INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
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OF ITU

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

Miscellaneous

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

ITU-T Recommendation J.185

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ITU-T Recommendation J.185

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

Summary

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

Source

ITU-T Recommendation J.185 was prepared by ITU-T Study Group 9 (2001-2004) and approved under the WTSA Resolution 1 procedure on 13 February 2002.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. 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.

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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, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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ITU-T Recommendation J.185

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

1 Background

For an undetermined period during the crossover from analogue to digital transmission, it will be necessary for optical access networks to carry both formats. Digital signals should be carried via Frequency-Division Multiplexing (FDM) together with analogue signals in order to assure an orderly transition from analogue to digital formats.

2 Scope

This Recommendation describes a method of transmitting multi-channel television signals over an optical access network that utilizes 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 CATV signals. The interface for this FM transmission system is the same as that of the AM-SCM system. Therefore, the FM transmission system can replace the AM-SCM system. The FM transmission system must 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.

The system can be added to the G.983.1 ATM-based optical access system by using G.983.3 WDM technology. 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 G.983.1 ATM-based optical access system technology, upstream signals, e.g. control functionality and upstream data indicating the user's requirements, can be transmitted as well.

3 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.

3.1 Normative references

– ITU-T Recommendation J.83 (1997), *Digital multi-programme systems for television, sound and data services for cable distribution*.

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

3.2 Informative references

– ITU-T Recommendation G.983.1 (1998), *Broadband optical access systems based on Passive Optical Networks (PON)*.

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

4 Abbreviations, symbols and conventions

4.1 Abbreviations

This Recommendation uses the following abbreviations:

AMP/BRC-U	Amplifier and Branch Unit
AM-VSB	Amplitude Modulation Vestigial Sideband
CATV	Cable Television
CNR	Carrier-to-Noise Ratio
CSO	Composite Second Order distortion
CTB	Composite Triple Beat distortion
D/U	Desired-to-Undesired signal ratio
FDM	Frequency-Division Multiplexing
FM	Frequency Modulation
IF	Intermediate Frequency
OMI	Optical Modulation Index
PIN-PD	p-i-n Photo Diode
QAM	Quadrature Amplitude Modulation
RF	Radio Frequency
RIN	Relative Intensity Noise
SCM	Sub-Carrier Multiplexing
SL-APD	Super Lattice Avalanche Photo Diode
STB	Set-Top Box
TX	Transmitter
V-OLT	Optical Line Terminal for Video signals
V-ONT	Optical Network Terminal for Video signals
WDM	Wavelength-Division Multiplexing
XM	Cross Modulation distortion

4.2 Symbols

This Recommendation uses the following symbols:

F_{tr}	Video signal frequency
B_{FM}	Bandwidth of FM signal
C_0	Amplitude of J_0 component (electrical level) when video modulation is not applied

C_{rAM}	Maximum amplitude of residual AM components
f	Carrier frequency
N_{ph}	Electrical noise level at the frequency of f_{meas} MHz far from IF when video modulation is not applied.
γ	Optical signal wavelength

4.3 Conventions

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

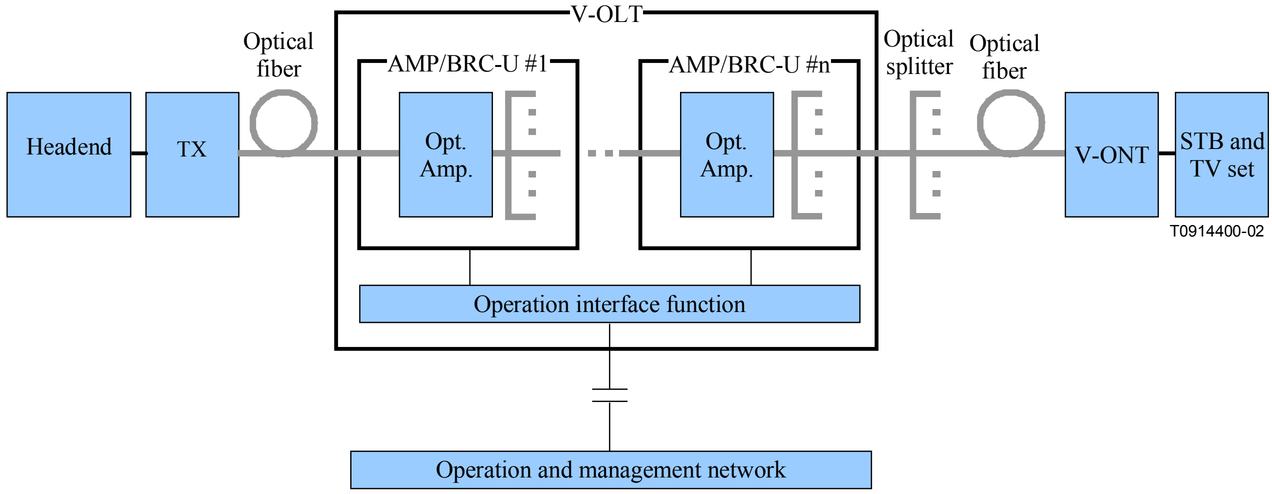
The key words indicating a certain level of significance of a particular requirements that are used throughout this Recommendation are summarized below.

"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 exist 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 behaviour 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.

5 System description

5.1 System configuration

Figure 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. Frequency-Division Multiplexing (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 1/J.185 – 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 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 1 summarizes the functions of each device.

Table 1/J.185 – 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 convert 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.

5.2 Main characteristics

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

Table 2/J.185 – Main characteristics of FM-converted multi-channel video signal transmission system

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

5.3 Total number of FDM carriers and their frequency deviation

The total number of carriers and their FM frequency deviation must 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, $MHz_{0\text{-}p}$/carrier

f_{max} Maximum carrier frequency, MHz

6 TX

6.1 Configuration of TX

Figure 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 intensity-modulated (IM) optical signal by an electrical/optical converter (E/O). The IM optical signal is input to a dispersion compensation fiber, and then amplified by an optical amplifier. The amplified optical signal from OPT OUT is transmitted to the V-OLT. The dispersion compensation fiber compensates the chromatic dispersion of the primary transmission fiber from TX to V-OLT.

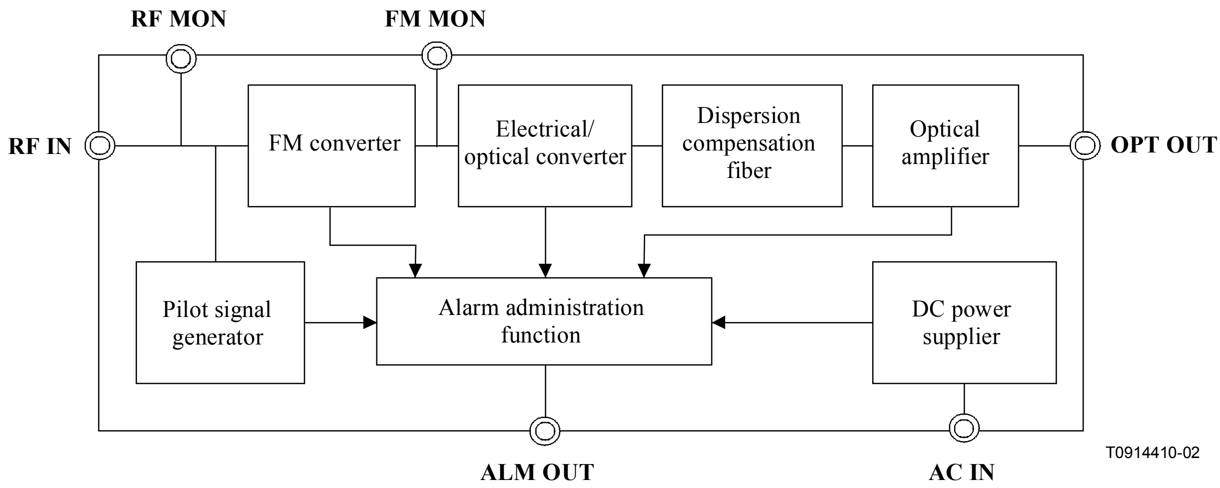


Figure 2/J.185 – Configuration of TX

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.

6.2 Main characteristics of TX

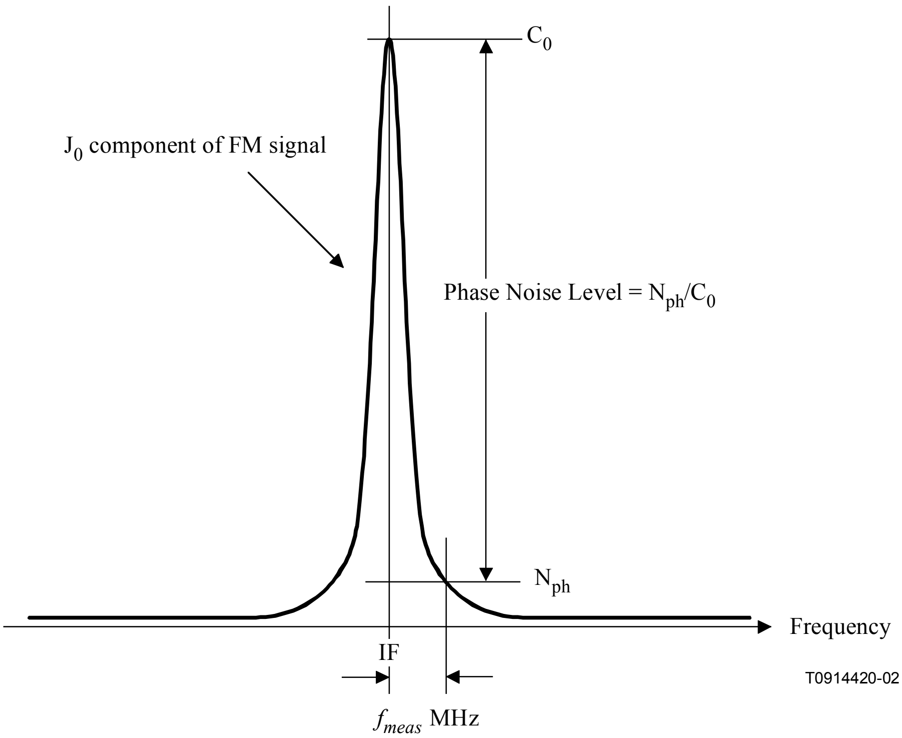
Main characteristics of TX are shown in Table 3. Figure 3 shows how to measure the electrical phase noise level. Electrical phase noise is measured at the frequency of f_{meas} MHz far from IF when video modulation is not applied.

Table 3/J.185 – 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	

Table 3/J.185 – Main characteristics of TX

Item and parameter		Limit	Meaning and condition
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 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	
Intermediate 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 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 3/J.185 – Definition of electrical phase noise level

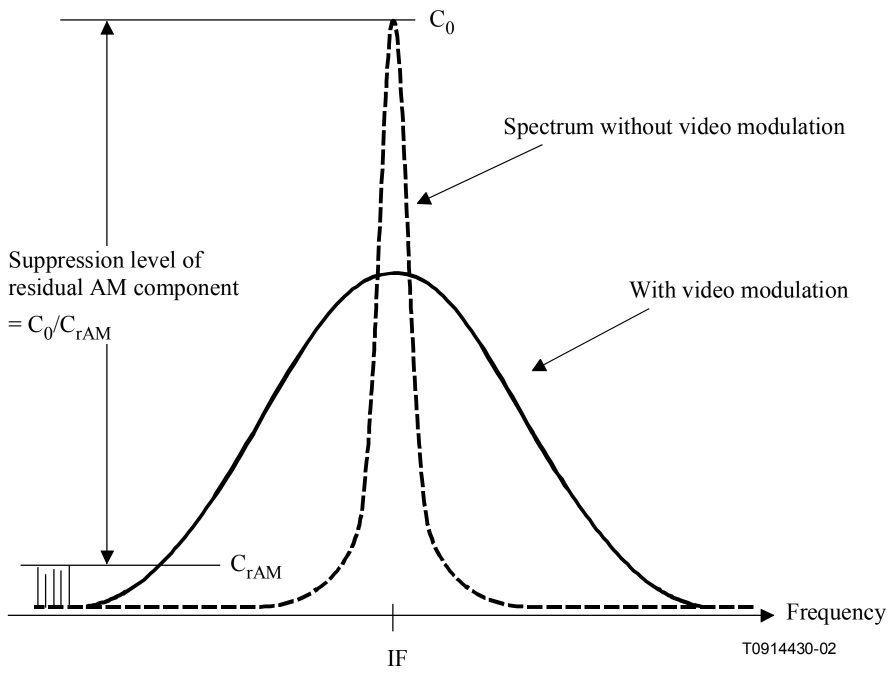


Figure 4/J.185 – Definition of suppression level of residual AM component

6.3 Alarm administration items of TX

Alarm administration items that should be observed by the TX are shown in Table 4.

Table 4/J.185 – 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

7 V-OLT

7.1 Main characteristics of V-OLT

Table 5 shows the main characteristics of V-OLT.

Table 5/J.185 – 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	

7.2 Alarm administration items

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

Table 6/J.185 – Alarm administration items of V-OLT

Name of the function	Item of alarm administration	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

8 V-ONT

8.1 Configuration of V-ONT

Figure 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.

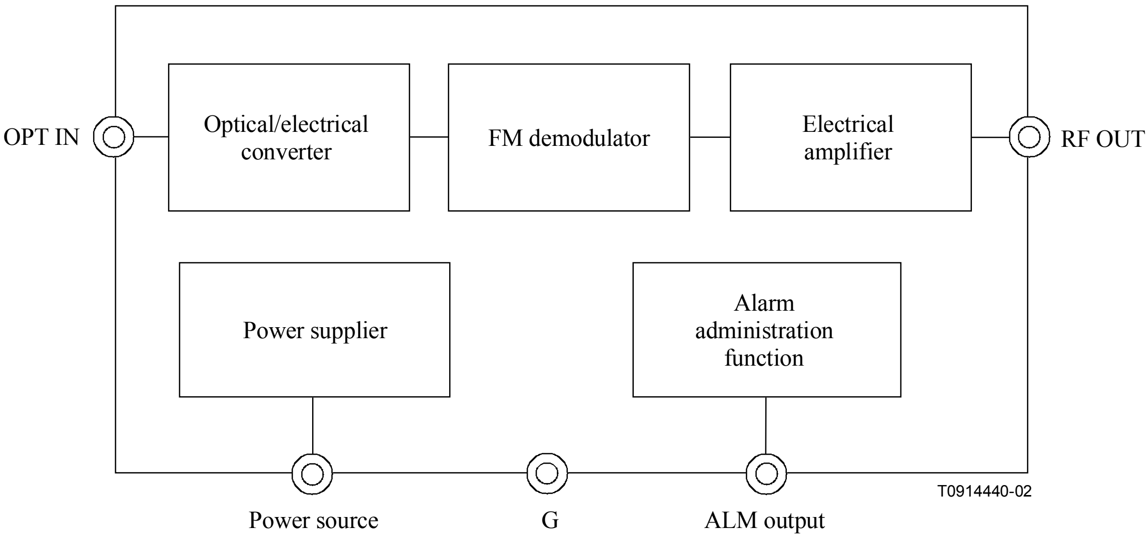


Figure 5/J.185 – Configuration of V-ONT

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.

8.2 Main characteristics of V-ONT

Table 7 shows main characteristics of V-ONT.

Table 7/J.185 – 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	

8.3 Alarm administration items of V-ONT

Table 8 lists the alarm item of V-ONT.

Table 8/J.185 – Alarm administration item of V-ONT

Item of alarm administration	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 A

Performance of analogue and/or digital video transmission system

A.1 Specified transmission quality for analogue video signal

Table A.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 A.1/J.185 – Specified transmission quality for analogue video signal

TV system	M-system NTSC	B, G-system PAL	L-system SECAM
Noise bandwidth	4.2 MHz	4.75 MHz	5.0 MHz
CNR	≥ 44 dB	≥ 44 dB	≥ 44 dB
CSO	≤ −55 dB	≤ −52 dB	≤ −52 dB
CTB	≤ −54 dB	≤ −52 dB	≤ −52 dB
XM	≤ −46 dB	≤ −46 dB	≤ −46 dB

A.2 Specified transmission quality for digital video signal

Table A.2 show specified transmission quality for the digital video signal.

Table A.2/J.185 – Specified transmission quality for the digital video signal

	64-QAM signal			
	Annex A/J.83	Annex B/J.83	Annex C/J.83	256-QAM signal
Noise bandwidth	8.0 MHz	6.0 MHz	4.0 MHz	6.0 MHz
CNR	≥ 27 dB [a), b)]	≥ 27 dB [a), b)]	≥ 31 dB [c)]	≥ 33 dB [a), b)]
Second-order D/U	Not specified	Not specified	Under study [d)]	Not specified
Third-order D/U	Not specified	Not specified	≤ −43 dB [e)]	Not specified

a) This value includes the simultaneous presence of all impairments in the 6-MHz channel bandwidth including composite distortion or other discrete interference components.

b) The carrier power is measured as the average RMS signal power.

c) The carrier power is measured as the peak envelope power.

d) Refer to Annex A/J.87.

e) These undesired signals are caused by interference among AM-VSB channels.

Appendix I

FM frequency deviation and minimum received optical power

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 jth 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.

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

Here, ΔF_C is the FM frequency deviation of the carrier, which has center frequency of fc. f_j [MHz] is the frequency of the jth carrier. Substituting these assumed values and Equation (I-1) into the formula described in 5.3 yields the formula shown below.

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

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

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

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

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).

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

Here, m is the modulation index of the transmitted FM signal, B_W is noise bandwidth, CNR_{req} is required CNR, Δv 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:

Δv	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/J.83
Carrier frequency	Ranges from 93 MHz to 747 MHz, 6 MHz steps
Number of carriers, N	110
Center carrier frequency, f_C	420 MHz

By substituting these values into Equation (I-2), 61.0 [$MHz_{0\text{-}p}$/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).

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

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

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