

Specification for

ControlNet —

Part 2: Physical layer and media

ICS 25.040.40; 35.100.10

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW



Document Sharing Hub

Committees responsible for this Draft for Development

The preparation of this Draft for Development was entrusted to Technical Committee AMT/7, Monitoring and control aspects of AMT, upon which the following bodies were represented:

- ABB Kent plc
- Cegelec Industrial Controls Ltd.
- Department of Trade and Industry
- Fisher-Rosemount Ltd.
- Foxboro Great Britain
- Institution of Electrical Engineers
- Measurement Technology Ltd.
- Phoenix Contact Ltd.
- Process Automation and Computer Systems Ltd.
- Rockwell Automation Ltd.
- Schneider Ltd.
- Siemens Automation Ltd.
- University of Warwick
- Wago Ltd.

This Draft for Development, having been prepared under the direction of the Advanced Manufacturing Technology Assembly, was published under the authority of the Standards Board and comes into effect on 15 November 1997

© BSI 05-1999

The following BSI reference relates to the work on this publication:
Committee reference AMT/7

ISBN 0 580 28681 9

Amendments issued since publication

Amd. No.	Date	Comments

Contents

	Page
Committees responsible	Inside front cover
Foreword	iii
0 Introduction	1
1 Scope	1
2 PLS sublayer	2
2.1 Clock accuracy	2
2.2 Data recovery	2
2.3 Data encoding rules	2
2.4 MAC to PLS interface	3
3 PMA sublayer	5
3.1 Varies by Physical Layer variant	5
3.2 PLS to PMA interface	5
4 Media	5
4.1 Varies by Physical Layer variant	5
4.2 PMA to Media interface	5
5 Coaxial medium and its Physical Layer variant	5
5.1 General	5
5.2 Coax PMA sublayer	5
5.3 Coax transceiver	7
5.4 Environmental specifications	16
5.5 Transformer	16
5.6 Connectors	17
5.7 Topology	17
5.8 Taps	18
5.9 Trunkline	21
6 Fibre medium and its Physical Layer variant	22
6.1 General	22
6.2 Fibre PMA sublayer	22
6.3 Topology	24
6.4 Trunkline fibre	24
6.5 Trunkline connectors	24
6.6 Fibre specifications	24
7 NAP medium and its Physical Layer variant	25
7.1 General	25
7.2 PLS to PMA interface	26
7.3 NAP PMA requirements	27
8 RM sublayer and redundant Physical Layers	30
8.1 General	30
8.2 Repeater Machine (RM) sublayer	31
8.3 Redundant Physical Layer	33
Figure 2-1 — Relationship to the OSI/ISO model	1
Figure 2-2 — Bit rate for Manchester encoding	3
Figure 2-3 — Components of the coax Physical Layer variant	6
Figure 2-4 — Coax PMA block diagram	7
Figure 2-5 — Coax transmitter	8
Figure 2-6 — Coax receiver operation	9
Figure 2-7 — Transmit mask	11
Figure 2-8 — Receive mask	12

	Page
Figure 2-9 — Rx data detector	13
Figure 2-10 — RxCarrier detection	14
Figure 2-11 — Redundant coax transceiver	15
Figure 2-12 — Single channel coax transceiver	15
Figure 2-13 — Transformer symbol	16
Figure 2-14 — Topology example	17
Figure 2-15 — Coax medium topology limits	18
Figure 2-16 — Tap electrical characteristics	19
Figure 2-17 — Coax medium tap	21
Figure 2-18 — Fibre PMA block diagram	23
Figure 2-19 — Example of transient and permanent nodes	26
Figure 2-20 — NAP reference model	26
Figure 2-21 — NAP transceiver	28
Figure 2-22 — Non-isolated NAP transceiver	28
Figure 2-23 — Isolated NAP transceiver	29
Figure 2-24 — NAP Cable	30
Figure 2-25 — Physical Layer repeater device reference model	31
Figure 2-26 — Reference model for redundancy	33
Figure 2-27 — Block diagram showing coax redundancy and NAP	34
Table 2-1 — PLS timing characteristics	2
Table 2-2 — Data encoding rules	2
Table 2-3 — pls_status_indication truth table	4
Table 2-4 — Jabber indications	4
Table 2-5 — PLS to PMA interface definitions	7
Table 2-6 — Transmit control line definitions	8
Table 2-7 — Receiver data output definitions	9
Table 2-8 — Receiver carrier output definitions	9
Table 2-9 — Coax interface — transmit specifications	10
Table 2-10 — Coax interface — receive	11
Table 2-11 — Coax interface — general	12
Table 2-12 — Receiver output definitions	14
Table 2-13 — Environmental specifications (informative)	16
Table 2-14 — Transformer electrical specifications	17
Table 2-15 — Dropline cable specifications	20
Table 2-16 — Tap specification	20
Table 2-17 — Trunk cable specifications	21
Table 2-18 — PLS to PMA interface	22
Table 2-19 — Transmit control line definitions	23
Table 2-20 — Fibre interface — receive	23
Table 2-21 — Fibre interface — transmit	23
Table 2-22 — Environmental specifications	24
Table 2-23 — Fibre signal specification	29
Table 2-24 — NAP requirements	27
Table 2-25 — NAP connector pin definition	29

Foreword

The DD 241 specification was developed by the Allen-Bradley Company, Inc. as "ControlNet". Allen-Bradley has granted BSI a right to publish the specification as an open communications standard for digital communications networks in industrial control applications.

This part of DD 241 describes the General Description of the deterministic control network.

This publication consists of the following parts:

- *Part 1: General description;*
- *Part 2: Physical layer and media;*
- *Part 3: Data link layer;*
- *Part 4: Network and transport layer;*
- *Part 5: Data management;*
- *Part 6: Object model;*
- *Part 7: Device profiles;*
- *Part 8: Electronic data sheet;*
- *Part 9: Station management;*
- *Part 10: Object library.*

This Draft for Development is not to be regarded as a British Standard.

It is being issued in the Draft for Development series of publications and is of a provisional nature because the subject matter is still under development requiring wider exposure. It should be applied on this provisional basis so that information and experience of its practical application may be obtained.

A review of this Draft for Development will be carried out not later than 2 years after its publication. Notification of the start of the review period, with a request for the submission of comments from users of this Draft for Development, will be made in an announcement in *Update Standards*.

According to the replies received the responsible BSI Committee will judge whether the Draft for Development can be converted into a British Standard or what other action should be taken.

Observations which it is felt should receive attention before the official call for comments will be welcomed.

These should be sent to the Secretary of BSI Technical Committee AMT/7 at BSI, 389 Chiswick High Road, London, W4 4AL, giving the document reference and clause number and proposing, where possible, an appropriate revision of the text.

Disclaimer of warranties

This document is provided on an "as is" basis without warranty by BSI and Allen-Bradley as to the accuracy or completeness of the information it contains or as to the results which may be achieved through the use of this information. Further, BSI and Allen-Bradley are not providing any warranties as to whether products produced based on DD 241 may infringe the intellectual property rights of any third parties except that, at the date of publication, to the best of BSI's and Allen-Bradley's knowledge, no written claims have been made against BSI and/or Allen-Bradley alleging that any such products would infringe the intellectual property rights of any third parties. In no event shall BSI and/or Allen-Bradley be responsible for any losses, damages, costs or expenses incurred as a result of the information contained in DD 241.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 34 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

0 Introduction

The Physical Layer and Media clauses specify normative requirements and provide informative reference design examples for both coaxial copper and fibre media.

Clauses 5, 6, 7, and 8 represent various Physical Layer variants. Coaxial copper cable medium is used for the primary variant. Optical fibre based variants are also specified. The Physical Layer supports the inclusion of an access port connector which allows for a simple and convenient connection to the network. This is referred to as the Network Access Port (NAP) and provides a convenient point-to-point temporary attachment mechanism which can be used for programming, configuration, diagnostics or other purposes.

The Physical Layer Signalling (PLS) sublayer performs those functions related to bit representation and timing and allows information to be exchanged with the MAC sublayer and the Physical Medium Attachment (PMA) sublayer. The PMA sublayer comprises the circuitry necessary for transmission and reception of signals on the bus. The medium consists of those components, outside the device's electronic components, that convey signals from one node to another.

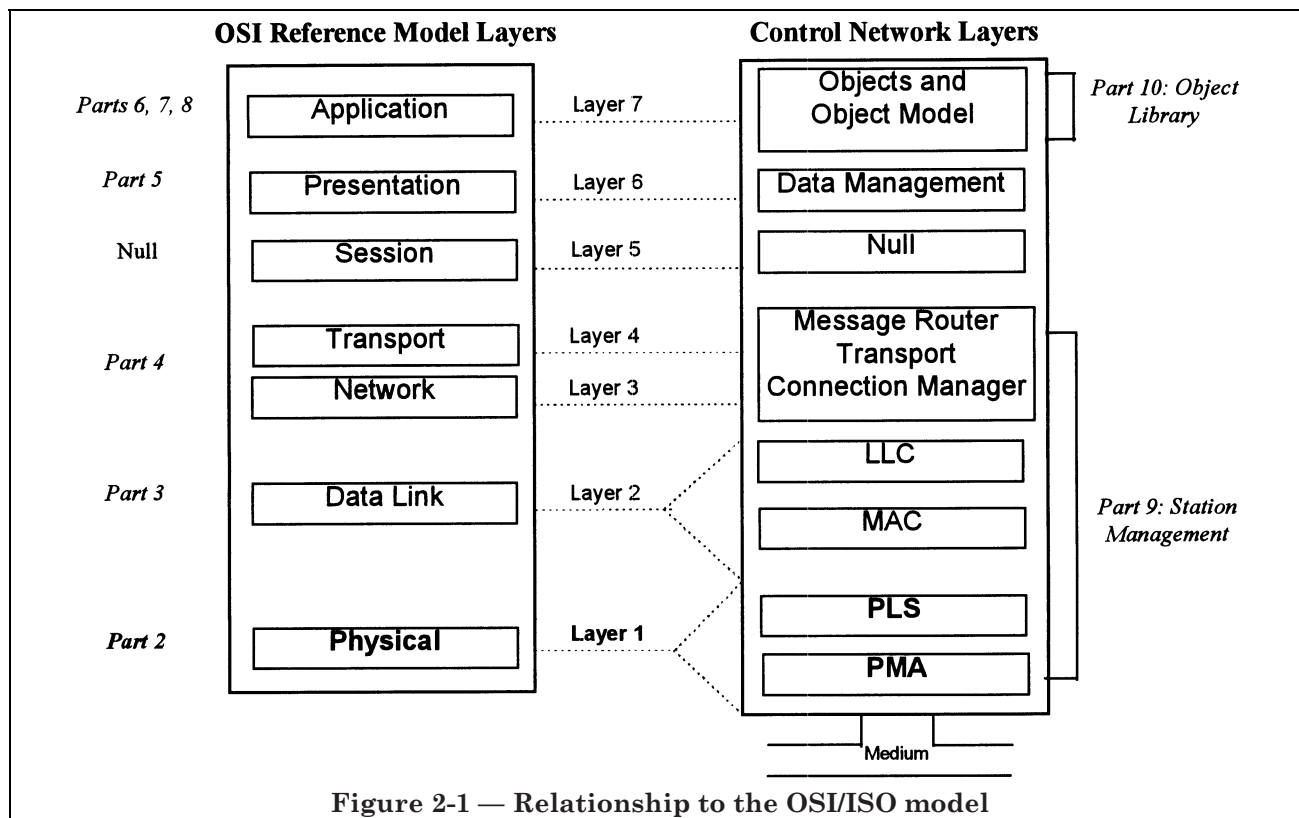
Signals and specifications are defined for three interfaces including the PLS to MAC interface, PLS to PMA interface, and the PMA to medium interface. A node may include any (or more than one) Physical Layer variant but the appropriate PMA to medium interface is provided for each Physical Layer variant implemented. This interface specifies the electrical and mechanical requirements between each medium and the PMA. This interface is exposed and accessible in any embodiment of the Physical Layer in a node.

1 Scope

This part of the standard defines the requirements for the Physical Layer of a node and the transmission media on the deterministic control network.

The Physical Layer and Media of the deterministic control network corresponds to the definition of Layer 1 of the seven layer OSI model in accordance with ISO 7498. Figure 2-1 shows the location of the Physical Layer and Media within the OSI model. This figure applies to all Physical Layer variants;

NOTE Most of the terms and models for the Physical Layer and Media were adopted from those in ISO/IEC 8802-4 or ISO 8802-3.



2 PLS sublayer

2.1 Clock accuracy

The timing specifications for Physical Layer Signalling shall be as defined in Table 2-1.

Table 2-1 — PLS timing characteristics

Specification	Limits/Characteristics	Comments
Data Rate	5 Mbit/s +/- CA	also called MAC_Symbol rate, <i>data “zero” or “one”</i>
Bit Time	200 ns +/- CA	also called MAC_Symbol time, <i>data “zero” or “one”</i>
Physical Layer symbol time	100 ns +/- CA	also called Phy_Symbol time, see data encoding rules
Clock Accuracy (CA)	+/- 150 ppm max.	including temperature, long term, and short term stability

2.2 Data recovery

The signals at the PLS to MAC interface shall be synchronised to the local Data Rate as shown in Table 2-1. Each Physical Layer (PLS Layer) implementation shall provide a data recovery mechanism that recovers or reconstructs the data received from the appropriate medium to meet the timing requirements shown in Table 2-1. When data synchronisation has been attained by the PLS, the `pls_lock_indication` shall be true.

A portion of the received data frame may be lost or discarded in the process of attaining data synchronisation. The specification for data timing shown in Table 2-1 shall be achieved prior to the beginning of the start delimiter (see Dam Link Layer, part 3, for definition of start delimiter).

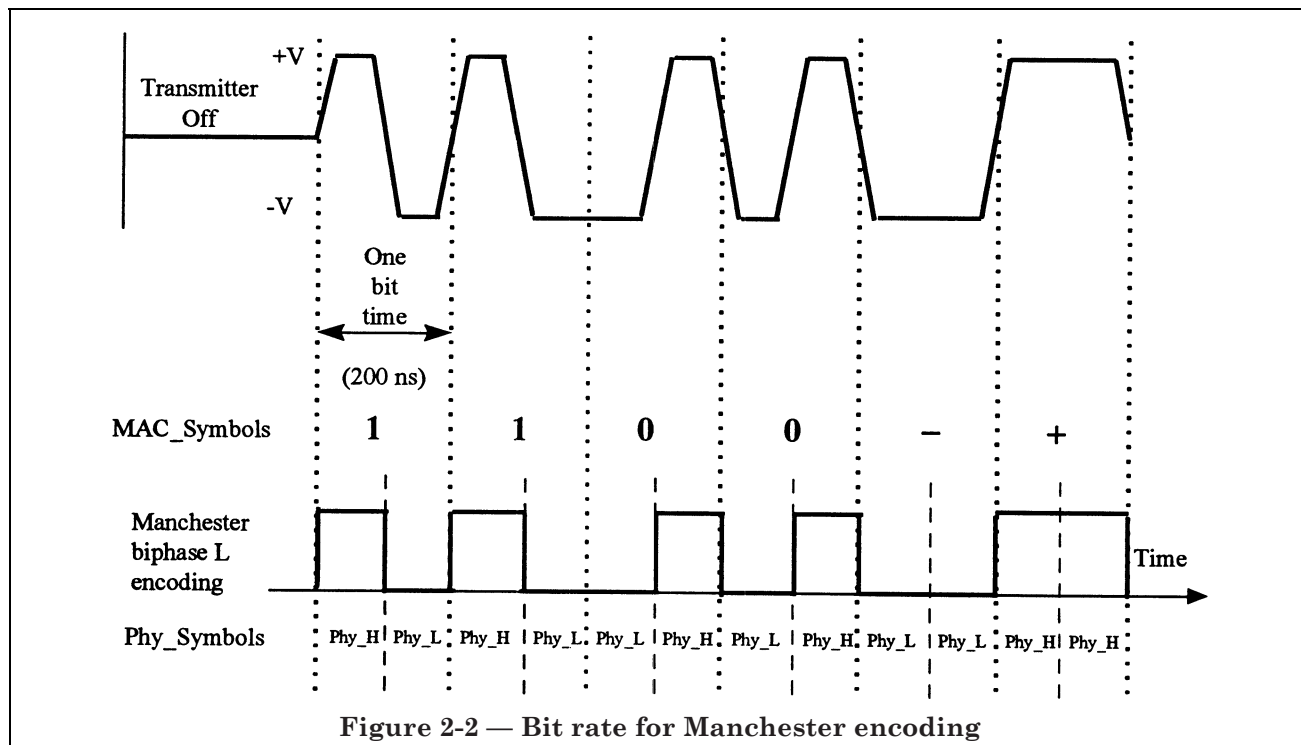
2.3 Data encoding rules

The MAC_Symbols present at the MAC to PLS interface shall be encoded into the appropriate Phy_Symbols as shown in Table 2-2 and Figure 2-2. The MAC_0 and MAC_1 shall be encoded into Phy_Symbols that represent Manchester Biphase L data encoding rules as shown in Table 2-2. The MAC_ND symbols shall be used to represent violations of the Manchester encoding rules to allow for the creation of unique data patterns used for start and end delimiters.

Table 2-2 — Data encoding rules

data bits (common name)	MAC_Symbol representation	Phy_Symbol encoding	Manchester encoded
data “zero”	MAC_0 or {0}	Phy_L, Phy_H or {L,H}	0
data “one”	MAC_1 or {1}	Phy_H, Phy_L or {H,L}	1
“non_data+”	MAC_ND+ or {+}	Phy_H, Phy_H or {H,H}	code violation
“non_data-”	MAC_ND- or {-}	Phy_L, Phy_L or {L,L}	code violation

Signal voltage waveform (from Coax PMA Sublayer) is shown below in idealised form to provide an example of the Data Encoding Rules shown in Table 2-2.



2.4 MAC to PLS interface

2.4.1 General

The MAC to PLS interface need not be exposed in the implementation of any Physical Layer variant. This interface may be internal to the node and possibly internal to a semiconductor device. If, however, conformance to the MAC to PLS interface is claimed, it shall conform to the requirements of this clause.

2.4.2 *pls_lock_indication*

pls_lock_indication shall provide an indication of data lock or *Phy_Symbol* synchronisation by the PLS sublayer. Valid states for *pls_lock_indication* shall be true and false. *pls_lock_indication* shall be true whenever valid *Phy_Symbols* are present at the PMA to PLS interface and the PLS to MAC interface timing of *MAC_Symbols* shall conform to the requirements in Table 2-1 (see Data Recovery). It shall be false between frames (when no *Phy_Symbols* are present on the medium) or whenever data synchronisation is lost or the timing fails to conform to the requirements in Table 2-1. *pls_lock_indication* shall be true prior to the beginning of the start delimiter.

2.4.3 *pls_frame_indication*

pls_frame_indication shall provide an indication of a valid data frame from the PMA sublayer. Valid states for *pls_frame_indication* shall be true and false. *pls_frame_indication* shall be true upon *pls_lock_indication* = true and reception of the first valid start delimiter. *pls_frame_indication* shall be false at reception of next *MAC_ND* symbol (following the start delimiter) or *pls_lock_indication* = false.

NOTE This signal provides byte synchronisation to the Data Link Layer.

2.4.4 *pls_carrier_indication*

pls_carrier_indication shall represent the presence of a signal carrier on the medium. The *pls_carrier_indication* shall be true if *RxCARRIER* (*RxCARRIER* = true) at the PLS to PMA interface has been true during any of the last 4 *MAC* symbol times and it shall be false otherwise (see associated PMA sublayer for definition of *RxCARRIER*).

2.4.5 *pls_data_indication*

pls_data_indication shall represent the MAC_Symbols that are decoded from the PMA sublayer Phy_Symbols as shown in Table 2-2. Valid symbols shall be MAC_0, MAC_1, MAC_ND+ or MAC_ND– (or MAC_Symbols). The *pls_data_indication* shall represent the MAC_Symbols as decoded from the PMA sublayer whenever *pls_lock_indication* is true.

2.4.6 *pls_status_indication*

pls_status_indication shall represent the status of the frame which was received from the PMA sublayer as shown in Table 2-3. Valid symbols shall be Normal, Abort, and Invalid. *pls_status_indication* shall indicate Normal after reception of a frame (*pls_frame_indication* = true) composed of a start delimiter, valid Manchester encoded data (no MAC_ND symbols) and an end delimiter, *pls_status_indication* shall indicate Abort after reception of a frame (*pls_frame_indication* = true) composed of a start delimiter, valid Manchester encoded data, and a second start delimiter, *pls_status_indication* shall indicate Invalid after reception of a frame (*pls_frame_indication* = true) composed, of a start delimiter and the detection of any MAC_ND symbol which was not part of a start or end delimiter.

Table 2-3 — *pls_status_indication* truth table

<i>pls_status_indication</i>	<i>pls_frame_indication</i>	start delimiters in a single frame	end delimiter detection	any non-delimiter Manchester violations
Normal	true	1	true	false
Abort	true	2	don't care	false
Invalid	true	1	don't care	true

2.4.7 *pls_data_request*

pls_data_request shall represent the MAC_Symbols to be transmitted. Valid symbols shall be MAC_0, MAC_1, MAC_ND+ or MAC_ND– as shown in Table 2-2. *pls_data_request* shall indicate MAC_0 when no data is to be transmitted (and *pls_frame_request* = false).

2.4.8 *pls_frame_request*

pls_frame_request shall be true when *pls_data_request* represents MAC_Symbols to be encoded to the appropriate Phy_Symbols and transferred to the PMA sublayer, and shall be false when no valid MAC_Symbols are to be transferred to the PMA sublayer.

2.4.9 *jabber_indication*

jabber_indication shall be true if the PLS to PMA interface detects a single frame (*pls_frame_indication* = true) that equals or exceeds 1 024 bytes (8 192 MAC_Symbols) and *jabber_type_request* is true. *jabber_indication* shall be true if the PLS to PMA interface detects a single frame (*pls_frame_indication* = true) that equals or exceeds 2 048 bytes (16 384 MAC_Symbols) and *jabber_type_request* is false. *jabber_indication* shall be false otherwise. If *jabber_indication* goes true, it shall be latched in this state by the PLS sublayer until the *jabber_clear_request* is true or power to the node is removed and restored or node is initialised.

2.4.10 *jabber_clear_request*

jabber_clear_request (optional) shall be false under normal operating conditions and shall be true to reset a jabber indication which has been latched in a true state.

2.4.11 *jabber_type_request*

jabber_type_request shall be true if the node is the source of transmit data (“node”) and shall be false if the node is retransmitting data received from another node (e.g., acting as a “repeater” of data from another node see clause 8.2).

The combinations for *jabber_indication* and *jabber_type_request* shall be as shown in Table 2-4.

Table 2-4 — Jabber indications

<i>jabber_indication</i>	<i>jabber_type_request</i>	frame length
true	true = “node”	> or = 1 024 bytes
true	false = “repeater”	> or = 2 048 bytes
false	true = “node”	< 1 024 bytes
false	false = “repeater”	< 2 048 bytes

3 PMA sublayer

3.1 Varies by Physical Layer variant

The PMA sublayer shall comply with the requirements specified for the appropriate Physical Layer variant as specified in clauses 5, 6 and 7.

3.2 PLS to PMA interface

The PLS to PMA interface shall comply with the requirements specified for the appropriate Physical Layer variant as specified in clauses 5, 6 and 7. This interface need not be exposed.

4 Media

4.1 Varies by Physical Layer variant

The Media shall comply with the requirements specified for the appropriate Physical Layer variant as specified in clauses 5, 6 and 7.

4.2 PMA to Media interface

The PMA to Media interface shall comply with the requirements specified for the appropriate Physical Layer variant as specified in clauses 5, 6 and 7. A node may include any (or more than one) Physical Layer variant but the appropriate PMA to Media interface shall be provided for each Physical Layer variant implemented.

5 Coaxial medium and its Physical Layer variant

5.1 General

Only one attachment method is specified for each medium. Other methods may be used but they shall conform to the same signalling and performance characteristics. If the specified coax medium attachment method is used, then it shall incorporate transformer coupling in the node and it shall use a Passive Tap for attachment to the medium. The tap shall include a 1 m drop cable.

The coax Physical Layer variant shall connect to an RG-6 coax medium with network segments up to 1 000 m long with up to 48 nodes as shown in Figure 2-15.

5.2 Coax PMA sublayer

5.2.1 Requirements

The PMA sublayer in a node shall consist of the coax transceiver, transformer, and coax connector. The transceiver shall use the signals defined in the PLS to PMA Interface to generate those necessary to drive the transformer. Attachment to the medium shall be via standard BNC connectors as specified in clause 5.6. Ground isolation shall be provided via the transformer as specified in clause 5.5. Figure 2-3 shows the components of the coax Physical Layer variant.

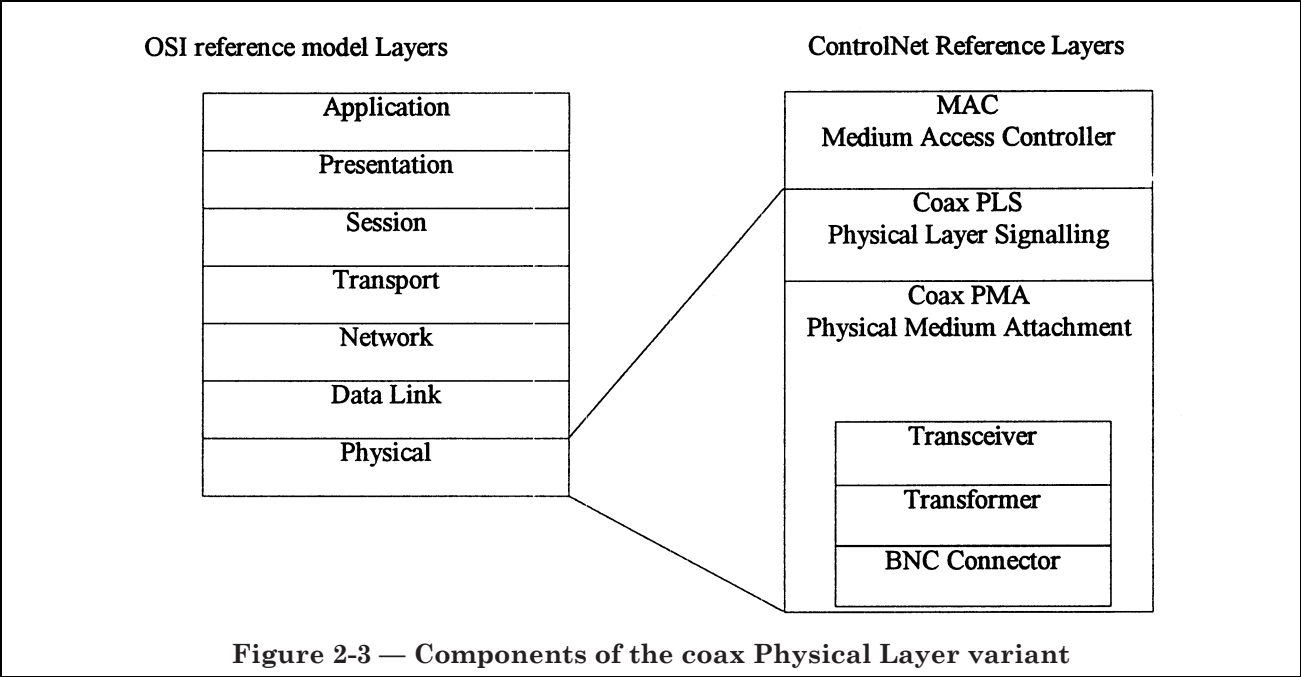


Figure 2-3 — Components of the coax Physical Layer variant

5.2.2 PLS to PMA interface

5.2.2.1 Conformance

The PLS to PMA interface need not be exposed in the implementation of any Physical Layer variant. This interface may be internal to the node and possibly internal to a semiconductor device. If, however, conformance to the PLS to PMA interface is claimed, the implementation shall conform to the requirements of this clause.

NOTE This clause lists the signals defined for the coax PLS to PMA Interface.

5.2.2.2 TxDataOut

TxDataOut shall be true to represent Phy_H from the PMA sublayer, and shall be false to represent Phy_L as shown in Table 2-5. TxDataOut shall be false when no Phy_Symbol data is to be transmitted (pls_frame_request = false)

5.2.2.3 TxDataBar

TxDataBar shall be true to represent Phy_L from the PMA sublayer, and shall be false to represent Phy_H as shown in Table 2-5. TxDataBar shall be false when no Phy_Symbol data is to be transmitted (pls_frame_request: = false)

5.2.2.4 NetEnable

NetEnable shall be true to enable the PMA sublayer for transmission of TxDataOut and TxDataBar Phy_Symbol data on the coax medium. NetEnable false shall prevent transmission of TxDataOut and TxDataBar Phy_Symbol data as shown in Table 2-5.

5.2.2.5 RxData

RxData shall represent the row, distorted, unsynchronised Phy_Symbols (Phy_H or Phy_L) as recovered from the coax medium. This signal shall be true when the voltage on the medium meets the requirements shown in Table 2-7, otherwise this signal shall be false. After data recovery and resynchronisation to meet the PLS timing requirements (from Table 2-1), these Phy_Symbols shall be decoded into the appropriate pls_data_indication MAC_Symbols as shown in Table 2-2.

5.2.2.6 RxCarrier

RxCarrier shall be true when the signal level on the coax medium exceeds the carrier detection threshold voltage shown in Table 2-8, otherwise it shall be false. This signal shall be used to create the pls_carrier_indication at the PLS to MAC interface as defined in clause 2.4.

Table 2-5 — PLS to PMA interface definitions

TxDataOut	TxDataBar	NetEnable	RxData	RxCarrier	Phy_Symbol
x	x	0	undefined	0	no transmission pls_frame_request = false
0	0	1	undefined	0	no transmission pls_frame_request = false
1	0	1	1	1	Phy_H
0	1	1	0	0	Phy_L
1	1	1	—	—	not allowed, transmitter damage may occur

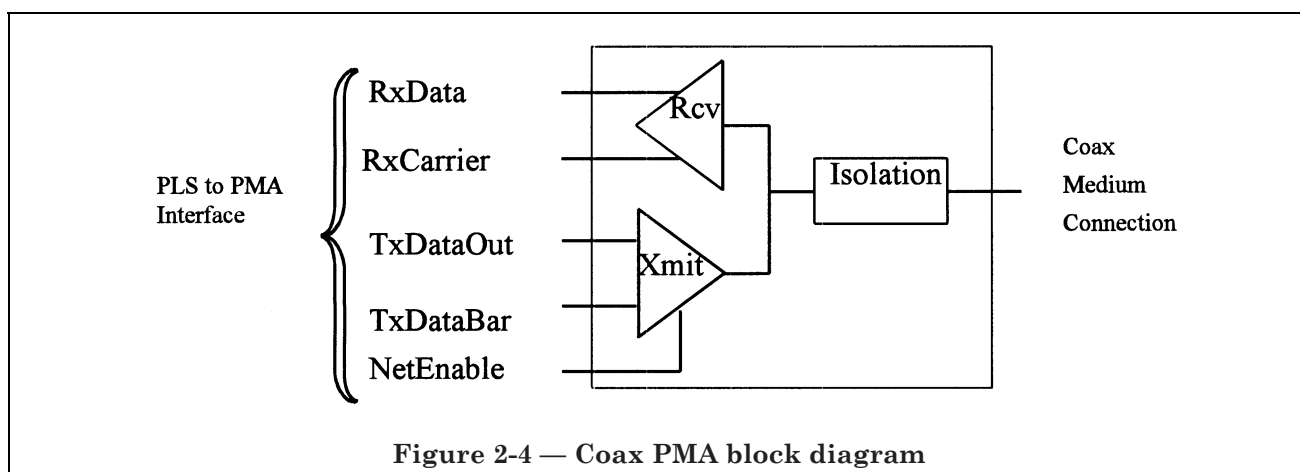
5.3 Coax transceiver

5.3.1 Requirements

When using a coax medium, a coax transceiver shall be used to transmit and receive the Phy_L and Phy_H signals. The transmitter portion of the transceiver shall obtain transmit signals from the PLS to PMA Interface, representing Phy_H and Phy_L symbols. It shall transmit a single-ended, ground isolated signal onto the cable via the isolation transformer. The complement of this function shall be performed in the receiver which shall provide RxData and RxCarrier indications to the PLS to PMA interface.

A functional block diagram depicting the PMA sublayer components is shown in Figure 2-4.

Figure 2-11 shows a schematic of a redundant coax transceiver and Figure 2-12 shows an example of a single channel coax transceiver.



In the coax PMA block diagram, Figure 2-4, the blocks labelled “Xmit” and “Isolation” combine to represent the coax transmitter. Figure 2-5 shows a simplified functional diagram of the coax transmitter.

NOTE Refer to the example schematics found in Figure 2-11 and Figure 2-12 for more detail.