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

Submission Title: [Considerations on VLC Modulation]

Date Submitted: [12 November 2008]

Source: [Hyuk-Choon Kwon, Taehan Bae, Jaeseung Son, Euntae Won] Company [Samsung Electronics Co.,LTD]

Address [Dong Suwon P.O. Box 105, 416 Maetan-3dong, Yeongtong-gu, Suwon-si, Gyeonggi-do, 443-742 Korea]

Voice:[82-31-279-7316], FAX: [82-31-279-5130], E-Mail:[hyukchoon.kwon@samsung.com]

Re: []

Abstract: [The considerations on the visible light communication (VLC) modulation are presented in this document.]

Purpose: [Contribution to IEEE 802.15 SG-VLC]

Considerations on VLC Modulation

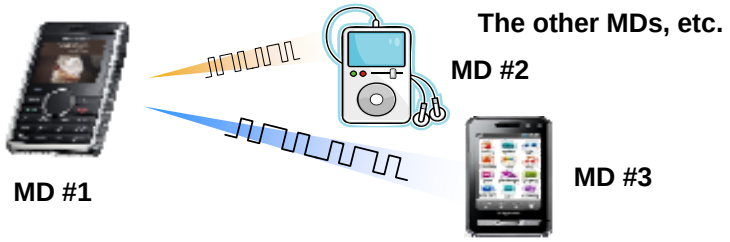
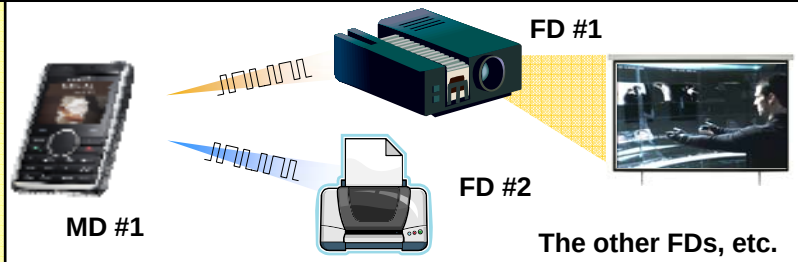
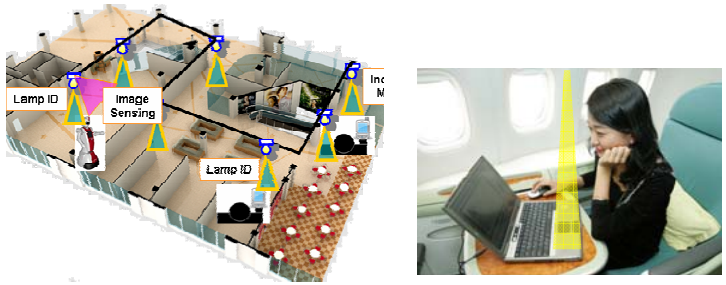
2008. 11. 12.

Samsung Electronics

Outline

- Grouping of VLC applications
- Considerations of VLC PHY Modulation
- Details of Considerations
  - Illumination property, background noise reduction, high data rate, channel model etc.
- Summary

Grouping of VLC Applications

		Application	Available Service	Major Functions
Machine To Machine	MD to MD		• Contents sharing • Multimedia transfer	• High Data Rate Communication • Color-attractive for emphasizing visibility
	MD to FD		• File transfer • Video streaming • Remote Control	
Infra structure To MD/FD			• Indoor LBS • Information Broadcasting • Visible LAN	• Lighting • Multiple Access

* MD : Mobile Device, FD : Fixed Device

Considerations of VLC PHY Modulation [1/4]

- Technical requirements for VLC PHY modulation
  - VLC modulation scheme for the purpose of applying to infrastructure shall support the existing Illumination control function.
    - Therefore, it needs to be discriminated from communication between mobile/fixed devices.
  - VLC modulation should consider a direct baseband or subcarrier modulation using optical sources such as LED or LD.
  - VLC modulation scheme should support the visibility of the VL wavelength characteristic itself.

Considerations of VLC PHY Modulation [2/4]

- Technical requirements for VLC PHY modulation
  - VLC modulation scheme should guarantee up to higher data rate (10kbps ~ 1Gbps) as application scenarios.
    - The higher data rate should be satisfied in order to transmit enhanced multimedia data.
    - Environments for supporting data rate classes
      : MD-to-MD, MD-to-FD, Infrastructure-to-MD/FD
  - VLC modulation scheme should support background noise reduction.
    - The background noise from external noises such as sunlight, illuminator, traffic signal etc. should be avoided and excluded.
  - VLC modulation should support the enhanced parallel transmission of RGB color or multiple wavelength.

Considerations of VLC PHY Modulation [3/4]

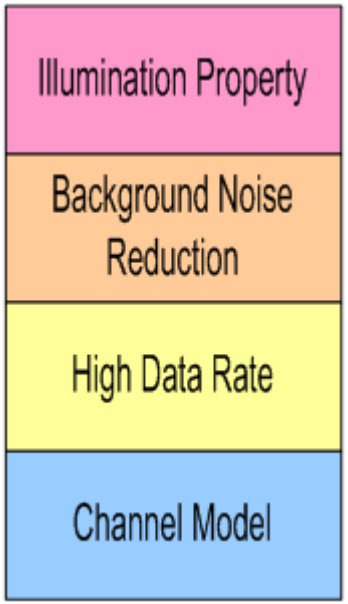
- Technical requirements for VLC PHY modulation
  - VLC modulation scheme should support signal distortion avoidance in both Tx/Rx (LED/PD) and channel environment.
  - VLC modulation scheme should consider the various channel models.
  - In general, the VLC channel has almost a characteristic of LOS.
    - Here, multi-path distortion and adjacent channel interference should be minimized.

Considerations of VLC PHY Modulation [4/4]

- Technical requirements for VLC PHY modulation
  - VLC modulation scheme should support the bidirectional communication based on full and half duplex.
  - Wavelength reuse should be supported for both full and half duplex.
    - Here, bidirectional use with single wavelength is possible.

Considerations as VLC Applications

- The required considerations can be discriminated as application environments.
  - The priority is as follows.



	Illumination Property	Background Noise Reduction	High Data Rate	Channel Model
Mobile to Mobile Device	V	V	VVV	Simple
Mobile to Fixed Device	V	V	VVV	Simple
Infrastructure	VVV	VVV	VV	complex

* VVV : certainly required , VV : very required , V : required , X : not required

1. Illumination Property

- Can be mainly used and considered in case of lighting communication using an LED.

  (e.g. Indoor LBS, Information Broadcasting, and Visible LAN)

  - In general, PWM method is used in order to adjust the brightness of LED lighting.
  - But, the method may not be suitable for high speed communication.
  - Also, the lighting function can not be ignored.
  - In case of lighting communication by LED, PWM signal bandwidth higher than comm. signal bandwidth should be required to have a good signal performance .
  - In other words, severe bandwidth waste
  - New modulation method required

2. Background Noise Reduction

- Can be mainly used and considered in case of lighting communication using LED.
  - Additionally external ambient optical noise with visible light spectrum band (380 ~ 780nm)

    (e.g. Sun light, Fluorescent and Incandescent lamp)
  - Low noise characteristic (in photo detection)
  - Bad influence in direct baseband modulation of an LED
  - To enhance signal performance, the noise reduction or elimination is required.

    (e.g. subcarrier modulation : Data spectrum and noise spectrum can be divided.)

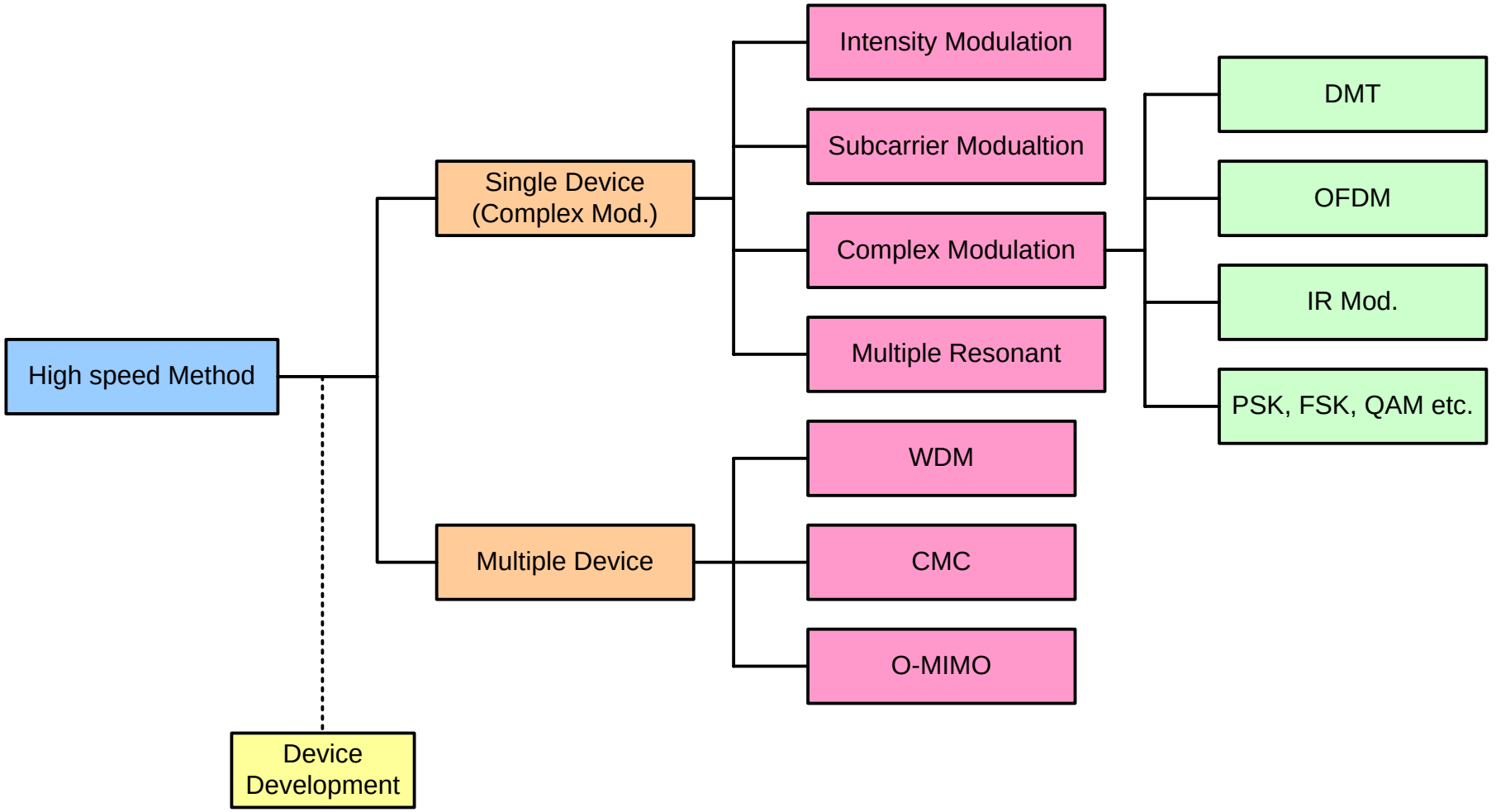
3. High Data Rate

- Can be mainly used in peer to peer environment

  (Target : more than 1Gbps in about 1m range)

  - Single LED device based
    - Intensity Modulation
    - Complex Modulation (Amplitude and Phase considered)
      (e.g. PSK, QAM, or DMT, OFDM)
    - Multiple resonant circuit in low speed LED (Pre-equalization)
  - Multiple LED device based
    - WDM Multiplexing method
    - Optical MIMO
    - Color Multiplexing Code

High Speed Modulation Categorization



4. Channel Model

- The visible light communication channel may be almost expected to LOS channel by various references until now.
  - MD-to-MD/FD

    : Communication between portable or fixed devices

    Short range peer-to-peer environment

    (relatively little multipath/Interference distortion)
  - Infra-to-MD

    : many interference can be existed.

    - New modulation method may be required.
  - Especially, the downlink of Infra-to-Mobile
  - Because, the beam divergence of downlink source is relatively wider.

Summary

- VLC PHY modulation requirements
  - Support general characteristics of visible light
  - A few different modulation approaches are required as each application.
    - Mobile-to-Mobile/Fixed devices (Between Devices)
    - Infra-to-Mobile/Fixed device
  - Here, illumination property, background noise reduction, high data rate, channel model characteristic etc. should be considered.
- For supporting requirements, P802.15 VLC should reflect the above when designing the VLC PHY.