Burst Mode Receiver Testing in Passive Optical Networks (PON)

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Hewlett-Packard Company

Lightwave Transmission
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Abstract

This paper describes a new method of characterizing the transmission performance of burst-mode receivers used in Passive Optical Networks (PON). PON's are used as local access networks for interactive broadband services, such as Fiber-To-The Curb (FTTC), Fiber-To-The-Home (FTTH), or Personal Handy Phone Systems (PHS). It is shown how the optical receiver characterization can be performed easier and faster with the new Serial Cell generator and Analyzer System HP E4859A. In an example a PON receiver is characterized. The test setup and measurement results are presented and it is shown, where the receiver could be improved.

Authors

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Authors Background

Lutz Kristen is a sales development specialist in marketing at Hewlett - Packard's Böblingen Instruments Division in Germany. He studied electronic engineering at the Technische Universität Karlsruhe and joined HP in 1974. Since 1994 he is responsible for sales development of Böblingen Instruments Division's serial cell generator and analyzer system.

Peter Schinzel is an R&D engineer at Hewlett - Packard's Böblingen Instruments Division. He studied electronic engineering at the Univerisität Stuutfart. Since 1993 he is responsible for the design of the receiving circuits of Böblingen Instruments Division's serial cell generator and analyzer system.

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Slide 1: Burst Mode Receiver Testing in Passive Optical Networks (PON)

New interactive broadband services require a higher bandwidth demand in local access networks for upstream and downstream traffic.

Passive Optical Networks used in FTTC and FTTH networks provide this.

The optical receiver is a critical part in the PON, especially the upstream receiver who deals with TDMA signals in the central office.

This paper describes how to characterize the PON receiver on the physical layer by measuring the BER (bit error rate) under different conditions in an R&D environment.

Today's Agenda 1

a) Passive Optical Networks and receiver design challenges

b) HP's proposal for characterizing PON receivers

c) Example of a test setup and the results of measurements on a 12.624 Mbit/s O/E receiver module

Slide 2: Today's Agenda 1

The presentation today is split up into three parts:

a) Passive optical networks usage and receiver design challenges

b) HP's proposal for characterizing PON receivers.

c) Example of a test setup and the results of measurements on a 12.624 Mbit/s optical receiver module.

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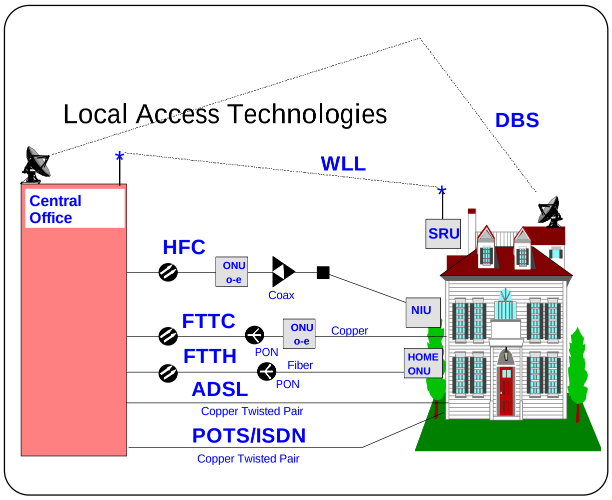
Burst Mode Receiver Testing in Passive Optical Networks (PON)



Slide 3: Local Access

This is an overview about today's local access technologies.

POTS = Plain Old Telephone Services

ISDN = Integrated Services Digital Network

ADSL = Asymmetric Digital Subscriber Loop

FTTH = Fiber To The Home

FTTC = Fiber To The Curb

HFC = Hybrid Fiber Coax

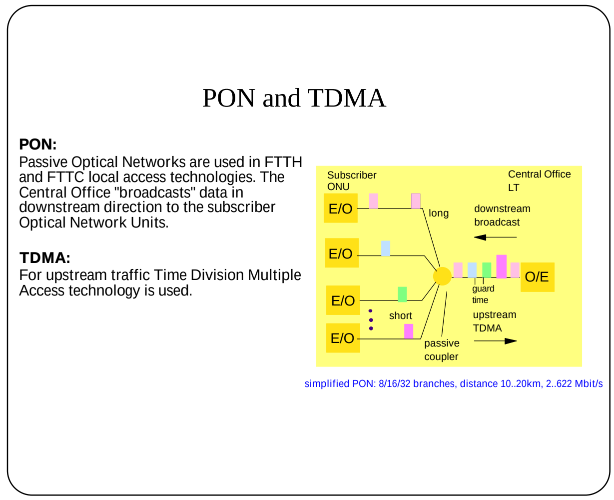
ONU = Optical Network Unit

WLL = Wireless Local Loop

DBS = Digital Broadband Satellite

NIU = Network Interface Unit

PON's are used in FTTH, FTTC and may be in hybrid fiber/wireless applications such as PHS (Personal Handy system).



Slide 4: PON and TDMA

The picture shows an example for a passive optical network using TDMA technology for upstream traffic.

Today cell-based time division multiple access is becoming important (because of ATM cells transmitted in the payload)

TDMA is used for upstream transmission ("back channel") from subscriber (ONU= optical network unit) to central office.

Upstream data is for interactive services (Video on demand, telebanking, etc.)

Each ONU has a certain time slot to transmit data.

The target application for the HP E4859A serial cell generator and analyzer is the characterization of Time Division Multiple Access (TDMA) transmitters and receivers in R&D.

Burst Mode Receiver Testing in Passive Optical Networks (PON)

Challenges in O/E Receiver Design

- no standard yet
- proprietary cell formats (# of preamble bits, etc.)
- input power -34 dBm
- different power levels of burst mode data
- phase/clock recovery (odd guard times)
- measurement equipment

Emulate (proprietary) burst-mode data in the network

- verify received signal quality with an oscilloscope
- measure the bit-error rate of individual cells
- measure bit error rate versus input power
- measure bit error rate verus line bit rate
- measure bit error rate versus guard time
- measure bit error rate versus timing of control signals
- measure eye window (BER versus phase)

Slide 5: Challenges in O/E Receiver Design

There are several design challenges in the design of an O/E receiver. No standards have been established, the receiver has to be able to handle very low power signals and what makes it even more difficult, handle those low power signals after high power signals.

Today's solution: BERT + data generator + self built equipment. This is an unsatisfactory solution because of time spent to design the equipment, proprietary cell formats and the synchronization between generator and analyzer is quite difficult for various timing conditions.

Slide 6: Emulate (proprietary) burst-mode data in the network

These are typical measurement tasks in the R&D lab to make sure the device will work in the network and at the next field trial.

All the parameters such as bit rate, guard time, bit error rate, input power have a strong impact on the design goals for local access network devices which are typically:

Upstream bandwidth, quality of service, distance and # of ONU's, and the very important "per-subscriber-cost"

Burst Mode Receiver Testing in Passive Optical Networks (PON)

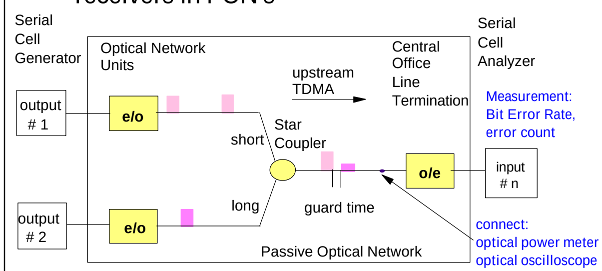
Today's Agenda 2

a) Passive Optical Networks and receiver design challenges

b) HP's proposal for characterizing PON receivers

c) Example of a test setup and the results of measurements on a 12.624 Mbit/s O/E receiver module

HP's proposal to characterize O/E receivers in PON's



Slide 7: Today's Agenda 2

Lets now focus on the main contributions of the new HP E4859A serial cell generator and analyzer.

HP's proposal to characterize O/R receivers in PON's.

Block diagram
Timing capabilities
Signal types
Cell content
Analyzer capabilities
Connection window
Key features of the HP E4859A

Slide 8: HP's proposal to characterize O/E receivers in PON's

This shows a typical test set-up for characterizing time division multiple access (TDMA) transmitters and receivers in a Passive Optical Network.

Receiver design is a challenge because of different power levels (i.e. -17 dBm and -34 dBm) caused by different distances between central office and ONU.

Typically proprietary transmission formats (bit rate, cell length, cell overhead) are used.

Each serial cell generator emulates digital ,burst-mode data (cell) for one line termination (electrical outputs)

The data is added in the star coupler, a passive directional coupler.

The analyzer measures the error performance of the cells

Optical power is measured by switching one generator to continous mode, the actual peak power is + 3 dB greater.

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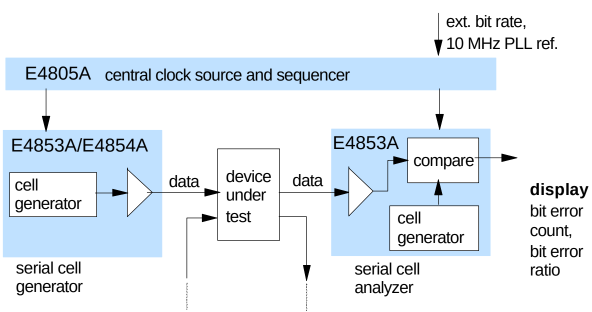
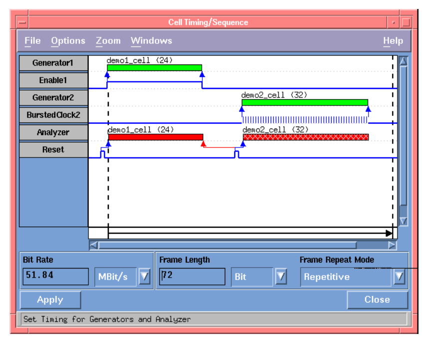
Burst Mode Receiver Testing in Passive Optical Networks (PON)

Block Diagram



multiple serial cell generators and analyzer can be connected

Flexible Cell Timing with the HP E4859A



Cell/Timing Sequence Window

Slide 9: Block Diagram

Central clock: provides same clock to generator and analyzer and the start/stop signals to synchronize the system.

Generator: each generator has it's own pattern memory and PRBS generator; the cell generator

Analyzer: each analyzer compares the received bits with the expected bits of the cell which is sent out by one of the generators. Error count and error rate are displayed.

Synchronization: the sampling rate of the analyzer is the same as the line bit rate. The sampling point is set to the middle of the eye opening.

Slide 10: Flexible Cell Timing with the HP E4859A

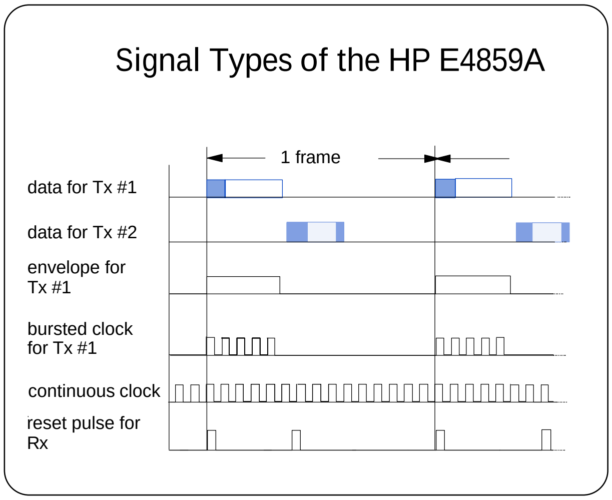
One of the key strength of the HP E4859A is the capability to set up all relevant timing information in terms that are actually used, i.e guard time, frame length, cell length, etc.

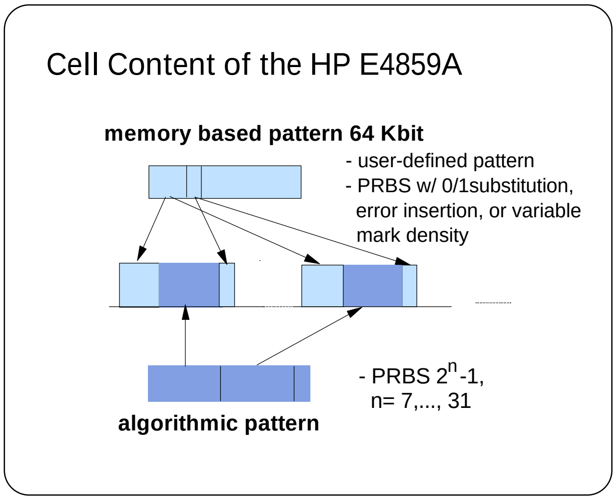
This is the Cell Timing/Sequence window. It shows all timing information as well as all connected generators and analyzers including their control signals. Also cell names and the cell length can be displayed

In this window also the Bit Rate, the Frame Length as well as the Frame Repeat Mode are set.

The delay value is entered on a separate window, either manually or by using the Auto-Adjust Cell Transfer Delay feature.

Burst Mode Receiver Testing in Passive Optical Networks (PON)





Slide 11: Signal Types

These signal types can be set up:

1. data: bursted cells. A cell consists of user-definable pattern, PRBS, or a mix of both. A cell can have up to 28 segments.

2. control signals for transmitter or receiver. e.g.: LASER on/off, clocks , etc. The position of control signals is linked to the data (bursted cells). The following control signals are offered: envelope (Tx on/off), bursted clock, continuous clock, reset pulse. All these control signals can be provided by an optional auxiliary output (except reset pulse), option 001. Sometimes two or more control signals are required per Tx or Rx. Then additional main channels have to be used to provide the 2nd, 3rd, etc. control signal.

Slide 12: Cell Content of the HP E4859A

A cell can consist of up to 28 segments of mixed algorithmic (PRBS) and memory based pattern .

PRBS can be 2^7-1 to 2^31-1.

Memory based pattern depends on bit rate: it is 64 Kbit (@< 42 Mbit./s) and 512 Kbit (@ <250 Mbit/s) per channel.

It can be either user-defined pattern or PRBS with consecutive 0's and 1's.

Each generator channel has independent memory and algorithmic pattern resources.

One generator can generate only one cell, the header is repeated in the subsequent cell, the PRBS is continued.

Special note: by editing a cell which includes a sequence with 0's, it seems that 2 cells (with the 0 sequence as guard time) are generated by the same generator.

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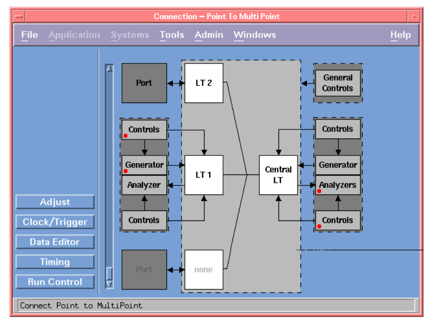
Burst Mode Receiver Testing in Passive Optical Networks (PON)

Analyzer Capabilities of the HP E4859A

Graphical User Interface of the HP E4859A



Connection - Point To Multi Point Window

Slide 13: Analyzer Capabilities of the HP E4859A
Measures bit error rate and error count
Measures only cells coming from one of the generators
Measures only individual segments of the cell, other segments are ignored during the measurement. This is helpful when some of the preamble bits are lost during clock recovery.

Slide 14: Graphical Usert Interface of the HP E4859A
This is the main connection window. It emulates a network and enables an easy setup of generators for the ONU (LT1..LT16) and of the analyzer for the central office (Central LT). In this window all generator and analyzer connections will be done. Also all control signal have to be connected in this window.

Burst Mode Receiver Testing in Passive Optical Networks (PON)

HP E4859A Serial Cell Generator and Analyzer System

Slide 15: System Components

HP E1401B 13-slot VXI mainframe

HP E1497A V743 HP-UX controller (32Mbyte RAM)

HP E4208B disc drive

HP E4805A #001 central clock module

HP E4853A serial cell generator and analyzer

All of the above: HP E4859A (bundled system)

Required in addition: monitor, keyboard, mouse

Recommend: DAT tape drive

As needed: up to 9 additional HP E4854A dual serial cell generator and/or HP E4853A serial cell generator and analyzer.

Key Features of the HP E4859A

- generates all types of burst-mode data
- error performance analysis (bit error rate, error count)
- up to 16 serial cell generator channels
- cell content mixed user defined-pattern/ PRBS
- automatic adjust of cell transfer delays
- variable bit rate 170 kbit/s to 250 Mbit/s (optional up to 660 Mbit/s)
- variable cell length and timing
- variable guard time between cells
- easy generation of control signals
- C-size, 1 slot VXI modules

Slide 16: Key Features

HP now offers a new type of test equipment which allows to characterize TDMA transmitters and receivers.

It's the Serial Cell Generator and Analyzer

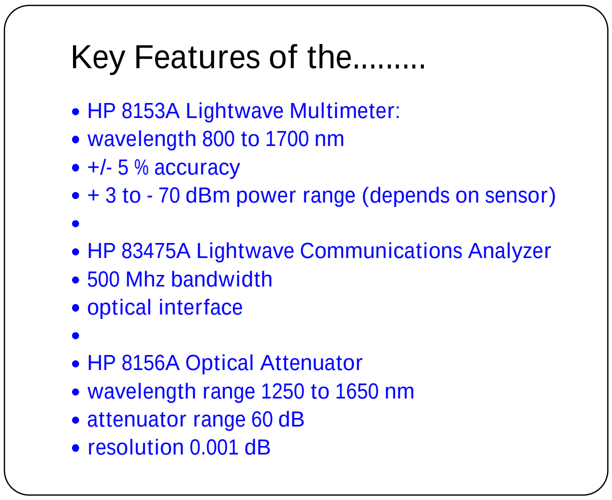
It generates repetitive bursts of data ("cells").

The cell length and content can be programmed.

Cell timing relations between the generators can be programmed.

It measures the BER of single cells.

Burst Mode Receiver Testing in Passive Optical Networks (PON)



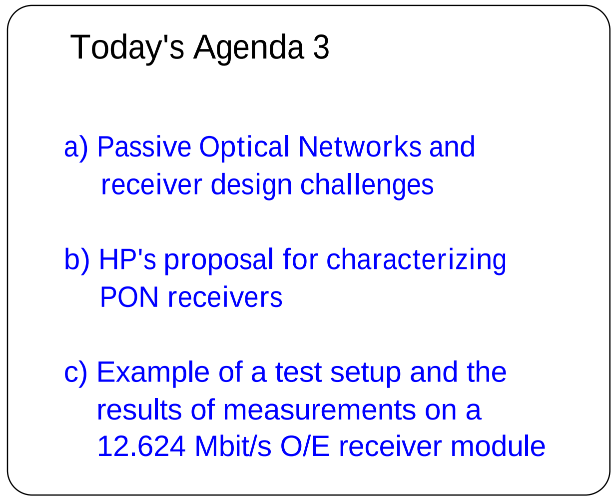
Slide 17: Key Features of the...........

The following instruments complement the serial cell generator and analyzer system

HP 8153A Lightwave Multimeter

HP 83475A Lightwave Communications Analyzer

and the HP 8156A Optical Attenuator



Slide 18: Today's Agenda 3

The last part of the presentation will show the test setup, the one you already have seen during the product fair, and discusses measurement results and possible enhancements.

Burst Mode Receiver Testing in Passive Optical Networks (PON)

Measurement Task

We have characterized an O/E receiver, and the following measurements have been performed:

- BER (Bit Error Rate) versus power
- BER versus guard time
- BER verus reset pulse width and position
- Bit error distribution versus bit location

Specifications of the O/E and E/O modules

• Bit rate	12.624 Mbit/s
• Frame length	4016 Bit
• Wavelength	1310 nm
• Length of cell A, B	2000 Bit
• Input levels	TTL
• Output levels	PECL
• Guard time	8 Bit (nominal)
• Reset pulse width	4 Bit (nominal)
• Rx input power	-17... -34 dBm
• Tx output power	0 dBm
• BER	10 e $^{-8}$

Slide 19: Measurement Task

To characterize the O/E receiver the following measurements have been performed:

BER versus power

BER versus guard time

BER versus reset pulse width and location

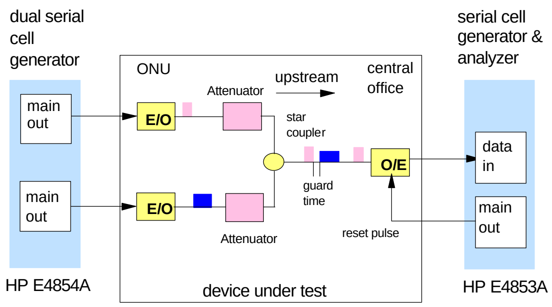
Bit error distribution versus bit location

Slide 20: Specifications of the O/E and E/O modules

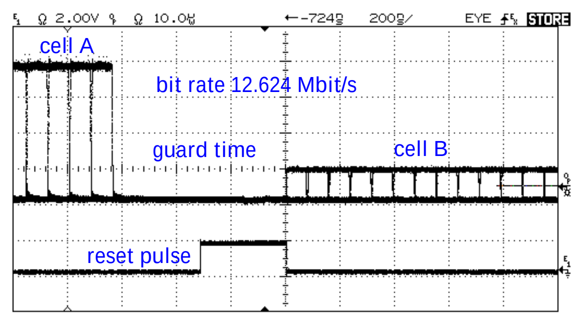
The following settings were used in the initial setup of the measurement. These are the recommended settings as indicated in the manufacturers specification. The initial power settings were -17 dBm for the generator generating the "leading" cell, the "trailing" cell's power was varied down to -34 dBm. This is the scenario where the receiver's gain control is challenged the most: a high power signal followed by a low power signal.

Burst Mode Receiver Testing in Passive Optical Networks (PON)

Test Set-Up



Optical Receiver Input Signal



Slide 21: Test Set-Up

Shown is how the serial cell generator and analyzer modules HP E4853A and E4854A can be connected to the device under test.

Left side: the main outputs are used to reproduce burst-mode data ("cell") to stimulate the transmitter.

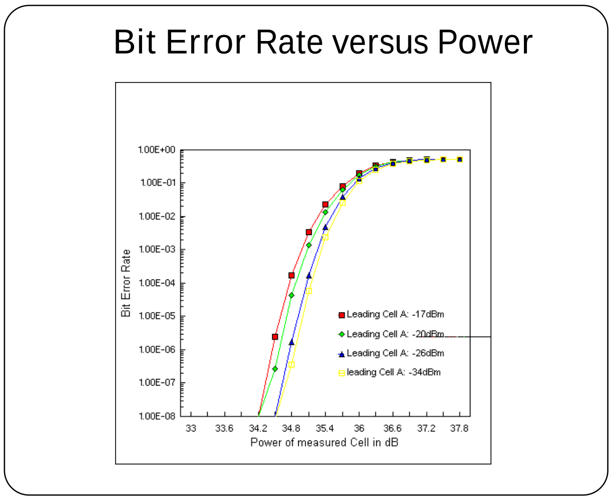
Right side: the analyzer is connected to the receiver. The receiver, our Device-Under-Test, has a gain controlled amplifier, which requires a reset pulse before every cell, to reset an internal control circuit. Without the reset pulse, small optical power level signals that closely follow large ones, could not be detected. Since the E4853A has also one generator, this can be used to generate the reset pulse.

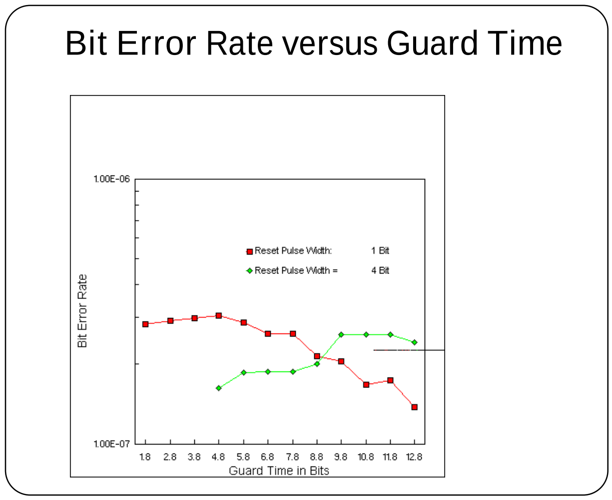
Slide 22: Optical Receiver Input Signal

The receiver can detect data from the first bit, therefore no preamble is necessary to characterize the data transfer.

The traffic cell consist of only one segment, data content is pure PRBS.

Burst Mode Receiver Testing in Passive Optical Networks (PON)





Slide 23: Bit Error Rate versus Power

This graph shows how the bit error rate of cell B depends on the optical power of cell B itself and the power of the leading cell A.

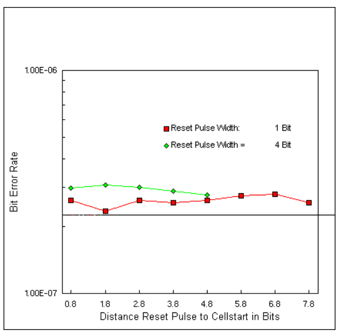
The measurement shows that the power of the leading cell A influences the BER of the following cell B only by a small amount.

Slide 24: Bit Error Rate versus Guard time

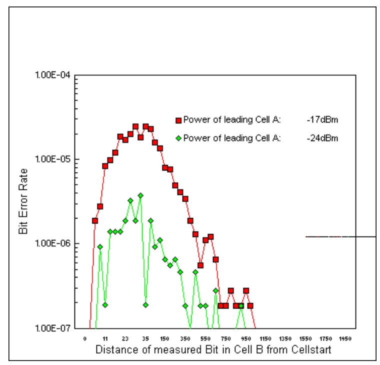
In the following measurements two different reset pulse width were used and the guard time was varied. As it is clearly seen, there is no influence on the BER, the timing specifications are very conservative, higher throughput could be achieved by narrowing the guard time.

Burst Mode Receiver Testing in Passive Optical Networks (PON)

Bit Error Rate versus Reset Pulse Position



Bit Error Rate versus Bit Location



Slide 25: Bit Error Rate versus Reset-pulse Position

At this measurement the guard time was kept constant but the position of the reset pulse between the two cells was varied for two different pulse width. Again it could be shown that the bit error rate is almost independent of timing parameters.

Slide 26: Bit Error Rate versus Bit Location

In the last measurement the capability to measure the BER of individual parts of a cell (the segment) was used to perform a BER measurement of bits versus the bit location. It could be shown that the error rate varies with respect to the bit location within the cell. An even more detailed measurement can be done to analyze if 1's or 0's failed. If the threshold is too high, there will be a majority of failed 1's, if its too low failed 0's. This measurement gave a valuable hint that the receivers threshold adjust circuit could be optimized to improve the overall BER performance.

Burst Mode Receiver Testing in Passive Optical Networks (PON)

Slide 27: Measurement Results

Changing timing parameters led to the conclusion that there is not much to improve with the design of the receiver module. The specifications seem to be very conservative, varying the guard time or reset pulse width or reset pulse location did not change the bit error performance. The design is very stable and will also do its job if the specified timing parameters are not always met.

The last measurement revealed that the receivers threshold adjust circuit could be optimized to improve the overall BER performance.

Slide 28: Summary

For today's innovative designs on receivers for optical access networks a new measurement tool was introduced that allows reliable, accurate and easy to set up measurements of the bit error rate on burst mode data receivers.

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