5G-XHaul

Dynamically Reconfigurable Optical-Wireless Back-haul/Fronthaul with Cognitive Control Plane for Small Cells and Cloud-RANs

D6.2: Contribution on Optical Communications Standardisation

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Advanced 5G Network Infrastructure for the Future Internet

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Executive Summary

The purpose of this document is to present the standardization activities of 5G-XHaul, undertaken up to Month 21 of the project lifetime, focusing on Optical Communications. ADVA Optical Networking SE, has been participating and contributing to an extensive set of activities in the framework of ITU-T SG15 relating to their 5G-XHaul technical work. More specifically based on the work in 5G-Xhaul, a number of contributions were submitted and introduced in meetings of Question 6 of ITU-T SG15 on the topic of the new Recommendation G.metro. The relevant contributions are described in this report, while the documents produced as part of the standardization activities are included as appendices to the deliverable. In addition, UNIVBRIS is contributing to the MEF and specifically MEF LSO (Lifecycle Services Orchestration), where 5G-XHaul related contributions are under discussion.

1. Introduction

5G-XHaul proposes a converged 5G network infrastructure and an overarching layered architecture, to jointly support operational network and end-user services. The 5G-XHaul infrastructure adopts a common fronthaul/backhaul network solution, deploying a wealth of wireless technologies and an optical transport, supporting flexible fronthaul split options.

The high capacity, flexible optical transport has been proven to be a key enabler for the proposed architecture. The 5G-XHaul data plane architecture comprises a hybrid solution integrating together passive and active optical network segments that play a central role in the overall 5G-XHaul infrastructure. The passive solution employs Wavelength Division Multiplexed (WDM) - Passive Optical Networks (PONs), while the active solution adopts the Time-Shared Optical Network enhanced with novel features for improved granularity and elasticity. These can provide the required connectivity, capacity and flexibility to offer jointly FH and BH functions and support a large variety of end-user and operational services.

In addition, to address the challenge of managing and operating the complex and heterogeneous 5G-XHaul infrastructure efficiently, the project proposes the integration of the Software Defined networking (SDN) and Network Function Virtualisation (NFV) approaches. Through joint SDN and NFV consideration, significant benefits can be achieved, associated with flexible, dynamic and efficient use of the infrastructure resources, simplification of the infrastructure and its management, increased scalability and sustainability as well as provisioning of orchestrated end-to-end services.

In view of this, significant part of the project work focuses on optical communications/networking activities. The technical work focusing on optical communications/networking is accompanied by active involvement in a set of relevant standardisation activities with the aim to increase the project influence to the relevant communities as well as the acceptance and impact of the project output and findings to the relevant industries and stakeholders.

Organisation of the document

This document is structured as follows: Section 2 describes in detail the ITU-T SG15 activities that have been undertaken by ADVA Optical Networking SE together with a table summarizing all relevant contributions and participation to standards. In addition, a brief discussion on some ongoing activities in the MEF by UNIVBRIS is provided in Section 3. In Section 4 the summary and conclusions of the deliverable are outlined. Finally, all documents produced as part of ADVA's standardisation activities are included in the appendices of this deliverable.

2. Contributions to ITU-T SG15

ITU-T study group (SG) 15 - Networks, Technologies and Infrastructures for Transport, Access and Home.

As described in [1] the ITU-T SG15 details “the technical specifications giving shape to global communication infrastructure.” In this context, it deals with “technologies and architectures of optical transport networks enabling long-haul global information exchange; fibre- or copper-based access networks through which subscribers connect; and home networks connecting in-premises devices and interfacing with the outside world”.

ADVA Optical Networking SE, has been participating and contributing to a set of activities in the framework of ITU-T SG15 that relate very closely with the work and technical focus of 5G-XHaul. A summary of these activities is provided in Table 1.

More specifically, ITU-T SG15, Question 6 is responsible for standardizing physical layer optical interfaces to enable interoperability of equipment from different vendors. Driven by input from network operators like China Unicom, British Telecom and Telecom Italia, in April 2014 Q.6 has started a new activity to develop a standard for “Multichannel bi-directional DWDM applications with port agnostic single-channel optical interfaces”. This standard draft has received the temporary name “G.metro”. An early application of systems using these interfaces is front-haul for mobile networks, as also proposed, further developed and demonstrated in the 5G-XHaul project.

In *5G-Xhaul*, ADVA Optical Networking SE is investigating details for these interfaces and contributing results of the work to the G.metro standard development in ITU-T Q.6/15. Since the start of the project in July 2015, sixteen contributions have been provided, especially on the wavelength control interaction between head end and tail end and on parameters for the system.

Most of these contributions were shared before submission with other members of Q.6/15 and have received their support. This is shown in additional names and organizations on the contact list of the documents. Always, the first contact refers to the original contributor, who also usually introduces the contribution to the group. Out of the 16 contributions reported here, 13 were originally contributed by ADVA, based on work performed in the framework of the 5G-XHaul project.

A description of ADVA’s involvement and contribution to ITU-T SG15 is provided in the sections below.

2.1 Communication channel topics

To enable low-cost operation, a communications channel between the head-end and the tail-ends of the system is required. Furthermore, a communications channel back from the tail-ends to the head-end is desired to enable performance monitoring. In contribution **Turin_WD06-03** (detailed in Appendix 1), such an upstream communications channel was proposed, including the performance information that should be carried over this channel. It was proposed to transport the memory pages of the tail-end transceiver device with a content according to the standard SFF-8472. As, however, Q.6 would only consider the physical parameters of such a communications channel, the proposal was also made to Question 11 (in **Turin_WD11-10**, detailed in Appendix 2) and Q.14 (in **Wuhan_WD08-multi**, detailed in Appendix 3), dealing with the framing of the information bit stream and with performance monitoring of an optical system, respectively.

Question 14 responded to the proposal with some questions, which were addressed in follow-up contribution **C-1663** (detailed in Appendix 4) to that group in the following meeting. The discussion on the details of the upstream communications channel is still ongoing.

In contribution **Pisa_WD06-02** (detailed in Appendix 5), the question was addressed, which minimum modulation depth of the message channel would be required to yield a sufficient bit error rate (BER). At the same time, the impact of the message channel modulation depth onto the payload data signal was investigated. As the payload data can be considered as noise for the message channel, a BER floor was observed for low values of the modulation depth. For a modulation depth around 12%, a BER of 10^{-6} was observed, sufficiently low to be corrected by simple forward error correction methods (e.g. Hamming code). In a follow-up contribution, **C-1919** (Appendix 6), more details on the payload impact were reported. It was shown that for a modulation depth of 15% the received power penalty for the payload was around 0.5 dB.

2.2 Pilot tone topics

To enable the detection of a tuning tail-end channel as well as to distinguish between signals coming from different sources in the wavelength control unit, distinct pilot tones are added to the optical channels in the tail-end as additional envelope modulation. While a low-pilot tone would limit the impact on the payload signal, concerns were raised in Question 6, if the use of an optical amplifier – especially an Erbium-Doped Fibre Amplifier (EDFA) would still be supported, if low tones were used. Cross-talk between the tones due to cross-gain modulation in the EDFA was expected. In contribution **C-1528** (Appendix 7), the amount of cross-gain modulation in a state-of-the-art EDFA with automatic gain control was investigated. It was found that the cross-gain modulation was below

1% and below 0.5% for modulation frequencies of 20 kHz and 50 kHz, respectively. The current proposal, resulting from these investigations, uses pilot tone frequencies between 47 and 53 kHz.

Furthermore, the impact of the pilot tone on the payload signal was investigated, varying modulation depth and frequency. Experimental results were contributed in **Pisa_WD06-03** (Appendix 8), a theoretical analysis was given in **Pisa_WD06-04** (Appendix 9). It was found that, depending on the low-frequency cutoff of the payload receiver, the impact increases with increasing tone frequency with a 3dB-cutoff between 50 and 100 kHz. It was also found that additive tone modulation, where the tone signal is linearly added to the payload data modulation, is preferred to multiplicative modulation, where both, mark and space rails of the signal are envelope modulated by the tone. In practice, however, multiplicative modulation can be implemented with less effort, wherefore all investigations were based on this tone modulation type. It was also observed that results reported by different members of the group had large deviations. Therefore, further input was requested on this topic.

2.3 Application parameters

The results obtained during the investigations on pilot tones and message channel were used to specify a set of parameters, which were proposed in contribution **C-1943** (detailed in Appendix 9). Meanwhile, these values have been included in a provisionally agreed parameter document. In addition to these parameters, ADVA has discussed with other members of Q.6/15 wavelength plans as well as physical layer parameters for the payload channel. Three contributions (**C-1608**, **C-2000**, **Sunnyvale_WD06-03** available in Appendices 10, 11, 12 and 13 respectively) were co-signed by ADVA.

2.4 Various topics and Recommendation Appendix

As the G.metro system strongly relies on a close interaction between head-end and tail-ends, a detailed description of this interaction is necessary to enable multi-vendor interoperability. In contribution **C-1942** (detailed in Appendix 13 of this document), an Appendix was proposed, describing details on the principle of operation, including the start-up and the in-service operation of a channel. While an Appendix of an ITU-T Recommendation is considered as “non-normative” (in contrast to a normative “Annex”), the Appendix refers to the details in the main body of G.metro and explains in further detail the normative specifications.

To make faster progress on G.metro, ADVA initiated an e-mail correspondence with all group members with an interest in G.metro. This group comprised three network operators, four equipment vendors and one module vendor. Most items could be agreed during this e-mail exchange, such that the joint contribution **Sunnyvale_WD06-04** (Appendix 14) could be submitted, including seven items related to Scope of the Recommendation, channel plan, and tail-end state-machine. Most of these proposals were then accepted into the current draft of G.metro. Furthermore, contribution **Sunnyvale_WD06-05** (Appendix 15) was submitted after alignment with the G.metro Editor, detailing six editorial (minor) items, correcting the text of the draft. This also helped to speed up the progress on the standard development.

Table 1: Summary of ITU-T SG-15 contributions.

Title of the contribution	Standardization body (including subgroups if applicable)	Meeting identifier (name/number of meeting to which the contribution was submitted)	Date of meeting	Document number (standardization body's document	Link to SDO document (if applicable)	Source 5G-PPP project	Contribution organization(s) (5G-PPP project partner(s) submitting the	Presenter	Comments	Location
Communication Channel in G.metro	ITU-T Q.6/SG15	Turin Q.6 interim meeting	12.-15.10.2015	WD06-03	q6/Meetings/2015-10-Turin/Contributions/WD06-03.docx	5G-XHaul	ADVA, Ericsson	Michael Eiselt, ADVA	upstream communications channel in new G.metro	Turin
Communication Channel in G.metro	ITU-T Q.11/SG15	Turin Q.11 interim meeting	12.-15.10.2015	WD11-10	q11/2015-10-Turin/WD11-10_multi-comp_Comm-channel-in-G.metro.docx	5G-XHaul	ADVA, Ericsson	Ghani Abbas, Ericsson	upstream communications channel in new G.metro	Turin
Communication Channel in G.metro	ITU-T Q.14/SG15	Wuhan Q.14 interim meeting	19.-22.10.2015	WD14-08	2015-10-19-Wuhan_Q10_Q14/wd/wd08_multi_Application-for-	5G-XHaul	ADVA, Ericsson	Ghani Abbas, Ericsson	upstream communications channel in new G.metro	Wuhan
Analysis of cross gain modulation caused by pilot tones	ITU-T Q.6/SG15	SG15 Plenary Meeting	15.-26.2.2016	C-1528	http://www.itu.int/md/T13-SG15-C-1528/en	5G-XHaul	ADVA, Ericsson	Michael Eiselt, ADVA	of pilot tone cross gain modulation in G.metro	Geneva
Application code proposal in G.metro	ITU-T Q.6/SG15	SG15 Plenary Meeting	15.-26.2.2016	C-1608	http://www.itu.int/md/T13-SG15-C-1608/en	5G-XHaul	China Unicom, ADVA	Shikui Shen, China Unicom	application code in G.metro tro support mobile front haul	Geneva
Communication channel in G.metro	ITU-T Q.14/SG15	SG15 Plenary Meeting	15.-26.2.2016	C-1663	http://www.itu.int/md/T13-SG15-C-1663/en	5G-XHaul	ADVA, Ericsson	Michael Eiselt, ADVA	previous proposal to add upstram communication	Geneva
Message channel in G.metro	ITU-T Q.6/SG15	Pisa Q.6 interim meeting	20.-22.6.2016	WD06-02	q6/Meetings/2016-06-Pisa/Contributions/WD06-02.docx	5G-XHaul	ADVA	Michael Eiselt, ADVA	of the impact of a Manchester coded communications	Pisa, Italy
Measurements of the impact of pilot tones in G.metro	ITU-T Q.6/SG15	Pisa Q.6 interim meeting	20.-22.6.2016	WD06-03	q6/Meetings/2016-06-Pisa/Contributions/WD06-03.docx	5G-XHaul	ADVA	Michael Eiselt, ADVA	of impact of pilot tones in G.metro standard	Pisa, Italy
Considerations on pilot tones in G.metro	ITU-T Q.6/SG15	Pisa Q.6 interim meeting	20.-22.6.2016	WD06-04	q6/Meetings/2016-06-Pisa/Contributions/WD06-04.docx	5G-XHaul	ADVA	Michael Eiselt, ADVA	different implementations of pilot tone modulation	Pisa, Italy
Impact of pilot tone and message channel on the payload in G.metro	ITU-T Q.6/SG15	SG15 Plenary Meeting	19.-30.09.2016	C-1919	http://www.itu.int/md/T13-SG15-C-1919/en	5G-XHaul	ADVA	Michael Eiselt, ADVA	impact of message channel in G.metro	Geneva, Switzerland
Appendix on Principles of Operation for G.metro	ITU-T Q.6/SG16	SG15 Plenary Meeting	19.-30.09.2016	C-1942	http://www.itu.int/md/T13-SG15-C-1942/en	5G-XHaul	Telecom, China Unicom, Ericsson	Michael Eiselt, ADVA	method of operation of a G.metro system, including	Geneva, Switzerland
Parameters for pilot tones and message channel for G.metro	ITU-T Q.6/SG15	SG15 Plenary Meeting	19.-30.09.2016	C-1943	http://www.itu.int/md/T13-SG15-C-1943/en	5G-XHaul	Telecom, China Unicom, Ericsson	Michael Eiselt, ADVA	for pilkot tones and message channels in G.metro	Geneva, Switzerland
Wavelength Plan Proposal for G.metro	ITU-T Q.6/SG15	SG15 Plenary Meeting	19.-30.09.2016	C-2000	http://www.itu.int/md/T13-SG15-C-2000/en	5G-XHaul	ADVA, Ericsson, British Telecom	Fabio Cavalliere, Ericsson	Proposal for wavelength assignment for G.metro	Geneva, Switzerland
Proposed 10G application code for G.metro	ITU-T Q.6/SG15	Sunnyvale Q.6 interregnum meeting	16.-19.1.2017	WD06-03	q6/Meetings/2017-01-Sunnyvale/Contributions/WD06-03.docx	5G-XHaul	China Unicom, Telecom Italia,	Fabio Cavalliere, Ericsson	Parameter proposal for 10G, 20ch., 20 km application code	Sunnyvale, CA, USA
Various items on G.metro	ITU-T Q.6/SG15	Sunnyvale Q.6 interregnum meeting	16.-19.1.2017	WD06-04R1	q6/Meetings/2017-01-Sunnyvale/Contributions/WD06-04R1.docx	5G-XHaul	British Telecom, Telecom Italia,	Michael Eiselt, ADVA	Various items on G.metro technical content	Sunnyvale, CA, USA
Editorial items on G.metro	ITU-T Q.6/SG15	Sunnyvale Q.6 interregnum meeting	16.-19.1.2017	WD06-05	q6/Meetings/2017-01-Sunnyvale/Contributions/WD06-05.docx	5G-XHaul	ADVA, Ericsson	Michael Eiselt, ADVA	improve the text of G.metro draft	Sunnyvale, CA, USA

3. Contributions to MEF

University of Bristol is an active member of MEF. “MEF is the enabling force for developing and implementing agile, assured and orchestrated Third Network services for the digital economy and the hyper-connected world [2]. Dr Reza Nejabati is a member of MEF research council. In this role, he disseminates the outcome of the project to MEF and specifically to MEF LSO (Lifecycle Services Orchestration) specifications. The outcomes of the project are being discussed in particular for the LSO Presto (The resource Management Interface Reference Point needed to manage the network infrastructure) specifications. Currently, a Proof of Concept (PoC) is being planned with the University of Bristol, for showcasing an implementation LSO Presto over an SDN controlled optical+wireless (WiFi) network.

"PRESTO (SOF:ICM): The resource Management Interface Reference Point needed to manage the network infrastructure, including network and topology view related management functions. For example, the Service Orchestration Function will use Presto to request Infrastructure Control and Management (ICM) to create connectivity or functionality associated with specific Service Components of an end-to-end Connectivity Service within the domain managed by each ICM. Presto may also allow the ICM to describe the resources and capabilities it is able to instantiate.

University of Bristol used the project outcome to enhance its SDN controller in order to support the LSO Presto for the following functionalities:

- Multiple topology views
  - Mostly abstract, it is a single node exposing only UNIs/NNIs.
  - But optionally allow drilling down all the way to the underlying physical topology.
  - Intermediate views are also possible.
- Connectivity service provisioning
  - Between UNIs.
  - Optionally allows routing across internal nodes to be specified.

4. Summary and Conclusions

Based on the work in 5G-XHaul, a number of contributions were submitted and introduced in meetings of Question 6 of ITU-T SG15 on the topic of the new Recommendation G.metro. This strongly helped to progress the Recommendation and to support the choice of parameter values for the first release. Further work will be necessary to align all group members on the details of the interface parameters. It is currently expected that the Recommendation will be agreed at the SG15 plenary meeting in the spring of 2018. In addition, the project is being represented to the MEF and its outcomes are considered in the LSO specification discussions.

References

[1] http://www.itu.int/en/ITU-T/about/groups/Pages/sg15.aspx

[2] https://www.mef.net/about-mef

Appendices

Appendix 1

Question(s):	Q11, Q6	**Meeting, date:**	Turin, 12 - 15 October 2015
Study Group: 15	**Working Party:**	3, 2	**Intended type of document** (R-C-TD):
WD06-03 Source:	ADVA, Ericsson, British Telecom, China Unicom, Deutsche Telekom		
Title:	Communications channel in G.metro		

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Introduction

Question 6/15 is currently working on G.metro, which is a specification of physical layer interfaces for dense wavelength division multiplexing (DWDM) systems, where the tail-end transmitters have the capability to automatically adapt their DWDM channel frequency to the optical multiplexer port, using feedback information from the head-end equipment. The payload data might not be OTN framed, and an in-band general communications channel (GCC) might not be present. Therefore, the feedback requires an out-of-band communications channel from the head-end to the tail-end, which is independent of the payload data format and framing. In G.metro, such a communications channel will be defined. It has been proposed to use this communications channel for other purposes than mere wavelength control and to also specify a communications channel for the tail-end to head-end direction. However, Q.6 does currently not have a mandate from either Q.11 or Q.14 to specify a communications channel beyond what is necessary for wavelength control.

A proposal to expand the use of the control channel was made in contribution C1221 to the June/July 2015 Geneva plenary meeting and was discussed in a joint Q.6/11/12/14 meeting. In TD378/PLEN, the report of the joint meeting contains the following discussion of C1221:

C1221 The consideration of communication channel for G.metro [ADVA, China Unicom, ETRI, Fiberhome, Ericsson, ZTE] was briefly summarized and discussed. Q6/15 had determined that no more than 50 kb/s was available for the OAM communications over a pilot tone on the link. It was agreed that Q6/15 had nothing more to do on the subject, until it received further input from Q11/15 and/or Q14/15. Contributors were urged to submit contributions to Q11/14 (sic!) *and Q14/15 to explain the application and the information that needed to be carried over the communications channel to support it. Once the functionality and information to be carried were better understood and agreed, the three Questions could proceed with standardizing the portions that were within their individual scopes.*

This Contribution describes an application for a communications channel in G.metro. It will also be submitted to the Q14/15 Interim Meeting in Wuhan, October 19-23, 2015.

Discussion

The tree and add-drop architectures provided in the current draft of G.metro will allow the use of the tail-end equipment as the demarcation device between two network sections, without being directly connected to a management network. Main applications currently seen for G.metro systems are in the field of front haul and back haul for the next generations of mobile communications systems (4G and 5G). The G.metro system is specified to be agnostic to the payload, which therefore might not be OTN framed, so that no in-band control channel or GCC might be available. Only the out-of-band communications channel currently discussed for wavelength control would be present from the head-end to the tail-end. To still be able to monitor the performance of the tail-end equipment, it is necessary to enable the transport of physical layer performance information via a tail-end to head-end communications channel.

Parameters to monitor should comprise received and transmitted optical power, laser and module temperature, etc. Furthermore, identification information of the remote device (part number, vendor, serial number etc.) should be transmitted via the communications channel.

For a small form factor device, like an SFP+, this information is located in the memory of the device [1]. A method to transfer the remote tail-end monitoring parameters to the head-end side is mirroring the memory regions from the remote device to the head-end via the communications channel.

The SFF-8472 document describes a memory map to provide diagnostic information about the module's present operating conditions. The transceiver generates this diagnostic data by digitization of internal analogue signals. Calibration and alarm/warning threshold data is written during device manufacture.

In addition to the diagnostic data, identification information of the device should be regularly transmitted. Furthermore, memory locations of the SFF allow user accessible write access.

Transferring these data should also be enabled by the communications channel in order to monitor performance information generated outside the device.

As state changes of the alarm flags occur within 100ms of the event, a refresh rate of the performance information of 10 times per second should be sufficient. The same is true for information entered into the user accessible memory. ID information can be transmitted with a lower refresh rate of once per second.

The following Table 1 and Table 2 list the memory locations according to SFF-8472 that should be mirrored via the communications channel.

Table 1: Performance monitoring parameters to be mirrored with a 10 Hz refresh rate.

Memory page	Memory location	Content	Remark
A2h	96 - 109	Analog values	
A2h	110 - 111	Optional status / control bits	
A2h	112 - 117	Alarm and warning flag bits	
A2h	118 – 119	Extended module control / status bytes	
A2h	128 - 247	User accessible memory	2 alternative pages, selected by A2h / 127
A2h	248 - 255	Vendor specific control function	2 alternative pages, selected by A2h / 127

Table 2: ID and user defined information to be mirrored with 1 Hz refresh rate.

Memory page	Memory location	Content
A0h	0 - 63	Base ID fields
A0h	64 - 95	Extended ID fields
A0h	96 - 255	Vendor specific ID fields
A2h	0 - 95	Diagnostic and control / status fields, incl. diagnostic calibration

According to Table 1, (24 + 2 x 128=) 280 bytes should be transmitted every 100 ms, and according to Table 2, (256 + 96 =) 352 bytes should be transmitted every second, resulting in a net data rate requirement for the communications channel of 25.216 kb/s.

Proposal

Q.14 should specify the requirements enabling the monitoring of performance information at a remote transceiver device, based on SFF-8472 and as detailed above, and to provide this monitoring information to the management system.

Q.11 should specify the communications protocol and framing necessary to transport such monitoring information, e.g from the tail-end of a G.metro system to the head-end equipment.

The data rate for the transmission of the monitoring information should be at least 25.2 kb/s.

References

[1] SFF-8472, "Specification for Diagnostic Monitoring Interface for Optical Transceivers ", e.g. online at ftp://ftp.seagate.com/sff/SFF-8472.PDF

Appendix 2

Question(s):	Q11, Q6	**Meeting, date:**	Turin, 12-16 October 2015
Study Group: 15	**Working Party:** 3,2	**Intended type of document** (R-C-TD):	WD11-10
Source:	ADVA, Ericsson, British Telecom, China Unicom, Deutsche Telekom		
Title:	Communications channel in G.metro		

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A proposal to expand the use of the control channel was made in contribution C1221 to the June/July 2015 Geneva plenary meeting and was discussed in a joint Q.6/11/12/14 meeting. In TD378/PLEN, the report of the joint meeting contains the following discussion of C1221:

C1221 The consideration of communication channel for G.metro [ADVA, China Unicom, ETRI, Fiberhome, Ericsson, ZTE] was briefly summarized and discussed. Q6/15 had determined that no more than 50 kb/s was available for the OAM communications over a pilot tone on the link. It was agreed that Q6/15 had nothing more to do on the subject, until it received further input from Q11/15 and/or Q14/15. Contributors were urged to submit contributions to Q11/14 (sic!) *and Q14/15 to explain the application and the information that needed to be carried over the communications channel to support it. Once the functionality and information to be carried were better understood and agreed, the three Questions could proceed with standardizing the portions that were within their individual scopes.*

This Contribution describes an application for a communications channel in G.metro. It will also be submitted to the Q14/15 Interim Meeting in Wuhan, October 19-23, 2015.

Discussion

The tree and add-drop architectures provided in the current draft of G.metro will allow the use of the tail-end equipment as the demarcation device between two network sections, without being directly connected to a management network. Main applications currently seen for G.metro systems are in the field of front haul and back haul for the next generations of mobile communications systems (4G and 5G). The G.metro system is specified to be agnostic to the payload, which therefore might not be OTN framed, so that no in-band control channel or GCC might be available. Only the out-of-band communications channel currently discussed for wavelength control would be present from the head-end to the tail-end. To still be able to monitor the performance of the tail-end equipment, it is necessary to enable the transport of physical layer performance information via a tail-end to head-end communications channel.

Parameters to monitor should comprise received and transmitted optical power, laser and module temperature, etc. Furthermore, identification information of the remote device (part number, vendor, serial number etc.) should be transmitted via the communications channel.

For a small form factor device, like an SFP+, this information is located in the memory of the device [1]. A method to transfer the remote tail-end monitoring parameters to the head-end side is mirroring the memory regions from the remote device to the head-end via the communications channel.

The SFF-8472 document describes a memory map to provide diagnostic information about the module's present operating conditions. The transceiver generates this diagnostic data by digitization of internal analogue signals. Calibration and alarm/warning threshold data is written during device manufacture.

In addition to the diagnostic data, identification information of the device should be regularly transmitted. Furthermore, memory locations of the SFF allow user accessible write access. Transferring these data should also be enabled by the communications channel in order to monitor performance information generated outside the device.

As state changes of the alarm flags occur within 100ms of the event, a refresh rate of the performance information of 10 times per second should be sufficient. The same is true for information entered into the user accessible memory. ID information can be transmitted with a lower refresh rate of once per second.

The following Table 1 and Table 2 list the memory locations according to SFF-8472 that should be mirrored via the communications channel.

Table 1: Performance monitoring parameters to be mirrored with a 10 Hz refresh rate.

Memory page	Memory location	Content	Remark
A2h	96 - 109	Analog values	
A2h	110 - 111	Optional status / control bits	
A2h	112 - 117	Alarm and warning flag bits	
A2h	118 – 119	Extended module control / status bytes	
A2h	128 - 247	User accessible memory	2 alternative pages, selected by A2h / 127
A2h	248 - 255	Vendor specific control function	2 alternative pages, selected by A2h / 127

Table 2: ID and user defined information to be mirrored with 1 Hz refresh rate.

Memory page	Memory location	Content
A0h	0 - 63	Base ID fields
A0h	64 - 95	Extended ID fields
A0h	96 - 255	Vendor specific ID fields
A2h	0 - 95	Diagnostic and control / status fields, incl. diagnostic calibration

According to Table 1, (24 + 2 x 128=) 280 bytes should be transmitted every 100 ms, and according to Table 2, (256 + 96 =) 352 bytes should be transmitted every second, resulting in a net data rate requirement for the communications channel of 25.216 kb/s.

Proposal

Q.14 should specify the requirements enabling the monitoring of performance information at a remote transceiver device, based on SFF-8472 and as detailed above, and to provide this monitoring information to the management system.

Q.11 should specify the communications protocol and framing necessary to transport such monitoring information, e.g. from the tail-end of a G.metro system to the head-end equipment.

The data rate for the transmission of the monitoring information should be at least 25.2 kb/s.

References

[1] SFF-8472, "Specification for Diagnostic Monitoring Interface for Optical Transceivers ", e.g. online at ftp://ftp.seagate.com/sff/SFF-8472.PDF

Appendix 3

Question(s): Q14 **Meeting, date:** Wuhan, 19-23 October 2015

Study Group: 15 **Working Party:** 3 **Intended type of document** (R-C-TD): WD 08

Source: ADVA, Ericsson, British Telecom, China Unicom, Deutsche Telekom

Title: Communications channel in G.metro

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Introduction

Question 6/15 is currently working on G.metro, which is a specification of physical layer interfaces for dense wavelength division multiplexing (DWDM) systems, where the tail-end transmitters have the capability to automatically adapt their DWDM channel frequency to the optical multiplexer port, using feedback information from the head-end equipment. The payload data might not be OTN framed, and an in-band general communications channel (GCC) might not be present. Therefore, the feedback requires an out-of-band communications channel from the head-end to the tail-end, which is independent of the payload data format and framing. In G.metro, such a communications channel will be defined. It has been proposed to use this communications channel for other purposes than mere wavelength control and to also specify a communications channel for the tail-end to head-end direction. However, Q.6 does currently not have a mandate from either Q.11 or Q.14 to specify a communications channel beyond what is necessary for wavelength control.

A proposal to expand the use of the control channel was made in contribution C1221 to the June/July 2015 Geneva plenary meeting and was discussed in a joint Q.6/11/12/14 meeting. In TD378/PLEN, the report of the joint meeting contains the following discussion of C1221:

C1221 The consideration of communication channel for G.metro [ADVA, China Unicom, ETRI, Fiberhome, Ericsson, ZTE] was briefly summarized and discussed. Q6/15 had determined that no more than 50 kb/s was available for the OAM communications over a pilot tone on the link. It was agreed that Q6/15 had nothing more to do on the subject, until it received further input from Q11/15 and/or Q14/15. Contributors were urged to submit contributions to Q11/14 (sic!) *and Q14/15 to explain the application and the information that needed to be carried over the communications channel to support it. Once the functionality and information to be carried were better understood and agreed, the three Questions could proceed with standardizing the portions that were within their individual scopes.*

This Contribution describes an application for a communications channel in G.metro. It was also submitted to the Q6/15 & Q11/15 Interim Meeting in Turin, October 12-16, 2015.

Discussion

The tree and add-drop architectures provided in the current draft of G.metro will allow the use of the tail-end equipment as the demarcation device between two network sections, without being directly connected to a management network. Main applications currently seen for G.metro systems are in the field of front haul and back haul for the next generations of mobile communications systems (4G and 5G). The G.metro system is specified to be agnostic to the payload, which therefore might not be OTN framed, so that no in-band control channel or GCC might be available. Only the out-of-band communications channel currently discussed for wavelength control would be present from the head-end to the tail-end. To still be able to monitor the performance of the tail-end equipment, it is necessary to enable the transport of physical layer performance information via a tail-end to head-end communications channel.

Parameters to monitor should comprise received and transmitted optical power, laser and module temperature, etc. Furthermore, identification information of the remote device (part number, vendor, serial number etc.) should be transmitted via the communications channel.

For a small form factor device, like an SFP+, this information is located in the memory of the device [1]. A method to transfer the remote tail-end monitoring parameters to the head-end side is mirroring the memory regions from the remote device to the head-end via the communications channel.

The SFF-8472 document describes a memory map to provide diagnostic information about the module's present operating conditions. The transceiver generates this diagnostic data by digitization of internal analogue signals. Calibration and alarm/warning threshold data is written during device manufacture.

In addition to the diagnostic data, identification information of the device should be regularly transmitted. Furthermore, memory locations of the SFF allow user accessible write access.

Transferring these data should also be enabled by the communications channel in order to monitor performance information generated outside the device.

As state changes of the alarm flags occur within 100ms of the event, a refresh rate of the performance information of 10 times per second should be sufficient. The same is true for information entered into the user accessible memory. ID information can be transmitted with a lower refresh rate of once per second.

The following Tables 1 and 2 list the memory locations according to SFF-8472 that should be mirrored via the communications channel.

Table 1 - Performance monitoring parameters to be mirrored with a 10 Hz refresh rate

Memory page	Memory location	Content	Remark
A2h	96 - 109	Analog values	
A2h	110 - 111	Optional status / control bits	
A2h	112 - 117	Alarm and warning flag bits	
A2h	118 – 119	Extended module control / status bytes	
A2h	128 - 247	User accessible memory	2 alternative pages, selected by A2h / 127
A2h	248 - 255	Vendor specific control function	2 alternative pages, selected by A2h / 127

Table 2 - ID and user defined information to be mirrored with 1 Hz refresh rate

Memory page	Memory location	Content
A0h	0 - 63	Base ID fields
A0h	64 - 95	Extended ID fields
A0h	96 - 255	Vendor specific ID fields
A2h	0 - 95	Diagnostic and control / status fields, incl. diagnostic calibration

According to Table 1, (24 + 2 x 128=) 280 bytes should be transmitted every 100ms, and according to Table 2, (256 + 96 =) 352 bytes should be transmitted every second, resulting in a net data rate requirement for the communications channel of 25.216 kb/s.

Proposal

Q.14 should specify the requirements enabling the monitoring of performance information at a remote transceiver device, based on SFF-8472 and as detailed above, and to provide this monitoring information to the management system.

Q.11 should specify the communications protocol and framing necessary to transport such monitoring information, e.g. from the tail-end of a G.metro system to the head-end equipment.

The data rate for the transmission of the monitoring information should be at least 25.2 kb/s.

References

[1] SFF-8472, “Specification for Diagnostic Monitoring Interface for Optical Transceivers “, e.g. online at ftp://ftp.seagate.com/sff/SFF-8472.PDF

Appendix 4

INTERNATIONAL TELECOMMUNICATION UNION

COM 15 – C-1663 – E

TELECOMMUNICATION STANDARDIZA-TION SECTOR

STUDY PERIOD 2013-2016

February 2016
English only

Original: English

-

Question(s): 14/15

STUDY GROUP 15 – CONTRIBUTION C-1663

Source: ADVA Optical Networking, Ericsson, Deutsche Telekom, China Unicom, British Telecom

Title: Communications channel in G.metro

Introduction

In Contribution WD08 to the September 2015 Wuhan meeting of Q14/15, it was proposed that Q.14 should specify the requirements enabling the monitoring of performance information in a G.metro system at a remote transceiver device and to provide this monitoring information to the management system. According to the meeting report, the following questions were raised in the discussion and Contributions to answer these questions were invited:

The management architecture of G.metro system? What aspects of the system, in particular the tail-end, that need to be managed? What management information needs to be carried?

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Regarding what kind of management information might need to be carried, wouldn't this depend upon the Q6/15 agreement upon which parameters should be monitored?

The present Contribution tries to give more information in order to develop the management requirement for G.metro.

Discussion

Question 6/15 is currently working on G.metro, which is a specification of physical layer interfaces for dense wavelength division multiplexing (DWDM) systems. Q.6 will only specify the physical layer interfaces of this system in order to enable interoperability between head-end device, black link, and tail-end devices. It is not intended by Q.6 to specify the management of a G.metro system or physical monitoring parameters. Therefore, in Contribution WD08 we gave information on physical parameter monitoring requirements in G.metro and asked Q.14 to provide, based on this, the management channel requirements. These, in turn, can be used by Q.6 to specify the physical parameters of a management channel.

Figure 1 shows the architecture of a G.metro system, connecting a head-end through the DWDM link with (passive, unmonitored and unmanaged) DWDM network elements to multiple tail-ends. Management information needs to be exchanged between the head-end and each of the tail-ends. This management information comprises system parameters to be transported from the head-end to an individual tail-end and system parameters to be transported from an individual tail-end to a head- end. As individual wavelengths connect the head-end with each of the tail-ends, individual and **independent management channels, providing a data rate of approximately 50 kbps, are available between the head-end and each of the tail-ends**.

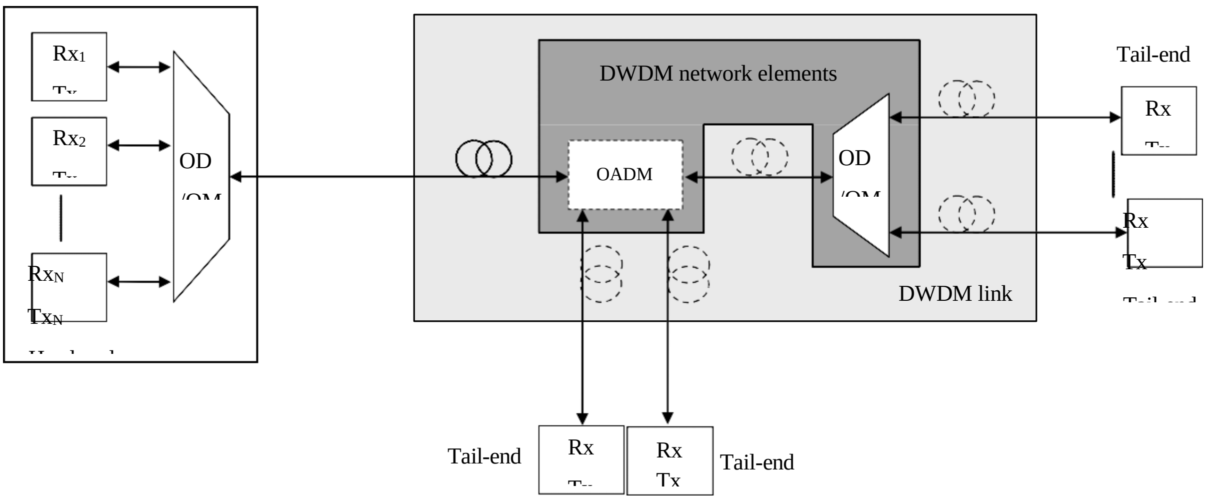

Figure 1 – G.metro physical architecture (adapted from G.metro Draft Fig 5-1).

What management information needs to be carried?

What aspects of the system, in particular the tail-end, that need to be managed?

The management information to be carried from each of the tail-ends to the head-end comprises ID information and physical monitoring parameters generated in the tail-ends. As detailed in Contribution WD08, these parameters should comprise received and transmitted optical power, laser and module temperature, etc. as well as identification information of the remote device (part number, vendor, serial number etc.). The list of parameters to be monitored is shown in Table 1. The set of parameters should be compatible with the parameters monitored by a small form factor device, as per SFF-8472. That document also contains a detailed description of the parameters and can be used by Q.14 as input to develop the monitoring requirements.

Table 1 – List of parameters to be sent from tail-end to head-end

# of Bytes	**General description**	**Content**
Performance monitoring parameters		

14	Analog monitoring data	Module temperature Supply voltage TX bias current TX output power RX input power Laser temperature TEC current
4	Status bits	
6	Alarm and warning flag bits	Temperature low /high alarm Vcc low/high alarm TX bias low/ high TX power low/high RX power low/high Laser temp low/high TEC current low/high
16	Vendor specific control functions	
240	User writable memory	External performance parameters to be written to a user accessible memory space
ID information		
64	Base ID information	Transceiver type Con- nector type Signalling rate Supported link length Vendor name Vendor part number Laser wavelength
32	Extended ID information	Bit rate margin Vendor serial number Vendor manufacturing date
160	Vendor specific ID information	Vendor specific information
96	Diagnostic and control status	Alarm and warning thresholds Calibration constants Checksum

The management information to be carried from the head-end to the tail-end is currently restricted to the polling command, instructing the tail-end to send either a message with performance monitoring parameters or a message with ID information. It is expected that the performance monitoring parameters will be requested approximately every 100ms, while the ID information will be requested approximately every 1 second.

Table 2 lists the system information to be sent from the head-end to the tail-end and vice versa. Additional control and monitoring information might be added if required.

Table 2 – List of system information to be exchanged

Message content	Content length
Message to be sent from head-end to tail-end	
Request for ID information	2 bytes (?)
Request for performance monitoring information	2 bytes (?)
Additional control information?	*TBD*
Message to be sent from tail-end to head-end	
Performance monitoring parameters (as per upper part of Table 1)	280 bytes
ID Information (as per lower part of Table 1)	352 bytes
Additional monitoring information?	*TBD*

As listed in Table 2, the system information to be exchanged between head-end and tail-end consists of messages with variable lengths. It is therefore proposed to frame the message with a start-of-message byte, two bytes signifying the length of the content (in bytes), the message content, and an end-of-message byte, as shown in Figure 2.

Start of message (1 byte)	Content length (2 bytes)	Message content (variable length)	End of message (1 byte)

Figure 2 – Proposed message frame format.

Proposal

Based on the additional information above and Contribution WD08 to the September 2015 Wuhan meeting, Q.14 should specify the message exchange between head-end and tail-ends, including control, ID and performance monitoring information.

Appendix 5

Question(s): Q6 **Meeting, date:** Pisa, 20 – 22 June 2016

Study Group: 15 **Working Party:** 2 **Intended type of document** (R-C-TD):

WD06-02 Source: ADVA

Title: Message channel in G.metro

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Introduction

During the recent meetings of Q.6, the impact and requirements of a HEE-to-TEE message channel have been discussed. In a Correspondence Contribution, contained in the Correspondence Report TD178-WP2, as well as in Contribution WD06-22 to the Turin interim meeting, the impact of a direct NRZ modulated message channel on the data payload and vice versa were investigated.

In WD06-16 to the Turin meeting, concerns were raised about the low-frequency content of NRZ modulation, and several modulation formats were proposed with reduced low-frequency content. Manchester coding was shown to have the main spectral content around the data rate, with little power at low frequencies.

In this Contribution, we report on measurements on the impact of a Manchester coded message channel onto the data payload as well as on the sensitivity of the Manchester coded message channel in the presence of a 2.5-Gbps payload data modulation.

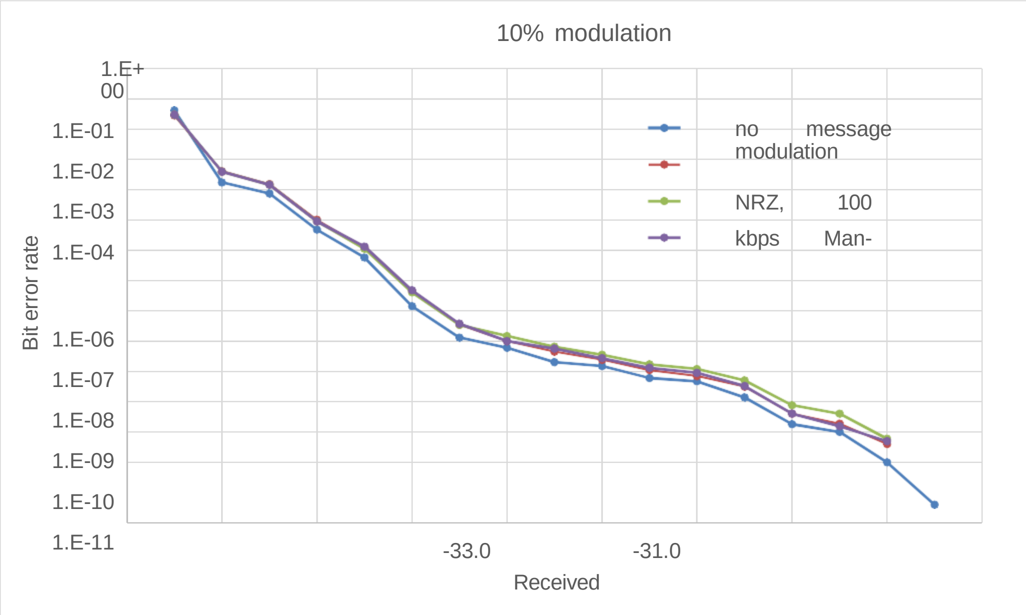
Discussion

In the following, we refer by “message channel” to the communication channel which is transmitted from the HEE to the TEE via envelope modulation of the optical signal. By payload, we refer to the (high speed) data content of the optical signal.

Impact of envelope modulation on the payload sensitivity

The amplitude of a 2.5 Gbps, PRBS31, optical signal was modulated with a binary data sequence using a Mach-Zehnder modulator. The modulation index of the envelope modulation (message channel) was varied between 10% and 15%. The modulation index is here defined as the peak-to- peak power variation of the payload “one” rail divided by the maximum payload “one” rail power, as per the G.metro draft. The message channel modulation was changed between NRZ at 100 kbps and Manchester coding at 50 and 100 kbps.

Figure 1 shows the bit error rate (BER) versus received power for the payload channel. The case without envelope modulation is depicted as the blue line (“no message channel”). It can be seen that the impact of the message channel only marginally depends on the modulation format or the data rate. At a BER of 10^{-9}, the penalty due to a 10% and 15% message channel modulation is approximately 0.5 dB and 1 dB, with a 0.5 dB higher penalty for the 100 kpbs Manchester modulation.



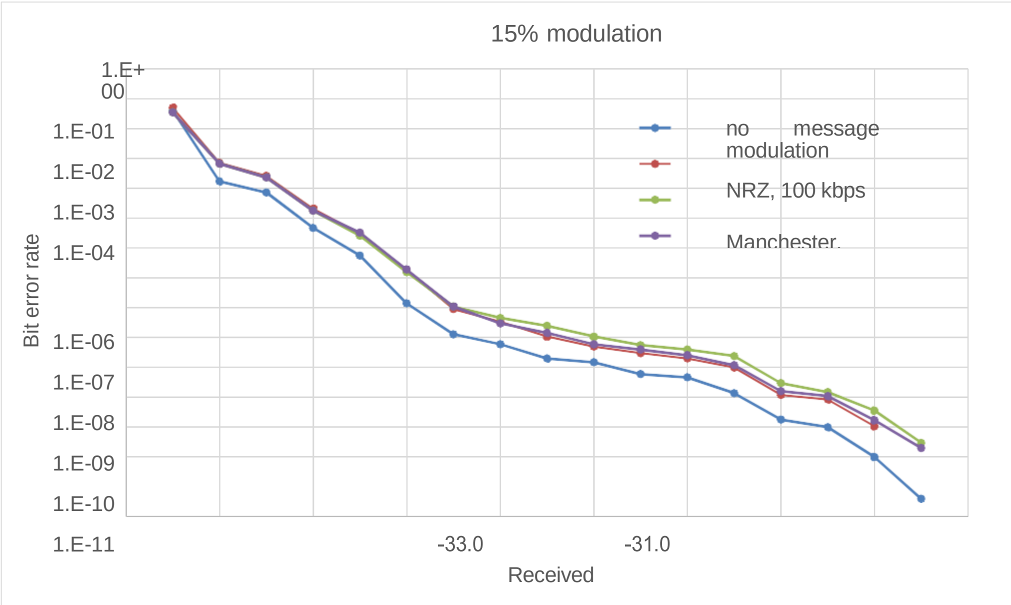


Figure 1 - Bit error rate of the 2.5-Gbps payload channel vs. received power with 10% (top) and 15% (bottom) modulation depths of the envelope modulation. "no message modulation" is the case without envelope modulation. The modulation formats and rates are NRZ/100 kbps, Manchester/100 kpbs, and Manchester/50 kbps.

Sensitivity of the message channel

The sensitivity of the message channel under the impact of the 2.5-Gbps PRBS31 payload was determined by measuring the BER of the message channel as a function of received optical power with the modulation format and data rate combinations as above. An error floor was observed for a received power larger than approximately -43 dBm. Figure 2 shows the error floor, measured at a received power of -35 dBm as a function of the modulation depth. For each data point, 2x 10^{-7} bits were measured, while BER values shown at 10^{-7} indicate that no bit error was observed.

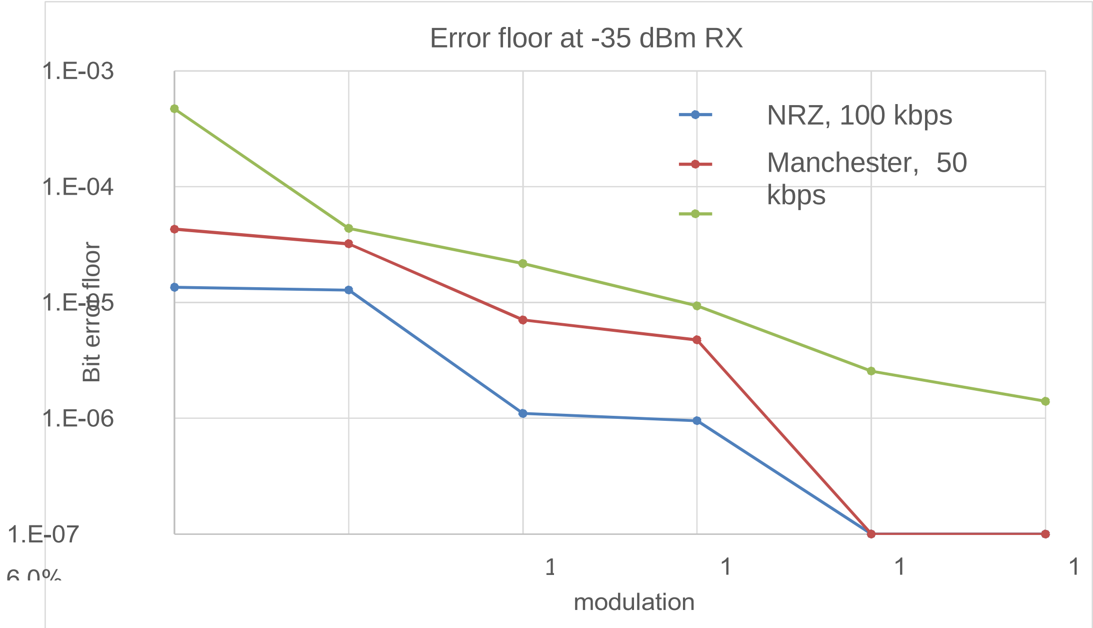


Figure 2 – Bit error floor of the message channel as a function of the modulation depth. The modulation formats and rates are NRZ/100 kbps, Manchester/100 kpbs, and Manchester/50 kbps.

The results shown in Figure 2 indicate that a 100-kbps message channel with NRZ modulation is comparable to a 50-kbps message channel with Manchester modulation. In both cases, a BER of better than 10^{-6} is achieved with a modulation index of 14% and above. For a Manchester coded 100 kbps message channel, a BER floor below 10^{-6} is not achieved even for a modulation depth of 18%.

Summary

In order to reduce the low-frequency content of an envelope modulated message channel, Manchester coding can be chosen. It was shown that the modulation format has only a minor impact on the resulting penalty for the data channel. A modulation depth of 10% results in a penalty of 0.5 dB, a modulation depth of 15% in a penalty of 1-1.5 dB. In order to achieve a BER of 10^{-6} in the message channel, a modulation depth of 14% is required for a 50 kbps Manchester coded signal.

Appendix 6

INTERNATIONAL TELECOMMUNICATION UNION

COM 15 – C-1919 – E

September 2016

English only

TELECOMMUNICATION STANDARDIZATION SECTOR

STUDY PERIOD 2013-2016

Original: English

-

Question(s): 6/15

STUDY GROUP 15 – CONTRIBUTION C-1919

Source: ADVA Optical Networking

Title: Impact of pilot tone and message channel on the payload in G.metro

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Introduction

In Contribution WD06-02 to the Pisa June Interim meeting, measurement results on the impact of a 50 kbps Manchester coded message channel onto a 2.5 Gbps payload data channel were reported. During the discussion, the shape of the BER vs. received power curve was disapproved. Furthermore, other results reported in earlier contributions were based on a 10 Gbps payload data and reported higher penalty.

In this Contribution, the measurements from WD06-02 were repeated with a different pluggable transceiver for 2.5 Gbps and results obtained for a 10 Gbps payload were added. In addition, as the pilot tone could be generated by binary 0101… modulation, the impact of such modulation around 50 kHz was investigated.

Discussion

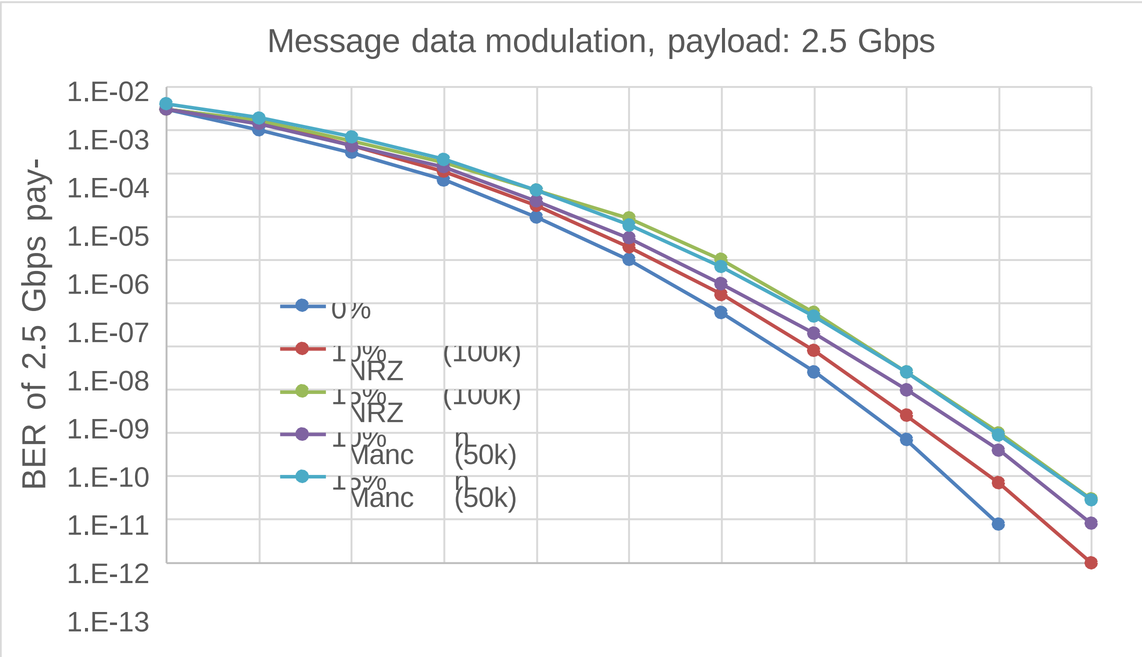
In the following, we refer by “message channel” to the communication channel which is transmitted from the HEE to the TEE via envelope modulation of the optical signal. By payload, we refer to the (high speed) data content of the optical signal.

In two different setups, the amplitudes of PRBS-31 optical signals at 2.5 Gbps, and at 10.3 Gbps were modulated with binary data sequences using a Mach-Zehnder modulator. The modulation index of the envelope modulation (message channel, PRBS-7) was varied between 10% and 15%. Here, the modulation index is defined as the difference between the average optical power in the “ones” of the message channel and the average optical power in the “zeros”, divided by the average optical power in the “ones”, as per Clause 7.2.8 of the G.metro draft:

$$m_{MC} = \frac{P(1) - P(0)}{P(1)}$$

The message channel modulation was changed between NRZ at 100 kbps and Manchester coding at 50 and 100 kbps.

Figure 1 shows the bit error rate (BER) versus received power for the payload channel. The case without envelope modulation is depicted as the blue line (“0%”). It can be seen that the impact of the message channel only marginally depends on the modulation format or the data rate. At a payload BER of 10^{-12}, the penalty due to a 15% message channel modulation is less than 0.5 dB for a 10.3 Gbps payload and less than 0.7 dB for a 2.5 Gbps payload, for 100 kbps NRZ as well as for 50 kbps Manchester modulation.



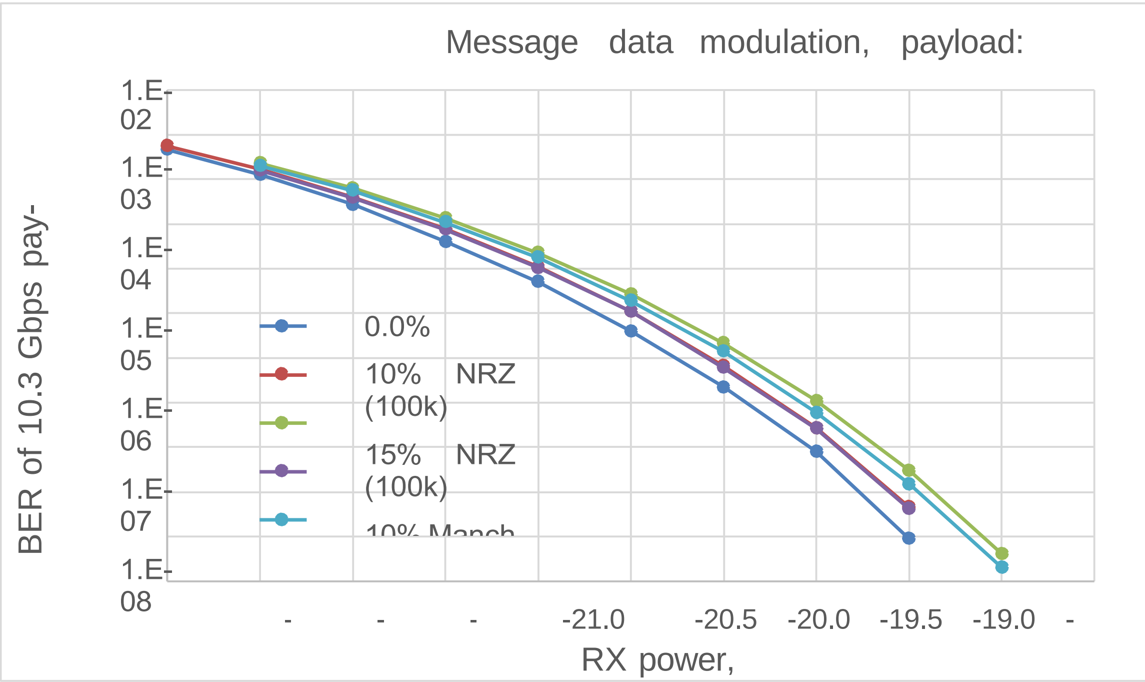


Figure 1 – BER vs. RX power of 2.5 Gbps (top) and 10.3 Gbps (bottom) payload in the presence of message channel envelope modulation

In a next step, the envelope modulation was changed from PRBS-7 to a 0101… sequence, yielding a tone frequency at the data rate of the Manchester coded signal (50 kHz). The modulation depths were chosen as before. However, according to Clause 7.2.9 of the G.metro draft, the modulation depth of the pilot tone is the peak-to-peak power excursion of the optical signal at the pilot tone frequency, divided by twice the average optical power:

$$m_{PT} = \frac{Pmax - Pmin}{Pmax + Pmin}$$

Therefore, a message channel modulation depth of 10% or 15% corresponds to a pilot tone modulation of 5.3% or 8.1%, respectively.

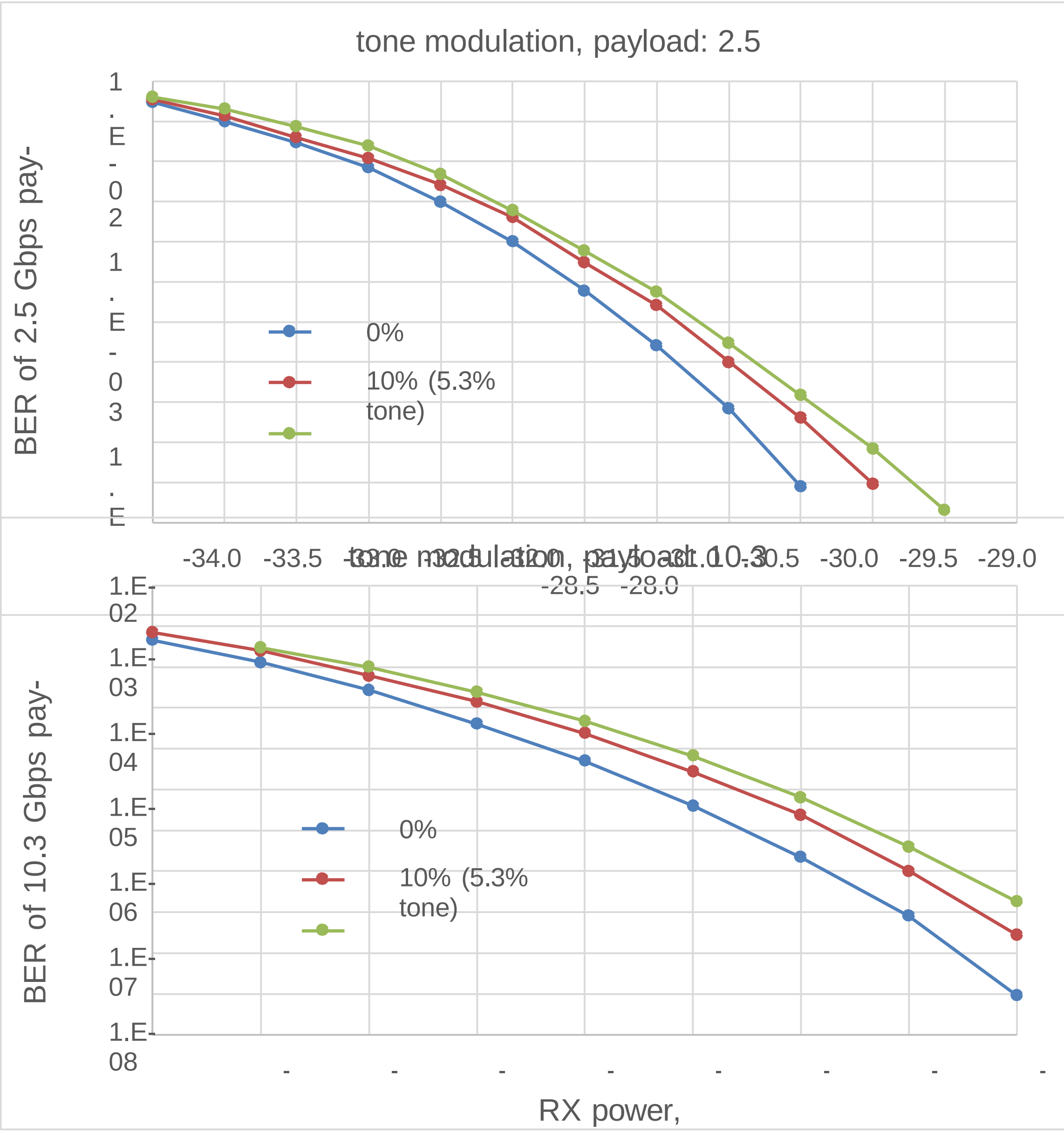


Figure 2 – BER vs. RX power of 2.5 Gbps (top) and 10.3 Gbps (bottom) payload in the presence of binary 0101 envelope modulation at 50 kHz

Figure 2 shows the bit error rate (BER) versus received power for the payload channel. It can be seen that the pilot tone modulation has a slightly larger impact than the message channel. At a payload BER of 10^{-10}, an 8.1% tone modulation introduced a penalty of less than 0.6 dB for both payload data rates, while for a BER of 10^{-12} the penalty was less than 0.8 dB for the 2.5 Gbps payload. Unfortunately, the measurement results don't reach to 10^{-12} BER for 10.3 Gbps with tone modulation.

Conclusion

The measurement results presented here show that a Manchester coded message channel at 50 kbps with max. 15% modulation depth and a 50 kHz pilot tone with max. 8% modulation depth would lead to less than 1 dB penalty in a 2.5 Gbps or 10 Gbps payload.

Appendix 7

INTERNATIONAL TELECOMMUNICATION UNION

TELECOMMUNICATION STANDARDIZATION SECTOR

STUDY PERIOD 2013-2016

COM 15 – C 1528 – E
January 2016
English only

Original: English

-

Question(s): 6/15

STUDY GROUP 15 – CONTRIBUTION 1528

Source: ADVA Optical Networking

Title: Analysis of cross gain modulation caused by pilot tones

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Introduction

During the discussion of G.metro during the October 2015 Q.6 Turin interim meeting the question of minimum pilot tone frequency and message channel data rate was raised. As a G.metro system is required to work in the presence of optical amplifiers (OAs), concern was raised that saturation effects in the OA can lead to interference effects between the pilot tones of different channels.
Contribution WD06-07 to the Turin meeting mentioned a minimum pilot tone frequency of 10 kHz, and Contribution WD06-16 proposed a minimum frequency of 1 kHz.

This contribution presents measurements of the cross gain modulation (XGM) occuring in an EDFA due to amplitude modulated pilot tones from 100 Hz up to 100 kHz. From these measurements, a minimum pilot tone modulation frequency in amplified WDM systems is derived.

Discussion

Optical power variations in an Erbium doped fibre amplifier (EDFA) can lead to a variation of the carrier density and a related variation of the EDFA gain. As the carrier lifetime in an EDFA is on the order of 1 ms, only slow power variations result in a gain variation. The gain variation can have two effects on pilot tone modulated optical signals. First, as the gain variation is inverse to the optical power (lower gain for higher power), the modulation index of the pilot tone is reduced.
Secondly, a gain variation induced by one optical carrier with a specific pilot tone frequency will modulate the power of a second optical carrier and therefore impress the specific pilot tone frequency onto this second carrier. This effect is called cross-gain modulation (XGM).

Current EDFAs are working with an efficient gain control, which, for instance, modifies the optical pump power based on the measured gain of the EDFA. However, this only equalizes the average gain of the EDFA, still leaving a potential variation in the gain shape and a resulting XGM.

While, according to our measurements, the effect of modulation index reduction can be sufficiently suppressed using effective gain control methods, the effect of XGM is still measureable. In this Contribution, we present measurements of the XGM as a function of the modulation frequency for a worst case assumption of one large and one small optical carrier.

The measurement setup is shown in Figure 1. The CW signal from a tuneable laser was modulated by a Mach-Zehnder-Modulator (MZM) with a sinusoidal tone. The modulation frequencies were modified between 100 Hz and 100 kHz. The polarization controller (PC) was adjusted to minimize the insertion loss of the MZM. An in-line power meter (PM) with integrated attenuator was used to vary the EDFA input power. An arrayed wave-guide grating (AWG) was used to suppress the modulated amplified spontaneous emission and side modes of the tuneable laser, which would have caused crosstalk effects. The modulation depth of the tone was measured on an oscilloscope.

An unmodulated SFP output signal was used as probe wavelength to observe the XGM from the EDFA. The tone modulated signal and the CW light were combined in a 3 dB coupler and were sent to the EDFA. The EDFA had a gain of 13 dB and was operated in constant gain control mode. After the EDFA, two cascaded AWGs were used to separate the probe channel wavelength from the tone modulated wavelength and any modulated ASE noise. The in-line PM with integrated attenuator was used to keep the PD input power constant. The modulation depth was measured on an oscilloscope.

For all measurements, the (single-sided) tone modulation depth was set to 20%. The emission frequency of the tuneable laser was varied between 193.9 THz and 192.4 THz, and three SFPs with emission frequencies of 192.5 THz, 194.3 THz and 195.3 THz were used to test the wavelength dependency of the XGM.

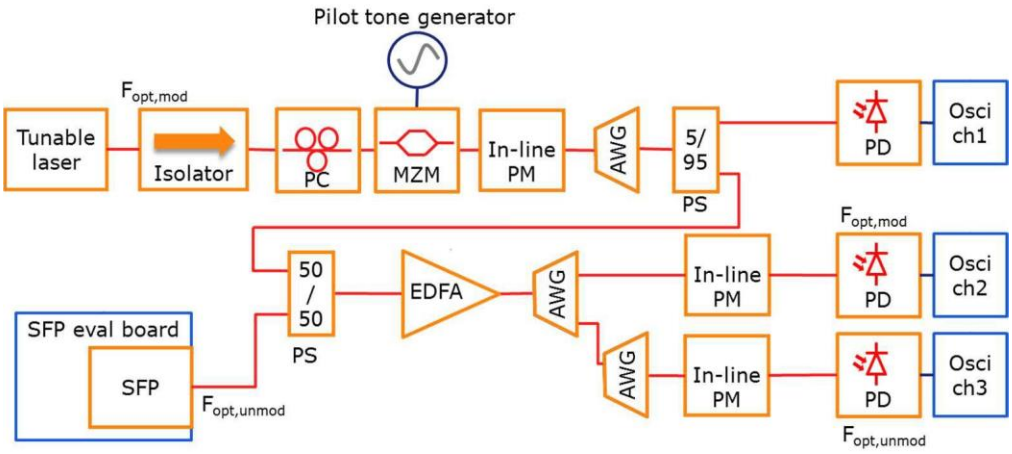

Figure 1 – Measurement setup.

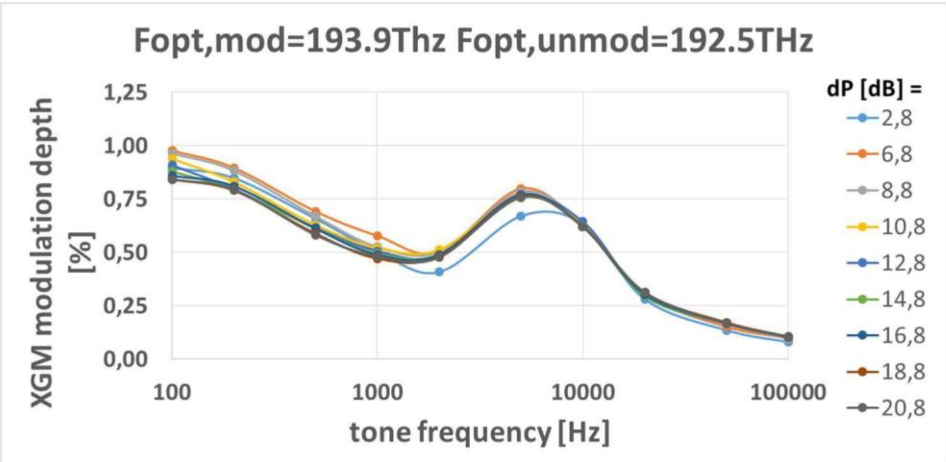

Figure 2 – Cross gain modulation vs. tone frequency for several power differences between tone channel (-8.2 dBm input power) and unmodulated probe channel at EDFA input

Figure 2 shows the XGM for several differential EDFA input powers dP, where dP[P_{tone}[dB]-P_{probe}[dB]]. The EDFA input power of the tone modulated signal was set to -8.2 dBm, which was the maximum power due to the measurement setup. The highest XGM in this measurement configuration was observed for power differences of 6.8 dB. However, over all measured power differences between 2.8 dB and 20.8 dB, the XGM changes by less than 0.15%. A local maximum can be observed at a tone frequency around 5 kHz. We assume this can be attributed to the interplay between EDFA gain control and carrier dynamics.

Next, we evaluated the wavelength dependency of the XGM. We modulated the tone on optical carrier frequencies of 193.9 THz, and 192.4 THz. The unmodulated probe channel, was placed at 192.5 THz, 194.3 THz, and 195.3 THz, respectively. The power difference between tone and probe channels was 6.8 dB. The corresponding XGM over tone frequencies is shown in Figure 3.

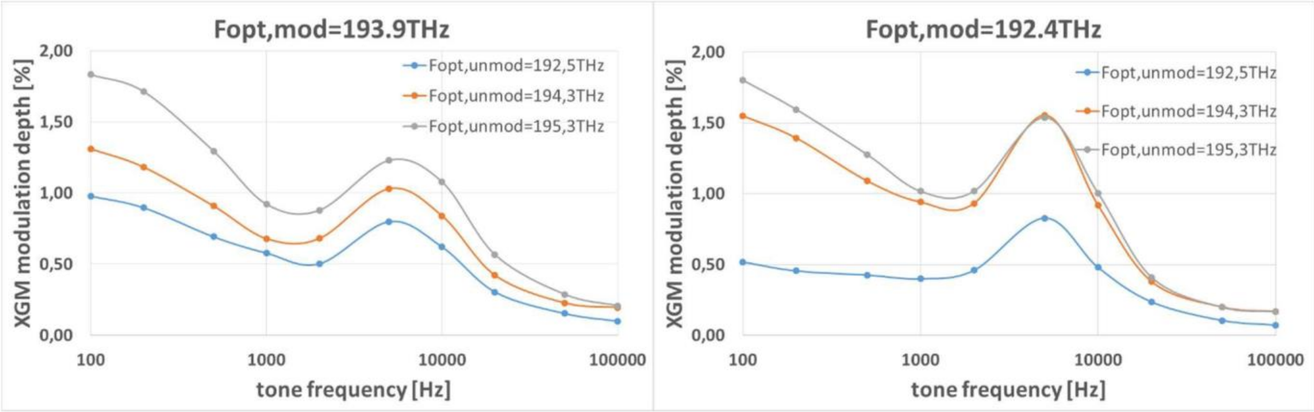

Figure 3 – Cross gain modulation vs. tone frequency for different unmodulated channel wavelengths and tone wavelength = 193.9 THz (left) and 192.4 THz (right)

It can be seen that the probe channel frequency of 192.5 THz suffers least from XGM for both tone carrier frequencies. In contrast, the probe channel frequency of 195.3 THz is most heavily impaired. However, for tone frequencies of 20 kHz the XGM is well below 1% for all measured cases. With higher tones the XGM can be reduced further, e.g. for 50 kHz tone frequency and up the measured XGM is smaller than 0.5%.

Summary

For amplified WDM-PON systems XGM can occur in an EDFA, when a slow pilot modulated signal is sent through the EDFA. The level of the probe power has almost no influence on the XGM. With higher modulation frequencies the XGM effect is reduced.

Proposal

Based on the measurements, we propose a minimum pilot tone frequency of 20 kHz for acceptable XGM lower than 1%, or 50 kHz for acceptable XGM lower than 0.5%.

The acceptable XGM is left for future discussion.

Appendix 8

Question(s):	Q6	**Meeting, date:**	Pisa, 20 – 22 June 2016
Study Group: 15	**Working Party:**	2	**Intended type of document** (R-C-TD): **WD06-03**
Source:	ADVA Optical Networking		
Title:	Measurements of the impact of pilot tones in G.metro		

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Introduction

During the recent meetings of Q.6, the frequency and modulation index of pilot tones have been discussed. In Contribution WD06-16 to the Turin meeting as well as in C-1713 to the February 2016 Plenary meeting, the impact of a (single frequency) pilot tone onto the data channel was investigated.

While the detailed penalty values reported differed between the Contributions, the general trend was that lower pilot tone frequencies resulted in lower power penalties of the data signal. As one reason for this behaviour, the high-pass characteristics of the receiver was mentioned, which suppresses low pilot tone frequencies in the data path. In a different Contribution to the current meeting, it is discussed that this suppression would only be effective for additive modulation of the pilot tone, while for multiplicative modulation some residual penalty would remain. In the present contribution we present further measurements on the impact of a pilot tone onto the data signal.

Discussion

An optical signal from an SFP transceiver was modulated with a PRBS-31 sequence at a data rate of 2.5 Gbps with an extinction ratio of approximately 8 dB. A pilot tone was added to the optical signal by external modulation using a Mach-Zehnder modulator ("multiplicative modulation"). The signal was then observed on an oscilloscope to monitor the modulation depth. Another part of the signal was received on the SFP receiver and the BER was measured as a function of the received power. The test setup is shown in Figure 1. The frequency of the pilot tone as well as the modulation depth was varied. Alternative to the 2.5 Gbps SFP transceiver, an SFP+ transceiver was used on the TX and RX sides for a data rate of 10 Gbps.

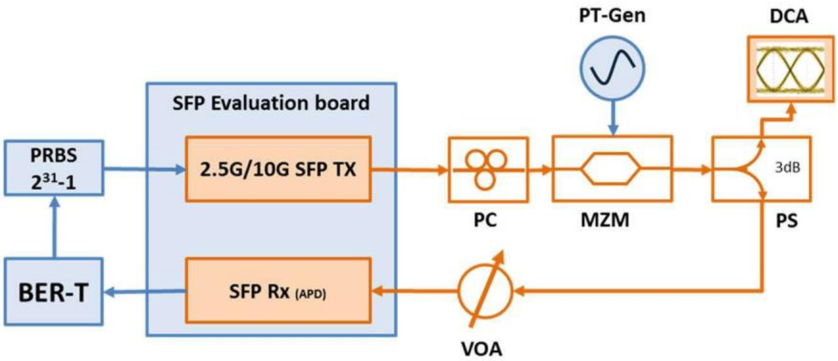

Figure 1: Test setup

For a BER of 10^{-9}, the sensitivity power penalty due to the tone modulation is plotted in Figure 2. No large difference between the 2.5 Gbps and 10 Gbps results can be observed.

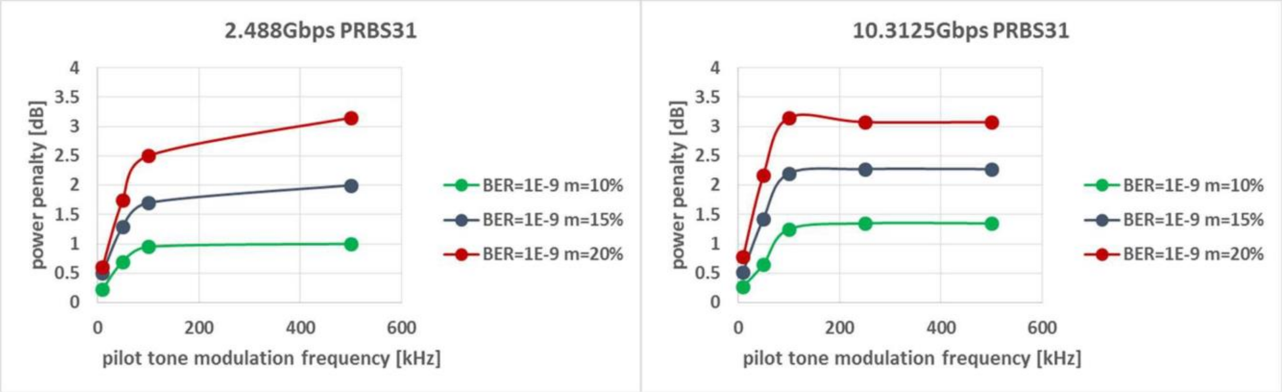

Figure 2: Sensitivity penalty on 2.5 and 10 Gbps signals as function of pilot tone frequency and modulation depth.

The increase of the penalty around a tone frequency of 50 kHz leads to the assumption that the low- frequency cutoff of both receivers is around this value. Table 1 shows the penalty values for frequencies far below and far above the cutoff for the 10 Gbps signal. Also included in Table 1 are results from Contributions WD06-16 (Turin) and C-1713 for the highest and lowest frequencies reported there, and for the modulation depths reported. While there are gaps in the Table, a comparison between the results can be made by interpolation. In all cases, the penalty is negligible for low frequencies and a low modulation index. There also appears to be a good match between the results measured here and in Contribution WD06-16, while the penalties reported in C-1713 appear to be about twice as large.

The difference between the reported results might be based on system parameters, which were not reported, like the signal extinction ratio or the pilot tone modulation method.

Table 1: Sensitivity penalty due to pilot tone modulation for low and high pilot tone frequencies

	1 kHz / 5 kHz			**500 kHz / 1000 kHz**		
	measured	**WD06-16**	**C-1713**	**measured**	**WD06-16**	**C-1713**
m=2%			0.0 dB			0.4 dB
m=3%		0.0 dB			0.2 dB	
m=5%						1.1 dB
m=6%		0.0 dB			0.6 dB	
m=10%	0.2 dB		0.5 dB	1.3 dB		3.1 dB
m=12%		0.2 dB			2.1 dB	
m=15%	0.5 dB			2.3 dB		
m=20%	0.8 dB		1.8 dB	3.1 dB		

Conclusion

Measurements were reported on the penalty introduced by a pilot tone onto a directly modulated high-speed data signal. For frequencies below the low-frequency cutoff of the receiver, a tone with a 10% modulation depth leads to a penalty of 0.2 dB, while for a frequency above the cutoff, the penalty for a 10% modulation index is approximately 1.3 dB. The results compare well to those reported in one previous Contribution, while they are larger by a factor of two in another Contribution.

Proposal

We propose to encourage further input on the impact of pilot tones on 2.5 Gbps and 10 Gbps data signals including details on the modulation method and signal parameter details.

Appendix 9

Question(s): Q6		**Meeting, date:**	Pisa, 20 – 22 June 2016
Study Group: 15	**Working Party:** 2	**Intended type of document** (R-C-TD):	**WD06-04**
Source:	ADVA Optical Networking		
Title:	Considerations on pilot tones in G.metro		

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Introduction

During the recent meetings of Q.6, the frequency and modulation index of pilot tones and of a message channel have been discussed. In a Correspondence Contribution, contained as Annex II in TD178/WP2 to the June 2015 Plenary meeting, and in Contribution WD06-22 to the October 2015 Turin interim meeting, the impact of an NRZ message channel onto the data channel was investigated. In WD06-16 to the Turin meeting as well as in C-1713 to the February 2016 Plenary, the impact of a (single frequency) pilot tone onto the data channel was investigated.

While the detailed penalty values reported differed between the Contributions, the general trend was that lower pilot tone frequencies resulted in lower power penalties of the data signal. On the other hand, discussions during the meeting as well as several Contributions, e.g. C-1528 to the February 2016 Plenary meeting, pointed out that a low pilot tone frequency would lead to cross gain modulation onto other channels, if an EDFA is used in the system. This effect is more pronounced for lower pilot tone frequencies. Therefore, a compromise between these two effects needs to be found. In this Contribution we theoretically analyse two different implementations to modulate the pilot tone onto the optical signal and discuss their implications for the resulting penalty.

Discussion

In WD06-16 to the Turin meeting, several modulation methods were shown to imprint the pilot tone onto the optical signal. Of those shown in Fig. 2 of that Contribution, two are displayed in Fig. 1a) and b).

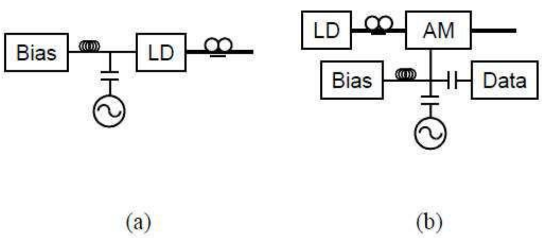

Fig. 1. Pilot tone generation and detection methods: (a) adding a small sinusoidal current to the laser's bias current, (b) dithering of the bias voltage of external modulator (Source: WD06-16 to Turin meeting)

In Fig. 1a), the pilot tone is added to the bias of a directly modulated laser resulting in a modulation of the laser power. The data *d(t)* are modulated onto this laser power in an external modulator, such that the resulting optical power can be expressed as

$$P(t) = \hat{P} \cdot (1 + m \cdot \cos 2\pi f_{tone} t) \cdot d(t).$$

Here, the pilot tone is introduced as a multiplier to the data, as shown in the top row of Figure 2, resulting in a convolution of the pilot tone spectrum with the data spectrum. The same result would be obtained by modulating the pilot tone onto the data modulated optical signal via an external modulator or a VOA.

For the implementation in Fig. 1b), the pilot tone is added to the bias of the external modulator, such that the resulting optical power can be expressed as

$$P(t) = \hat{P} \cdot \left[d(t) + \frac{m}{2} \cdot \cos 2\pi f_{tone} t \right].$$

Here, the pilot tone is added to the data, as shown in the bottom row of Figure 2, such that the pilot tone spectrum is linearly added to the data spectrum and only appears as an additional line at the pilot tone frequency. The coefficient to the cosine function is m/2 to yield the same pilot tone modulation depth as for the first method.

It has been pointed out in other contributions that a pilot tone frequency below the lower cut-off frequency of the data receiver would be desirable, as the receiver filter would in this case filter out the pilot tone frequency and the data signal remains undistorted. According to the considerations above, this is only true for the additive pilot tone modulation, as for the multiplicative modulation mixing products of the pilot tone and the data are present over the full data spectrum.

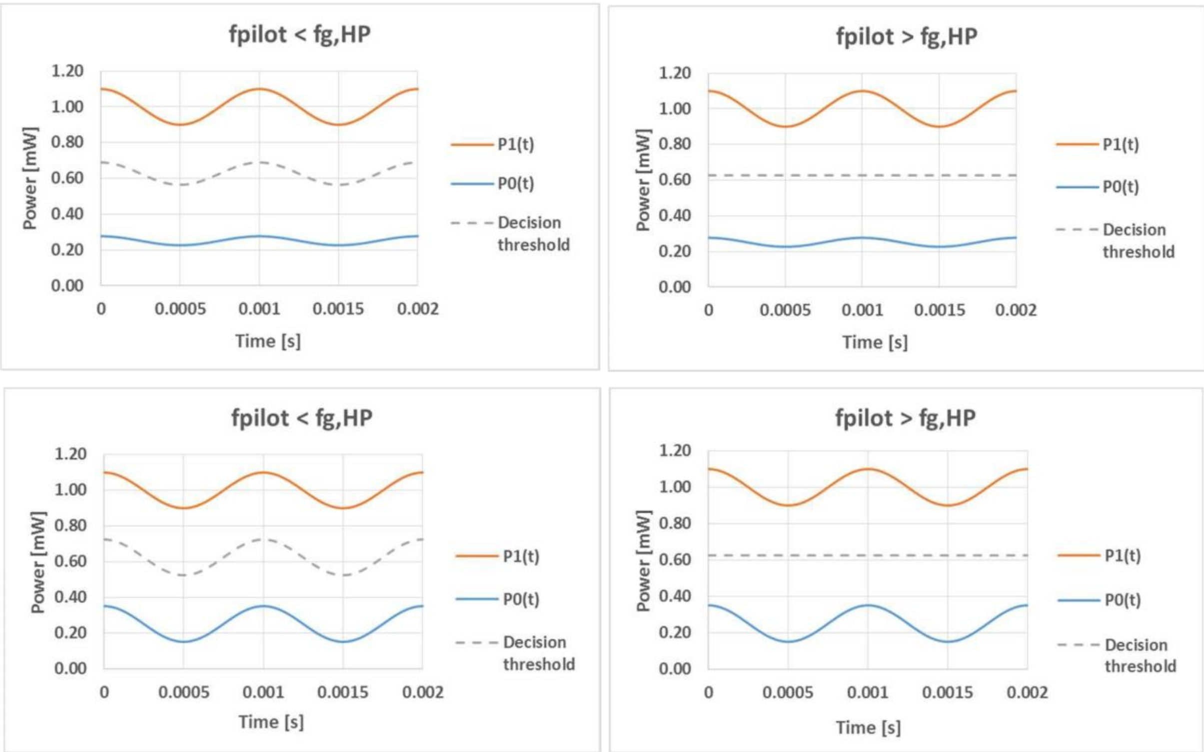

Figure 2: Time evolution of mark [P1(t)] and space [P0(t)] levels of the optical data signal and variation of the decision threshold. Top row: multiplicative modulation, bottom row: additive modulation; left column: pilot frequency below low frequency cut-off f_g (decision threshold follows average power), right column: pilot frequency above low-frequency cut-off f_g (decision threshold stays constant).

The different situations were modelled as shown in Figure 2. For a pilot tone frequency below the low-frequency cut-off of the receiver (left column in Fig. 2), the slowly varying average power is dropped at the filter, which is equivalent to the decision threshold following the average power of the data signal. For a higher pilot tone frequency (right column), the decision threshold does not follow the average power variations, leading to a non-optimum threshold.

Using a simple assumption of Gaussian noise and equal variances on mark and space rails, this model has been used to simulate the time variation of the BER of the optical signal for modulation depths of 10% and 20%. In addition, the extinction ratio of the data signal was varied.

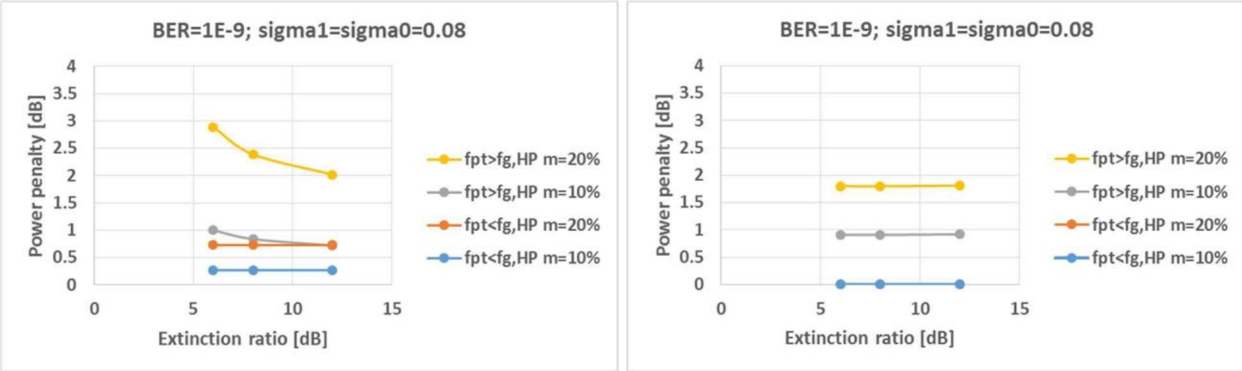

Figure 3: Power penalty of data signal as function of extinction ratio. Left: multiplicative tone modulation; right: additive tone modulation (orange and blue curves coincide).

Figure 3 shows the power penalty of the data signal for multiplicative (left) and additive (right) modulation. It can be seen that for low pilot tone frequencies and additive modulation the penalty is negligible, while for multiplicative modulation a penalty can be observed even for low pilot tone frequencies. For a large pilot tone frequency (and high extinction ratio of the data signal), the penalties of both modulation methods are comparable.

Conclusion

This Contribution demonstrated that the implementation of the pilot tone modulation onto the data channel affects the resulting penalty. A low pilot tone frequency only leads to negligible penalty, when additive modulation is used. For multiplicative modulation, the data signal extinction ratio also has an impact on the pilot tone penalty.

Appendix 9

INTERNATIONAL TELECOMMUNICATION UNION

COM 15 – C-1943 – E
September 2016 English only

TELECOMMUNICATION STANDARDIZATION SECTOR

STUDY PERIOD 2013-2016

Original: English

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Question(s): 6/15

STUDY GROUP 15 – CONTRIBUTION C-1943

Source: ADVA Optical Networking, Ericsson, British Telecom, China Unicom

Title: Parameters for pilot tones and message channel for G.metro

Introduction

During the Q.6 interim meeting in Pisa, pilot tone and message channel specifications for G.metro were discussed. The meeting report contained “The meeting further agreed to request complete specification proposals to the next SG15 Plenary Meeting addressing modulation depth, pilot tone frequency and pilot tone spacing, including considerations on the penalties that pilot tones and message channel would cause, noting that probably spending 1 dB on penalty due to the in-service pilot tone principle may be extravagant.” The meeting report also mentioned that “The meeting further agreed to specify a G.metro upstream message channel.”

The present contribution presents a specification proposal addressing pilot tone and message channel parameters. The specifications are based on the previous reported measurements of the impact of pilot tones and message channel on the data channel and vice versa,

Discussion

In a separate Contribution to the present meeting, the principles of operation of a G.metro system are described. The current Contribution is based on these tuning principles.

In a G.metro system, a message channel is envelope modulated onto the optical signals in both, downstream (head-end to tail-end) and upstream (tail-end to head-end) directions. It is proposed to use the same specification (data rate, modulation format, modulation depth) for the message

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channels in both directions. In order to avoid low frequency contents in this message channel and to alleviate implementation by supporting clock recovery, Manchester coding according to IEEE

802.3-2012, Sect. 7.3.11 is proposed for the message channel.

Various measurements have been reported in previous Contributions on the impact of the message channel modulation on the optical signal and on the impact of the optical signal modulation resulting in a minimum modulation depth for the message channel. For a data rate of 50 kbps in the message channel to achieve a bit error rate of the message channel of less than 10^{-6}, a modulation depth of 12% is required. The penalty on the optical data channel is 0.5 - 1dB for a modulation depth of 15%. Therefore, the range of modulation depth of 12% - 15% is proposed.

To distinguish separate wavelengths at the head-end during tuning and during operation, each tail- end to head-end optical channel is envelope modulated by a pilot tone with a distinct frequency. It has been discussed in several Contributions that a minimum pilot tone frequency between 20 kHz and 50 kHz is required to permit the use of an optical amplifier at the head end and to avoid cross- gain modulation. On the other hand, previous Contributions pointed to a reduced impact of the tone modulation on the data channel for modulation frequencies below approximately 50 kHz.

In the principles of operation, it is explained that pilot tone and message channel are not simultaneously in operation. In fact, simultaneous modulation of both would lead to a large impact on the data channel. One implementation option for the pilot tone would be the use of a periodic rectangular signal at the pilot tone frequency. As an example, a constant bit signal, Manchester encoded, would lead to a fundamental frequency at the data rate. By adapting the clock rate different tone frequencies can be achieved.

To support such an implementation, the pilot tone frequency range should be limited, preferably in a range +/- 5% around the standard data rate. With a central tone frequency of 50 kHz, the proposed tone frequency range is between 47.5 and 52.5 kHz. With a tone frequency spacing of 50 Hz, 101 distinct tones can be generated. The acquisition of the tones at the head end by filtering (e.g. FFT) takes approximately three to five times the inverse of the frequency spacing, corresponding to 60 - 100 ms. 101 tones are sufficient to support a system with 80 channels. For lower channel count, a reduced subset of these tones can be used with increased frequency spacing (100 Hz for 40 channels, 200 Hz for 20 channels). This enables a faster tone acquisition at the head end.

The tone modulation depth can be derived from the message channel modulation depth. For rectangular modulation, the fundamental frequency modulation depth is approximately 1.27 times the modulation depth of the rectangular signal. However, the modulation depth of the pilot tone is defined differently than the message channel modulation depth in the current draft of G.metro. A maximum message channel modulation depth of 15% corresponds to a maximum pilot tone modulation depth of 8.1%. To enable different tone modulation implementations, the range of the tone modulation depth should be sufficiently large.

Proposal

We propose the following parameter values Pilot tone parameters (tail-end to head-end):

Parameter	Units	value
Interface at point SS		
Maximum modulation depth of pilot tone during operation	%	8
Minimum modulation depth of pilot tone during operation	%	5
Minimum modulation depth of pilot tone during tuning	%	40
Maximum modulation frequency of pilot tone	Hz	52500
Minimum modulation frequency of pilot tone	Hz	47500
Minimum frequency spacing of pilot tones	Hz	50

Message channel parameters (tail-end to head-end and head-end to tail-end):

Parameter	Units	value
Data rate of message channel	kbps	50
Modulation format of message channel		RZ, Manchester coded
Maximum modulation depth of message channel	%	15
Minimum modulation depth of message channel	%	12

Appendix 10

INTERNATIONAL TELECOMMUNICATION UNION

TELECOMMUNICATION STANDARDIZATION SECTOR

STUDY PERIOD 2013-2016

COM 15 – C 1608– E

15 Feb-26 Feb, 2016

English only

Original: English

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Question(s): 6/15

STUDY GROUP 15 – CONTRIBUTION 1608

Source: China Unicom, Ericsson, Finisar, Huawei, ZTE, ADVA

Title: Application code proposal in G.metro

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Background

During the Turin interim meeting, the wavelength plan was discussed based on the WD06-17 (Finisar, China Unicom). The report (TD 246 (GEN)) stated that:

> *…the meeting agreed that further inputs to the next meeting were required to progress towards Q6 being able to take decisions on G.metro channel spacings and wavelength bands…*
>
> *…Contributions were invited on this topic of G.metro channel spacings, wavelength bands and number of channels.*

In the contribution, considerations on the above topics are discussed.

Discussion

In the scope of draft G.metro, the system capacity is up to 80 bidirectional channels, and channel spacing is TBD.

After the Turin meeting, discussions were carried out on the progress of G.metro with main optical device and equipment vendors, and the tunable laser was recognized as the most important topic.

C band tunable lasers have some cost advantage compared to L band lasers due to the larger deployment amount.

Different techniques were discussed to achieve the tunability at a low cost: an output of the discussion is that this probably requires to target a tunability range lower than the full C band.

On the other hand, in one the most important applications of G.metro, which is mobile fronthaul in 3G/LTE, the wavelengths counts is not fixed and depends on the wireless network configuration (RRU co-location and cascading, carrier aggregation, and so on).

For such reasons it would be convenient to distinguish three application categories, with decreasing cost:

1) A 80 channels system with 50 GHz channel spacing and C band wavelengths for TEE to HEE signals and L band wavelengths for HEE to TEE signals.

2) A 40 channels system that could be implemented in two ways 2a) Only

C band wavelengths with 50 GHz channel spacing;

2b) C and L band wavelengths with 100GHz channel spacing and L band wavelengths for HEE to TEE signals, and C band wavelength for TEE to HEE signals.

3) A 20 channels system in C band with 100GHz channel spacing. Application

codes could be generated accordingly.

Proposal

The wide deployment of G.metro depends on the low cost of optical transceivers, especially in early installations. Therefore, application codes with low number of wavelengths are proposed.

Appendix 11

INTERNATIONAL TELECOMMUNICATION UNION

TELECOMMUNICATION STANDARDIZATION SECTOR

STUDY PERIOD 2013-2016

COM 15 – C 2000 – E

September 2016

English only

Original: English

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Question(s):	06/15

STUDY GROUP 15 − CONTRIBUTION 2000

Source:	Telefon AB - LM Ericsson, British Telecommunications plc, ADVA Optical Networking Ltd.
Title:	Wavelength Plan Proposal for G.metro

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Introduction

Discussing G.metro wavelength plan at the Interim Q 6/15 meeting in Pisa (20 – 22 June 2016), itwas agreed to investigate if filters with a minimum guard band in the range of 9 – 10 nm would provide workable solutions for separating downstream and upstream directions.

The meeting also agreed that in order to achieve lowest cost transmitters, C-band wavelengths would be preferable. It was also recognized that the boundaries of the C-band are not rigidly fixed and a limited amount of potentially more costly transmitters at the extended edges of the C-band could potentially still provide an overall attractive configuration.

Based on this, the authors of this contribution investigated with the help of optical filters manufacturers if a 45-degree edge filter in the C-band can be provided at acceptable cost and isolation > 15 dB.

Based on the positive outcome of this study, the following wavelength plan is proposed. Lower wavelengths are used in downstream for allowing the use of commercial EDFAs at the HEE.

Proposal

Based on the considerations above, we propose to adopt the following wavelength plan in G.metro.

#	THz	nm	
1	196	1529.55	
2	195.9	1530.33	
3	195.8	1531.12	
4	195.7	1531.90	
5	195.6	1532.68	
6	195.5	1533.47	
7	195.4	1534.25	
8	195.3	1535.04	
9	195.2	1535.82	
10	195.1	1536.61	DS
11	195	1537.40	
12	194.9	1538.19	
13	194.8	1538.98	
14	194.7	1539.77	
15	194.6	1540.56	
16	194.5	1541.35	
17	194.4	1542.14	
18	194.3	1542.94	
19	194.2	1543.73	
20	194.1	1544.53	
21	194	1545.32	
22	193.9	1546.12	
23	193.8	1546.92	
24	193.7	1547.72	
25	193.6	1548.51	
26	193.5	1549.32	GAP
27	193.4	1550.12	
28	193.3	1550.92	
29	193.2	1551.72	
30	193.1	1552.52	
31	193	1553.33	
32	192.9	1554.13	
33	192.8	1554.94	
34	192.7	1555.75	
35	192.6	1556.55	
36	192.5	1557.36	
37	192.4	1558.17	
38	192.3	1558.98	
39	192.2	1559.79	
40	192.1	1560.61	
41	192	1561.42	US
42	191.9	1562.23	
43	191.8	1563.05	
44	191.7	1563.86	

45	191.6	1564.68
46	191.5	1565.50
47	191.4	1566.31
48	191.3	1567.13
49	191.2	1567.95
50	191.1	1568.77
51	191	1569.59

Appendix 12

Question(s): 6 **Meeting, date:** Sunnyvale, 16 – 19 January 2017 **Study Group:** 15 **Working Party:**

Intended type of document **WD06-03** **Source:**

Telefon AB-LM Ericsson, ADVA, China Unicom, TIM, ZTE Corporation

Title: Proposed 10G application code for G.metro

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Introduction

During the meeting in Geneva, February 2016, Q6/15 agreed to add application codes with a target distance of up to 20km to the terms of reference for G.metro because it would cover the current high priority mobile front-haul application space.

During the following meeting in Geneva, September 2016, Q6/15 agreed a strawman proposal for a 20-channel bidirectional application following the wavelength plan proposed in C 1979, on the basis of a 5 nm guard band.

Proposal

This contribution proposes to include in G.metro a 10 Gbit/s application code in line with previous agreements on distance and number of channels.

Parameters are also proposed for the codes.

According to the nomenclature for G.metro application codes (ADcW-y-tz , Clause 5.3), the proposed code will be identified by:

- c=100
- A letter (tbd) replacing W and identifying a distance of 20 km
- y=2
- t=D

- z=2.

Since CPRI is one of the most important client signals carried by G.metro optical channels and it has stringent requirements as regards the difference of propagation delay between the downstream and upstream directions, it is also proposed that, for each bidirectional optical channel, the difference between HE-TE and TE-HE central frequencies is kept constant and set at the minimum value compatible with the application code central frequency plan. Hence, for the proposed code, the HE-TE and TE-HE frequencies for the n-th optical channel (n=0 … 19), will be, respectively:

HE-TE: 194.1 + n□0.1
THz TE-HE: 191.5 +
n□0.1 THz

Application code parameters

Table 8-x: From HEE to TEE

Parameter	Units	
General information		
Minimum channel spacing	GHz	100
Bit rate/line coding of optical tributary signals	–	NRZ 10G
Maximum bit-error ratio	–	10^{-12}
Fibre type	–	G.652
Interface at point MPI-SM		
Maximum mean channel output power	dBm	+1
Minimum mean channel output power	dBm	-2
Maximum mean total output power	dBm	TBD
Minimum central frequency	THz	194.1
Maximum central frequency	THz	196
Maximum spectral excursion	GHz	±12.5
Minimum channel extinction ratio	dB	8.2
Eye mask	-	NRZ 10G 1550 nm region per G.959.1
Bit rate of message channel	kbit/s	50
Maximum modulation depth of message channel	%	8
Minimum modulation depth of message channel	%	6.5
Optical path from point MPI-SM to RS		
Maximum channel insertion loss	dB	14
Minimum channel insertion loss	dB	8
Maximum ripple	dB	2
Maximum chromatic dispersion	ps/nm	400
Minimum optical return loss at MPI-SM	dB	24
Maximum discrete reflectance between MPI-SM and RS	dB	-27
Maximum differential group delay	ps	11
Maximum inter-channel crosstalk at RS	dB	-16
Maximum loss difference between HE-to-TE and TE-to-HE di-	dB	Note 1
Interface at point RS		
Maximum mean channel input power	dBm	-7
Minimum mean channel input power	dBm	-16
Receiver sensitivity	dBm	-19
Maximum optical path penalty	dB	3
Maximum reflectance of receiver or optical network element	dB	-27

Note 1: this parameter is not needed if upper and lower limits are indicated for the link loss

Table 8-y: From TEE to HEE

Parameter	Units	
General information		
Minimum channel spacing	GHz	100
Bit rate/line coding of optical tributary signals	–	NRZ 10G
Maximum bit-error ratio	–	10^{-12}
Fibre type	–	G.652
Interface at point SS		
Maximum mean channel output power	dBm	+2
Minimum mean channel output power	dBm	-2
Minimum central frequency	THz	191.5
Maximum central frequency	THz	193.4
Maximum spectral excursion	GHz	±12.5
Minimum channel extinction ratio	dB	8.2
Eye mask	-	NRZ 10G 1550 nm region per G.959.1
Bit rate of message channel	kbit/s	50
Maximum modulation depth of message channel	%	8
Minimum modulation depth of message channel	%	6.5
Maximum modulation depth of pilot tone during operation	%	8
Minimum modulation depth of pilot tone during operation	%	5
Minimum modulation depth of pilot tone during tuning	%	40
Maximum frequency of pilot tone	Hz	52500
Minimum frequency of pilot tone	Hz	47500
Minimum frequency spacing of pilot tones	Hz	50
Maximum combined tolerance of Rx power measurement and Tx power setting at TEE (□)	dB	TBD
Optical path from point SS to MPI-RM		
Maximum channel insertion loss	dB	14
Minimum channel insertion loss	dB	8
Maximum ripple	dB	2
Maximum chromatic dispersion	ps/nm	400
Minimum optical return loss at SS	dB	24
Maximum discrete reflectance between between SS and MPI-	dB	-27
Maximum differential group delay	ps	11
Maximum loss difference between HE-to-TE and TE-to-HE di-	dB	Note 1
Interface at point MPI-RM		
Maximum mean channel input power	dBm	-6
Minimum mean channel input power	dBm	-16
Maximum mean total input power	dBm	TBD
Maximum channel power difference	dB	TBD
Minimum equivalent sensitivity	dBm	-19
Maximum optical path penalty	dB	3
Maximum reflectance of receiver or optical network element	dB	-27

Parameter	Units	
Maximum mean channel input power during tuning	dBm	TBD
Minimum mean channel input power during tuning	dBm	TBD

Appendix 13

INTERNATIONAL TELECOMMUNICATION UNION

TELECOMMUNICATION STANDARDIZATION SECTOR

STUDY PERIOD 2013-2016

COM 15 – C-1942 – E

September 2016

English only

Original: English

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Question(s): 6/15

STUDY GROUP 15 – CONTRIBUTION C-1942

Source: ADVA Optical Networking, Ericsson, British Telecom, China Unicom

Title: Appendix on Principles of Operation for G.metro

Introduction

In the WP2 report of the June 2015 Geneva Plenary meeting, discussion of Contribution C-1321 in Q6 contained the comment "After the discussion of C 1321 the meeting agreed that it would be necessary to generate an informative Appendix in G.metro to provide a tutorial on the principles of its operation."

The present Contribution presents wording that explains the general tuning concept of a G.metro TEE and that can be included as a "principles of operation" Appendix into G.metro.

Discussion

Principles of operation

Tail-end transmitters with interfaces specified in this Recommendation have the capability to automatically adapt their DWDM channel frequency to the optical demultiplexer/optical multiplexer (OD/OM) or optical add-drop multiplexer (OADM) port to which they are connected. To enable a low-cost implementation of these devices, wavelength control for all tail-end transmitters can be centralized in the head-end with control information sent from the head-end to the tail-end via a message channel. This message channel is transmitted by envelope modulation of the optical signal transmitted from the head-end to the tail-end.

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Channel start up

On each idle wavelength channel, the head-end equipment periodically (approx. every one to ten seconds) transmits, over the message channel, the message types TOM1, TOM2, TOM3, and TOM4 in order to inform the tail-end equipment connected to the corresponding OADM filter port of the wavelength to use for upstream transmission, the pilot tone frequency to use as a wavelength label, and of the transmit power during tuning. The target transmit power is derived from the
received power level at the tail-end and the power information in message type TOM3, as described in Clause 10.2.

Upon turn-on of a tail-end equipment, the receiver listens to the message channel. Upon having received a full configuration set (i.e. message types TOM1, TOM2, and TOM3) and the start sweep message (TOM4), the transmitter sweeps its wavelength without data modulation, but with a tone modulation defined by the pilot tone frequency in message type TOM2. If the tunable transmitter laser has the ability to tune exactly or close to the transmit wavelength communicated in TOM1, it can do so (and reduce the turn-up time), otherwise the tunable laser sweeps over the full allowed transmit wavelength range.

When the head-end equipment receives an optical power at the expected wavelength and modulated by the expected pilot tone, it transmits a message type TOM6 to inform the tail end of having reached the target wavelength. The tail-end now increases the transmit power to the operating range.

The head-end determines the frequency deviation from the target frequency and sends TOM8 to the tail-end to correct the transmit frequency. When the target frequency is within the allowed deviation, the tail-end sends TOM9 to initiate data transmission. The tail-end then initiates data modulation and switches to upstream message channel modulation with the operating modulation depth.

Channel maintenance

During most of the operating time, an upstream message channel is active by envelope modulation of the optical signal from the tail-end to the head-end. This upstream message channel transmits OAM information from the TEE to the HEE. For wavelength stability control and fine tuning, the head-end sends, over the downstream message channel, in intervals of approximately 10 seconds, a TOM10 message to each TEE. Upon receiving this message, the tail-end turns off the message channel data modulation and modulates the assigned pilot tone onto the optical signal.

The head-end determines, based on the received optical signals carrying pilot tone channel labels, the wave-length deviation of each channel and sends the tuning information (TOM8 and potentially TOM7) to each active tail-end. The measurement time of the wavelength deviation depends, among others, on the separation between allowed pilot tone frequencies. For appropriate filtering, approximately three to five times the inverse of the minimum frequency separation is required (60 – 100 ms for a 50 Hz pilot tone frequency spacing).

After wavelength correction of the tail-end lasers, based on the tuning information (TOM8), the head-end can initiate a further wavelength control measurement. The idle time between measurements needs to take into account the message channel frame duration, the optical roundtrip time and the tunable laser control time in the TEE.

After terminating one or multiple tuning cycles, the head-end sends a TOM11 message to each TEE. Upon receiving TOM11, the tail-end resumes the upstream message channel modulation.

Proposal

1. We propose to use the text above as an Appendix I of G.metro to describe the principles of operation.
2. We further propose to add message types TOM=10 and TOM=11 to Table 10-1 as follows:

TOM value	Message type	Message content
10	Send pilot tone	
11	Terminate sending pilot tone	

Appendix 14

Question(s):	Q6	**Meeting, date:**	Sunnyvale, 16 – 19 January 2017
Study Group:	15 **Working Party:** 2	**Intended type of document** (R-C-TD): WD06-05	
Source:	ADVA Optical Networking, Ericsson		
Title:	Editorial items on G.metro		
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Please don’t change the structure of this table, just insert the necessary information.

Introduction

Reading through the G.metro draft, a few items appear to be open, which can be solved partly by editorial work. In this Contribution, we address some of the open questions and propose solutions.

Discussion

1. In the current draft of G.metro, “tail end control channel” and “message channel” are both used as designator for the HEE-to-TEE message channel. After agreement in the previous meetings to also include a TEE-to-HEE message channel, a naming for this channel needs to be found and appropriate parameters need to be introduced. As all parameter definitions refer to “message channel”, it might be beneficial to have this name as common part in both names.
2. It is not clear if the Equation in Clause 7.2.11 refers to linear or logarithmic power values. This need to be explained.
3. In Clause 10.1.1, the TECC is described twice (2nd and 4th paragraph).
4. The title of Clause 10.2 currently reads “Power output power setting during tuning”. The word “power” is repeated.
5. In Clause 7, the definitions of several parameters need to be included.
6. There might be additional open items which have not been identified so far.

Proposals

1. It is proposed to rename the “tail end control channel” as “head-end to tail-end message channel”, HTMC, and to introduce the naming “tail-end to head-end message channel”, THMC, for the upstream message channel. It is further proposed to introduce these two abbreviations in Clause 4 and to include references to bit rate and minimum and maximum modulation depth of the message channel in Table 7-1 also for the TEE to HEE direction.
2. It is proposed to modify the last sentence in 7.2.11 to read “Where |.| indicates the absolute value, and the power values are given in dBm”.
3. It is proposed to revise 10.1.1 to consolidate the description of the TECC / HTMC.
4. It is proposed to change the title of 10.2 by deleting the first word “power”.
5. For those currently undefined parameters in Clause 7, which are defined in other Recommendations, it is proposed to include references to those Recommendations. It is proposed to schedule an Editing session for this.
6. The group might request the Editors of G.metro to identify further open items to start the discussion on those items and to permit a timely agreement on the Recommendation.

Appendix 15

Question(s):	Q6	**Meeting, date:**	Sunnyvale, 16 – 19 January 2017
Study Group: 15	**Working Party:**	2 **Intended type of document**:	**WD06-04R1**
Source:	ADVA, Ericsson, British Telecom, Telecom Italia, ZTE		
Title:	Various items on G.metro		

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Introduction

Recent discussions and Correspondence on G.metro have centered on message channel and pilot tone questions as well as channel frequency plans. However, reading through the G.metro draft, a few more questions appear to be open, which require agreement. In this Contribution, we address a few of the open questions and propose solutions.

Discussion

1. In the Scope of the G.metro draft, the use of amplifiers in the black link is still to be defined. The objective of G.metro is to provide a low-cost connection between a head-end and multiple tail ends. To reduce equipment and operating cost, the black link should remain passive. Therefore, it is proposed to not include amplifiers in the black link in the first version of G.metro.
2. In the Scope of the G.metro draft, an Editorial note mentions the potential inclusion of additional architectures like "horseshoes" or "folded-linear". As protection schemes are not a topic for Q.6, G.metro should be based on a simple HEE-TEE structure. Therefore, it is proposed to not include horseshoe architectures in the first version of G.metro. A revision of G.metro might include them at a later stage.
3. During the September 2016 Geneva meeting, the meeting agreed on a strawman proposal for a 20-channel wavelength plan, based on the proposal in C-1979 to that meeting. This plan uses the frequencies 191.5 THz – 193.4 THz for the TEE-to-HEE direction and 194.1 THz – 196.0 THz for the HEE-to-TEE direction. A 40-channel wavelength plan was not discussed, yet. To be able to re-use components on HEE and TEE sides, a 40-channel plan should use the same wavelength ranges as the 20-channel plan with the channels on a 50-GHz grid.
4. Currently, the pairing between HEE-to-TEE and TEE-to-HEE channels is undefined. To enable the transmission of timing sensitive signals (e.g. CPRI) over a G.metro system, the differential delay between both directions should be minimized. This is achieved, when the wavelength separation between the channels in both directions is approximately constant. If the lowest TEE-to-HEE wavelength is paired with the lowest HEE-to-TEE wavelength etc., the wavelength separation between the directions is 20.6 to 21.0 nm. For a 20-km link over G.652D fiber, this yields a maximum propagation delay difference between the directions of 20 km x 21 nm x 18.9 ps/(nm km) = 7.94 ns.
5. The measurement of the minimum and maximum modulation depth of the pilot tone, as specified in Clause 7.2.9 is indefinite. The filter bandwidth to measure the maximum modulation depth should include modulation harmonics, which can also lead to signal impairments. The consideration of up to the 5th harmonic of the tone frequency includes all high-power (down to ~ -15 dB from the fundamental) harmonics for the worst case of a rectangular modulation. Any spurious frequencies, which are not harmonics of the fundamental frequency, are also included.
6. Periodic wavelength correction of the TEE transmitters (state S4 in the TEE state diagram in Figure 10-2 of the draft) is initiated by the HEE. To decide on the proper timing, the stability of the TEE lasers without feedback needs to be specified. This will also determine the timer settings. The wavelength stability should be defined by a new parameter. Initial measurements of a few different tunable lasers showed a maximum drift rate of 1 GHz over a time of 5 hours. Based on this, a new parameter for the maximum laser drift over one hour could be defined. A value of 1 GHz would be supported by the tested lasers. To avoid a laser drift of more than 2 GHz, the wavelength correction procedure (state S4) should be run at least every hour.
7. In the draft of G.metro, a TEE state machine is provided in Figure 10-2, containing four different timers for different states. The state machine is reset to state S0 upon expiration of the respective timer without having received a message from the HEE. The proper initial value setting of each timer should depend on different parameters of the system. More details about the function of the timer should be described. Furthermore, a timer should be provided that controls the time between wavelength correction actions (state S4). This can be achieved by adding a timer T5, which is only reset by entering the state S4 and which, upon expiration, initiates a transition from S5 to S0.

Proposals

1. It is proposed to not include amplifiers in the black link in the first version of G.metro and include a corresponding wording in the Scope of G.metro.
2. It is proposed to not include horseshoe architectures in the first version of G.metro,to delete the corresponding Editor's note in the Scope, and to include wording in the Scope that the inclusion of these architectures in a revision are for further study.

3. It is proposed to use for a bidirectional 40-channel wavelength plan a 50-GHz channel spacing with the frequencies 191.45 THz – 193.4 THz for the TEE-to-HEE direction and 194.05 – 196.0 THz for the HEE-to-TEE direction.
4. It is proposed to pair the channel frequencies for HEE-to-TEE and TEE-to-HEE directions, such that in a 20-channel bidirectional system for channel number n (n = 0…19), the frequency 191.5 + n x 0.1 THz is used for the TEE-to-HEE direction and 194.1 + n x 0.1 THz for the HEE-to-TEE direction. For a 40-channel system, the respective frequencies are 191.45 + n x 0.05 THz for the TEE-to-HEE direction and 194.05 + n x 0.05 THz for the HEE-to-TEE direction (n = 0…39).
5. It is proposed to expand the Note under Clause 7.2.9 as follows:

Note: the cut-off frequency of the low pass filter is different for maximum and minimum modulation depth. To measure the modulation depth against the minimum modulation depth parameter value, only the fundamental frequency of the tone is considered and the low pass filter cut-off frequency is slightly above that frequency. To measure the modulation depth against the maximum modulation depth parameter value, also harmonics of the pilot tone, which might lead to impairments on the optical tributary signal, are considered and the low pass filter cut-off frequency is slightly above five times the maximum frequency of the pilot tone.

6. It is proposed to introduce a parameter for the "maximum laser frequency drift over one hour of the TEE transmitter", which defines the maximum center frequency deviation from the initial value over a time of one hour. We propose a value of 1 GHz for the first application code.
7. a. It is proposed to add the following wording to Clause 10.1.3: "Timers T0 – T4 are used to avoid the TEE operating for an excessive amount of time without receiving control messages from the HEE. The timers T0-T4 are reset, when the TEE enters a respective state according to Figure 10-2 (S1 for T1, S2 for T2, S3 for T3, S4 or S5 for T4) or receives a message with any message type while in the respective state. The timer is reset to the start value, and counts down with time."

   b. It is further proposed to add a timer T5 that, upon expiration, causes a transition from state S5 to S0. This timer is reset, when state S4 is entered.

   c. It is further proposed to develop wording on how the timer start value should be chosen, depending on other system parameters. This should include that the timer T5 start value should depend on the maximum laser frequency drift without control. According to proposal 6 above, a start value of 1 or 2 hours could be chosen.