Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Introduction of VLCC, VLC Physical Layer Specification Version 1.0.]
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Abstract: [Introduction of VLCC, Visible Light Communication Physical Layer Specification Version 1.0.]
Purpose: [Contribution to IEEE 802.15 TG7]

Introduction of VLCC Visible Light Communication Physical Layer Specification Version 1.0.

Gontaro Kitazumi

Visible Light Communications Consortium

VLC Physical Specification

Concepts & Usage Models

Concepts

- The existing white LEDs for illumination must be able to use.
  - LED down-lights, fluorescent-lamp style LEDs,
  - Light-bulb style LEDs, LED signboards, LED backlights etc.
- Don't spoil the original functions of LED illumination.
- Both of proximity communications are supported:
  - Broadcasting type (LED illumination -> Mobile)
  - Peer to Peer type (Mobile <-> Mobile)
- A transfer of broadcast information is possible, using power-source lines (using PLC or other)
- Minimize modifications of the existing mobile side devices (Only enhancement of IrDA devices)
- Construction of the physical layer is independent from upper protocol layers.

Relationships between Proximity Communications and Contents Data Size

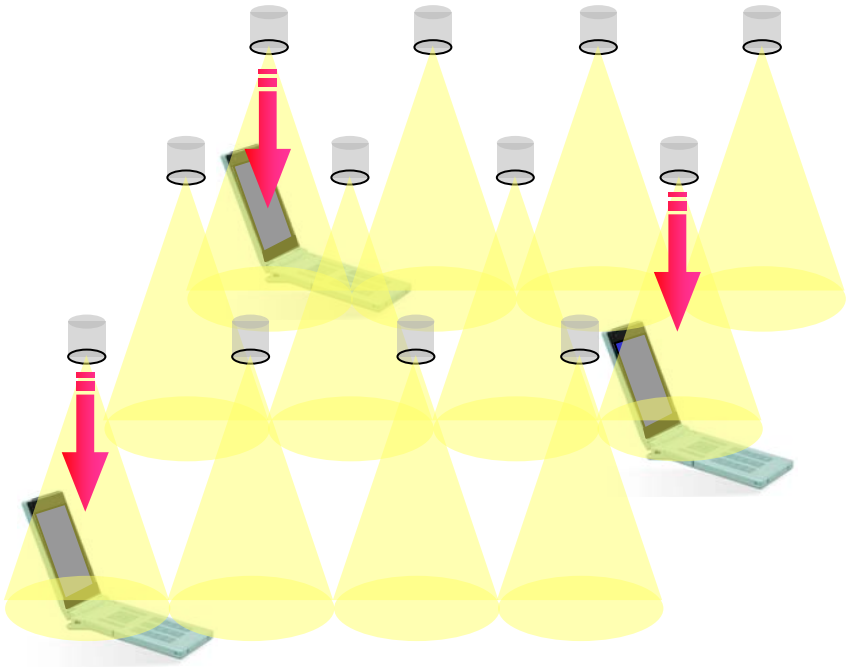
VLC & Related Technologies	Speed Bits / Sec (bps) (Bytes / Sec)	Text data 1000 characters 1k bytes	Image data JPEG 2M pixels 500k bytes	Music data MP3 3min 30sec 3.5M bytes
VLCC ID / TAG (JEITA CP-1221)	4.8k bps (480Bytes/sec)	2Sec	N/A	N/A
IrDA MIR	1M bps (125kbytes/sec)	1mSec	4Sec	28Sec
VLCC PHY V1.0 (IrDA FIR)	4M bps (500kbytes/sec)	250 μ Sec	1Sec	7Sec
IrDA VFIR	16M bps (2.0Mbytes/sec)	63 μ Sec	0.25Sec	1.75Sec
IrDA UFIR	100M bps (12M bytes/sec)	1 μ Sec	0.04Sec	0.3Sec
IrDA Giga-IR	1G bps (120M bytes/sec)	0.1 μ Sec	4mSec	30mSec

V1.0

4Mbps transfer capability is good solution for Minimized multimedia contents.
Note: Currently, VLCC and IrDA are co-working for VLC solutions.

Typical usage models (1)

(A) Point to Multipoint usage Model
(broadcasting type)



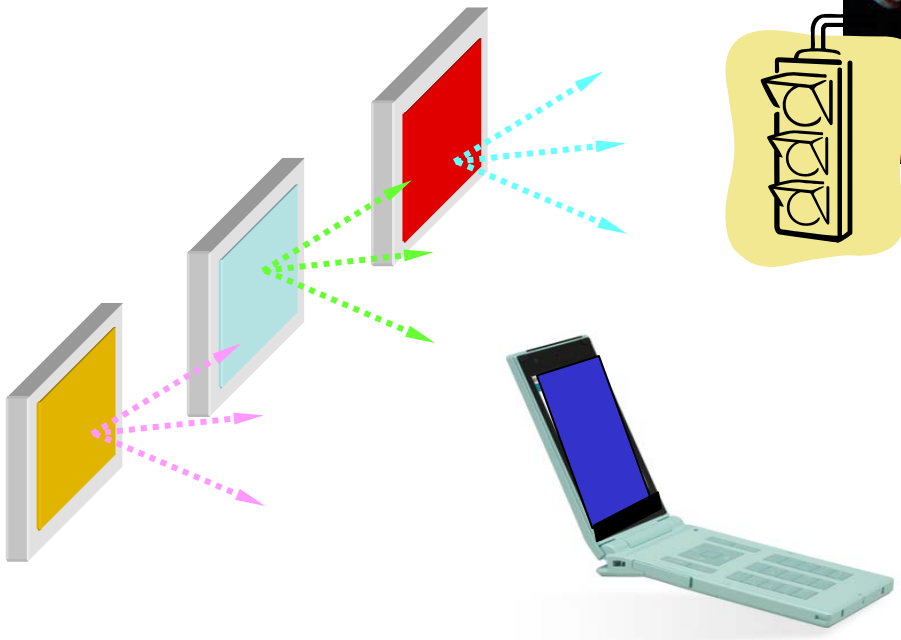
Pinpoint information system using
Down-light illuminations

Special feature:
Two or more information deliveries using the ***directivity*** of light independently.

Applications:
Audio / Picture guidance for Museums, Art Museums, Exhibition halls,
Public area information,
Show room description of items or etc

Typical usage models (2)

(A) Point to Multipoint usage Model
(broadcasting type)



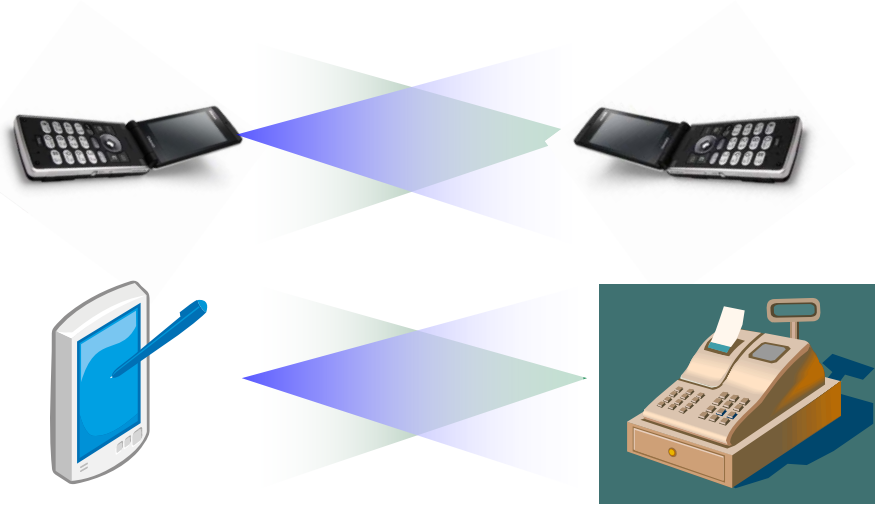
Advertising illuminations or
Digital signage systems

Special feature:
information are
directly gettable from
a signboards.

Applications:
Text / Picture Information for
Shops, Bus-stops,
Train station, Airports,
Inside of vehicles,
Traffic Signals,
etc

Typical usage models (3)

(B) Point to Point usage Model



Information exchange between mobile devices

Special feature:
Reliable information interchange

Applications:
Personal Information Exchange for
Cell phone,
Portable devices,
POS resister / cashier,
etc

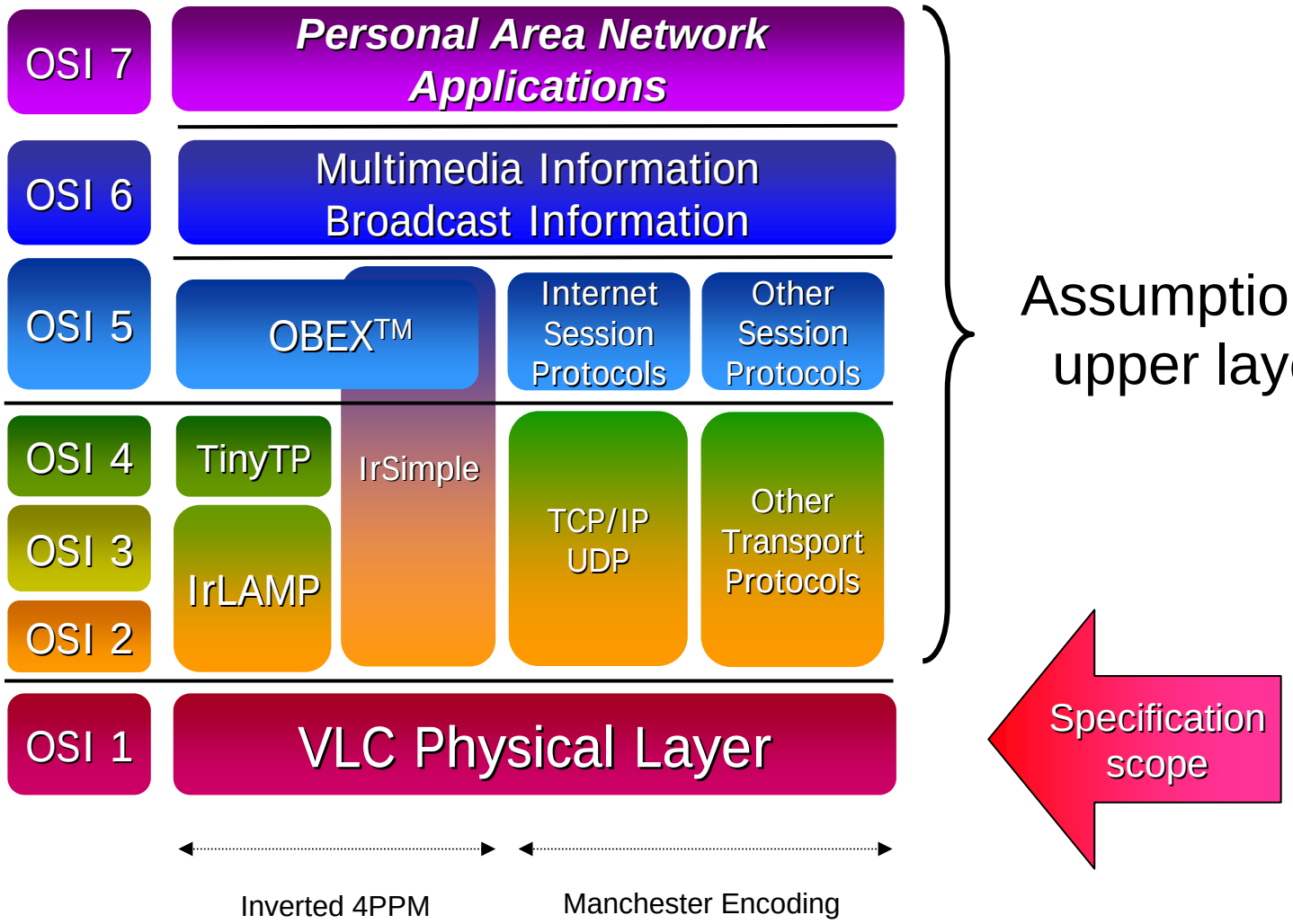
VLC Physical Specification

Protocol layer positioning

&

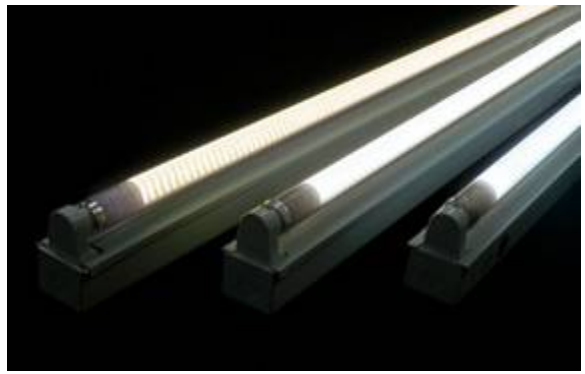
Market Requirements

Scope of VLC physical Layer



Assumption physical devices (Market Requirements)





- White LED which uses fluorescent materials.
- High-intensity single color LEDs (R,G,B…).
- fluorescent-lamp style LEDs.

VLC Physical Specification

Overview of Specification

Visible Light Communication Link Overview

- Optical Wavelength ranges:
  - from 400nm to 780nm (Human visible area)
- Moderation Data rate:
  - 4.0 Mbps (Clock = 8.0MHz)
- Modulation Method:
  1. Manchester data code encoding
  2. Inverted-4 Pulse Position Modulation
     …for compatibility of IrDA FIR modulation method

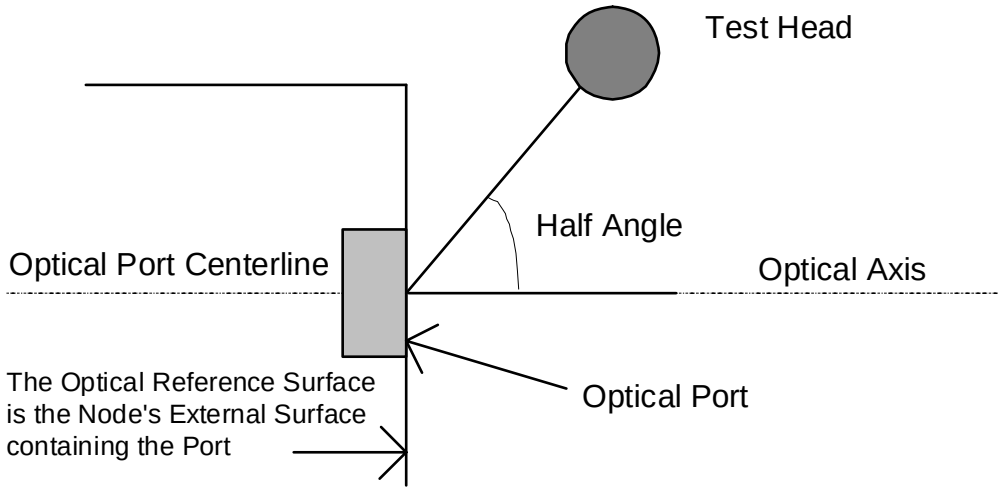
Eye Safety Standards

- VLC Physical Layer Specification complies with CIE S 009/IEC 62471.
  - CIE S 009/IEC 62471 gives guidance for evaluating the photo-biological safety of lamps and lamp systems including luminaries.
  - Specifically it specifies the exposure limits, reference measurement technique and classification scheme for the evaluation and control of photo-biological hazards from all electrically powered incoherent broadband sources of optical radiation, including LEDs but excluding lasers, in the wavelength range from 200 nm through 3000 nm.

VLC Physical Specification

Optical measurement conditions

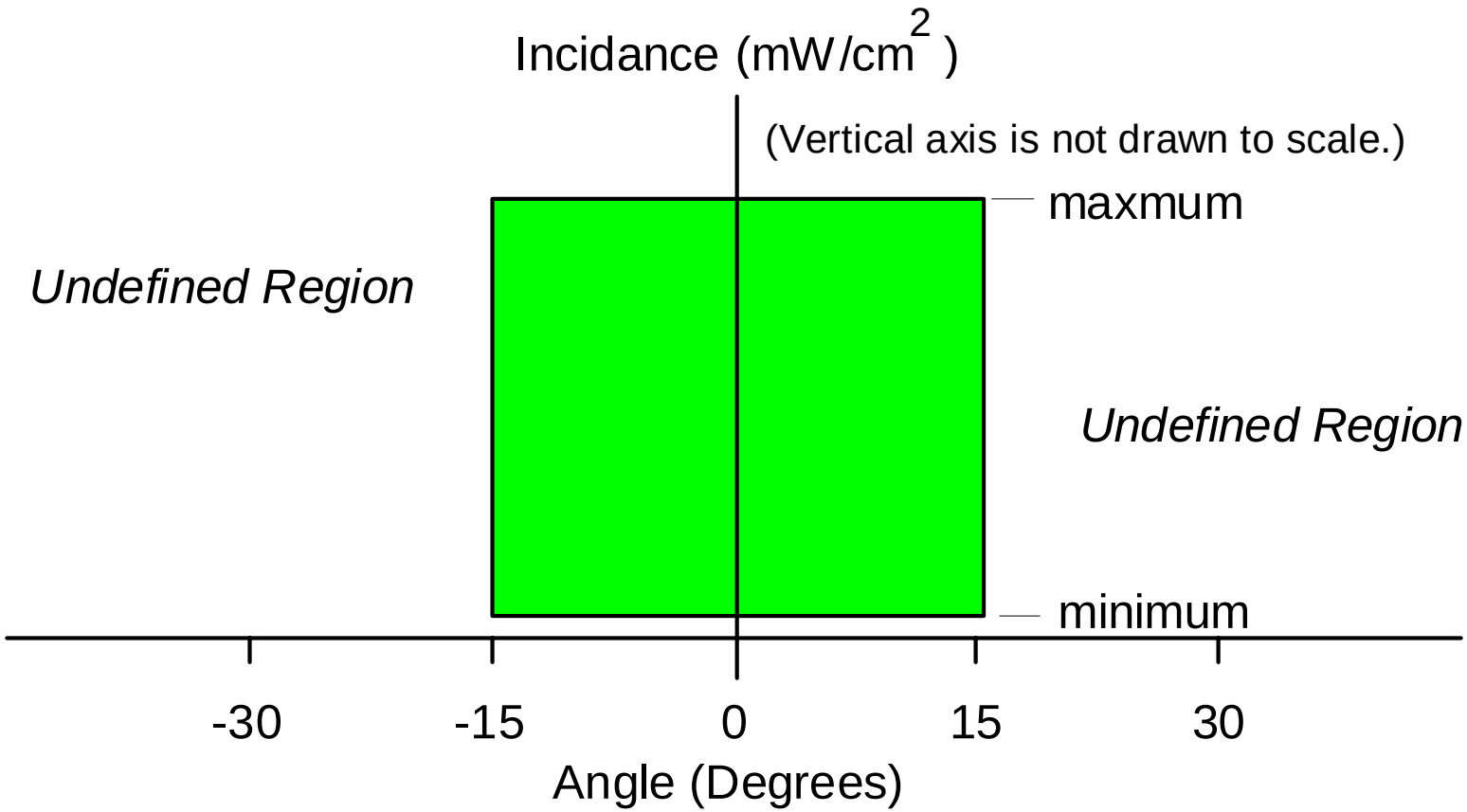
Optical Port Measurements (1)



Optical Port Angle Measurement Geometry

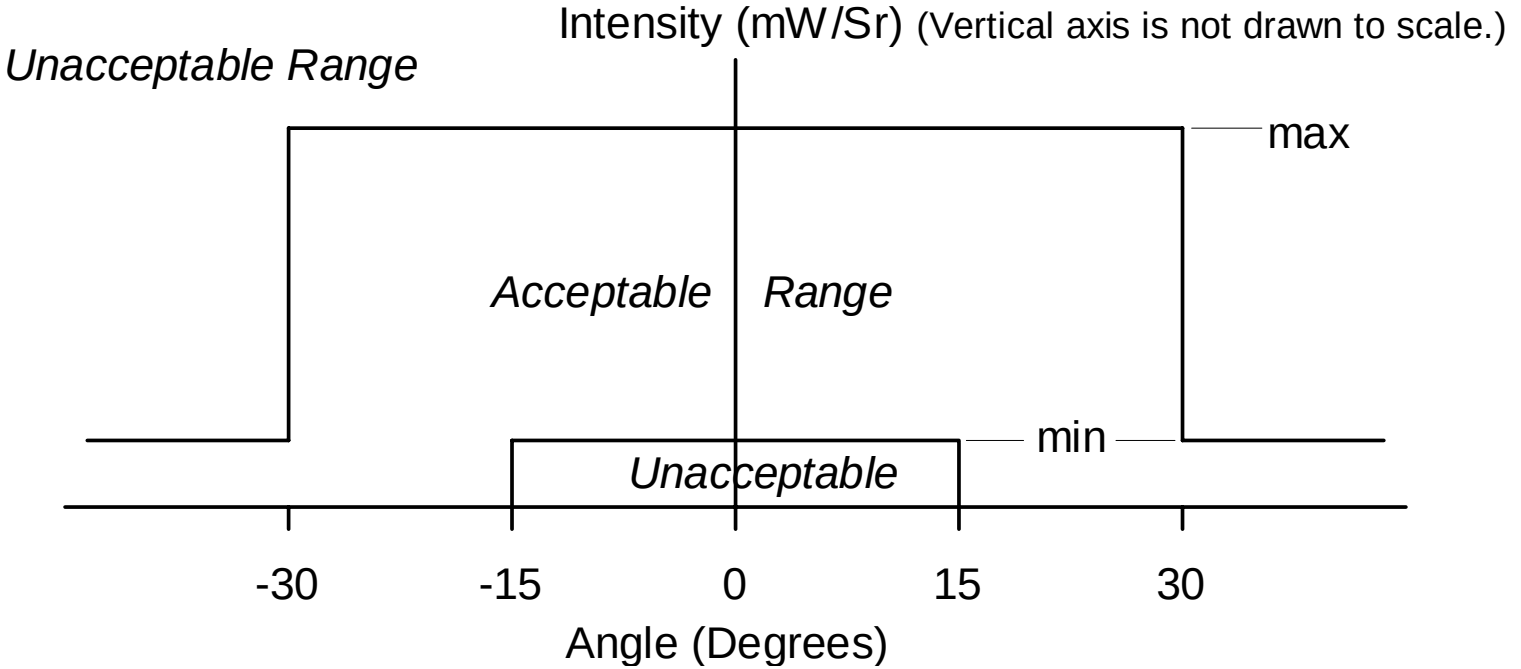
- Define minimum Bit Error Ratio (BER)
- Define BER test conditions
  - Background Optical Noise or Ambient Noise
  - Testing data bit pattern
- Define acceptable angle or geometric profile
- Define min-max receiver sensitivities [W/m^2]
- Define min-max connection distances [m]

Optical Port Measurements (2)



Optical Receiver Acceptable Range (Half angle 15)

Optical Port Measurements (3)

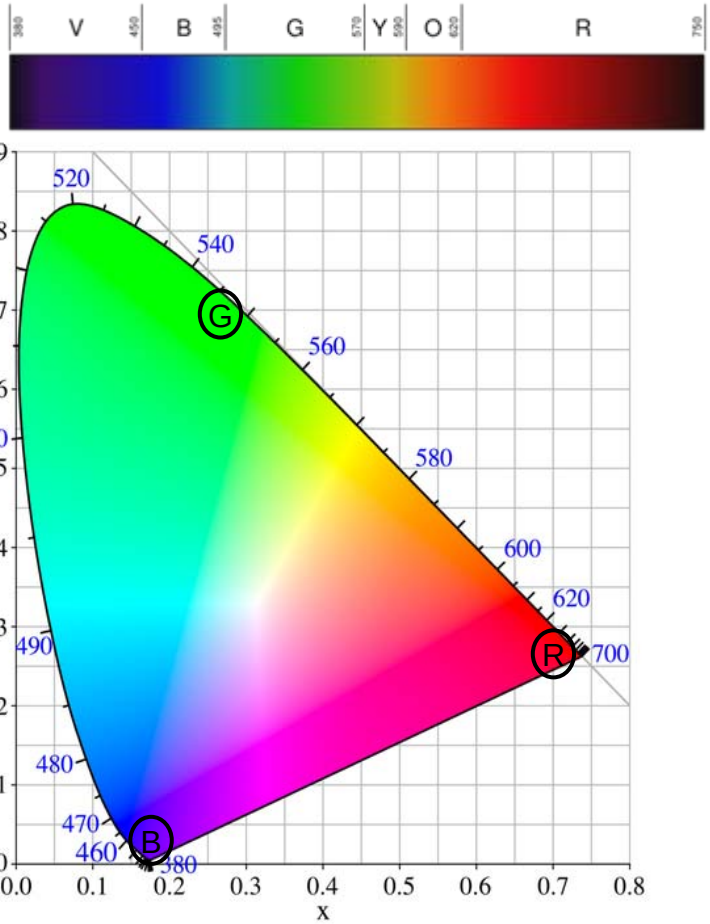


Acceptable Optical Output Intensity Range for Peer to Peer

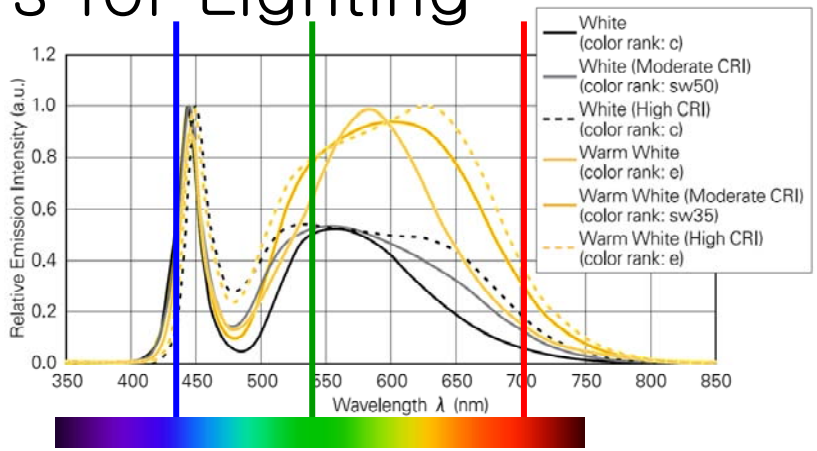
Light source of illumination output power is not defined:

- •Communication distances are depend on applications.
- •Light source power can be calculated from receiver spec.
- •Maximum power is regulated by Eye Safety Standards.

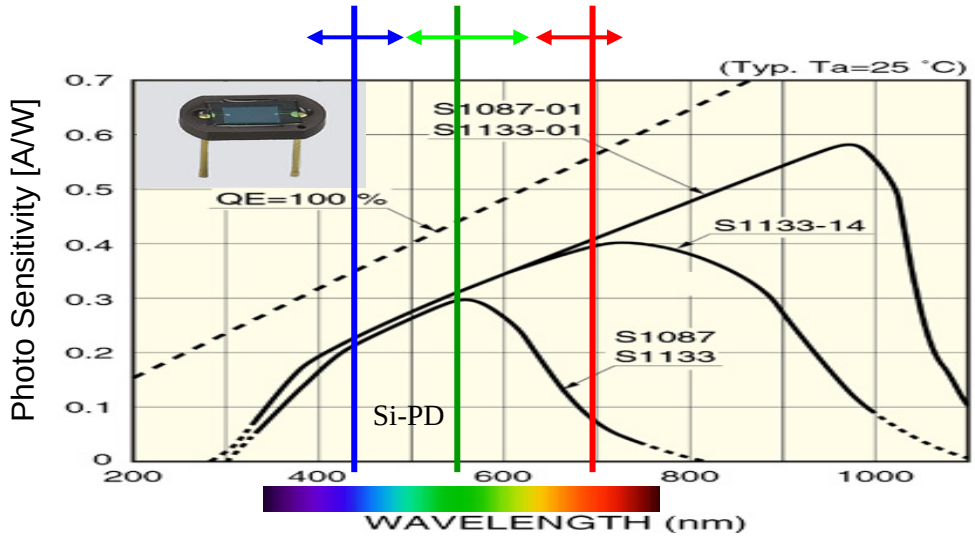
Considerations of Recover Sensitivity and Pure Colors for Lighting



CIE 1931
Pure R(700nm) Pure G(546.1nm) Pure B(435.8nm)



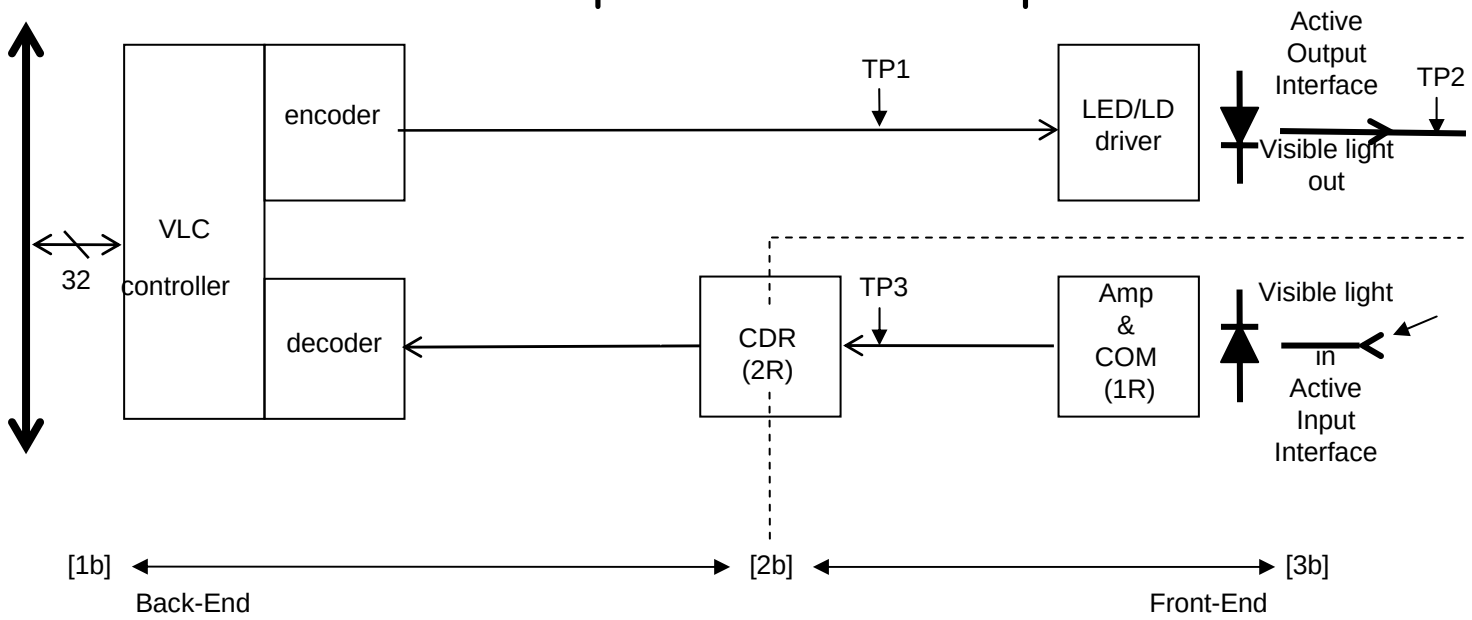
Typical white LED spectrum



Typical Si-PD Sensitivity

VLCC
Visible Light Communications Consortium

Measurement points of specification



TP1: Electronic Measurement point for Transmitter
TP2: Optical Measurement point
TP3: Electronic Measurement point for Receiver

Specification Class		Item	TP#	Test Methods
				Test Bit Sequences
[I]	Pulse Parameters	Rise/Fall Time	*TP1*	Pseudorandom Binary (Bit) Sequence
			TP3	$PRBS2^{15}-1$
	Eye Diagram	Eye-Mask Violation	*TP2*	$X^{15}+X^{14}+1$ ITU-T O.151

VLC Physical Specification

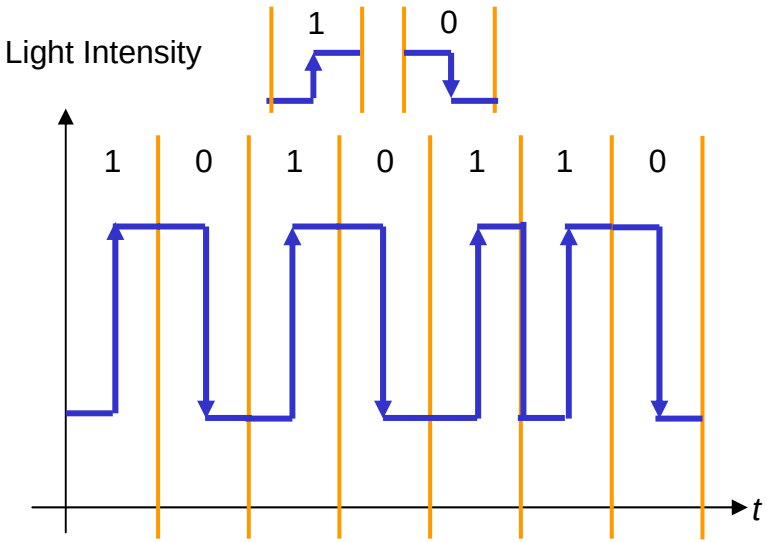
Details of Specification

Media Interface (1)

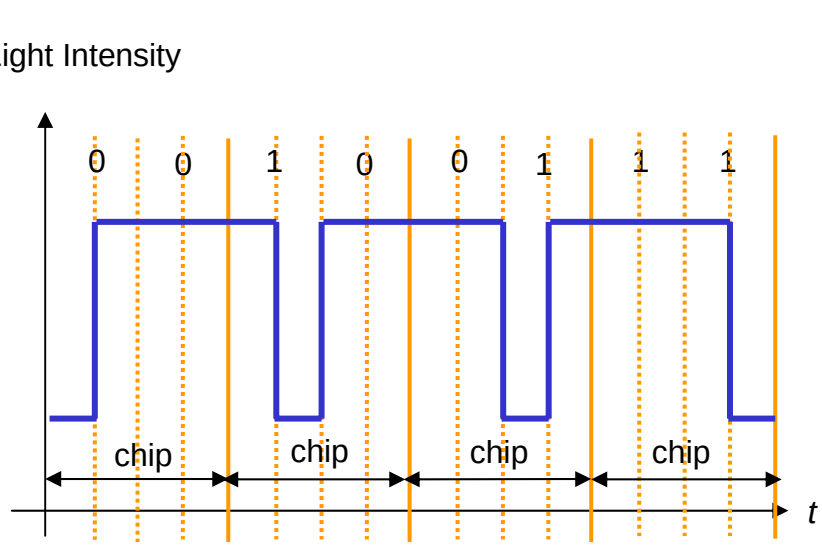
- Signaling Rate:
  - 4.0Mb/s
- Bit Error Ratio:
  - Bit Error Ratio (BER) $< 10^{-8}$.
- Moderations method:
  - Manchester code data encoding
  - Inverted 4 PPM (Pulse Position Moderation)
- Signaling Rate and Pulse Duration:
  - The maximum and minimum single pulse du rations:
    - nominal 25% of the symbol duration
    - +/- 2% of the symbol duration

Modulation Methods

- Manchester Encoding • Inverted-4PPM



Signal edge (Rise 1 / Fall 0)



Inverted Pulse Position Modulation

Media Interface (2)

- Signaling rate / tolerances and Pulse durations

Signaling Rate	Modulation	Rate Tolerance % of Rate	Pulse Duration Minimum	Pulse Duration Nominal	Pulse Duration Maximum
4.0 Mb/s (single pulse) (double pulse)	Inverted 4PPM or Manchester Code Data Modulation	 +/-0.01 +/-0.01	 115.0 ns 240.0 ns	 125.0 ns 250.0 ns	 135.0 ns 260.0 ns

- Active Output Interface

SPECIFICATION	Minimum	Maximum
Wavelength [μm]	0.4	0.78

- Active Input Interface:

SPECIFICATION	Minimum		Maximum	
	Manchester Code	Inverted 4PPM	Manchester Code	Inverted 4PPM
Minimum & Maximum Irradiance In Angular Range, [μW/cm²]			500000	
Wavelength 623-780nm (Red)	31.6	47.4		
Wavelength 491-622nm (Green)	42.0	63.0		
Wavelength 400-490nm (Blue)	63.0	94.5		
Receiver Latency Allowance, [ms]			10	

Cf: CIE 1931 Pure R(700nm) Pure G(546.1nm) Pure B(435.8nm)

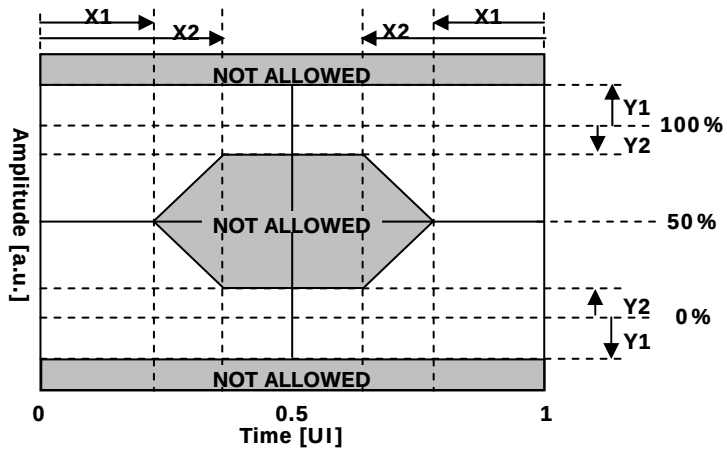
Output / Input Test Points (TP1-TP3)

- Test Point 1 Specifications

SPECIFICATION	Symbol	Min	Typ	Max	Unit
Signaling Rate (clock accuracy)		7.9992 (-100ppm)	8	8.0008 (+100ppm)	MHz
Rise/Fall Time 10%-90%	Tr1/Tf1	-	-	25	ns

- Test Point 2 Specifications

SPECIFICATION	Symbol	Typical	Unit
Signaling Rate (effective data rate)		4	Mbit/s
X1	X1_2	15	%UI
X2	X2_2	30	%UI
Y1	Y1_2	25	%pp
Y2	Y2_2	20	%pp



- Test Point 3 Specifications

SPECIFICATION	Symbol	Min	Typ	Max	Unit
Signaling Rate (effective data rate)		-	4	-	Mbit/s
Rise/Fall Time (10%-90%)	Tr3/Tf3	-	-	25	ns

Packet Overview

•Packet format

Idling flags	Preamble (I-4PPM)	Start flag	Data Payload for Upper layer	Field check Sequence	Stop flag

•Idling flags

1 0 — Manchester Code Data Modulation

1110 — Inverted-4PPM Modulation

•Start & Stop flags

Manchester encoding start flag

1000	1110	0011	1001	0110	0011	1000	1110

LSB MSB

Manchester encoding stop flag

0111	0001	1100	0110	1001	1100	0111	0001

LSB MSB

Inveted-4PPM encoding preamble, start & stop flag:
Same as IrDA FIR Specification

•Field check Sequence

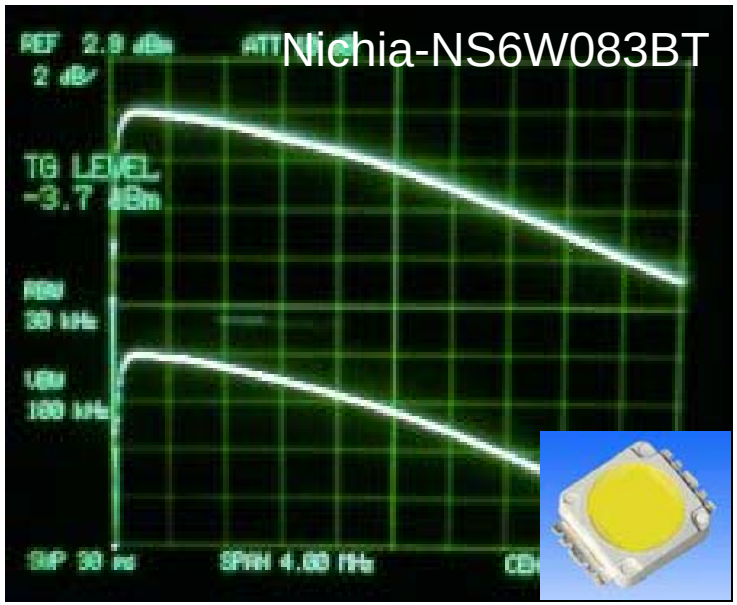
Same as IrDA FIR Method : CRC 32bits (IEEE 802 CRC32)
Refer to the Infrared Data Association Serial Infrared Physical Layer Link Specification Vertion1.2. [1] (5.3.2.5: Frame Check Sequence Field (FCS) Definition)

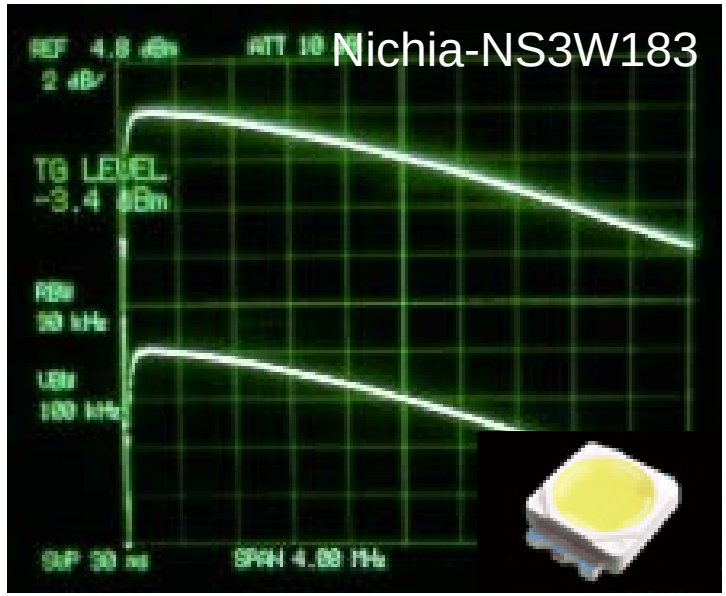
$$CRC(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$$

VLC Physical Specification

Study of Existing Devices

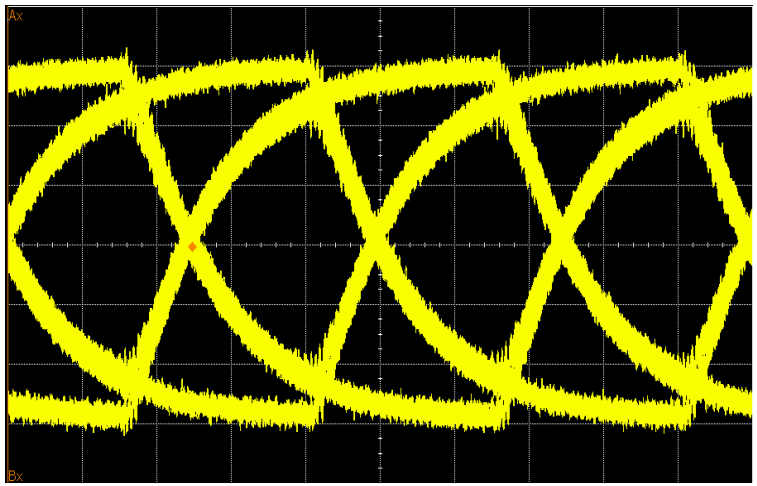
Actual physical device characteristics



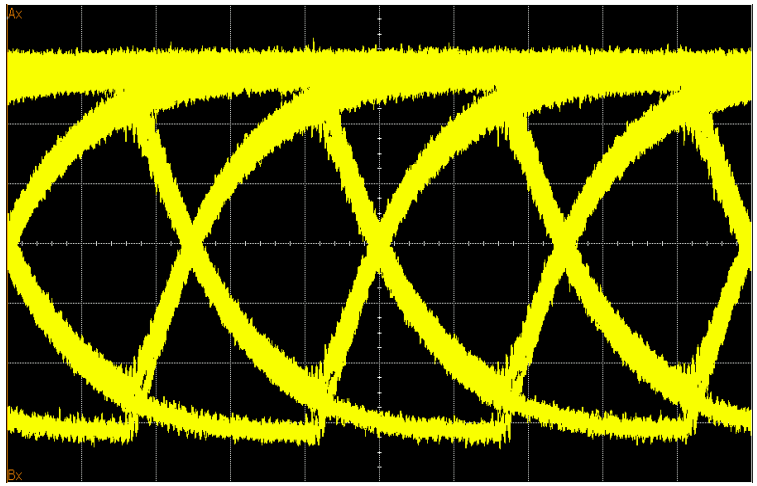


- White LED signal bandwidth (fc): 2.4MHz ~ 2.6MHz (-3dB)
- Possible modulation frequency: < 5Mbps
- Possible modulation technique: Manchester or Inverted-4PPM
  - Reduction of flickering
  - Guarantee of sufficient quantity of light.

Actual physical device response



Manchester Code Data Modulation



Inverted-4PPM

- Measurement Conditions
  - Used device: Nichia NS3W183 (White LED)
  - Data Bit Rate: 4.0Mbps (Clock = 8.0MHz)
  - LED drive current: 340mA$_{P-P}$
  - Modulation method: Manchester & Inverted-4PPM

VLC Physical Specification

Q & A