International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

J.186
(06/2008)

SERIES J: CABLE NETWORKS AND TRANSMISSION OF TELEVISION, SOUND PROGRAMME AND OTHER MULTIMEDIA SIGNALS

Digital transmission of television signals

Transmission equipment for multi-channel television signals over optical access networks by sub-carrier multiplexing (SCM)

Recommendation ITU-T J.186

ITU-T

Recommendation ITU-T J.186

Transmission equipment for multi-channel television signals over optical access networks by sub-carrier multiplexing (SCM)

Summary

Recommendation ITU-T J.186 describes a transmission method for multi-channel television signals over optical access networks. J.186 transmission equipment is capable of transmitting multi-channel AM-VSB, and digital video signals by using sub-carrier multiplexing (SCM).

Source

Recommendation ITU-T J.186 was approved on 13 June 2008 by ITU-T Study Group 9 (2005-2008) under Recommendation ITU-T A.8 procedure.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure e.g. interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

CONTENTS

Introduction

For an undetermined period before digital transmission fully replaces analogue transmission, it will be necessary for optical access networks to carry both formats. Digital signals should be transmitted using Frequency-Division Multiplexing (FDM) in addition to analogue signals in order to assure an effective transition from analogue to digital transmission.

Recommendation ITU-T J.186

Transmission equipment for multi-channel television signals over optical access networks by sub-carrier multiplexing (SCM)

1 Scope

This Recommendation describes a method of transmitting multi-channel television signals over optical access networks through the use of Sub-Carrier Multiplexing (SCM).

In the SCM technique, the main carrier is the optical frequency signal carrier; the sub-carriers transfer the electrically multiplexed FDM video signals in the optical sideband. The format of the signals output by the Photo Detector (PD) of the Optical Network Terminal (ONT) is the same as that of the signals input to the modulator of the optical transmitter. The SCM method is used in the trunk line of Hybrid Fibre-Coax (HFC) systems.

The system described in this Recommendation transmits FDM analogue AM-VSB and digital video signals by SCM technology. The optical modulation format is Intensity Modulation (IM).

Optical amplifiers are used to compensate the losses of the optical transmission/splitters used to create the access network. Dispersion compensation fibres (DCF) are used to compensate the chromatic dispersion of access network fibres. DCF imposes the reverse chromatic dispersion in advance in order to offset the degradation due to CSO created by the transmission of 1.55 µm optical signals over 1.3 µm zero-dispersion access fibres.

SCM technology is simple, and is based on an electrical/optical (E/O) converter and optical amplifiers in the transmitter side, and an optical/electrical (O/E) converter in the receiver side. However, the allowable optical transmission/splitter loss is smaller than that in the FM converted system. Moreover, optical reflections in the transmission lines may degrade video quality.

This system can be integrated with the G.983 series B-PON system by using G.983.3 WDM technology, with the G.984 series G-PON system by using G.984.5 WDM technology, and with the IEEE 802.3ah EPON systems. This allows the PON system to offer broadcast services and also data and voice communication services over the same optical access network. By using the bidirectional data PON system, upstream signals, e.g., control functionality and data to indicate user requirements, can be transmitted as well.

NOTE – The structure and content of this Recommendation have been organized for ease of use by those familiar with the original source material; as such, the usual style of ITU-T recommendations has not been applied.

2 References

2.1 Normative References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[1] Recommendation ITU-T J.83 (2007), *Digital multi-programme systems for television, sound and data services for cable distribution*.

[2] Recommendation ITU-T J.87 (2001), *Use of hybrid cable television links for the secondary distribution of television into the user's premises*.

[3] ANSI/SCTE 85-1 (2003), *HMS HE Optics Management Information Base (MIB) Part 1: SCTE-HMS-HE-OPTICAL TRANSMITTER MIB.*

[4] ANSI/SCTE 85-2 (2003), *HMS HE Optics Management Information Base (MIB) Part 2: SCTE-HMS-HE-OPTICAL RECEIVER-MIB.*

[5] ANSI/SCTE 85-3 (2004), *HMS HE Inside Plant Management Information Base (MIB) SCTE-HMS-HE-OPTICAL-AMPLIFIER-MIB.*

[6] Recommendation ITU-T G.984.4 (2008), *Gigabit-capable Passive Optical Networks (G-PON): ONT management and control interface specification*.

[7] Recommendation ITU-R BT.1306-3 (2006), *Error-correction, data framing, modulation and emission methods for digital terrestrial television broadcasting*.

[8] Recommendation ITU-R BO.1408-1 (2002), *Transmission system for advanced multimedia services provided by integrated services digital broadcasting in a broadcasting-satellite channel*.

[9] IEC 60728-1 (2007), *Cable networks for television signals, sound signals and interactive services-Part 1; System performance of forward paths*.

2.2 Informative References

– Recommendation ITU-T G.983.1 (2005), *Broadband optical access systems based on Passive Optical Networks (PON)*.

– Recommendation ITU-T G.983.3 (2001), *A broadband optical access system with increased service capability by wavelength allocation*; Amendment 2 (2005).

– Recommendation ITU-T G.984.1 (2008), *Gigabit-capable Passive Optical Networks (GPON): General characteristics*.

– Recommendation ITU-T G.984.2 (2003), *Gigabit-capable Passive Optical Networks (GPON): Physical Media Dependent (PMD) layer specification*; Amendment 1 (2006).

– Recommendation ITU-T G.984.3 (2008), *Gigabit-capable Passive Optical Networks (GPON): Transmission convergence layer specification*.

– Recommendation ITU-T G.984.5 (2007), *Gigabit-capable Passive Optical Networks (GPON): Enhancement band*.

– IEEE Standard 802.3 (2005), *Information technology – Telecommunications and Information Exchange Between Systems – Local and metropolitan area networks – Specific Requirements – Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications.*

3 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AGC Automatic Gain Controller

ALC Automatic Level Controller

AM-VSB Amplitude Modulation Vestigial Sideband

AMP/BRC-U	Amplifier and Branch Unit
A-RA	Receiver Amplifier for Analogue video transmission
A-TA	Transmitter Amplifier for Analogue video transmission
CNR	Carrier-to-Noise Ratio
CSO	Composite Second Order distortion
CTB	Composite Triple Beat distortion
D/U	Desired-to-Undesired distortion ratio
DCF	Dispersion Compensation Fibre
DI	Discrete Interference
D-RA	Receiver Amplifier for Digital video transmission
D-TA	Transmitter Amplifier for Digital video transmission
E/O	Electrical to Optical
FDM	Frequency-Division Multiplexing
HE	Head End
HFC	Hybrid Fibre Coax
IM	Intensity Modulation
ISDB-T	Integrated Services Digital Broadcasting for Terrestrial
LE	Line Extender
O/E	Optical to Electrical
ONT	Optical Network Terminal
PD	Photo Detector
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase-Shift Keying
RA	Receiver Amplifier
RIN	Relative Intensity Noise
SCM	Sub-Carrier Multiplexing
SNMP	Simple Network Management Protocol
STB	Set-Top Box
TA	Transmitter Amplifier
TC8PSK	Trellis Coded 8-Phase Shift Keying
TX	Transmitter
V-OLT	Optical Line Terminal for Video signals
V-ONT	Optical Network Terminal for Video signals
VSWR	Voltage Standing Wave Ratio
WDM	Wavelength-Division Multiplexing
XM	Cross Modulation distortion

3.1 Symbols

This Recommendation uses the following symbols:

N Total number of FDM carriers

m_j Intensity modulation index of the jth carrier

3.2 Conventions

If this Recommendation is implemented, the key words "MUST" and "SHALL" as well as "REQUIRED" are to be interpreted as indicating a mandatory aspect of this Recommendation.

The keywords indicating a certain level of significance of particular requirements which are used throughout this Recommendation are summarized below.

"MUST" This word or the adjective "REQUIRED" means that the item is an absolute requirement of this Recommendation.

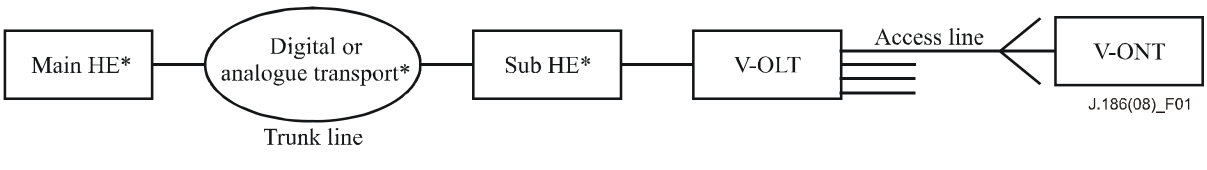
"MUST NOT" This phrase means that the item is an absolute prohibition of this Recommendation.

"SHOULD" This word or the adjective "RECOMMENDED" means that there may be valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before choosing a different course.

"SHOULD NOT" This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.

"MAY" This word or the adjective "OPTIONAL" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.

4 System description



* Is out of scope

Figure 1 – System description of the SCM multi-channel video signal transmission system

Figure 1 is a system description of multi-channel television signals transmission using Sub-Carrier Multiplexing (SCM). To minimize the deterioration in video signal quality, this system was optimized in two steps: trunk line transmission and access network transmission. The trunk line transmission system consists of digitally encoded signals transmission or analogue signal transmission. In the second step, all video signals (both analogue and digital modulation formats) are mixed in the V-OLT, and then transmitted from the V-OLT to the V-ONT across the access network.

5 Performance of analogue and/or digital video transmission system

5.1 Specified transmission quality for analogue video signal

Table 1 shows specified transmission quality for the AM-VSB analogue video signal. The carrier power of the analogue video signal is measured as the peak envelope power.

Table 1 – Specified transmission quality for analogue video signal

TV system	M-system NTSC		B, G-system PAL	L-system SECAM
	North America	Other regions		
Noise bandwidth	4.0 MHz	4.0 MHz	4.75 MHz	5.0 MHz
CNR	≥ 46 dB (Note 1)	≥ 43 dB (Note 2)	≥ 44 dB	≥ 44 dB
CSO	≤ –53 dB	≤ –53 dB	≤ –52 dB	≤ –52 dB
CTB	≤ –53 dB (Note 1)	≤ –54 dB (Note 2)	≤ –52 dB	≤ –52 dB
XM	≤ –46 dB	≤ –46 dB	≤ –46 dB	≤ –46 dB
DI	≤ –60 dB (Note 1)	≤ –57 dB (Note 2)	Not specified	Not specified

NOTE 1 – North America commonly used value.

NOTE 2 – Refer to [9].

5.2 Specified transmission quality for digital video signal

Table 2 shows specified transmission quality for the digital video signal.

Table 2 – Specified transmission quality for digital (xQAM) video signal

	64-QAM signal			256-QAM signal	
	Annex A/J.83	Annex B/J.83	Annex C/J.83	Annex B/J.83	Annex C/J.83
Symbol Rate	Not specified	5.057 Mbaud	5.274 Mbaud	5.36 Mbaud	5.274 Mbaud
CNR (Note 4)	≥ 27 dB (Notes 1, 2)	≥ 27 dB (Notes 1, 2)	≥ 26 dB (Note 2)	≥ 40 dB (Notes 1, 2)	≥ 34 dB (Notes 1, 2)
MER	Not specified	Not specified	Not specified	≥ 32 dB (Note 1)	Not specified
CSO/CTB	Not specified	Not specified	≤ –39 dB (Note 3)	≤ –47 dB (Note 3)	≤ –45 dB (Note 3)
Pre-FEC BER	Not specified	$1x10^{-5}$	Not specified	$1x10^{-9}$	Not specified
Post-FEC BER	Not specified	$1x10^{-12}$	Not specified	$1x10^{-15}$	Not specified

NOTE 1 – This value includes the simultaneous presence of all impairments in the 6-MHz channel bandwidth including composite distortion or other discrete interference.

NOTE 2 – The carrier power is measured as the average RMS signal power.

NOTE 3 – These undesired signals are caused by interference among AM-VSB channels.

NOTE 4 – Noise bandwidth is defined by symbol rate.

Table 3 – Specified transmission quality for digital video signal

	TC8PSK signal (Note 5)	**ISDB-T (Note 6)**
Noise bandwidth	28.86 MHz	5.6 MHz
CNR (Note 4)	≥ 11 dB (Notes 1, 2)	≥ 24 dB (Notes 1, 2)
CSO/CTB	Not specified	≤ –45 dB (Note 3)

NOTE 1 – This value includes the simultaneous presence of all impairments in the 6-MHz channel bandwidth including composite distortion or other discrete interference.

NOTE 2 – The carrier power is measured as the average RMS signal power.

NOTE 3 – These undesired signals are caused by interference among AM-VSB channels.

NOTE 4 – Noise bandwidth is defined by symbol rate.

NOTE 5 – Refer to [8].

NOTE 6 – Refer to [7].

Annex A

Optical Systems for Broadcast Signal Transmission: system A

(This annex forms an integral part of this Recommendation)

A.1 System description

A.1.1 System configuration

Figure A.1 is a block diagram of one configuration of the equipment needed by the optical access network to transmit multi-channel television signals by using Sub-Carrier Multiplexing (SCM). All video signals (both analogue and digital modulation formats) are mixed in the V-OLT, and then transmitted from the V-OLT to the V-ONT across the access network. The V-OLT is able to connect with the 2nd stage V-OLT, the 3rd stage V-OLT, and more.

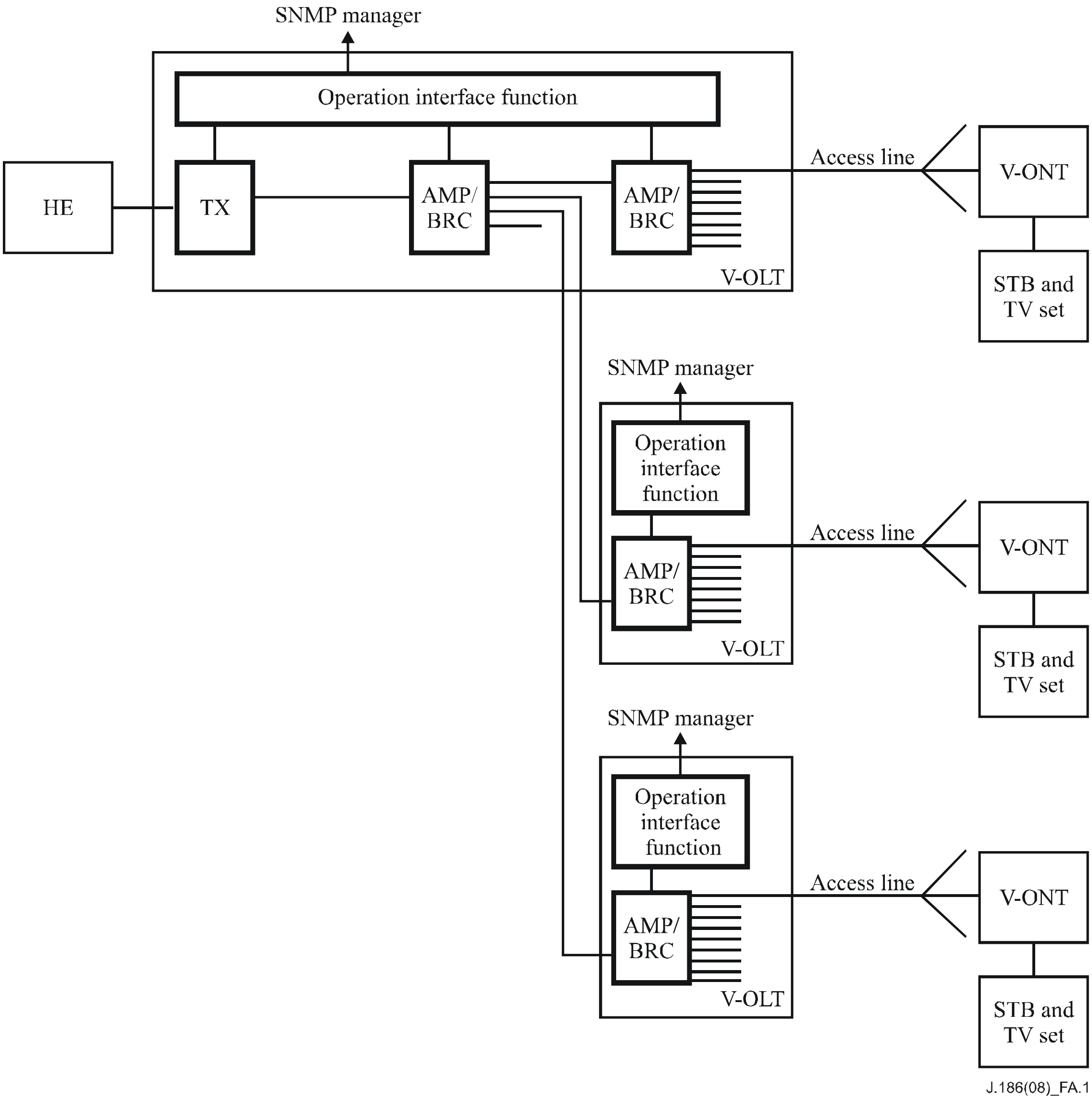


Figure A.1 – One configuration of the SCM multi-channel video signal transmission system

V-OLT consists of TX and cascaded Optical Amplifier and splitter unit (AMP/BRC), which amplify and branch the optical signal output by the TX. AMP/BRCS can be cascaded in several stages up to the specified RIN deterioration permitted. The operation interface function collects alarms from the whole system by Simple Network Management Protocol (SNMP) and transmits them to the SNMP manager. Optical signals output from V-OLT are branched again by optical splitters and transmitted to V-ONTs through the optical access network.

V-ONT converts the optical input signal into FDM multi-channel electrical video signals, and then amplifies those signals. The output signals from V-ONT are input to the user's TV set.

The functions of each device are shown in Table A.1.

Table A.1 – Summary of functions of each device

Device	Function
V-OLT (TX, AMP/BRC)	The V-OLT converts FDM signals, analogue AM-VSB and digital video signals transmitted from HE to optical intensity modulation signal. The V-OLT then branches them to V-ONTs.
V-ONT	The V-ONT converts received optical signal to electrical FDM video signals. The V-ONT outputs them to set-top box (STB) and TV monitor.

A.1.2 Main characteristics

Table A.2 shows the main characteristics of the SCM multi-channel video signals transmission system.

Table A.2 – Main characteristics of the SCM multi-channel video signals transmission system

Item and parameter	Limit	Condition and meaning
Frequency of transmitted FDM video signals, F_{tr}	$47 \le F_{tr}$ ≤ 2150 MHz (Note 1)	
Relative intensity noise degradation due to optical fibre transmission from V-OLT to V-ONT	70-770 MHz ≤ –145 dB/Hz 1000-2150 MHz (Note 2) ≤ –140 dB/Hz (Note 2)	
NOTE 1 – Frequency bands of transmitted FDM video signals, $47 \le F_{tr} \le 2150$ MHz, include regional CATV bands of 54 to 864 MHz for North America, 47 to 862 MHz for Europe, 90 to 770 MHz and 90 to 2150 MHz for Japan. NOTE 2 – Optional.		

A.1.3 Total number of FDM carriers and their intensity modulation indexes

The total number of carriers and their intensity modulation indexes must comply with the following formula.

$$\sqrt{\sum_{j}^{N} m_j^2} \le 0.33$$

where:

N Total number of FDM carriers

m_j Intensity modulation index of jth carrier

In general, each carrier type is set to a nominal modulation index that is uniform over that type. The modulation index of the QAM carriers is conventionally set to be 6-10 dB lower than the modulation index of the analog carriers.

Additionally, some carriers may be given a modulation index that is somewhat higher than the nominal value, so that the delivered CNR for these carriers is kept above the service requirement. Typically, this includes the lowest frequency carriers (e.g., below 100 MHz), because this spectral region suffers from the Raman crosstalk and other impairments.

A.2 Transmitter (TX)

A.2.1 Configuration of TX

Figure A.2 shows a block diagram of a typical TX located in V-OLT. FDM analogue AM-VSB and digital video signals are directed into one or more RF input ports. SNMP management signals may also be input into the TX. These FDM signals are amplified and are mixed together with the optional pilot signal. The RF multiplexer may also implement an equalization function to provide groups of channels a different modulation index. These mixed FDM electrical signals are converted into an Intensity Modulated (IM) optical signal by the Electrical/Optical (E/O) converter. One very important feature of the E/O converter is the suppression of Stimulated Brillouin Scattering via frequency dithering of the optical signal. This optical signal is then optically amplified, if required. The amplified optical signal is branched at the optical splitter, if needed. The output optical signals from TX OUT are transmitted to AMP/BRC-Us located in V-OLT.

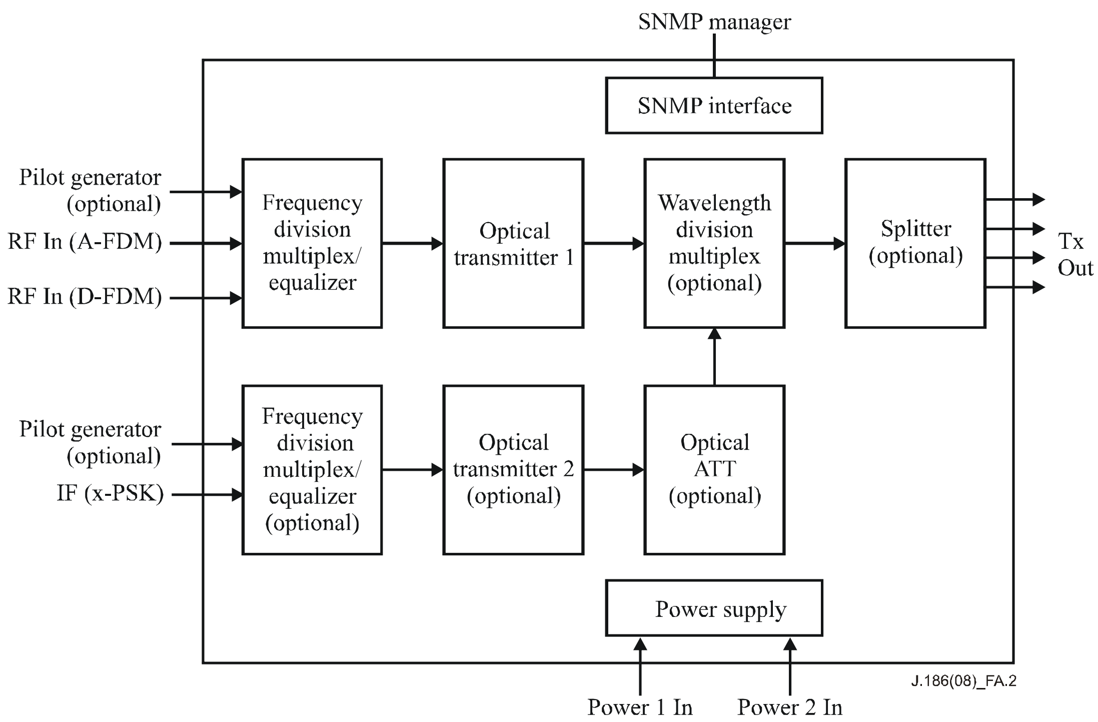


Figure A.2 – Block diagram of TX

The pilot signal can be used in order to make sure that the signal from TX is being transmitted to V-OLT and V-ONT successfully. Alternatively, total RF power can be used for these purposes, thereby eliminating the need for a pilot signal.

A variety of signal monitoring ports is provided, including the RF inputs, the composite signal, and the optical output.

The operations, administration and management interface function takes care of the OAM functions implemented by each function. Raw data and events from the functions are mapped into SNMP protocol frames for transmission to the management network.

A.2.2 Characteristics of TX

The main characteristics of TX are listed in Table A.3.

Table A.3 – Main characteristics of TX

Item and parameter		Limit	Condition
Electrical input	Reference level	Not specified	
Optical output	Output power level	≥ 0 dB(mW)	
	Output power tolerance	+2 dB/0 dB	
	Number of output ports	Not specified	
	Wavelength, λ	1555 ± 5 nm	ITU grid
	Composite optical modulation index	≤ 33%	
	Relative intensity noise, RIN	70-770 MHz ≤ –155 dB/Hz 1000-2150 MHz ≤ –150 dB/Hz	RIN of optical output signal from TX without optical amplifier Optional
	Dispersion Tolerance	65 km G.652 fibre	
	SBS Tolerance	+16 dB(mW)	Launch into 65 km G.652 fibre

A.2.3 Operations, administration and management items of TX

Alarm interface should be SNMP format.

Alarm administration items, which should be observed by TX, are shown in Table A.4.

Table A.4 – Alarm administration items of TX

Alarm administration item	Alarm occurrence condition
RF signal input alarm	When the level of input video signal is abnormal
OPT output alarm	When optical output power level is abnormal
AGC alarm	When AGC level is abnormal
Power supply alarm	When an error is found in the power supply

A.3 AMP/BRC

A.3.1 Configuration of Optical AMP/BRC

Figure A.3 shows a block diagram of the typical optical amplifier and optical splitter (AMP/BRC) unit.

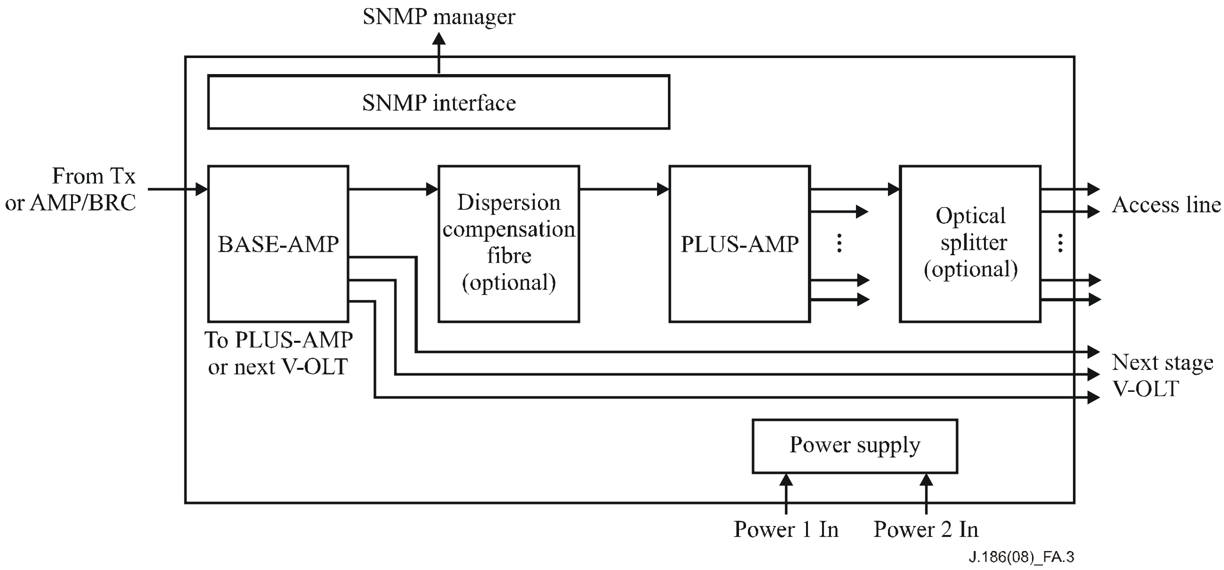


Figure A.3 – Block diagram of AMP/BRC

The optical amplifier and splitter unit consists of cascaded optical amplifiers and optical splitters. It amplifies and branches the optical signal output by TX.

The optical transmitters in TX usually consist of an external modulator. If the optical transmitter in TX consists of a directly modulated laser, the optical amplifier and splitter unit should also have dispersion compensation fibre and the optical branching function (DCF/Splitter). In this case, access lines are grouped according to their length, and each access line is connected to an appropriate DCF/splitter. Thus, the chromatic dispersion generated in each access line is less than the specified limit.

If one or more optical outputs ports are not used for transmission, and the transmitter in TX uses direct modulation, they must be optically terminated.

A.3.2 Main characteristics of Optical amplifier and splitter

The main characteristics of the optical amplifier and splitter unit are shown in Table A.5.

Table A.5 – Main characteristics of optical amplifier and splitter

Item and parameter		Limit	Conditions
BASE AMP	Input/output optical signal wavelength, λ	1555 ± 5 nm	
	Input power	+0 dB(mW)	
	Output power	MAX +21.3 dB(mW) (Note)	Input power is +0 dB(mW)
	NF	6.5 dB	Input power is +0 dB(mW)
	Relative intensity noise, RIN	≤ –149 dB/Hz	Input power is +0 dB(mW)
	Number of output ports	Not specified	
PLUS AMP	Input/output optical signal wavelength, λ	1555 ± 5 nm	
	Input power	+10 dB(mW)	
	Output power	MAX +21.3 dB(mW) (Note)	Input power is +10 dB(mW)
	NF	6.5 dB	When combined with BASE AMP, input power is +0 dB(mW)
	Relative intensity noise, RIN	≤ –149 dB/Hz	When combined with BASE AMP, input power is +0 dB(mW)
	Number of output ports	16 or 32 ports	
DCF	Permissible chromatic dispersion	Not specified	
NOTE – Output power of trunk line and access line is less than SBS suppression level.			

A.3.3 Operations, administration, and management items of Optical amplifier and splitter

Alarm interface should be SNMP format. The OAM items of optical amplifier and splitter are shown in Table A.6.

Table A.6 – OAM items of Optical amplifier and splitter

Alarm administration item	Alarm occurrence condition
Optical signal input alarm	When optical input power level is abnormal
Optical amplifier alarm	When pump LD power level is abnormal When optical output power level is abnormal
Power supply alarm	When an error is found in the power supply

A.4 Optical network terminal for video signals (V-ONT)

A.4.1 Configuration of V-ONT

Figure A.4 shows a typical function block of the V-ONT. Note that in many applications, the V-ONT is integrated in the digital ONT, even to the extent that the optics of both units are integrated into a single 'triplexer'. The optical signal transmitted from the V-OLT is converted into electrical FDM signals by the optical/electrical (O/E) converter, and then amplified to the appropriate power level. In SCM systems, the carrier level of signals output from the O/E converter depends on received optical power; however, the carrier level of signals output from V-ONT should be constant. To compensate any decrease in amplitude, the gain of the electrical amplifier is automatically controlled by the Automatic Gain Controller (AGC), which refers to the signal level. The signal level can be found by measuring the optical received power, the total RF power or the pilot signal amplitude. The choice of measurement method is an ONT implementation issue. The alarm administration function also refers to this signal level. The alarm is output when the signal level is no longer within the specified range. This alarm is used to judge whether transmission signal error has occurred.

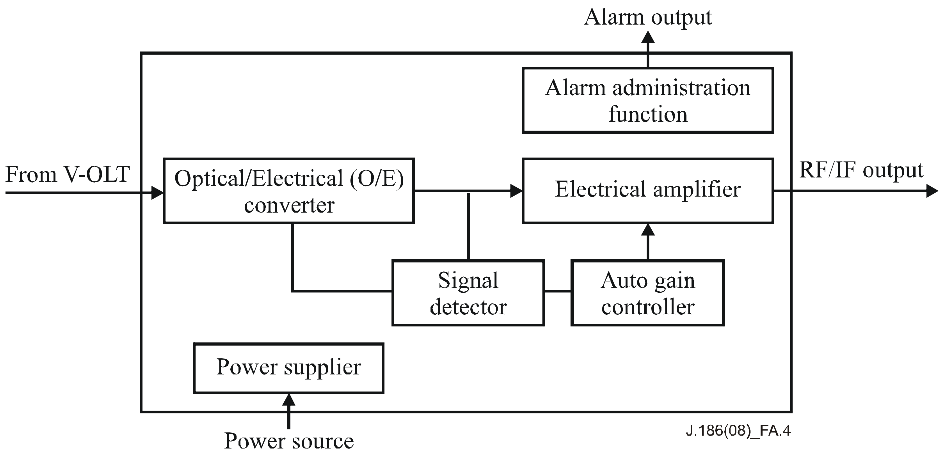


Figure A.4 – Block diagram of V-ONT

A.4.2 Main characteristics of V-ONT

The main characteristics of V-ONT are listed in Table A.7.

Table A.7 – Main characteristics of V-ONT

Item		Limit	Conditions
Optical signal input	Minimum input power	≤ –8 dB(mW)	
	Wavelength	1555 ± 5 nm	
Electrical signal output	VSWR	≤ 2.5	
	Impedance	75 Ω unbalanced	
	Output level	Min 80 dBμV/ch	Levels are for analog channels. Digital channels will be 6-10 dB lower
	Maximum channel load	Permits 80 analog channels	

A.4.3 Operations, administration and management items of V-ONT

The OAM items of the V-ONT function are specified in ITU-T Rec. G.984.4.

Annex B

SCM transmission equipment: system B

(This annex forms an integral part of this Recommendation)

B.1 System description

B.1.1 System configuration

Figure B.1 shows a block diagram of a typical configuration. In this system, the HE sources digitally encoded signals, and these are carried to the video serving office using some type of digital transport. The digital signals are decoded, and the resulting analogue and digital QAM signals are modulated onto the desired frequencies. The combined channel spectra are then input into the V-OLT. The V-OLT consists of a TX and several types of AMP/BRC-U devices. Three broad classes of AMP/BRC-U are employed: the pre-amplifier (PA), the PON driver (PD), and the line-extender (LE).

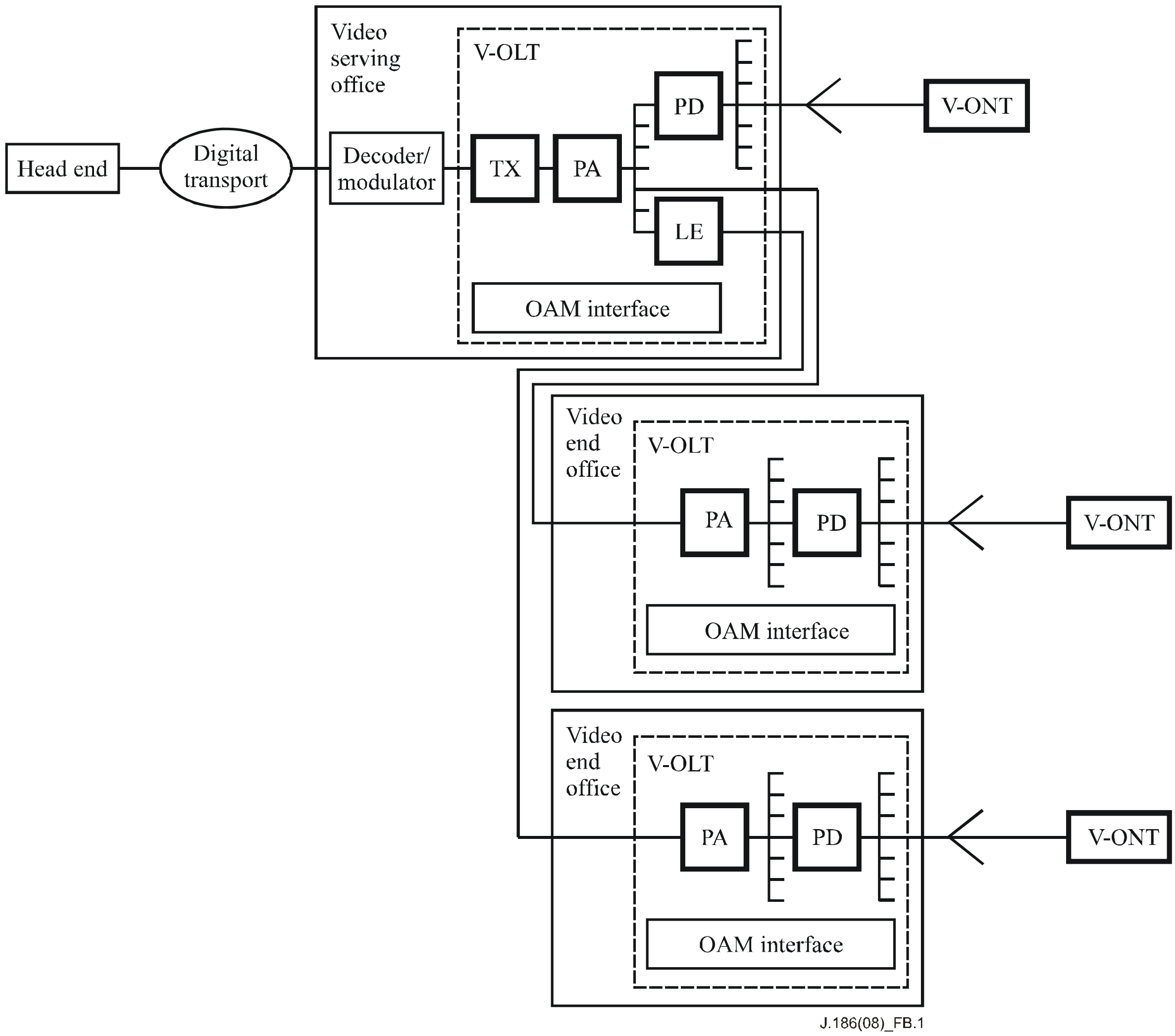


Figure B.1 – Configuration of the SCM video signal transmission system

The detailed arrangement of the AMP/BRC-Us is highly variable, but Figure B.1 shows the most common schemes. In the first system, the TX feeds a PA, which feeds many PDs, each of which feeds many PONs. It is not unusual to serve up to 256 PONs from a single TX in this way. In the second system, some of the outputs from the PA are used to feed additional PA units, both in the same office and in nearby offices. This allows for even greater sharing of the RF signal. The third system uses LE devices to boost the signal for transmission over even larger distances, to reach outlying offices. The design of the V-OLT amplifier network must be optimized to ensure that the effective RIN and non-linear impairments are kept within tolerances.

Note that the OAM interface function can be centralized for an entire V-OLT, or distributed. For example, if the V-OLT is implemented as a chassis-based system, then it is likely that there will be a single OAM interface. Conversely, if the V-OLT is composed of several separate network elements, then each element will have its own OAM interface.

The functions of each device are shown in Table B.1.

Table B.1 – Summary of functions of each device

Device	Function
V-OLT (TX, AMP/BRC)	The V-OLT amplifies optical analogue AM-VSB and digital video signals transmitted from the HE. The V-OLT then branches them to V-ONTs.
V-ONT	The V-ONT converts received optical signal to electrical FDM video signals. The V-ONT outputs them to set-top box (STB) and TV monitor.

B.1.2 Main characteristics

Table B.2 shows the main characteristics of the SCM multi-channel video signals transmission system.

Table B.2 – Main characteristics of the SCM multi-channel video signals transmission system

Item and parameter	Limit	Condition and meaning
Frequency of transmitted FDM video signals, F_{tr}	Type 1: $47 \le F_{tr} \le 864$ MHz Type 2: $47 \le F_{tr} \le 2050$ MHz	Type 2 is used for transmission of QPSK signals.
Relative intensity noise degradation due to optical fibre transmission from V-OLT to V-ONT	≤ –153 dB/Hz	
NOTE – Frequency bands of transmitted FDM video signals, $47 \le F_{tr} \le 864$ MHz, include regional CATV bands of 54 to 864 MHz for North America, 47 to 862 MHz for Europe, and 90 to 770 MHz for Japan.		

B.1.3 Total number of FDM carriers and their intensity modulation indexes

The total number of carriers and their intensity modulation indexes must comply with the following formula.

$$\sqrt{\sum_{j}^{N} m_j^2} \le 0.33$$

where:

N Total number of FDM carriers

m_j Intensity modulation index of jth carrier

In general, each carrier type is set to a nominal modulation index that is uniform over that type. The modulation index of the QAM carriers is conventionally set to be 6-10 dB lower than the modulation index of the analog carriers.

Additionally, some carriers may be given a modulation index that is somewhat higher than the nominal value, so that the delivered CNR for these carriers is kept above the service requirement. Typically, this includes the lowest frequency carriers (e.g., below 100 MHz), because this spectral region suffers from the Raman crosstalk and other impairments.

B.2 Transmitter (TX)

B.2.1 Configuration of TX

Figure B.2 shows a block diagram of a typical TX located in V-OLT. FDM analogue AM-VSB and digital video signals are directed into one or more RF input ports. RF modulated out of band (OOB) management signals may also be input into the TX. These FDM signals are amplified and are mixed together with the optional pilot signal. The RF multiplexer may also implement an equalization function to provide groups of channels a different modulation index. These mixed FDM electrical signals are converted into an Intensity Modulated (IM) optical signal by the Electrical/Optical (E/O) converter. One very important feature of the E/O converter is the suppression of Stimulated Brillouin Scattering via frequency dithering of the optical signal. This optical signal is then optically amplified, if required. The amplified optical signal is branched at the optical splitter, if needed. The output optical signals from TX OUT are transmitted to AMP/BRC-Us located in V-OLT.

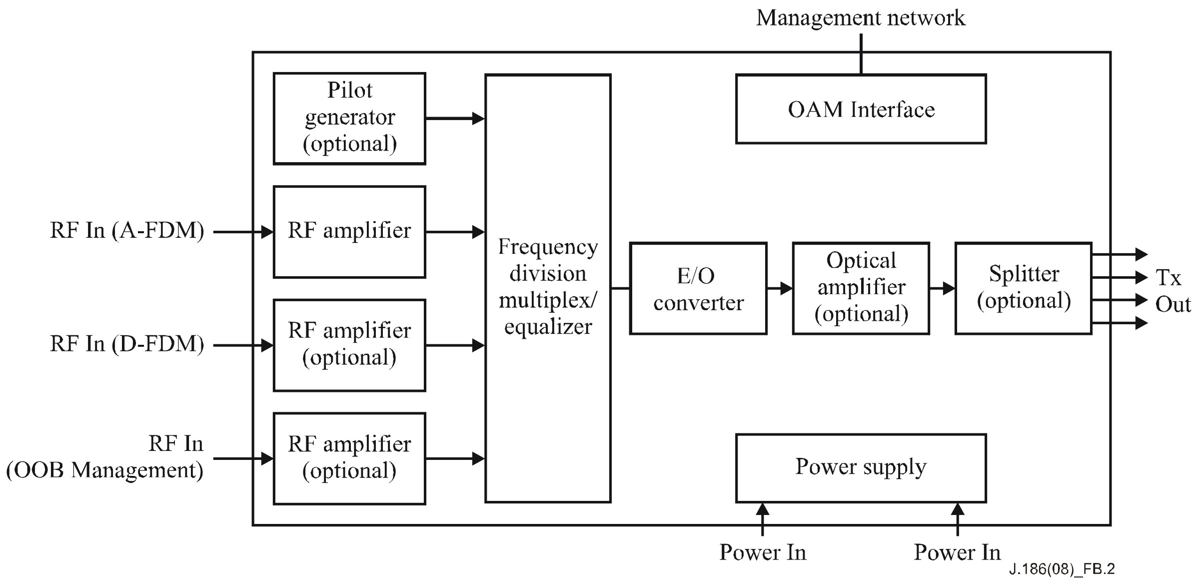


Figure B.2 – Block diagram of TX

The pilot signal can be used in order to make sure that the signal from TX is being transmitted to V-OLT and V-ONT successfully. Alternatively, total RF power can be used for these purposes, thereby eliminating the need for a pilot signal.

A variety of signal monitoring ports is provided, including the RF inputs, the composite signal, and the optical output.

The operations, administration and management interface function takes care of the OAM functions implemented by each function. Raw data and events from the functions are mapped into SNMP protocol frames for transmission to the management network.

B.2.2 Characteristics of TX

The main characteristics of TX are listed in Table B.3.

Table B.3 – Main characteristics of TX

Item and parameter		Limit	Condition
Electrical input	Reference level	85 dBμV/ch	Carrier level of AM-VSB signal
Optical output	Output power level	≥ +8 dB(mW)	
	Output power tolerance	+1 dB/0 dB	
	Number of output ports	Not specified	
	Wavelength, λ	1555 ± 5 nm	
	Composite Optical modulation index	≤ 33%	
	Relative intensity noise, RIN	≤ –153 dB/Hz	RIN of optical output signal from TX One port is open
	Optical spectrum	Single longitudinal mode	
	Dispersion Tolerance	120 km G.652 fibre	
	SBS Tolerance	+17 dB(mW)	Launch into 80 km G.652 fibre
Pilot signal (optional)	Frequency accuracy	≤ 50 ppm	
	Amplitude	82 ± 0.5 dBμV	Converted value as a signal input level

B.2.3 Operations, administration, and management items of TX

The OAM items of the TX function are specified in ANSI/SCTE 85-1 [3].

B.3 Amplifier and branch unit (AMP/BRC)

B.3.1 Configuration of AMP/BRC

Figure B.3 shows a block diagram of the typical optical amplifier and optical branch (AMP/BRC) unit.

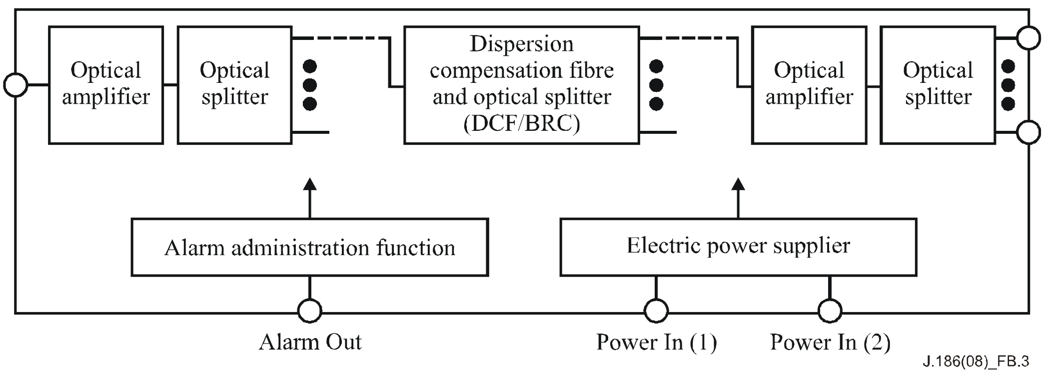


Figure B.3 – Block diagram of AMP/BRC

The AMP/BRC unit consists of cascaded optical amplifiers and optical splitters. It amplifies and branches the optical signal output by TX.

When the E/O converter in TX consists of a directly modulated laser, the AMP/BRC unit should also have dispersion compensation fibre and the optical branching function (DCF/BRC). In this case, access lines are grouped according to their length, and each access line is connected to an appropriate DCF/BRC. Thus, the chromatic dispersion generated in each access line is less than the specified limit.

If one or more optical output ports are not used for transmission, and the E/O converter in TX uses direct modulation, they must be optically terminated.

B.3.2 Main characteristics of AMP/BRC

The main characteristics of the amplifier and branching (AMP/BRC) unit are shown in Tables B.4 to B.7.

Table B.4 – Main characteristics of AMP/BRC unit

Item and parameter		Limit	Conditions
Optical amplifier	Input/output optical signal wavelength, λ	1555 ± 5 nm	
	Output power	~+16 dB(mW)	Input power is ~+6 dB(mW)
	Relative intensity noise, RIN	≤ –150.4 dB/Hz	Input power is ~+6 dB(mW)
	Number of amplifier stages	Not specified	
	Number of output ports	Not specified	
DCF	Relative intensity noise, RIN	≤ –151.4 dB/Hz	
	Permissible chromatic dispersion	≤ 39.6 ps/nm	

Table B.5 – Characteristics of pre-amplifier (PA) AMP/BRC unit

Item and parameter	Limit	Conditions
Output power	~+10 dB(mW)	Input power is ~+6 dB(mW)
Relative intensity noise, RIN	≤ –150.4 dB/Hz	Input power is ~+6 dB(mW)
Number of amplifier stages	1 or more	
Number of output ports	10 or more	

Table B.6 – Characteristics of PON driver (PD) AMP/BRC unit

Item and parameter	Limit	Conditions
Output power	~+17 dB(mW)	Input power is ~+6 dB(mW)
Relative intensity noise, RIN	≤ –150.4 dB/Hz	Input power is ~+6 dB(mW)
Number of amplifier stages	1 or more	
Number of output ports	16 or more	

Table B.7 – Characteristics of line extender (LE) AMP/BRC unit

Item and parameter	Limit	Conditions
Output power	~+17 dB(mW)	Input power is ~+6 dB(mW)
Relative intensity noise, RIN	≤ –150.4 dB/Hz	Input power is ~+6 dB(mW)
Number of amplifier stages	1 or more	
Number of output ports	1 or more	

B.3.3 Operations, administration, and management items of AMP/BRC

The OAM items of the AMP/BRC function are specified in ANSI/SCTE 85-3 [5].

B.4 Optical network terminal for video signals (V-ONT)

B.4.1 Configuration of V-ONT

Figure B.4 shows a typical function block of the V-ONT. Note that in many applications, the V-ONT is integrated in the digital ONT, even to the extent that the optics of both units are integrated into a single 'triplexer'. The optical signal transmitted from the V-OLT is converted into electrical FDM signals by the optical/electrical (O/E) converter, and then amplified to the appropriate power level. In SCM systems, the carrier level of signals output from the O/E converter depends on received optical power; however, the carrier level of signals output from V-ONT should be constant. To compensate any decrease in amplitude, the gain of the electrical amplifier is automatically controlled by the Automatic Gain Controller (AGC), which refers to the signal level. The signal level can be found by measuring the pilot signal amplitude, the optical received power, or the total RF power. The choice of measurement method is an ONT implementation issue. The alarm administration function also refers to this signal level. The alarm is output when the signal level is no longer within the specified range. This alarm is used to judge whether transmission signal error has occurred.

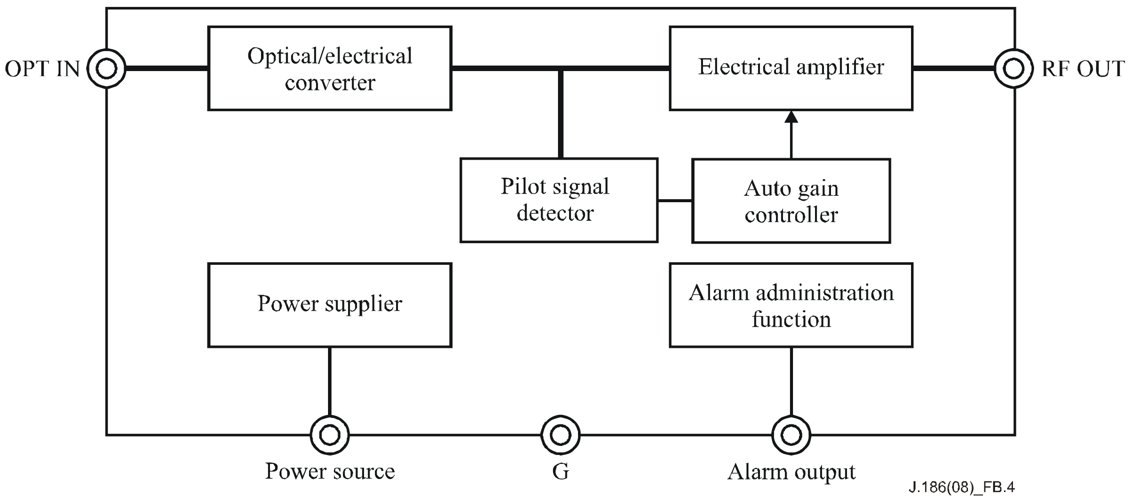


Figure B.4 – Block diagram of V-ONT

B.4.2 Main characteristics of V-ONT

The main characteristics of V-ONT are listed in Table B.8.

Table B.8 – Main characteristics of V-ONT

<table>
<tr><th colspan="2">Item</th><th>Limit</th><th>Conditions</th></tr>
<tr><td rowspan="4">Optical signal input</td><td>Minimum input power</td><td>Type 1: ≤ –12 dB(mW)
Type 2: ≤ –20 dB(mW)</td><td>Type 2 is used for transmission of QPSK signals</td></tr>
<tr><td>Effective Noise Current</td><td>≤ 6.5 pA/√Hz</td><td></td></tr>
<tr><td>Responsivity</td><td>≥ 0.9 A/W</td><td></td></tr>
<tr><td>Wavelength</td><td>1555 ± 5 nm</td><td></td></tr>
<tr><td rowspan="2">Electrical signal output</td><td>VSWR</td><td>≤ 2.5</td><td></td></tr>
<tr><td>Impedance</td><td>75 Ω unbalanced</td><td></td></tr>
<tr><td rowspan="4">AGC</td><td>Output level</td><td>Depends on ONT type:
Single user ONT:
>18 dBmV/ch
Multiple user ONT:
>33 dBmV/ch</td><td>Levels are for analog channels. Digital channels will be 6-10 dB lower</td></tr>
<tr><td>Maximum channel load</td><td>Depends on ONT type:
Single user ONT:
>37 dBmV
Multiple user ONT:
>52 dBmV</td><td>Permits 80 analog channels</td></tr>
<tr><td>Gain Range</td><td>>10 dB (rf)</td><td></td></tr>
<tr><td>Offset</td><td>Should be configurable/ provisionable to accommodate the range of channel plans</td><td></td></tr>
</table>

B.4.3 Operations, administration, and management items of V-ONT

The OAM items of the V-ONT function are specified in ITU-T Rec. G.984.4 [6].

Appendix I

Modulation index and minimum received optical power

(This appendix does not form an integral part of this Recommendation)

When all carriers are modulated by the same format, the formula described in A.1.3 can be changed to the formula shown below.

$$m_j \leq \frac{0.30}{\sqrt{N}} \qquad \text{(I-1)}$$

The required minimum received optical power, $P_{\min}$, is given by equation I-2.

$$P_{\min} = \frac{e + \sqrt{e^2 + \alpha \cdot \left(2eI_{d0} + N_{th}{}^2\right)}}{\alpha \cdot R} \quad [\mathrm{W}] \qquad \text{(I-2)}$$

Here, e is the charge of the electron, R is the quantum efficiency of photo detector in V-ONT, I_{d0} is the dark current, N_{th} is the thermal noise. α is given by equation I-3.

$$\alpha = \frac{m_j{}^2}{2B_W \cdot CNR_{req}} - RIN \quad [\mathrm{s}] \qquad \text{(I-3)}$$

Here, B_W is noise bandwidth, CNR_{req} is required CNR, and RIN is relative intensity noise of the optical signal launched into V-ONT. In equation I-3, the carrier power of CNR_{req} is measured as the peak envelope power. The assumed values for all these parameters are the following:

RIN	–145.8 dB/Hz
I_{d0}	100 nA
N_{th}	10 pA/√Hz
R	0.8 A/W

The condition given in the following is assumed:

Modulation format of transmitted signal	64-QAM of Annex B/J.83
Number of carriers N	110

According to equation I-1, m_j of 0.0286 is the calculated maximum modulation index for the jth carrier. Required minimum received optical power, $P_{\min}$, is calculated to be –11.0 dBm.

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	**Cable networks and transmission of television, sound programme and other multimedia signals**
Series K	Protection against interference
Series L	Construction, installation and protection of cables and other elements of outside plant
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Terminals and subjective and objective assessment methods
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects and next-generation networks
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2009