Got Datacom Questions? ASK BO!

Bo Conrad knows the difference between theory and practice. He has been an integral contributor for TIA/EIA international datacom standards committees and a VDV design consultant for Intel and Hewlett-Packard. He will answer your questions here in future issues of POWER OUTLET– e-mail questions to poweroutlet@rexelusa.com.

By D.A. "Bo" Conrad

Metrics & Cabling

Question

Could you give a basic, clear explanation of metrics as it applies to datacom cabling?

Did you know NASA's first bazillion-dollar Mars Lunar Landing module went crashing into the Mars surface? Why? Because the coordinates were sent in meters from satellites abroad – and here in the States they were interpreted as feet. Subsequently, the guidance system was given the wrong data for its descent entry.

Hey! If scientists can get this wrong, so can cabling installers, estimators, project managers . . . and even salespeople!

Networking parameters are defined by the ISO (International Organization of Standards) – in the OSI Open System Interconnect 7-Layers Model of Networking. It is also the reference for the International IEEE LAN applications. In turn, both become the references for establishing America's ANSI/TIA/EIA telecommunications cabling standards for the Layer One physical layer to support the higher Layer Two and Three Layers.

Accordingly, these standards become the "guidance system" for cabling manufacturers and contractors. To ensure compliance to these national and international standards everyone should have a basic understanding of metrics. Additionally, have you also taken in consideration how many of your customers are internationally based?

Spools of copper cable are commonly manufactured and minimum testing parameters are expressed usually per 1,000 feet (or per Mft) spools or pull boxes. Fiber, on the other hand, is **metric-based**. Therefore, *ALWAYS verify that fiber length is given in feet or meters.*

There's nothing worse than estimating or even interpreting a project's specifications in feet and getting quotes from the distributor in meters ...or vice versa. Here's a simple rule of length conversion:

A meter is abbreviated with the small case "m" as large case "M" means, in the U.S., 1000 feet. 1 m = 3.281 feet or 39.4 inches (or one yard plus approximately 10%). Thus, a rule of thumb is you reduce by 10% in the calculations from yards to meters: 50 yards = 45.7 m.

Just like the British Open, stretch a bit extra in your ball placement on the golf course, and instead of yards you'll be estimating in meters!

Now move the decimal over when calculating meters in multiples of ten: 1 m = 3.281 feet, 10 m = 32.81 feet, 100 m = 328.1 feet (the maximum Channel horizontal length).

As you may know, 1,000 m is expressed as 1 km (one kilometer) and equals 3,281 feet. If you are/were in military, 1 km also is known as one "click" (or, as correctly written, one "klick").

"Kilo" means a "thousand," "Mega" means a "million" – like the lottery's "Megabucks." The IEEE Ethernet 802.3 standard defines the 100BaseTX as the data rate speed or 100 "Megabits" . . . one million bits per second.

The "Basic" or "Permanent Link" in the horizontal is 90 m or 295

feet (90 x 3.281 = 295.29). The reverse is true. Your project manager was quoted a price for fiber from an international source for $8.47. How much! Per foot? *Probably meant per meter.* Divide $8.47 by 3.281 for $2.58 per feet.

When calculating a project's usable work area space, the standard is 10 feet by 10 feet per workstation equaling 100 square feet – or 10.76 square meters (32.81 x 32.81 = 1,076). *Note:* Here in the States, we commonly drop the figures off the right of the decimal.

Besides having more international applications to standards, it is easier to use metrics to express fiber's measurements. See Table One for the most common Metric Applications Table for fiber.

"Millimeters" or "mm" define fiber cable O.D. (outside diameter or thickness). "Milli" means 1/1000th of a meter. The most common jacketed simplex and duplex "zip" patch cordage sizes are 2.8 to 3 mm. Note that 25 mm is about one inch. (Remember the old Virginia Slims cigarette commercial "... a millimeter longer" ... heck, that's only about a 1/32nd of an inch extra!)

"Micrometers" – expressed as "Microns" or "µm" – define fiber cable's buffering, coating and glass O.D. size. "Microns" means 1/1,000,000th of a meter. Tight buffer size is 900 µm covering the 245-250 µm acreylate coating over the raw glass. Loose-tube buffer/coating is 250 µm and a Furcation or a breakout kit's spaghetti tubes builds the 250 µm to 900 µm.

To accommodate a connector, another short 3 mm O.D. 25 mm (one inch) spaghetti tube is required unless it is built into the strain relief. Multimode fiber core/cladding sizes are commonly 62.5 µm /125 µm and 50 µm/125 µm, whereas single-mode is 8.3 µm/125 µm.

How small is a micron? The average human hair is 80-90 µm thick.

"Nanometers" or "nm" define the fiber optic wavelengths. "Nano" means 1/1,000,000,000th of a meter. Applicable wavelengths for multimode fiber are 850 nm and 1,300 nm; 1,310 nm and 1,550 nm for single-mode.

See Figure One for fiber construction.

Maximum pulling tension for outdoor loose tube cable is commonly 600 lb/f or 2,666 newtons/meter. A spool of cable weighs 50 pounds or 22 kilograms. See Table Two to assist you in the mathematics of metric conversion.

Decibels & Attenuation

Question

Please help me understand the significance of decibels (dB) when testing for attenuation?

Attenuation is defined as "signal loss" or "loss of signal strength." We measure the loss of amplitude (height) of a sine wave as it propagates down the cable. Think of a calm swimming pool. Suddenly, someone does a barrel roll into the center and causes this big splash!

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At the point of contact (the TX or "transmit" side of the signal) the waves (or "sine waves") are big and tall or peaked like a witch's hat. As the waves move out ("propagate") toward the sides of the pool (the RX or "receive" side of the signal) they become smaller (loss of amplitude) with distance . . . like a derby hat.

What's happened? The waves have been "attenuated." They also become flatter – "dispersion!"

Our objective is to try and keep that wave tall and peaked throughout the distance of the cable link. When the wave becomes too flat and spread out, the receiver may not be able to interpret the signal. See Figure Two.

This "loss of signal" is measured in dB or "decibels." The term "decibel" (named in honor of Alexander Graham Bell!) literally means "a ratio of two quantities." One decibel = one-tenth of a Bel. In fiber optics, it refers to the difference between two dBm or power levels of the TX transmit to the RX received signal. Attention (dB) = -10 Log10 [Pout/Pin] is logarithmic and not linear.

Note: If you graph a logarithmic measurement along the X and Y-axis, it would look like a bottle rocket dying out in flight versus a linear measurement that would be a straight continuous shot. The negative sign is added to give attenuation a positive value because of the laws of physics! The output or RX received power always is lower than the input or TX transmitted power for passive components – a flashlight beam gets weaker with length.

Attenuation is bad – so *the objective is to have low attenuation values.*

In fiber optics, we measure the TX transmit side or *power* in (Pin) – first in dBm (decibels per milliwatt). Power is measured in watts like a light bulb! In fiber applications, the power is very minimal (milliwatts, microwatts, nanowatts). We then measure the RX receive (Pout) side. The loss of amplitude or the signal loss is determined by comparing the TX dBm to the RX dBm – and the net result is measured in dB. The formula is dBm = 10 log10 [P/1mW].

Why is all this important? Because you must understand the relevance of decibels. In optical transmission equations, 0 dB equals one milliwatt (0 dB = 1mW). The 3 dB Rule states that: **For every added 3 dB of attenuation you loose 50% of your power!** (Inversely, removing 3 dB will double the power.)

Here's an analogy useful for

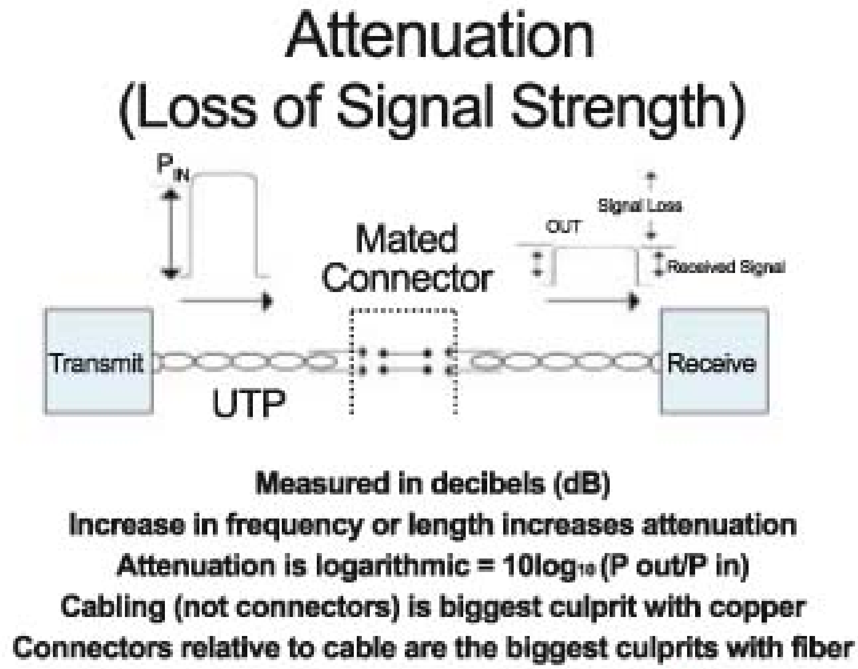

Figure Two © 1999 CrossBow

electricians: If you induced 3 dB onto a 100-watt fiber lighted Christmas tree by using a variable attenuator, it would only be as bright as a 50-watter. Add another 3 dB (totaling 6 dB) and it is only as bright as 25 watts; 9 dB represents 12.5 watts – and so forth. Thus, the more attenuation (or dB), the dimmer the light.

Conversely, if you started with 5.0 mW received signal, and removed 3 dB, it would achieve a power of 10.0 mW. See Figure Three.

Since cabling is the main cause of attenuation with copper, manufacturers try to achieve low attenuation by a variety of methods – including twists, conductor size, and jacketing materials.

Fiber optic cabling glass has significantly less attenuation than copper – therefore you can go longer distances with fiber. Both have fixed values from the factory, per industry standards. Fiber losses are caused by impurities in the glass, including absorption, scattering, and cladding modes. However, it is claimed by the glass manufacturers that a two-mile length of fiber optic glass has the same clarity of a 1/8th -thick windowpane!

Fiber attenuation can be reduced even after the cabling has been installed, but there's a cost. We can use a higher wavelength (not frequency) from 850 nm to 1,300 nm, µm multimode fiber, or a "brighter" light source than an LED (such as a VCSEL or laser).

To further reduce attenuation of multimode cabling, the primary choice would be to design 50 µm/125 µm glass instead of the common 62.5 µm/125 µm. See Table Three.

Since the continuing focus is controlling the loss on the connector while reducing labor time, manufacturers have a variety of solutions in the methods and procedures used to terminate and/or polish connectors.

The installer's job on attenuation: Your objective as an installer is to reduce attenuation through proper installation and termination techniques as specified in the ANSI/TIA/EIA 568B standards. This is critical to successfully supporting Ethernet Gignet applications given in the ISO Model of Networking and the IEEE LAN specifications:

- using the correct Category-rated UTP cable or the correct multimode glass size;
- adhering to minimum bend radius and pulling tensions;
- using Velcro™ straps in lieu of cinched ty-raps – *no staples*;
- staying away from heat sources (HVAC ducts); and
- adhering to maximum

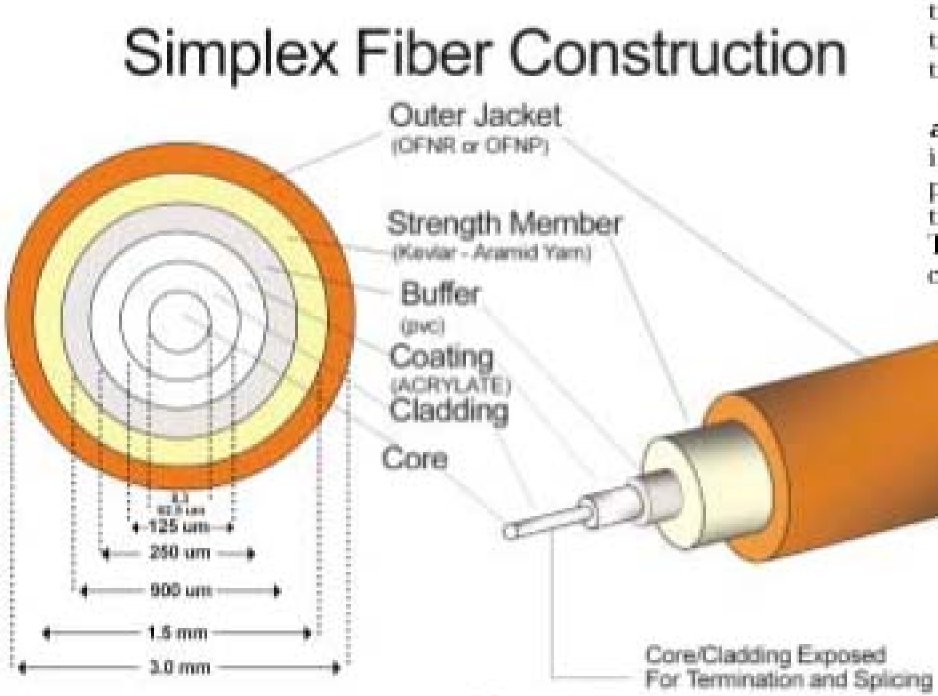

Figure One © 1999 CrossBow

Power dB	Power Ratio	Voltage Ratio
0	1.0000	1.000
1	0.8000	
3	0.5000	0.707
6	0.2500	0.500
9	0.1250	
10	0.1000	0.316
20	0.0100	0.100
30	0.001	0.032
40	0.0001	0.010
60	0.000001	0.001

- @ 3 dB induced is a 50% loss in power
- Cat 5 Attenuation is 67 dB/1000 feet
- Multimode fiber 1.06dB/1000 feet @850 nm
- Cat 5 Channel attenuation is 24 dB/328'

10Log10(Pout/Pin)

Figure Three

To ask a question of Power Outlet's datacom expert Bo Conrad, send your information in an e-mail to poweroutlet@rexelusa.com. Your questions will be answered in future issues.

length distances for the cable type (UTP vs. fiber).

When installing UTP connectors, the installer can reduce attenuation by maintaining a maximum amount of 13 mm (0.5 inch) of untwisting the cable pairs to ensure a maximum loss of 0.5 dB per mated pair. Conversely, following the fiber optic manufacturer's instructions, the installer should not exceed the standard of 0.75 dB per connector and 0.30 dB for a splice.

Fiber optic cable attenuation is fixed and measured in dB per kilometer (dB/km) – or per 3,281 feet. It is also a direct function of a fixed wavelength: Multimode @ 850 nm and 1,300 nm and single-mode @ 1,310 nm and 1,550 nm. *These attenuation values are directly proportional to length.*

Thus, a Budget Loss for cable can easily be calculated: 3.5 dB/3,281 feet = x dB/ 1000 feet x = 1.07 db/Mft. See Table Three, Transmission and Performance Parameters.

Now compare these fiber attenuation decibel specifications to copper: Category 5 UTP 24awg is 67dB per 1,000 feet – versus multimode fiber @ 850 nm of 1.07 db/Mft. This extrapolates to a loss of 99.9999% of the signal for copper versus a 20% loss on fiber!

Perhaps you can now understand

the reasoning behind the ANSI/TIA/EIA 568B standard for the Basic or Permanent Link of 90 meters (295 feet) and channel of 100 meters (328 feet) – there's too much attenuation with increasing copper cable length. Again, loss is linear and directly proportional to length. The copper loss is calculated to 21.4dB @ 90 m and 24.1dB @ 100 m – or approximately *99.1% of the signal is lost using UTP. At these same Basic Permanent/Channel distances, fiber would retain 97% of the signal.*

Combine this lower loss/longer distance advantage with higher bandwidth, and you can rationalize bringing multimode Fiber-to-the-Desk (FTTD). In fact, up to 2,000 meters for 100BaseFX and 220 meters to 550 meters for Gignet 1000BaseSX applications (depending on the core size and light source). ■

Table One

Metric Unit	Metric Length	Approximate U.S. Equivalent	Application
Metric (m)	1.0 m	39.4 Inches	Length (3.281')
Millimeter (mm)	.001m	.0394 Inches	Jacket O.D.
Micrometer (um)	.000001m	.0000394 Inches	Core/Cladding/ Buffer O.D.
Nanometer (nm)	.000000001m	.0000000394 Inches	Wavelength
Angstrom (A)	.0000000001m	.00000000394 Inches	Wavelength

Transmission & Performance Parameters

Optical Fiber Cable Type	Wavelength (nm)	Maximum Attenuation (dB/km)	Minimum Information Transmission Capacity (MHz)
50/125	850	3.5	500
	1300	1.5	500
62.5/125	850	3.5	160
	1300	1.5	500
Singlemode Intrabuilding Cable	1310	1.0	N/A
	1550	1.0	N/A
Singlemode Intrabuilding Cable	1310	0.5	N/A
	1550	0.5	N/A

The information transmission capacity of the fiber, as measured by the manufacturer, can be used by the cable manufacturer to demonstrate compliance.
These attenuation figures can be used in the calculation of loss budgets.

Do you have questions?

Please e-mail them to
my attention, care of
poweroutlet@rexelusa.com.

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POWERS OF TEN

Prefixes and symbols to form decimal multiples and/or submultiples.

Power of Ten	E Notation	Decimal Equivalent	Prefix	Phonic	Symbol
10^{12}	E+12	1 000 000 000 000	tera	ter'a	T
10^{9}	E+09	1 000 000 00	giga	go'ga	G
10^{6}	E+06	1 000 000	mega	meg'a	M
10^{3}	E+03	1 000	kilo	kil'o	k
10^{2}	E+02	100	hecto	hek'to	h
10	E+01	10	deka	dek'a	da
10^{-1}	E-01	0.1	deci	des'i	da
10^{-2}	E-02	0.01	centi	sen'ti	c
10^{-3}	E-03	0.001	milli	mil'i	m
10^{-6}	E-06	0.000 001	micro	mi'kro	u
10^{-9}	E-09	0.000 000 001	nano	nan'o	n
10^{-12}	E-12	0.000 000 000 001	pico	pe'ko	p
10^{-15}	E-15	0.000 000 000 000 001	femto	fem'to	f
10^{-18}	E-18	0.000 000 000 000 000 001	atto	at'to	a

Metric Conversion Chart

Symbol	Given	Multiply by	to Obtain	Symbol
mm	millimeters	0.0394	inches	in
cm	centimeters	0.394	inches	in
m	meter	3.281	feet	ft
km	kilometers	0.622	miles	mi
N	newtons	0.225	pound force	lbf
N-m	newton/meter	0.738	foot pounds	lbf-ft
N/cm	newton/centimeter	0.571	pounds force/inch	lbf/in
kg	kilograms	2.205	pounds	lb
kg/km	kilograms/kilometer	0.671	pounds/thousand feet	lb/1000 ft
C	celcius	1.8 (then add 32)	degrees Fahrenheit	F
Symbol	to Obtain	Divide by	Given	Symbol
When converting from F to C, subtract 32, then divide by 1.8				
Decimal Prefixes				
10 9 giga (G)	10 -3 milli (m)			
10 6 mega (M)	10 -6 micro (u)			
10 3 kilo (k)	10 -9 nano (n)			