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Foreword

This ETSI Standard (ES) has been produced by ETSI Technical Committee Environmental Engineering (EE).

Introduction

The present document defines the metric, methodology and the test conditions to evaluate the Equipment Energy Efficiency Ratio (EEER) of Transport equipments. Energy efficiency is, in fact, becoming a relevant issue in Telecommunication area, and increasing efficiency is a commitment in the Transport segment of the network too.

The present document adopts a "two steps" approach, with a system "description" (high level description of the application, e.g. general characteristics like whole capacity, client and network interfaces with type and number, optical features like gain, reach, noise figurer, etc.) and a system "configuration" (one of the possible configuration/implementation of a given system description), as done in ATIS standard on Transport equipment (see ATIS-0600015.02.2009 [i.2]).

The EEER is calculated with the same formula of the ATIS standard [i.2] but with the measurement conditions defined in the present document. The EEER is evaluated according to the present document for a given fixed or flexible configuration.

1 Scope

The present document defines the metric, methodology and the test conditions to evaluate the Equipment Energy Efficiency Ratio (EEER) of Transport equipments. The Transport equipments covered will include all the transmission equipment connected to the network by means of wired medium (i.e. copper or fiber), typically running at the network OSI level 1. The present document also covers the equipment running at the network OSI level 2 (e.g. MPLS-TP) that are not included in the ETSI standard on "Measurement Methods for Energy Efficiency of Router and Switch Equipment" (the same approach is followed by ATIS standard on Transport equipment, see ATIS-0600015.02.2009 [i.2]).

The present document is not applicable at node/network level but only at equipment level.

Examples of typical wired Transport equipments covered by the present document are switches or crosses connects (SDH, OTN) and add/drop multiplexers (DWDM). The present document covers also simpler systems as multiplexers/demultiplexers (DWDM), optical amplifiers, transponders.

Transport equipments that exploit radio or wireless interfaces (e.g. free space optics and point to point wireless/microwave transport) are out of the scope of the present document. It is highlighted that ATIS standard for transport equipment [i.2] includes wireless transport equipment.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

[1] ATIS-0600015.2009: "Energy Efficiency for Telecommunication Equipment: Methodology for Measurement and Reporting - General Requirements", February, 2009.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI EN 300 132-2: "Environmental Engineering (EE); Power supply interface at the input to telecommunications and datacom (ICT) equipment; Part 2: Operated by -48 V direct current (dc)".

[i.2] ATIS-0600015.02.2009: "Energy Efficiency for Telecommunication Equipment: Methodology for Measurement and Reporting - Transport Requirements", February, 2009.

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

Add Drop Multiplexer (ADM): network element that provides access to all, or some subset of the constituent signals contained within an STM-N signal (in SDH) or in an OTU-k signal (in OTN) the ODUk and ODUflex can be accessed in a similar way in the OTU. The constituent signals are added to (inserted), and/or dropped from (extracted) the STM-N or OTU-k in OTN the OTU signal, as it passes through the ADM

card: part of an equipment implementing a given functionality (i.e. data interfaces, switching, control). Line cards with data interfaces can have more ports

cross connect: apparatus enabling the termination of cable elements and their cross-connection, primarily by means of patch cords or jumpers

Dense WDM (DWDM): WDM system characterised by an high density of optical signals on a given bandwidth

Digital Cross Connect (DXC): apparatus enabling the termination and the cross connection of signals (including multiplexing and demultiplexing of signals according to a certain hierarchy) at electrical level

Forward Error Correction (FEC): technique which consists of transmitting the data in an encoded form such that the redundancy added by the coding allows the decoding to detect and correct errors (e.g. in actual application the FEC is used to extend the distance of transmission of optical signal)

hot-standby: state in which redundancy cards are not in use (stand-by), but are ready to work immediately when needed

multi service protocol platform: transport equipment that is able to terminate and switch signals with more than one protocol transport technology framing

Optical Add Drop Multiplexer (OADM): wavelength selective branching device (used in WDM transmission systems) having a wavelength "drop" function in which one or more optical signals can be transferred from an input port to either an output port or drop port(s) depending on the wavelength of the signal and also having a wavelength "add" function in which optical signals presented to the add port(s) are also transferred to the output port (in OTN these are the OCh signals)

optical amplifier: devices or subsystems in which optical signals can be amplified by means of the stimulated emission taking place in a suitable active medium

Optical Cross Connect (OXC): apparatus enabling the termination and the cross connection of signal at optical level

(Optical) regenerator: transmitter-receiver combination device that performs the regeneration of an input optical signal by means of conversion in the electrical domain and applying an FEC

(Optical) transponder: transmitter-receiver combination with or without pulse shaping and retiming that converts an optical signal into another optical signal by a conversion into the electrical domain

passive (chromatic) dispersion compensator: passive component used to compensate the chromatic dispersion of an optical path

port: part of a card in which a cable (typically a fiber) or a transceiver can be plugged to interconnect an equipment to another compatible one

rack: free-standing or fixed structure for housing electrical and/or electronic and/or optical equipment, usually organized in a number of slots

Reconfigurable OADM (ROADM): flexibly reconfigurable by means of control or management commands on the node

slot: part of a rack for housing a card

switch: node that is capable of switching slots or packets/frames from one interface to another

transcesiver: combination of transmitter and receiver in a single package that is pluggable on a port of a line card with compatible characteristics (in terms of rate and framing, for instance 40 GbEthernet)

transport equipment: transport equipment enables information transfer capabilities between originating and terminating access service facilities

Wavelength Division Multiplexing (WDM): bidirectional multiplexing using different optical wavelength for up and downstream signals

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AC	Alternating Current
ATIS	Alliance for Telecommunications Industry Solutions
CBR	Constant Bit Rate signal
CWDM	Coarse Wavelength Division Multiplexing
DWDM	Dense Wavelength Division Multiplexing
DXC	Digital Cross-Connect
EE	Energy Efficiency
EEER	Equipment Energy Efficiency Ratio
FEC	Forward Error Correction
GMPLS	Generalized Multi-Protocol Label Switching
IMIX	Internet MIX
MPLS	Multi Protocol Label Switching
MPLS-TP	MPLS- Transport Profile
OA	Optical Amplifier
OCh	Optical Channel
ODU	Optical Data Unit
OLA	Optical Line Amplifier
OSI	Open Systems Interconnection
OTN	Optical Transport Network
OTS	Optical Transmission Section
OTU	Optica Transport Unit
OXC	Optical Cross Connect
PT	Packet Transport
ROADM	Reconfigurable Optical Add/Drop Multiplexer
SDH	Synchronous Digital Hierarchy
SFP	Small Form-factor Pluggable
STM	Synchronous Transport Module
TEER	Telecommunications Energy Efficiency Ratio
VBR	Variable Bit Rate
WDM	Wavelength Division Multiplexing
WSON	Wavelength Switched Optical Networks
WSS	Wavelength Selective Switch
WXC	Wavelength Cross-Connect
XFP	10 Gigabit Small Form Factor Pluggable Module

4 System Description

This clause contains the rules to describe a Transport system.

The System Description provides a specification in terms of qualitative (i.e. which type of equipment) and quantitative (i.e. how many ports of a certain rate) features, without any details about practical/physical implementation (e.g. in terms of cards arranged on a rack) and number of racks part of a single node.

It is suggested that the system description will be "implementation independent" and it shall be provided following the framework reported in clause 4.2.

The present document covers the following non exhaustive list of Transport equipment types:

- Optical Amplifier, WDM Power Equalizer;
- WDM mux/demux (terminal for DWDM, CWDM);
- OADM, ROADM, OXC;
- SONET/SDH ADM, DXC;
- OTN ADM, DXC;
- Packet Transport switch (MPLS-TP);
- Multi Service Transport Platform (many combinations, i.e. SDH and Ethernet, OTN and Ethernet, OTN and MPLS-TP, etc.);
- OTN-WDM platform (integrated DXC and ROADM node).

And other Transport equipments as defined in the scope of the present document.

4.1 Transport System categories

The following three Transport system categories are defined in order to properly provide the System Description.

Category A: terminal and signal conditioning equipment

This category, as regards signal handling by the system, is characterized by two sides: side a and side b (sometimes with the meaning of Input and Output) as depicted in figure 1. The signals may be uni- or bi- directionally handled on each of the two sides of the equipment.

The following equipments are examples of the category A:

- line OA;
- power equalizer;
- WDM terminal (mux/demux).

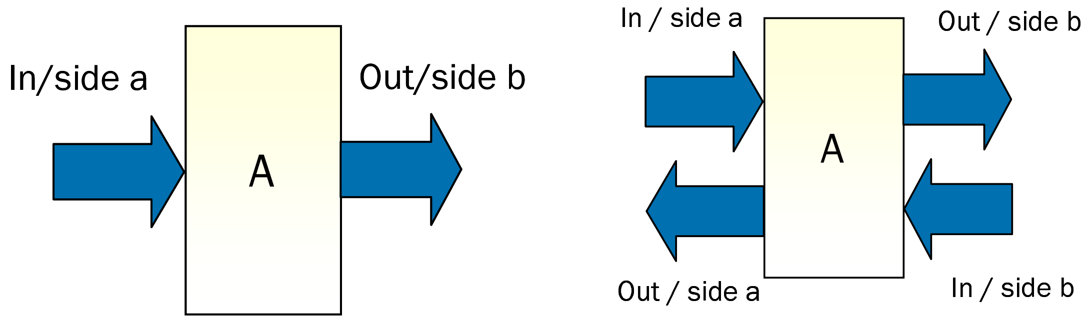

Figure 1: Schematic representation for Category A Transport equipment: unidirectional (on the left) or bidirectional (on the rigth)

Category B: switch and ADM without tributary add/drop ports

This category is characterized by switching or add/drop multiplexing functionalities and all the ports are used for network interconnection (none of the ports is used for tributary add/drop function). Equipment belonging to this category plays the role of pure transit equipment in a network.

The following equipment are examples of the category B:

- SDH switch or ADM;
- OTN switch or ADM;
- WDM ROADM;
- PT switch.

Figure 2 give a schematic representation of category B.

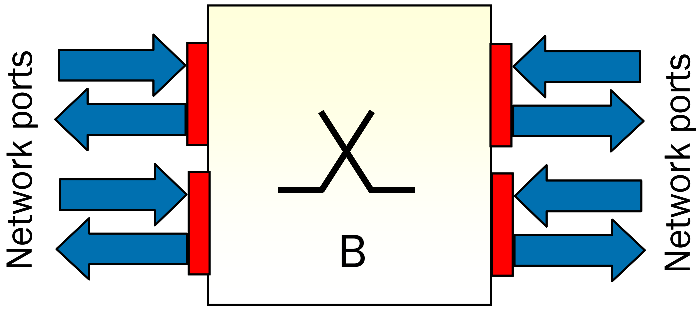

Figure 2: Schematic representation for Category B Transport equipment

Category C: switch and ADM with tributary add/drop ports

This category is characterized by switching or add/drop multiplexing functionalities and the ports are used both for network interconnection and for tributary add/drop function. Equipment belonging to this category plays the role of node in a network where part of the switched traffic is terminated towards network clients.

A list of examples of equipment for category C is the same as the one provided for category B, but in case of category C the equipment includes also tributary ports as depicted in figure 3.

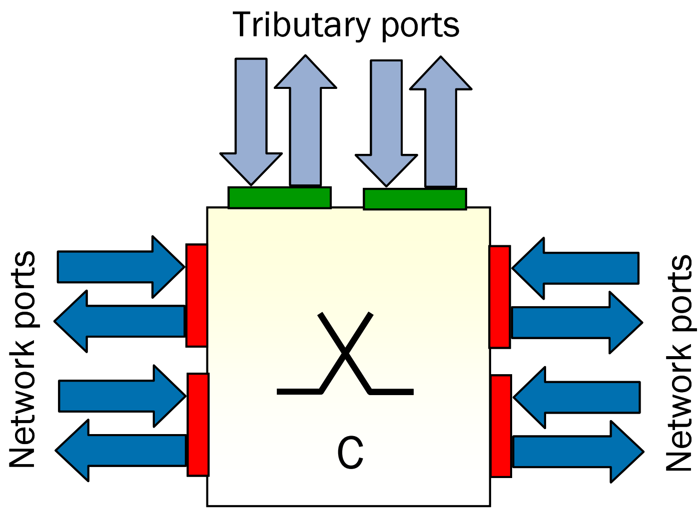

Figure 3: Schematic representation for Category C Transport equipment

4.2 System Description Framework

Each system shall be described according to the following framework:

a) **System Category** in accordance with the definitions of clause 4.1.

b) **Type of equipment** (i.e. for category A: OA, WDM terminal; for category B: switch, Add/Drop without tributary ports; for category C: switch, Add/Drop without tributary ports) with its **main high level characteristics** (e.g. for OA the Gain and the Noise Figure).

c) **System capacity** (when applicable, e.g. number of wavelengths for a Mux/demux DWDM terminal, number of degrees for a WSS ROADM, switch capacity [Gbit/s] for a DXC node, etc.).

d) **Data ports and interfaces** (eventually differentiated in tributary/client and line/network) with their main characteristics as single/combined signal, data rate, framing (STM, GbE, OTU, etc.), electrical/optical, technical requirements (modulation format, reach, type of port (XFP, SFP), (tunable or fixed), protection/resilience requirement (1 + 1, 1:N, other).

e) **Redundancy** (specify which functionality could be redundant, e.g. switch matrix).

f) **Other functionalities** (Management and/or Control Plane features including resilience capability, for instance restoration on the fly, Monitoring, etc.).

g) **Expansion requirement** (both in ports and capacity).

5 System Configuration

Given a System Description as specified in clause 4 a System Configuration is one of its possible implementations in terms of physical equipment.

Normally many System Configurations, satisfying a given System Description, are possible.

A configuration is normally based on a modular organization of the equipment in a rack/subracks or in a set of racks (i.e. master/slave hierarchy, where a master subtend several slaves).

For some particular applications (normally for the simpler systems) the system can be provided in a single box that incorporates all the necessary components and assures the fulfilment of all the required functionalities.

The common parts (as control module, fan modules, power supply modules and other service modules) shall be sufficient to support all the basic requirements (i.e. capacity and ports) specified in the System Description.

Additional items of common parts or the upgrade of the basic common parts to support expansion (specified in point g of clause 4.2) should be easily added to the system when they will be necessary in compliancy with the expansion requirements (capacity and ports).

A System Configuration obtained from the given System Description could also be specified by a Customer.

If a System Description is not available, a System Configuration shall be compliant with the following basic requirements:

- The level of utilization of the system, in relation with the nominal (maximum) traffic or bandwidth capacity, shall be at least 80 %.
- In case of category C equipment the percentage of bandwidth allocated to tributary ports shall be at least 20 % of the level of utilization of the system as defined in previous step 1.
- An example of configuration satisfying the requirements stated in step 1 and 2 is a transport switch of a maximum capacity of 1 Tbit/s that is used at 90 % (≥ 80 % in accordance to step 1): it shall have not less than 180 Gbit/s of bandwidth allocated to tributary ports (≥ 20 % in accordance to step 2). An allowed configuration would, therefore, be the following one: 700 Gbit/s of capacity on line ports and 200 Gbit/s of capacity on tributary ports. Other admitted configurations shall be in the following range: upper level of utilization (100 %) with 800 Gbit/s on line ports and 200 Gbit/s on tributary ports and lower level of utilization (80 %) with 640 Gbit/s on line ports and 160 Gbit/s on tributary ports.
- When a system can host many type of cards, one card of each type shall be present in the system configuration (when applicable) and/or several system configurations may apply in order to cover all card variants.
- Redundancy cards shall be provided for type and quantity as recommended by the Equipment Maker for proper resiliency scheme. Typical 1:1 redundant cards may be Common Parts such as: Control Cards, Fans Units, Power Units; while Switching Matrix typical redundancy scheme may be 1:N.
  Redundancy cards will be set to be Active or in Hot-Standby as recommended by the Equipment Maker and according to the proper resiliency scheme.

- The Optical amplifier shall be the one with the maximum power.

6 Metrics Definitions of the Equipment Energy Efficiency Ratio for Transport equipment

Transport Equipment Energy Efficiency Ratio (EEER) is defined as:

EEER = B/P (unit: Mbps/W)

with the following meanings:

B Total capacity of a defined configuration (the sum of the interface data rates; unit: Mbps); for category C equipments both Network and Tributary ports shall be considered.

P Power consumption of a defined configuration (unit: Watt).

The higher is the EEER, the better is the energy efficiency.

The above defined EEER is in line with the equivalent TEER defined in ATIS standard for transport equipment [i.2].

For measurement of Power consumption P in the present document (see clause 7) a methodology is provided to take into account equipments with both Constant Bit Rate and Variable Bit Rate (VBR) interfaces. In fact, in case of Variable Bit Rate (VBR) the power consumption could depend on the traffic load.

The following formula for **P** calculation takes into account three different level of load on VBR interfaces:

$$\mathbf{P = (P_{0\,\%} + P_{50\,\%} + P_{100\,\%})/3}$$

Where the power consumptions ($P_{0\,\%}$, $P_{50\,\%}$, $P_{100\,\%}$) are referred to power measurement performed on the correspondent percentages of traffic load of each VBR interfaces only (load of CBR is constant and equal to the maximum one). The percentages of traffic load on VBR interfaces refer to the nominal rate of each interface.

A given packet traffic in bit/s with different packet traffic populations (mix) could require different power consumptions (queuing and processing effort).

The complete packet lengths IMIX profile shall apply to traffic load percentage at the VBR interfaces of the equipment under test, according to the Complete IMIX profile in table 1.

Table 1: Complete IMIX

Packet Size (Bytes)	Proportion of Total	Bandwidth (Load)
40	55,0 %	5,15 %
576	15,0 %	20,25 %
1 500	12,0 %	42,20 %
40 - 1 500 (range)	18,0 %	32,40 %

In case of transport equipment that can be configured with optical amplifiers with different gain, the above EEER does not show the dependency of the equipment energy efficiency as function of the gain amplifier. To compare equipment with the same configuration but different optical gain amplifiers, the following EEER can be used:

EEER = B × G/P [unit: (Mbps/W) x dB]

with the following meanings:

B Total capacity of a defined configuration (the sum of the interface data rates; unit: Mbps); for category C equipments both Network and Tributary ports shall be considered.

P Power consumption of a defined configuration (unit: Watt) determined according to:

$$\mathbf{P = (P_{0\,\%} + P_{50\,\%} + P_{100\,\%})/3}$$

G Optical Amplifier gain (unit: dB)

In the case that Optical amplifier is not present then G = 1. In case of equipment with multiple amplifiers with different gains, the average gain will apply (e.g. G1 = 100 dB, G2 = 10 dB, then G average = 55 dB).

7 Measurement Method

7.1 Measurement Conditions

The measurement conditions reported in ATIS-0600015.2009 [1] shall be applied except for the follows points here reported.

1) Environmental conditions

2) The power measurements shall be performed in a laboratory environment under the following conditions:

- Room Temperature: 23 °C to 27 °C.
- Room Relative Humidity: 25 % to 75 %.
- Atmospheric pressure: 86 kPa to 106 kPa

3) Test voltage

4) The equipment shall be powered with a stable power source and the input voltage of the DC power source shall be relatively constant. The following voltages shall be used:

- DC Powered Equipment: for nominal voltage of -48 V DC powered equipment, a test voltage of -54,5 V DC ±1,5 V DC shall be used (according to EN 300 132-2 [i.1]). Equipment using voltage other than -48 V DC shall be tested at ±2 % of the nominal voltage.
- AC Powered Equipment: 230 V ± 5 % and at 50 Hz ± 1 % of frequency.

5) Requirements for the measurement instruments

6) All measurement instruments used shall be calibrated by counterpart national metrology institute and within calibration due date, and the measurement tolerance shall be within ±1 %.

- Power Source: Power sources used to provide power to the equipment under test shall be capable of providing a minimum of 1,5 times the power rating of the equipment under test.
- Power Measurement Instrument: power measurement instruments (such as voltmeter and amperometer or power analyser) shall have a resolution of 0,5 % or better. AC power measurement instrument shall have the following minimum characteristics:
    1) a minimum digitizing sample rate of 40 KHz;
    2) input circuitry with a minimum bandwidth of 80 KHz;
    3) it shall be capable of accurate readings of waveforms having Peak to Average Ratio (PAR) factors up to at least 5.

7.2 Fixed configuration method

Given a System Configuration (see clause 5), the Fixed configuration method requires that the power consumption measurement is performed on the overall system, under the conditions specified in clause 7.1.

Fixed Configuration Method matches with the Certified TEER from ATIS Standardization on EE of Transport [i.2].

7.3 Flexible configuration method

The Flexible configuration method is applicable when the System Configuration is composed by a set of subparts whose power consumptions is previously measured and separately known. Typical subparts for Transport equipments are: Fans modules, Power supply modules, service cards (i.e. Controller and communication units), Switching units, Data interface boards, subtended subracks.

The total power consumption of the given Sytem Configuration is obtained as the sum of the consumption of all the subparts composing it.

This Flexible configuration method allows to evaluate EEER for different System Configurations without performing a direct measurements on each of them.

Flexible Configuration Method matches with the Declared TEER from ATIS Standardization on EE of Transport [i.2].

The power consumption obtained applying the methodology of the present clause could be, in general, different from the measuread one obtained following the methodology of clause 7.2. The power consumption obtained with flexible configuration is expected to be conservative (not lower) with respect to the measured one.

7.3.1 Requirements for System subparts power measurement

The actual power consumption of a System subpart depends, in general, on its operational condition.

The following requirements are set, therefore, in order to make applicable the Flexible Configuration method:

- power consumption of Fans modules shall be provided under the full load condition rating with the maximum configuration of the system;
- power dissipation of Power modules shall be provided at their power rating with the maximum configuration of the system;
- power consumption of any other common part modules (e.g. Controller, Communication, Alarm, etc.) shall be performed at the full load condition.

Annex A (informative): Examples of EEER evaluation

This informative annex provides some application example of the present standard for EEER evaluation, giving a specific evidence on how the concepts of System Description and System Configuration could be applied.

Other examples of similar EEER evaluation are available in the ATIS standard on Transport equipments (see ATIS-0600015.02.2009 [i.2], where TEER indicator corresponds to EEER of the present document).

A.1 Example 1 - Optical Amplifier

This example shows how it can be calculated the EEER of an Optical Amplifier.

Given a System Description the EEER is calculated assuming two different manufacturers that provide the equipment into two industrial implementations.

The example EEER computation is given for both the approaches of Fixed configuration and Flexible configuration.

A.1.1 System Description

- **System Category: A**
- **Type of equipment:** two ways Optical Amplifier operating in C band (32 nm bandwidth) with asymmetrical gain (17 dB from A to B side and 25 dB in the opposite direction, 5 dB of noise figure at both directions) and identical level of output power (20 dBm), see figure A.1.
- **System capacity:** band C/80 optical channels of 40 Gbit/s (*) at ITU-T compliant 50 GHz spacing.
- **Data ports and Interfaces:** couple of fibers on each side.
- **Redundancy:** not applicable.
- **Other Functionalities:** no.
- **Expansion requirement:** not required.

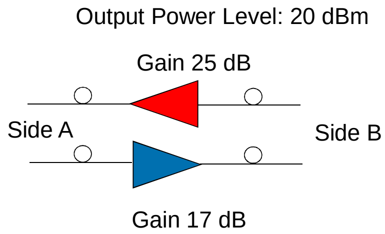

Figure A.1: Optical amplifier schematic (System Description)

(*) Network Elements such as OLA, Optical CrossConnect, etc. can work at many bit rates and as such cannot be characterized in these terms (e.g. the same Optical Amplifier can work at 40 G, 100 G, etc.). In the EEER computation it has to be considered in terms of bit rate accordingly to the given Application (40 G in the example). But assuming a different application, the given equipment may show a better (or worst) EEER since scaling up or down the bit rate at constant power consumption.

A.1.2 System Configuration from Manufacturer A

Configuration in a compact horizontal rack (10 slots), see figure A.2.

OA from A to B is realized with a Single Stage Amplifier SS04.

OA from B to A is realized with two amplifiers in cascade a Pre Ampl DS02.

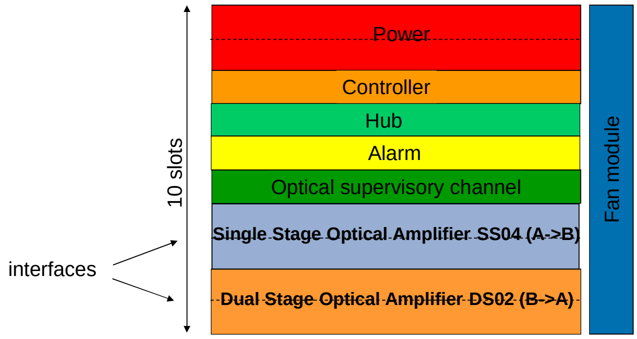

Figure A.2: Optical amplifier schematic (System Configuration from Manufacturer A)

A.1.3 System Configuration from Manufacturer B

Configuration in a compact vertical rack (10 slots), see figure A.3.

OA from A to B is realized with a single Stage Amplifier SA01.

OA from B to A is realize with two amplifiers in cascade a Pre Ampl PA05 and a Booster BA03.

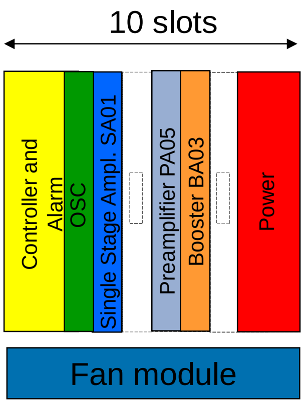

Figure A.3: Optical amplifier schematic (System Configuration from Manufacturer B)

A.1.4 EEER computation according to fixed configuration method

Total bandwidth:

80 channel @ 40 Gbit/s = 3 200 Gbt/s (full load)

Power measurement of the whole configuration at full load (all channels of DWDM are active on the lines):

Manufacturer A: 220 W

Manufacturer B: 245 W

EEER Man. A = 3 200 000 [Mbit/s]/220 [W] = 14 545 [Mbit/s/W]

EEER Man. B = 3 200 000 [Mbit/s]/245 [W] = 13 061 [Mbit/s/W]

A.1.5 EEER computation according to flexible configuration method

Manufacturers give the following consumption data:

Manufacturer A consumption data:

- Fans at full load (maximum speed): 30 W;
- Dissipation of Power supply at maximum power 40 W (Maximum power 400 W, ρ = 90 %);
- All necessary Common Parts for an OA on a 10 slots compact rack (Control, Supervision channel, Alarm): 25 W;
- Single stage amplifier Model SS04 (17 dB, 20 dBm): 65 W;
- Double Stage amplifier Model DS02 (25 dB, 20 dBm): 80 W.

Manufacturer B consumption data:

- Fans at full load (maximum speed): 32 W;
- Dissipation of Power supply at maximum power 36 W (Maximum power 450 W, ρ = 92 %);
- All necessary Common Parts for an OA on a 10 slots compact rack (Control, Supervision channel, Alarm): 28 W;
- Single stage amplifier Model SA01 (17 dB, 20 dBm): 65 W;
- Preamplifier Model PA05 (25 dB, 20 dBm): 48 W;
- Booster Model BA03 (25 dB, 20 dBm): 55 W.

EEER Man. A = 3 200 000 [Mbit/s]/(30 + 40 + 35 + 65 + 80) [W] = 13 333 [Mbit/s/W].

EEER Man. B = 3 200 000 [Mbit/s]/(32 + 36 + 28 + 70 + 45 + 60) [W] = 12 121 [Mbit/s/W]

Please note that EEER of the same equipment is not exactly the same with the two methods, i.e. Fixed and Flexible. The Flexible method is an approximated method and should give in general a pessimistic estimation (lower in value) of the EE index because it uses full load/worst case consumptions of Common Parts of the equipment.

A.2 Example 2 - ROADM WSS based (Optical)

A.2.1 System Description

- **System Description**
- **System Category: C**
- **Type of equipment:** WSS based ROADM with Add/Drop chains.
- **System capacity:** at least 4 network degrees (each one connected by a couple of fibers) and 2 Connectionless/Directionless Add/Drop chains.
- **Data ports and Interfaces:** couple of fibers on each network degree, 18 DWDM tunable interfaces of 40 Gbit/s each, (9 transponders for each Add/Drop chain). Transponders and optical amplifiers suitable to cover in transparency (without regeneration) at least 1 500 km on fiber G.655 with up to 10 hops path and span length of 80 km (max).
- **Redundancy:** no/(not applicable).

- **Other Functionalities:** WSON compliant (GMPLS control plane).
- **Expansion requirement:** 2 more network degrees and 2 more Add/Drop chain.

A.2.2 System Configuration

- With 9 port WSS it is possible to satisfy the requirements of up to 6 (4 + 2) network degrees and 4 (2 + 2) add/drop chains (expansion requirement is satisfied!).
- Rack is supposed of 10 + 10 slots each.
- Multi-rack structure is allowed in a master-slave hierarchy.
- The following pictures represents:
  - a logical scheme of the ROADM suitable to match the description;
  - an implemented equipment.

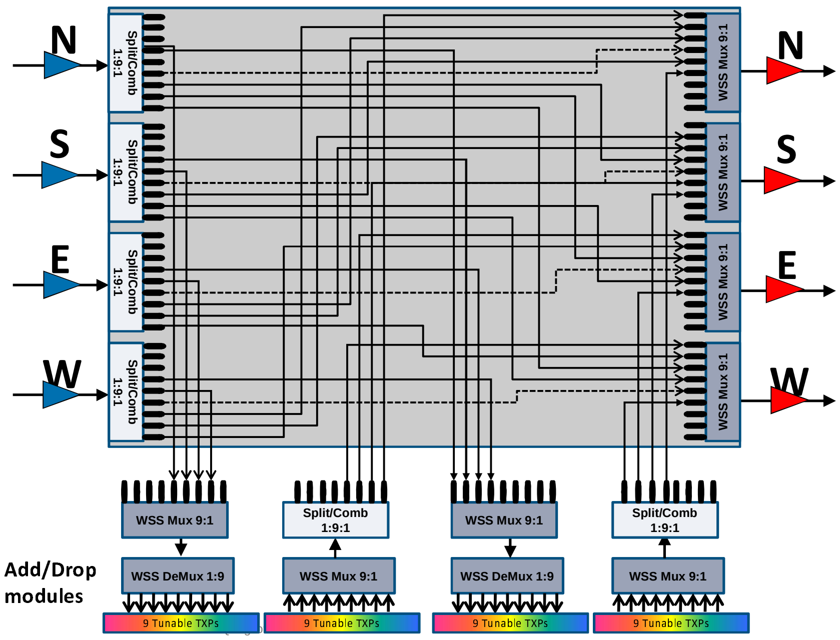

Figure A.4: ROADM WSS based schematic (System Configuration)

Figure A.5 represents the whole 4 degrees ROADM system on four 20 slots/two rows (shelves) racks.

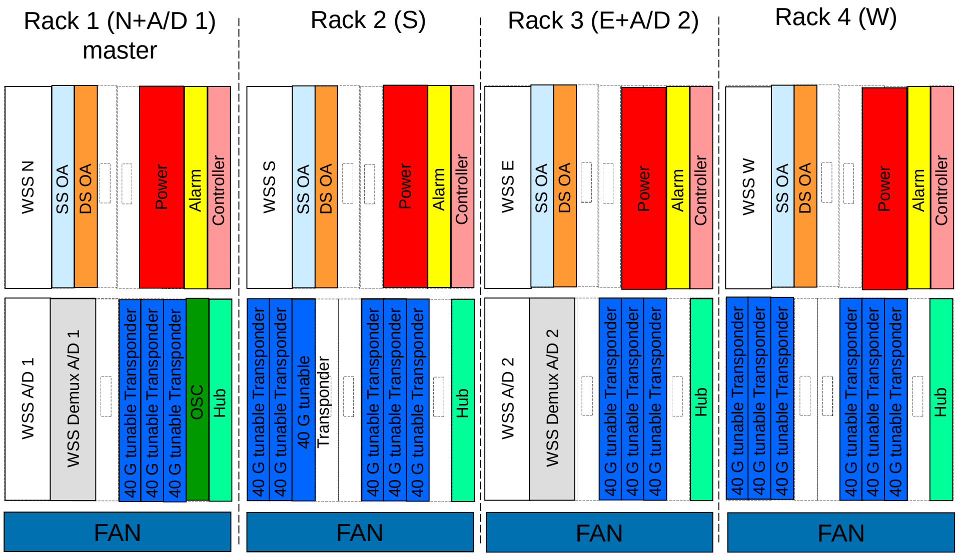

Figure A.5: ROADM WSS based schematic for whole 4 degrees system (System Configuration)

A.2.3 EEER computation according to fixed configuration method

Bandwidth computation.

4 Network degrees with 80 channels at 40 Gbit/s: 4 × 80 × 40 Gbit/s = 12 800 Gbit/s.

2 Add/Drop with 9 Transponder of 40 Gbit/s each: 2 × 9 × 40 Gbit/s = 720 Gbit/s.

Total: 13,520 Gbit/s = 13,52 × 10E6 Mbit/s.

Power consumption Measurement:

Rack 1 (master): 1 120 W

Rack 2: 1 095 W

Rack 3: 1 160 W

Rack 4: 1 100 W

Total Consumption: 5 662 W

EEER = 13,52 E6 Mbit/s/(1 120 + 1 095 + 1 160 + 1 100) = 3 021 [Mbit/s/W]

A.2.4 EEER computation according to flexible configuration method

Manufacturer give the following consumption data:

		Rack 1		Rack 2		Rack 3		Rack 4	
Part	Cons. [W]	No Parts	Cons. [W]	No Parts	Cons. [W]	No Parts	Cons. [W]	No Parts	Cons. [W]
Power [dissipation]	150	1	150	1	150	1	150	1	150
Alarm+Controller+OSC+Hub	30	1	30	1	30	1	30	1	30
WSS line	220	1	220	1	220	1	220	1	220
WSS A/D	220	1	220		0	1	220		0
WSS demux	120	1	120		0	1	120		0
40G Transport	90	3	270	6	540	3	270	6	540
SS OA	75	1	75	1	75	1	75	1	75
DS OA	90	1	90	1	90	1	90	1	90
		tot [W]	1175	tot [W]	1105	tot [W]	1175	tot [W]	1105

Total consumption = 5 662 W

EEER = 13,52E6 Mbit/s/5 662 W = 2 965 [Mbit/s/W]

Annex B (informative): Bibliography

VZ.TPR.9205: Verizon NEBSTM Compliance: "Energy Efficiency Requirements for Telecommunications Equipment Issue 4", Aug. 2009.

STRONGEST Deliverable D2.2: "STRONGEST node & network architectures for energy efficiency and scalability", 30 June 2011.

ITU-T Recommendation G.870/Y.1352: "Terms and definitions for optical transport networks (OTN)".

History

Document history		
V1.1.1	December 2012	Membership Approval Procedure MV 20130216: 2012-12-18 to 2013-02-18
V1.1.1	March 2013	Publication