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

Submission Title: A NEW BAND PLAN FOR 15.7m

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Re:

Abstract: A new band plan is suggested for the 15.7m standard due to a new wavelength range given for 15.7 revision. This new band plan revision design considered the OWC communication to operate on the application services like IoT/IoL, LED IT, Digital Signage with Advertisement Information etc.

Purpose: Draft D1 Comments Resolutions and Editorial Revision

A NEW BAND PLAN FOR 15.7m

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INTRODUCTION

- The existing 15.7 standard is being revised with a new wavelength range.
  - In the existing standard, light signals have wavelengths that range from 380 nm to 780 nm [1]. This frequency (or wavelength) band is divided into seven communication channels or subbands.
  - For the revised standard, a new wavelength range is defined from 190 nm to 10000 nm.
- Due to the increasing demand for wireless communications,
  - A frequency band must be divided into channels in a manner that maximizes the efficiency of the band.
  - Light's unique characteristics are considered in order to efficiently divide the visible light band into subbands.
- In this document, a new band plan is proposed for a new wavelength range.

[1] Reference: 15-10-0327-00

NEW PAR FROM 15-15-0064-00

- **Changes in scope of the PAR:**
  - This standard defines a Physical (PHY) and Media Access Control (MAC) layer for short-range optical wireless communications ~~using visible light~~ in optically transparent media~~. The~~ using ~~visible~~ light ~~spectrum~~wavelengths ~~extends~~ from ~~380~~ 10,000 nm to ~~780~~190 nm ~~in wavelength~~. The standard is capable of delivering data rates sufficient to support audio and video multimedia services and also considers mobility of the ~~visible~~optical link, compatibility with ~~visible~~-various light infrastructures, impairments due to noise and interference from sources like ambient light and a MAC layer that accommodates the unique needs of visible links as well as the other targeted light wavelengths. It also accommodates optical communications for cameras where transmitting devices incorporate light emitting sources and receivers are digital cameras with a lens and image sensor. The standard adheres to applicable eye safety regulations.

Changes in scope for wavelength range: 380 nm to 780 nm → 190 nm to 10000 nm

METHODS/METRICS FOR NEW SCHEME (1)

- A method suggested for 15.7 divides the frequency channel based on characteristics of photo detection devices rather than human eye sensitivity.
  - This method is for optimality of communication performance because the light signals for communications are not detected by human eyes, but by photo detection devices at receivers.
  - Thus characteristics of photo detection devices is to be considered for better communication performance.
- Another motivation for the new scheme is to ensure power-fairness across the channels (i.e., equal received power for all channels).
  - This fairness is very important in scenarios where wireless users have capability of accessing more than one channel.
  - Having an equal/constant received power, regardless of which channel the user operates on, enables users to have the same transmission range and thus makes the link more robust to failure. In contrast, having varied received power levels for the subbands increases potential for the link to fail.

METHODS/METRICS FOR NEW SCHEME (2)

- New band division into 8 subbands
  - Whole range of wavelengths assigned into 8 subbands to be represented by 3 bits
  - Each side out of the visible band – 380 nm to 780 nm – to be assigned to a subband
  - The visible band is divided into 6 subbands.

EXISTING BANDPLAN WITH 7 BANDS [2]

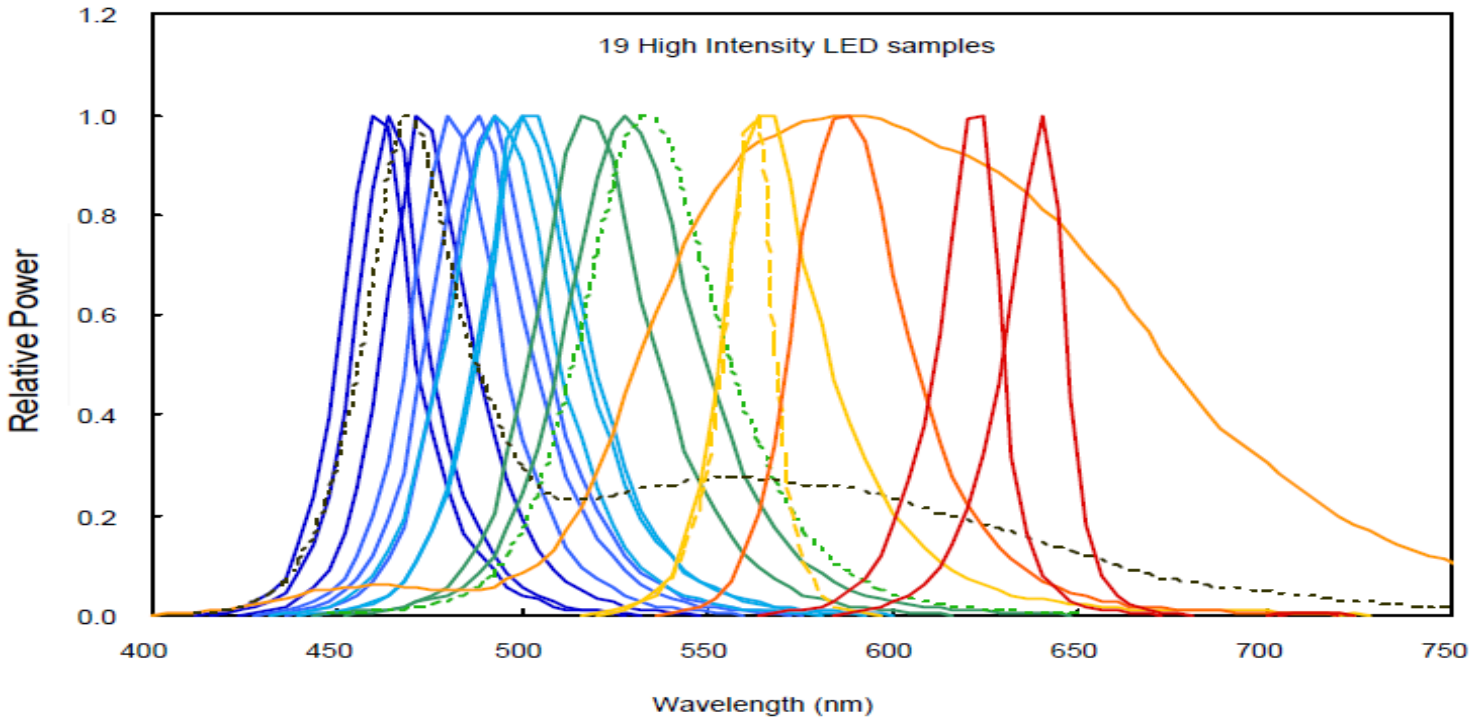
Table 87—Visible light wavelength band plan

Wavelength (nm)		Spectral width (nm)	Code
380	478	98	000
478	540	62	001
540	588	48	010
588	633	45	011
633	679	46	100
679	726	47	101
726	780	54	110
Reserved			111

[2] Table from the existing 15.7 standard

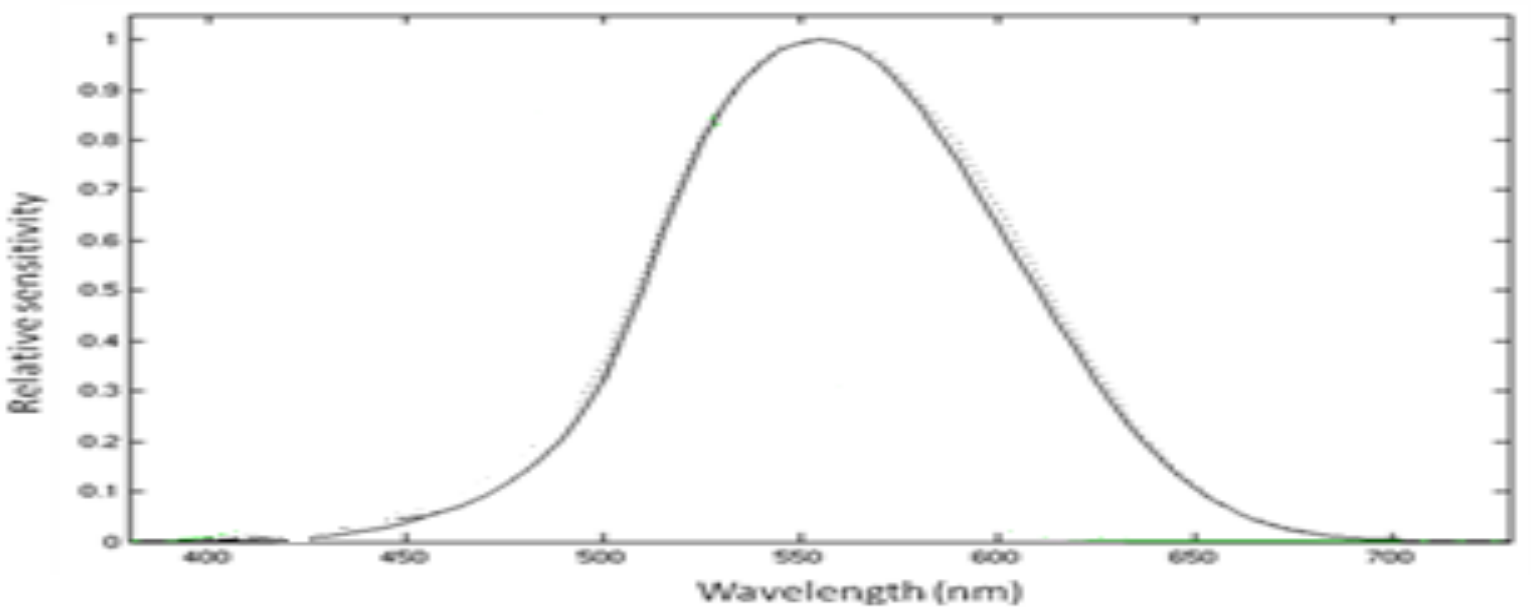
FACTORS TO BE CONSIDERED (1) LED SPECTRAL DISTRIBUTION

- LED Spectral Distribution
  - Spectral distributions for various color LEDs. Colored LEDs have narrower bands while white LEDs have broader bands.



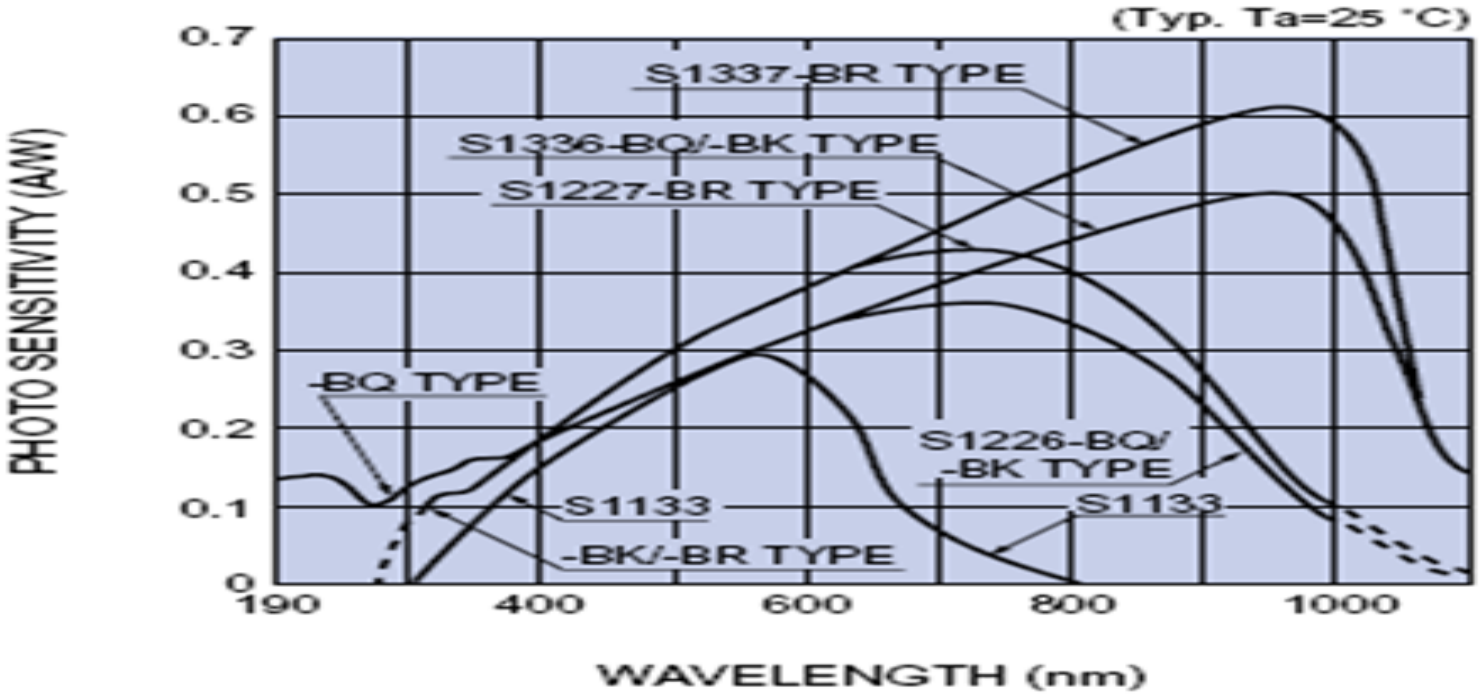
FACTORS TO BE CONSIDERED (2) HUMAN EYE SENSITIVITY

- Human Eye Sensitivity
  - Human eye sensitivity - luminosity function, the luminance response of the human eye cone photoreceptors. Human eyes are more sensitive to light components in the central part of visible light band.



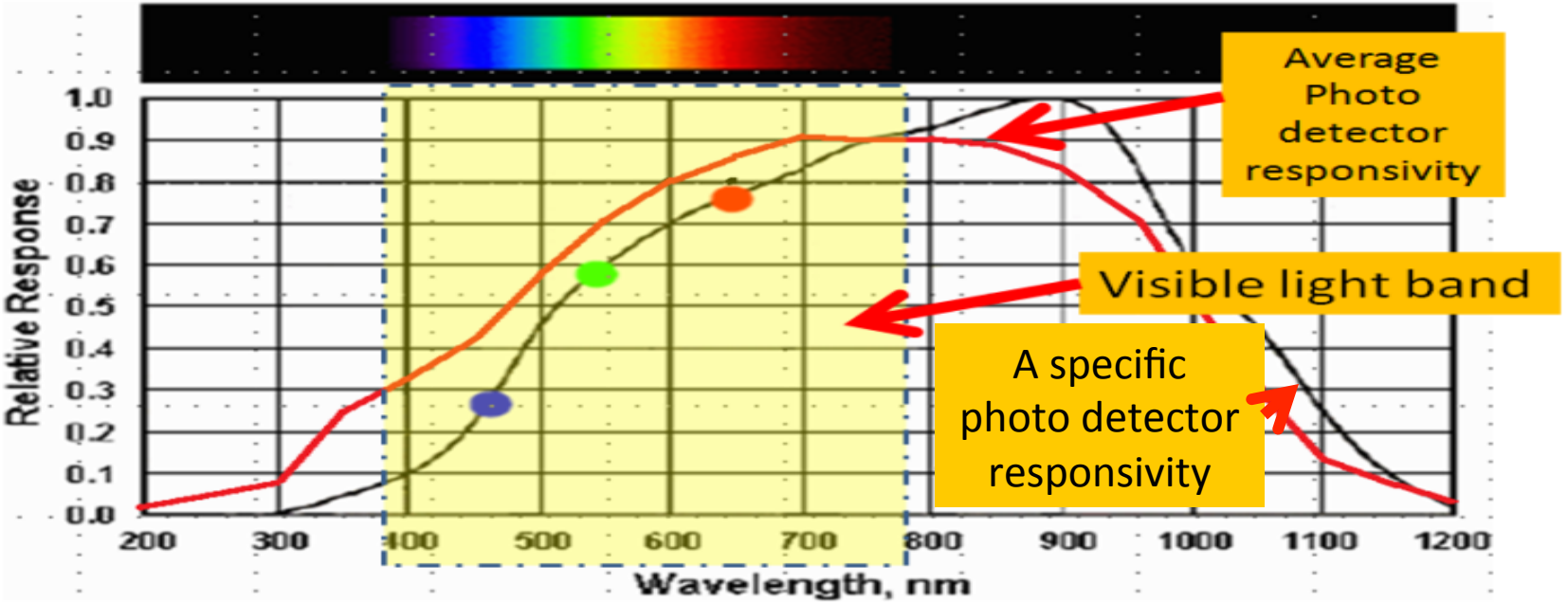
FACTORS TO BE CONSIDERED (3) PHOTO DETECTION RESPONSIVITY

- Photo Detector Responsivity
  - Examples of responsivity curves for various photo detection devices. In the visible light band, the responsivity increases approximately linearly with respect to wavelength.



USE OF RESPONSIVITY OF PHOTO DETECTORS

- Average Photo Detector Responsivity in Visible Light Range
  - Average responsivity of photo detectors which is calculated by averaging responsivity values of various types of photo detection devices from multiple vendors, shown in red.

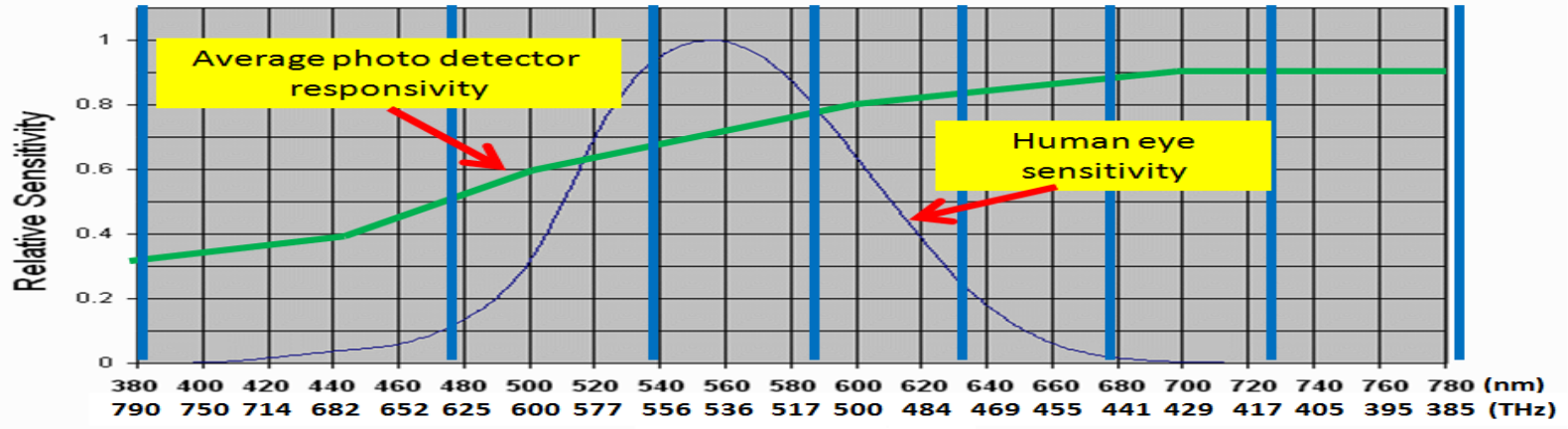


BAND DIVISION METHOD USING RESPONSIVITIES (1)

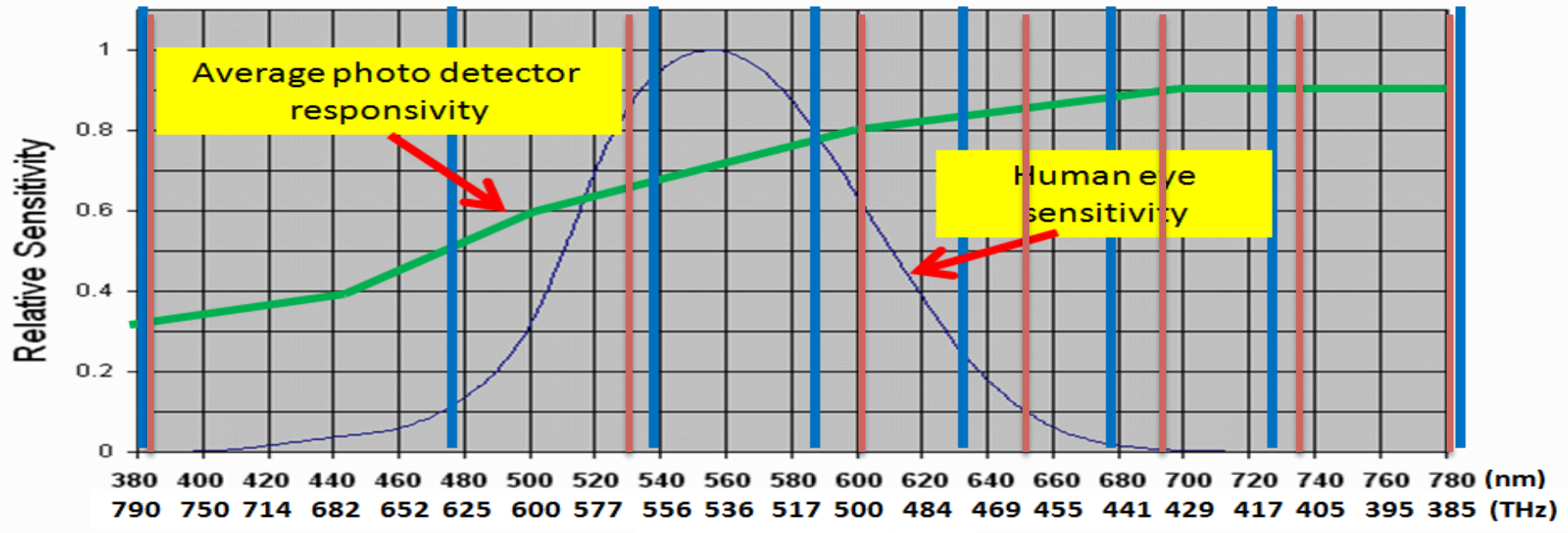
- **Based on responsivities of photo detection devices**, rather than human eye sensitivity
  - In order to make a receiver have evenly distributed power for all subbands

$$\int_{s_1} R^2(f)df = \int_{s_1} R^2(f)df = \ldots\ldots = const$$

where s_i is the frequency range of the ith subband and $R(f)$ is the average responsivity of photo detection devices as a function of frequency, f.



NEW BAND DIVISION (1)



New band boundary with 6 bands from 380 nm to 780 nm (6 subbands)

Old band boundary with 7 bands from 380 nm to 780 nm (7 subbands)

NEW BAND DIVISION (2)

- Responsivities of photo detection devices rather than human eye sensitivity applied for band division used

Frequency Band				Bandwidth		Code
(nm)		(THz)		(nm)	(THz)	
190	380	789	1579	190	790	000
380	529	567	789	149	222	001
529	598	502	567	69	65	010
598	649	462	502	51	40	011
649	694	432	462	45	30	100
694	737	407	432	43	25	101
737	780	385	407	43	22	110
780	10000	30	385	9220	350	111

CONCLUSION

- A novel metric to be used for wireless optical light band division - namely the photo detection responsivity.
  - By using the photo detection responsivity of the receiver device rather than a metric of the third party (not participating in communication), i.e., human's eye sensitivity, we achieve higher rate performance and more reliable communication, i.e., lower error rates.
  - The scheme divides the band so that all bands have equal E_b/N_o. Thus results in fairness for all users.
- A new band plan with 8 subbands for a new broader wavelength range for revised 15.7 standard is proposed.
  - An assumption is that each outside of the visible light band has totally different types of applications with different types of receiving devices.
  - Two subbands assigned for each of outside of the visible light band – one subband each for 190 nm to 380 nm and for 780 to 10000 nm
  - The visible light band is divided into 6 subbands using the above method – using photo detection responsivity.