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STANDARDIZATION SECTOR
OF ITU

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

Digital transmission of television signals

Transmission equipment for transferring multi-channel television signals over optical access networks by frequency modulation conversion

Recommendation ITU-T J.185

ITU-T

International Telecommunication Union

Recommendation ITU-T J.185

Transmission equipment for transferring multi-channel television signals over optical access networks by frequency modulation conversion

Summary

Recommendation ITU-T J.185 describes a transmission method for transferring multi-channel television signals over optical access networks. ITU-T J.185 transmission equipment is capable of realizing multi-channel AM-VSB, 64-QAM, and 256-QAM video signal transmission through the use of frequency modulation conversion.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T J.185	2002-02-13	9
2.0	ITU-T J.185	2012-06-13	9

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.

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

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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/.

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Recommendation ITU-T J.185

Transmission equipment for transferring multi-channel television signals over optical access networks by frequency modulation conversion

1 Scope

This Recommendation describes a method of transmitting multi-channel television signals over an optical access network that utilizes frequency modulation (FM) conversion. In this FM transmission system, multi-channel frequency-division multiplexing (FDM) television signals are simultaneously converted into one single wideband FM signal. This FM signal is then transmitted through the optical access network by using the intensity modulation technique. The video-optical network terminal (V-ONT) at the customer premises converts the received single FM signal into the original multi-channel FDM video signals, i.e., coaxial cable television (CATV) signals. The interface for this FM transmission system is the same as that of the amplitude modulation sub-carrier multiplexing (AM-SCM) system. Therefore, the FM transmission system can replace the AM-SCM system. The FM transmission system is required to have an FM converter, i.e., frequency modulator and frequency demodulator, in addition to the AM-SCM transmission system's equipment. However, it has a better efficiency than the AM-SCM transmission system against the noise deterioration caused by optical transmission/splitter loss and optical reflections.

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.

This system can be added to the ITU-T G.983.1 series B-PON system by using ITU-T G.983.3 wavelength-division multiplexing (WDM) technology, to the ITU-T G.984 series G-PON system and ITU-T G.987 series XG-PON system by using ITU-T G.984.5 WDM technology, and to the IEEE 802.3ah/802.3av EPON systems. This integration would allow the 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 upstream data indicating the user's requirements, can be transmitted as well.

2 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.

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

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

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

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

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 access network [b-ITU-T K.44]: That part of the overall telecommunication network that is located between a telecommunication centre and the customer premises building.

3.1.2 carrier [b-ITU-R V.662-3]: An oscillation or wave, usually periodic, some characteristic of which is intended to be constrained by modulation to follow the values of a signal or of another oscillation.

3.1.3 sub-carrier multiplexing [b-ITU-T G.982]: Multiplexing multiple electrical frequencies onto a single fibre at a single wavelength to provide an individual frequency to each multipoint-to-point path.

3.1.4 trunk network [b-ITU-T K.44]: That part of the telecommunication system that is located between two telecommunication centres and that provides the communication between the centres.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AC	Alternating Current
AM-SCM	Amplitude Modulation Sub-Carrier Multiplexing
AM-VSB	Amplitude Modulation Vestigial Sideband
AMP/BRC-U	Amplifier and Branch Unit
APD	Avalanche Photo Diode
BER	Bit Error Rate
B-PON	Broadband Passive Optical Network
CATV	Cable Television
CNR	Carrier-to-Noise Ratio
CSO	Composite Second Order distortion
CTB	Composite Triple Beat distortion
DC	Direct Current
DI	Discrete Interference
D/U	Desired-to-Undesired signal ratio
E/O	Electrical to Optical converter
EPON	Ethernet Passive Optical Network
FEC	Forward Error Correction
FDM	Frequency-Division Multiplexing
FM	Frequency Modulation
G-PON	Gigabit Passive Optical Network

IF	Intermediate Frequency
IM	Intensity Modulated
ISDB-T	Integrated Services Digital Broadcasting – Terrestrial
MER	Modulation Error Rate
NTSC	National Television System Committee
OFDM	Orthogonal Frequency Division Multiplexing
OMI	Optical Modulation Index
PAL	Phase Alternating Line
PIN-PD	p-i-n Photo Diode
PON	Passive Optical Network
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RA	Repeater Amplifier
RF	Radio Frequency
RIN	Relative Intensity Noise
RMS	Root Mean Square
SBS	Stimulated Brillouin Scattering
SCM	Sub-Carrier Multiplexing
SECAM	Séquentiel couleur à mémoire
STB	Set-Top Box
TC8PSK	Trellis-Coded Eight Phase Shift Keying
TX	Transmitter
V-OLT	Video-Optical Line Terminal
V-ONT	Video-Optical Network Terminal
VSWR	Voltage Standing Wave Ratio
WDM	Wavelength-Division Multiplexing
XG-PON	10-Gigabit Passive Optical Network
XM	Cross Modulation distortion

5 Conventions

In this Recommendation:

The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

The keywords "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option, and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with this Recommendation.

6 System description

Figure 1 is a system description of multi-channel television signals transmission employing frequency modulation (FM) conversion. Video signal from the headend is input to the transmitter (TX) and E/O converted, and then transmitted to the video-optical network terminal (V-ONT) via the video-optical line terminal (V-OLT). For actual installations, this system covers not only the optical access network, but also the optical trunk network with cascaded V-OLTs.

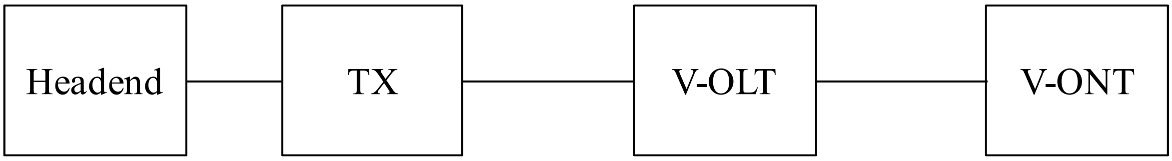


Figure 1 – System configuration of an FM-converted multi-channel television signal transmission system

7 Performance of analogue and/or digital video transmission system

7.1 Specified transmission quality for analogue video signal

Table 1 shows specified transmission quality for the amplitude modulation vestigial sideband (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
Noise bandwidth	4.0 MHz	4.75 MHz	5.0 MHz
CNR	≥ 43 dB (Note)	≥ 44 dB	≥ 44 dB
CSO	≤ −53 dB	≤ −52 dB	≤ −52 dB
CTB	≤ −54 dB	≤ −52 dB	≤ −52 dB
XM	≤ −46 dB	≤ −46 dB	≤ −46 dB
DI	≤ −57 dB (Note)	Not specified	Not specified
NOTE – Refer to [IEC 60728-1].			

7.2 Specified transmission quality for digital video signal

Tables 2 and 3 show specified transmission quality for the digital video signal.

Table 2 – Specified transmission quality for the digital video signal

	64-QAM signal			256-QAM signal	
	Annex A of [ITU-T J.83]	**Annex B of [ITU-T J.83]**	**Annex A of [ITU-T J.83]**	**Annex B of [ITU-T J.83]**	**Annex A of [ITU-T 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	1×10^{-5}	Not specified	1×10^{-9}	Not specified
Post-FEC BER	Not specified	1×10^{-12}	Not specified	1×10^{-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 root mean square (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 the digital video signal

	QPSK signal (Note 5)	**TC8PSK signal (Note 5)**	**ISDB-T (Note 6)**
Noise bandwidth	28.86 MHz	28.86 MHz	5.6 MHz
CNR (Note 4)	≥ 8 dB (Notes 1, 2)	≥ 11 dB (Notes 1, 2)	≥ 24 dB (Notes 1, 2)
CSO/CTB	Not specified	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 [ITU-R BO.1408-1].

NOTE 6 – Refer to [ITU-R BT.1306-3].

Annex A

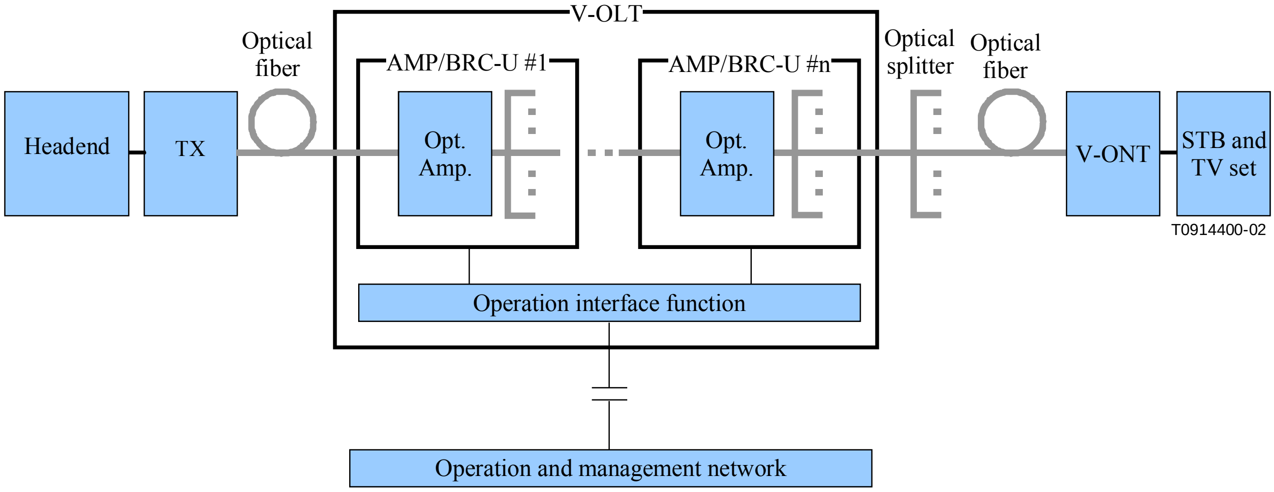
Multi-channel video broadcast system over optical access network: system A

(This annex forms an integral part of this Recommendation.)

A.1 System description

A.1.1 System configuration

Figure A.1 shows a block diagram of the equipment needed to transmit multi-channel television signals over optical access networks by FM conversion. This system consists of TX, V-OLT, and V-ONT. FDM multi-channel AM-VSB analogue and 64-/256-QAM digital video electrical signals output from the headend are converted into a single, electrical super-wideband FM signal by an FM converter, and then converted into an intensity modulated (IM) optical signal by the electrical/optical converter (E/O) in TX.



Opt. Amp. Optical Amplifier

Figure A.1 – System configuration of an FM-converted multi-channel video signal transmission system

V-OLT consists of cascaded amplifier/branch-units (AMP/BRC-U), which amplify and branch the optical signal output by the TX. The operation interface collects alarms from the whole system and transmits them to the operation and management network. AMP/BRC-Us can be cascaded in several stages provided the specified relative intensity noise (RIN) degradation is not exceeded. The optical signal output by V-OLT is further branched by optical splitters and transmitted to the V-ONT in the customer's premises.

The V-ONT converts the optical input signal into a single electrical super-wideband FM signal in the optical/electrical converter, and the electric signal is then demodulated into FDM multi-channel video signals by the frequency demodulator. The demodulated signal output by the V-ONT is input to the STB and the TV set.

Table A.1 summarizes the functions of each device.

Table A.1 – Functions of each device

Device	Functions
TX	TX converts frequency-division multiplexed AM-VSB analogue and 64-/256-QAM digital video signals into one single electrical super-wideband FM signal, and then converts this FM signal into an intensity-modulated optical signal. Alarm signals are transmitted from TX to V-OLT through metallic pairs by using a data modem.
AMP/BRC-U	AMP/BRC-U amplifies and branches input optical signal.
Operation interface function	Operation interface function collects alarms from TX and V-OLT and transfers them to the operation and management network.
V-ONT	V-ONT converts input optical signal to a single electrical super-wideband FM signal, and then demodulates it to frequency-division multiplexed AM-VSB analogue and 64-/256-QAM digital video signals.

A.1.2 Main characteristics

Table A.2 shows the main characteristics of the FM-converted multi-channel video signal transmission system.

Table A.2 – Main characteristics of FM-converted multi-channel video signal transmission system

Item and parameter	Limit
Frequency of transmitted FDM video signals, F_{tr}	$47 \le F_{tr} \le 864$ MHz
Relative intensity noise of the optical fibre between TX and V-OLT	≤ -153 dB/Hz
Relative intensity noise of the optical fibre between V-OLT and V-ONT	≤ -152 dB/Hz

NOTE – Frequency band of transmitted FDM video signals, $47 \le F_{tr} \le 864$ MHz, includes regional CATV bands of 54 to 864 MHz for North America, 47 to 862 MHz for Europe, and 90 to 770 MHz for Japan.

A.1.3 Total number of FDM carriers and their frequency deviation

The total number of carriers and their FM frequency deviation is required to comply with the following formula:

$$\sqrt{\sum_{j}^{N} \Delta F_j^{\,2}} \le 0.41 \times (2500 - f_{\max})$$

where:

N Total number of FDM carriers

ΔF_j FM frequency deviation of jth carrier, $\text{MHz}_{0\text{-p}}$/carrier

f_{max} Maximum carrier frequency, MHz

A.2 TX

A.2.1 Configuration of TX

Figure A.2 provides a block diagram of a typical TX. The FM converter multiplexes the pilot signal with the FDM video signals input via the RF IN port, and then converts them to a single super-wideband FM signal with emphasis. The emphasis compensates the triangular noise generated by FM conversion. This FM signal is converted into an IM optical signal by an electrical/optical converter (E/O). The IM optical signal is input to a dispersion compensation fibre, and then amplified by an optical amplifier. The amplified optical signal from OPT OUT is transmitted to the V-OLT. The dispersion compensation fibre compensates the chromatic dispersion of the primary transmission fibre from TX to V-OLT.

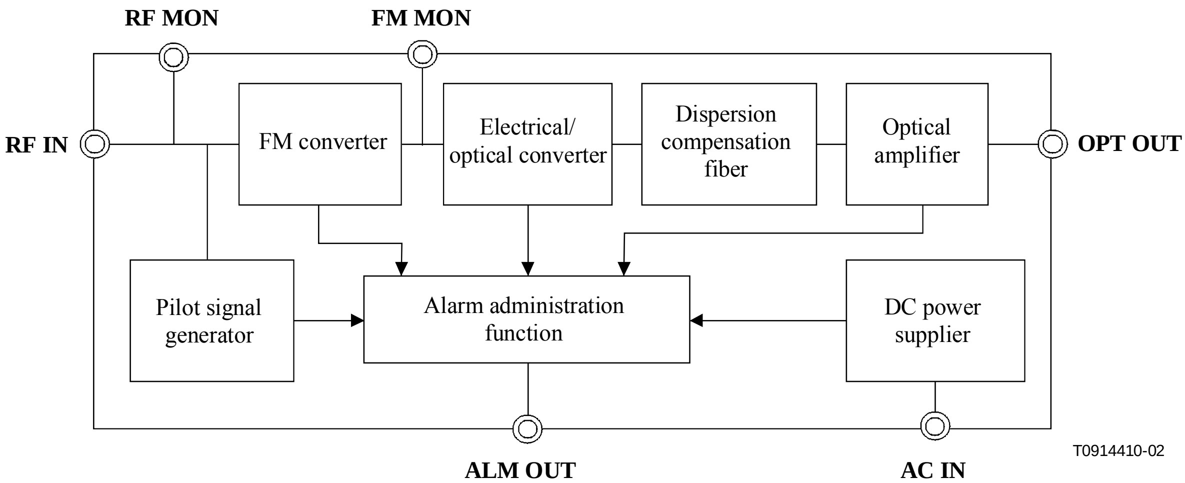


Figure A.2 – Configuration of TX

The pilot signal is used in order to confirm that signal transmission was normal. It is possible to modulate the pilot signal with angular modulation if necessary.

The RF MON port is the RF signal monitor port used for measuring the input RF signal quality and its level during system operation.

The input RF signal is divided with the appropriate splitting ratio in order to output the RF monitor signal from the RF MON port. The ratio is small so that the splitting does not degrade the main RF signal.

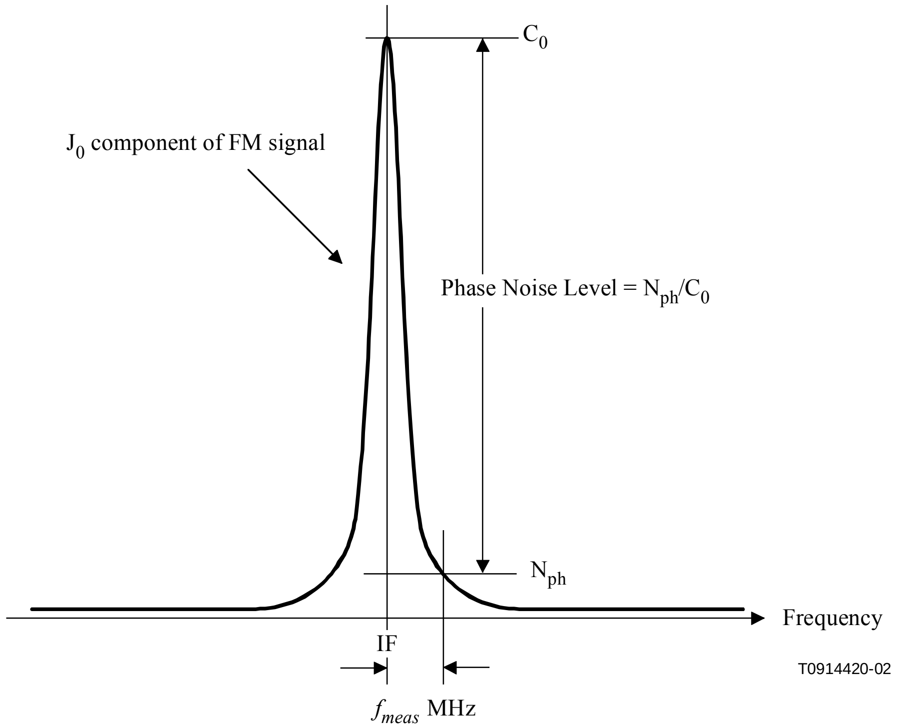
The alarm administration function collects the alarms generated by each function. When an alarm is collected, it is transferred from ALM OUT to the operation interface function of the V-OLT.

A.2.2 Main characteristics of TX

Main characteristics of TX are shown in Table A.3. Figure A.3 shows how to measure the electrical phase noise level. Electrical phase noise is measured at the frequency of f_{meas} MHz far from IF when video modulation is not applied.

Table A.3 – Main characteristics of TX

Item and parameter		Limit	Meaning and condition
Electrical input signal	Reference level	85 dBμV/carrier	Carrier level of AM-VSB signal.
	Impedance of RF IN port	75 Ω unbalanced	
FM frequency deviation		$70.0\times10^{\frac{12.9\cdot(f-47)}{16340}}\times10^{\frac{V_{in}-85\pm1}{20}}$ $MHz_{0\text{-}p}$/carrier	When carrier frequency is f MHz, and signal input level is V_{in} dBμV/ch.
Emphasis level difference for triangular noise of FM modulation		12.9 ± 1.0 dB	For input RF frequencies from 47 MHz to 864 MHz.
Output optical signal	Optical spectrum	Single longitudinal mode	
	Wavelength	1555 ± 5 nm	
	Output power	≥ +12 dBm	
Output optical signal	Optical modulation index, OMI	70 ≤ OMI ≤ 95%	
	Relative intensity noise, RIN	≤ −140 dB/Hz	RIN of optical output signal from TX.
Electrical phase noise		$\le 10\log_{10}\left(\frac{50\times10^{-9}}{2\pi f_{meas}^{2}}\right)$ dB/Hz	See Figure A.3.
Harmonic distortion	Second-order	≤ −27 dBc	Electrical level comparison against J_0 component at IF frequency when video modulation is not applied.
	Third-order	≤ −19 dBc	
FM carrier frequency, IF		3.0 ± 0.50 GHz	
Drift range of IF frequency		≤ 0.15 GHz	Drift for 5 minutes.
Suppression level of residual AM components		≥ 50 dB	See Figure A.4.
Pilot signal	Frequency accuracy	≤ 50 ppm	Video modulation not applied.
	Amplitude	82 ± 0.5 dBμV	Converted value as a signal input level from the "RF IN" port.



TX output spectrum when no video modulation is applied.

Figure A.3 – Definition of electrical phase noise level

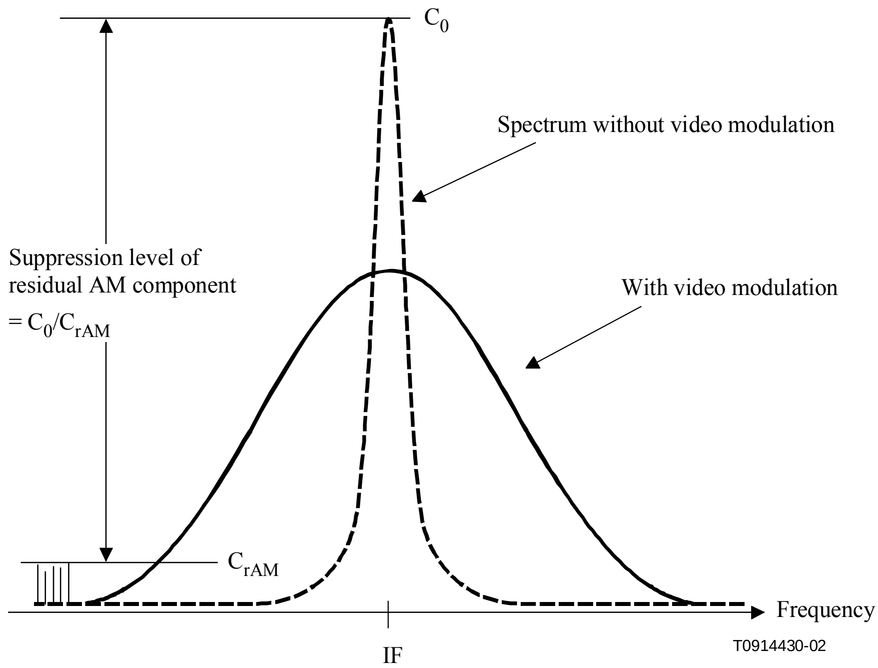


Figure A.4 – Definition of suppression level of residual AM component

A.2.3 Alarm administration items of TX

Alarm administration items that are recommended to be observed by the TX are shown in Table A.4.

Table A.4 – Alarm administration items of TX

Alarm administration item	Symbol	Alarm occurrence condition
Video transmission signal input alarm	REC	When input signal level is less than that of a single carrier.
MOD output alarm	MOD OUT	When FM converter output signal is abnormal.
E/O output alarm	E/O OUT	When optical output power level is abnormal.
Optical amplifier alarm	AMP OUT	When pump light power level is abnormal. When optical input/output power level is abnormal.
Power supply alarm	PWR ALM	When an error is found at the power supply.
AC power input interruption	AC DWN	When an error is found in AC power input.
Fan alarm	FAN	When an error is found in FAN.

A.3 V-OLT

A.3.1 Main characteristics of V-OLT

Table A.5 shows the main characteristics of V-OLT.

Table A.5 – Main characteristics of V-OLT

	Item and parameter	Limits	Meaning and condition
Optical amplifier	Input/output optical signal wavelength, λ	1555 ± 5 nm	
	Output power	≥ +14 dBm	
	Relative intensity noise, RIN	≤ −137.7 dB/Hz	Input power is −8 dBm. Includes RIN degradation caused by opening of connector.
	The number of AMP accommodated in the V-OLT	Not specified	
	The number of output ports	Not specified	

A.3.2 Alarm administration items

Alarm administration items of V-OLT are shown in Table A.6.

Table A.6 – Alarm administration items of V-OLT

Name of the function	Alarm administration item	Symbol	Alarm occurrence conditions
Optical amplifier function	Optical input alarm	REC	When optical input power level is abnormal.
	Optical output alarm	OUT	When pump light power level is abnormal. When optical output power level is abnormal.
	Power supply alarm	PWR ALM	When an error is found in the power supply.
TX monitor function	Pilot alarm	PIL	When the power level of pilot signal that is transmitted from TX is abnormal.
	Alarm administration line alarm	MODEM	When alarm administration line between TX and V-OLT is interrupted.
	Power supply alarm	PWR ALM	When an error is found in the power supply.
Common	FUSE alarm	FUSE	When fuse of equipment is out.

A.4 V-ONT

A.4.1 Configuration of V-ONT

Figure A.5 shows a block diagram of V-ONT. The optical signal output by V-OLT is converted into a single electrical super-wideband FM signal by the optical/electrical converter, and then converted into the original FDM video signals by the FM demodulator. The demodulated signal is output after it is amplified to the appropriate level by the electrical amplifier.

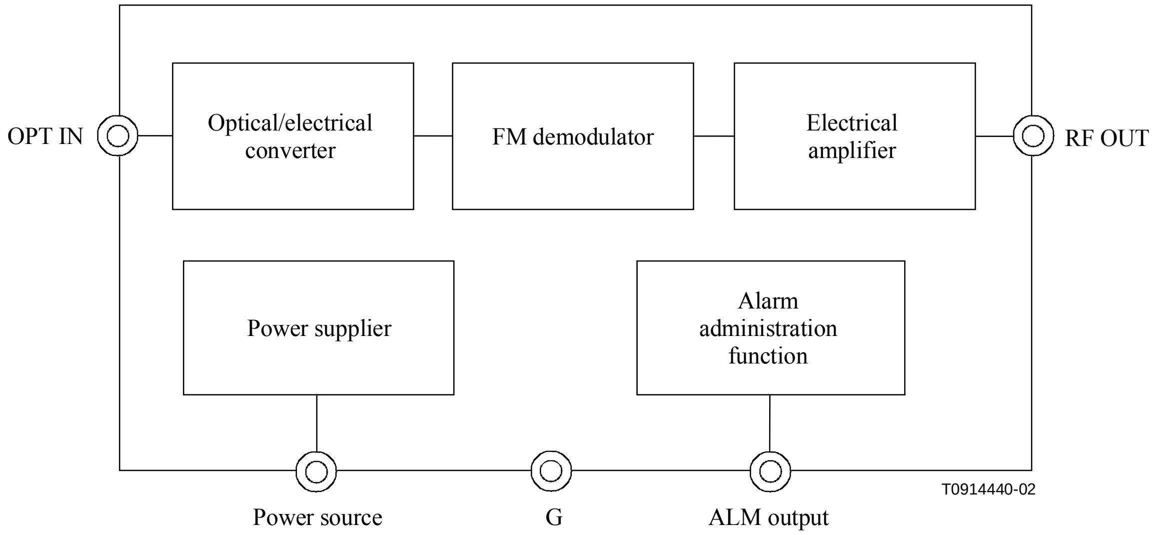


Figure A.5 – Configuration of V-ONT

Pilot signal level is observed by the alarm administration function. An alarm is output when the pilot signal level does not meet the specified value. This alarm indicates whether there is transmission signal error or not.

A.4.2 Main characteristics of V-ONT

Table A.7 shows the main characteristics of V-ONT.

Table A.7 – Main characteristics of V-ONT

Item and parameter		Limit and specification	Meaning and condition
Optical input	Minimum input power	≤ −15 dBm	
	Wavelength, λ	1555 ± 5 nm	
Electrical output	Power level	≥ 75 dBμV	When signal input level of TX is 85 dBμV/carrier.
	VSWR	≤ 2.5	
	Impedance	75 Ω unbalanced	

A.4.3 Alarm administration items of V-ONT

Table A.8 lists the alarm item of V-ONT.

Table A.8 – Alarm administration item of V-ONT

Alarm administration item	Symbol	Alarm occurrence conditions	Remark
Output alarm	OUT	When the power level of pilot signal is lower than the specified value	Pilot signal is measured at RF OUT port.

Annex B

Multi-channel video broadcast system with cascaded V-OLTs: 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 the equipment needed to transmit multi-channel video signals over optical trunk and access networks by FM conversion. This system consists of TX, V-OLT, and V-ONT. Frequency-division multiplexing (FDM) multi-channel AM-VSB analogue and 64-/256-QAM, OFDM, PSK, and TC8PSK digital video electrical signals output from the headend are converted into a single, electrical super-wideband FM signal by an FM converter, and then converted into an intensity modulated (IM) optical signal by the electrical/optical converter (E/O) in TX.

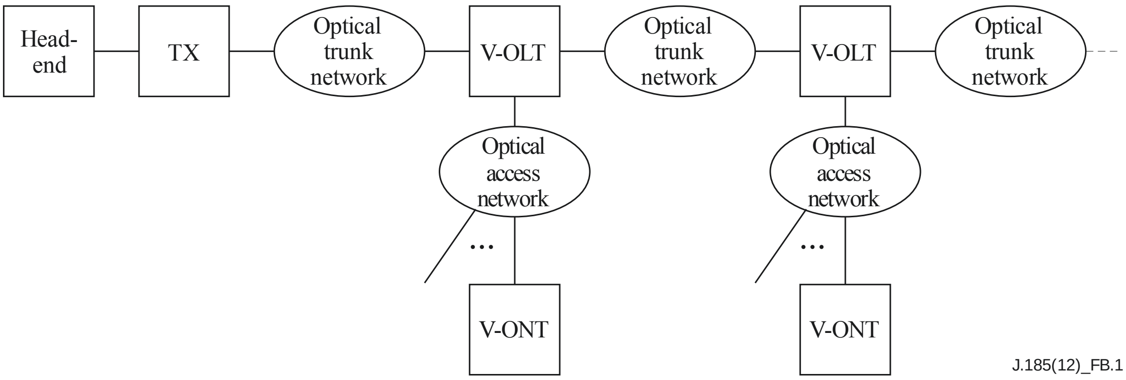


Figure B.1 – System configuration of an FM-converted multi-channel video signal transmission system

V-OLT consists of a repeater amplifier unit (RA-U) and amplifier/branch-units (AMP/BRC-U). The RA amplifies the optical signal from the TX and launches its optical output to the trunk network to the next V-OLT or to the AMP/BRC-Us. The AMP/BRC-Us amplify and branch the optical signal output from the RA. The operation interface collects alarms from the whole system and transmits them to the operation and management network. AMP/BRC-Us can be cascaded in several stages provided the specified RIN degradation is not exceeded. The optical signal output from V-OLT is further branched by optical splitters and transmitted to the V-ONT in the customer's premises.

The V-ONT converts the optical input signal into a single electrical super-wideband FM signal in the optical/electrical converter, and the electric signal is then demodulated into FDM multi-channel video signals by the frequency demodulator. The demodulated signal output by the V-ONT is input to the STB and the TV set.

Table B.1 summarizes the functions of each device.

Table B.1 – Functions of each device

Device	Functions
TX	TX converts frequency-division multiplexed AM-VSB analogue and digital video signals into one single electrical super-wideband FM signal, and then converts this FM signal into an intensity-modulated optical signal. Alarm signals are transmitted from TX to V-OLT through metallic pairs by using a data modem.
V-OLT	The V-OLT amplifies the optical input signal from the TX or the precedent V-OLT and launches the optical output power to the following optical trunk network or the optical access network.
V-ONT	V-ONT converts input optical signal to a single electrical super-wideband FM signal, and then demodulates it to frequency-division multiplexed AM-VSB analogue and digital video signals.

B.1.2 Main characteristics

Table B.2 shows the main characteristics of the FM-converted multi-channel video signal transmission system.

Table B.2 – Main characteristics of FM-converted multi-channel video signal transmission system

Item and parameter	Limit
Frequency of transmitted FDM video signals, F_{tr}	$47 \le F_{tr} \le 864$ MHz $1000 \le F_{tr} \le 2150$ MHz
Relative intensity noise due to optical fibre transmission from TX to V-ONT	≤ -136 dB/Hz

NOTE – Frequency band of transmitted FDM video signals, $47 \le F_{tr} \le 2150$ MHz, includes regional CATV bands of 54 to 864 MHz for North America, 47 to 862 MHz for Europe, and 90 to 770 MHz and 1000 to 2150 MHz for Japan.

B.1.3 Total number of FDM carriers and their frequency deviation

The total number of carriers and their FM frequency deviation is required to comply with the following formula:

$$\sqrt{\sum_{j}^{N} \Delta F_j^{\,2}} \le 700$$

where:

N Total number of FDM carriers

ΔF_j FM frequency deviation of jth carrier, $MHz_{0\text{-}p}$/carrier

B.2 TX

B.2.1 Configuration of TX

Figure B.2 provides a block diagram of a typical TX. The FM converter multiplexes the optional pilot signal with the FDM video signals input via one or more RF IN ports, and then converts them to a single super-wideband FM signal with emphasis. The emphasis compensates the triangular noise generated by FM conversion. This FM signal is converted into an IM optical signal by an electrical/optical converter (E/O). The IM optical signal is input to an optional dispersion compensation fibre and then amplified by an optional optical amplifier, if necessary. The amplified optical signal from OPT OUT is transmitted to the V-OLT. The dispersion compensation fibre compensates the chromatic dispersion of the primary transmission fibre from TX to V-OLT.

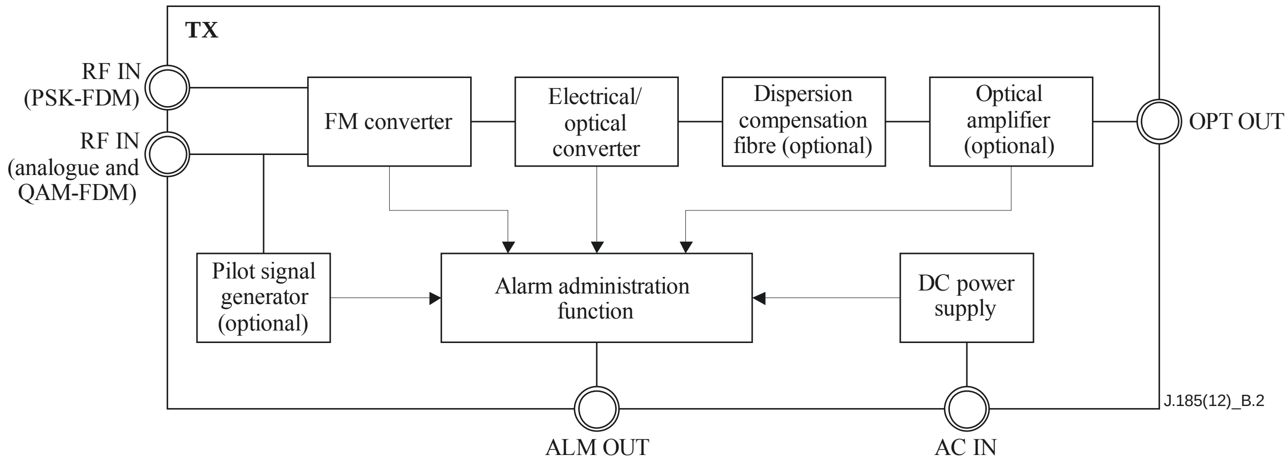


Figure B.2 – Configuration of TX

The pilot signal is used in order to confirm that signal transmission to V-OLT and V-ONT was normal. It is possible to modulate the pilot signal with angular modulation if necessary. 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 optionally provided, including the RF input signal, the FM converted signal, and the optical output signal for measuring the signal quality during system operation.

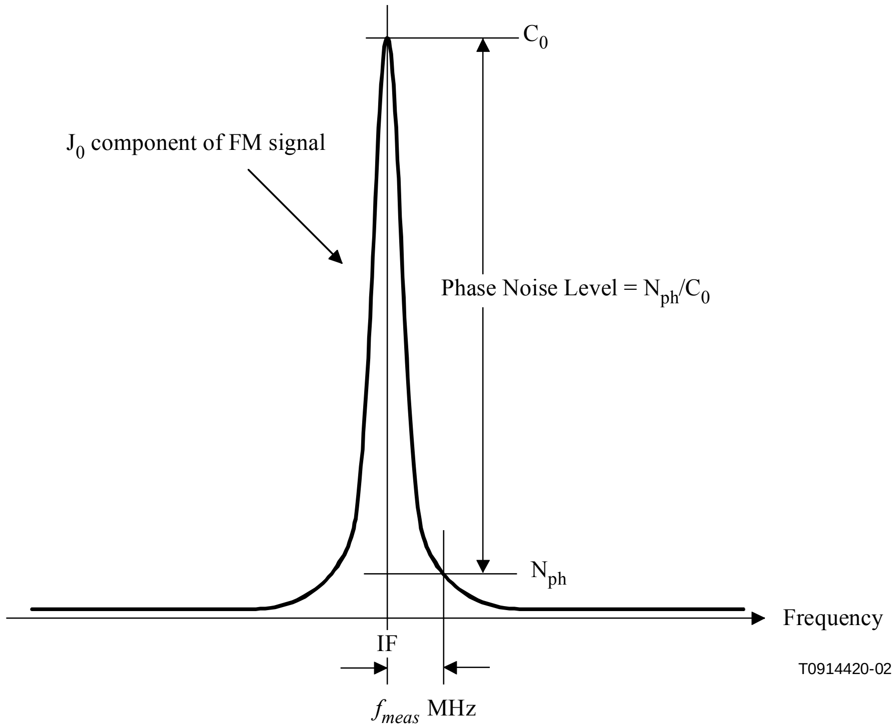
The alarm administration function collects the alarms generated by each function. When an alarm is collected, it is transferred from ALM OUT to the operation interface function of the V-OLT.

B.2.2 Main characteristics of TX

Main characteristics of TX are shown in Table B.3. Figure B.3 shows how to measure the electrical phase noise level. Electrical phase noise is measured at the frequency offset of f_{meas} MHz from IF when video modulation is not applied.

Table B.3 – Main characteristics of TX

Item and parameter		Limit	Meaning and condition
Electrical input signal	Reference level	Not specified	
	Impedance of RF IN port	75 Ω unbalanced	
Total deviation of RF carriers		700 MHz	
Emphasis level difference for triangular noise of FM modulation		12.9 ± 1.0 dB	For input RF frequencies from 47 MHz to 864 MHz.
		8.4 ± 1.0 dB	For input RF frequencies from 1000 to 2150 MHz.
Output optical signal	Optical spectrum	Single longitudinal mode	
	Wavelength	1555 ± 5 nm	
	Output power	≥ +0 dBm	When optical amplifier is not used.
	Optical modulation index, OMI	70 ≤ OMI ≤ 95%	
	Relative intensity noise, RIN	≤ −140 dB/Hz	RIN of optical output signal from TX.
	SBS tolerance	+12 dBm	Launch into 65 km ITU-T G.652 fibre.
Electrical phase noise		$\leq 10\log_{10}\left(\frac{50\times10^{-9}}{2\pi f_{meas}^{2}}\right)$ dB/Hz	See Figure B.3.
Harmonic distortion	Second-order	≤ −27 dBc	Electrical level comparison against J_0 component at IF frequency when video modulation is not applied.
	Third-order	≤ −19 dBc	
FM carrier frequency, IF		3.0 ± 0.50 GHz	
Drift range of IF frequency		≤ 0.15 GHz	Drift for 5 minutes.
Suppression level of residual AM components		≥ 50 dB	See Figure B.4.



TX output spectrum when no video modulation is applied.

Figure B.3 – Definition of electrical phase noise level

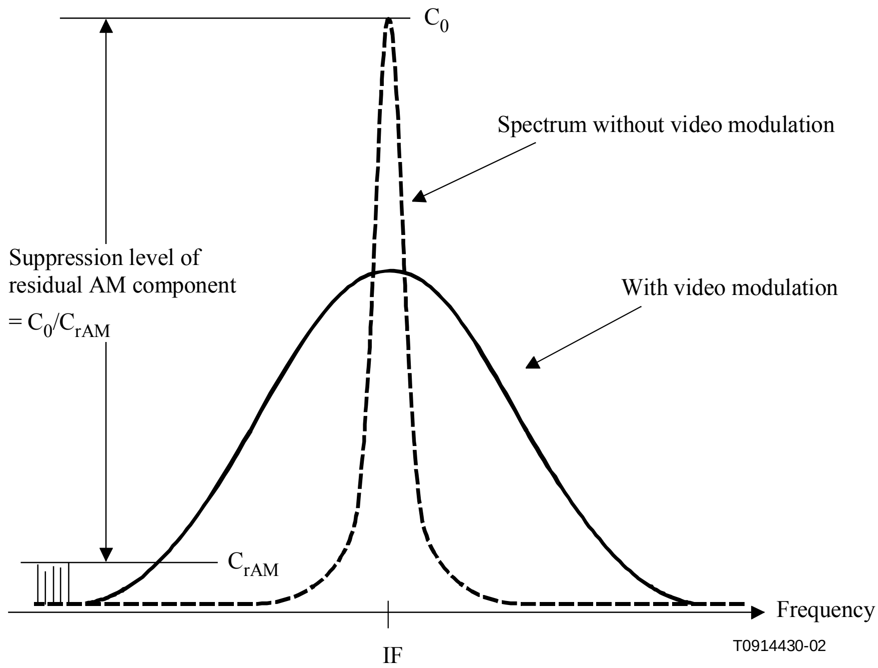


Figure B.4 – Definition of suppression level of residual AM component

B.2.3 Alarm administration items of TX

Alarm administration items that are recommended to be observed by the TX are shown in Table B.4.

Table B.4 – Alarm administration items of TX

Alarm administration item	Symbol	Alarm occurrence condition
Video transmission signal input alarm	REC	When input signal level is less than that of a single carrier.
MOD output alarm	MOD OUT	When FM converter output signal is abnormal.
E/O output alarm	E/O OUT	When optical output power level is abnormal.
Power supply alarm	PWR ALM	When an error is found in the power supply.

B.3 V-OLT

B.3.1 Configuration of V-OLT

Figure B.5 shows a block diagram of the V-OLT. The optical input signal to the V-OLT travels through optional dispersion compensation fibre (DCF) which compensates the optical chromatic dispersion of the trunk network before the V-OLT. The optical signal is then amplified by an optical repeater amplifier (RA). One or more of the RA output ports are followed by the optical trunk network to the next V-OLTs, and other output ports by cascaded distribution amplifiers and branches (AMP/BRCs). The optical output signal from the AMP/BRC is launched into the optical access network. Note that the detailed arrangement of the V-OLT is variable. For example, when a V-OLT does not accommodate optical access networks and is used only to extend the optical trunk network, the AMP/BRC can be removed. When the system does not cover the optical trunk network, the RA can be removed.

The alarm administration function collects the alarms generated by each function and transfers them to the operation interface.

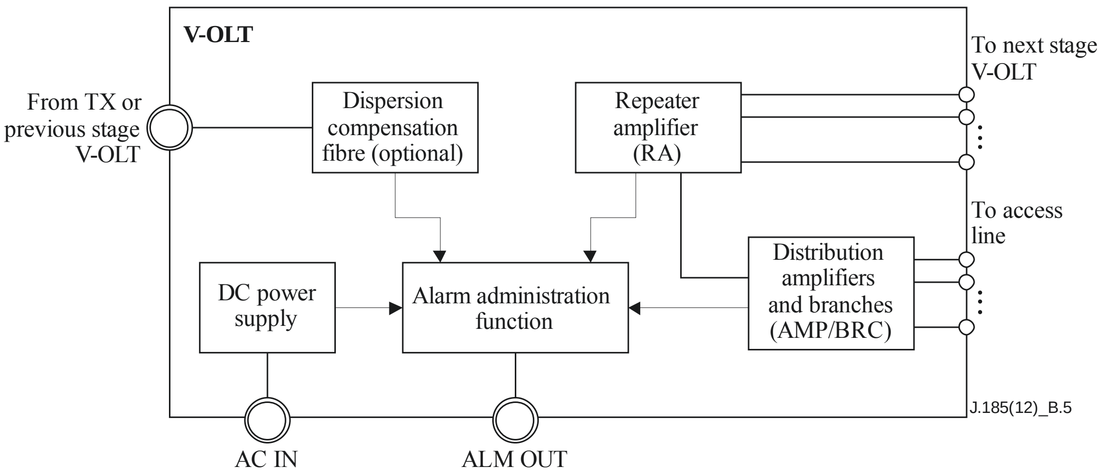


Figure B.5 – Configuration of V-OLT

B.3.2 Main characteristics of V-OLT

Table B.5 shows the main characteristics of V-OLT.

Table B.5 – Main characteristics of V-OLT

	Item and parameter	Limits	Meaning and condition
RA	Input/output optical signal wavelength, λ	1555 ± 5 nm	
	Input power	≥ –8 dBm	
	Output power	MAX +21.3 dBm (Note)	
	Noise figure	≤ 6 dB	Input power is –8 dBm.
	Relative intensity noise, RIN	≤ –141 dB/Hz	Input power is –8 dBm. Includes RIN degradation caused by opening of connector.
	The number of output ports	Not specified	
AMP/BRC	Input/output optical signal wavelength, λ	1555 ± 5 nm	
	Input power	≥ +5 dBm	
	Output power	MAX +21.3 dBm (Note)	
	Noise figure	≤ 13 dB	Input power is +5 dBm.
	Relative intensity noise, RIN	≤ –148 dB/Hz	Input power is +5 dBm.
	The number of output ports	Not specified	
NOTE – Output power of trunk network and access network is less than SBS suppression level.			

B.3.3 Alarm administration items

Alarm administration items of V-OLT are shown in Table B.6.

Table B.6 – Alarm administration items of V-OLT

Name of the function	Alarm administration item	Symbol	Alarm occurrence conditions
Optical amplifier function	Optical input alarm	REC	When optical input power level is abnormal.
	Optical output alarm	OUT	When pump light power level is abnormal. When optical output power level is abnormal.
	Power supply alarm	PWR ALM	When an error is found in the power supply.

B.4 V-ONT

B.4.1 Configuration of V-ONT

Figure B.6 shows a block diagram of V-ONT. The optical signal output from V-OLT is converted into a single electrical super-wideband FM signal by the optical/electrical converter, and then converted into the original FDM video signals by the FM demodulator. The demodulated signal is output after it is amplified to the appropriate level by the electrical amplifier. Note that in many applications, the V-ONT is integrated into the digital ONT, even to the extent that the optics of both units are integrated into a single 'triplexer'.

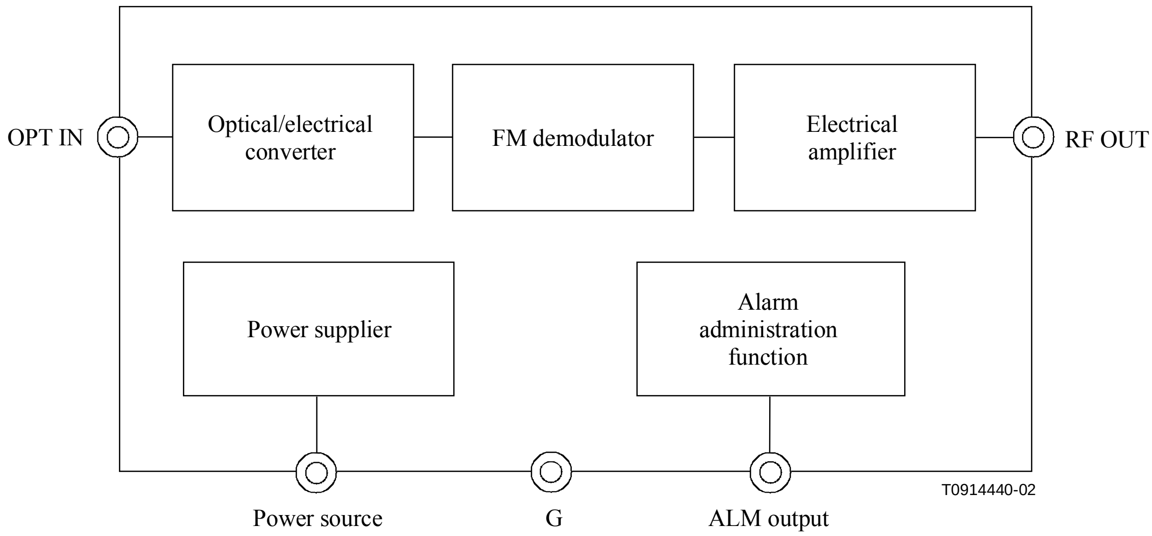


Figure B.6 – Configuration of V-ONT

Pilot signal level or total RF signal power level is observed by the alarm administration function. An alarm is output when the pilot signal level or total RF power level does not meet the specified value. This alarm indicates whether there is a transmission signal error or not.

B.4.2 Main characteristics of V-ONT

Table B.7 shows main characteristics of V-ONT.

Table B.7 – Main characteristics of V-ONT

Item and parameter		Limit and specification	Meaning and condition
Optical input	Minimum input power (Note)	≤ −15 dBm	When an O/E device is APD.
		≤ −12 dBm	When an O/E device is PIN-PD.
	Wavelength, λ	1555 ± 5 nm	
Electrical output	Power level	≥ 80 dBμV	Levels are for analogue channels. Digital channels will be 6-10 dB lower.
	VSWR	≤ 2.5	
	Impedance	75 Ω unbalanced	
NOTE – When the V-ONT is integrated in the digital ONT with a single 'triplexer', optical loss of the triplexer is recommended to be considered.			

B.4.3 Alarm administration items of V-ONT

Table B.8 lists the alarm item of V-ONT.

Table B.8 – Alarm administration item of V-ONT

Alarm administration item	Symbol	Alarm occurrence conditions
Output alarm	OUT	When the optical input power level is lower than the specified value or output RF level is abnormal.

Appendix I

FM frequency deviation and minimum received optical power for CATV band of 47 to 864 MHz

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

The acceptable level of FM frequency deviation depends on the minimum received optical power, required CNR, and noise bandwidth. The last two values depend on the modulation format of the video signal. In the FM conversion system, which is specified in this Recommendation, the transmitted signals are given an amplitude tilt of 12.9 dB to compensate the triangular noise created by FM modulation. Therefore, the FM frequency deviation of the *j*th carrier is given by Equation I.1.

NOTE – The tilt amplitude of 12.9 dB corresponds to the CATV band of 47 to 864 MHz.

$$\Delta F_j = \Delta F_C \times 10^{\frac{12.9 \cdot (f_j - f_c)}{16340}} \quad [\mathrm{MHz_{0\text{-}p}/carrier}] \tag{I.1}$$

Here, ΔF_C [MHz] is the FM frequency deviation of the carrier, which has centre frequency of *fc* [MHz]. f_j [MHz] is the frequency of the *j*th carrier. Substituting these assumed values and Equation I.1 into the formula described in clause A.1.3 yields the formula shown below.

$$\sqrt{\sum_j^N \Delta F_j^{\,2}} = \Delta F_C \sqrt{\sum_j^N 10^{\frac{12.9 \cdot (f_j - f_C)}{8170}}} \le 717.5 \qquad [MHz_{0\text{-}p}]$$

$$\Rightarrow \Delta F_C \le \frac{717.5}{\sqrt{\sum_j^N 10^{\frac{12.9 \cdot (f_j - f_C)}{8170}}}} \qquad [MHz_{0\text{-}p}/carrier] \tag{I.2}$$

Required minimum received optical power, P_{min}, is given by Equation I.3.

$$P_{min} = \frac{e + \sqrt{e^2 + \alpha \times \left(2eI_{do} + N_{th}^{\,2}\right)}}{\alpha \times R} \qquad [\mathrm{W}] \tag{I.3}$$

Here, *e* is the charge of the electron, *R* is the quantum efficiency of the photo detector in V-ONT, I_{do} is the dark current, N_{th} is the thermal noise. α is given by Equation I.4.

$$\alpha = \frac{(m \times \Delta F_C)^2}{4B_W f_C^{\,2} \times CNR_{req}} - \frac{\Delta\nu \times m^2}{4\pi f_C^{\,2}} - RIN \qquad [\mathrm{s}] \tag{I.4}$$

Here, *m* is the modulation index of the transmitted FM signal, B_W is noise bandwidth, CNR_{req} is required CNR, $\Delta\nu$ is the FM signal spectrum line width, and *RIN* is the relative intensity noise of optical signal launched into V-ONT. In Equation I.4, the carrier power of CNR_{req} is measured as peak envelope power. The assumed values for all these parameters are the following:

$\Delta\nu$	50 kHz
RIN	−135.5 dB/Hz
I_{do}	100 nA
R	0.8 A/W
N_{th}	15 pA/√Hz
m	0.7

The following conditions are assumed:

Modulation format of transmitted signal	64-QAM of Annex B of [ITU-T J.83]
Carrier frequency	Ranges from 93 MHz to 747 MHz, 6 MHz steps
Number of carriers, N	110
Centre carrier frequency, f_C	420 MHz

By substituting these values into Equation I.2, 61.0 [$\mathrm{MHz}_{0\text{-}p}$/carrier] is determined to be the maximum FM frequency deviation (ΔF_C). Therefore, the ΔF_j of this condition is given by Equation I.5.

$$\Delta F_j = 61.0 \times 10^{\frac{12.9 \cdot (f_j - 420)}{16340}} \ [\mathrm{MHz}_{0\text{-}p}/\mathrm{carrier}] \quad \text{(I.5)}$$

Thus, the required minimum received optical power, P_{min}, is calculated to be –14.7 dBm.

Appendix II

FM frequency deviation and minimum received optical power for CATV band of 47 to 2100 MHz

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

The acceptable level of FM frequency deviation depends on the minimum received optical power, required CNR, and noise bandwidth. The last two values depend on the modulation format of the video signal. In the FM conversion system specified in this Recommendation, the transmitted signals are given an amplitude tilt of 12.9 dB and 8.4 dB to compensate the triangular noise created by FM modulation. Therefore, the FM frequency deviation of the *j*th carrier is given by Equations II.1 and II.2.

NOTE – The tilt amplitude of 12.9 dB and 8.4 dB corresponds to the CATV band of 47 MHz to 864 MHz and satellite intermediate frequency band of 1000 MHz to 2150 MHz, respectively.

$$\Delta F_j = \Delta F_C \times 10^{\frac{12.9\cdot(f_j - f_C)}{16340}} \text{ [MHz}_{0\text{-p}}\text{/carrier]} \quad \text{(II.1)}$$

$$\Delta F_j = \Delta F_{SAT} \times 10^{\frac{8.4\cdot(f_j - f_{SAT})}{23000}} \text{ [MHz}_{0\text{-p}}\text{/carrier]} \quad \text{(II.2)}$$

Here, ΔF_C [MHz] is the FM frequency deviation of the carrier, which has centre frequency of f_C [MHz] for 47 to 864 MHz, and ΔF_{SAT} [MHz] is the FM frequency deviation of the carrier, which has lowest frequency of f_{SAT} for 1000 MHz to 2150 MHz. f_j [MHz] is the frequency of the *j*th carrier. ΔF_{SAT} is obtained with Equation II.1 by substituting f_{SAT} for f_j and adjusting the difference in required CNR with peak power and noise bandwidth from 64QAM, by 11.3 dB. Substituting these assumed values and Equations II.1 and II.2 into the formula described in clause B.1.3 yields the formula shown below.

$$\sqrt{\sum_{j}^{N} \Delta F_j^{\,2}} = \Delta F_C \sqrt{\sum_{j}^{N1} 10^{\frac{12.9\cdot(f_j - f_C)}{8170}} + 10^{\frac{-11.3}{10}} \sum_{j}^{N2} 10^{\frac{8.4\cdot(f_j - f_{SAT})}{11500}}} \le 700 \qquad [\text{MHz}_{0\text{-p}}]$$

$$\Rightarrow \Delta F_C \le \frac{700}{\sqrt{\sum_{j}^{N1} 10^{\frac{12.9\cdot(f_j - f_C)}{8170}} + 10^{\frac{-11.3}{10}} \sum_{j}^{N2} 10^{\frac{8.4\cdot(f_j - f_{SAT})}{11500}}}} \qquad [\text{MHz}_{0\text{-p}}/\text{carrier}] \quad \text{(II.3)}$$

N_1 and N_2 are the number of carriers for 47 MHz to 864 MHz band and for 1000 MHz to 2150 MHz band, respectively.

Required minimum received optical power, P_{min}, is given by Equation II.4.

$$P_{min} = \frac{e + \sqrt{e^2 + \alpha \times \left(2eI_{do} + N_{th}^{\,2}\right)}}{\alpha \times R} \qquad [\text{W}] \quad \text{(II.4)}$$

Here, e is the charge of the electron, R is the quantum efficiency of the photo detector in V-ONT, I_{do} is the dark current, N_{th} is the thermal noise. α is given by Equation II.5.

$$\alpha = \frac{(m \times \Delta F_C)^2}{4B_W f_C^{\,2} \times CNR_{req}} - \frac{\Delta\nu \times m^2}{4\pi f_C^{\,2}} - RIN \qquad [\text{s}] \quad \text{(II.5)}$$

Here, m is the modulation index of the transmitted FM signal, B_W is noise bandwidth, CNR_{req} is required CNR, $\Delta\nu$ is the FM signal spectrum line width, and RIN is the relative intensity noise of optical signal launched into V-ONT. In Equation II.5, the carrier power of CNR_{req} is measured as peak envelope power. The assumed values for these parameters are as follows:

$\Delta\nu$	50 kHz
RIN	−136 dB/Hz
I_{do}	100 nA
R	0.9 A/W
N_{th}	15 pA/√Hz
m	0.7

The following conditions are assumed:

Modulation format of transmitted signal	64-QAM of Annex B of [ITU-T J.83] and TC8PSK
Carrier frequency	Ranges from 93 MHz to 747 MHz, 6 MHz steps for 64QAM, and from 1049.48 MHz to 1471.44 MHz, 38.38 MHz steps and from 1613 MHz to 2053 MHz, 40 MHz steps for TC8PSK based on the intermediate frequency allocation of the digital satellite video signals in Japan
Number of carriers, N	110 for 64QAM and 24 for TC8PSK
Centre carrier frequency of 64 QAM, f_C	420 MHz

By substituting these values into Equation II.3, 51.5 [$\text{MHz}_{0\text{-p}}$/carrier] is determined to be the maximum FM frequency deviation (ΔF_C). Therefore, the ΔF_j for 64 QAM and TC8PSK of this condition is given by Equations II.6 and II.7.

$$\Delta F_j = 51.5 \times 10^{\frac{12.9 \cdot (f_j - 420)}{16340}} \ [\text{MHz}_{0\text{-p}}/\text{carrier}] \tag{II.6}$$

$$\Delta F_j = 44.0 \times 10^{\frac{8.4 (f_j - 1049.48)}{23000}} \ [\text{MHz}_{0\text{-p}}/\text{carrier}] \tag{II.7}$$

Thus, the required minimum received optical power, P_{min}, is calculated to be –14.6 dBm.

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