

**IEEE P802.15**  
**Wireless Personal Area Networks**

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Project	IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)	
Title	CSK constellation description	
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Re:		
Abstract	Full description about CSK constellation	
Purpose	[TG 7 received about CSK constellation comment in LB. This document is the response about CSK constellation comments]	
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### 6.8.5. CSK constellation Overview

CSK signal is generated by 3 color light sources in 7 color bands that are defined in 6.1.2 Operating frequency range and channel assignments. The 3 tops of CSK constellation triangle are decided by the center wave length of the 3 color bands on xy color coordinates. Table 29 shows the xy color coordinates values of those 7 color bands. Figure 39 shows the center of color bands on xy color coordinates.

Table 29 xy color coordinates values of 7 color bands

ColorCode	color	Band (nm)	Center (nm)	(x, y)
000	pB	380-450	415	(0.18, 0.01)
001	B,BG	450-510	480	(0.09, 0.13)
010	G	510-560	535	(0.19, 0.78)
011	yG,gY	560-600	580	(0.51, 0.49)
100	rO	600-650	625	(0.70, 0.30)
101	R	650-710	680	(0.72, 0.28)
110	R	710-780	745	(0.73, 0.27)
111	Reserved	-	-	-

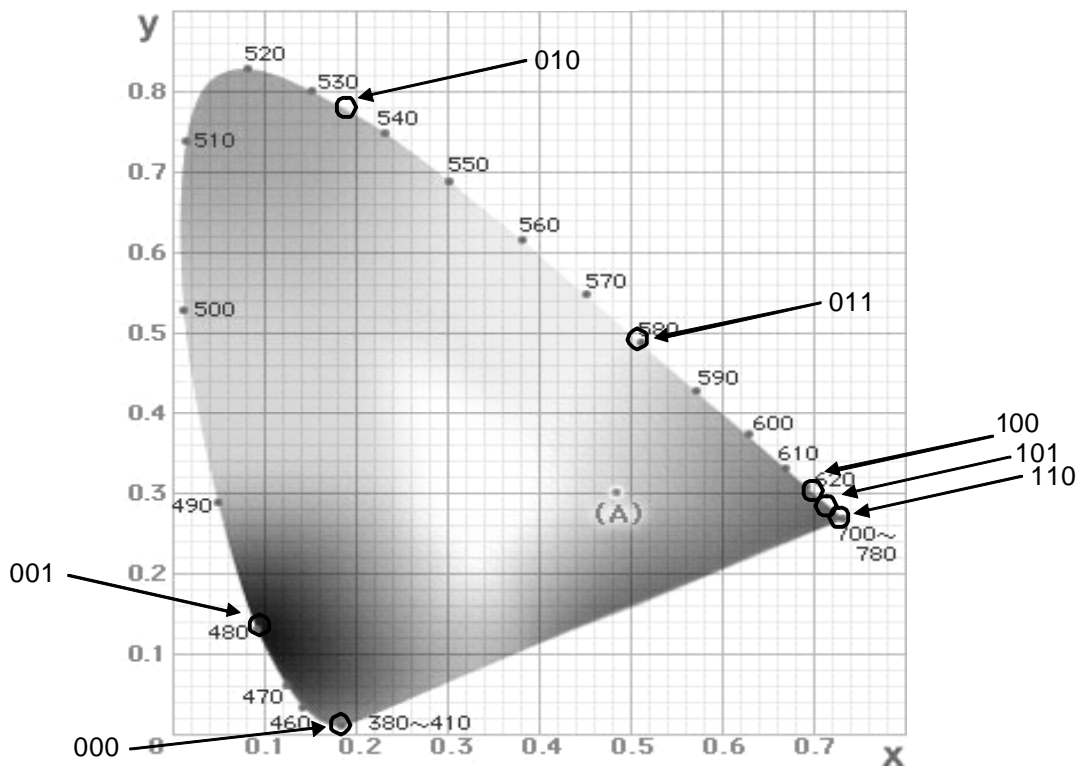


Figure 39 Center of color bands on xy color coordinates

#### 6.8.5.1. CSK constellation rule

#### 6.8.5.1.1 4 CSK

4 CSK symbol points are defined by the design rule in Figure 40. In Figure 40, Points I, J and K show the center of the 3 color bands on xy color coordinates. P0 to P3 are 4 symbol points of 4CSK. P0, P2 and P3 are 3 tops of the triangle IJK. P1 is a gravity center of the triangle IJK.

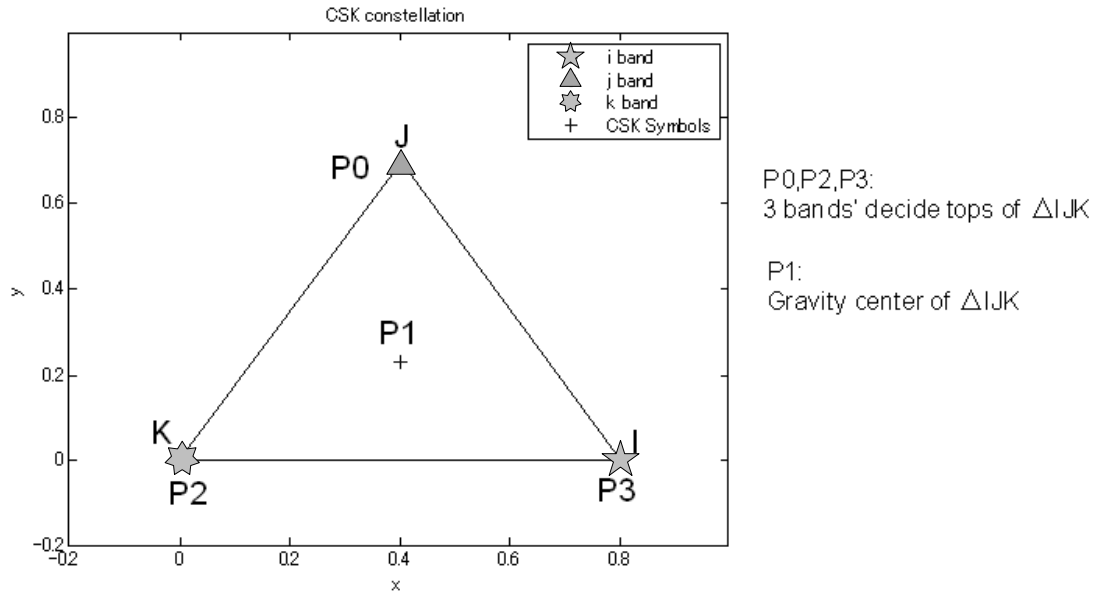
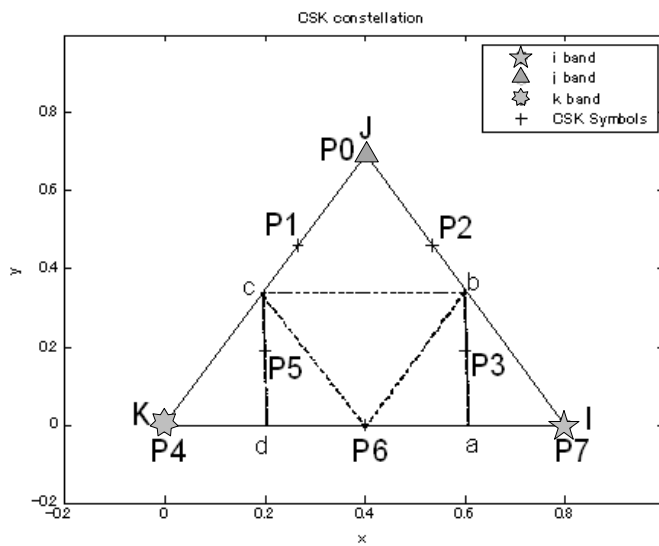


Figure 40 Symbol points allocation design rule for 4CSK

#### 6.8.5.1.2 8 CSK

8 CSK symbol points are defined by the design rule in Figure 41. In Figure 41, Points I, J and K show the center of the 3 color bands on xy color coordinates. P0 to P7 are 8 symbol points of 8CSK. P0, P4 and P7 are 3 tops of the triangle IJK. P1 and P2 are points that divide side JK and side JI in the ratio 1:2. Point c and b are midpoints of the side JK and side JI. Line ba and line cd meet at right angles with line KI. P3 is a point that divides line ba in the ratio 1:2. P5 is a point that divides line cd in the ratio 1:2. P6 is a midpoint of the line KI.



P0,P4,P7:  
3 bands' decide tops of  $\triangle IJK$

P1,P2:  
Points divide sides in the ratio 1:2.

c,b:  
Midpoint of the sides

Line ba and line cd meet at right angles with line KI.

P3:  
Points divide line ab in the ratio 1:2.

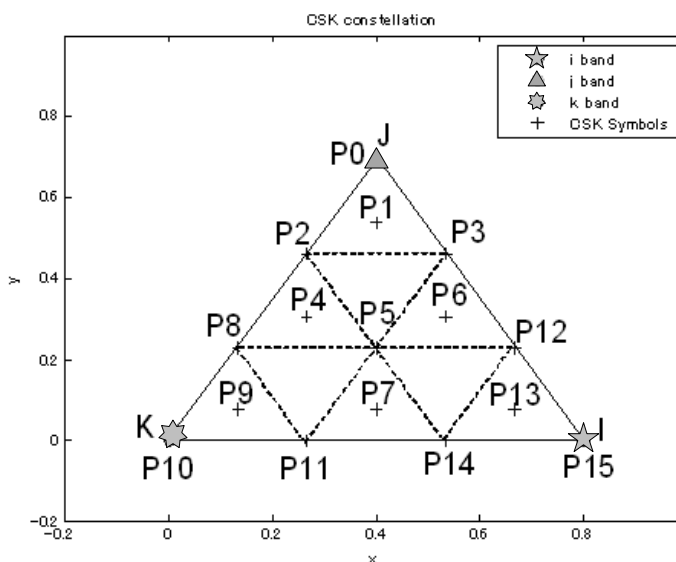
P5:  
Points divide line cd in the ratio 1:2.

P6:  
Midpoint of the line KI

Figure 41 Symbol points allocation design rule for 8CSK

#### 6.8.5.1.3 16 CSK

16CSK symbol points are defined by the design rule in Figure 42. In Figure 42, Points I,J and K show the center of the 3 color bands on xy color coordinates. P0 to P15 are 16 symbol points of 16CSK. P0, P10 and P15 are 3 tops of the triangle IJK. P2 and P8 are points that divide side JK in one third. P3 and P12 are points that divide side JI in one third. P11 and P14 are points that divide side KI in one third. P5 is a gravity center of the triangle IJK. P1, P4, P6, P7, P9 and P13 are gravity centers of small triangles.



P0,P10,P15  
3 bands' decide tops of  $\triangle IJK$

P2,P3,P8,P11,P12,P14:  
Points divide sides in one third

P5:  
Gravity center of  $\triangle IJK$

P1,P4,P6,P7,P9,P13  
Gravity center of each small  $\triangle$

Figure 42 Symbol points allocation design rule for 16CSK

#### 6.8.5.2. Data allocation

##### 6.8.5.2.1 4 CSK

4 CSK data allocation is shown in Figure 43.

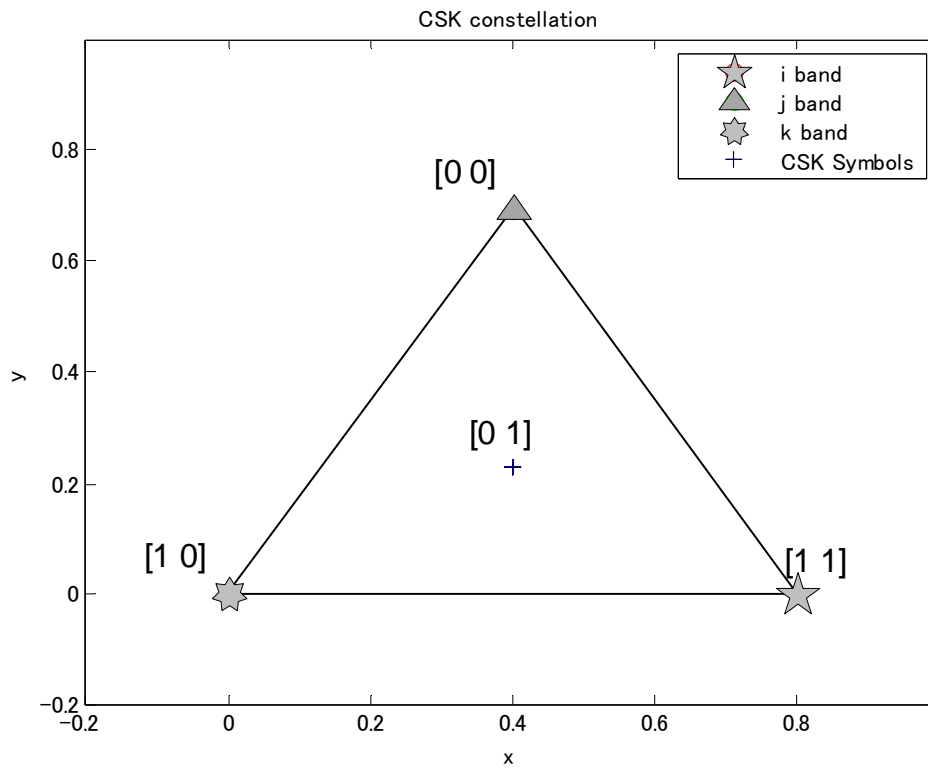


Figure 43 Data allocation for 4CSK

#### 6.8.5.2.2 8 CSK

8 CSK data allocation is shown in Figure 44.

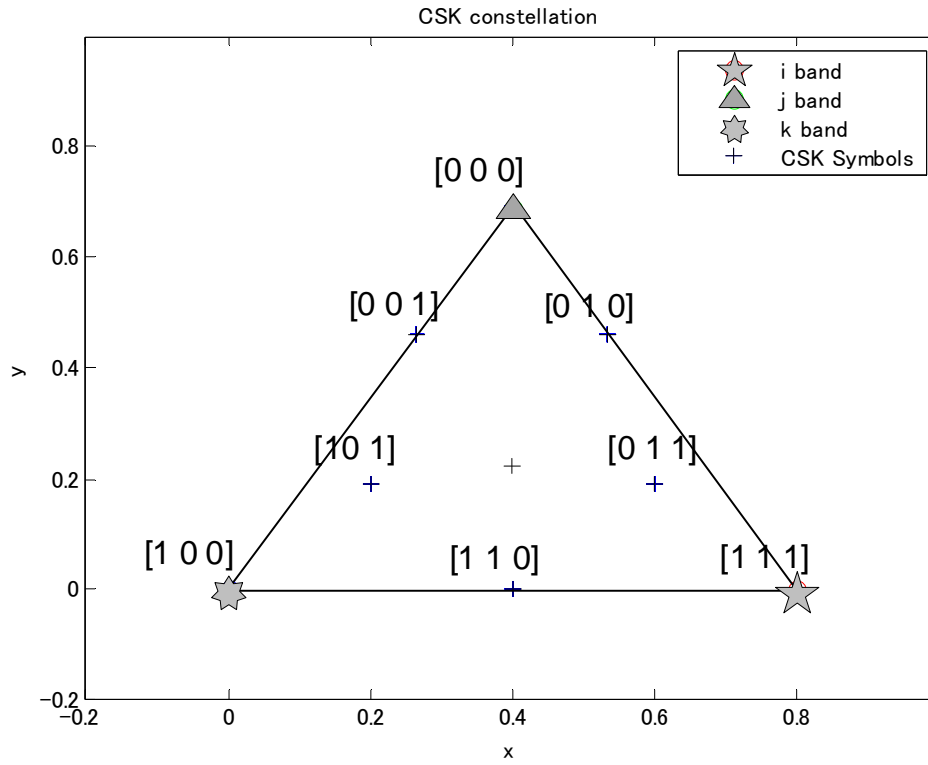


Figure 44 Data allocation for 8CSK

#### 6.8.5.2.3 16 CSK

16 CSK data allocation is shown in Figure 45.

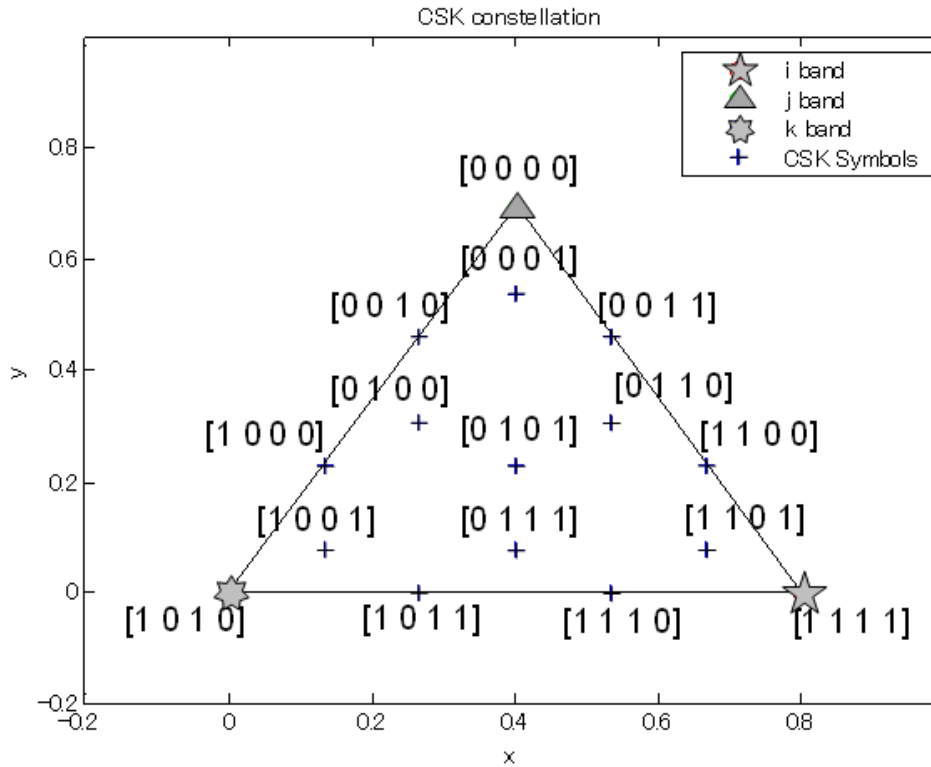


Figure 45 Data allocation for 16CSK

#### 6.8.5.3.. Color band combinations

CSK constellation is decided by the combination of the 3 color bands. The system cannot select the combination which cannot make a triangle on the xy color coordinates, like as (110-101-100) or (100-011-010). Because, in those example combinations, the center points of 3 color bands are on a line in xy color coordinates in Figure 39. Table 30 shows color band combinations that can make triangles for CSK constellations.

Table 30 Color band combinations for CSK

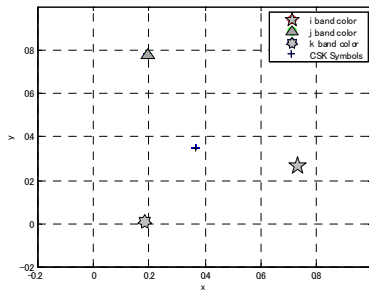
No.	Color codes for Color band combinations		
	Band i	Band j	Band k
1	110	011	001
2	110	011	000
3	110	010	001
4	110	010	000
5	101	011	001
6	101	011	000
7	101	010	001
8	101	010	000
9	100	011	001
10	100	011	000
11	100	010	001
12	100	010	000
13	011	010	001
14	011	010	000

Some of the color band combinations and their xy coordinates' values are shown in Table 31,32 and 33.And their constellations are shown in Figure 46,47 and 48.

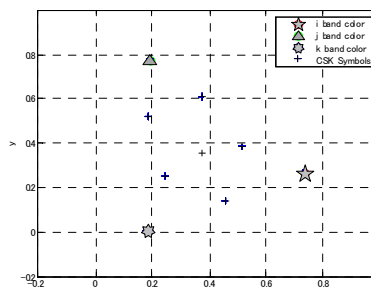
Table 31 Color band combination (No.4)



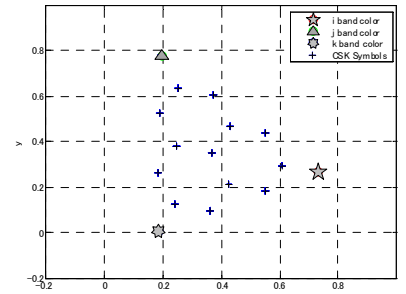
Color band combination (No.4)		xy coordinates values of symbols		
Color codes	Center of band (x,y)	4CSK [data] - (xp,yp)	8CSK [data] - (xp,yp)	16CSK [data] - (xp,yp)
110	(0.730 0.270)	[0 0] - (0.190 0.780)	[0 0 0] - (0.190 0.780)	[0 0 0 0] - (0.190 0.780)
010	(0.190 0.780)	[0 1] - (0.367 0.353)	[0 0 1] - (0.187 0.523)	[0 0 0 1] - (0.249 0.638)
000	(0.180 0.010)	[1 0] - (0.180 0.010)	[0 1 0] - (0.370 0.610)	[0 0 1 0] - (0.187 0.523)
		[1 1] - (0.730 0.270)	[0 1 1] - (0.519 0.383)	[0 0 1 1] - (0.370 0.610)
			[1 0 0] - (0.180 0.010)	[0 1 0 0] - (0.246 0.381)
			[1 0 1] - (0.244 0.253)	[0 1 0 1] - (0.367 0.353)
			[1 1 0] - (0.455 0.140)	[0 1 1 0] - (0.429 0.468)
			[1 1 1] - (0.730 0.270)	[0 1 1 1] - (0.426 0.211)
				[1 0 0 0] - (0.183 0.267)
				[1 0 0 1] - (0.242 0.124)
				[1 0 1 0] - (0.180 0.010)
				[1 0 1 1] - (0.363 0.097)
				[1 1 0 0] - (0.550 0.440)
				[1 1 0 1] - (0.609 0.298)
				[1 1 1 0] - (0.547 0.183)
				[1 1 1 1] - (0.730 0.270)



4CSK



8CSK

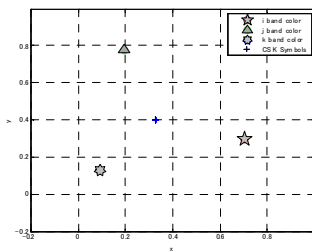


16CSK

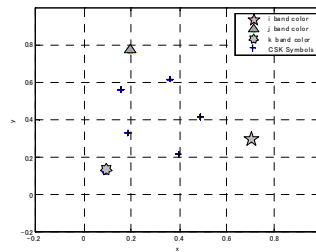
Figure 46 CSK constellations made by color band combination (No.4)

Table 32 Color band combination (No.11)

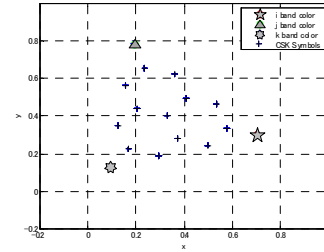
Color band combination (No.11)		xy coordinates values of symbols		
Color codes	Center of band (x,y)	4CSK [data] - (xp,yp)	8CSK [data] - (xp,yp)	16CSK [data] - (xp,yp)
100	(0.700 0.300)	[0 0] - (0.190 0.780)	[0 0 0] - (0.190 0.780)	[0 0 0 0] - (0.190 0.780)
010	(0.190 0.780)	[0 1] - (0.327 0.403)	[0 0 1] - (0.157 0.563)	[0 0 0 1] - (0.236 0.654)
001	(0.090 0.130)	[1 0] - (0.090 0.130)	[0 1 0] - (0.360 0.620)	[0 0 1 0] - (0.157 0.563)
		[1 1] - (0.700 0.300)	[0 1 1] - (0.491 0.414)	[0 0 1 1] - (0.360 0.620)
			[1 0 0] - (0.090 0.130)	[0 1 0 0] - (0.202 0.438)
			[1 0 1] - (0.186 0.329)	[0 1 0 1] - (0.327 0.403)
			[1 1 0] - (0.395 0.215)	[0 1 1 0] - (0.406 0.494)
			[1 1 1] - (0.700 0.300)	[0 1 1 1] - (0.372 0.278)
				[1 0 0 0] - (0.123 0.347)
				[1 0 0 1] - (0.169 0.221)
				[1 0 1 0] - (0.090 0.130)
				[1 0 1 1] - (0.293 0.187)
				[1 1 0 0] - (0.530 0.460)
				[1 1 0 1] - (0.576 0.334)
				[1 1 1 0] - (0.497 0.243)
				[1 1 1 1] - (0.700 0.300)



4CSK



8CSK

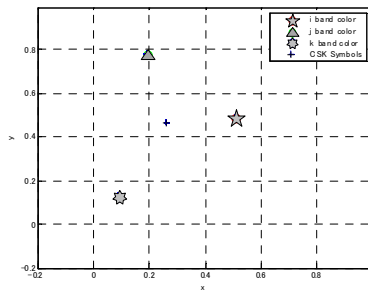


16CSK

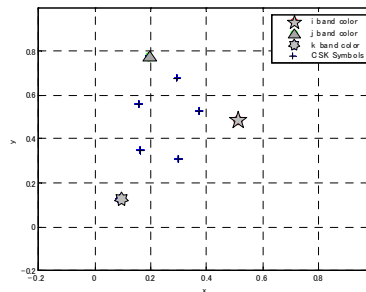
Figure 47 CSK constellations made by color band combination (No.11)

Table 33 Color band combination (No.13)

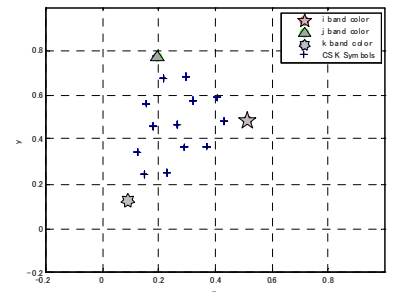
Color band combination (No.13)		xy coordinates values of symbols		
Color codes	Center of band (x,y)	4CSK [data] - (xp,yp)	8CSK [data] - (xp,yp)	16CSK [data] - (xp,yp)
011	(0.510 0.490)	[0 0] --> (0.190 0.780)	[0 0 0] - (0.190 0.780)	[0 0 0 0] - (0.190 0.780)
010	(0.190 0.780)	[0 1] --> (0.263 0.467)	[0 0 1] - (0.157 0.563)	[0 0 0 1] - (0.214 0.676)
001	(0.090 0.130)	[1 0] --> (0.090 0.130)	[0 1 0] - (0.297 0.683)	[0 0 1 0] - (0.157 0.563)
		[1 1] --> (0.510 0.490)	[0 1 1] - (0.374 0.531)	[0 0 1 1] - (0.297 0.683)
			[1 0 0] - (0.090 0.130)	[0 1 0 0] - (0.181 0.459)
			[1 0 1] - (0.164 0.351)	[0 1 0 1] - (0.263 0.467)
			[1 1 0] - (0.300 0.310)	[0 1 1 0] - (0.321 0.579)
			[1 1 1] - (0.510 0.490)	[0 1 1 1] - (0.288 0.362)
				[1 0 0 0] - (0.123 0.347)
				[1 0 0 1] - (0.148 0.242)
				[1 0 1 0] - (0.090 0.130)
				[1 0 1 1] - (0.230 0.250)
				[1 1 0 0] - (0.403 0.587)
				[1 1 0 1] - (0.428 0.482)
				[1 1 1 0] - (0.370 0.370)
				[1 1 1 1] - (0.510 0.490)



4CSK



8CSK



16CSK

Figure 48 CSK constellations made by color band combination (No.13)