69.2.4 Auto-Negotiation

Auto-Negotiation shall be implemented in all 802.3.ap PHY devices. The use of Auto-Negotiation is optional and parallel detection shall be provided for legacy devices that do not support Auto-Negotiation.

Auto-Negotiation provides a linked device with the capability to detect the abilities (modes of operation) supported by the device at the other end of the link, determine common abilities, and configure for joint operation.

Auto-Negotiation for backplane Ethernet is based on the Clause 28 definition of Auto-Negotiation for twisted-pair link segments. Since the connection of twisted-pair and backplane physical layer signaling systems is not expected, Auto-Negotiation for backplane Ethernet utilizes an extended base page and next page format and modifies the timers to allow rapid convergence. Furthermore, Auto-Negotiation does not utilize Fast Link Pulses (FLPs) for link code word signaling and instead uses a signaling more suitable for electrical backplanes.

Auto-Negotiation for backplane Ethernet is defined in Clause 73

69.2.5 Management

Managed objects, attributes, and actions are defined for all backplane Ethernet components. Clause 30 consolidates all IEEE 802.3 management specifications so that 10/100/1000 Mb/s and 10 Gb/s agents can be managed by existing network management stations with little or no modification to the agent code.

69.3 Interconnect Characteristics (informative)

69.3.1 Overview

Backplane Ethernet links are primarily intended as point-to-point interfaces of up to 1m using differential controlled impedance traces on low-cost printed circuit boards (PCBs) between integrated circuits residing on different boards residing in a backplane environment. The performance of such interfaces is highly dependent on the specific implementation.

69.3.1.1 Reference model

The interconnect reference model is shown in Figure 69–2. Informative characteristics and methods of calculation for the channel insertion loss, crosstalk, and ratio of channel insertion loss to crosstalk between TP1 and TP4 are defined in 69.3.3.1, 69.3.4 and 69.3.5**.** TP1 exists at the edge of the transmitter, while TP4 exists at the edge of the AC coupling network closest to the connector plug side.

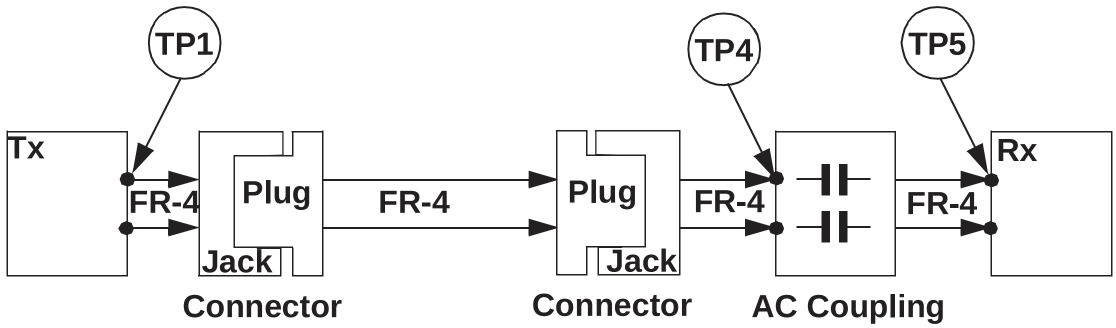

Figure 69–2— Interconnect reference model

69.3.2 Characteristic impedance

The recommended differential characteristic impedance of circuit board trace pairs is 100 ohms +/- 10%.

The total differential skew from TP1 to TP4 is recomended to be no more than 20ps.

69.3.3 Overview of Channel Model Parameters

A series of models have been created to evaluate a channel. These models address the channel insertion loss parameters and crosstalk. The maximum amount of insertion loss (ILDmin) is defined by 69.3.3.1 The amount of attenuation (Amin) due to trace skin effect and dielectric properties is defined by 69.3.3.2. The amount of deviation from the actual insertion loss in comparison to the attenuation (IDF) is defined by 69.3.3.3. The limit on crosstalk in relation to insertion loss (ICR) is defined by 69.3.3.4.

To enable system tradeoffs for the designer a series of confidence curves have been created for the different parameters. All of the different parameters must be considered together in evaluating the overall channel performance.

69.3.3.1 Insertion loss

The insertion loss is defined as the magnitude, expressed in decibels, of the differential response measured from TP1 to TP4. It is recommended that IL(f) limits be evaluated together with ICR limits and ILD(f) limits to assess risk of channel operation.

It is recommended that the insertion loss magnitude, IL(f), be greater than the lower limit defined by Equation (69–1).

(69–1)

$$IL(f) \le IL_{min}(f) = A_{min}(f) + \left| \begin{array}{l} -(1.1 + f*9.0*10^{-10}\,\mathrm{sec}),\ f_1 \le f \le f_2 \\ -(1.1 + f_2*9.0*10^{-10}\,\mathrm{sec} + (f - f_2)*2*10^{-8}\,\mathrm{sec}),\ f_2 \le f \le f_{max} \end{array} \right.$$

where the values of f1, f2, are fmax are given in Table 69–2 and the attenuation limit $A_{min}(f)$ is given in Equation (69–3).

To achieve a higher confidence level, "green limit area", for IL(f) it is recommended that the insertion loss magnitude, IL(f) be greater than the lower limit defined by Equation (69–2)

(69–2)

$$IL(f) \le IL_{\min}(f) = A_{\min}(f) - \begin{cases} (0.8 + f * 2.0 * 10^{-10}\ \text{sec}), & f_1 \le f \le f_2 \\ (0.8 + f_2 * 2.0 * 10^{-10}\ \text{sec} + (f - f_2) * 10^{-8}\ \text{sec}), & f_2 \le f \le f_{\max} \end{cases}$$

A gray or lower confidence insertion loss area is defined between the first set of recommended lines Equation (69–1) and the "green limit area" for IL(f). The insertion loss limit and respective green and gray areas are illustrated in Figure 69–2.

In addition, it is recommended that the insertion loss also satisfy the attenuation limit defined in 69.3.3.1 and the insertion loss deviation limit defined 69.3.3.2. The insertion loss limit is illustrated in Figure 69–2.

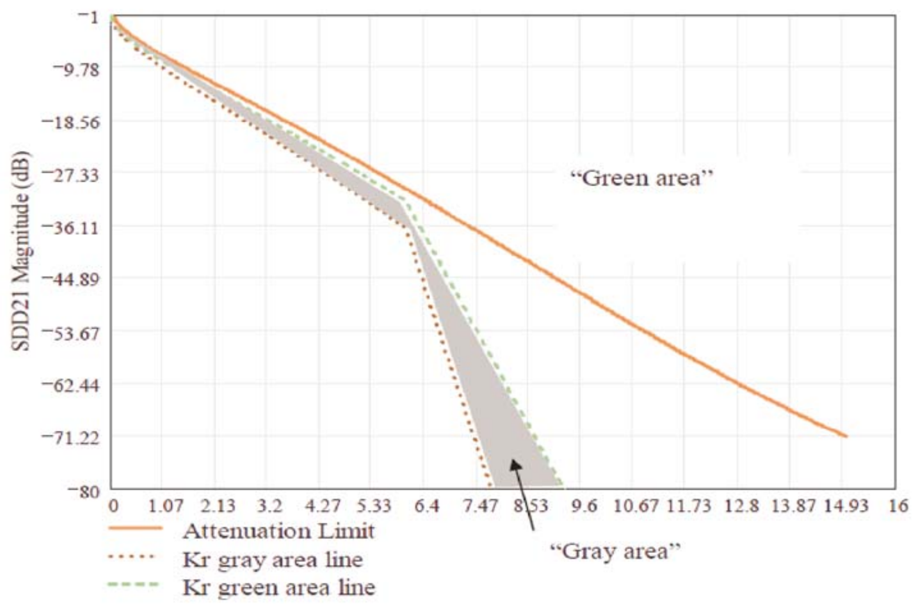

Figure 69–3— Insertion loss and attenuation limits for 10GBASE-KR

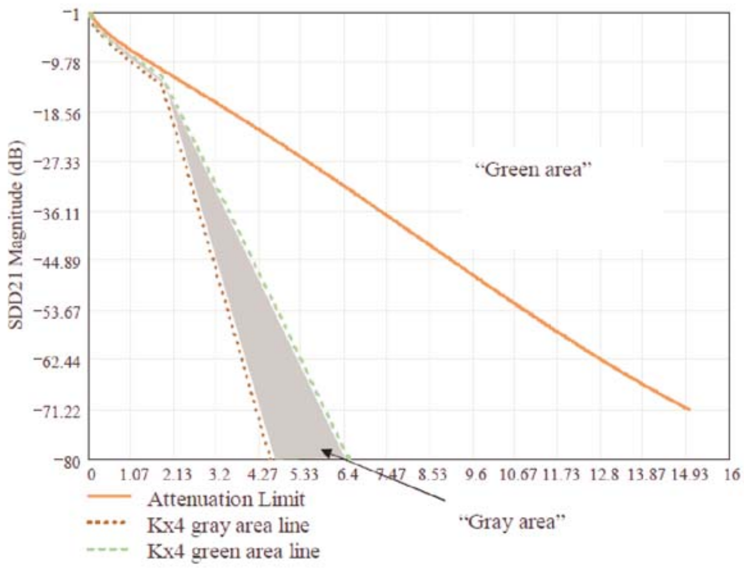

Figure 69–4— Insertion loss and attenuation limits for 10GBASE-KX4

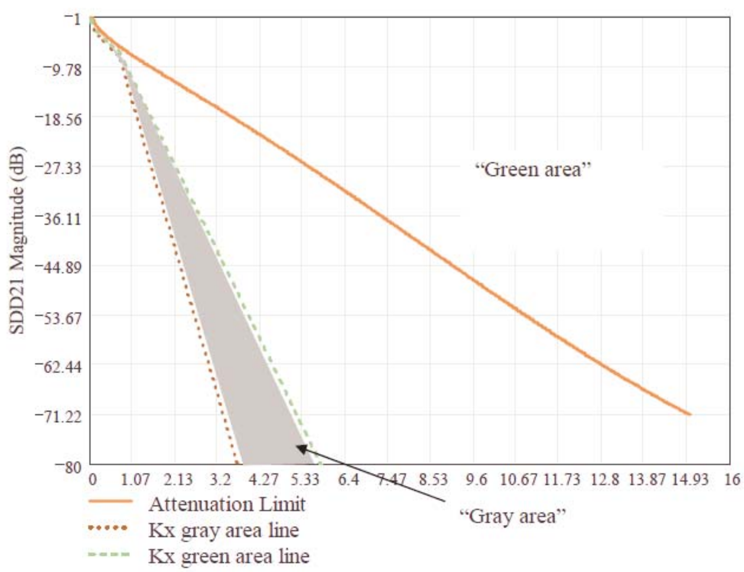

Figure 69–5— Insertion loss and attenuation limits for 1000BASE-KX

69.3.3.2 Attenuation

The attenuation, A(f) is defined to be least mean squares line fit to the insertion loss computed over the frequency range f_1 to f_2. It is recommended that attenuation of the channel be greater than the worst-case attenuation limit described by the equation:

$$A(f) \geq A_{min}(f) = -20\log(e) \cdot (b_1\sqrt{f} + b_2 f + b_3 f^2 + b_4 f^3), f_{min} \leq f \leq f_{max} \quad (69\text{–}3)$$

where f is expressed in Hz and the coefficients b_1 through b_4 are given in Table 69–2. The worst-case attenuation limit is illustrated in Figure 69–3.

69.3.3.3 Insertion loss deviation

The insertion loss deviation is defined the follow equation to be the difference between the insertion loss and the least mean squares line fit defined in 69.3.3.2 over the frequency range f1 to f2.

(69–4)

$$ILD(f) = IL(f) - LMS\_fit(f)$$

The *LMS_fit(f)* is defined as

$$slope = m = \frac{\sum_{i=F1index}^{F2index}[f_i - f_{avg}]*[IL(f_i) - IL_{avg}]}{\sum_{i=F1index}^{F2index}[f_i - f_{avg}]^2}$$

$$b = IL_{avg} - m * f_{avg}$$

$$LMS\_fit(f) = m * f + b$$

The insertion loss deviation, ILD(f) is recommended to be constrained within the limits defined by the equations

(69–5)

$$ILD(f) \geq ILD_{\min}(f) = -(2.1 + f * 0.9 * 10^{-9}\ \mathrm{sec}),\ f_1 \leq f \leq f_2$$
$$ILD(f) \leq ILD_{\max}(f) = 1.5 + f * 1.0 * 10^{-9}\ \mathrm{sec},\ f_1 \leq f \leq f_2$$

A high confidence, "green limit area", for ILD(f) may be constrained by the following equations

(69–6)

$$ILD(f) \geq ILD_{\min}(f) = -(1.0 + f * 0.5 * 10^{-9}\ \mathrm{sec}),\ f_1 \leq f \leq f_2$$
$$ILD(f) \leq ILD_{\max}(f) = 1.0 + f * 0.5 * 10^{-9}\ \mathrm{sec},\ f_1 \leq f \leq f_2$$

where the values of f1 and f2 are given in Table 69–2. A gray or lower confidence area is defined by the equation set in Equation (69–5) and the green limit area is defined by the equation set in Equation (69–6).The insertion loss limit deviation is illustrated in Figure 69–6. It is recommended that ILD(f) limits be evaluated together with ICR limits and AF(f) limits to assess risk of channel operation.

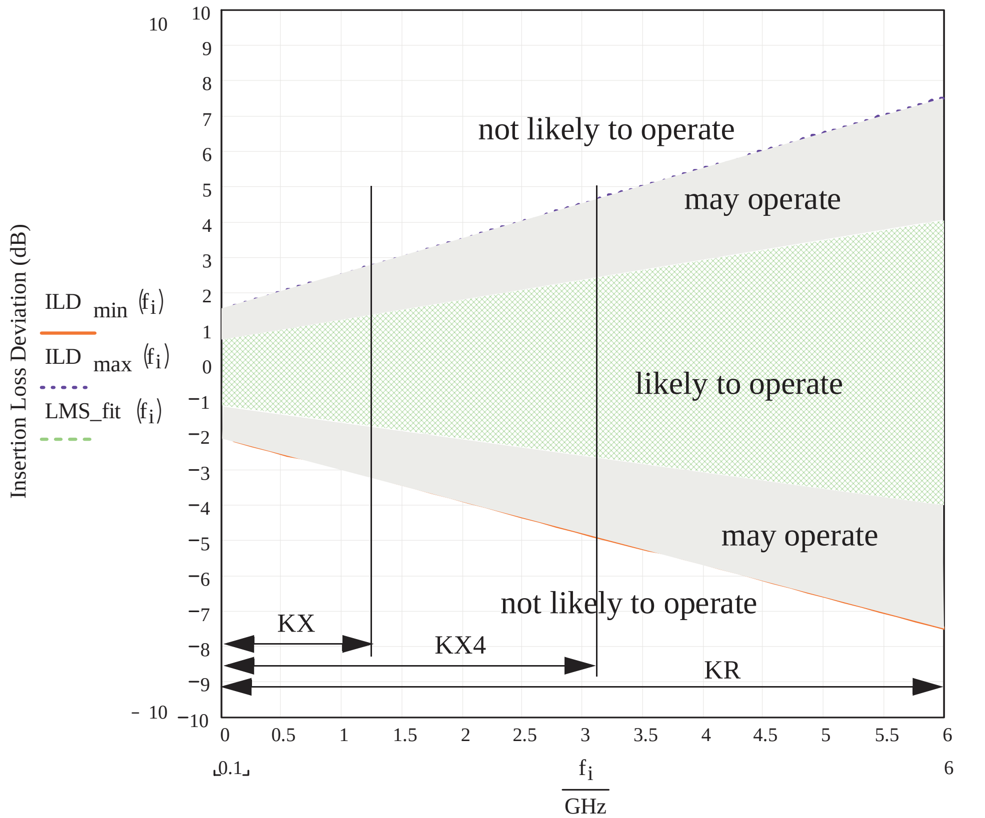

Figure 69–6— Insertion loss and deviation limits

69.3.3.4 Insertion loss parameters

Table 69–2 summarizes all parameters related to the channel insertion loss.

Table 69–2—Insertion loss parameters

Parameter	KX Value	KX4 Value	KR Value	Units
fmin	0.05			GHz
fmax	15			GHz
b1	2.25E-0.5			
b2	1.20E-10			
b3	3.50E-20			
b4	–1.25E-30			
f1	0.125	0.312	1	GHz
f2	1.25	3.125	6	GHz
Gray Maximum Peak Attenuation, $IL_{min}(f)$	$A_{min}(f) - \begin{cases} (1.1 + f * 9.0 * 10^{-10}\ \text{sec}), & f_1 \le f \le f_2 \\ (1.1 + f_2 * 9.0 * 10^{-10}\ \text{sec} + (f - f_2) * 2 * 10^{-8}\ \text{sec}), & f_2 \le f \le f_{max} \end{cases}$			dB
Gray Positive Peak Deviation, $ILD_{max}(f)$	$1.5 + f * 1.0 * 10^{-9}\ \text{sec},\ f_1 \le f \le f_2$			dB
Gray Negative peak Deviation , $ILD_{min}(f)$	$-(2.1 + f * 0.9 * 10^{-9}\ \text{sec}),\ f_1 \le f \le f_2$			dB
Green, Maximum Peak Attenuation, $IL_{min}(f)$	$A_{min}(f) - \begin{cases} (0.8 + f * 2.0 * 10^{-10}\ \text{sec}), & f_1 \le f \le f_2 \\ (0.8 + f_2 * 2.0 * 10^{-10}\ \text{sec} + (f - f_2) * 10^{-8}\ \text{sec}), & f_2 \le f \le f_{max} \end{cases}$			dB
Green, Positive Peak Deviation, $ILD_{max}(f)$	$1.0 + f * 0.5 * 10^{-9}\ \text{sec},\ f_1 \le f \le f_2$			dB
Green Negative peak Deviation , $ILD_{min}(f)$	$-(1.0 + f * 0.5 * 10^{-9}\ \text{sec}),\ f_1 \le f \le f_2$			dB

69.3.4 Crosstalk

In order to limit the crosstalk at the receiver of the link segment, the total differential crosstalk due to NEXT and FEXT aggressors has been specified in order to meet the BER objective stated in 69.1.2.

69.3.4.1 Total Differential Near-End Crosstalk (NEXT)

The total differential near-end crosstalk at the receiver (in dB with f in MHz) shall be calculated as the power sum of the individual NEXT aggressors. For cases of a single NEXT aggressor, the total differential near-end crosstalk at the receiver will be equal to the individual aggressor (in dB with f in MHz).

$$TNEXT(f) = 10\log\left(\sum_n \left|NEXT_n(f)\right|^2\right) \quad (69\text{–}7)$$

69.3.4.1.1 Total Differential Far-End Crosstalk (FEXT)

The total differential far-end crosstalk at the receiver (in dB with f in MHz) shall be calculated as the power sum of the individual FEXT aggressors. For cases of a single FEXT aggressor, the total differential far-end crosstalk at the receiver will be equal to the individual aggressor (in dB with f in MHz).

$$TFEXT(f) = 10\log\left(\sum_{n}\left|FEXT_{n}(f)\right|^{2}\right) \tag{69–8}$$

69.3.4.1.2 Total Differential Crosstalk

The amount of differential crosstalk at the receiver from NEXT and FEXT aggressors (in dB with f in MHz) shall be calculated as the power sum of the total differential aggressor near-end crosstalk Equation (69–7) renumber) and the total differential far-end crosstalk (Equation (69–8)).

$$PSXT(f) = 10\log\left(10^{\frac{TNEXT(f)}{10}} + 10^{\frac{TFEXT(f)}{10}}\right) \tag{69–9}$$

The amount of differential crosstalk at the receiver from a single aggressor (in dB with f in MHz) should be less than

69.3.5 Insertion Loss - Crosstalk Ratio (ICR)

The ratio of the insertion loss, IL, measured from TP1 to TP4 to the total differential crosstalk (in dB with f in MHz) shall be calculated using Equation (69–10).

$$ICR(dB) = IL - PSXT(f) \tag{69–10}$$

The ICR at the receiver (in dB with f in MHz) should be at least

$$ACR(dB) \geq 12.5 - 20\log_{10}\left(\frac{f}{5GHz}\right), f = 0.1...kGHz \tag{69–11}$$

For 1000BASE-KX - k = 1.25 GHz
For 10GBASE-KX4 -k = 3.125 GHz
For 10GBASE-KR - k = 5 GHz

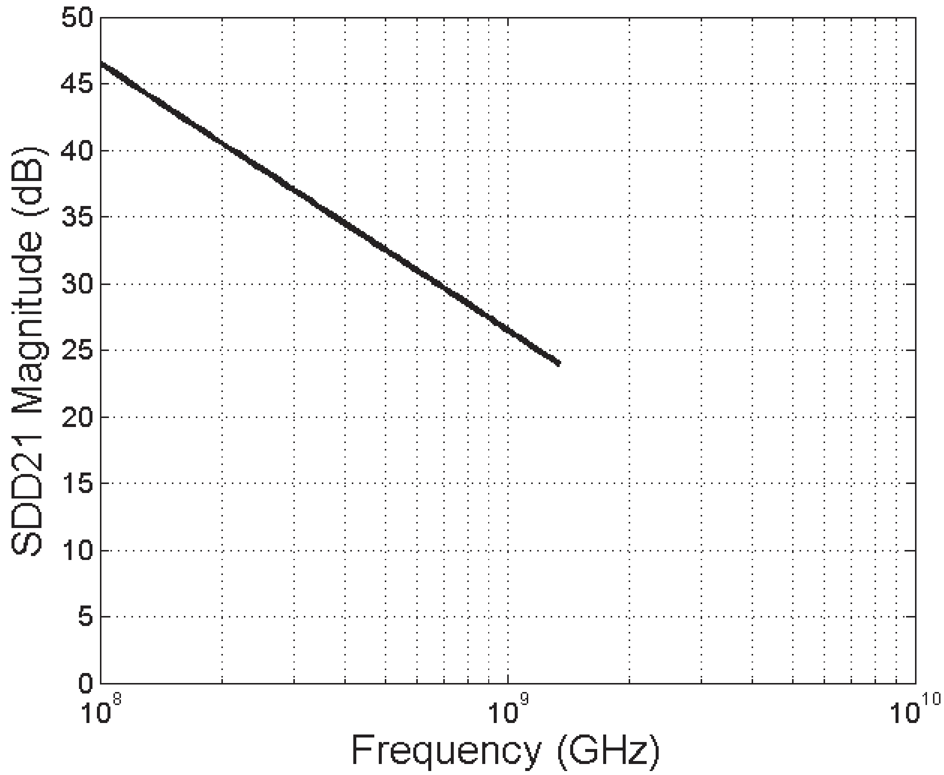

Figure 69–7—Insertion Loss – Crosstalk Ratio 1000BASE-KX

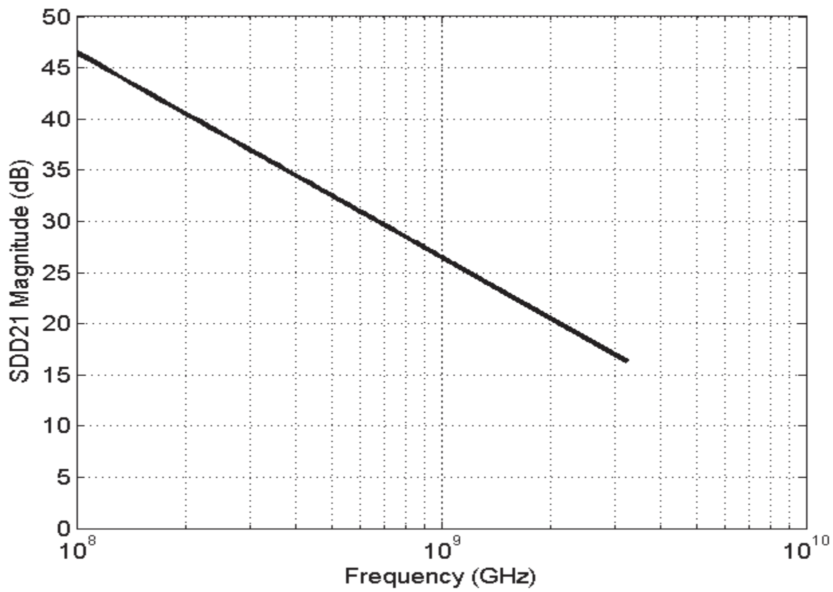

Figure 69–8—Insertion Loss – Crosstalk Ratio 10GBASE-KX4

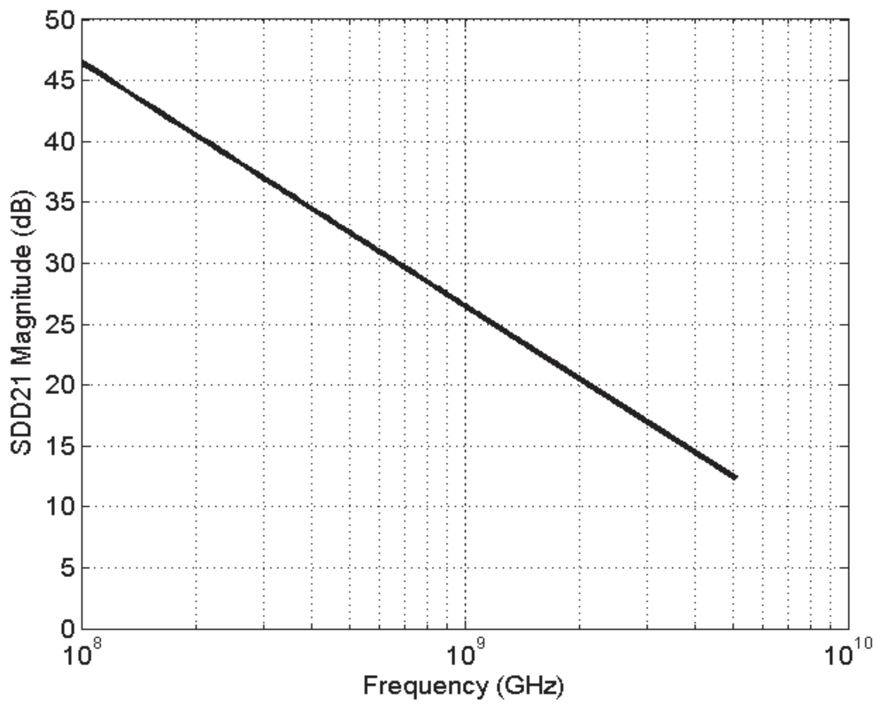

Figure 69–9—Insertion Loss – Crosstalk Ratio 10GBASE-KR