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ORIGINAL RESEARCH ARTICLE

EMPIRICAL DETERMINATION OF LOSSES IN AN OPTICAL FIBRE LINK

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ABSTRACT

This paper analyses the characteristics of signal loss in optical fibre link with splicing loss forming part of the total loss with the loss measurement carried out with the aid of Optical Time Domain Reflector.An Optical Time Domain Reflectometer (OTDR) is made up of a detector and a laser. Light signals are sent into the fibre using a laser and a demodulator or a detector on the other end to receive the signals. The received signal is displayed on a graph. The transmitted signal is a pulse with a given amount of energy. A clock determines the time duration of the signal. This paper explains the splicing using Optical Time Domain Reflectometer. These losses in an optical fibre cable arise from spliced points and joints with either connectors or any other passive fibre optic device. The study shows that losses along optical fibre arise from the splice joint, connector joint and along the fibre length as attenuation loss. These losses were obtained from readings of the optical time domain reflectometer. The study also shows that the combined splicing and connector loss is higher than attenuation loss. Here, splicing and connector loss contributes 75% of the total losses while attenuation losses account for the remaining 25%. An attempt should, therefore, be made to reduce splices in order to minimize losses when using optical fibre cabling.

1.0 Introduction

Advances in Communication Engineering has led to a huge increase in bandwidth with optical fibre capable of handling a higher bandwidth compared to another form of wired communication (Kartalopoulos, 2008). In addition to large bandwidth requirement, new innovative services evolving daily is pushing bandwidth higher (Visawanathan, 2006). The effect of microwave radiation on health together with the noise pollution from generators mounted on Base Transceiver station makes Optical fibre a better alternative. The introduction of optical fibre for mobile communication in Nigeria has its own challenges. These include the absence of a regulatory framework, unstable electricity (power) supply, lack of qualified and skilled manpower, communication system compatibility issues, environmental impact assessment issues, cost implications for the new technology and issues of returns on investment.

Installation of Optical fibre for long and short distances require joining cables which contribute significantly to a loss at the various joints. Input power, fibre length, fibre end characteristics of the waveguide and end quality of fibre are some of the factor causing loss along with a fibre link. The power that can be transmitted from one fibre to another is dependent on the number of modes propagating in the individual fibre. A fibre with a higher number of modes coupled to one with a lesser number will lead to a substantial loss along the two fibres with all the modes present (Gerd, 2003). Analytical methods designed to determine signal loss at fibre joints are inexhaustible. This is because mathematical equations developed addresses only a few causes of losses in the joint. (Gerd, 2003). Asides these, practical field working conditions where this research is done seldom used a complex method to obtain losses from the fibre joints (Koontz and Mandloi, 2000).

Optical fibres are used to confine and guide photo signals. A simple optical network includes a laser diode as an optical source and fibre optic as a medium of transmission and detector as a part of a receiver. To achieve this, fibre cable is joined at a certain interval to form a communication link. It is not possible to use optical fibre over a long distance without joining them. The choice of the joint to be made is based on whether a permanent bond or an easily demountable joint is desired. A permanent bond on an optical fibre cable is known as a splice and a detachable joint is called a connector. Various methods can be used to determine the power a given optical fibre link can carry and this can be done with the aid of optical time domain reflector (OTDR). In this paper, OTDR is used to determine connector, splices and fibre loss.

OTDR is an optoelectronic instrument used to characterize an optical fibre. Optical pulses are sent into the test fibre and light are reflected. This is similar to how also an electronic time-domain meter works using changes in impedance of the cable under test. The reflected pulse is measured and sum as a function of time. OTDR is also used to measure the attenuation of the fibre cable. Also splicing and connector losses at selected points along the test fibre link were measured.

An optical power meter (OPM) is used to measure the power in a fibre optic cable. General purpose photo power devices are usually called radiometers, photometers. An optical power meter is only used to measure the power at the other end of a fibre link and only gives an output power of the additional losses parameters from the link such as the splice losses, cables losses, connector losses, and its accuracy might not be compared to an OTDR.

Predictions of losses in fibre are very difficult (Gerd 2003). For instance, analytical models can predict instantaneous result but fail to give accurate results because of the nature and behaviours of electromagnetic waves as it propagates along a fibre after a considerable distance (Koji et al 2008). In an optical fibre transmission system, mathematical analysis of losses is based on assumptions which introduce errors which reduces the accuracy of the obtained result(Marcuse, 1997).There are a number of ways to tackle the problem of determining the power requirement for a particular fibre optic link. The easiest and most accurate way is to perform an Optical Time Domain Reflectometer (OTDR) trace of the actual link.

This is because power budget can only be determined only after losses along the fibre are determined. This paper outlines the various losses in an optical fibre link using the optical time domain reflectometer. The studies show that the combined splicing and connector loss account more for the total loss compared to attenuation loss.

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2. Materials and Methods

The method employed is the use of OTDR and Optical power meter for the measurement of losses in an optical fibre. A Nanjing DVP-105 cleaver was used for the cleaving process. A Nanjing DVP-730 fusion splicer with splice time of 1800mS was used for the optical fibre fusion splicing. The output of the completed fusion splicing process is shown on the LCD panel of the splicing machine. A threshold value of splice loss of ≤0.05dB was used. This was adopted to reduce the splice loss contribution to the link's loss.

2.1 Materials

A Nanjing DVP-105 cleaver is an instrument used for holding and cutting fibre materials. A Nanjing DVP-730 fusion splicer is also used the joined two fibres together. It has a splice time of 1800mS. Optical time domain reflectometer is used to determine the losses after the fibre had been spliced.

2.2 Methods

The method employed involves taking readings of the various losses using OTDR. A Nanjing DVP-730 fusion splicer is used. The output of the completed fusion process shows at the liquid crystal display of the fusion splicer. An end threshold value of 5Db was implemented. Figure 1 shows the flowchart explaining the various steps of splicing. After splicing, OTDR is used to determine the losses in the link or cable that was terminated by a patch cord to create a connection between the OTDR and the terminated link.

2.2.1 Splicing preparation steps

Fusion splices refers to thermally bonding prepared fibre ends, where the fibre ends are first aligned and then butted together. This takes place either in a grooved fibre holder or under a microscope with a micromanipulator (Agawar,2003). Fusion splicing is the act of joining two optical fibre end-to-end using heat.

Step 1 Stripping the fibre:

Stripping is the removal of the outer layer of the optical fibre.

Step 2 Cleaning the fibre:

This involves cleaning the fibres with ethanol and spirit. The main concern here is the cleanliness of the surface of the fibre lengths

Step 3 Cleaving the fibre:

This involves cutting or trimming of fibre. The fibre face is held at 90 degrees to the axis of the fibre. The closer to 90 degrees the cleave angle is the lower optical loss the splice will yield.

Step 4 Splicing the fibre:

This is the joining of the two fibres by heating.

Step 5 Protect the fibre:

The bare fibre area is additional coated or covered with a splice protector

Step 6 Buried underground:

The encapsulation is place firmly using fasteners at the pole or buried underground in a trench.

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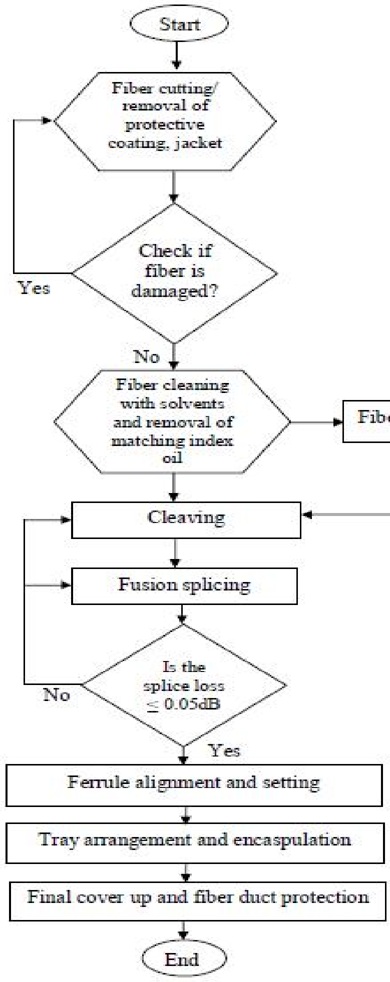

Figure 1: Flow chart for Fibre fusion splicing

2.3 Theoretical Calculations

Power Budget for fibre optic Cable

$$PB = PT - PR \quad (1)$$

where: PT is minimum transmitted power dB and PR is receiver sensitivity dB

Power Margin for fibre optic Cable

The Power margin.

$$PM = PB - LL \quad (2)$$

where: PM is Power margin (dB), LL refers to Link loss(dB) and PB is Power budget(dB).

PM greater than zero indicates that the power budget is sufficient to operate the receiver

Total Link Loss

In this paper, the link loss using a safety margin of 3.0dB is :

Link Loss = [fiber length (km) x fiber attenuation per km] + [splice loss x no of splices] + [Connector loss x no of connectors] + [safety margin] (3)

$$\text{Percentage of Splice loss} = \frac{\text{Splice loss}}{\text{Total link loss}} * 100 \quad (4)$$

$$\text{Percentage of connector loss} = \frac{\text{Connector loss}}{\text{Total link loss}} * 100 \quad (5)$$

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According to TIA/EIA industry specifications, fibre attenuation per km is 0.3dB, connector loss is 0.75dB and splice loss is 0.1dB. The studies show readings which are close to the industry standards.

3. Results and Discussion

The result gotten from 4 locations of a single mode fibre with a distance range of 0 – 50km are shown in the Table 1.

3.1. Event Analysis From four different Locations

According to the IEEE standard distance, 1550nm single mode 9/125µm cable is required for a 70km distance, this studies use the single mode 9/125µm cable for a 50km distances from 4 locations shown in the Tables 1 to 4, which provide details of the various losses.

Table 1: Location A OTDR Trace Result with the End Threshold of 5.0dB.

S/N	Type	Location (km)	Reflectance (dB)	Insertion Loss (dB)	Splices (dB)	Attenuation (dB)	Connectors (dB)
1	Reflective	0.000	-13.55		0.085	0.206	0.750
2	Non-Reflective	4.595		0.3337	0.104	0.248	0.356
3	Non-Reflective	6.643		0.343	0.058	0.188	0.576
4	Non-Reflective	10.689		0.119	0.184	0.188	0.297
5	Non-Reflective	11.708		0.328	0.106	0.186	0.442
6	Non-Reflective	15.773		1.805	0.615	0.187	0.520
7	Non-Reflective	19.044		0.148	0.115	0.187	0.425
8	Non-Reflective	19.813		0.207	0.140	0.176	0.554
9	Non-Reflective	21.291		-0.306	0.101	0.196	0.378
10	Non-Reflective	23.339		-1.860	0.136	0.196	0.723
11	End	25.020	-21.17				
TOTAL				1.121	1.644	1.958	5.021

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Table 2: Location B OTDR trace result with the End Threshold of 5.0dB.

S/N	Type	Location (km)	Reflectance (dB)	Insertion Loss(dB)	Splices (dB)	Attenuation (dB)	Connectors (dB)
1	Reflective	0.000	-15.02				
2	Non-Reflective	1.804		-0.283			
3	Non-Reflective	2.293		-0.018			
4	Non-Reflective	3.067		0.000	0.153	0.176	0.654
5	Non-Reflective	4.631		3.387	0.316	0.200	0.332
6	Non-Reflective	6.628		0.285	0.126	0.194	0.278
7	Non-Reflective	10.821		0.040	0.163	0.194	0.667
8	Non-Reflective	11.687		0.430	0.214	0.187	0.334
9	Non-Reflective	15.773		4.636	0.222	0.174	0.541
10	Non-Reflective	18.896		0.358	0.154	0.174	0.339
11	Non-Reflective	19.885		-0.049	0.078	0.152	0.667
12	Non-Reflective	23.257		-4.024	0.054	0.152	0.730
13	End	25.020	-14.06				
TOTAL				4.762	1.48	1.596	4.542

Table 3: Location C OTDR trace result with the End Threshold of 5.0dB.

S/N	Type	Location (km)	Reflectance (dB)	Insertion Loss(dB)	Splices (dB)	Attenuation (dB)	Connectors (dB)
1	Reflective	0.000	-13.83				
2	Non-Reflective	1.146		0.672			
3	Non-Reflective	2.257		-0.002			
4	Non-Reflective	3.383		0.029			
5	Non-Reflective	4.514		-0.040			
6	Non-Reflective	5.176		0.097	0.143	0.217	0.543
7	Non-Reflective	6.623		0.284	0.056	0.193	0.734
8	Non-Reflective	10.663		0.215	0.028	0.193	0.632
9	Non-Reflective	11.629		1.400	0.278	0.189	0.702
10	Non-Reflective	14.581		0.049	0.168	0.189	0.276
11	Non-Reflective	15.753		0.141	0.189	0.188	0.472
12	Non-Reflective	19.054		0.374	0.301	0.188	0.522
13	Non-Reflective	19.839		0.794	0.098	0.207	0.457
14	Non-Reflective	21.311		0.893	0.162	0.195	0.521
15	Non-Reflective	23.329		-0.299	0.119	0.195	0.711
TOTAL	End		-17.06	4.607	1.542	1.954	5.57

Table 4: Location D OTDR trace result with the End Threshold of 5.0dB.

S/N	Type	Location (km)	Reflectance (dB)	Insertion Loss (dB)	Splices (dB)	Attenuation (dB)	Connectors (dB)
1	Reflective	0.000	-14.35				
2	Non-Reflective	1.080		2.003	0.342	0.171	0.282
3	Non-Reflective	5.125		0.195	0.245	0.187	0.621
4	Non-Reflective	6.613		0.218	0.253	0.187	0.459
5	Non-Reflective	7.097		-0.081	0.147	0.203	0.334
6	Non-Reflective	10.668		0.137	0.246	0.203	0.509
7	Non-Reflective	11.662		0.157	0.324	0.189	0.621
8	Non-Reflective	15.768		2.799	0.176	0.183	0.511
9	Non-Reflective	19.044		0.158	0.092	0.183	0.346
10	Non-Reflective	19.818		0.206	0.137	0.187	0.711
11	Non-Reflective	23.334		-0.281	0.243	0.187	0.655
TOTAL	End	25.025	-16.47	5.511	2.205	1.88	5.049

3.2 Discussion

The return (reflectance) loss measurement test was carried out using the optical time domain reflectometer (OTDR) machine on location C of a fibre cable. At location A, it was observed that where noises occur in the cable, attenuations, insertion loss are recorded. At location B, it was observed that location B has higher insertion loss compared to location A since both have the same distance of 25.020km of trace recorded. This might due to more occurrence of noise in location B. However, location A has higher attenuation loss compared to location B. It is observed that the noises recorded at location C is quite much compare to location A and B. This is due to the error introduced by the patch cord, coupler, splices or scattering in the fibre. It is observed in location D that noises occurred occurred along the fibre length leading to attenuation and insertion loss. However, there is a drop in the slope of the OTDR trace of location D, this induced error can be attributed to marginal errors introduced by the OTDR machine, chromatic dispersion losses from the fibre cable, micro and. macro-bending losses emanating from the fibre. The splicing, attenuation and connector losses for location A are 1.644dB, 1.958dB and 5.021dB. For location B, the splicing, attenuation and connector losses are 1.48dB, 1.596dB and 4.542dB. Also for location C, the splicing, attenuation and connector losses are 1.542dB, 1.954dB and 5.57dB. The splicing, attenuation and connector losses for location D are 2.205dB, 1.88dB and 5.049dB.

4. Conclusion

The study shows that losses along optical fibre arise from the splice joint, connector joint and along the fibre length as attenuation loss. This loss was obtained from readings of the optical time domain reflectometer. The study shows connector losses was highest compared to splicing and attenuation for all the four locations (A, B, C, D) investigated. The study also shows that the combined splicing and connector loss is higher than attenuation loss. Here, splicing and connector loss contributes more to the total loss compared to attenuation loss. In this studies, combined splicing and connector loss account for 75% of the total losses while attenuation losses account for the remaining 25%.

Losses in fibre are highly unpredictable but can be reduced if the number of splices and connectors are reduced. Effort should, therefore, be made to reduce the number of splicing along optic fibre link.

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