEE 1394 supports a variety of transmission media, including Data-Strobe, Beta, and Bilingual cables for local communication and UTP, POF, and GOF for longer distance communication. However, IEEE 1394 does not support communication over coaxial cable which is widely used in automotive, residential, and industrial applications.

This document defines a baseband coax PMD sublayer which supports data rates S400β and S800β over a single coaxial cable in duplex mode. This interface will be referred to as the BBC PMD.

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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 1394-2008, Standard for a High Performance Serial Bus

2.3 Reference acquisition

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

1394 Trade Association, 315 Lincoln, Suite E, Mukilteo, WA 98275 USA; (425) 514-8454 / (425) 710-9971 (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/

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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, octets 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, octets 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 Alpha mode: An operating mode that utilizes data-strobe (D-S) transmission (see reference [B2].)

3.1.2.2 Coaxial cable: A cable in which a single center conductor is surrounded by a dielectric material and then a cylindrical shield that is often composed of layers of foil and metallic braid.

3.1.2.3 Inline connector: A connector which is in addition to the connectors at the ends of the cabling run (as illustrated in Figure 2.)

3.1.2.4 Return loss: The ratio of outgoing signal power to reflected signal power.

3.1.3 Abbreviations

The following are abbreviations that are used in this specification:

3.1.3.1 BBC: Baseband coax

3.1.3.2 EMC: Electromagnetic compatibility

3.1.3.3 FOT: Fiber-optic transceiver

3.1.3.4 GOF: Glass optical fiber

3.1.3.5 PMD: Physical Medium Dependent

3.1.3.6 POF: Plastic optical fiber

3.1.3.7 UTP: Unshielded twisted pair

3.1.3.8 WOL: Wake-on-LAN

3.1.3.9 WOT: Wake-on-Tone

4 Overview (informative) – Applications for the BBC PMD

Coaxial cabling is widely used for a number of applications. Support of a baseband coax PMD could potentially increase the use of IEEE 1394 networks in areas such as:

- Automotive – Coaxial cable is well-suited to use in automobile wiring harnesses due to its small size, high bandwidth, low-cost, and excellent EMC performance.

- Home networking – IEEE 1394 is an ideal backbone protocol for home networks because of its capability to support isochronous streams for audio and video and its ability to transport Internet Protocol (IP) packets for applications such as PC networking and IPTV. Since coaxial cable is widely deployed for video/CATV transmission in homes, a low-cost baseband coax solution would facilitate the use of IEEE 1394 in residential backbone networks.

- Industrial – Coaxial cable is often used in industrial applications (imaging, control, instrumentation, etc.) because of its high bandwidth, ruggedness, and EMC performance.

In addition, a low-cost baseband coax interface might also be useful in other applications, such as Pro Audio, external data storage, and consumer A/V equipment.

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5 Media Specification

5.1 Coaxial cables

There are many types of coaxial cable which are used for different applications. They differ in several ways:

- Characteristic impedance – 50 and 75 Ω are the most common types.
- Attenuation (dB/100m)
- DC resistance of the center conductor (Ω/100m)
- Capacitance (pF/m)
- Shielding – cables are made with varying numbers of foil and braded shields depending on the level of EMC performance that is needed and the nature of the signal being transmitted.
- Cable diameter – standard coax is about 6.4 mm (0.25 inches) in diameter, while mini-coax is approximately 2.5 mm (0.1 inches) in diameter.

Coaxial cables used with the BBC PMD shall have a nominal characteristic impedance of either 50 or 75 ohms with a tolerance of ± 2 ohms. RG-174, RG-58, RG-59, Series 6, and Series 11 are among the most commonly used types. Nominal specifications for these five types of coaxial cable are given in Table 1. The attenuation values[1] in Table 1 will be used for example cable length calculations in clause 6.10.

Type	Characteristic Impedance (Ω)	Center Conductor DC Resistance (Ω/100m)	Attenuation (dB/100m)		Approx. Diameter (mm)
			250 MHz	500 MHz	
Sample RG-174	50	31.8	46	70	2.5
Sample RG-58	50	3.4	27	41	6.4
Sample RG-59	75	5.0	17	24	6.4
TIA Series 6	75	2.0	12.4	17.4	6.9
TIA Series 11	75	1.2	7.4	10.7	10.4

Table 1 -- Coaxial cable example specifications

NOTE – Series 6 and Series 11 are also known as RG-6 and RG-11, respectively.

Cable segments within a single cabling run may consist of different types of cable, but all cable segments shall have the same characteristic impedance.

5.2 Coaxial connectors

There are also many different types of coaxial connectors. Some of the most popular types of coaxial connector are listed in Table 2.

[1] The attenuation values for the Series 6 and 11 coaxial cables are based on TIA-570-B-1 (Residential Telecommunications Infrastructure Standard, Addendum 1 – Additional Requirements for Broadband Coaxial Cabling), while the values for the cables labeled "Sample" are for particular cables that are commercially available. Note that the attenuation of different types of coaxial cable, as well as cables from different manufacturers, may vary considerably from the sample values shown in the table.

Connector	Impedance (Ω)	
	50 Ω	75 Ω
SMB / FAKRA	✓	✓
Type F		✓
SMA	✓	
BNC	✓	✓
Type N	✓	
MMC/MCX	✓	✓
TNC	✓	

Table 2 -- Commonly used coaxial connectors

Coaxial connectors shall have a nominal characteristic impedance that matches the cable and shall be mechanically and electrically compatible with the coaxial cable being used.

Inline connectors are permitted. Note that the number of inline connectors may affect the maximum transmission distance as per clause 6.10.

5.2.1 Return loss

The return loss of a mated connector pair shall be 30dB or greater at all frequencies from 1 MHz up to the fundamental frequency (Table 4). The mated connector pair can be board mount connectors or inline connectors.

The use of connectors not meeting this criterion will result in a lower attenuation budget (Table 4).

5.3 Specific applications (informative)

Different types of coaxial cable and connectors are typically used by different applications. Table 3 illustrates some commonly used examples.

Application	Cable	Connectors
Automotive	RG-174	FAKRA
Residential Backbone	Series 11 Series 6 RG-59	Type F
Industrial (imaging)	RG-174 RG-58	various

Table 3 – Commonly used cables and connectors for specific applications

6 BBC PMD Specification

6.1 Overview

This clause specifies overall BBC PMD requirements which apply to all configurations. Additional requirements may be added by application-specific specifications.

6.2 Compatibility

Though various coaxial cable media and connectors are permitted by this specification, all implementations using a common cable impedance (either 50 or 75 ohms) shall be interoperable at the S400β base rate within the length limits dictated by the choice of the cable media and connectors.

6.3 Block diagram

The BBC PMD sublayer is architecturally similar to the other PMD's that have previously been defined in IEEE 1394, as illustrated in Figure 1. The BBC PMD only supports beta mode operation.

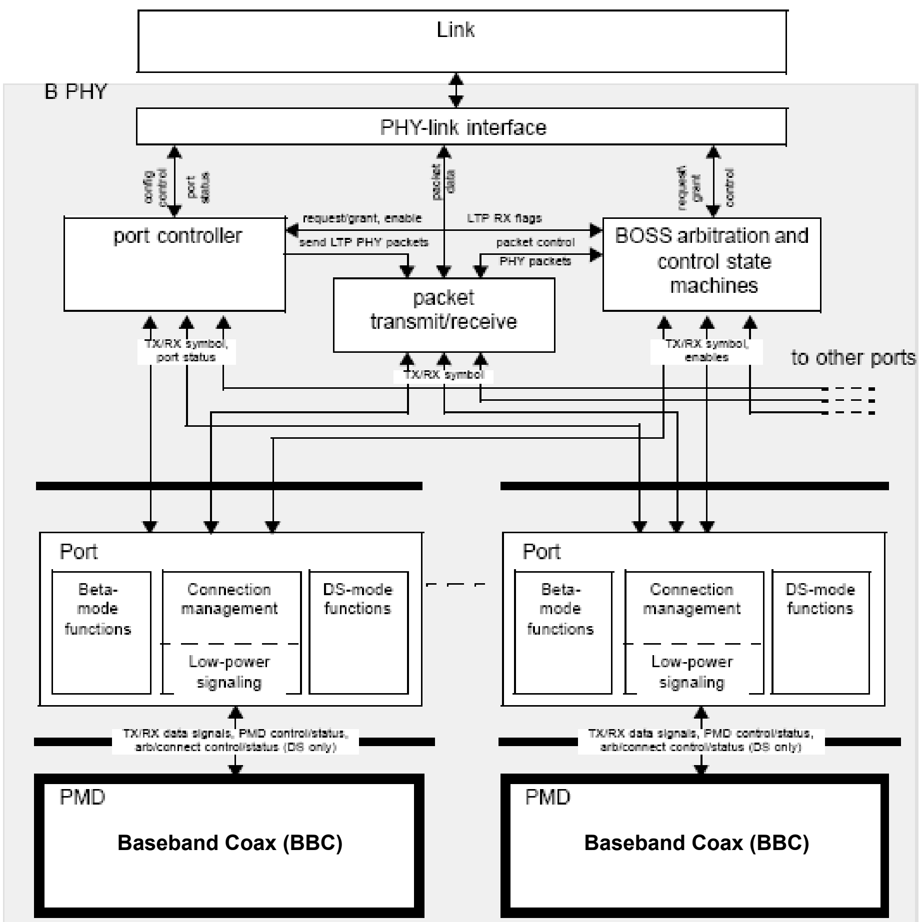

Figure 1. PMD sublayer architecture

6.4 Interfaces

All interface specifications apply at the points of entry and exit from the equipment, which are identified as points TP2 and TP3 in Figure 2. The interface specifications may also be valid at other places. The specifications assume that all measurements are made after a mated connector pair, relative to the source or destination. TP1 and TP4 are reference points for use by implementers to specify vendor components.

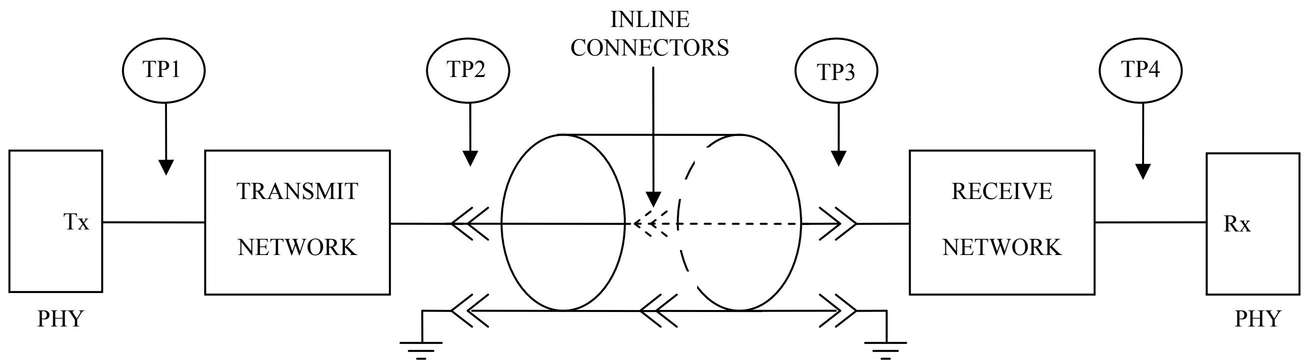

Figure 2. Measurement points (half of a duplex connection)

The reference points for all connections are the points TP2 and TP3 at the transitions between the equipment and the cable. If sections of transmission line exist within the equipment, they are considered to be part of the associated transmit or receive network and not part of the cable plant.

Figure 2 shows half of a duplex connection. For BBC, the other half of the duplex connection is using the same conductor, and thus for the data carried in the opposite direction, TP1 is equal to TP4, TP2 is equal to TP3, the transmit network is equal to the receive network, and the Tx pin is equal to Rx pin. For clarity, this document uses the terminology of Figure 2, defining the behavior at TP2 and TP3 although these test points are actually the same.

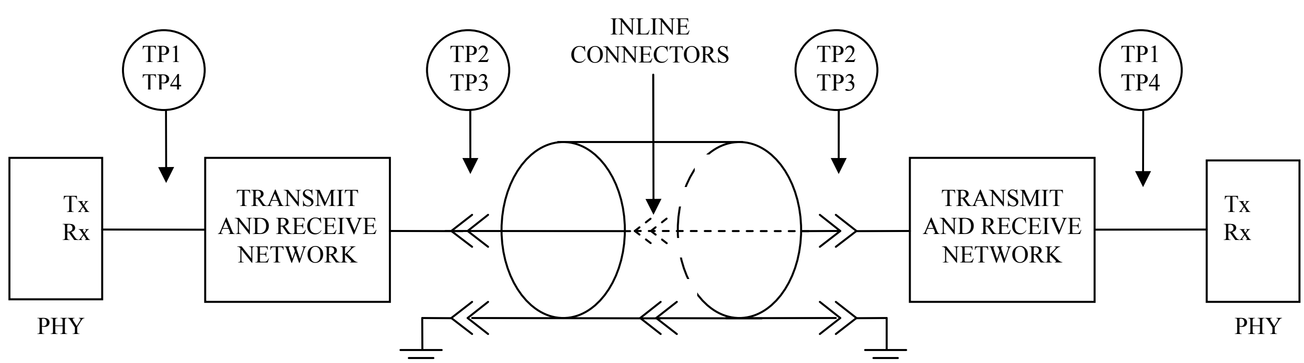

Figure 3. Measurement points (full duplex connection)

6.5 Cabling media

The coaxial cabling used with the BBC PMD shall meet the requirements of Clause 5. The cabling shall not contain any splitters, taps, or other discontinuities between TP2 and TP3 except for inline connectors, as shown in Figure 2.

6.6 Direction of transmission

The BBC PMD shall support bidirectional transmission over a single coaxial cable.

6.7 Error Rates

Data transmission over the BBC PMD shall provide a BER of 10^{-12} or better.

6.8 Data rate

The BBC PMD shall support Beta-mode operation at S400[2]. Operation may optionally be supported at S800. S1600 and S3200 are for future study. Specific applications may require operation at S800 or higher speeds.

6.9 Attenuation budget

The BBC PMD shall support links, consisting of either 50 or 75 ohm cable and connectors, with a maximum attenuation as specified in Table 4. The attenuation budget includes the loss of the coaxial cable and inline connectors (if any.) Both the maximum node-to-node attenuation and the frequency at which to measure the attenuation depend on the data rate.

Data rate	Fundamental Frequency (MHz)	Maximum Node-to-Node Attenuation (dB)
S400	250	12
S800	500	12

Table 4. Coax link attenuation budget

6.10 Cable length

The maximum cable length can be calculated from the attenuation budget, and is a function of the data rate, type of coaxial cable and connectors used, and the number of inline connectors. The maximum cable length (in meters) is:

$$Max\_length = \frac{Atten\_budget - \sum Inline\_connr\_atten - cable\_pwr}{cable\_atten}$$

Where:

Atten_budget is given by Table 4.

$\sum Inline\_connr\_atten$ is the sum (in dB) of the attenuation of all the inline connectors (if any) at the frequency specified in Table 4.

[2] Alpha-mode ports are not directly supported due to the presence of common-mode speed signaling. Alpha mode ports can be supported by communicating through a Beta-mode port which is attached to the BBC-PMD.

cable_atten is the attenuation of the coaxial cable (in dB/m) at the frequency specified in Table 4.

cable_pwr is the additional attenuation margin required when supplying cable power. It is vendor-specified and shall not be greater than 2 dB.

If there are no inline connectors and cable power is not supplied, then the maximum cable length is simply 12dB divided by the cable attenuation (in dB per meter).

As an example, Table 5 shows the maximum cable lengths for the sample cables of Table 1 with no inline connectors or cable power.

Cable type	Data Rate	
	S400	S800
Sample RG-174	26	17
Sample RG-58	44	29
Sample RG-59	71	50
TIA Series 6	97	69
TIA Series 11	162	112

Table 5. Maximum cable length (meters) with no inline connectors or cable power

The effect of inline connectors is to reduce the total attenuation budget available for the cable, as illustrated in the equation above. For example, if there are five inline connectors, each with a typical attenuation of 0.2 dB, then the attenuation budget is reduced from 12 dB to 11 dB, and the maximum cable lengths in Table 5 are reduced by approximately 8%.

6.11 Transmitter electrical specification

A BBC PMD transmitter shall be designed to operate over either 50 or 75 ohm cabling. The BBC PMD transmitter shall comply with the specifications provided in Table 6 when measured at TP2 and connected to coaxial cabling with the same characteristic impedance as the transmitter.

Parameter		S400	S800	Units
Signal Amplitude	Maximum	350	350	mV
	Minimum	250	250	mV
	Maximum (OFF)	15	15	mV
Rise/Fall time (20% - 80%)	Maximum	1200	600	ps
	Minimum	80	80	ps
Jitter	Pk-pk	500	250	ps

Table 6. Transmitter Specifications

6.12 Receiver electrical specification

The BBC PMD receiver shall meet or exceed the specifications provided in this subclause.

6.12.1 Impedance

The BBC PMD receiver shall be designed to have the same characteristic impedance as its associated transmitter.

6.12.2 Coupling

The BBC PMD receiver shall be AC-coupled. The capacitor is sized to give less than 1% distortion of a worst-case run length of 10 S400 bits (i.e., a 20 ns pulse).

6.12.3 Bit-error rate

The BBC PMD receiver shall operate with a BER of 10^{-12} or better when receiving a signal from a transmitter compliant with clause 6.11 over cabling media compliant with clause 5.

6.12.4 Return loss

When measured at TP3 in Figure 2, the BBC PMD transceiver shall have a return loss of 15 dB or greater at all frequencies from 20 MHz up to the fundamental frequency (Table 4).

6.13 Cable power

Cable power may optionally be supplied over the coaxial cable. When cable power is provided, a positive voltage shall be applied to the center conductor and a return path provided via the shield. The cable power voltage shall comply with the IEEE 1394 range of 8 - 30 V dc (see clause 9.4 of IEEE 1394-2008 [B2].) The maximum current shall not exceed 1 A.

NOTE – When supplying cable power, care must be taken not to violate the return loss specification in clause 6.12.4.

The maximum power which can be delivered to the load will depend on the voltage and current supplied by the port as well as the DC resistance of the cable which is used. The voltage drop in the coaxial cable (V_{COAX}) can be calculated from the formula:

$$V_{COAX} = I_{LOAD} \text{ x } (R_{DC} + R_{SHIELD})$$

where R_{DC} is the DC resistance of the center conductor from Table 1. The shield resistance (R_{SHIELD}) is typically a factor of 3 or 4 lower than the center conductor resistance, so the voltage drop can be approximated by:

$$V_{COAX} \approx I_{LOAD} \text{ x } 1.3R_{DC}$$

For example, if a 250 mA load current is carried over 40m of RG-59 coax (R_{DC} is 5 ohms per 100m), the voltage drop in the cable is approximately:

$$V_{COAX} \approx 250\text{mA x } 1.3\text{x}2\Omega = 0.65 \text{ volts}$$

6.14 Wake-on-Tone

Wake-on-Tone (WOT) functionality may be provided. When WOT is supported, it shall be compliant with the requirements of this subclause.

NOTE – WOT functionality may be required by specific applications.

WOT operation is modeled after Wake-on-LAN (WOL) operation as described in reference [B3]. When the BBC PMD is operating in WOT mode, it shall meet the power consumption requirements specified in [B3] section 5, and all timing requirements of [B3] sections 6. In [B3] section 6, the SD signal is optional, and the WSD signal is replaced by the PWR_STATUS signal of 6.14.1.3. An informative summary is given in the following paragraphs, the norms can be found in [B3].

6.14.1 Power consumption requirements (informative)

The BBC PMD has three power states for the transmitter, and three power states for the receiver. They are indicated in Table 7. The power states of the transmitter and receiver are independent of each other.

Power State	Description	Maximum TX current	Maximum RX current
Full	Normal data transmission/reception	60 mA	80 mA
Low	Not transmitting / Not receiving	20 µA	20 µA
Off	Transmitter off / Receiver off	0	0

Table 7. BBC PMD Power States (informative)

6.14.1.1 Transmitter operation (informative)

When the BBC PMD transmitter is in the full power state and stops receiving data to transmit from its PHY on the TX+ and TX- lines, it shall enter the low power state within 20 µs.

When the BBC PMD transmitter is in the low power state and begins receiving data to transmit from its PHY on the TX+ and TX- lines, it shall enter the full power state within 5 µs.

Consult reference [B3] for detailed timing diagrams.

6.14.1.2 Receiver operation (informative)

When the BBC PMD receiver is in the full power state and stops receiving data from the coaxial cable, it shall enter the low power state in a time of at least 50 ms but less than 128 ms.

When the BBC PMD receiver is in the low state and begins to receive toning from the coaxial cable, it shall enter the full power state within 128 ms.

Consult reference [B3] for detailed timing diagrams.

6.14.1.3 PWR_STATUS signal operation

The PWR_STATUS signal is used to indicate when the BBC PMD is in the low power state, as shown in **Figure 4**. The PWR_STATUS signal may be used to power down additional circuitry in the port including the PHY.

PWR_STATUS replaces the Wake Signal Detect (WSD) signal defined in [B3] section 6.4.

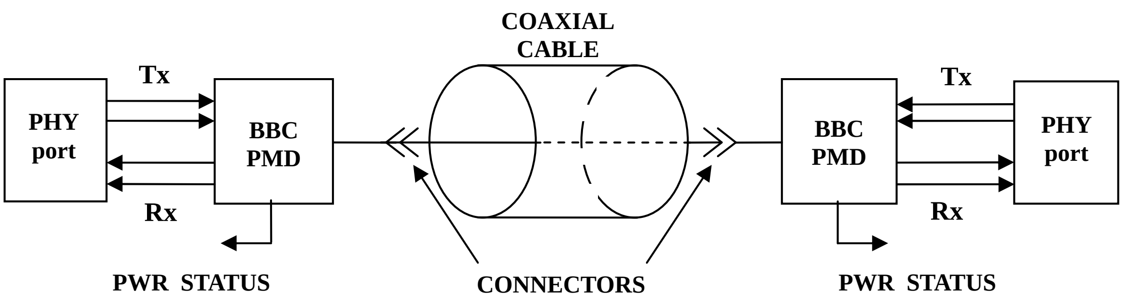

Figure 4. BBC PMD PWR_STATUS signal

The PWR_STATUS signal is active–low. It shall be asserted whenever the receiver is in the full power state and deasserted whenever the receiver is in the low power state. Figure 5 illustrates the operation of the PWR_STATUS signal.

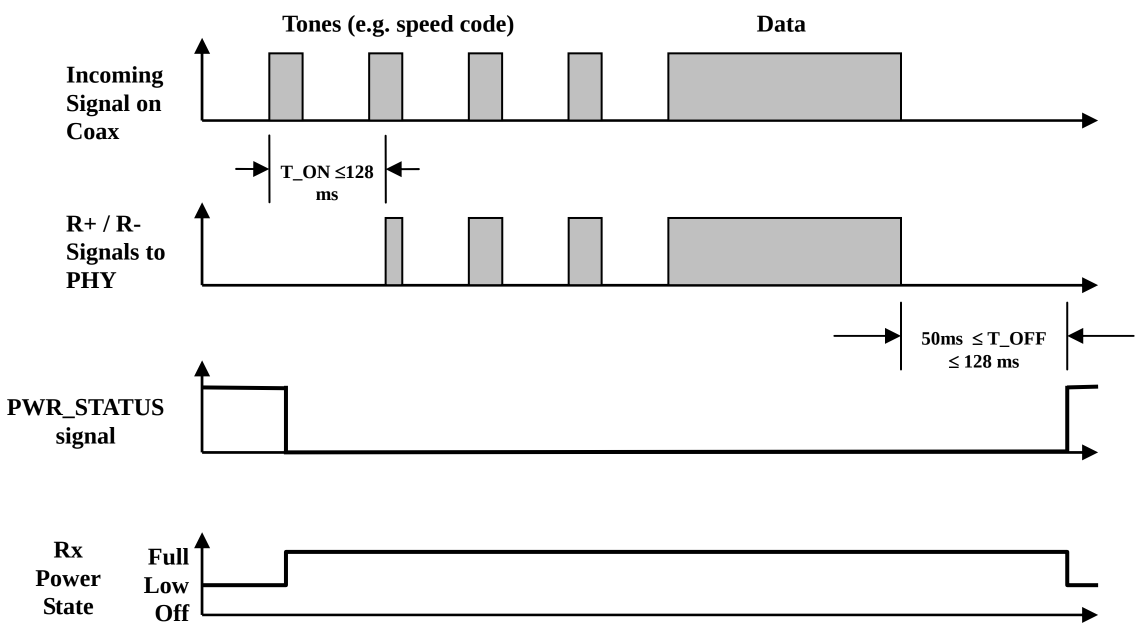

Figure 5. Operation of PWR_STATUS signal

6.15 EMC

EMC performance is a requirement for systems and equipment, not chips or interfaces. It should be noted that not all cable types can be used in all applications: the system which incorporates the BBC PMD must, at a minimum, meet all relevant CE and FCC requirements. In addition, more stringent EMC requirements may be mandated by specific applications.

6.16 Environmental

Temperature and other environmental conditions will vary for different applications. In all applications, the BBC PMD shall operate within specification over the commercial temperature range of 0 to +70 degrees C. Specific applications may require performance in more stringent conditions.

6.17 Stand-alone BBC PMD (Informative)

It is likely that first versions of the BBC PMD will not be integrated into a PHY. For a stand-alone PMD, the test points of Figure 6 are applicable. The grey test points must be compliant to the short haul copper PMD specification. The white test points must be compliant to this document.

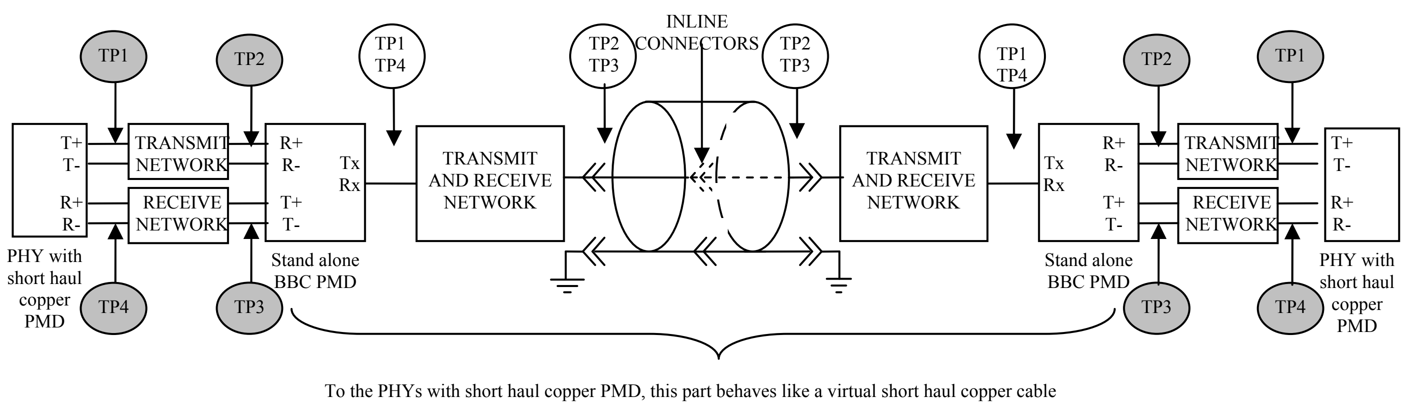

Figure 6. Test Points for Stand-Alone BBC PMD

Annex A
(normative)

Compliance Requirements

This annex is intended to assist designers, implementers, and conformance test developers; it provides a concise summary of mandatory and optional features and, for each feature, reference to the governing normative clauses.

The conformance requirements for the baseband coax PMD are divided into two parts. The coaxial cabling media shall comply with the requirements of Table 8 and the BBC PMD implementation shall comply with the requirements of Table 9.

Number	Description	Implementation	Reference
CX-1	Coaxial cable	Mandatory	5.1
CX-2	Coaxial connectors	Mandatory	5.2
CX-3	Connector return loss	Mandatory	5.2.1

Table 8 -- Coaxial cabling media requirements

Number	Description	Implementation	Reference
BBC-1	Compatibility	Mandatory	6.2
BBC-2	Cabling media	Mandatory	6.5
BBC-3	Direction of transmission	Mandatory	6.6
BBC-4	Error Rates	Mandatory	6.7
BBC-5	Data rate	Mandatory	6.8
BBC-6	Attenuation budget	Mandatory	6.9
BBC-7	Cable length	Mandatory	6.10
BBC-8	Transmitter electrical specification	Mandatory	6.11
BBC-9	Receiver electrical specification	Mandatory	6.12
BBC-10	Impedance	Mandatory	6.12.1
BBC-11	Coupling	Mandatory	6.12.2
BBC-12	Bit-error rate	Mandatory	6.12.3
BBC-13	Return loss	Mandatory	6.12.4
BBC-14	Cable power	Optional	6.13
BBC-15	Wake-on-Tone	Optional	6.14
BBC-16	Power consumption requirements	Optional	6.14.1
BBC-17	Transmitter operation	Optional	6.14.2
BBC-18	Receiver operation	Optional	6.14.3
BBC-19	PWR_STATUS signal operation	Optional	6.14.4
BBC-20	EMC	Mandatory	6.15
BBC-21	Environmental	Mandatory	6.16

Table 9 -- BBC PMD conformance requirements

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Annex B
(informative)

Bibliography

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

[B2] IEEE Std. 1394-2008, Standard for a High Performance Serial Bus

[B3] 1394 TA Document 2004024, PMD for Fiber Optic Wake-on-LAN, July 24, 2006.

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