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

Submission Title: Panasonic Chanel Models for Image Sensor-based Communication

Date Submitted: July, 2015

Source: Hideki Aoyama
Panasonic Corporation
contact: aoyama.hideki@jp.panasonic.com

Abstract: Channel models for image sensor-based visible light communication

Purpose: Call for Channel Models Response

Contents

- Transmitter models
- Channel impulse response
- Channel filter (Image on screen)
- Receiver signal/noise model

- Appendix A: Unit Conversion (Candela to Watt)

Transmitter Models

- Panasonic proposes three channel models for image sensor-based communication protocols
  - Transmitter as “Light Panel” model
  - Transmitter as “LCD Signage” model
  - Transmitter as “Spot Light with Reflection Panel” model

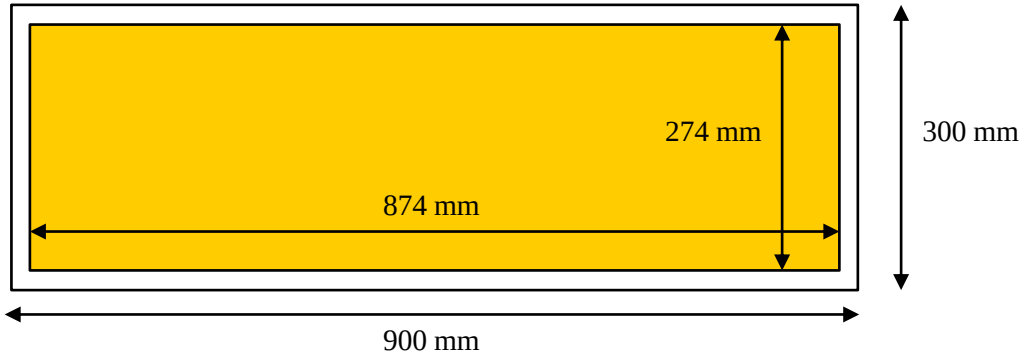
Model Design Basis

- The models were designed for application A1 in the TCD (Offline to Online Marketing / Public Information System)
- Time difference of multipath arrivals was not considered because the difference is negligibly small to signal frequency of image sensor-based communication protocol
- The models were designed with commercial products that have typical specifications

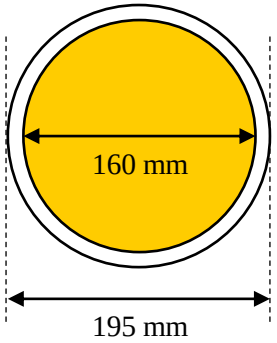
Light Panel - Size

Light panel (Transmitting light)

Photo will be shown
in updated version

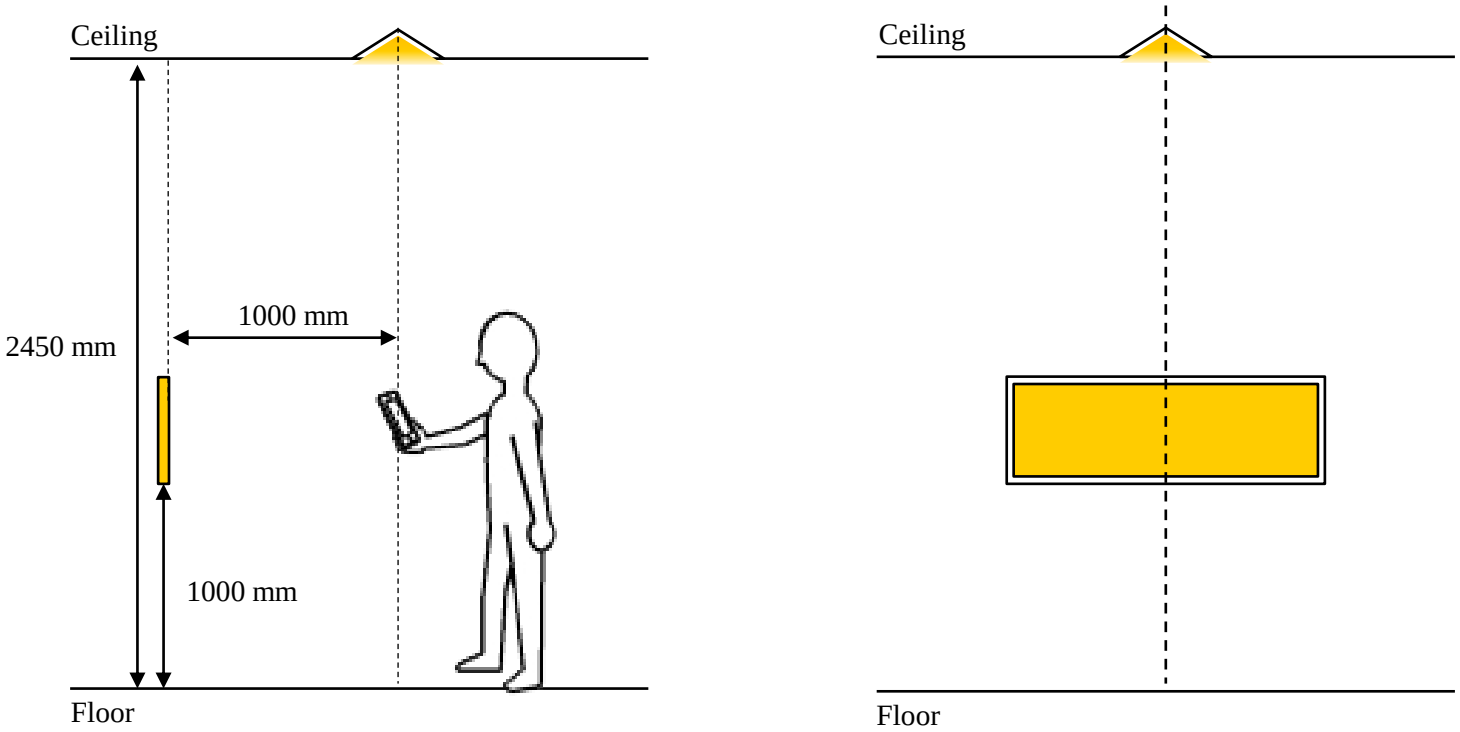


Down light (Ambient light)

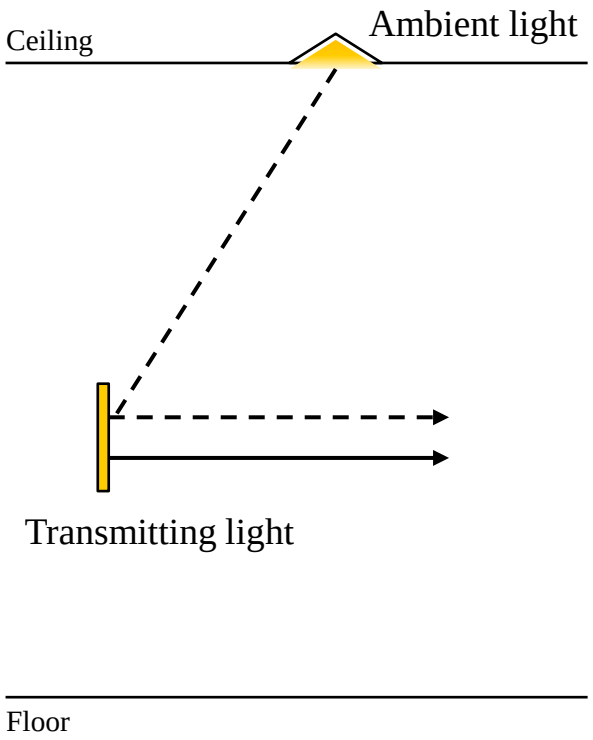


Light-emitting part

Light Panel - Layout



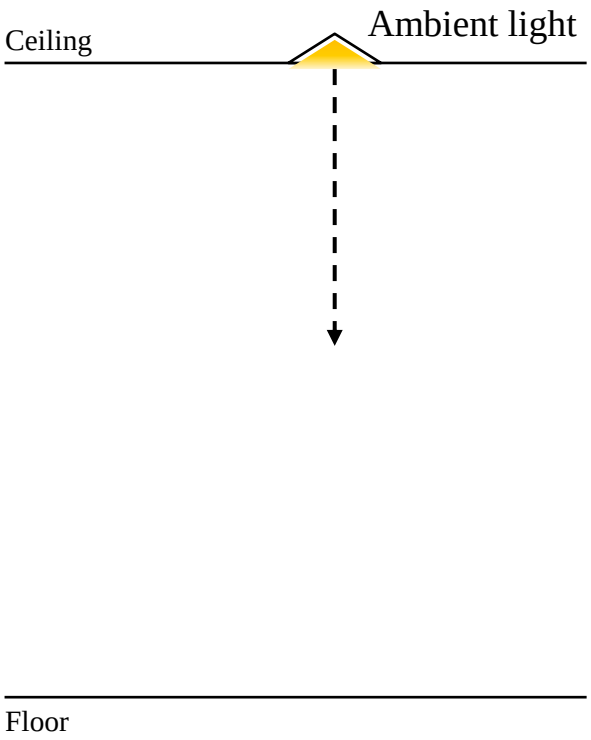
Light Panel - Luminance



Transmitting light	ON	ON
Ambient light	ON	OFF
Horizontal angle (Vertical angle = 0)	Luminance [cd/m²]	
0	552	533
10	554	532
20	557	538
30	575	554
40	583	564
50	610	597
60	626	610
70	617	608
80	571	566
Vertical angle (Horizontal angle = 0)	Luminance [cd/m²]	
+30	707	690
+20	682	662
+10	630	613
0	552	533
-10	607	587
-20	604	588
-30	612	594

Vertical angle > 0 is ceiling side angle, and that < 0 is floor side angle.

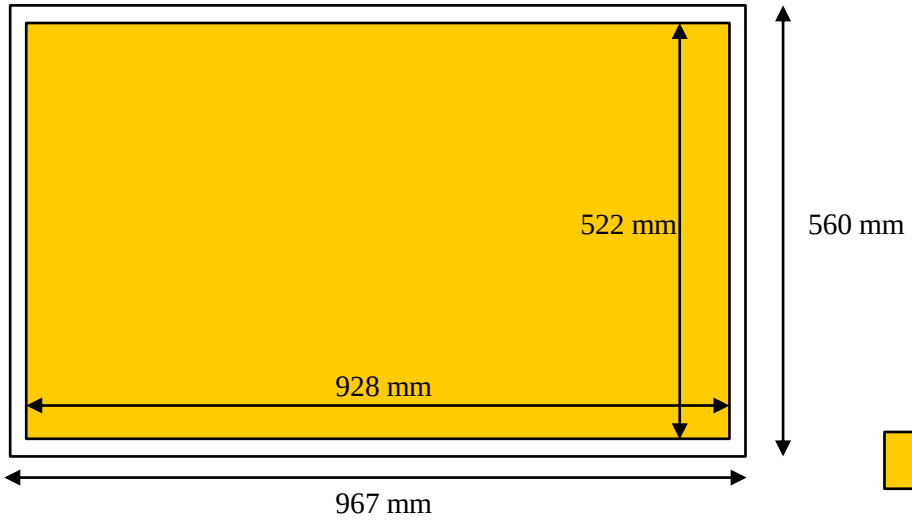
Ambient Light - Luminance



Angle	Luminance [cd/m^2]
0	57280
10	54720
20	53440
30	41440
40	32800
50	23520
60	17280
70	3328
80	194

Digital Signage - Size

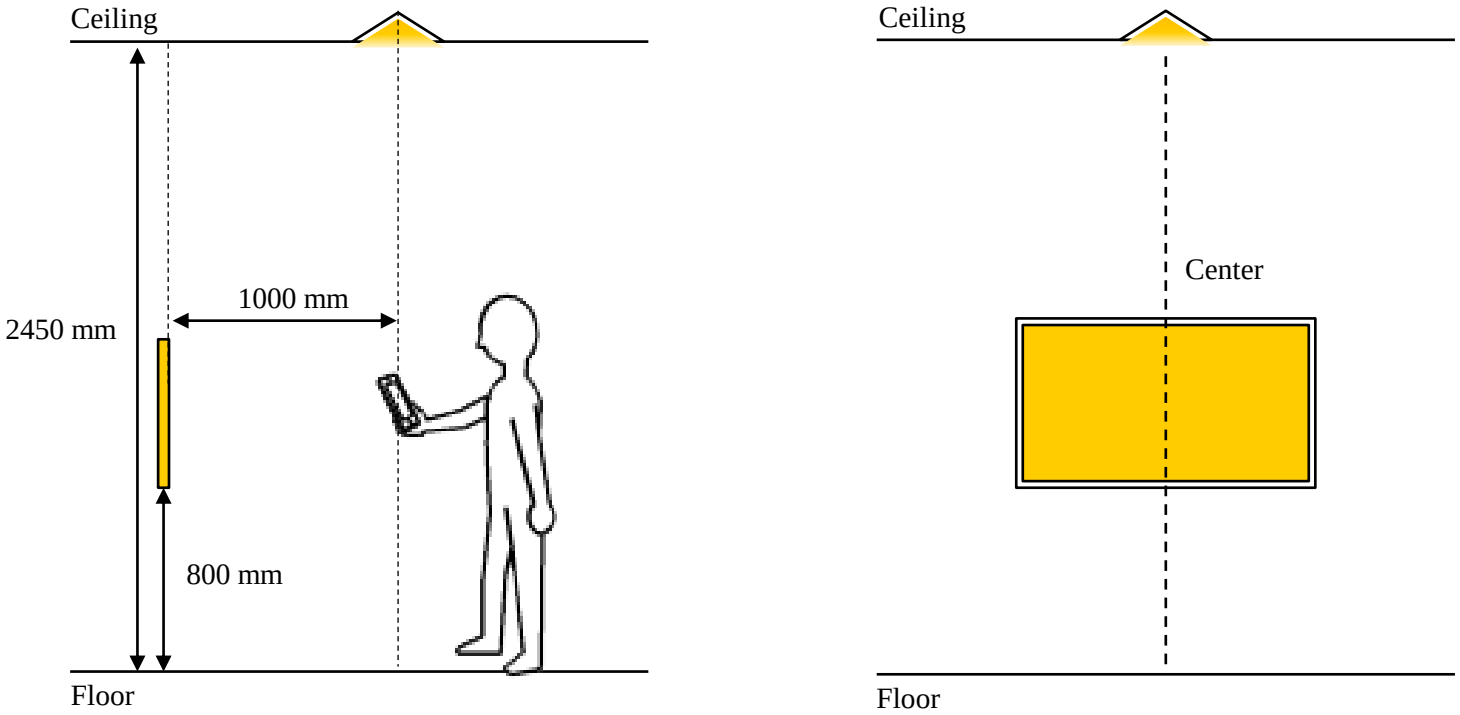
LCD signage (Transmitting light)



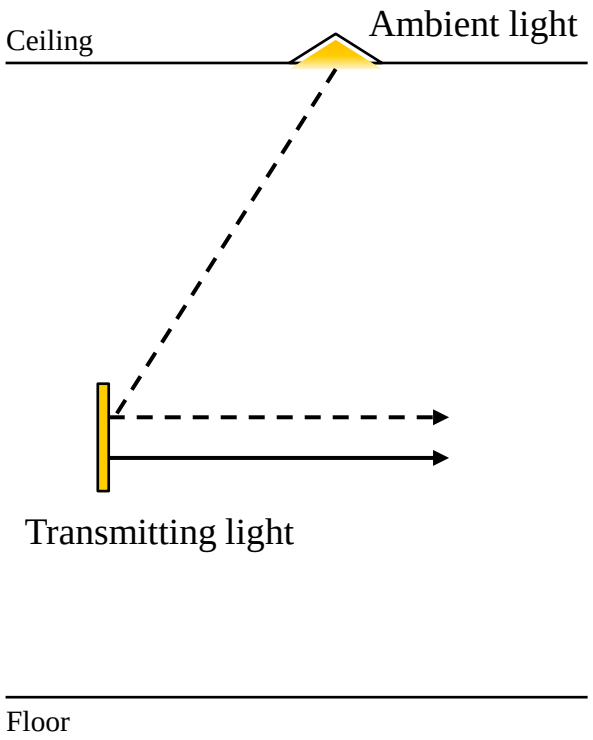
Down light (Ambient light)

(Same)

Light Panel - Layout



Digital Signage - Luminance



Transmitting light	ON	ON
Ambient light	ON	OFF
Horizontal angle (Vertical angle = 0)	Luminance [cd/m²]	
0	818	819
10	817	818
20	809	807
30	771	772
40	688	693
50	550	573
60	352	335
70	234	223
80	125	127
Vertical angle (Horizontal angle = 0)	Luminance [cd/m²]	
+30	611	607
+20	713	710
+10	806	796
0	818	819
-10	740	737
-20	593	581
-30	419	414

Vertical angle > 0 is ceiling side angle, and that < 0 is floor side angle.

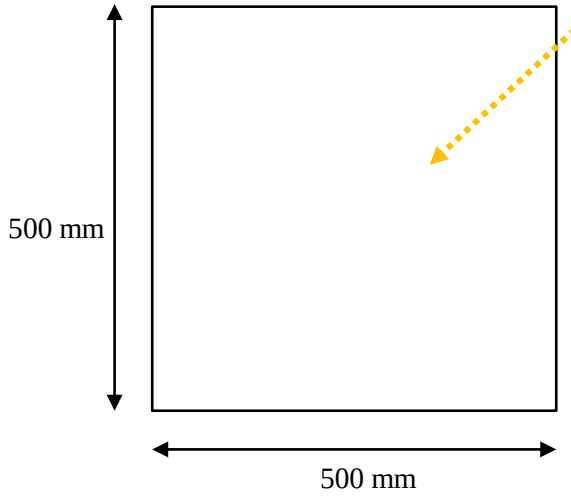
Reflected Light - Size

Down light (Ambient light)

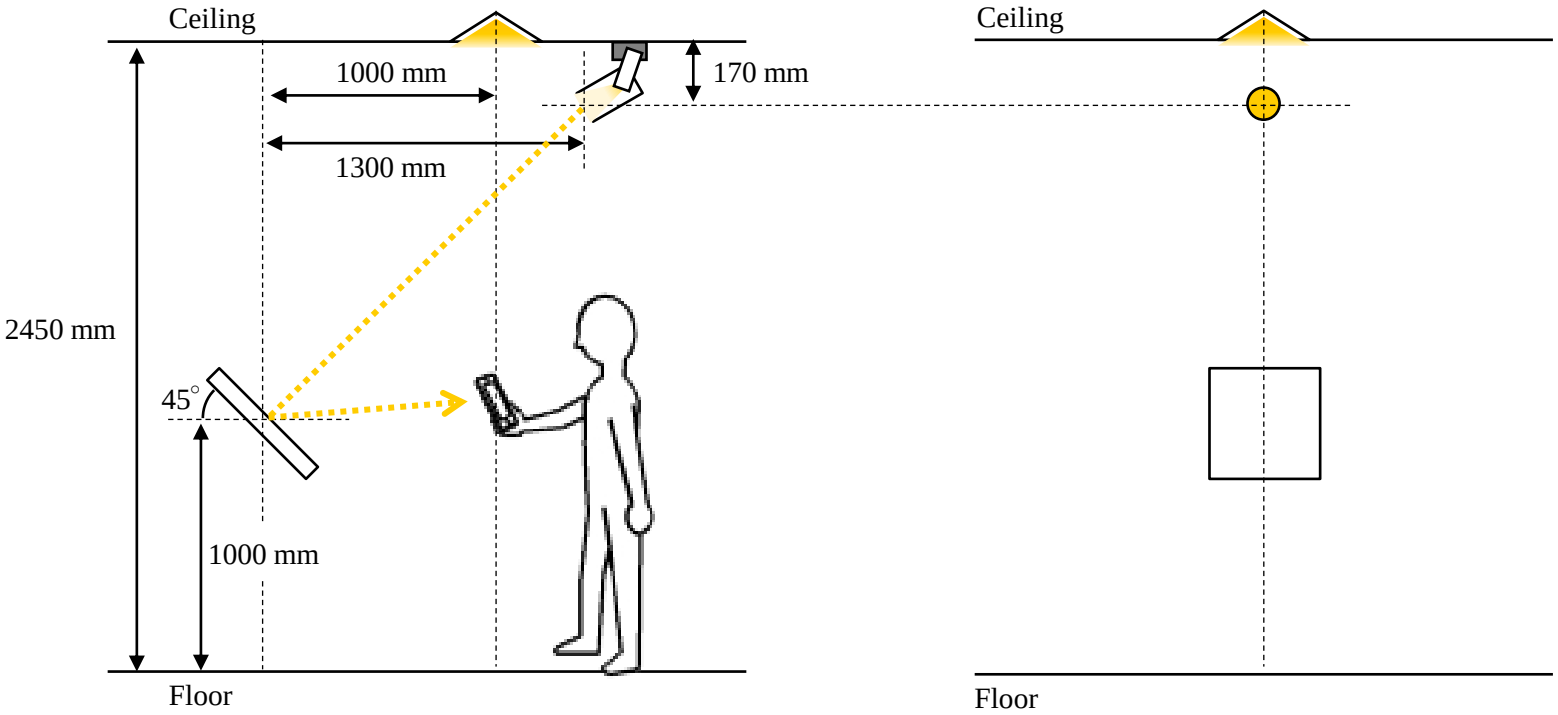
(Same)

Spot light (Transmitting light)

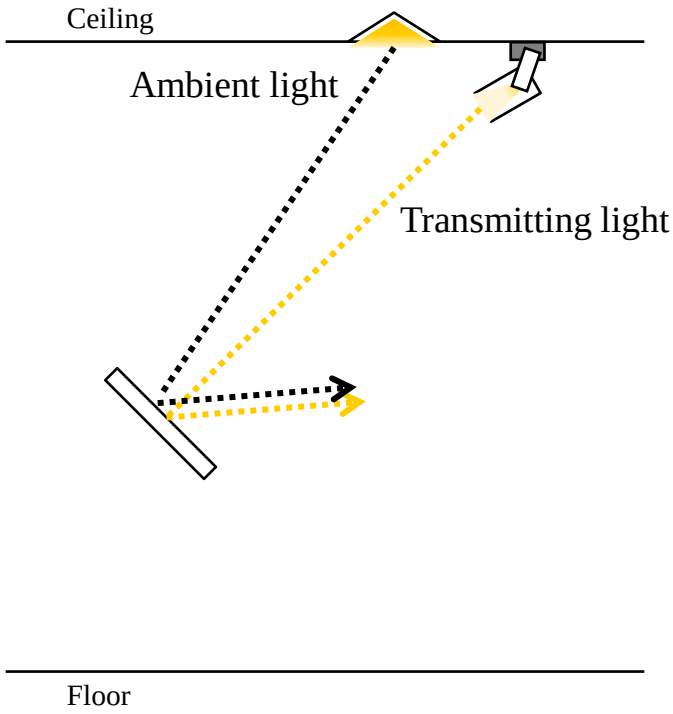
Reflection panel



Reflected Light - Layout



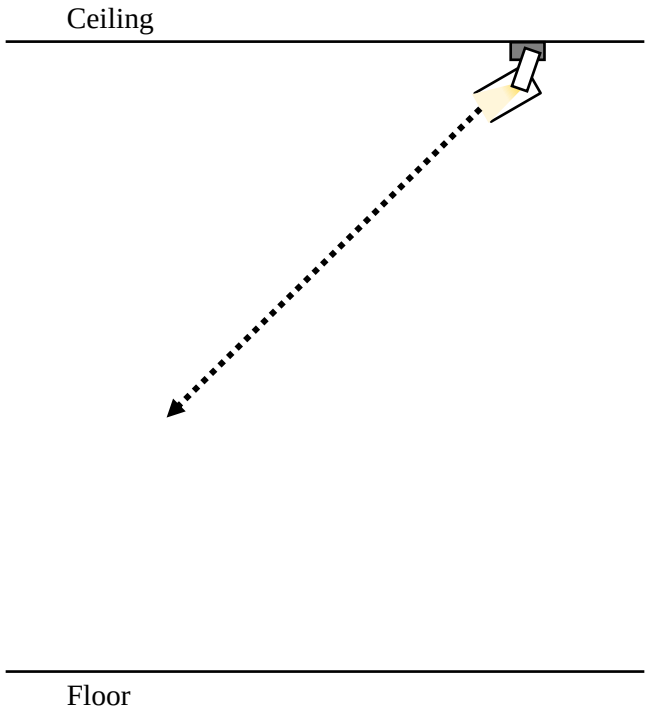
Reflected Light - Luminance



Transmitting light	ON	ON
Ambient light	ON	OFF
Horizontal angle (Vertical angle = 0)	Luminance [cd/m²]	
0	912	882
10	909	872
20	898	858
30	880	850
40	835	802
50	816	796
60	768	740
70	702	670
80	493	491
Vertical angle (Horizontal angle = 0)	Luminance [cd/m²]	
+30	970	933
+20	950	910
+10	920	891
0	912	882
-10	857	821
-20	836	793
-30	595	576

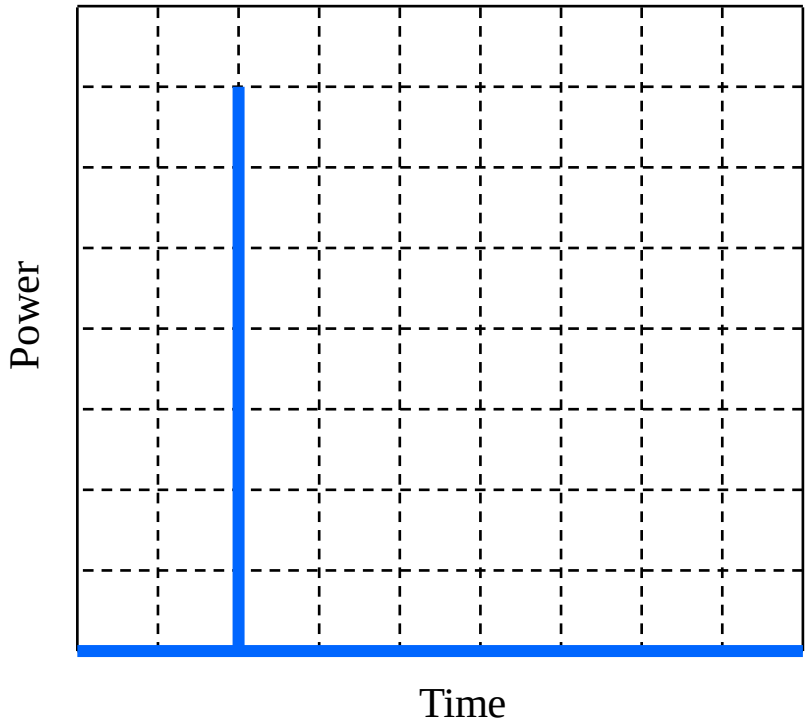
Vertical angle > 0 is ceiling side angle, and that < 0 is floor side angle.

Spot Light - Luminance



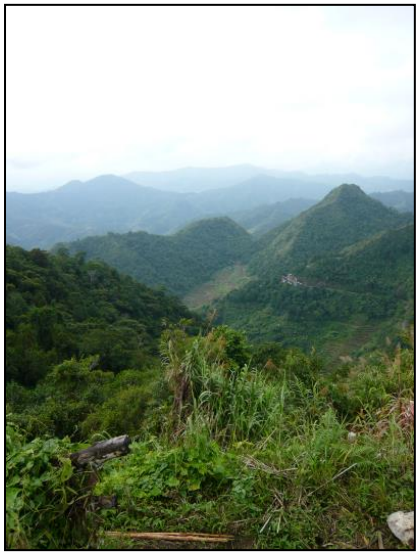
Angle	Luminance [cd/m^2]
0	705600
10	425600
20	61600
30	24800
40	9280
50	6064
60	4688
70	2944
80	693

Channel Impulse Response



Time difference of multipath arrivals can be ignored because it is negligibly small compared to read-out time of image sensors.

Channel Filter (Image on Screen)



The INRIA Holidays dataset[1], including 1491 high-resolution images, is shown on Light Panel, Display and Reflection Panel.

1) http://lear.inrialpes.fr/~jegou/data.php
Herve Jegou, Matthijs Douze and Cordelia Schmid, "Hamming Embedding and Weak geometry consistency for large scale image search," Proceedings of the 10th European conference on Computer vision, October, 2008

Receiver Signal/Noise Model

- Noise of image sensor consist of random noise (shot noise, amplifier noise, reset noise) and fixed pattern noise, and shot noise is the main source
- Shot noise consists of light shot noise and dark current shot noise
- Light shot noise level is proportional to the square root of signal level

Receiver Signal/Noise Model

	Signal	Light shot noise	Dark current noise
Source luminance	Proportional	Squared proportional	Constant
ISO speed	Exponential	Exponential	Exponential
Exposure duration	Proportional	Squared proportional	Constant

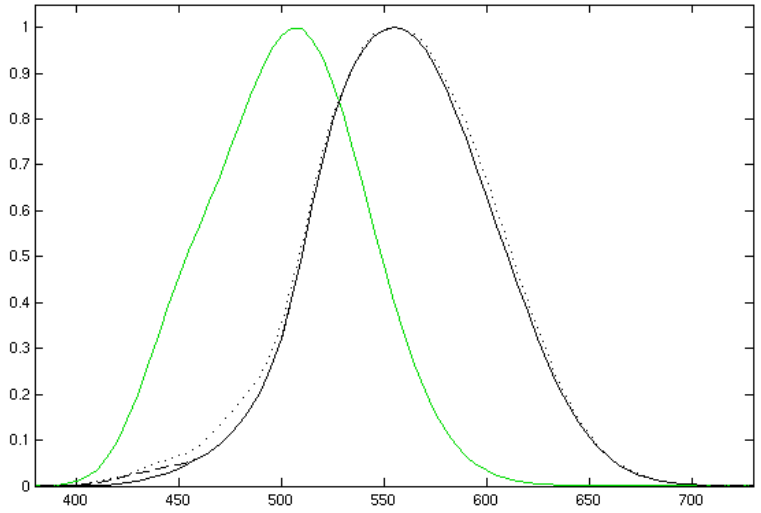
Appendix A: Unit Conversion (Candela to Watt)

Definition of Candela:

The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} Hz (= 550 nm in wavelength) and that has a radiant intensity in that direction of 1⁄683 W/steradian.

[16th General Conference on Weights and Measures (CGPM) in 1979]

The other frequency lights are weighted by the standard luminosity function (a model of the sensitivity of the human eye to different wavelengths).



Photopic (black) and scotopic (green) luminosity functions.

https://en.wikipedia.org/wiki/Candela