Abstract

The Power losses between optical source and detector is referred to as the power budget. To ensure that the fiber system has sufficient power for correct operation, we need to calculate the span's power budget, which is the maximum amount of power it can transmit. Transmission distance depends on transmitter output power, receiver's sensitivity, fiber quality, splice loss, connector loss, safety margin and signal losses caused by other factors. The reliability or performance of a fiber optic communication system can be enhanced through careful selection and matching of all the subparts (transmitter, fiber optic, receiver, connectors).The optic fiber should be matched and verified according to its applications. It should be stresses that the optimization of communication system based on fiber optics has quite a number of parameters. The only way to enhance on such system is to use a thorough designing approach and tuning it with the feed-back received from an economical analysis.

List of contents

INTRODUCTION:

The allocation of power losses between optical source and detector is referred to as the power budget. The power budget is obtained by first determining the optical power emitted by the source, usually expressed in dBm, and subtracting the power (expressed in same units, e.g., dBm) required by the detector to achieve the design quality of performance.

To ensure that the fiber system has sufficient power for correct operation, we need to calculate the span's power budget, which is the maximum amount of power it can transmit. From a design perspective, worst-case analysis calls for assuming minimum transmitter power and minimum receiver sensitivity. This provides for a margin that compensates for variations of transmitter power and receiver sensitivity levels.

In order to implement or design a fiber-optic circuit, a span analysis is recommended to make certain the system will work over the proposed link. Both the passive and active components of the circuit have to be included in the loss budget calculation. Passive loss is made up of fiber loss, connector loss, splice loss, and losses involved with couplers or splitters in the link. Active components are system gain, wavelength, transmitter power, receiver sensitivity, and dynamic range.

The design procedure requires the selection of the most advantageous combination of source, fiber and detector types that best meets the system requirements. Cost is also Considered.

LITERATURE SURVEY:

To be able to judge whether a fiber optic cable plant is good, one does a insertion loss test with a light source and power meter and compares that to an estimate of what is a reasonable loss for that cable plant. The estimate, called a "loss budget" is calculated using typical component losses for each part of the cable plant - the fiber, splices and/or connectors. If the measured loss exceed the calculated loss by a significant amount (remembering the inherent uncertainty in all measurements), the system should be tested segment-by-segment to determine the cause of high loss.

PROBLEM STATEMENT:

The calculated loss budget is an estimate that assumes the values of component losses and does not take into account the uncertainty of the measurement. Be aware of this because if measurements are close to the loss budget estimates, some judgement is needed to not fail good fibers and pass bad ones.

OBJECTIVES:

- Testing The Power Budget For A Link
- Calculating Cable Plant Link Loss Budget
- Analyze Link Loss In The Design Stage
- Equipment Link Power Budget Calculation

THEORY:

Power Budgets And Loss Budgets

The terms "**power budget**" and "**loss budget**" are often confused.

The **power budget** refers to the amount of fiber optic cable plant loss that a datalink (transmitter to receiver) can tolerate in order to operate properly. Sometimes the power budget has both a minimum and maximum value, which means it needs at least a minimum value of loss so that it does not overload the receiver and a maximum value of loss to ensure the receiver has sufficient signal to operate properly.

The **loss budget** is the amount of loss that a cable plant should have if it is installed properly. It is calculated by adding the estimated average losses of all the components used in the cable plant to get the estimated total end-to-end loss. The loss budget has two uses, 1) during the design stage it is used to ensure the cabling being designed will work with the links intended to be used over it and 2) after installation, the loss budget for the cabling is compared to the actual test results to ensure the cable plant is installed properly.

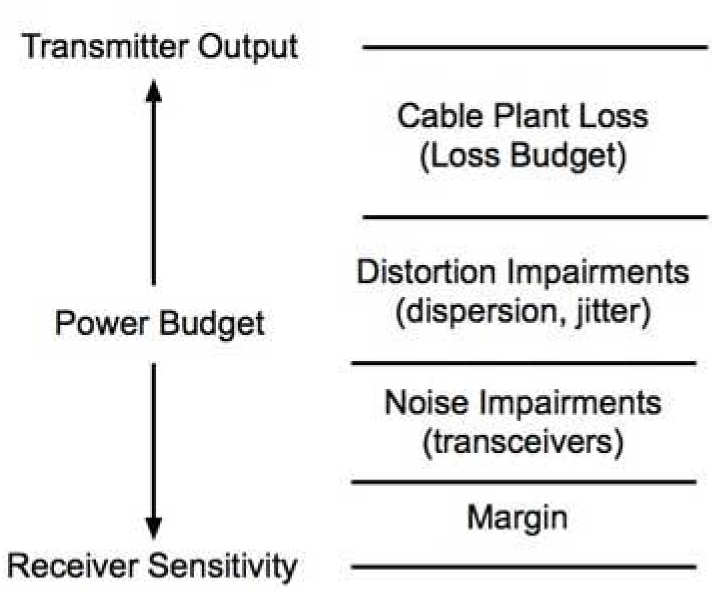
Some standards refer to the loss budget as the "attenuation allowance" but there seems to be very limited use of that term.

Obviously, the power budget and loss budget are related. A data link will only operate if the cable plant loss is within the power budget of the link.

Power Budget

All datalinks are limited by the power budget of the link. The power budget is the difference between the output power of the transmitter and the input power requirements of the receiver, both of which are defined as power coupled into or out of optical fiber of a type specified by the link. The power budget is not just a straightforward determinant of the maximum loss in the cable plant that the link can tolerate. As shown below, cable plant loss is only a part of the power budget. Distortion impairments, for example from dispersion (modal and chromatic dispersion in MM fiber, chromatic and polarization mode dispersion in SM fiber), reduce the power budget. In multimode gigabit Ethernet networks, for example, transceivers have a dynamic range (transmitter output to receiver sensitivity) of about 5-6 dB before dispersion is factored in, leaving a power budget of about 2 dB.

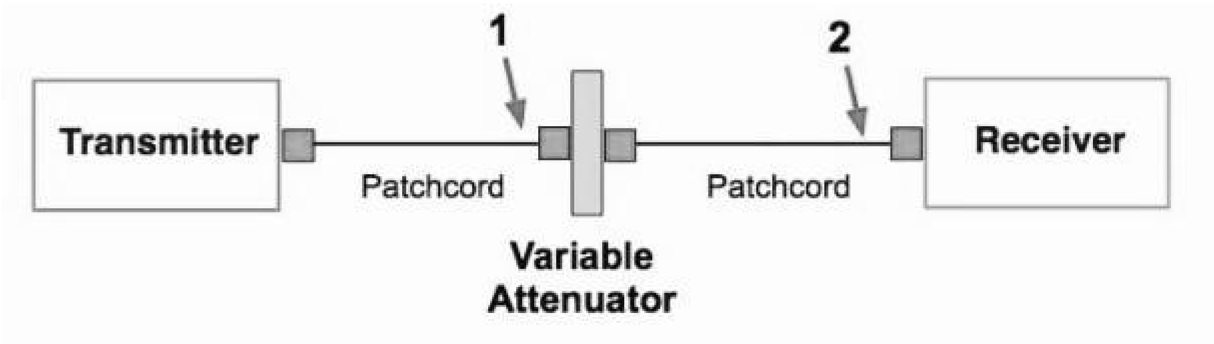
Noise in transceivers, mainly in the receiver, affect the power budget also. The receiver has an operating range determined by the signal-to-noise ratio (S/N) in the receiver. The S/N ratio is generally quoted for analog links while the bit-error-rate (BER) is used for digital links. BER is practically an inverse function of S/N. Transceivers may also be affected by the distortion of the transmitted signal as it goes down the fiber, a big problem with multimode links at high speeds or very long OSP singlemode links.



When testing a fiber in a cable plant to determine if the cable plant will allow a specific link to operate over it, the test should be made from transceiver to transceiver, e.g. the cable plant with patchcords installed on either end that would be used to connect the transceivers to the cable plant. When doing a link loss budget (below) for the cabling to be used with a given link to determine if the link will operate over that link, the loss of the patchcords may also be included.

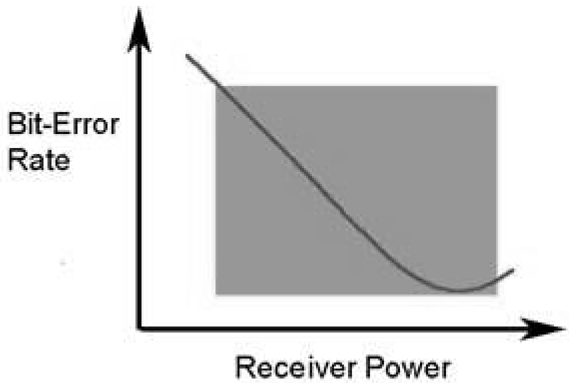
Testing The Power Budget For A Link

How is the power budget determined? You test the link under operating conditions and insert loss while watching the data transmission quality. The test setup is like this:



Connect the transmitter and receiver with patchcords to a variable attenuator. Increase attenuation until you see the link has a high bit-error rate (BER for digital links) or poor signal-to-noise ratio (SNR for analog links). By measuring the output of the transmitter patchcord (point #1) and the output of the receiver patchcord (point #2), you can determine the maximum loss of the link and the maximum power the receiver can tolerate.

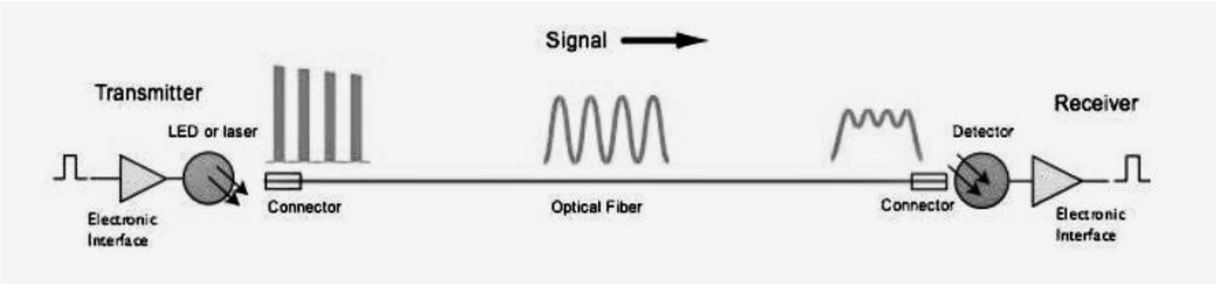
From this test you can generate a graph that looks like this:



A receiver must have enough power to have a low BER (or high SNR, the inverse of BER) but not so much it overloads and signal distortion affects transmission. We show it as a function of receiver power here but knowing transmitter output, this curve can be translated to loss - you need low enough loss in the cable plant to have good transmission but with low loss the receiver may overload, so you add an attenuator at the receiver to get the loss up to an acceptable level.

You must realize that not all transmitters have the same power output nor do receivers have the same sensitivity, so you test several (often many) to get an idea of the variability of the devices. Depending on the point of view of the manufacturer, you generally error on the conservative side so that your likelihood of providing a customer with a pair of devices that do not work is low. It's easier that way.

DESIGN:- BLOCK DIAGRAM



Furthermore, if your link uses multimode fiber at high bit rates (or singlemode on long links at very high bit rates), there will be dispersion. Dispersion spreads out the pulses, causing a power penalty. That's why high speed Ethernet at 10G has a loss budget of 2dB while the power budget calculated from transmitter and receiver specifications is about 6dB.

Calculating Cable Plant Link Loss Budget

Loss budget analysis is the calculation of a fiber optic cabling system's estimated loss performance characteristics. This is sometimes confused with the communication system "power budget" which is a specification of the dynamic range of the electronics, the difference between the output power of the transmitter coupled into the fiber and the minimum received power required at the receiver for proper data transmission. The communications system power budget will set a limit for the loss of the cable plant.

The cable plant loss budget needs to consider transceiver wavelength, fiber type, and link length plus the losses incurred in splices, connections and other passive devices like FTTH or OLAN PON splitters. Attenuation and bandwidth/dispersion are the key parameters for the cable plant loss budget analysis.

Analyze Link Loss In The Design Stage

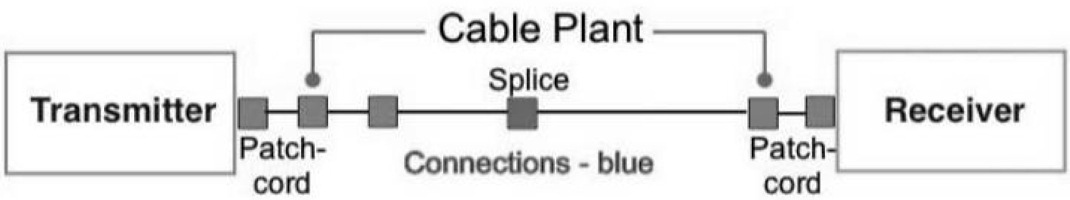
Prior to designing or installing a fiber optic cabling system, a loss budget analysis is recommended to make certain the system will work over the proposed link. That same loss budget will be used as to compare test results after installation of the cabling to ensure that the components were installed correctly. Both the passive and active components of the circuit have to be included in the loss budget calculation. Passive loss is made up of fiber loss, connector loss, and splice loss. Don't forget any couplers or splitters in the link. Active components are system gain, wavelength, transmitter power, receiver sensitivity, and dynamic range. Prior to system turn up, test the circuit with a source and FO power meter to ensure that it is within the loss budget.

The idea of a loss budget is to ensure the network equipment will work over the installed fiber optic link. It is normal to be conservative over the specifications! Don't use the best possible specs for fiber attenuation or connector loss - give yourself some margin!

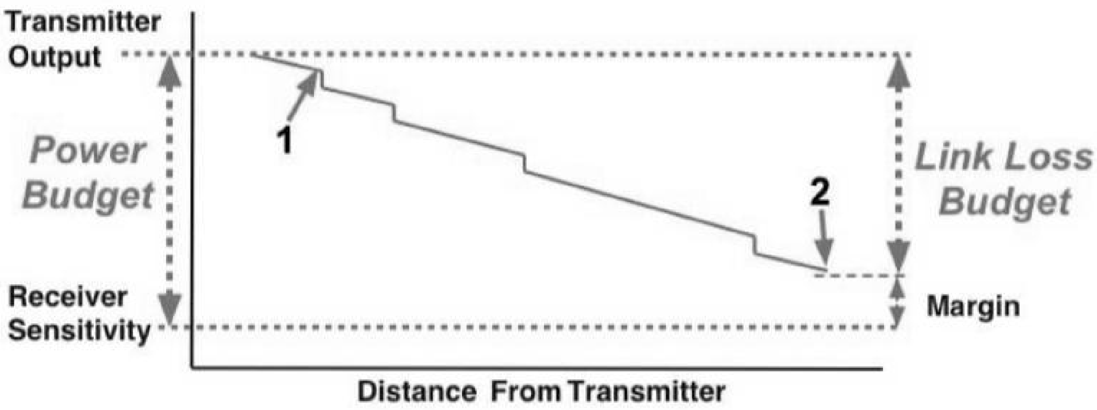
The best way to illustrate calculating a loss budget is to show how it's done for a typical 0.2 km multimode link. The link may be analyzed and tested in two ways, with or without the patchcords that connect the equipment. With the patchcords, the cable plant has 5 connections (2 connectors at each end to connect to patchcords connecting to the transmitter and receiver), 3 connections at patch panels in the link) and one splice in the middle. Without the patchcords, the cable plant has 3 connections (2 connectors at each end for the transmitter and receiver), 1 connection at a patch panel in the link) and one splice in the middle.

See the drawings below of the link layout and the instantaneous power in the link at any point along it's length, scaled exactly to the link drawing above it.

ACTUAL DESIGN:



DESIGN PARAMETER:



At the top is a fiber optic link with a transmitter connected to. a cable plant with a patchcord. The cable plant has 1 intermediate connection and 1 splice plus, of course, "connectors" on each end which become "connections" when the transmitter and receiver patchcords (or reference test cables) are connected. At the receiver end, a patchcord connects the cable plant to the receiver.

Note: A connector is the hardware attached to the end of a fiber which allows it ti be connected to another fiber or a transmitter or receiver. When two connectors are mated to join two fibers, usually requiring a mating adapter, it is called a connection. *Connectors have no loss; only connections have loss.*

Below the drawing of the fiber optic link above is a graph of the power in the link over the length of the link. The vertical scale (Y) is optical power at the distance from the transmitter shown in the horizontal (X) scale. As optical signal from the transmitter travels down the fiber, the fiber attenuation and losses in connections and splice reduces the power as shown in the green graph of the power.

On the left side of the graph, we show the power coupled from the transmitter into its patchcord, measured at point #1 (the end of the transmitter patchcord) and the attenuated signal at the end of the patchcord connected to the receiver shown at point #2. We also show the receiver sensitivity, the minimum power required for the transmitter and receiver to send error-free data.

The difference between the transmitter output and the receiver sensitivity is the **power budget**. Expressed in dB, the power budget is the amount of loss the link can tolerate and still work properly - to send error-free data. The difference between the transmitter output (point #1) and the receiver power at its input (point #2) is the actual loss of the cable plant experienced by the fiber optic data link.

The difference between the power coupled into the cable plant and the power at the receiver is the loss of the cable plant. That's what we estimate when we calculate a **loss budget**.
It's also what is called "insertion loss" tested with a test source and power meter.

Equipment Link Power Budget Calculation: Link loss budget for network hardware depends on the dynamic range of the electronics, the difference between the sensitivity of the receiver and the output of the transmitter into the fiber. You need some margin for system degradation over time or environment, so subtract that margin (as much as 3dB) to get the loss budget for the link.

RESULT:

CODE:

```
import math

# create a table with keys and data

# ask about the type of connection on point A

# ask about the length of connection

# patching points number - by default 2

# ask about the type of connection on point B

file_dictionary = {'overview': 'overview.txt', 'maximum_distance': 'maximum_distance.txt'}

# Attentuation table with average optical fiber losses for multimode in dB/km
multimode_attentuation_dB = {'850': 3, '1300': 1}

# Attentuation table with average optical fiber losses for multimode in dB/km
singlemode_attentuation_dB = {'1310': 0.3, '1550': 0.2}

# Initial global parameters

optical_output_power_dBM = 0
receiver_sensitivity_dBM = 0
receiver_saturation_dBM = 0
power_budget_total = 0
losses_total = 0
net_budget_total = 0
Connector_Loss_dB = 0.5
Splice_Loss_db = 0.1
SingleMode = False
MultiMode = False
SafetyMargin = 3


# Function to search inside dictionary
def item_searching(item_required, item_list):
    # List of files, need to be created
    item = None
    if item_required in item_list:  # Checking if the key is in the dictionary
        item = item_list.get(item_required)  # Get item by key
    else:
        print("Error")
    return item


# Converting average value to peak

def convert_avg_to_peak(avg):
    peak = avg + 3

    return peak


# Converting peak to average value

def convert_peak_to_avg(peak):
```

```python
    avg = peak - 3

    return avg


# Calculating power budget

def power_budget_calculation(output_power, receiver_sensitivity):
    power_budget = output_power - receiver_sensitivity
    print("Your power budget is: ", power_budget)
    return power_budget


# Calculating net optical power budget

def net_optical_power_budget(power_budget, power_losses):
    net_power_budget = power_budget - power_losses
    print("Your net power budget is: ", net_power_budget)
    return net_power_budget


# Multimode or single mode
def mode_select():
    global SingleMode
    global MultiMode

    mode = int(input("What is the type of the fiber?\n"
                     "1 = Single Mode\n"
                     "2 = MultiMode\n"))

    if mode == 1:
        SingleMode = True
        MultiMode = False

    elif mode == 2:

        MultiMode = True
        SingleMode = False

    else:
        print("Wrong input")

    return None


# Calculating optical loss
def optical_loss_calculation(length, attentuation_local, splices=2, connectors=2):
    loss = (length * attentuation_local) + (splices * Splice_Loss_db) + (connectors * Connector_Loss_dB)
    total_loss = loss + SafetyMargin
    return total_loss


#
############################################################################################################
# This is actual code for the program with choices and menus
#

# Call to write overview
file_opened = open(item_searching('overview', file_dictionary))  # Open file to file_opened object
```

```
contents = file_opened.read()  # Read object to contents
print(contents)  # Print contents

optical_output_power_dBM = int(input("What is power of your output?\n"))
receiver_sensitivity_dBM = int(input("What is your receiver sensitivity?\n"))

mode_select()

if SingleMode is True:
    attentuation = item_searching(input("What is the wavelength? 1310 Or 1550nm?\n"),
singlemode_attentuation_dB)
elif MultiMode is True:
    attentuation = item_searching(input("What is the wavelength? 850 Or 1300nm?\n"),
multimode_attentuation_dB)
else:
    attentuation = 0.2
    print("Something went wrong with wavelength\n")

length_of_connection = int(input("What is the length of connection in KM?\n"))

number_of_splices = int(input("How many splices?\n"
                        "Default is 2"))
```

OUTPUT:

```
What is power of your output?
100
What is your receiver sensitivity?
-21
What is the type of the fiber?
1 = Single Mode
2 = MultiMode
1
What is the wavelength? 1310 Or 1550nm?
1310
What is the length of connection in KM?
13
How many splices?
Default is 24
How many connectors?
Default is 24
Optical loss on the length 13 km is :
9.3
Your power budget is:  121
Your net power budget is:  111.7
```

NOVELTY:

Power budget calculation can be used in a number of ways, for example if the fiber attenuation was known then a system designer could use a power budget calculation to determine the maximum distance between the transmitter and receiver or between regenerators. This distance is called the power-limited distance of the link.

However, the power budget calculations may become significantly more complex for two reasons:

(a) A number of extra factors may be included in the power budget calculation. For example a margin may be included to account for variations with temperature and age. The transmitter output power for example may vary with temperature and decrease with time over a number of years. To account for this a transmitter degradation margin is included, which is typically 1 dB. This appears in the power budget calculation as if it is a "real" attenuation, whereas in practice when the system first becomes operational and assuming the temperature is correct the received power would be 1 dB more than that predicted by the power budget calculation5-8 .

(b) All the power level and attenuation values used in the power budget calculation above are average values. When the optical transmission system is installed some variation in these values will naturally take place. The system designer has little control over such variations and therefore must resort to statistical techniques to ensure that the power budget calculation is realistic.

Ignoring the statistical nature of component performance by using worst case values, in every case can create extremely over-conservative designs. If for example, in finding the total loss caused by fusion splices, the worst case loss for a fusion splice is simply multiplied by the number of splices involved, the result would be a figure for the total splice loss that would virtually never occur in practice

CONCLUSION & FUTURE SCOPE:

The reliability of the communication of fiber optic systems can be done only through a careful selection and matching of all the subparts (transmitter, fiber optic, receiver, connectors).The fiber optic should be matched to the application such that it satisfied the overall power budget. It should be stresses that the optimization of communication system based on fiber optics has quite a number of parameters. The only way to enhance on such system is technical improvements and tune it with the feed-back received from an economical analysis.

In nut shell, the system should be effective, useful and economically viable.

REFERENCES:

- International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-3, Issue-6, January 2014
- International J ournal o f Computer S cience, C ommunication & Information T echnology (CSCIT)

  CSCIT - Vol.2 - issue1 - 2015
- https://www.youtube.com/watch?v=k8MFFXPXNh4
- https://www.thefoa.org/tech/lossbudg.htm
- http://www.fiber-optics.info/ 5/7/2013