

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

Submission Title: Contribution for CSK Related Comments

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Abstract: Remedies for CSK related comments, Comments 312, 474, 475, 489, 496, and 512 are suggested for the 15.7 standard.

Purpose:

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CSK RELATED COMMENTS AND REMEDIES

Comments, 312, 474, 475, 489, 496, 512

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CURRENT CONSTELLATION IN D1

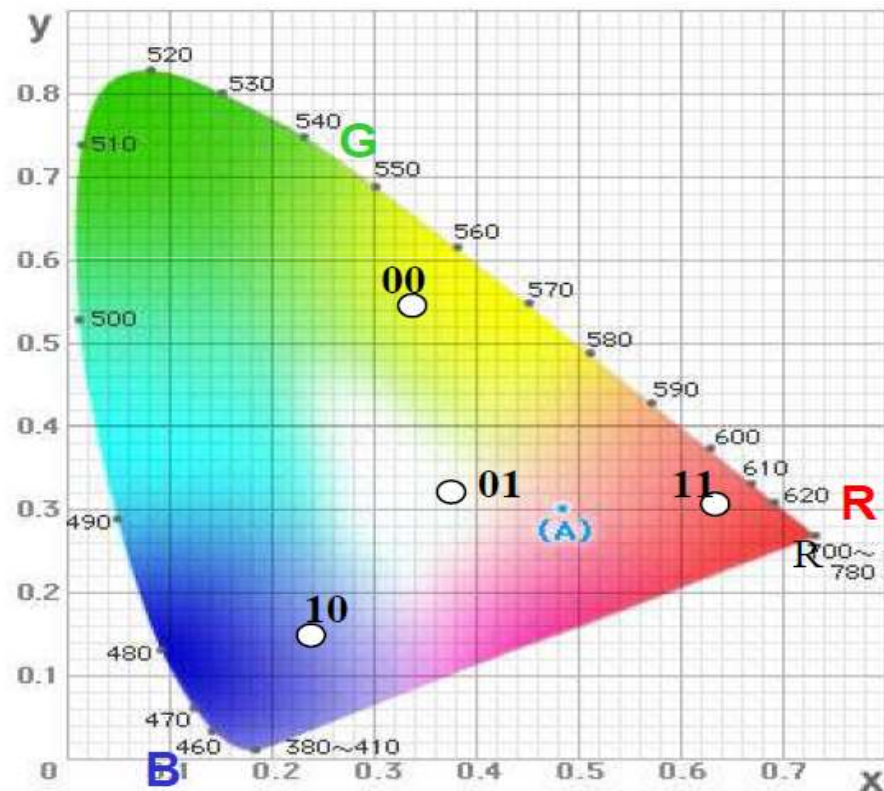
- A constellation diagram for quaternary cases (6.8.6)

$$x_p = P_i \cdot x_i + P_j \cdot x_j + P_k \cdot x_k$$

$$y_p = P_i \cdot y_i + P_j \cdot y_j + P_k \cdot y_k$$

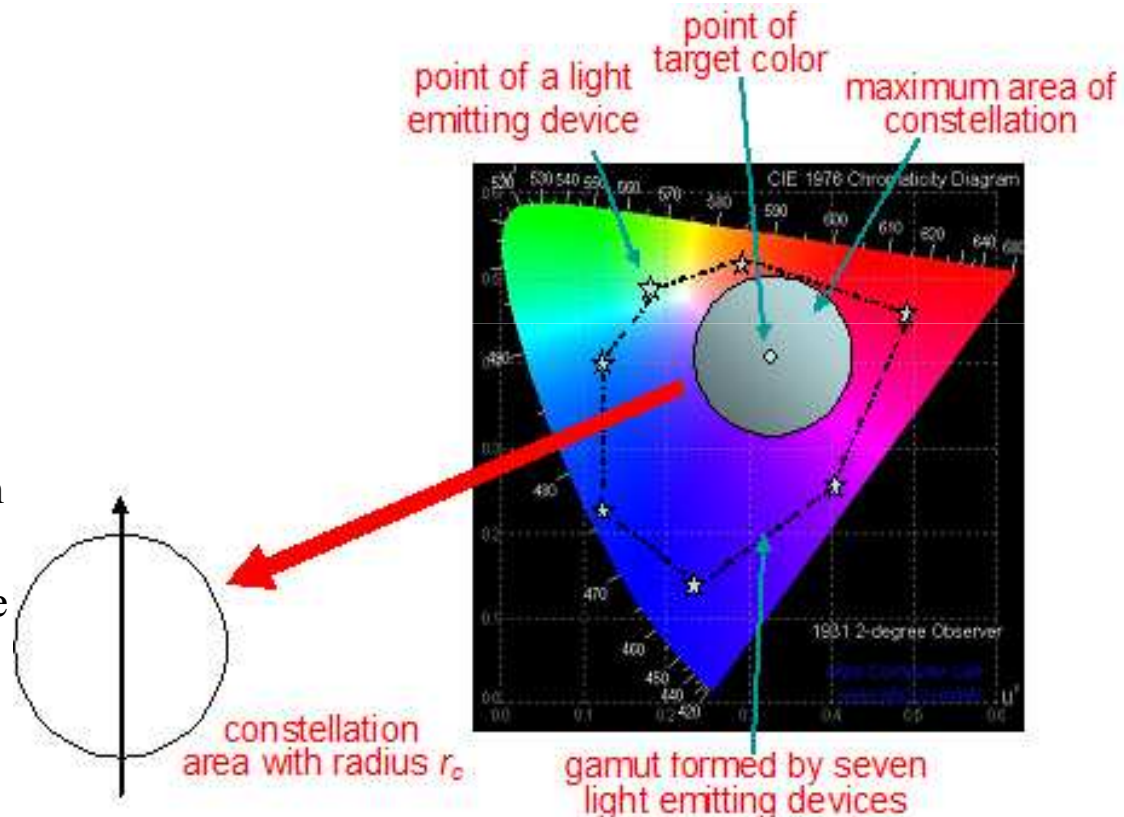
$$P_i + P_j + P_k = 1$$

- Problem with this constellation
 - Points of light sources should be outside of the constellation.
 - Some light sources can be located inside the constellation.
 - For this case, light signals for corresponding constellation points can not be generated.
 - Constellation and formulae in the above should be modified.



MODIFIED CONSTELLATION

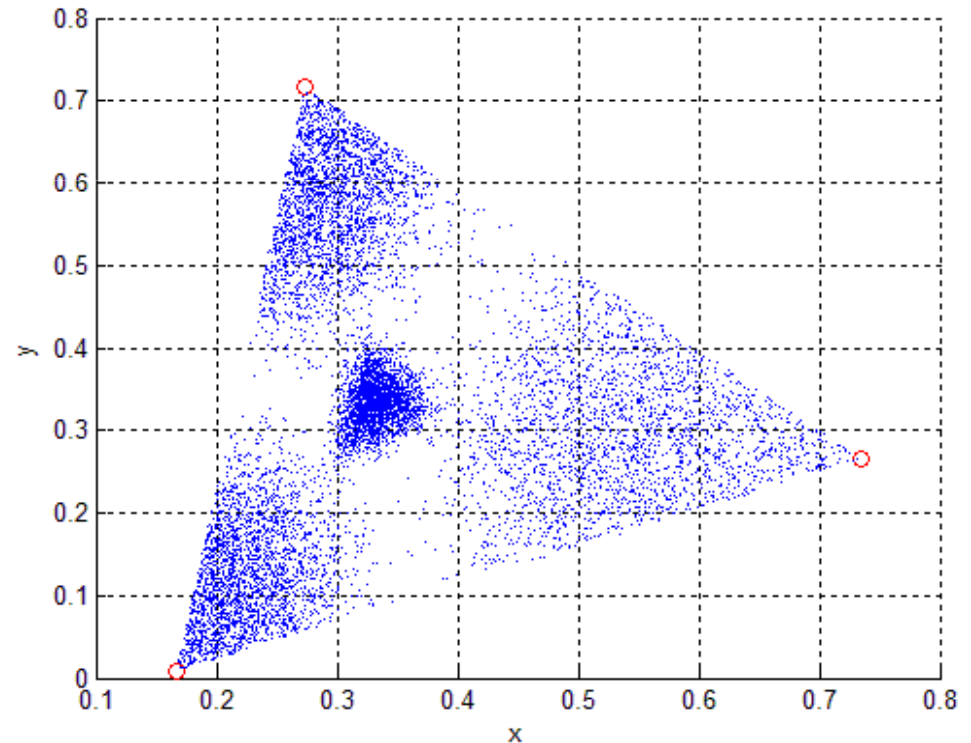
- Formation of a maximum constellation area
 - Light sources determine the gamut area.
 - Depending on the target color
 - A specific target color can be generated.
 - Current constellation is one with white target color and three light sources.
- More flexibility
 - Any target color
 - Any number of light sources



an example with seven light emitting devices

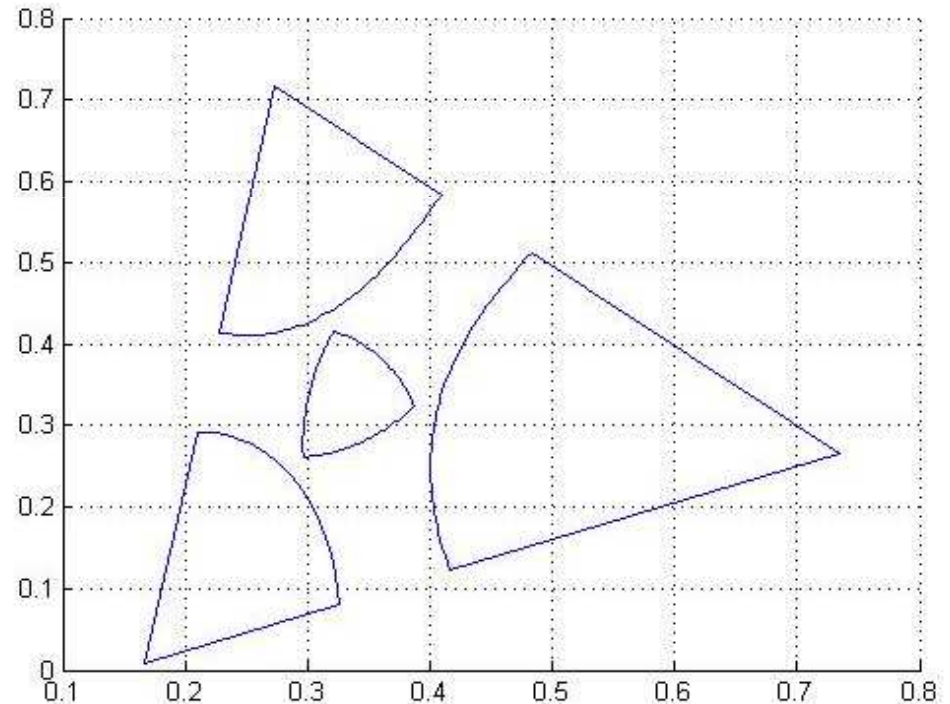
SYMBOL POINT DISPERSION (1)

- Dispersion of received symbols for CSK due to added AWGN noise on CIE 1931 with current formulae
 - Each symbol has a different dispersion area depending on the location of the point.



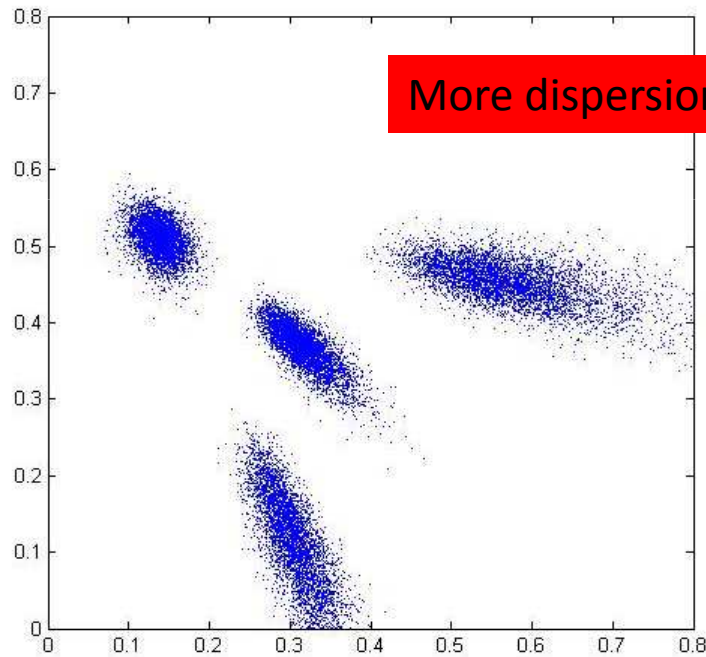
SYMBOL POINT DISPERSION (2)

- Subareas each of which represents its own symbol due to added AWGN noise on CIE 1931 with current formulae
 - Each symbol has a different dispersion area depending on the location of the point.

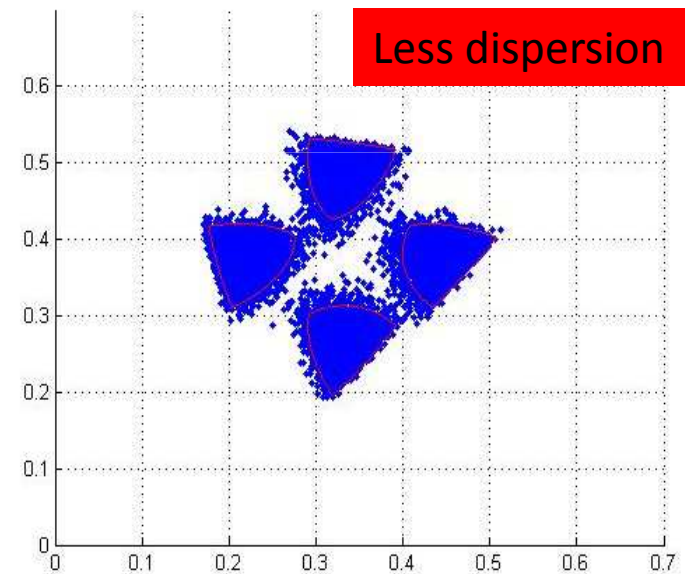


SYMBOL POINT DISPERSION (3)

- Dispersion of received symbols for CSK which results in degradation of performance on CIE 1976



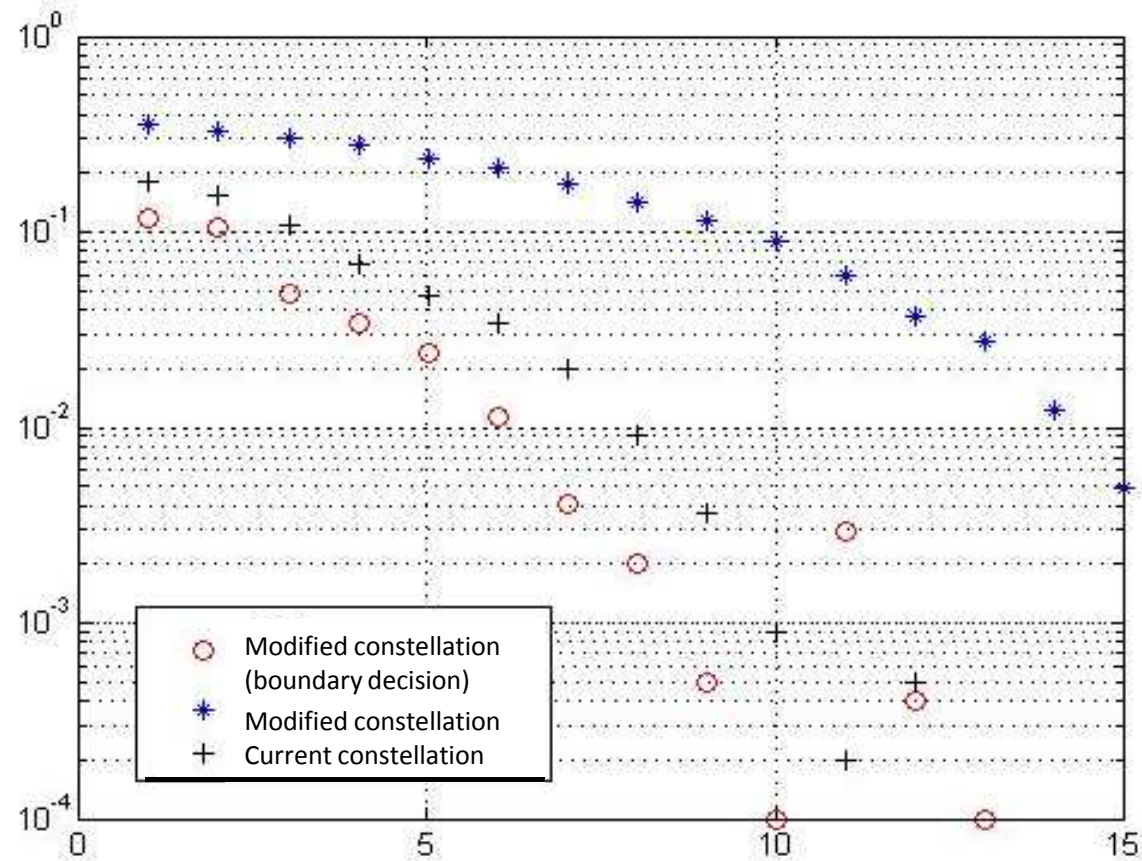
Dispersion with current constellation and formulae



Dispersion with modified constellation and formulae

PERFORMANCE COMPARISON

- BER performance comparison between current constellation and modified constellation



COMMENT 312

- Clause and Page: 6.4.1 Page 39 Line 21

Octets: variable	TBD				variable	2
Preamble	Frame length	Channel estimation sequence [where is this defined?]	Reserved	HCS (see 6.4.1.5)	PSDU	Frame Check Sequence (see 6.4.1.6)
	(7 bits)	(TBD)	(1 bit)	(16 bits)		
SHR	PHR				PHY payload	FCS

Figure 22—CSK PPDU

- Comment 312
 - “In Figure 22, channel estimation sequence may not be needed if the receiver is able to compensate distortion from the channel.”
- Suggested Remedy
 - “A channel compensation algorithm can rearrange constellation points at receiver without channel estimation for better performance.”

REMEDY FOR COMMENT 312

- Comment for the current 15.7 draft
 - In the current draft, some information should be exchanged for channel estimation or calibration. It is not needed because the receiver can compensate the inference effect from channel.
- Fact
 - At the receiver, the constellation for data symbol points can easily be identified at the receiver **by simply examining a fixed number of previous received points**. From these points, the constellation can be re-established/calibrated at the receiver without any information from outside.
 - Therefore channel estimation or calibration by exchanging information between transmitter and receiver is redundant and not needed.
- Suggested Remedy
 - “A channel compensation algorithm can rearrange constellation points at receiver without channel estimation for better performance.” Therefore , **delete this estimation. No estimation or calibration is needed.**

COMMENT 474

- Clause and Page: **6.8.4 Run Length Limiting Encoder**
 - All CSK modes use the 8B10B RLL code as defined in 6.7.3.2.
- Comment 474: 6.8.4 Page 55 Line 17
 - “CSK does not need RLL because it is a constant intensity modulation.”
 - **RLL is needed only for intensity (or power) balancing among symbol elements, which is not the case for CSK.**
- Suggested Remedy
 - “Figure 36 needs to be modified and add explanations.”

COMMENTS 475 & 512

- Clause and Page: **6.8.5 CSK bit to symbol mapping & 6.8.6.1 CSK Calibration**

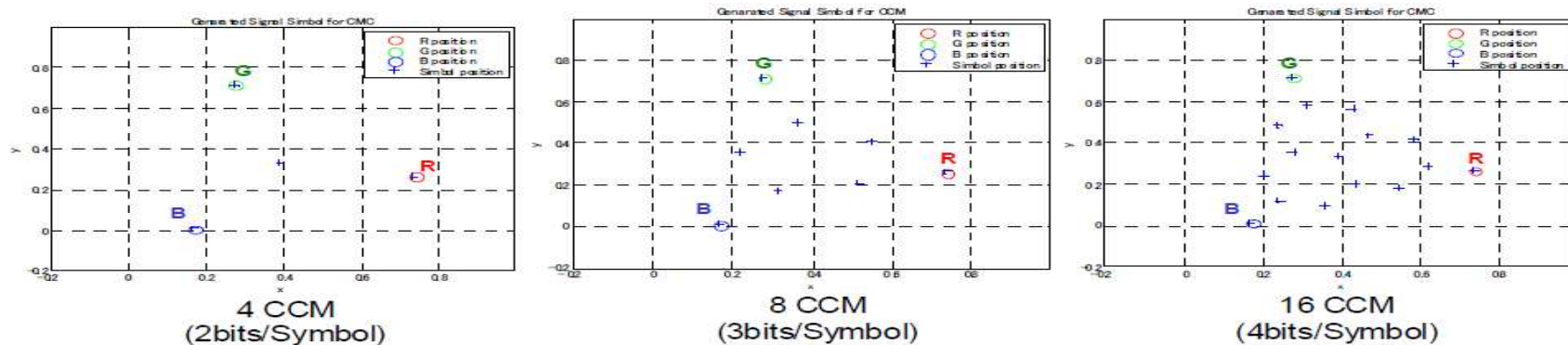


Figure 39—Color constellations for CSK

- Comment 475: 6.8.5 Page 55 Line 21 & Comment 512: 6.8.6.2 Page 59 Line 22
 - “CSK's constellation can be optimized with the characteristics light sources used. Therefore better constellation can be used for better performance for CSK.”
- Suggested Remedy
 - Better constellations depending on the symbol sizes should be used for better performance. **Apply the modified constellation and corresponding mapping formulae described in one of previous slides.**

COMMENT 489

- Clause and Page : **6.8.6 Symbol to Optical Mapping**
- Comment 489: 6.8.6 Page 56 Line 25
 - “Same issue as for Section 6.8.5. CSK's constellation can be optimized with the characteristics light sources used. Therefore better constellation can be applied for better performance for CSK.”
- Suggested Remedy
 - Better constellations depending on the symbol sizes should be used for better performance. **Apply the modified constellation and corresponding mapping formulae described in one of previous slides.**

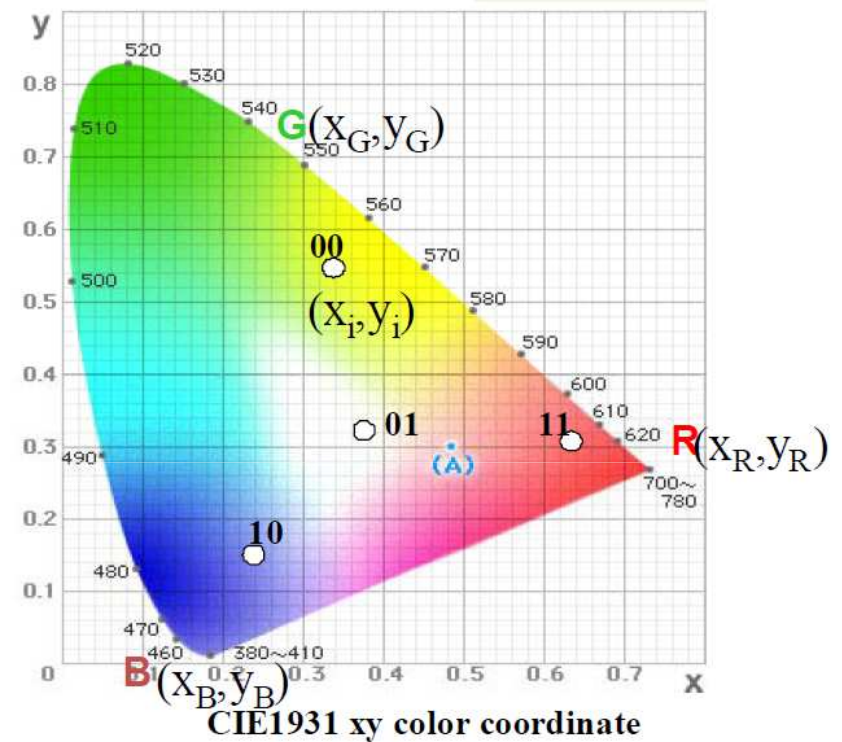


Figure 41—CIE 1931 xy color coordinate

$$x_p = P_i \cdot x_i + P_j \cdot x_j + P_k \cdot x_k$$

$$y_p = P_i \cdot y_i + P_j \cdot y_j + P_k \cdot y_k$$

$$P_i + P_j + P_k = 1$$

COMMENT 496

- Clause and Page: **6.8.6.1 CSK Calibration**
- Comment 496: 6.8.6.1 Page 57 Line 21
 - “CSK does not need to have calibration. The receiver can calibrate by itself using received signals.”
 - This calibration makes systems more complicated and becomes burdensome for link establishment.
- Suggested Remedy
 - “Constellations can be calibrated at the receiver without calibration signals from the transmitter.”
 - **No calibration is needed. So deletion of this clause is recommended.**

$$\begin{bmatrix} h_{ii} & h_{ij} & h_{ik} \\ h_{ji} & h_{jj} & h_{jk} \\ h_{ki} & h_{kj} & h_{kk} \end{bmatrix}$$

Figure 42—channel propagation matrix

$$\begin{bmatrix} P_i \\ P_j \\ P_k \end{bmatrix} = \begin{bmatrix} h_{ii} & h_{ij} & h_{ik} \\ h_{ji} & h_{jj} & h_{jk} \\ h_{ki} & h_{kj} & h_{kk} \end{bmatrix}^{-1} \begin{bmatrix} P_i' \\ P_j' \\ P_k' \end{bmatrix}$$

Figure 43—Propagation compensation

SUMMARY

- This contribution is prepared to provide remedies for Comments 312, 474, 475, 489, 496, and 512.
- CSK does not require information exchange between transmitters and receivers for any estimation and calibration.
 - This exchange should be unnecessary burden for communication networks.
- Modified constellation and corresponding formulae for determining intensities of light sources are suggested for better performance.
 - Current constellation in D1 has a problem when light sources are located outside the constellation.
 - Thus it needs to be modified and corresponding formulae for light source intensities.
 - Modified constellation allows us to have freedom for realization of any target color with any number of light sources.
 - Modified constellation has less dispersion and better BER performance than current constellation.