PQM995(v1.2) May 12, 2009

Programmable Quality Monitor for Optical Fiber Communication

Summary

This PQM application note document describes the installation and operational procedure of the PQM.

1. Preface

Optical fiber communication is an extremely fast communication system which features the high Baud rate up to 40 Gbps per channel and the high information density up to 32 channels in a 9 micro meter diameter fiber in a DWDM system.

The applications have been extended from voice, video communication to business such as the back bone of e-commence. Therefore it is very easy to understand if a malfunction occurs in an optical fiber communication system, it would cause much more serious results than a low speed communication system.

How to keep an optical fiber communication in good communication quality has become an important consideration. In order to improve optical fiber communication liability, it is necessary to integrate an optical fiber communication quality monitor and quality management system (it is abbreviated as QS) in the communication system.

1.1 Basic Functions

The basic functions of a QS are on two aspects:

1. In the normal operation, a QS can measure the optical fiber communication quality quantitatively, perform statistical procession of the quality data and display and report all the information so that the optical fiber communication quality management bases on a very solid quantitative data foundation. The following messages from a QS are much better than a simple state of " Communication is normal":

   - "The input optical intensity of Channel 4 of Station 2 is 5.3 dBm above the minimum level required"
   - "The output optical power of Channel 3 of Station 1

has been dropped 0.1dBm from the initial value in the past 2 years and 3 month it is recommended to be replaced May 2004"

- "The input optical intensity of Channel 1 of Station 5 has been dropped 1.2 dBm: 0.1 dBm drop due to the transmitter, 1.1 dBm drop due to the fiber. The examination of the fiber is recommended"

2. When a malfunction happened or would happen, a QS can send pre warning and/or alarm signals, determine the malfunction level, malfunction cause and malfunction location, start spare channels very fast so that the malfunction can be eliminated as soon as possible. The following messages from QS are much useful than a simple statement of "Communication malfunction" or customer complain:

- "Degradation Warning!The input optical intensity of Channel 8, Station 4 has been dropped 3.5 dB due to the output power drop of transmitter of Station 5. The communication is still OK, please check the transmitter"
- "Serious Degradation Warning !!The input optical intensity of Channel 3, Station 2 has been dropped 6.3 dB due to fiber from Station1. The spare Channel 1 has been started"
- "Very Serious Degradation Warning !!!The output optical power of Channel 2, Station 10 was dropped to -10 dBm 5:51PM, Jun. 1998. The spare Channel 1 was started "
- "No light Warning !!!!The input optical intensity of Channel 3, Station 5 was dropped to –65 dBm 3:45 AM, Feb. 1998 due to the fiber from Station 4 is broken. The spare Channel 1 was started"

The information is very important for the maintenance team to find the malfunction cause and fix it to recover the communication soon.

2. Basic System

A qualified optical fiber communication quality monitor and management system (abbreviated as QS) should possess the following features:

Requirements

2.1 Completeness

An optical fiber communication system consists two main parts: communication terminal devices and optical fiber networks. A QS should have the capability to monitor and manage both of them.

2.2 Quantitatively

It is necessary to select a communication quality parameter as the quality indicator so that the QS can show the communication quality status quantitatively such as the instant quality value, the degradation from the initial value and the margin to the low limit. Thus the quality monitor and management base on solid quantitative data foundation, not a simple status like “ normal “ or “malfunction”.

The parameter should be simple, that means the parameter should be measured simply and processed easy, Ideally only one value or one parameter is preferred to indicate one channel communication quality. The parameter should be common, that means by the parameter the other communication quality parameters can be deduced by the indicator.

2.3 Real time operation

A QS should monitor the optical fiber communication system all time.

2.4. Online monitoring

A QS should monitor the optical fiber communication system when the optical fiber communication is carrying on without affecting it.

2.5. Reliability

a QS must meet two reliability requirements: first the failure rate of a QS must be much lower than the optical fiber communication system to be monitored and managed, second if some failure occurs in a QS, the possibility of the failure affecting the optical fiber communication must be minimized.

It requires that the number of the OS optical components which is inserted to the optical fiber communication system must be reduced to the minimum.

2.6 Fast responsibility

It involves two aspects: at the normal operation, a QS can indicate the quality status fast. When some malfunction happens, the QS can response it fast : detecting the malfunction fast, finding the malfunction cause fast, sending alarm signal fast and so on.

Also the function of "cause finding" involves:
1) In which station and which line the malfunction occurred
2) The malfunction occurred in the transmitter or the optical cable
3) If the malfunction occurred in the optical fiber, where is the malfunction point in the fiber.

2.7. Pre warning capability

A QS should have the ability to set several pre warning thresholds , when the communication quality degrades to one of the thresholds, but has not reached the level of causing the communication interruption yet, the system should send pre warning signal and ask for maintenance or other procession.

2.8. Predication

Based on the accumulation of the quality parameter data and the degradation approach, a QS can predict when a malfunction may occur for each channel in future.

2.9 Expansion

A QS should have the capabilities to expand the functions of the other fields such as power interrupt process, security and so on.

2.10 Independence

It is easy to understand that a quality monitor system should be independent on the system under its monitor.

2.11. Optical insertion loss

When a QS is used, it will introduced some extra optical insertion loss in the optical fiber communication system. It can not be avoided, but it should be minimized. The insertion loss is divided to portions: the connector insertion loss and the QS internal insertion loss.

The connector insertion loss depends on the number of the optical connectors that are added to optical fiber communication system due to the QS. It can be eliminated by the use of fusion slice.

The QS internal insertion loss depends on the number of the QS internal optical components that are inserted in the optical fiber communication system and the insertion loss of each component. The QS internal insertion loss is quite important, it can be considered as one of the measurements of the QS quality.

Fig.2-1 shows an optical communication channel before a QS is inserted. There are two connectors in one channel

Fig.2-1

A complete connectorized QS shown in Fig.2-2 is inserted in an optical fiber communication channel, the number of the connectors are 6, three time of number before the QS is inserted.

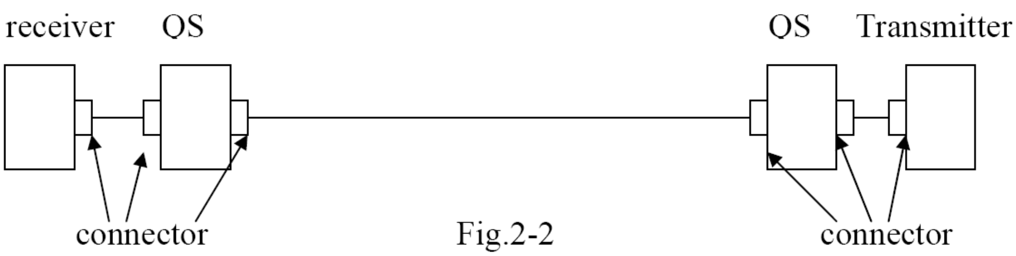

Fig.2-2

A QS with fusion slice on one side and pigtail on the other side, the number of connectors per channel are the same as that before the QS is inserted. Which is shown in Fig.2-3

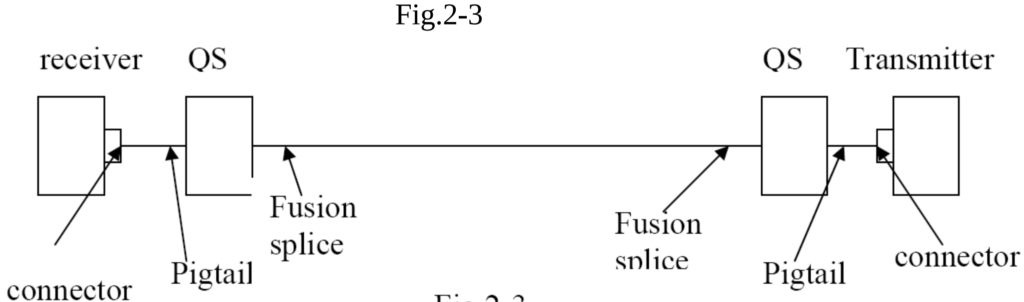

Fig.2-3

Chapter 3 QM and PMQM

3.1 What is QM?

QM is the abbreviation of Quality Monitor that is an optical passive, high sensitive and high speed optical/electrical sensor. The input of a QM is optical energy while the output of the QM is electrical voltage.
The term of "optical passive " means when a QM is integrated to an optical fiber communication system, it never sends any optical signal to the system, it is absolutely quiet optically.

High sensitive means when the optical power is as low as –42 dBm, the output voltage of a QM is still about 0.4 V.
High speed has meanings in two aspects, the first, optically QM can operate up to 2.5Gb/s or higher system Baud rate, the second, electrically, a QM can present the optical intensity changes in ms even in us order.

3.1 What is PQM?

A PQM is developed from QM, but it is added a function of programmable gain control. A PQM has 4 O-E (Optical-Electrical) gain settings: G1(lowest gain setting), G2,G3 and G4(highest gain setting). The highest O-E gain setting is equivalent to the sensitivity of the QM.

The O-E gain is defined as the ratio of electrical output voltage from a PQM over the optical power input to the PQM.

The minimum gain values of 4 gain settings are
G1: 5V/mW
G2: 50V/mW
G3: 500V/mW
G4: 5000V/mW

The highest O-E gain selection bases on the sensitivity of the optical fiber communication receiver: -32dBm or –39dBm

When a 90:10 optical power splitter is used with a PQM in the receiver side, the minimum PQM output voltage can be no less than 400mV for the receiver sensitivity of –32 dBm or 80 mV for the receiver sensitivity of –39 dBm. The minimum PQM output voltage is enough for the operation of a analog to digital converter (A/D) or a

voltage comparator.
Associated with an optical power splitter, PQM can be used in all of optical fiber communication systems.

A PQM has a plastic package with twelve electrical pins at the bottom and one optical connector in the front. The electrical pin pitch is 0.1 inch of standard and the optical connector can be FC, ST or pigtail depending on user selection. More detail information can be found in PQM data sheets.

4. PQM Based Computerized Optical Fiber Communication Quality Monitor and Management System

4.1. Leakage Method

The PQM based QS is also called "Leakage Method of QS" because the basic concept of the method is to take a small portion of the optical signal from each channel at both transmitter side and receiver side of an optical fiber communication system.

The small portion of the signal is input to a PQM and the PQM converts it to the electrical voltage with huge gain and large dynamic range. Since the portion is so small, 1% to 10 % , it is just like a leakage. Since a PQM output voltage is proportional to the input optical signal intensity, the optical signal intensity is taken as the quantitative measurement of the optical fiber communication quality.

The implement of the leakage is by the use of an optical component of optical power splitter or optical power coupler.
An optical power splitter is a three terminal device: one input and two outputs, which is shown in Fig. 4-1.

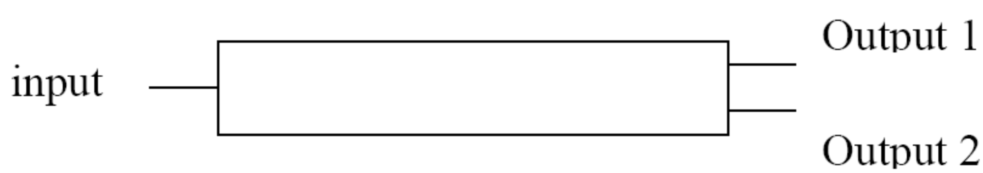

Fig.4-1

The optical power into the input is split to two portions that are output from output1 and output2 respectively with a certain ratio. For example an optical power splitter with the ratio of 99:01, 99% of input optical power is output from the terminal output1 and 1% is output from the terminal output2.

The ratio selected depends on the optical power range in the transmitter side or the receiver side and the PQM gain range. A large ratio is preferred to reduce the QS internal optical insertion loss.

The ratio of 99:1 is recommended on the transmitter side and the ratio of 90:10 on the receiver side. Thus the optical insert loss can be as low as 0.04 dB on the transmitter side and 0.4 dB on the receiver side. The total QS internal optical insertion loss of one channel can be as low as 0.44 dB.

4.2. Basic System Structure

The PQM based computerized QS block diagram is shown in Fig. 4-2

In the block diagram, an IBM personal computer ISA bus is used as an example. A PQM control card is required in the both sides of the transmitter and receiver. The PQM control card may be a standard ISA bus card or PCI bus card or it is in a separate box. But no matter what kind of structure is selected, an electrical communication bridge must be between the PQM card and the computer. The bridge may be a direct inserting to the computer bus, or a bus extension or a serial port or a parallel port.

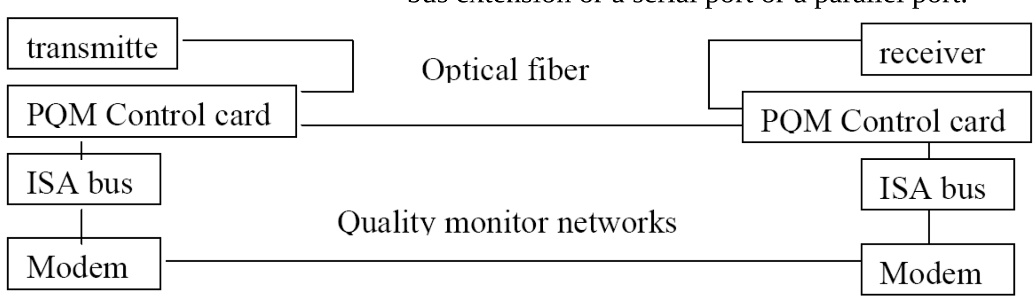

Fig.4-2

A direct inserting bus card is the simplest structure, but its disadvantage is the size of the card is limited, if more than 8 channels are required, the size may not be enough.

The structure of bus extension is simple as well, but the length of the extension is limited, otherwise it would affect the bus normal operation.

Serial port and parallel port are common in the computer communication, the communication cable length can be more than 1 meter, but it needs a micro controller built-in the PQM card and the communication speed would be low, especially for a serial port. Now universal serial bus version 2.0 provides a high speed of 400 Mb/s, it would be a good communication bridge.

The quality monitor networks and the related modem or other networks interface will be discussed in detail in the late chapters.

The block diagrams of the PQM control cards on a transmitter and the receiver are shown in Fig. 4-3 and Fig. 4-4 respectively.

The block diagrams for transmitter side and the receiver side are similar, but the differences are the optical power splitter, D/A and voltage comparator.

4.3 A/D operation

The basic operation of the PQM control card is the analog to digital conversion in the normal condition. Before an A/D operation, the computer must set the PQM gain according to the data obtained from the initialization procedure so that the PQM output voltage should be within 0.4V and 4.5V, if the output voltage is beyond the range, the computer will change the gain setting.

The computer triggers an A/D operation triggers, usually by a memory write instruction. The A/D converter converts the PQM output voltage to digital data and the computer read back data through the bus. But the data read back from the A/D is raw data which can't be displayed directly, the computer will process the data according to the PQM gain setting, a linear-logarithm look up table or least square fitting coefficients that is generated in the initialization, transfers the data with the unit of dBm. dBm is the commonly used unit in an optical fiber communication system for optical power.

After the process, the computer displays the data on the screen.

Each PQM control card should have one A/D converter at least, one A/D converter at one channel is preferred , but one A/D converter shared by several channels through a built-in or an external analog multiplexer. is acceptable . The resolution of the A/D is recommended 8 bits at least.

Based on the basic operation, the following information for each channel can be easily obtained after a simple data procession:

1) current optical power
2) the initial optical power
3) the optical power drop from the initial value.
4) the minimum optical power required of the channel
5) the margin of the optical power, that is the difference between the current optical power and the minimum optical power required.

Because of the information mentioned above, the optical communication quality monitor and quality management base on the solid quantitative data foundation, not only a simple statement “communication is normal or not”

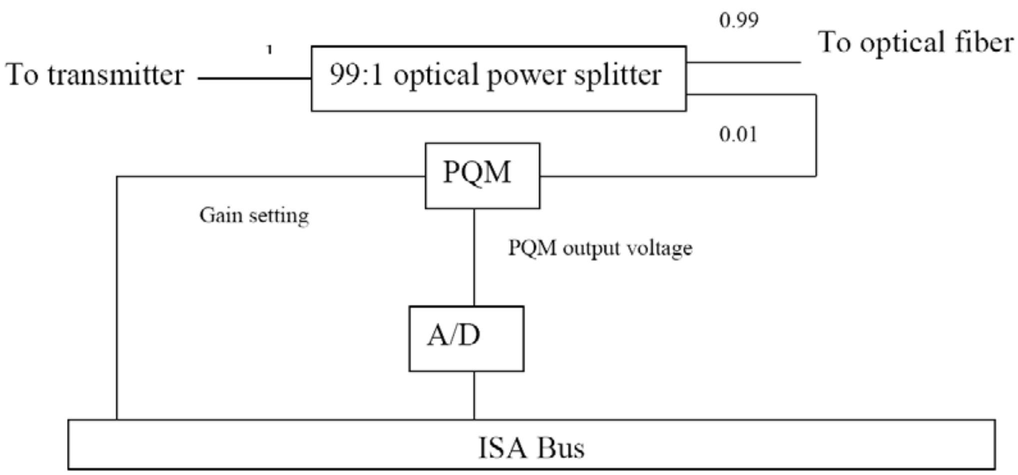

Fig.4-3 PQM control card structure on transmitter side

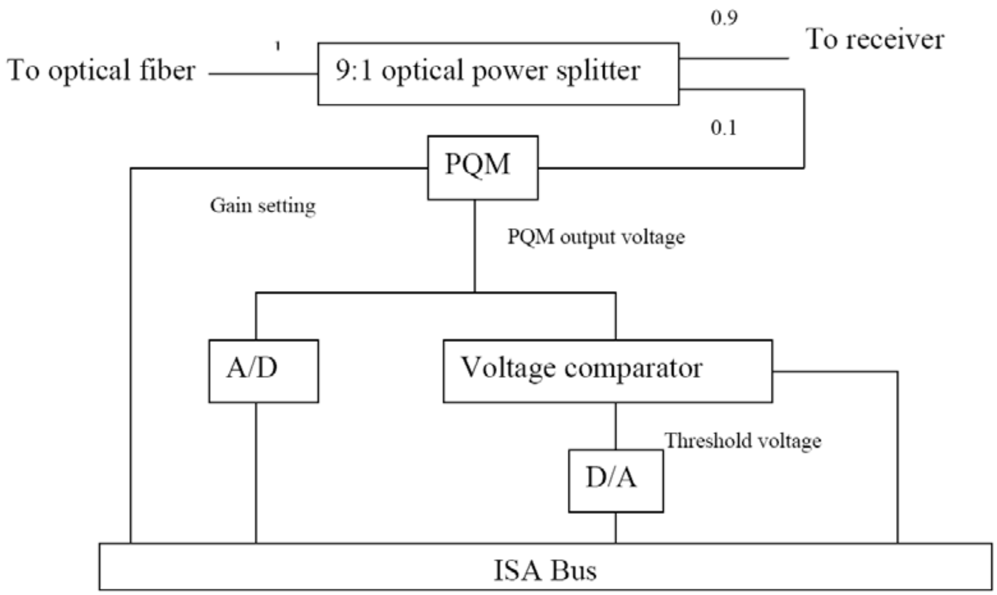

Fig.4-4 PQM control card structure on receiver

4.4 Voltage Comparison

The second basic operation of a PQM based QS is the voltage comparison of the voltage comparator.

The voltage comparison operation is for quality degradation and malfunction warning. Three voltage comparators are recommended for each channel, which have three different thresholds for degradation warning, serious degradation warning and very serious degradation warning respectively.

The threshold voltages are set by a D/A converter during the initialization procedure which will be explained late.
When the optical power drops to below any threshold voltage of comparators on the receiver side for any kind of reason: the transmitter output optical power decreased or the optical fiber attenuation increased, the voltage comparator responses immediately and changes its output logical level, the logical level change will invoke an interrupt. When the computer CPU responses the interrupt, the following reactions are taken:

<1> If a serious degradation or a very serious degradation is detected, the spare channel is started on the receiver side immediately, meanwhile an message is sent to the

PQM control card of the transmitter on the other end of the channel through the quality monitor networks and inform the transmitter side to start the corresponding spare channel immediately to keep the communication going and at the same time the message inquires the quality information at the same channel of the transmitter side.
If a degradation is detected, the communication is still normal, no spare channel is started, but the message is still sent out and inquiries the quality information at the same channel of the transmitter side.

<2> if the PQM output voltage in the transmitter side drops as well, it is a transmitter malfunction, then send a transmitter malfunction alarm message to the central office and the maintenance people, the message should include the following information:

- The malfunction station
- The malfunction channel number
- The malfunction cause: transmitter ,
- The malfunction type: degradation or serious degradation or no light
- The malfunction occurs time and date,
- The optical power data of the malfunction channel on the both side, which includes the optical power values before and after the malfunction occurred.

<3>If the PQM output voltage in the transmitter side is normal, it is a optical fiber malfunction, the QS reaction steps are same as those for transmitter malfunction, but the contents of the alarm message should have the following difference:
1) Malfunction cause: optical fiber
2) Inform the maintenance people to find the malfunction point location in the fiber by means of an OTDR. If an OTDR is equipped in the QS, the OTDR is requested to start to search the fiber malfunction point location.

Since the optical power change in transmitter side must affect the optical power in the receiver side, the D/A converter and the voltage comparator are not required on the transmitter side.

The detail operations of a PQM based QS will be described in the late chapters.

5. Analysis of a PQM based computerized QS

The PQM based computerized QS (PQM system is used as the abbreviation hereafter) will be analyzed in this chapter to show how it can meet the requirements

5.1. Completeness

Since PQMs are used in both transmitter side and receiver side, a PQM based QS can monitor both of transmitter output power and the optical fiber attenuation, also when a degradation occurs, the system can distinguish the cause, that is described in 4.4. It meets the completeness requirement obviously

5.2. Quantitavity

The PQM system selects the optical signal intensity or the optical power as the indication of the optical fiber communication quality. It is a true quantitative description so that it can meet the requirement of quantitativity.

The advantages of the selection of the optical power are:
1) It is a common sense that high optical signal power means good communication quality.
2) It is simple. Only one numeric value is used to describe the communication quality for each communication channel, therefore it is easy to process and to store the quality data.
3) It is basic because the optical power or intensity can be used to calculate or estimate other communication quality parameters quite easy. For example signal to noise ratio is another communication quality parameter, if a receiver sensitivity is –32 dBm, the noise power of the receiver must less than –44 dBm to reach the baud error rate less than 10-9 .When the receiver input optical power is –26dBm that is detected by the PQM, the signal to noise rate is 18dB.

5.3 Real time operation

Because PQM and optical power splitter are cheap devices, it is possible to use them in each channel permanently to monitor the optical communication quality in real time. The sample rate of an eight bit A/D converter is up to 100 MHz and a voltage comparator response time can be in the time order of us, even ns. Therefore A/D converter can provide the optical power data in real time and the voltage comparator monitor all the malfunction all the time. No doubt, PQM system can meet the real time operation requirement.

5.4 On Line monitoring

Both of PQM and the optical power splitter are optical passive devices, they never emit any optical signal to the optical fiber communication system under monitor. Therefore a PQM based QS can operate on line monitor without interfering the normal communication. As per the optical insertion loss, a PQM based QS internal insertion loss can be as low as 0.44 dB, which is acceptable in almost all of the optical fiber communication systems.

5.5 Reliability

In a PQM system only one optical component (optical power splitter) is inserted on each side of a channel. The number of inserted optical components is minimized. PQM is a very stable component because it is basically a very large scale integrated circuit.

The reliability of an optical power splitter is guaranteed by its manufacture procedures. The procedure is that two bare optical fiber are tested the optical power coupling ratio when they are heated, twisted and extended until the specified ratio is reached, so that the reliability of an optical power splitter is the same as an optical fusion slice which is very common in any optical fiber communication system.

The basic units of a PQM system are A/D converter, D/A converter, ISA bus, all of them are mature and reliable components. Therefore a PQM system is very reliable.
Even if some malfunction happens in a PQM system, the optical fiber communication still can operate normally as long as the optical power splitter is normal.

5.6 Fast responsibility

In normal condition, the PQM response time of getting the optical signal intensity or optical power depends on the sampling speed of the A/D converter, it can as short as 10 ns if a 8 bit, 100 M sample/s A/D is used.
The malfunction detection response time lies on the

voltage comparator, it can be us or ns time order, plus quality monitor networks communication time, it is possible to start a spare channel, find out the malfunction station, malfunction channel, malfunction cause in the time order of ms. It should meet the fast response requirements of a QS.

5.7 Pre warning capability

The pre warning function of a PQM system was described in Section 4.4

5.8. Predication

Based on the data accumulation of each channel optical signal intensityor optical power, it can found decay of the data against time. A linear or high order exterpolation can be used to predict the time when the optical signal intensity or optical power would decrease to the minimum required level.

The optical fiber communication system should be updated before the date to avoid the malfunction. It is the prediction of a PQM system. Since only one parameter for each channel in a PQM system, the prediction procession is relative simple.

5.9. Extension

A PQM system is computerized, so it is easy to integrate other functions by inserting ISA bus or PCI cards or by serial and parallel ports.

A PQM system can integrate an OTDR in the system to find out the malfunction point in optical fiber automatically. A GPS (Global Position System) can integrated as well to provide more accurate fiber malfunction point location information.

5.10 Independence

A PQM system takes the optical signal intensity from the optical fiber directly and no any electrical information is required from the communication system, therefore it is a complete independent system.

5.11 Optical insertion

In a PQM system, only one optical component (optical power splitter) is inserted in each side of a channel, the QS internal optical insertion loss is as low as 0.44 dB.

loss

5.12 Cost estimation analysis of a PQM system

The cost estimation analysis is divided to station based and channel based.

1) Station based:
- A IBM personal computer costs: US$2k
- The electronic parts cost : around US$200
- The total cost per station is about US$2.2k

2) Channel based:
- A PQM costs US$150
- Two PQM per channel cost US$300
- Two optical power splitters cost US$600
- The cost of a multi channel A/D and D/A is only several dollars, it can be ignored
- The total cost per channel is about US$900

5.13 Conclusions

PQM system is a qualified QS.

6. PQM System Operations

A PQM system has the following basic operations:

6.1 A/D operation

The analog to digital conversion is the most basic operation of a PQM system. The operation is very simple, the CPU performs a write operation with the A/D address to start an analog to digital conversion. When the conversion is completed, A/D converter invoke an interrupt, the CPU responses the interrupt and performs a read operation with the A/D address to read the digital data.

The resolution of the A/D is recommended 8 bits or more in most of the applications. The sampling rate depends on the system requirements and the system structure. When a voltage comparator is used to monitor any malfunction or degradation, the A/D sampling rate can be low, for example one sample every 5 seconds, so that the CPU doesn't need to spend too much time on the operation.

If a PQM system uses so call software pre alarm threshold without a voltage comparator, when the CPU reads an datum from the A/D converter, the software compares the datum with a pre set threshold value stored in the memory and judges a malfunction or a degradation, in this kind of systems, the hardware is simplified, but the A/D sampling rate must be high to reduce the insensitive period of time. In this case, the sample rate of several hundred thousand samples per second is recommended

6.2 Calibration operation

The calibration procedure is a necessary step for a new PQM controller card. The purpose of the step is to make a lookup table for establishing the relationship among:
1)Optical power
2)PQM gain setting
3)PQM analog output voltage value
4)Optical wavelength if the controller card may be used for different wavelength such as 1310 nm or 1550 nm.

The lookup table must be saved in a non volatility memory such as EEROM or flash memory on the controller card. For demo or test, the hard disk may be an easy choice.

The optical power measurement at 8 equal spacing PQM output voltage values are required for each gain setting.
The optical setups of the calibration for transmitter and receiver are shown in Fig. 6-1 and Fig.6- 2 respectively

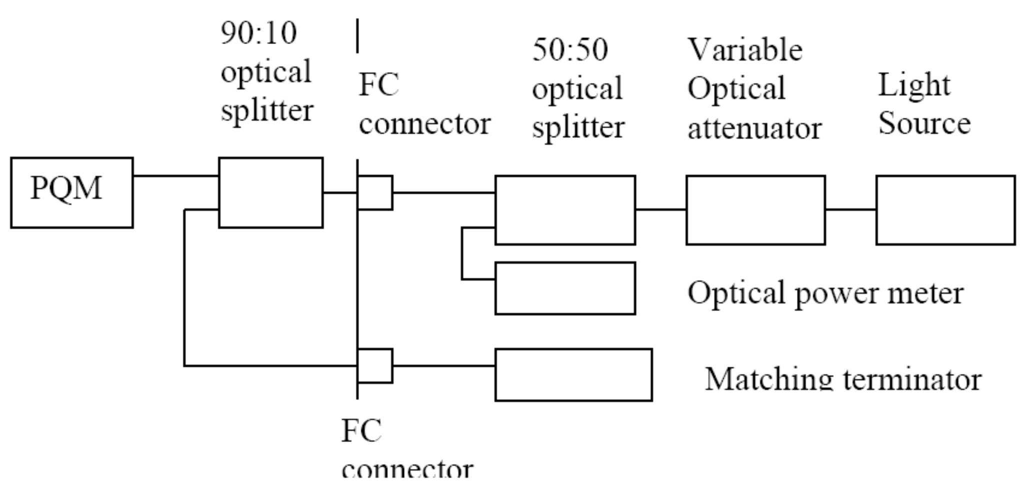

Fig. 6-1 Receiver Channel Calibration Optical Circuit

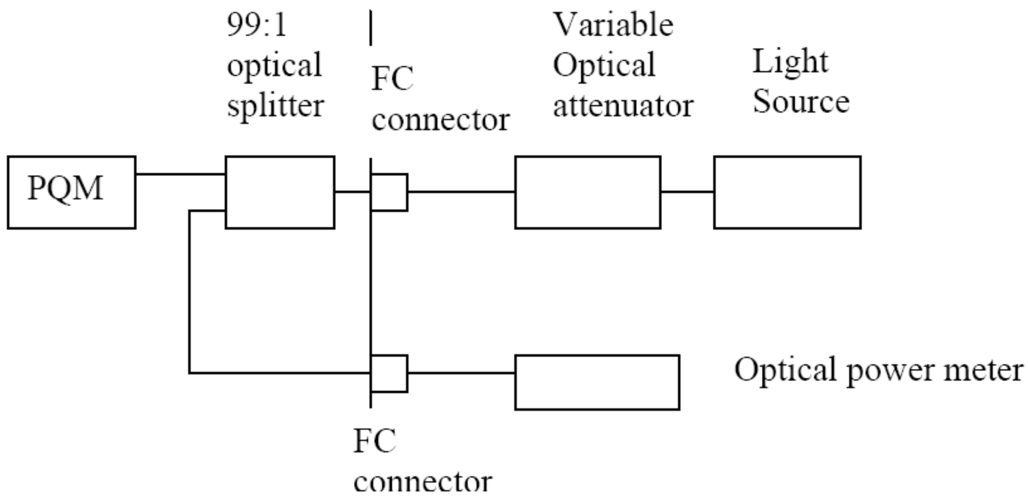

Fig. 6-2. Transmitter Channel Calibration Optical

The procedures are described as follows:

The initial attenuation of the attenuator is set to maximum.
The initial gain is set to G4 (highest).

The software keeps acquiring the QM output voltage by repeating the basic operation of A/D acquitting and converts the binary data to the value in unit of volts and displays it on the screen.

Tune the attenuator, decrease the attenuation to increase the PQM output voltage. When the voltage reaches around 0.5 V,1.0 V, 1.5 V,2.0 V, 2.5 V, 3.0 V, 3.5 V and 4.0 V, the operator should hit “Enter” key, the acquisition pauses, prompts the operator to key in the optical power in unit of dBm . After the optical power is input, the PQM output voltage in volts and the corresponding optical power in dBm are displayed on the screen.

The software prompts the operator to confirm them by pressing “Y” or “N”. If the response is “Y”, save the data including gain, QM output voltage and optical power and the wavelength as an option in the non volatility memory i.e. add one set of the data to the lookup table. Then resume acquitting. If the response is “N”, resume acquitting without saving the data.

When the data for voltage of 4.0 V is completed, change the gain setting to G3, G2 and G1 in turn and repeat the steps described above.

There are two methods to process the calibration data, lookup table interpolation and least square fitting. In the both methods, the variables should be optical power in dBm and common logarithm (with the base of 10) of the PQM output voltage in mV.

If the lookup table interpolation is used, an example of a lookup table is shown below:

```
-3957 7 97 1330
-3603 7 195 1330
-3419 7 273 1330
-3114 7 546 1330
-3001 7 683 1330
-2806 7 1093 1330
-2607 7 1679 1330
-2502 7 2148 1330
-2405 7 2656 1330
-2300 7 3398 1330
-2207 7 4199 1330
-2108 7 4980 1330
-2312 11 332 1330
-2213 11 410 1330
-2107 11 527 1330
-2009 11 664 1330
-1802 11 1054 1330
-1708 11 1328 1330
-1602 11 1679 1330
-1504 11 2109 1330
-1402 11 2656 1330
-1301 11 3281 1330
-1207 11 4179 1330
-1106 11 4980 1330
-1515 13 214 1330
-1401 13 273 1330
-1319 13 332 1330
-1204 13 429 1330
-1105 13 527 1330
```


19

```
-1001 13 664 1330
-908 13 859 1330
-803 13 1054 1330
-703 13 1328 1330
-605 13 1679 1330
. . . . . . ..........
```

The first column is the optical power in dBm, “-1207” means “-12.07dBm”.

The second column is the gain setting :7(binary number of “0111”) means G4, 11 (binary number of ”1011”) means G3 and so on.

The third column is the PQM output voltage in mV

The last column is the wavelength as an option

When a datum is read from A/D during normal operation, find the two adjacent values of the same gain as the PQM operating setting in the lookup table, one is greater than the datum and the other less than the datum, do linear interpolation and get the corresponding the power for the datum in dBm .

If the least square fitting is used, the optical power is considered as a linear function of the common logarithm of the PQM output voltage, y=kx+b. The tangent , k and the intersection, b can be obtained for each gain when the fitting is done, so that only values of k and b of each gain need to be saved instead of all the calibration data. The detail algorithm of the least square fitting can be found in Appendix B.

The PQM has very stable gain over temperature change, but the dark voltage is temperature dependent. Usually the PQM is used in the room temperature environment and the dark voltage is very small, so the temperature compensation is not necessary.

In the cases of high accuracy required or in temperature variance environment, a temperature sensor should be mounted on PCB with PQMs, measure the dark voltage under different gains at different temperatures and form another lookup table saved in a non volatility memory. During the normal operation, the effective PQM output voltage due to optical input should be the PQM output voltage measured subtracted by the dark voltage at the environment temperature. The effective PQM output voltage will be used for the further processions.

6.3 D/A operation

The purpose of the D/A operation is to establish a set of pre alarm or degradation thresholds for the voltage comparators.

Users can decide the number of the thresholds, usually three thresholds are recommended : degradation, serious degradation and very serious degradation (or no light). The calculation method of the degradation thresholds will be described in Section 6.4 initialization.

The following threshold voltages are recommended :
Degradation threshold: half of the normal PQM output voltage.
Serious degradation threshold: half of the degradation threshold.

Very serious degradation or no light: If the optical signal intensity is lower than the serious degradation threshold, the system should judge if it is no light by setting the highest gain to the PQM and compare the PQM output voltage with 0.1 V. If the output voltage is less than 0.1 V, the malfunction of no light is found.

The D/A operation is performed in the initialization or the system is powered on.

When software threshold is used, no voltage comparator is on the PQM control card, the D/A operation is omitted

6.4 Initialization

The procedure of initialization is called Self Study as well. The purpose of initialization is to collect the parameters for a normal operation of the optical fiber communication as the initial comparison reference. The parameters include the proper PQM gain setting, the PQM output voltage, the pre alarm or degradation thresholds. The initialization should be done for each channel before its normal operation.

In this procedure, the operator needs to input the following channel information:
1) The PQM is used for a transmitter side or receiver side
2) The channel number of the PQM
3) The station name and channel number of the other side of the channel, usually the station name is specified as the telephone number or networks address.
4) Central station telephone number or networks address
5) Maintenance telephone number.

The information 4) and 5) are used when a pre alarm occurs or a malfunction is detected.

The initialization is required for the following situations:
1) When a PQM controller card is connected to a fiber communication
channel at the first time.
2) After the fiber of the channel is replaced
3) After the transmitter of the channel is replaced
4) The central office or the maintenance telephone is changed, the initialization file should be modified, but don’t need to run the initialization procedure.
5) A station telephone number is changed, all relative stations need to modify the initialization files, but don’t need to run the initialization procedure.

The initialization procedures are described as follows:

1) Gain setting
Starting the lowest gain setting, acquire PQM output voltages 100 times by repeating PQM A/D operation.
If the mean value of the 100 time data is less than 0.5 V, set the next greater gain, until the mean value is equal to or greater than 0.5 V
If the mean value is greater than 4 V at the lowest gain of G1, send an error message
If the gain setting is G4, the highest one, but the mean value is still

less than 0.5 V, display an error message on the screen.

2) Initial value and degradation thresholds setting:
When the mean value of the PQM output is between 0.5 to 4 V at a gain setting, it is a proper initial value. The PQM output voltage value, gain setting and measurement date and time are saved in a non volatility memory.
The gain setting is used for the normal operation of the channel.

3) Pre alarm threshold calculation:
Calculate the variance of the 100 data at the gain setting obtained in 2)

If the variance is equal to or greater than 17% of the mean value, the pre alarm threshold is set as the mean value –3 x variance.

If the variance is less than 17% of the mean value,
The pre alarm threshold is half of the mean value.
The pre alarm threshold may be sent to a comparator as the reference voltage through a D/A operation.

Here is an example of an initialization file:

```
N02 (the PQM channel number)
R(the channel is a receiver)
7(the highest gain G4 0111)
2.15(the mean value is 2.15 V)
3.7 (the variance is 3.7mV)
1.07(the pre alarm threshold is 1.07V)
980315 (the test date is March 15, 1998)
1003( the test time is 10:03)
6534258(the telephone number of the station at the
other end of the channel)
04 (the channel number of the station at the other
end of the channel)
6529876(the central station telephone number)
5677855(the maintenance telephone number)
5687653(the maintenance telephone number)
N03( the PQM channel number)
T(the channel is a transmitter)
…..
```

When the PQM based system is powered on, the initialization file should be downloaded into RAM.

6.5 Malfunction detection and procession

It is quite important operation of a PQM system, but it is dependent on applications and the user requirements. According to the basic operations mentioned above, users can make own decisions.

1) Both side or single side malfunction detection.
Some PQM systems have the malfunction detection in both sides of transmitter and receiver, but some have it in the receiver side only. The single side malfunction is recommended because any optical power change will affect the input optical signal amplitude or optical power in receiver side.

2) The number of pre alarm threshold.
User can set any number of pre alarm threshold for each channel, but one is the minimum. When multi thresholds are set and the address of D/A is not enough, a simple resistor voltage divider can be used.

3) The malfunction cause judgment.
Some times the optical signal amplitude or optical power drop in the receiver side has the contribution from both of the transmitter output power decrease and the optic fiber attenuation increase, in these cases a fuzzy concept should be used. The rule of 80% may be a reasonable criterion, that means, if the optical fiber attenuation increase has more than 80% contribution of input optical power drop in the receiver side, the system will judge it as an optical fiber malfunction with 100% possibility, or if the transmitter output decrease has more than 80% contribution of the input optical power drop in the receiver side, the system will judge it as a transmitter malfunction with 100% possibility.

Any situation between them, the system would say the contribution percentage of the malfunction causes.

7. Quality Monitor

Usually a three level monitor system is required: station, province and country. It is necessary that a quality

Networks

monitor network links all the stations so that they can get information each other.

The basic requirements of the quality monitor networks are:

1) The quality monitor networks should be independent from the optical fiber communication networks, otherwise once the optical fiber communication networks has malfunctions, the quality monitor networks would be out of order and can't perform the functions.

2) The communication messages should have at least three priorities: inquiring message, malfunction message and normal information message.

The inquiring message is the message sent from a receiver side to the transmitter side to inquire the transmitter output power information when a malfunction is detected in the receiver side. It has the highest priority.
The malfunction message is sent to the central station and the maintenance persons when a malfunction is found. It has the second priority .

The normal information message is the message sent when a station requests the normal operation information of other stations. It has lowest priority.

3) The Baud rate of the quality monitor networks is not required very high, several hundred thousand bits per second is enough for most of QS systems.

4) No central station is required in the quality monitor networks to simplify the system. Therefore each station should behave a receiver, a transmitter and a relay. When a message package arrives a station, the station will accept the message if the message is for the station. The message will be transmitted if the message address is in the relay list.

Telephone line can be used as the quality monitor networks, but now more and more telephone communication uses optical fiber, it is not independent any more. Therefore RF communication and satellite communication or an optical fiber communication system other than the one under monitor are recommended.

8. Integration of an OTDR to a PQM System

An OTDR based system is not a qualified QS, the detail analysis is described in Appendix A. Since an OTDR is still a useful tool to find the location of a broken point of a fiber, it should be combined or integrated to a PQM system. This chapter introduces integration methods.

8.1. OTDR integration to cold spare fibers

The optical fiber communication standards require the spare fibers in any optical fiber cables in the network. There are two types of spare fibers: hot and cold. A hot spare fiber is still connected to a transmitter and a receiver, the optical communication packages are transferred, but the packages are empty.

A cold fiber is an isolated fiber with two connectors at two ends, no any optical signal is transferred. The method of OTDR integration to a cold spare fiber supposes the performances of all fibers in a cable are identical.

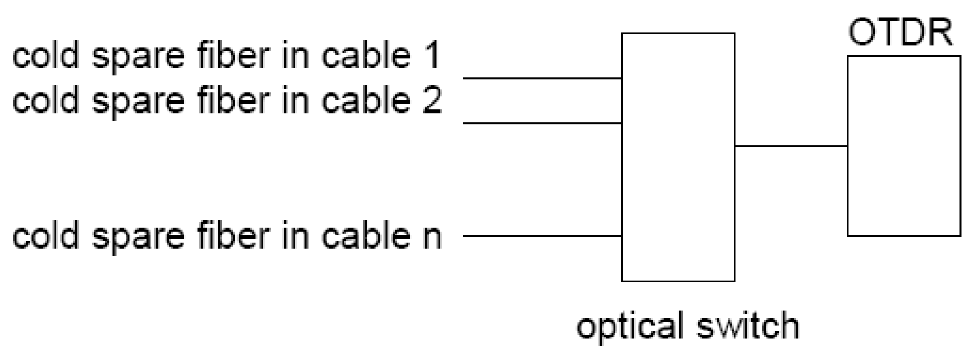

Fig. 8-1

The block diagram of this method is shown in Fig. 8-1.

Since there is no optical signal in a cold spare cable, no WDM or filter is required.

When the PQM system detects a malfunction in a fiber, the computer will control the optical switch to connect the OTDR to the cold spare fiber in the cable of the fiber with malfunction and start the OTDR to find the location of broken point, then inform the maintenance people to fix the malfunction.

The advantages of this method are

<1> No interference to the optical fiber communication because the optical signals from OTDR do not enter the active optical fibers

<2> Relative cheap because no WDM, no filter is required.

But the assumption of all fibers in a cable identical is not always true. For example, a water leakage occurs in a fusion connection of an active fiber, but not occurs in the cold spare fiber so that the PQM system detected the malfunction in the active fiber, but the OTDR is not able to find any malfunction in the cold spare fiber.

In this situation, the maintenance people should start a hot spare fiber instead of the active fiber with the malfunction, connect the OTDR to the fiber with malfunction manually and find the malfunction location.

8.2 OTDR integrated to active fibers

This method allows the OTDR measure all of the active fibers in the communication system. Fig. 8-2 is the block diagram of an OTDR in a transmitter side. Fig. 8-3 is the block diagram of an OTDR in a receiver side.

In Fig. 8-2 ad Fig. 8-3, R is a receiver, T is a transmitter, P is a PQM, SW is an optical switch, F is an optical filter.

Unlike an OTDR based QS described in Appendix A, the OTDR integrated to a PQM system doesn't send optical pulses to the fiber all time, only when a malfunction is detected by the QS and the QS finds the malfunction cause is the fiber, the computer starts the spare channel and forces the fiber with malfunction become to a cold fiber, then connect the OTDR to the fiber and starts the OTDR to looks for the malfunction point location. When the malfunction point location is found, the QPM system passes the information to the maintenance people to fix the malfunction.

The important advantages of an OTDR integrated to a PQM system over an OTDR based QS are

1) The OTDR doesn't emits optical pulses during the normal optical fiber communication, it doesn't affect the signal to noise ratio of the communication signal.

2) The OTDR doesn't need to operate all time, the operation life becomes longer.

The OTDR optical wavelength must be different from the optical wavelength of the optical fiber communication, otherwise the OTDR optical pulses can't be coupled to the fibers.

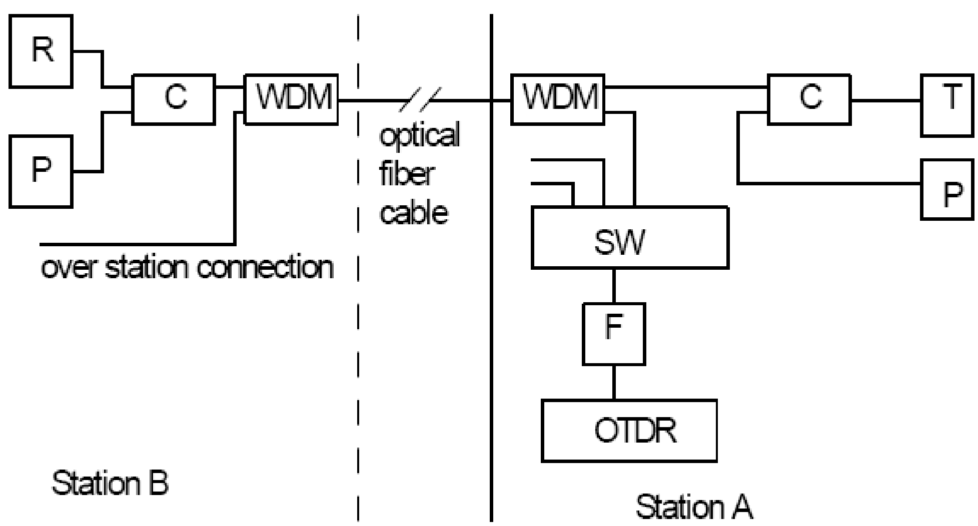

Fig. 8-2

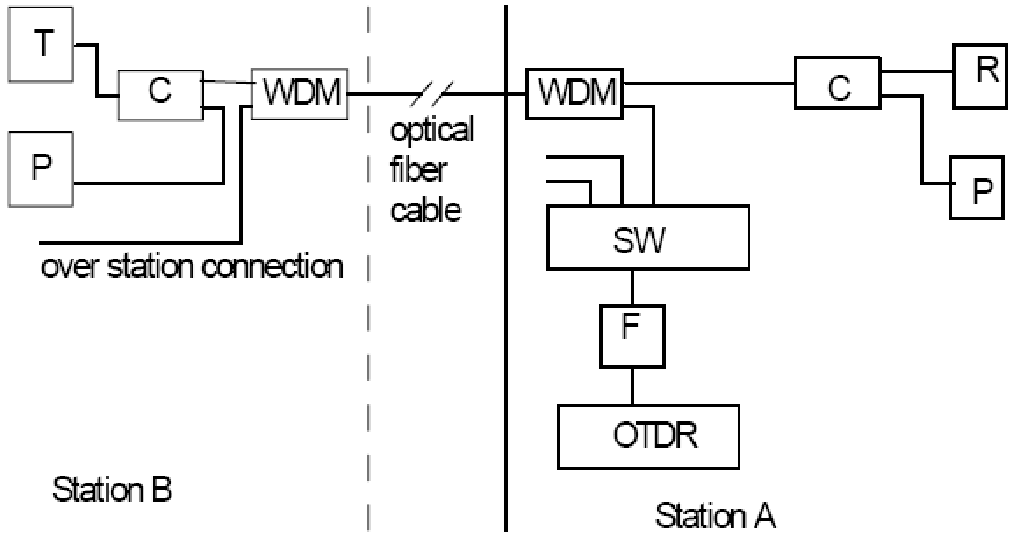
T
C
WDM
P
over station connection
optical
fiber
cable
Station B
WDM
C
R
P
SW
F
OTDR
Station A

Fig. 8-3