TECHniques™
Application Notes From Communications Specialties

UNDERSTANDING THE CONCEPT OF "dB" AS A MEASUREMENT OF SYSTEM LOSS

MARKET: General Fiber Optics **DOC. NUMBER: T-22**

Overview:

One of the specifications used when describing a fiber optic transmission system is the allowable "system loss", measurable in a unit called "dB" (decibels). In simple terms, this specification describes the maximum percentage of signal strength that can be lost from the point where a signal is launched by a fiber optic transmitter until the signal reaches and enters the fiber optic receiver. However, the concept of what loss in "dB" represents and how it is calculated can be a bit confusing. The following TECHnique is designed to help demystify how a "dB" value is calculated and to clearly explain the relationship between the dB number and the percentage of signal lost during the transmission process.

Details:

As just described, system loss, measured in dB, describes the ratio between the strength of signal launched by a transmitter and the strength of that signal as it exits the fiber at the receiver. Along the path from transmitter to receiver there are various factors that contribute to the diminishing of signal strength. The type of fiber used, the type of connectors used, the wavelength of the transmitted signal, and several other factors all contribute to how much or little of the original signal ultimately reaches and can be processed by the system's receiver. This article does not address the level to which each of these factors contributes to signal loss. For this discussion, it is sufficient to simply understand that these types of factors contribute to a weakening of signal strength as it passes through the system. Now let's get into the specifics of how loss, in dB, is calculated.

Hypothetically, let's pretend that we have a device that measures the strength or power of a signal as it is launched by a fiber optic transmitter in "imaginary units" — "IUs" for short. We'll use this same device to measure signal strength as it reaches the receiver.

In our first example, the launched signal is measured at a strength of 100 IUs. When it reaches and exits the receiver, it has a strength of 50 IUs. The first step in calculating signal loss in dBs is to determine the ratio between the second number (50) and the first one (100). In this case, that ratio is 50:100, which equals 1:2, ½ or .5. In other words, the signal that reaches the receiver is half as strong as when it was launched along its transmission path.

Here's where it may get confusing. Rather than describe the loss in terms of this ratio, we now apply a function to the ratio, and the resulting number is what we use to describe the loss. The function we apply to the ratio is:

$$\textbf{Gain (dB)} = 10 \log \frac{P\ out}{P\ in}$$

What does this really mean? First of all, the "Gain" at the front of the equation indicates that this function is used not only to measure system loss, but also to measure system gain – or an increase in power. In some instances, such as when amplifiers are used, a system may have a net gain instead of loss. However, when the number we end up with is negative, as it will be in our example, it means we have a negative "gain" – or, in other words, a "loss."

Now, let's look at the function to the right of the equal sign. As it applies to our example, "P out" means the power or signal strength that exits or comes "out" of the fiber. "P in" means the strength of the signal that is put "in" to the fiber. So, "P out/P in" really just refers to the ratio that we already calculated. In our example, it's ½ or .5.

Substituting ".5" in place of "P out/P in", we now we have an equation that says:

$$\textbf{Gain (dB)} = 10 \log .5$$

Finally, we have to apply the log function to the number .5, and then multiply it by 10. How do you calculate the Log of .5? Get your hands on a cheap, scientific calculator that has a "Log" function key on

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Equation From Previous Page:
Gain (dB) = 10 Log .5

it. Just type in ".5", hit the Log key, and you get -.301. (It would be virtually impossible to figure this out without the help of a calculator.) Multiply -.310 by 10 and you end up with -3.1. Our ratio of "1/2" translates to -3.1 dB. Our system loss is therefore –3.1 dB.

Using the same math process, the following table shows what the loss would be in dB as a function of the ratio between original launched signal strength and signal strength reaching the receiver.

IU = Imaginary Units

A:. Stregth of Signal at Transmission (in IUs)	B: Strength of Signal Reaching Receiver (in IUs)	Ratio of A:B	Loss in dB
100	50	.5	-3.01
100	40	.4	-3.98
100	30	.3	-5.23
100	20	.2	-6.99
100	10	.1	-10.00
100	5	.05	-13.01
100	3	.03	-15.23
100	2	.02	-16.99
100	1	.01	-20.00

What's important to understand from looking at this table is the relationship between the numbers in the third and fourth columns. As the ratio in the third column decreases – meaning less and less signal is reaching the receiver – the dB number also decreases. The dB value is another way of expressing this ratio.

When looking at the specifications for fiber optic transmission systems, a range or loss budget, in dBs, is usually given for the maximum allowable transmission loss. For some systems, the allowable loss may be as low as 0 to -3 dB. For other systems, the number may be as great as -30 dB. It all depends on the specific system, the components being used, the type and number of signals being transmitted, the type of fiber, and many other considerations. However, after reading this article, you should now understand the basics of what that number means. For example, a maximum system loss of -6.99 dB means that the signal reaching the system receiver must be at least 1/5th (20/100s) as strong as the original, launched signal. (See above chart.) If it becomes any weaker than that, the system will not be able to function.

As explained at the beginning of this TECHnique, there are many factors that contribute toward system loss. Refer to *TECHnique 21, Calculating Maximum Transmission Distance for Fiber Optic Systems,* for an introduction to these issues. Also, it should be noted that the term dB is not limited to use in measuring system loss for fiber optic systems. It is used throughout the worlds of engineering and electronics to measure the loss (or gain) of almost any type of signal.

CSI Products Used in this TECHnique:

All Fiberlink® and Pure Digital Fiberlink® transmission modules

Related TECHniques

- TECHnique 21, Calculating Maximum Transmission Distance for Fiber Optic Systems
- Education Guide: *Introduction to Fiber Optics*
- Educational Guide: *Introduction to Fiber Optic Cables and Connectors*
- Education Guide: *Why Digital? Advantages of Digital Transmission Over Fiber*

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