XX.7 Link segment characteristics

10GBASE-T is designed to operate over a 4-pair balanced cabling system. Each of the four pairs supports an effective data rate of 2500 Mbps in each direction simultaneously. The term "link segment" used in this clause refers to four duplex channels in a single cable. The term "duplex channel" will be used to refer to a single channel with full duplex capability. The term "external channel" will be used to refer to a single channel external to the link segment. Specifications for a link segment apply equally to each of the four duplex channels. All implementations of the balanced cabling link shall be compatible at the MDI.

XX.7.1 Cabling system characteristics

The cabling system used to support 10GBASE-T requires 4 pairs of balanced cabling with a nominal impedance of 100 Ω. Additionally:

a) 10GBASE-T uses a star topology to connect PHY entities.
b) The width of the PMD transmit signal spectrum is approximately **TBD** MHz.
c) Will support up to a 4 connector link segment.
d) Will support a distance of at least 100 meters.
e) The use of shielding is outside the scope of this standard.

For a link segment less than 100 m refer to sub clause XX.7.2**.** An ISO/IEC 11801 Class **TBD** or Class F, 4 connector, and 100 meter link segment will meet the requirements of sub clause XX.7.1.

XX.7.1.1 Link transmission parameters

The transmission parameters contained in this sub clause are specified to ensure that a link segment of up to at least 100 m will provide a reliable medium. The transmission parameters of the link segment include insertion loss, delay parameters, characteristic impedance, return loss, Near End Crosstalk (NEXT) loss, Equal Level Far-end crosstalk (ELFEXT) loss, and Multiple Disturber Alien Crosstalk (MDA XTLK) between two different link segments.

Link segment testing shall be conducted using source and load impedance of 100 Ω. All values shall be limited to a maximum of 65 dB.

XX.7.1.2 Insertion loss

The insertion loss of each duplex channel shall be less than

$$\text{Insertion\_Loss}\ (f) \le 1.05 \times (1.8\sqrt{f} + 0.01f + 0.2/\sqrt{f}) + 4 \times .02 \times \sqrt{f}\ \ \text{(dB)}$$

at all frequencies from 1 MHz to 625 MHz. This includes the attenuation of the balanced cabling pairs, including work area and equipment cables plus connector losses within each duplex channel.

XX.7.1.3 Differential characteristic impedance

The nominal differential characteristic impedance of each link segment duplex channel, which includes cable cords and connecting hardware, is 100 Ω for all frequencies between 1 MHz and 625 MHz.

XX.7.1.4 Delay

In order to simultaneously send data over four duplex channels in parallel, the propagation delay of each duplex channel as well as the difference in delay between any two of the four channels are specified. This ensures the 10 Gbps data that is divided across four channels can be properly reassembled at the far-end receiver.

XX.7.1.4.1 Maximum link delay

The propagation delay of a link segment shall not exceed 570 ns at all frequencies between 2 MHz and 625 MHz.

XX.7.1.4.2 Link delay skew

The difference in propagation delay, or skew, between all duplex channel pair combinations of a link segment, under all conditions, shall not exceed 50 ns at all frequencies from 2 MHz to 625 MHz. It is a further functional requirement that, once installed, the skew between any two of the four duplex channels due to environmental conditions shall not vary more than 10 ns.

XX.7.1.5 Return loss

Each link segment duplex channel shall meet or exceed the return loss specified in the following equations at all frequencies from 1 MHz to 625 MHz.

$$\text{Return\_Loss}\,(f) \geq \begin{cases} 19 & 1 \leq f < 10 \\ 24 - 5\log(f) & 10 \leq f < 40 \\ 32 - 10\log(f) & 40 \leq f \leq 625 \end{cases} \text{ (dB)}$$

where f is the frequency in MHz.

XX.7.1.6 Internal Coupling parameters

In order to limit the noise coupled into a duplex channel from adjacent duplex channels in a link segment, Near-End Crosstalk (NEXT) loss and Equal Level Far-End Crosstalk (ELFEXT) are specified for each link segment.

XX.7.1.6.1 Near-End Crosstalk

The NEXT loss between any two duplex channels in a link segment shall be at least

$$\text{NEXT\_Loss} \geq -20\log\left(10^{\frac{74.3-15\log(f)}{-20}} + 2\times 10^{\frac{94-20\log(f)}{-20}}\right) \text{ (dB)}$$

where f is the frequency over the range of 1 MHz to 625 MHz.

XX.7.1.6.2 Equal Level Far-End Crosstalk (ELFEXT) loss

Far-End Crosstalk (FEXT) is crosstalk that appears at the far end of a duplex channel (disturbed channel), which is coupled from another duplex channel (disturbing channel) with the noise source (transmitters) at the near end. FEXT loss is defined as

$$\text{FEXT\_Loss}\,(f) = 20\log\left[V\text{pds}(f)/\,V\text{pcn}(f)\right]$$

and ELFEXT_Loss is defined as

$$\text{ELFEXT\_Loss}(f) = 20\log\left[V\text{pds}(f)/\,V\text{pcn}(f)\right] - \text{ILS\_Loss}(f)$$

where

Vpds	is the peak voltage of disturbing signal (near-end transmitter)
Vpcn	is the peak crosstalk noise at far end of disturbed channel
ILS_Loss	is the insertion loss of disturbed channel in dB.

The worst pair ELFEXT loss between any two duplex channels in a link segment shall be greater than:

$$\text{ELFEXT\_Loss} \geq -20\log\left(10^{\frac{67.8-20\log(f)}{-20}} + 4\times 10^{\frac{83.1-20\log(f)}{-20}}\right) \text{ (dB)}$$

where f is the frequency over the range of 1 MHz to 625 MHz.

XX.7.1.7 External Coupling parameters

The crosstalk coupled from an external channel to the link segment is referred to as Alien crosstalk. Since the transmitted symbols from the external channel are not available for cancellation it is difficult to cancel the alien crosstalk. In order to meet the symbol error rate objective specified in sub clause XX.1 the alien crosstalk is specified to meet the requirements of XX.7.2.7.2 and XX.7.2.7.3.

XX.7.1.7.1 Multiple Disturber Alien Crosstalk

Since multiple disturber channels can couple into the disturbed duplex channel, the alien crosstalk for any duplex channel in a link segment is determined by summing the magnitude of the individual crosstalk from all the external channels over the frequency range 1 to 625 MHz:

$$\text{MDA\_Crosstalk\_Loss}(f) = -10\log\sum_{I-1}^{I=N} 10^{\frac{-A\_XTLK(f)^I}{10}}$$

where

A_XTLK(f)^I	is the magnitude of Alien Crosstalk loss at frequency f of the disturbed duplex channel and the external disturbing channel I.
I	is the external channel.
N	is the number of external channels.

XX.7.1.7.2 Multiple Disturber Alien Near-End Crosstalk

The worst pair MDA_NEXT loss for any duplex channels in a link segment shall be greater than:

$$\text{MDA\_NEXT\_Loss}(f) \geq 60 - 15\log(f/100) \quad \text{(dB)}$$

where f is the frequency over the range of 1 MHz to 625 MHz.

XX.7.1.7.3 Multiple Disturber Alien Equal Level Far-End Crosstalk

TBD

XX.7.1.8 Background Noise

In addition to coupling noise from external channels an additional background or gaussian noise will be present. In order to meet the symbol error rate objective specified in Clause XX.1 the background noise shall not exceed –150 dBm/Hz.

XX.7.2 Alternative cabling requirements

10GBASE-T is designed to operate up to a 100 m over a 4-pair and 4 connector cabling system as defined in ISO/IEC 11801. Cabling systems that meet or exceed the requirements in sub clause XX.7.1 are recommended for new installations. It is possible that existing installations may support the operation of 10GBASE-T at distances of less than or equal to 100 meters. This sub clause provides cabling requirements for those installations.

XX7.2.1 Link segment characteristics

The cabling system used to support 10GBASE-T requires 4 pairs of balanced cabling with a nominal impedance of 100 Ω. The cabling system components (cables, cords, and connectors) used to provide the link segment shall consist of components as specified in ISO/IEC 11801.
Additionally:

1) The link segment will be less than 100 meters
2) Consist of at least 2 connectors.

An ISO/IEC 11801 Class E, 55 meter, and 4 connector link segment will meet the requirements of this sub clause.

XX7.2.2 Link transmission parameters

The transmission parameters of the link segment include insertion loss, delay parameters, characteristic impedance, return loss, NEXT loss, ELFEXT loss, and MDA XTLK loss.

NEXT loss, ELFEXT loss, and MDA NEXT loss requirements specified in sub clause XX.7.1 are defined for duplex channels whose insertion loss is that defined in sub clause XX.7.1.2, the maximum for a 100 meter link segment. Those requirements may be relaxed for distances of less than 100 meters. For every 1 dB decrease in insertion loss at 250 MHz the MDA NEXT may be reduced by 1 dB, the link segment NEXT requirement can be reduced by 0.5 dB, and the link segment ELFEXT can be reduced by 0.25 dB.

A link segment whose insertion loss at 250 MHz is 13.5 dB less than that specified in sub clause XX.7.1.2 shall meet the requirements of sub clause XX.7.1 with the following exceptions:

a. The NEXT loss requirement may be relaxed by 6.75 dB.
b. The ELFEXT loss requirement may be relaxed by 3.38 dB.
c. The MDA NEXT loss requirement may be relaxed by 13.5 dB.