Journal of the Nigerian Association of Mathematical Physics
***Volume 30,* (*May, 2015*), pp 373 – 378**

Power Budget Analysis of Fiber Optics Communication Links Along Benin-Asaba Route

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Abstract

With the development of optical fiber communication system most telecommunication companies now prefer to use optical fiber transmission medium for higher information bandwidth. The design of such a system involves many aspects such as the type of source to be used, the kind of fiber to be employed and detector. The designer must select from a set of device components to meet a given set of system requirements, one of which is the power budget analysis. In this work, four different optical fiber communication links under limited attenuation condition were studied. The design parameters include; power budget analysis, maximum link length. A power margin greater than four decibel was obtained; this indicates a healthy margin of signal strength.

Key words: Optical Networks, Fiber Optical Communication, Power Budget, Maximum link length.

1.0 Introduction

Optical fiber is the medium in which communication signals are transmitted from one location to another in form of light guided through thin fibers of glass or plastic [1-3]. These signals can be voice, data and video.

Fiber optic communication is based on the principle that light in a glass medium can carry more information over long distances than electrical signals can carry in a copper or coaxial medium at radio frequencies through a wireless medium. Optical fiber is superior to other transmission media because it combines high bandwidth with low attenuation.

Today, fiber Optics telecommunication is now the preferred means of data transmission over distances greater than one kilometer. The role of optical fiber is now increasingly significant because of the high bandwidth and low attenuation it can provide, replacing copper cables and satellite communication.

The role of a communication channel in optical fiber communications or optical fiber networks is to transport the optical signal from transmitter to receiver with as little loss in quality as possible. In practice, optical fiber broadens light pulses bymodal or chromatic dispersion. Ideally, a communication channel should not degrade the quality of the optical signal launched into it. If optical pulses spread significantly outside their allocated bit slot, the transmitter signal is degraded so severely that it becomes impossible to recover the original signal with high accuracy [4]. This loss in transmitted signal is referred to as attenuation. Attenuation limits the optical power which reaches the receiver due to various losses ranging from source to fiber coupling loss, fiber to fiber coupling loss, fiber to detector coupling loss and splice joints connectors. Attenuation in optical fibers arises from losses including dispersion, absorption, scattering, bending etc.

The aim of this work is to study the power budget of four different optical fiber links considering the design parameters in a fiber optics communication with respect to signal that can be transmitted reliably over limited attenuation conditions. This will help determine the maximum length the optical fiber cable can be safely run before signal degrades.

2.0 Power Budget Analysis

In system planning the power budget is an important parameter. The term power budget is a relationship between the power losses in fiber optics, associated equipment and available input power to the system [5]. The purpose of the power budget is to ensure that adequate power is reaching the receiver in all circumstances and no component has an excessive loss [6]. The preparation of link power budget requires parameters like optical power level P_r at the receiver to meet system requirements coupling losses etc.

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The power budget is defined as the difference between the maximum input power transmitted by the source and the minimum output power received by a detector. The average optical power launched into the channel should be as large as possible to enhance the bit error rate (BER) at the receiver end. If the signal is very weak when it arrives at the far end of the system the data will be difficult to separate from the background noise this will cause the number of errors in the received data bits to increase. The received power must be high enough to keep the BER to a low value. On the other hand, the received power must be low enough to avoid damage to the receiver. Power budget of link is calculated using power margin in decibel (dB). In order to operate properly, a fiber optic link must have an adequate power margin. A power margin, $P_m \geq 4$dB is acceptable [2]. The minimum power required is useful in estimating the fiber length, attenuation, loss in connectors and splices.

The equation for the power margin is given as [2].

$$P_m = P_t - P_r - L_{sf} - NL_{ff} - \alpha_L - L_{fd} \qquad (1)$$

Where P_m = Power margin
P_t = Transmitted power
P_r = Received power
L_{sf} = Source of fiber to coupling loss
N = Number of splice
L_{ff} = Fiber link length
L_{fd} = fiber to detector coupling loss
α = attenuation
α_L = Fiber loss

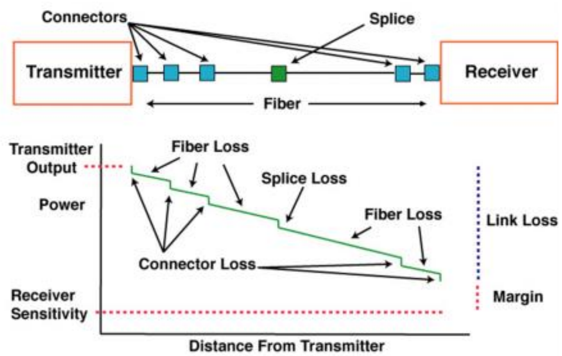

Figure 1: Power budget showing different component losses

As the light propagates in a steady state it decreases exponentially with the length (L) of the optical fiber which is known as attenuation. This parameter is measured in decibel per kilometer (dB/km). The relation between transmitted and received power is given as [7],

$$P_r = P_t \times 10^{-\alpha L} \qquad (2)$$

Where; P_r = Received power
P_t = Transmitted power
L = Length
= Attenuation coefficient

Attenuation falls with increasing wavelength i.e. as wavelength increases it decreases. The standard wavelengths used in fiber optic communication are called windows. The three low loss windows are 850nm, 1310nm and 1550nm but losses at the 1550nm which is about 0.25dB/km and higher at the 850nm window is 2.5dB/km. At some wavelength say 1380nm, the loss is very high due to water in glass, it is expected that in the future the 2500nm window will have lesser loss [6].

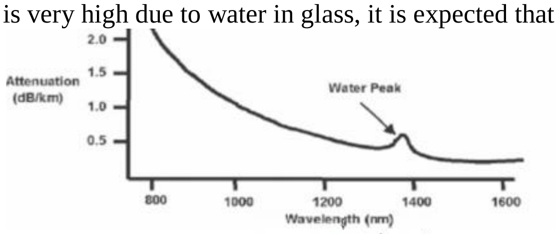

Figure 2: Attenuation versus wavelength curve (source).

The attenuation coefficient is given by [7],

$$\text{Attenuation (dB/Km)} = \left(\frac{10}{L}\right) \log\left(\frac{P_t}{P_r}\right) \qquad (3)$$

Where; L = Link Length
P_t = Transmitted power
P_r = Received power

3.0 Maximum Link Length

The maximum link length possible depends on how fast the link should operate and how much optical power is needed. It is given as [7]

$$L_{a(max)} = \frac{P_t - P_r}{\alpha} \qquad (4)$$

4.0 Result and Analysis

The project was carried out on a 96 core fiber optic transmission link using the single mode fiber cable at a wavelength of 1550nm to measurethe attenuation, transmitted power and received power. The attenuation measurement was carried out using the power source meter, the data were collected in four different transmission links, the transmit power in link A is -12.5dB while that of the links in B,C and D were placed at a constant value of -0.97dB but the received power varied among the cores of the various links; these variations is as a result of the splicing loss, absorption losses and bad connectors. Using standard estimated losses for the connector splice joint loss, cable type loss, fiber to fiber coupling loss, source to fiber coupling loss, fiber to detector coupling loss etc. The power margins for the four links were calculated using the mathematical model in equation (1). Calculated power margin exceeded 4dB which shows that the links are reliable; therefore they can retain a healthy margin versus attenuation for the difference fiber optic links are also presented in the figures below. The maximum link length was verified using equation (4) for all the four fiber links and corresponds with the respective link length.

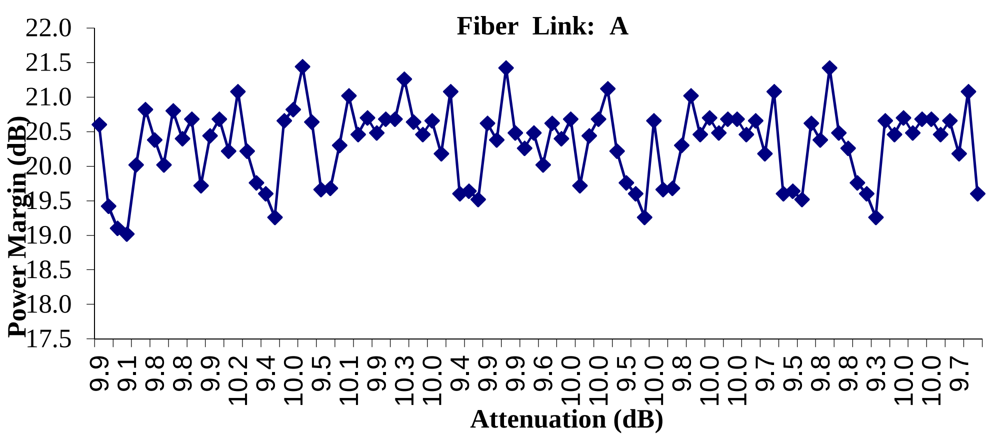

Figure 3: Graph of Power margin vs. Attenuation on link A.

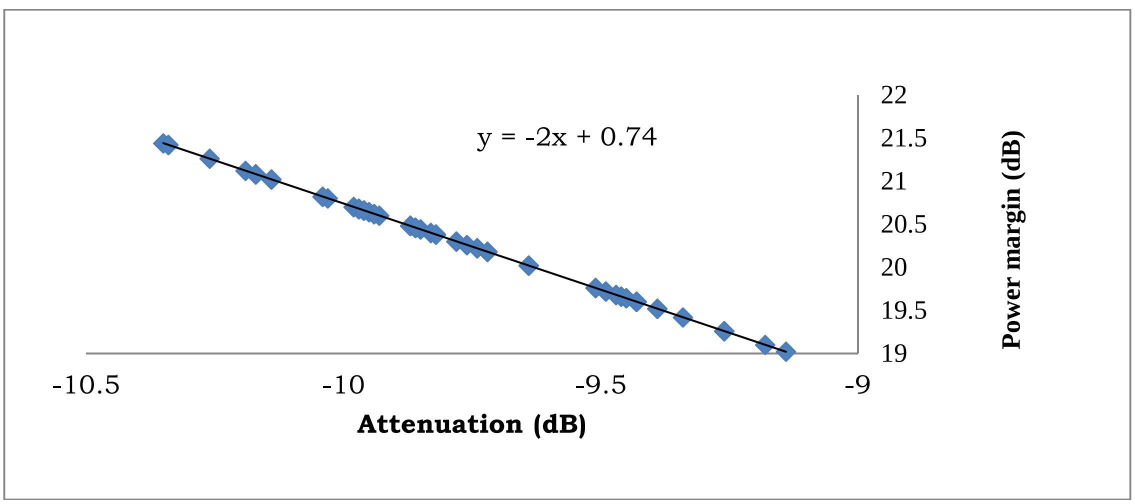

Figure 4: Scattered graph of Power margin vs. Attenuation on link A

The line graph in Figure 3 shows fluctuation in the attenuation on link A. The graph in Figure 4 shows an inverse linear relationship between power margin and attenuation, as the power margin increases the attenuation decreases.

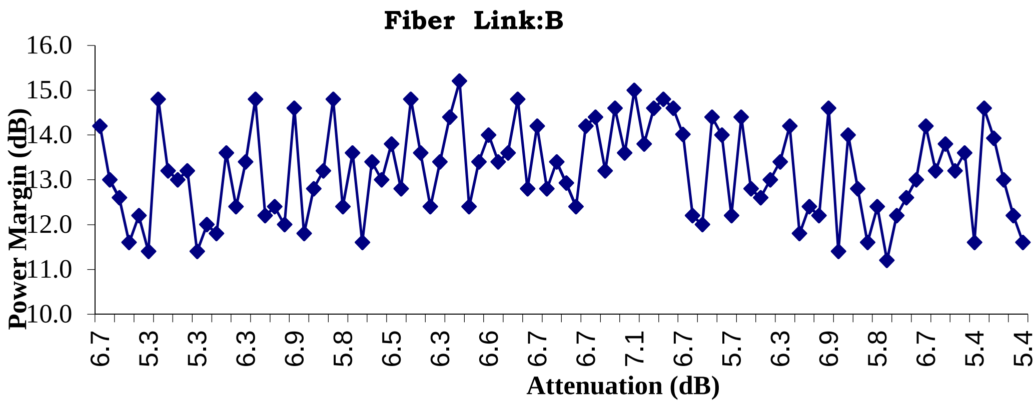

Figure 5: Graph of Power margin vs. Attenuation on link B.

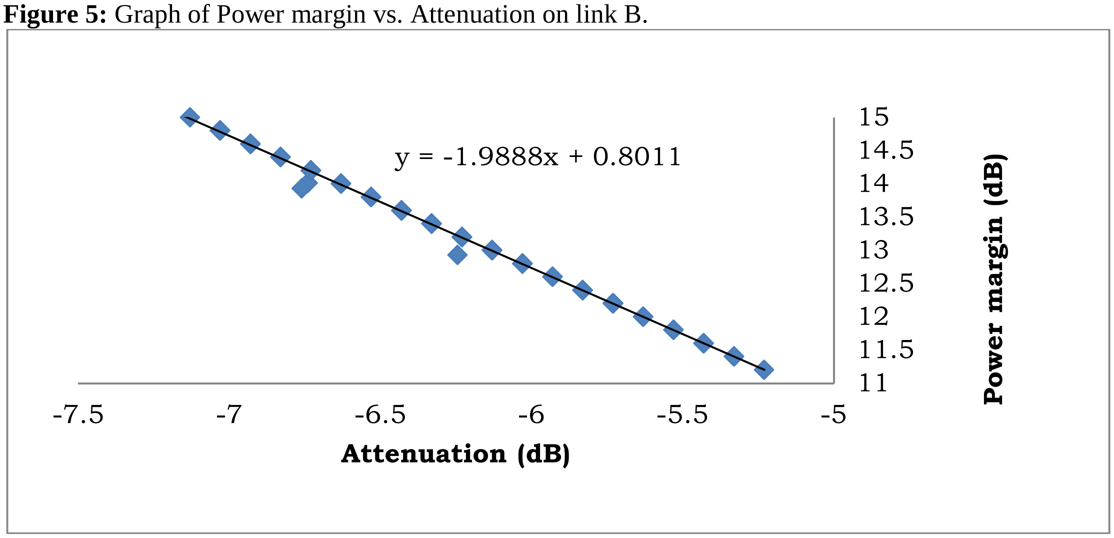

Figure 6: Scattered graph of Power margin vs. Attenuation on link B.

The line graph in Figure 5 shows fluctuation in the attenuation on link B. The graph in Figure 6 shows an inverse linear relationship between power margin and attenuation, as the power margin increases the attenuation decreases

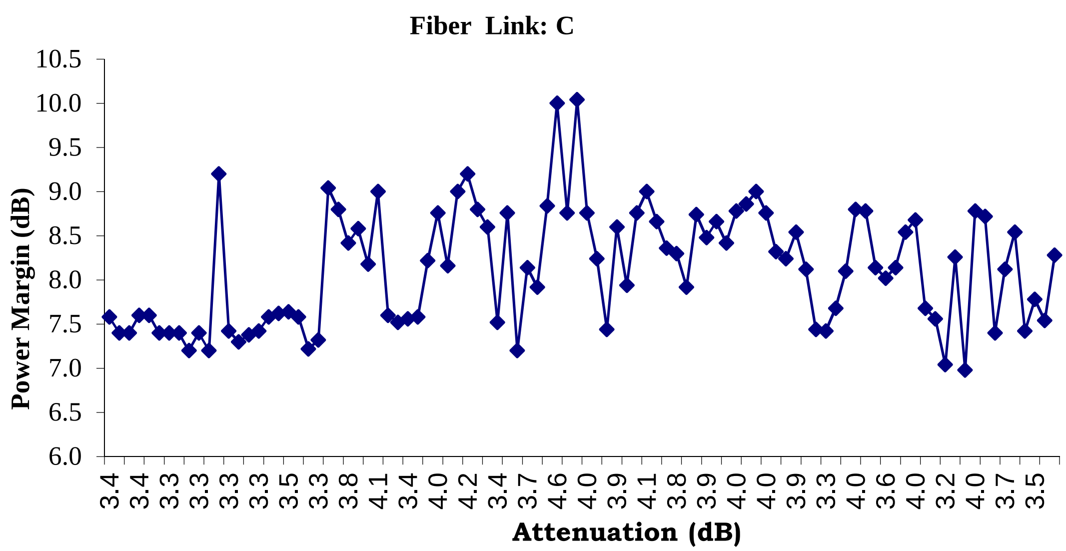

Figure 7: Graph of Power margin vs. Attenuation on link C.

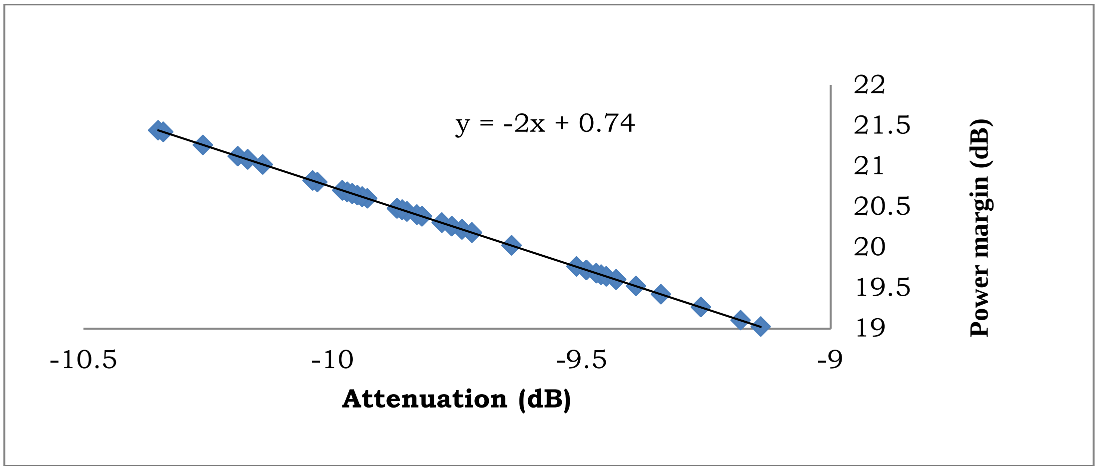

Figure 8: Scattered graph of Power margin vs. Attenuation on link C.

The line graph in Figure 7 shows the fluctuation in the attenuation on link C while the graph in Figure 8 shows the inverse relationship between power margin and attenuation, as the power margin increases, the attenuation decreases

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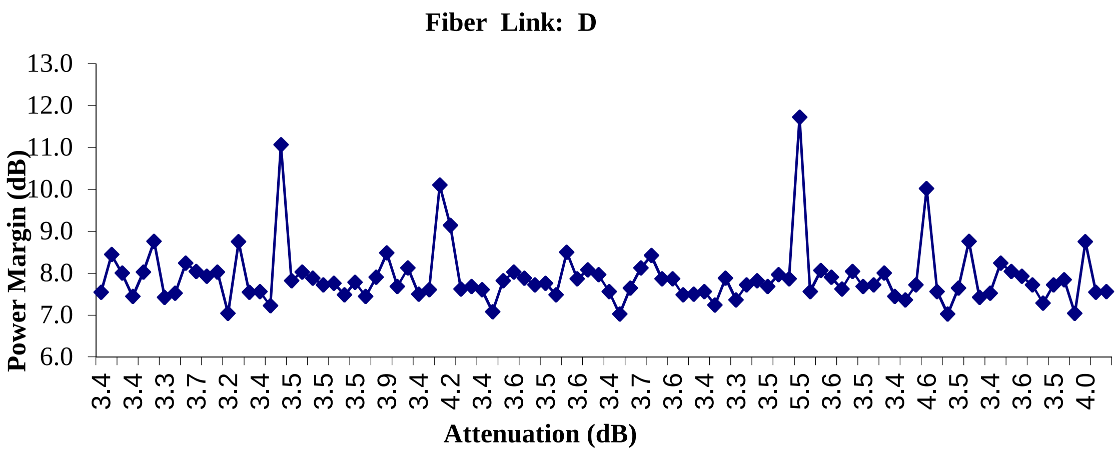

Figure 9: Graph of Power margin vs. Attenuation on link D.

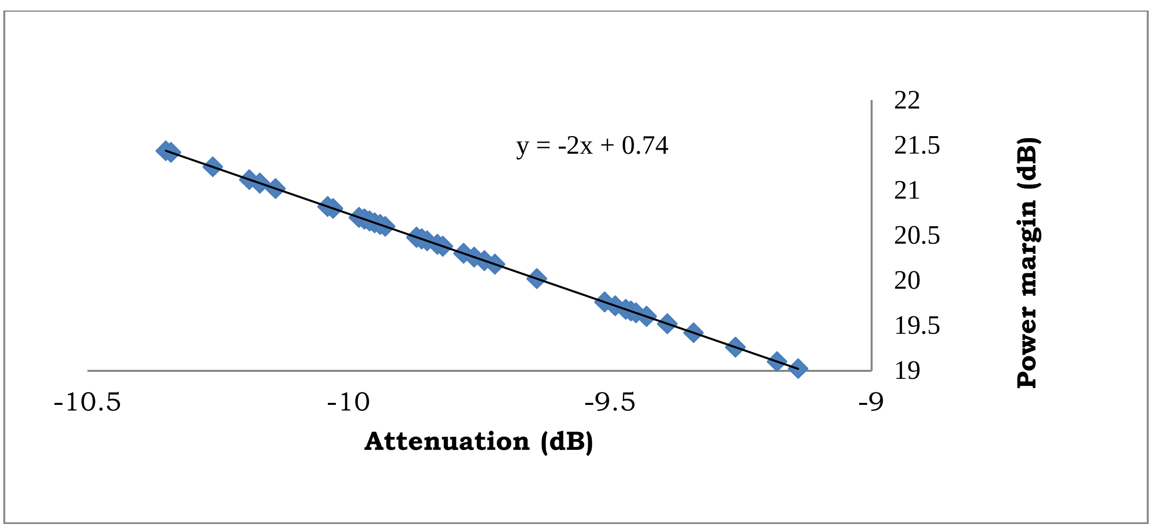

Figure 10: Scattered graph of Power margin vs. Attenuation on link D.

Figure 9 and 10 shows the graphical analysis that the power margin is inversely proportional to attenuation.

For links C and D the line equation have similar slope and intercept as in grapsh of link A. The different equation in link B is as a result of the connection. Generally, it is expected that all links A, B, C and D would have similar slope and intercept irrespective of the link length.

Table 1: shows the value of the mean attenuation, power margin, transmitted power and received power of the fiber optics of link A and B.

Mean	Fiber Link A	Fiber Link B	Fiber Link C	Fiber Link D
Received Power	-9.794	-6.228	-3.694	-3.583
Transmitted power	-12.500	-0.970	-0.970	-0.970
Attenuation	-9.794	-6.228	-3.694	-3.583
Power Margin	20.329	13.188	8.127	7.906

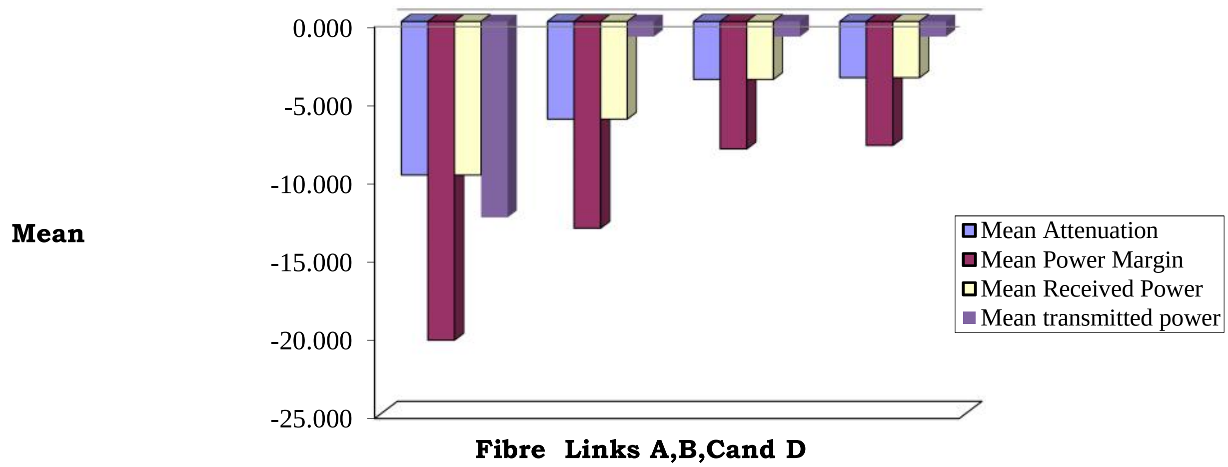

Figure 11: The bar chart was used to analyze the mean value of attenuation, power margin, transmitted and received power along all the four links.

The bar chart was used to analyze the mean values of attenuation, power margin, transmitted and received power along all the four fiber links.

5.0 Conclusion

The design of an optical fiber link involves many interrelated components amongst which are the fiber, optical source and photo detector. In designing an optical fiber transmission link, power budget analysis with different parameters are required to ensure limited attenuation before the link is satisfactorily completed.

Power budget of links A, B, C and D were analyzed using the mathematical model adopted by [2] and analyzed. This was used to evaluate system power margin as a safety factor. Since the calculated power margin was greater than 4dB, it showed that the links are reliable [2]. The graphical analyses illustrated that power margin is inversely proportional to attenuation. Also, maximum link length was verifiesd to ensure the links retains a healthy margin of signal strength at the receiving end.

6.0 References

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