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Submission Title: [Some comments on the power of LED light source for VLC]
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Source: [Sang-Kyu Lim, Kang Tae-Gyu, Dae Ho Kim, Ill Soon Jang] Company [ETRI]
Address [138 Gajeongno, Yuseong-Gu, Daejeon, Korea]
Voice:[+82-42-860-1573], FAX: [+82-42-860-5218], E-Mail:[sklim@etri.re.kr]
Re: [ ]

Abstract: [This document gives some comments on the power of LED light source for VLC.]

Purpose: [To provide some comments on the power of LED light source for VLC]

Some comments on the power of LED light source for VLC

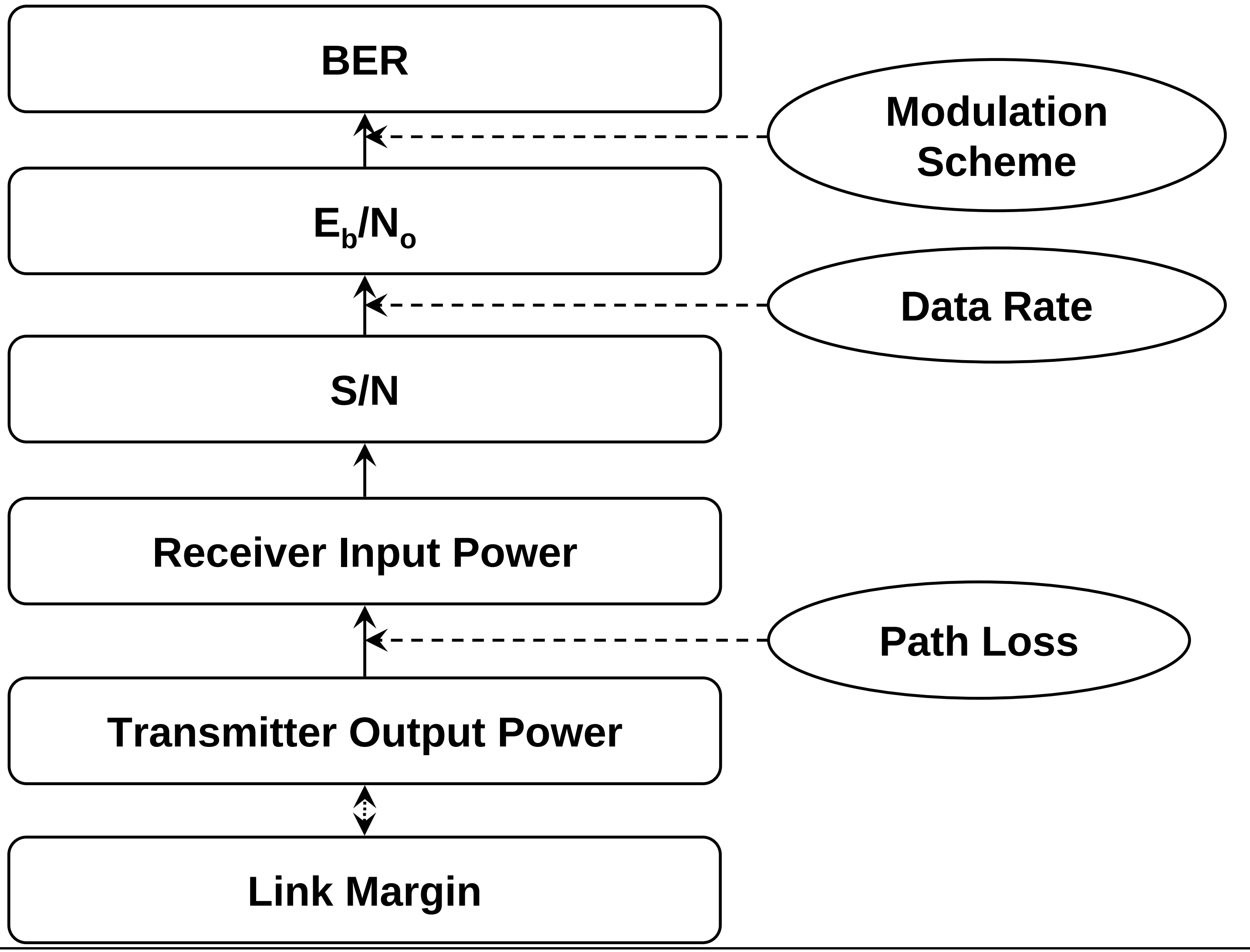
Sang-Kyu Lim
sklim@etri.re.kr
ETRI

Purpose of Link Budget Calculation

- **The purpose of a link analysis is to determine the actual system operating point and to establish that the error probability associated with that point is less than or equal to the system requirement.**

Ref. : Bernard Sklar, *Digital Communications Fundamentals and Applications*. Prentice Hall, 1988.

Procedure of Link Budget Calculation



Specifications of Commercial LED Lighting Product

Specifications

Item	Symbol	Value			Unit
		Min.	Typ.	Max.	
Luminous Flux [1]	Φ_V [2]	2.6	4.0	-	lm
Luminous Intensity	I_V	-	2500	-	mcd
Chromaticity Coordinate[3]	x, y	x=0.31, y=0.31			-
Forward Voltage[4]	V_F	-	3.4	4.0	V
View Angle	$2\theta_{½}$	70			deg.
Thermal Resistance	$R\theta_{J\text{-}P}$	130			°C /W
Optical Efficiency	η_{opt}	-	38	-	lm/W
Reverse Current (at V_R = 5V)	I_R	-	-	5	μA

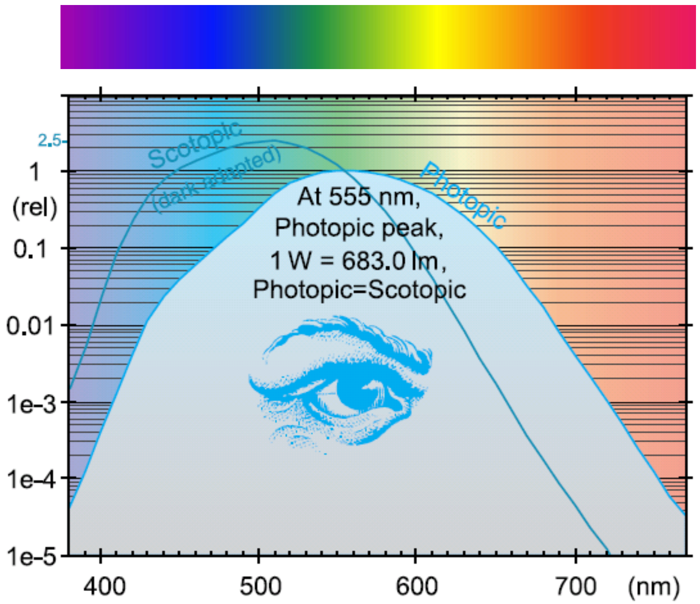
- At present, the output power of most commercial LED source is usually described by the photometry units such as lm and cd.
- The units of photometry such as lm and cd are the physical dimension which is expressed in viewpoint of standard human eye as a kind of photodetector.
- Phtodetectors such as Si-PD for VLC receiver have different responsivity or sensitivity depending on wavelengths(380 to 780 nm) from the standard human eye.

Relations between Two Unit Systems on Visible Light

Radiometric Units	
Radiant Flux	W
Radiant Intensity	W/sr
Radiance	$W/sr/m^2$
Irradiance	W/m^2

↔

Photometric Units	
Luminous Flux	lm
Luminous Intensity	cd = lm/sr
Luminance	cd/m^2 = $lm/sr/m^2$
Illuminance	lux = lm/m^2



IEEE 802.15-09-0159-00-0007

CIE Scotoptic and Photoptic Sensitivity Curves

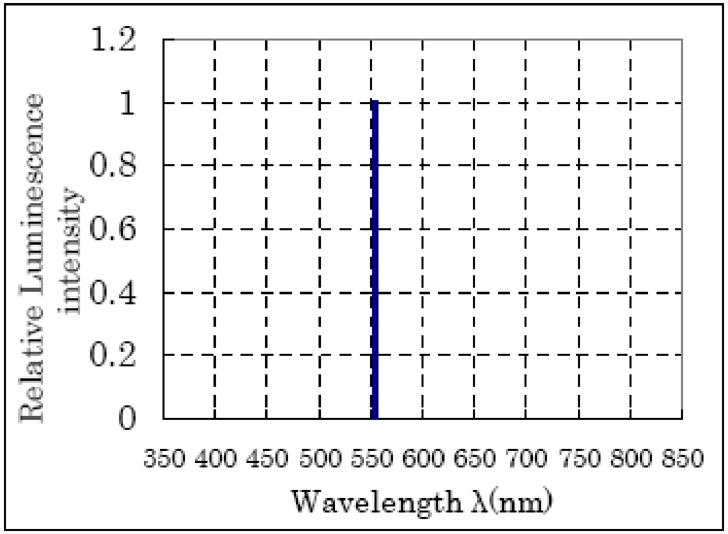
[Eye Sensitivity Function : V(λ)]

Light Measurement Handbook © 1998 by Alex Ryer, International Light Inc.

Our Homework on Transmitter Power for VLC Link Analysis

- The photometric unit is unsuitable for the transmitter power for VLC link analysis because we do not use human eye as a VLC detector.
- We need to convert the photometric transmitter power of VLC light source into the radiometric power, Watt, for VLC link analysis .

Unit Conversion on Monochromatic Light

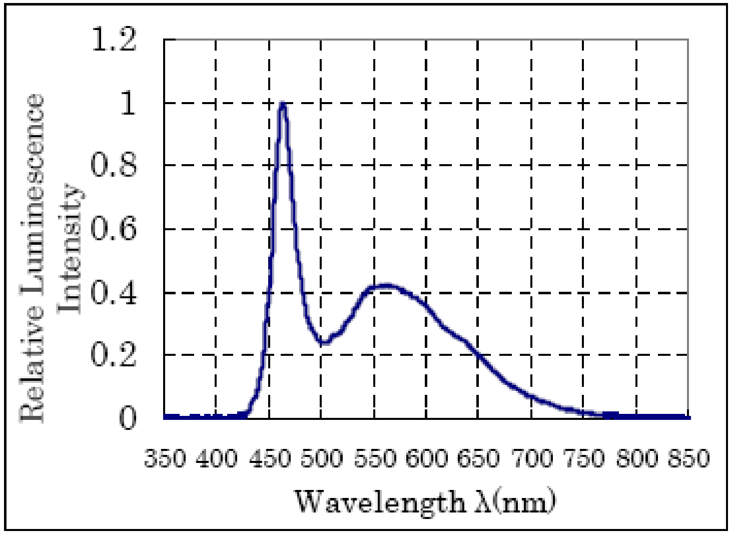


Spectral Distribution (Monochromatic)

- $1\ \text{Watt}\Big|_{\lambda=555\,\text{nm}} = 683\ \ (\text{lm})$
- $10\ \text{Watt}\Big|_{\lambda=\text{x nm}} = 10 \times 683 \times V(\lambda)\Big|_{\lambda=\text{x nm}}\ \ (\text{lm})$
- $1\ \text{lm}\Big|_{\lambda=555\,\text{nm}} = \dfrac{1}{683}\ \ (\text{Watt})$
- $100\ \text{lm}\Big|_{\lambda=\text{x nm}} = \dfrac{100}{683 \cdot V(\lambda)}\Bigg|_{\lambda=\text{x nm}}\ \ (\text{Watt})$

- **In case of monochromatic light, if we use human eye sensitivity function V(λ), we can easily calculate unit conversion between photometry and radiometry.**

Unit Conversion on Non-Monochromatic Light



Spectral Distribution (White LED Light)

- $$X \text{ (Watt)} = 683 \int_{380}^{780} P(\lambda) \cdot V(\lambda)\, d\lambda \text{ (lm)}$$

  $P(\lambda)$: Radiant Flux Spectral Distribution

- $$Y \text{ (lm)} = \frac{1}{683} \int_{380}^{780} \frac{L(\lambda)}{V(\lambda)}\, d\lambda \text{ (Watt)}$$

  $L(\lambda)$: Luminous Flux Spectral Distribution

- **However, in case of non-monochromatic light, we need to know the radiant flux spectral distribution to calculate radiometry-to-photometry conversion, or the luminous flux spectral distribution to calculate photometry-to-radiometry conversion in addition to human eye sensitivity function.**

Discussion (1)

- At present, the output power of most commercial LED light source for illumination is usually described by the photometry units.
- The units of photometry such as lm and cd are the physical dimension which is expressed in viewpoint of standard human eye as a kind of photodetector.
- Photodetectors such as Si-PD for VLC receiver have different responsivity or sensitivity depending on wavelengths(380 to 780 nm) from the standard human eye.

Discussion (2)

- **So, we need to know the radiometric power (Watt) of LED light source for VLC photodetectors such as Si-PD, not human eye, because the responsivities of Si-PD and human eye are different.**
- **LED Light source (white LED) = Non-monochromatic**
- **We need to know Radiant Flux Spectral Distribution for radiometry-to-photometry conversion or Luminous Flux Spectral Distribution for photometry-to-radiometry conversion in non-monochromatic light.**

Discussion (3)

- **So, I think we have to request LED product companies that we can know the Luminous Flux Spectral Distribution or Radiant Flux Spectral Distribution of commercial LED light source.**
- **Or we have to measure the Luminous Flux Spectral Distribution or Radiant Flux Spectral Distribution of commercial LED light source.**