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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]

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

Gontaro Kitazumi

Visible Light Communications Consortium

VLC Physical Specification

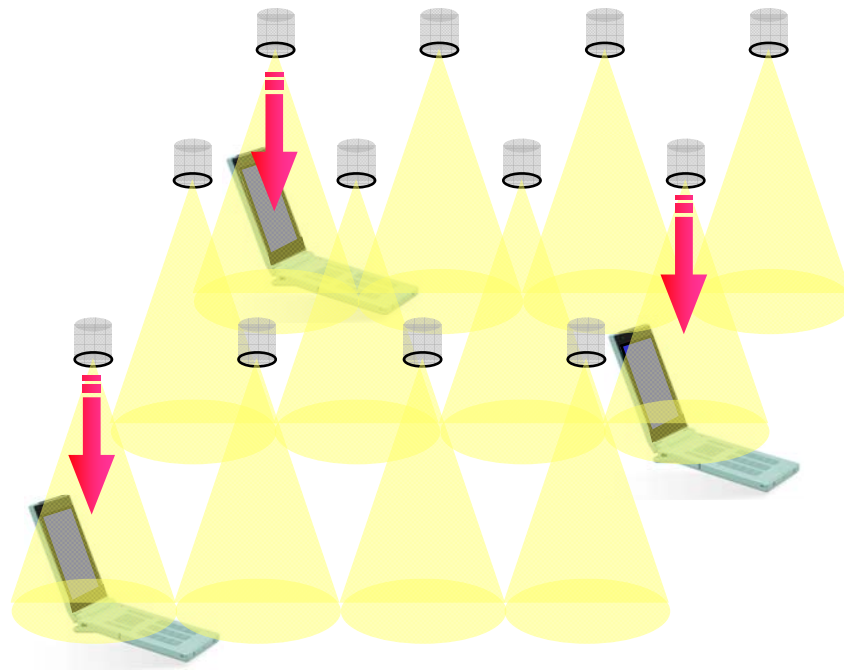
Concepts & Usage Models

Concepts

- The existing white LED 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:
 - Broadcast type (LED illumination → Mobile)
 - Pear to Pear 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 of upper protocol layers.

Typical usage models (1)

Point to Multipoint usage Model (broadcasting type)



Pinpoint information system using Down-light illuminations

Special feature:

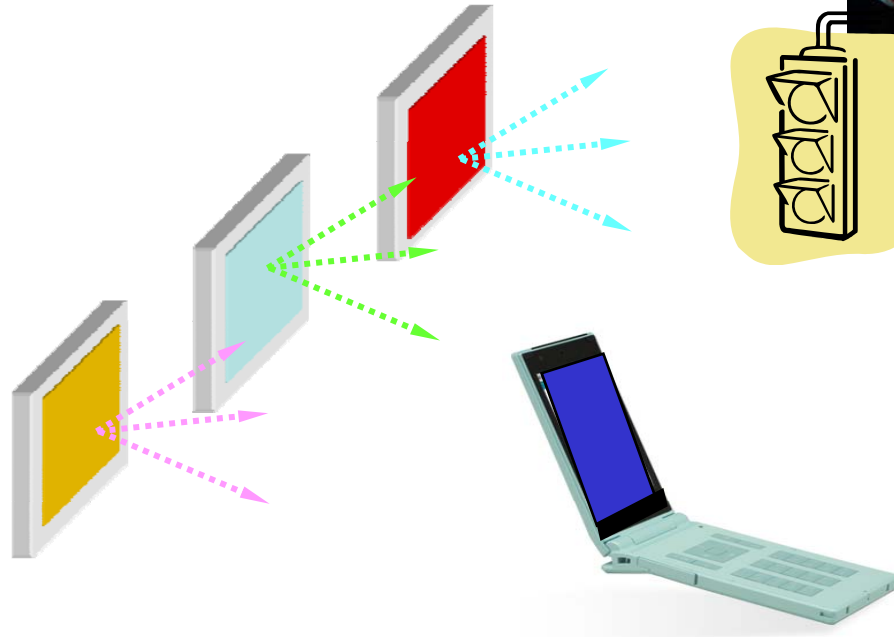
Two or more information deliveries using the *directivity* of light independently.

Applications:

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

Typical usage models (2)

Point to Multipoint usage Model
(broadcasting type)



Advertising illuminations or
Digital signage systems

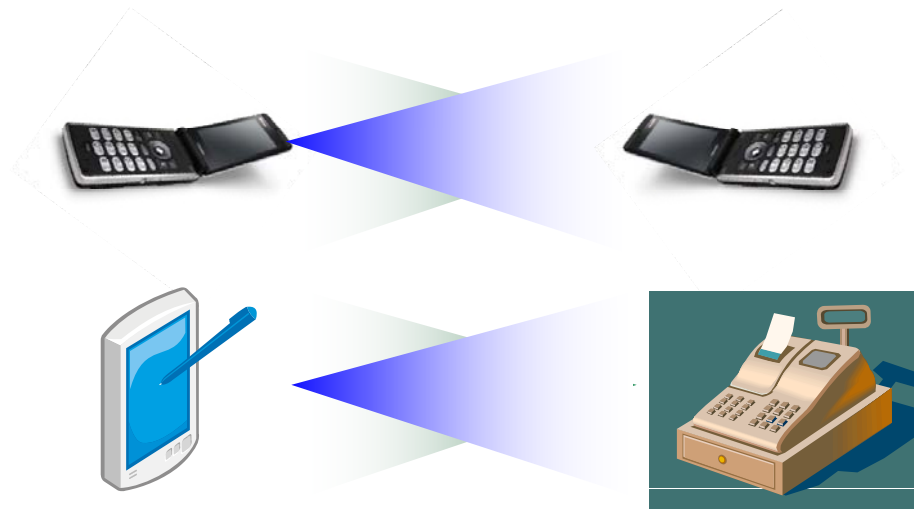


Special feature:
information are
directly gettable from
a signboards.

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

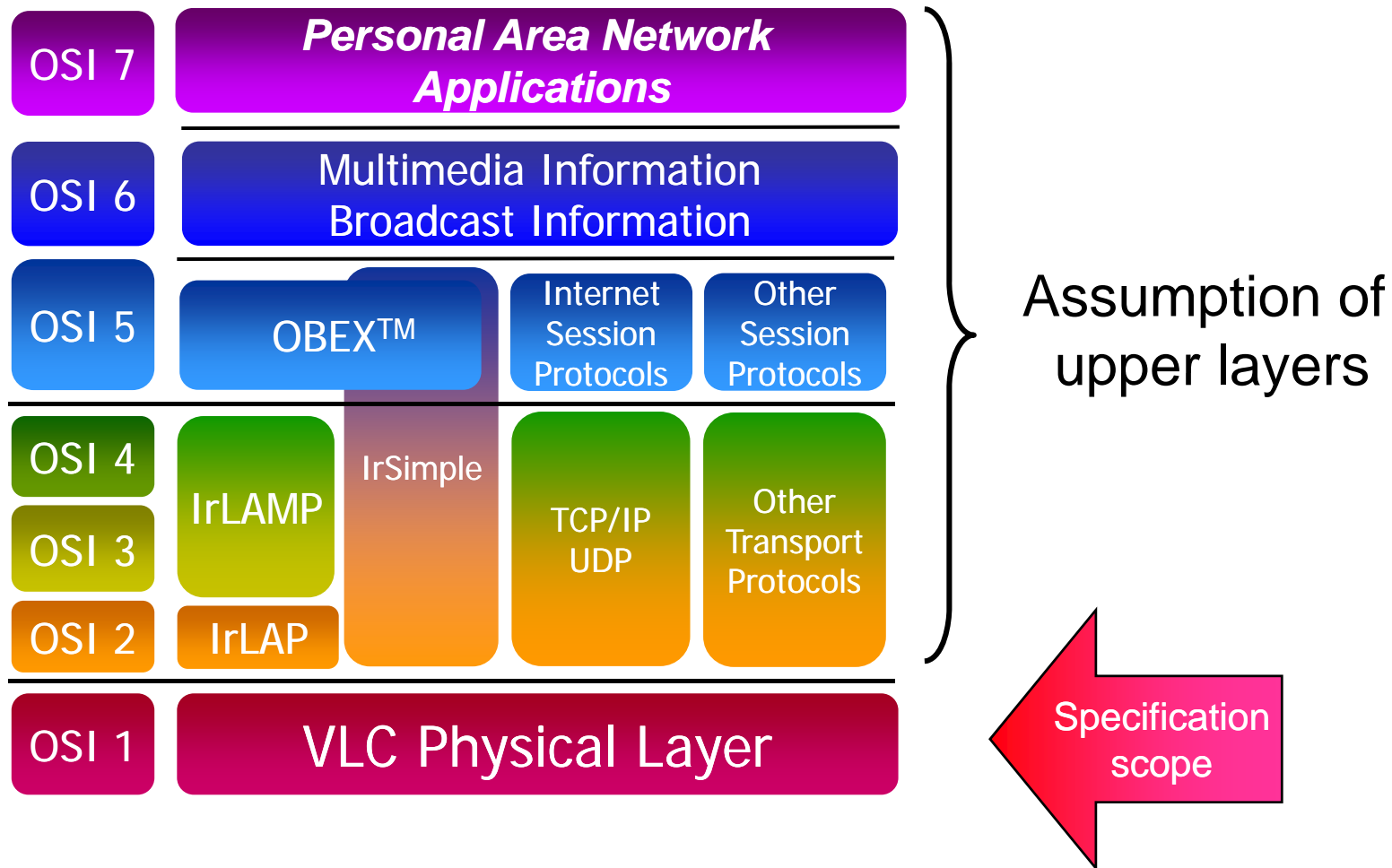
Special feature:
Reliable information
interchange

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

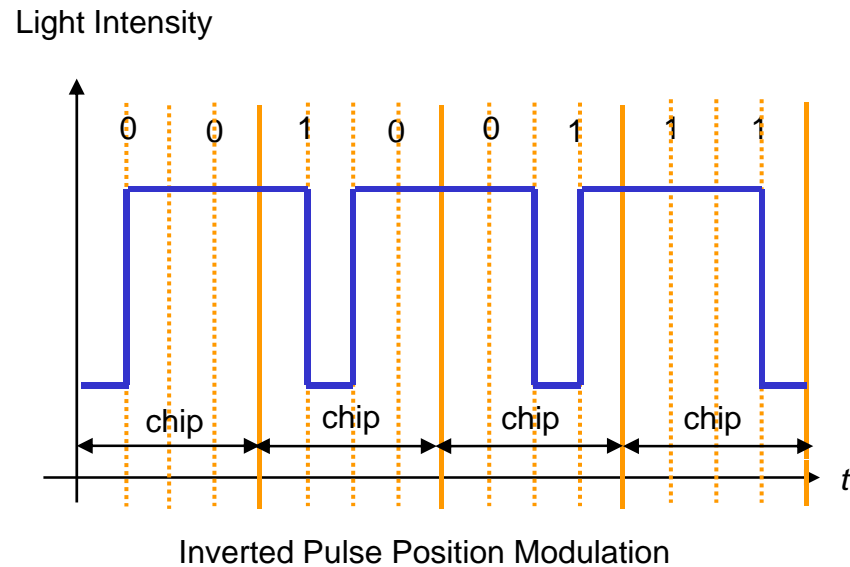
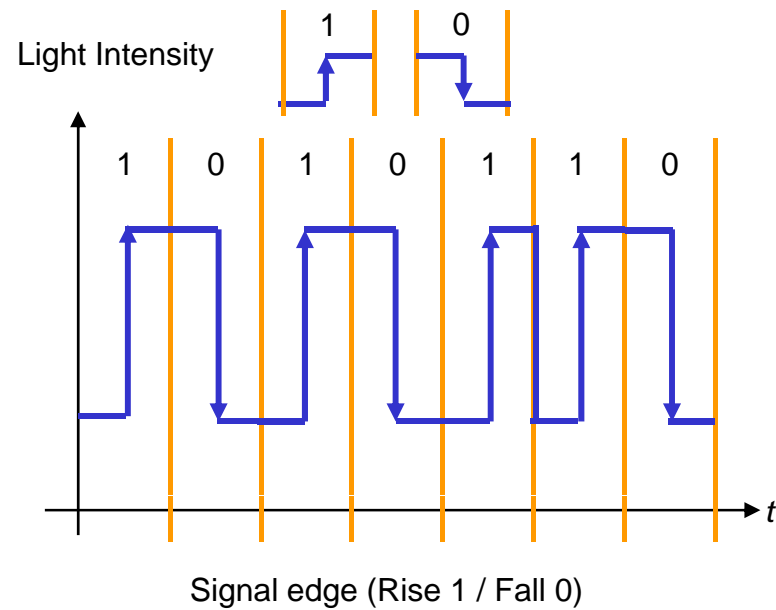
Details of Specification

Visible Light Communication Link Overview

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

Modulation Methods

- Manchester Encoding
- Inverted-4PPM



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.

Media Interface (1)

- Signaling Rate:
 - 4.0Mb/s
- Bit Error Ratio:
 - Bit Error Ratio (BER) $< 10^{-8}$.
- Signaling Rate and Pulse Duration:
 - The maximum and minimum single pulse durations:
 - nominal 25% of the symbol duration
 - $\pm 2\%$ of the symbol duration

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

Media Interface (2)

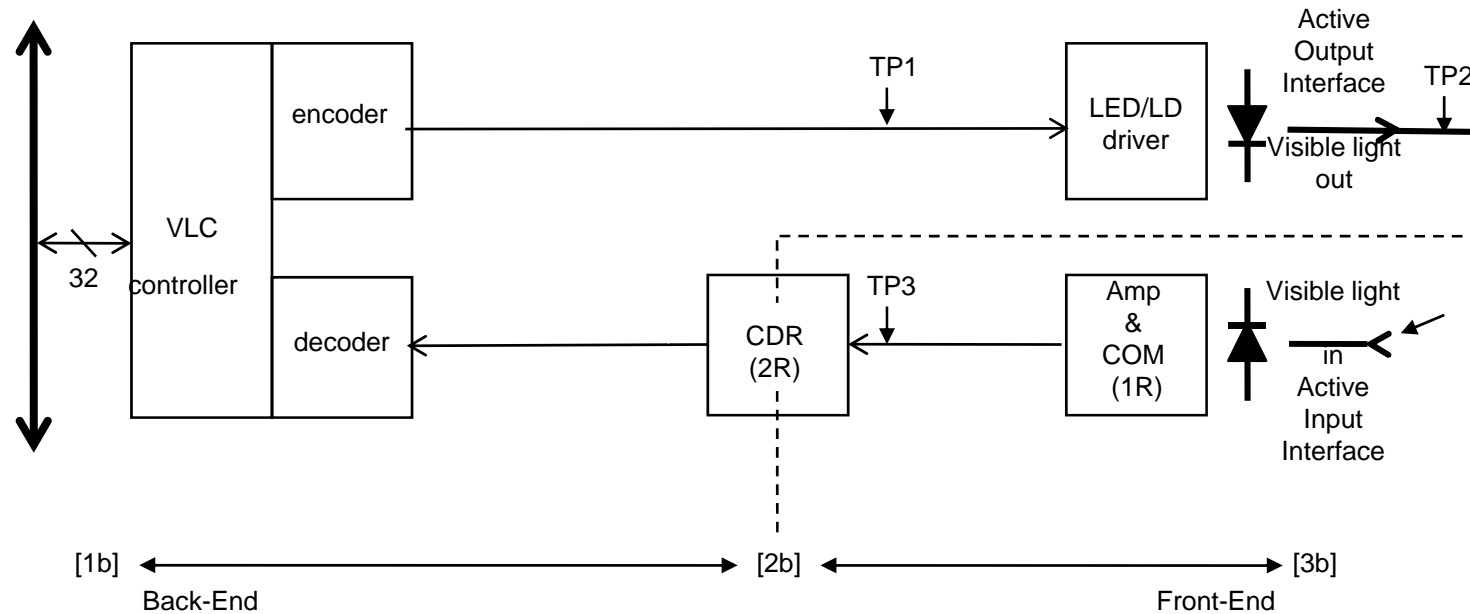
- Active Output Interface

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, $\mu\text{W}/\text{cm}^2$			500000	
Wavelength 623–780nm	31.6	47.4		
Wavelength 491–622nm	42.0	63.0		
Wavelength 400–490nm	63.0	94.5		
Receiver Latency Allowance, ms			10	

Test points of specification



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

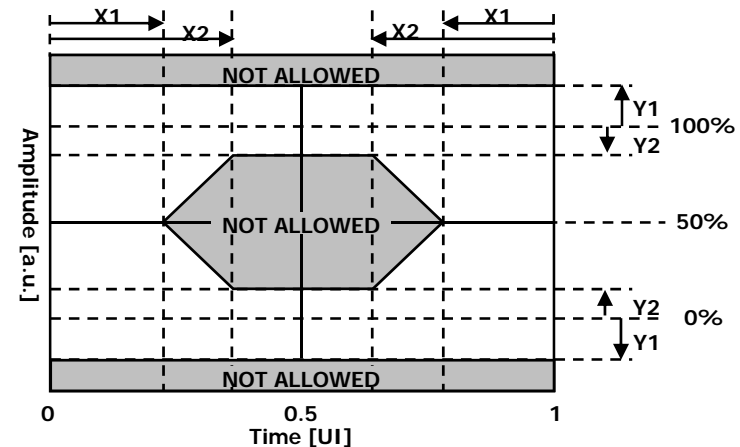
Output / Input Test Points (TP1-TP3)

- Test Point 1 Specifications

SPECIFICATION	Symbol	Min	Typ	Max	Unit
Signaling Rate		7.9992	8	8.0008	MHz
(clock accuracy)		(-100ppm)		(+100ppm)	
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

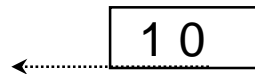
SPECIFICATION	Symbol	Min	Typ	Max	Unit
Signaling Rate (effective data rate)		-	4	-	Mbit/s
Rise/Fall Time (10%-90%)	Tr3/Tf3	-	-	25	ns

Packet Overview

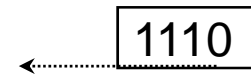
- Packet format



- Idling flags

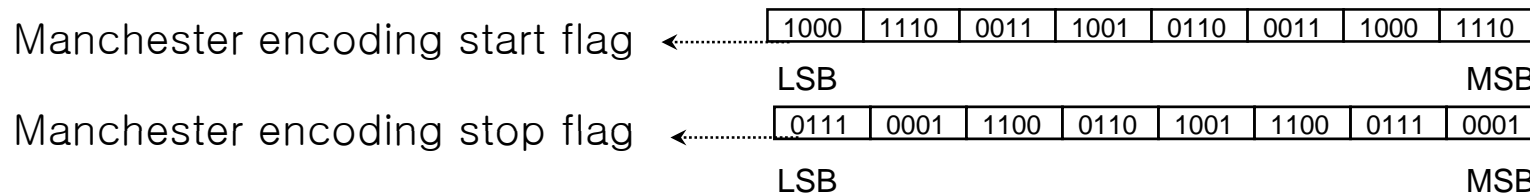


Manchester Code Data Modulation



Inverted-4PPM Modulation

- Start & Stop flags



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

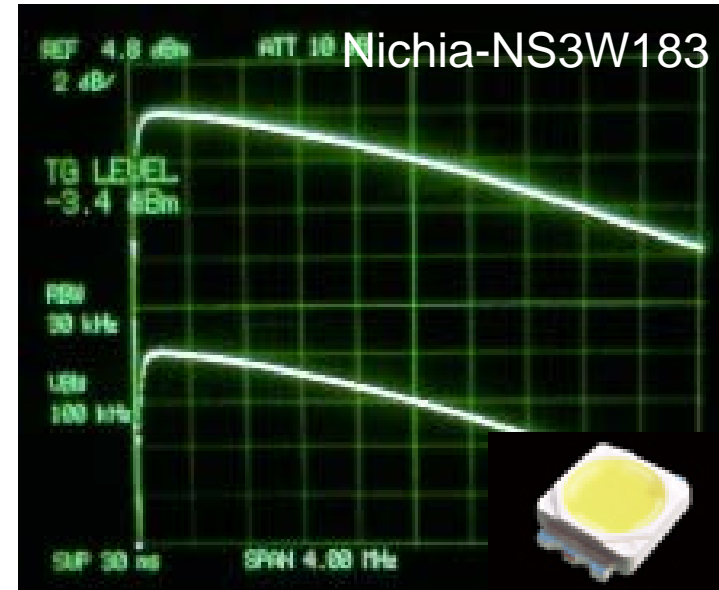
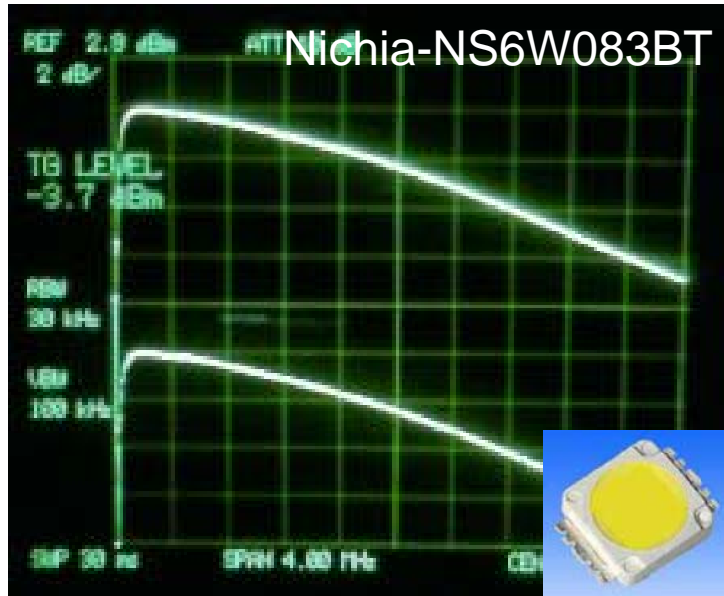
- Field check Sequence

Same as IrDA FIR Method : CRC 32bits,
Refer to the Infrared Data Association Serial Infrared Physical Layer Link Specification
Version 1.2. [1] (5.3.2.5: Frame Check Sequence Field (FCS) Definition)

VLC Physical Specification

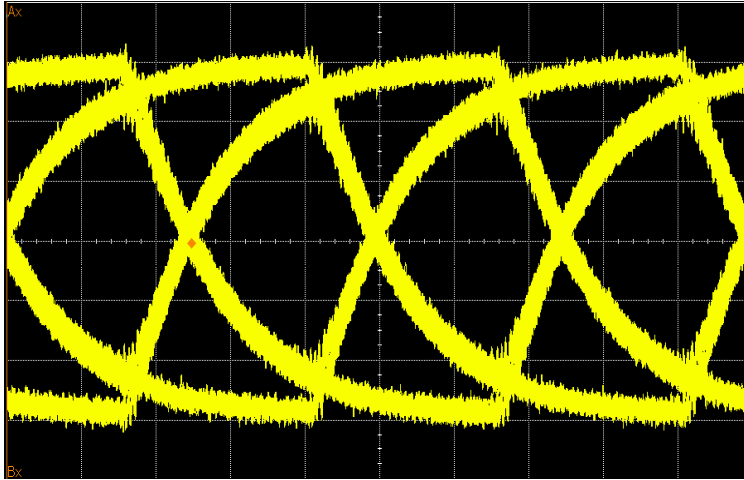
Study of Existing Devices

Actual physical device characteristics

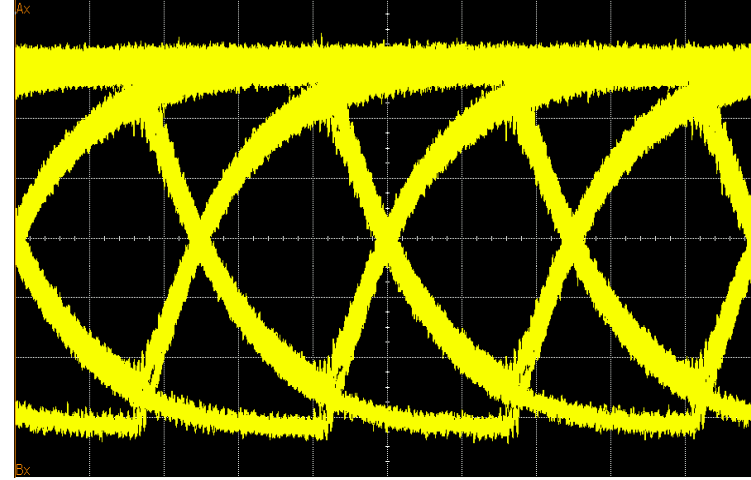


- White LED signal bandwidth (fc): 2.4MHz ~ 2.6MHz (-3dB)
- Possible modulation frequency: < 5Mbps
- Possible modulation technique: Manchester or Inverted-4PPM
 - Reduction of flickering
 - Guarantee of sufficient quantity of light.

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