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Calculating the Power Loss Budget in Long Haul Optical Fiber Links Using MATLAB

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***Abstract*—** The losses in optical fiber link based on passive elements such as fiber cable, connectors and splices. There are many types of fiber cables with different attenuation coefficients which is used in long haul links have to be used in this program . Also, this program calculated the number of splices which needed to connect fiber pieces for different link lengths and the resulting losses. Furthermore the connector losses.

Keywords-component; fiber; style; styling; insert (key words)

I. Introduction

In the last fifteen years the optical transmission networks in Libya have become one of the most important parts in the telecommunication hierarchy.

There are several thousands of optical fiber cables through Libya. It becomes more popular at both long haul and local wired transmission area owning to its many advantages such as high capacity, high speed, no electromagnetic interferences, and huge bandwidth. Selecting the best optical fiber for a given long haul route is not a simple decision.

One of the most important considerations in the fiber specification process is the fact that optical signals may need to be amplified and switched along the long haul route. When employing composite cables it is important to look at the overall system requirements and choose fiber types that provide the most flexibility for both today's deployment as well as tomorrow's.

II. Power Loss Budget

The first step in any fiber optic system design requires planning the rout to determining the distances between the repeaters, and making careful decisions based on operating parameters which apply for each component of a fiber optic transmission system such as fiber type, connector type , power transmitter, optical source, optical detector and splice type.

The power budget calculation is one of tools for system planning, the purpose of the power budget is to ensure that enough power will reach the receiver to maintain reliable performance during the entire system lifetime, the power budget concept is illustrated in figure 1. [1],[7]

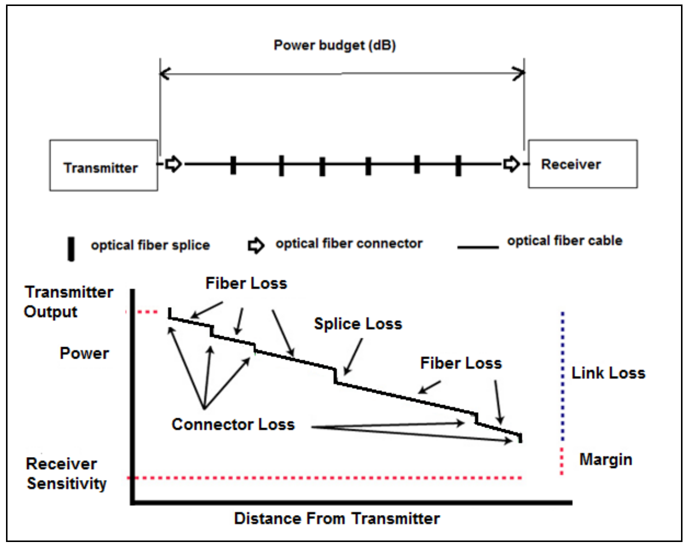

Figure 1. Power budget concept

To calculate the power loss budget many losses have to computed such as fiber cable losses, splices losses and connector losses, as illustrated in the following sub sections:

A. *Fiber Cable Loss (FL)*

The single mode fiber is used in long optical fiber network, the major drawback of single mode fiber is that it is relatively difficult to work with such as splicing and termination, because its small core size. Also, single mode fiber is typically used only with laser sources because of the high coupling losses associated with Light Emitting Diodes LEDs.

There are four basic classes of single mode fiber used in modern telecommunications systems such as:

1. ITU-T G.652 The oldest and most widely deployed type is non dispersion shifted fiber (NDSF). These fibers were initially intended for use near 1310 nm. Later, 1550 nm systems made NDSF fiber undesirable due to its very high dispersion at the 1550 nm wavelength. [2]

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2. ITU-T G.653 Dispersion shifted fiber (DSF) that moved the zero-dispersion point to the 1550 nm region. Years later, scientists would discover that while DSF worked extremely well with a single 1550 nm wavelength, it exhibits serious nonlinearities when multiple closely spaced wavelengths in the 1550 nm were transmitted in dense wavelength division multiplexing DWDM systems. [3]
3. ITU-T G.655 Non zero dispersion shifted fibers (NZ-DSF) that fiber is available in both positive and negative dispersion varieties. It is rapidly becoming the best choice in new fiber deployment.[4]
4. ITU-T G.656 non-zero dispersion fiber which has the positive value of the chromatic dispersion coefficient greater than some non-zero value throughout the wavelength range of anticipated use 1460-1625 nm. This dispersion reduces the growth of non-linear effects which are particularly deleterious in dense wavelength division multiplexing systems. [5]
   This fiber can be used for both CWDM and DWDM systems throughout the wavelength region between 1460 and 1625 nm.

A Matlab program was written to obtain the attenuation of three types of an optical fiber which used in long haul fiber network, they are G.655, G.653 and G.652. The table (1) illustrates the attenuation coefficients of three fiber types. [2] [3] [4].

Table (1) Fiber types and their Specifications.

Fiber Type	Attenuation Coefficient (dB/Km)
G.655	0.19
G.653	0.189
G.652	0.207

To calculate the fiber cable attenuation (FL) the following equation will be used:

$$FL = \alpha * L \quad (1)$$

Where:

FL = Fiber loss in dB

α = Typical attenuation coefficient of the fiber cable in a link in dB/km as illustrated in table (1)

L = Fiber length in km.

B. Connectors Losses (CL)

Fiber to fiber interconnection can consist of a splice, or a connector, which differs from the splice in its ability to be disconnected and reconnected.

There are two main types of connectors, FC and SC connectors their attenuation coefficient is 0.25 dB which used in long haul links as well as the number of connectors in link are two connectors minimum. [8]

The equation (2) is used to calculate the connector loss:

$$CL = Ca * N_c \quad (2)$$

Where:
CL is connectors losses in dB.
Ca is loss per connector.
N_c is number of connectors.

C. Splices Losses (SL)

An optical splice is a permanent connection of two optical fibers through fusion or mechanical means. Fiber optic cables may have to be spliced together for several reasons, to realize a link of a particular length, because the cable manufacturers offer cable in limited lengths usually 1 to 6 km.

The number of splices is calculated by the following equation:

$$N_s = \frac{L}{L_s} - 1 \quad (3)$$

Where:

N_s is number of splices.
L_s is span length, in this paper 6 km span was used.

So the splices losses are calculated by using equation (4), where the fusion splice is used with attenuation 0.05 dB. [6]

$$SL = Sa * N_s \quad (4)$$

Where:
SL is splices losses in dB.

Sa is losses per splice.

D. Minimum Loss (MN)

Minimum loss is calculated using the following equation:

$$MN = FL + CL + SL \quad (5)$$

Where:
MN is minimum loss in (dB).

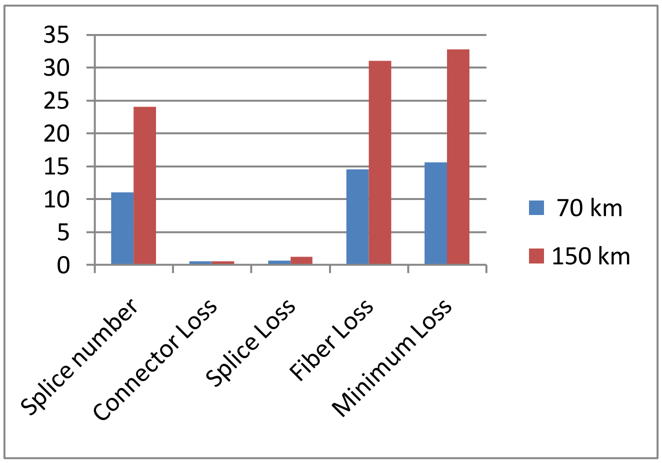
III. Running the Program and Viewing the Results

In this program we entered different lengths in km, the achieved program results are number of splices, losses due to installation of splices, losses due to connectors, cable loss and the total minimum loss for three fiber types G.652, G.653 and G.655. In the following table all that data are illustrated with different optical lengths, link 1 is assumed 70 km and link 2 is 150 km.

Table (2) Program results

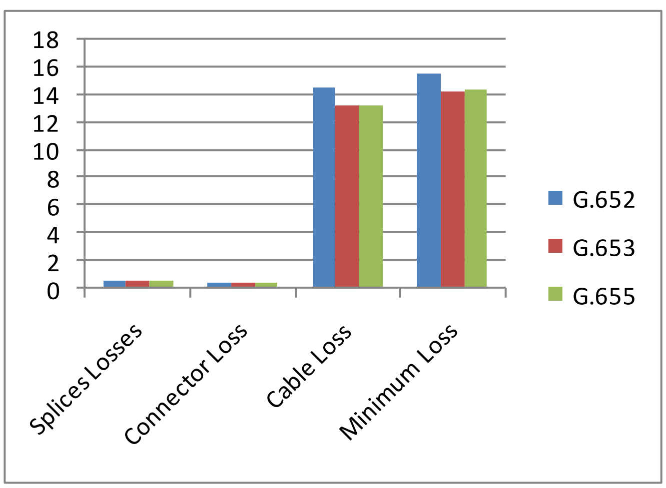
specification	Unit	Link1			Link 2		
Fiber length	Km	70			150		
Fiber type		G.652	G.653	G.655	G.652	G.653	G.655
Splices no		11			24		
Splices Losses	dB	0.55			1.2		
Conn Loss	dB	0.5			0.5		
Cable Loss	dB	14.49	13.23	13.3	31.05	28.35	28.5
Minimum Loss	dB	15.54	14.28	14.35	32.75	30.05	30.2

We can compare between two lengths 70 km and 150 km using one fiber type G.652 as illustrated in figure(2).

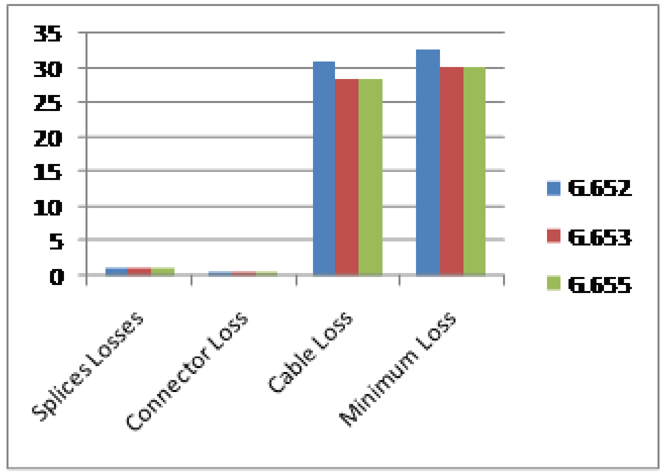


figure(2) comparison between 70 km and 150 km using G.652 fiber

when optical fiber network is designed with different types of fiber cables, different losses are resulted as appears in the following figures which are compare between all the losses of three fiber types in 70 km and 150 km respectively.



figure(3) comparison between all losses at 70 km fiber



figure(4) comparison between all losses at 150 km fiber

From previous figures we can note that:

1. When one fiber type is used in different lengths, the connectors losses have the same value, but the splices losses are increasing when fiber length increased because more splices are needed. In the other hand the fiber loss increased too.
2. For the same cable length the connectors losses are the same for three fiber types G.652, G.653and G.655, also the number of splices and splice losses are equal for each type. But the cable loss is different because each fiber type has different attenuation coefficient.
3. G.652 has the highest fiber loss. G.653and G.655 have convergent fiber losses value, the major difference between them is dispersion coefficient.
4. The main source of loss in power loss budget is fiber cable losses.

IV. Conclusion

Our main goal is to present various fiber lengths of three fiber types G.652, G.653 and G.655, to calculate the minimum fiber loss, This program involves connectors losses, splices losses and fiber cable losses equations.

but in the near future we would like to extended this program to calculate other important losses such as dispersion power penalty which is has the same effects as fiber cable loss.

There are another important factor must be in our consideration when designing optical fiber called system margin, the system margin include the cable repair margin, splice repair margin and ageing margin.

References

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[7] http://www.thefoa.org.25/8/2013

[8] http://www.fiber-optics.info/ 5/7/2013