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A comparative analysis of the characteristics of some fibre optics used in RF communication systems in Nigeria

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Abstract

In this paper, channel attenuation (link loss) and fiber loss budget for different types and sizes of optic fibres in selected applications in RF communications were measured and computed using relevant equations to ascertain accuracy of measurements and also for comparison sake. The results obtained agree with each other. The minor differences in values noticed in comparing the calculated and manufacturer's values make only a negligible impact in practical RF communication. In line with theory, the computed values show that channel attenuation increases as distance increases. Multi-mode fibers with smaller core diameters offer less attenuation. Multi-mode fiber operating in 1300 nm wavelength for application 100G-M-SN-I (500 m supportable distance) gives 2.95 dB compared to 850 nm fiber with 3.90 dB of the same size. Single-mode 1550 nm fibers offer less attenuation compared to 1310 nm fibers. Furthermore, the measured values of attenuation of different optic fiber colours at Zain, Abuja upholds the manufacturers' assertion that turquoise, red, brown, pink, and green fiber coatings are good for indoor connectivity while white, black, yellow, blue and orange are recommended for outdoor transmissions.

Keywords: Fibre optics, RF applications, channel attenuation.

Introduction

Wisegeek (2010, http:www.wisegeek.com/what-is-glass.com) describes optic fiber as a term for any sort of plastic or glass channel meant to transmit light. An optical fibre consists of a core, cladding, and a buffer (a protective outer coating), in which the cladding guides the light along the core by using the method of total internal reflection. The core and the cladding (which has a lower refractive index) are usually made of high-quality silica glass, although they can both be made of plastic as well (used for very short distances). Several layers of buffer coatings protect the core and the cladding. The layers act as a shock absorber to protect the core and cladding from damage. A strength member usually Aramid, is around the buffer layers to prevent pulling damage during installation and protects against environmental factors. John and Masound (2002) presented two basic types-single mode fiber and multimode fibers (step-index & graded index fibers). Single-mode is a single strand of glass fiber with a diameter of 8.3 to 10 microns that has one mode of transmission. In multimode, light waves are dispersed into numerous paths or modes as they travel through the cable's core typically at 850 or 1300 nm wavelength. Single-mode fiber has a much smaller core than multimode. The small core and single light-wave virtually eliminate any distortion that could result from overlapping light pulses, providing the least signal attenuation and the highest transmission speeds of any fiber cable type (Wikipedia, 2010, http://en.wikipedia.org/wiki/optical_fiber). Step-index multimode fiber has an abrupt change or step between the index of refraction of the core and the index of refraction of the cladding. Graded index fiber is made up of multiple layers with the highest index of refraction at the core. Each succeeding layer has a gradually decreasing index of refraction as the layers move away from the center.

Optic fibers are designed to transfer light energy from one point to another. Fibers have vast applications mainly telecommunications (Thought, 2001, http:/www.optimized.com/COMPENDI/L1-fiber.htm). Fiber systems are prone to losses of various kinds (insertions losses from connectors & link attenuation due scattering, bending & absorption). The choice of this research was prompted by the evolution in communication technology. Fibers perform with optimal efficiency over an average of 25-40 years, provided the connectors are appropriately terminated and the cables are installed correctly. For any type or size of fiber cable, the longer the distance from the transceiver the higher the loss. Also, the fewer the connector and splice used the lesser the link loss. This research aims to measure the link losses of some fibers used at Zain Abuja and to compute the losses of different sizes of fibers used in RF communications and compare them to manufacturer's values.

Materials and methods

Channel attenuation, loss budget and fiber distance of fiber optics

The channel attenuation, loss budget and fiber distance of some selected fibers in specific applications most commonly used in telecommunications were computed, tabulated and analyzed graphically.

Channel attenuation (link loss)

Attenuation is the degradation of signal magnitude due to the cumulative effects of various types of losses in a link. For optic fiber link, channel attenuation is obtained from the expression (Cisco, 2010, http://www.cisco.com/application/pdf/paws/27042/max_att_27042.pdf):

$\alpha_T = nC + cJ + L\alpha + M$ (1)

n is the number of connectors, C the attenuation for one optical connector (dB), c the number of splices in elementary cable section, J the attenuation for one splice (dB), M the system margin (patch cords, cable bend, unpredictable optical attenuation events, and so on, should be considered around 3dB), α the attenuation for optical cable (dB/km) and L the total length of the optical cable. Other specifications required for computing the mentioned parameters are shown in Appendix A.

Application 100G MX-SN-I (fiber of core diameter 62.5 μm, attenuation/km=3.0dB).

For L=500 m, Link loss=0.5x2.4 + 0.1 + 2x0.5 +1.5 =3.80dB.

Similarly, the link loss for L = 860 m; Application 100 Base-FX (l=550 m & 800 m) and application 1000 Base-SX (l=880 m) were obtained.

Application 100G MX-SN-I (operating wavelength of 1300 nm, fiber core diameter=50 μm, attenuation/km=0.70dB/km).

For L=500 m, Link loss=0.5x3 + 0.1 + 2x0.5 + 1.5 =4.10dB.

Solving for *applications 100 Base-FX and 1000 Base-SX*, the results are shown in Table 1.

Application 100 G MX-SN-I (operating wavelength of 1550 nm (Single-mode), 4 splices, two connectors, M=+3dB).

For L=500m, Link loss=0.5x0.7 + 0.1 +2x0.5 +1.5 =2.95dB.

Solving for applications 100 Base-FX and 1000 Base-SX, the results are shown in Table 2.

For L= 10 km, Link loss=10x0.22 + 2x0.5 + 4x0.01 + 3 =6.24dB.

Solving for L=20 km, 30 km, 40 km and 50 km, the results are shown on Table 3.

Similarly, considering operating wavelength=1310 nm and other specified specifications the same method was used to compute their attenuations at the stated distances.

Loss budget

System loss budget refers to the tolerance of fiber optic equipment between the transmit power and the receive sensitivity. Receive sensitivity is the minimum energy required for the fiber receiver to detect an incoming signal. This energy level is measured in dB relative to 1 mW (dBm). The manufacturer of the router offers three transmitter/receiver options for single mode as shown in Appendix B. For optic fiber link, system loss budget is obtained from the expression (Cisco, 2010):

Loss budget = Link loss + transmitter power (2).

To determine the correct power for some selected fiber links, the following specifications are considered- Operating wavelength = 1550 nm, number of splice = 4 and number of connectors = 2.

For L=10 km, link loss=-6.24 dB and Transmitter power=-3.0 dB.

For short reach, loss budget= -3 + (-6.24) = -9.24 dB.

Similar, computations were made for intermediate reach and long reach. Solving for L=20 km, 30 km, 40 km and 50 km, the results are shown in Table 4.

Estimation of fiber distance

This calculation will estimate the maximum tolerable distance of a particular fiber optic link, given the optical budget, the number of connectors and the number of splices contained in the link.

Fiber length= [(Optical budget) – (Link loss)] ÷ (Fiber loss/km) (3) = {(min T_X Power – R_X sensitivity) – link loss} ÷ Fiber loss

Assuming a fast ethernet single mode at 1310 nm with two connectors and 5 splices:

Link loss= 5x0.01 + 2x0.5 + 3 = 4.05 dB.

Also, using an optical card with specifications - Min T_X power= -8.0dB, R_X sensitivity= -34.0dB and Fiber loss/km= 0.35ddB then.

Fiber Length= {[-8-(-34)] – 4.05}/0.35 =63 km.

Results and discussion

The results of the computed values of the cable (850 nm/50 μm) in different applications were compared with the manufacturer's data as shown in Table 1. From the table it was observed that there are some fluctuations in the computed values. This may be as a result of the constant M (system margin) which may be slightly different from the company's value. The plot given in Fig. 1 was obtained from the computation on 50 μm and 62.5 μm multi-mode cables for different applications. This indicates that as the fiber core diameter increases, so also is the channel attenuation. Also, it can be seen in Appendix A that mode and operating wavelength affect the attenuation per km of any optic fiber. Single-mode fibers give less attenuation/km compared to the multi-mode fibers. Fig. 2 and 3 gave the relationship between the operating wavelength and channel attenuation of the same cable size for different applications. From these plots, it was observed that the channel attenuation decreases with increase in the operating wavelength since channel attenuation is inversely proportional to the operating wavelength. For instance, the computer center, University of Jos installed 1300 nm/62.5 μm multi-mode cables for indoors connectivity. The choice of this is because 1300 nm multi-mode cable is good for short distance transmission than 850 nm cables. More so, most communication companies in Nigeria use 1550 nm single-mode fiber cables for transmission from one mast to another. This is because single-mode cables are very good for long distant transmission even though they are expensive and more difficult to install. From the measured data at *Zain* Abuja as shown in Appendix C,

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Appendix A: In fini Cor & SMF-28 Standard fiber loss table (Ruggedcom, 2010; http://www.ruggedcom.com*).*

λ/mode	Fiber core dia.(μm)	Attenuation/km (dB)	Attenuation/splice (dB)	Attenuation/connector (dB)	Model bandwidth (MHz-km)
850/MM	50	2.40	0.10	0.50	500
850/MM	62.5/125	3.00	0.10	0.50	200
1300/MM	50	0.70	0.10	0.50	500
1300/MM	62.5/125	0.75	0.10	0.50	500
1310/SM	9	0.35	0.01	0.50	N/A
1550/SM	9	0.22	0.01	0.50	N/A

Appendix B: Manufacturer's transmitter/receiver options for single mode fiber (Imcnetworks, 2010).

Reach	Transmitter power (dBm)	Receiver sensitivity (dBm)
Short	-3	-18
Intermediate	0	-18
Long	+3	-28

Appendix C: Measured values of attenuation carried out at a 10km run for different optic fiber colours at Zain, Abuja, Nigeria (Anekwe, 2010).

Fiber	Colour	Attenuation at 1310 nm (dB)	Attenuation at 1550 nm (dB)
1	Blue	2.37	1.66
2	Orange	2.28	1.52
3	Green	1.85	1.27
4	Brown	1.64	1.09
5	Grey	2.01	1.40
6	White	2.85	1.90
7	Red	1.49	1.01
8	Black	2.41	1.66
9	Yellow	2.50	1.70
10	Violet	2.13	1.29
11	Pink	1.79	1.13
12	Turquoise	1.27	0.71

Table 1. Calculated values of channel attenuation for λ=850 nm.

λ=850 μm	Supportable distance (m)	50/125 μm Channel attenuation (dB) Manu.	Cal.	62.5/125 μm Channel-attenuation (dB) Cal.
100 G-MX-SN-I	500	3.90	3.80	4.10
	860	4.60	4.66	5.18
100 Base-FX	550	3.60	3.92	4.25
	800	4.50	4.52	5.00
1000 Base-SX	880	4.80	4.71	5.24

Table 2. Calculated values of channel attenuation for 1300 nm.

λ=1300nm	Supportable distance (m)	50/125 μm Channel-attenuation (dB)
100 G-MX-SN-I	500	2.95
	860	3.20
100 Base-FX	550	2.99
	800	3.16
1000 Base-SXz	880	3.22

Table 3. Calculated values of channel attenuation for single mode 1310 nm & 1550 nm.

Distance (km)	Channel attenuation (dB) λ=1310 nm	λ=1550 nm
10.0	7.54	6.24
20.0	11.04	8.44
30.0	14.54	10.64
40.0	18.04	12.84
50.0	21.54	15.04

Table 4. Calculated values of loss budget.

Length (km)	Link loss (dB)	Loss budget (dB) *short*	*intermediate*	*long*
10.0	-6.24	-9.24	-6.24	-3.34
20.0	-8.44	-11.44	-8.44	-5.44
30.0	-10.64	-13.64	-10.64	-7.64
40.0	-12.84	-15.84	-12.84	-9.84
50.0	-15.04	-18.04	-15.04	-12.04

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Fig. 4 is obtained. The plot affirms the fact that attenuation decreases with increase in the operating wavelength. Turquoise coloured fiber is observed to have the least attenuation followed by red, brown, pink, green, grey, violet, orange, blue, black, yellow and white in that order. The amount of signal attenuated in a fiber is seen to be dependent on the colour of the fiber coating which affects the link loss of a fiber optic system.

Summary and conclusion

In this research, some important properties of fiber optics-viz-attenuation, colour coating and loss budget were considered. The attenuations of various fiber colour coatings were measured at Zain, Abuja. The channel attenuations and loss budgets of some selected fibers were computed using relevant equations. The results obtained were compared to the values presented by the manufacturers as obtained from published literature. The results obtained agree with each other. The minor differences in values noticed in comparing the calculated and manufacturer's values as presented on Table 1 make only a negligible impact in practical transmission. In line with theory, the computed values show that channel attenuation increases as distance increases. Multi-mode fibers with smaller core diameters offer less attenuation. Multi-mode fibers operating at 1300 nm wavelength give less link loss compared to 850 nm fibers of the same size. Single-mode 1550 nm fibers offer less attenuation compared to 1310 nm fibers. The measured values of attenuation of different optic fiber colours at Zain, Abuja upholds the manufacturers' assertion that turquoise, red, brown, pink and green fiber coatings are good for indoor connectivity (multimode fibers). White, black, yellow, blue and orange are recommended for outdoor transmissions (single-mode fibers). The choice of a particular fiber cable will depend on the designer's ability to assess the system loss budget and the overall attenuation loss of the components in the link. The coating colours of the optic fibers should also be put into consideration when designing a fiber system.

References

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Fig. 1. Channel attenuation against distance for 50 μm & 62.5 μm multimode fibers at 850 nm.

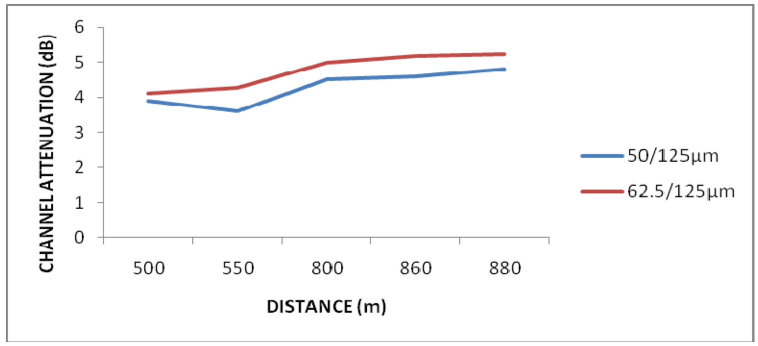

Fig. 2. Channel attenuation against distance for 850 nm & 1300 nm multimode fibers.

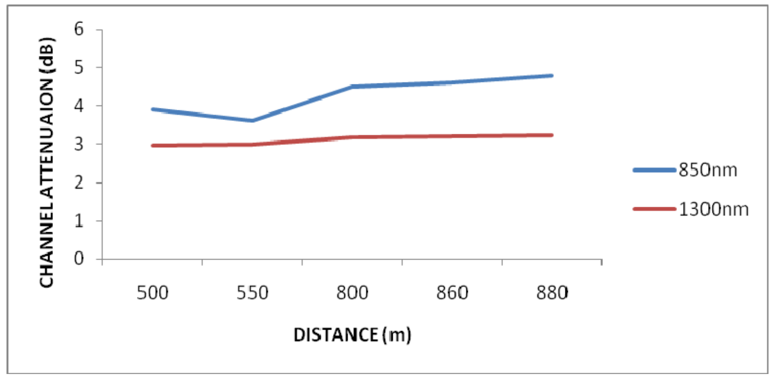

Fig. 3. Channel attenuation against distance for 1310nm & 1550nm

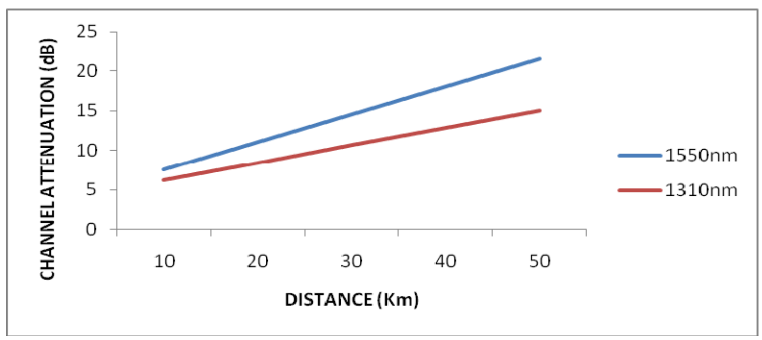

Fig. 4 Attenuation against fiber colour.