



800MHz 12D 12PAM Mapping and Frame Structure Proposal

**IEEE P803.2an Task Force
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Supporters



Problem Statement

- The proposed 2D 12PAM constellation is an inefficient mapping and results in both a power and baud rate penalty.
 - “donut” constellation has 0.43dB higher power than uniform 12PAM
 - >2% baud rate penalty vs. a square constellation
- The proposed frame structure is also inefficient and very complex
 - 51,200 payload bits over 4224 baud



12D 12PAM Mapping

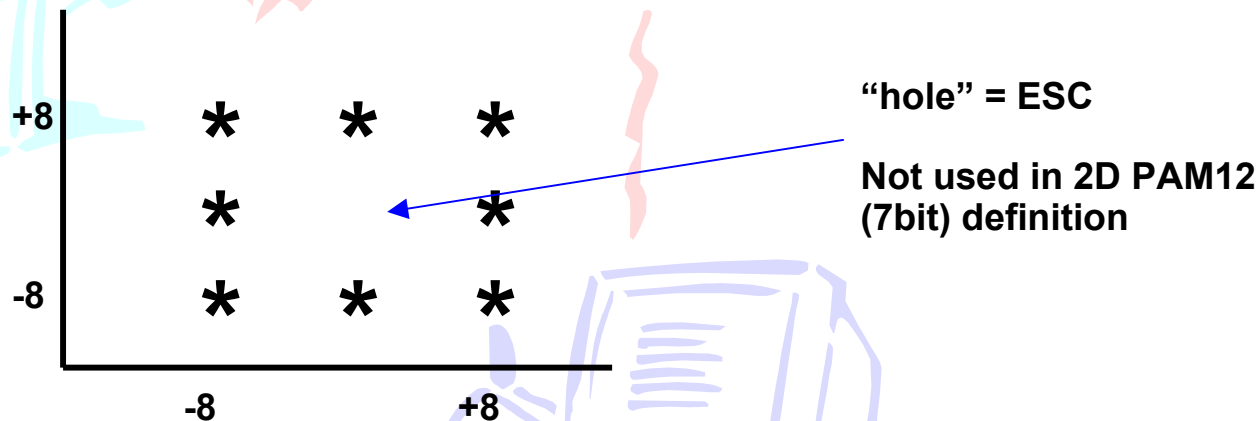
- **12-dimensional mapping**
 - 4 pairs x 3 baud = 12D constellation
- **43 bits per mapping (3 baud)**
 - 14.3333 bits per baud vs. 14
 - 8 coded + 6 1/3 uncoded bits per baud
 - 24 coded + 19 uncoded bits per 12D symbol
- **Uses the full 12x12 PAM constellation**
 - viewed from any 2D
- **Only 0.03dB TH precoding loss**
- **Transmit power independent of line length**

12D Mapping Construction

- Use the proposed “donut” as a base mapping for the 2D constellations
 - described in Powell (July)
 - Every 7 bits are mapped to 2 pair (2D)
 - 3 uncoded bits to select partition
 - 4 coded bits to select coset
- View 12D as 6 sets of 2D mappings
 - AB1, CD1, AB2, CD2, AB3, CD3
- Treat the missing partition as ESC
- 43-bit input- \rightarrow 1b + 6 x 7bits
 - For MSB=0 use the base mappings for all 6 2D groups
 - For MSB=1 replace 2D mappings with ESC

12D Mapping Construction

- Use the proposed “donut” as a base mapping for the 2D constellations
 - described in Powell (July)
 - Every 7 bits are mapped to 2 pair (2D)
 - 4 coded bits to select coset
 - 3 uncoded bits to select 1 of 8 partitions



- Treat the missing 9th partition as ESC

12D Mapping Construction

- **Create 12D symbol from 6 sets of 2D mappings**
 - AB1, CD1, AB2, CD2, AB3, CD3
 - 43-bit input → 1bit MSB + 6 x 7bits
 - for MSB=0 use the base mappings for all 6 2D groups
 - for MSB=1 replace some 2D mappings with ESC
 - 19 uncoded bits select the 6 2D partitions (see table T1)
 - The 6 2D mappings may contain 1, 2 or 3 ESC symbols based on the word value
 - coded bit mappings remain unchanged
 - 24-bits → 2 bits per pair per baud
 - 12D Mapping is described in 4 tables

12D ESC Mapping Tables

- Table T1**

19 uncoded bits select the 6 2D partitions

18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	AB1			CD1			AB2			CD2			AB3			CD3		
1	0	1 x ESC See T2		5 x 2DPAM12, in order as above in the remaining 2D partitions														
1	1	0	see T2	5 x 2DPAM12, in order as above in the remaining 2D partitions														
1	1	1	2 x ESC See T3				4 x 2DPAM12, in order as above in the remaining 2D partitions											
1	1	1	1	1	1	1	3 x ESC See T4			3 x 2DPAM12, in order as above in the remaining 2D partitions								

12D ESC Mapping Tables

Table T2 - Escape positions, 1 ESC

17	16	15	Escape position
0	0	0	AB1
0	0	1	CD1
0	1	0	AB2
0	1	1	CD2
1	0	0	AB3
1	0	1	CD3

12D ESC Mapping Tables

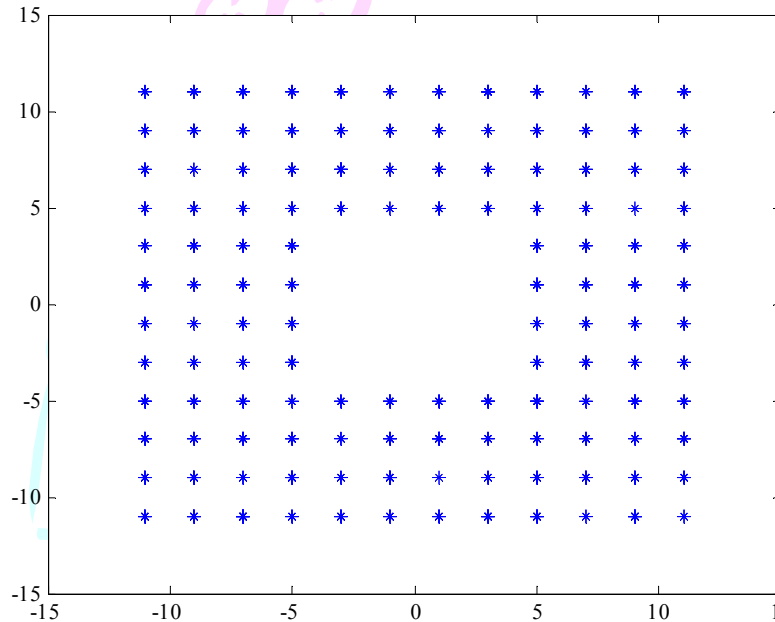
T3 - Escape positions, 2 ESC

15	14	13	12	Escape positions
0	0	0	0	AB1, CD1
0	0	0	1	AB1, AB2
0	0	1	0	AB1, CD2
0	0	1	1	AB1, AB3
0	1	0	0	AB1, CD3
0	1	0	1	CD1, AB2
0	1	1	0	CD1, CD2
0	1	1	1	CD1, AB3
1	0	0	0	CD1, CD3
1	0	0	1	AB2, CD2
1	0	1	0	AB2, AB3
1	0	1	1	AB2, CD3
1	1	0	0	CD2, AB3
1	1	0	1	CD2, CD3
1	1	1	0	AB3, CD3

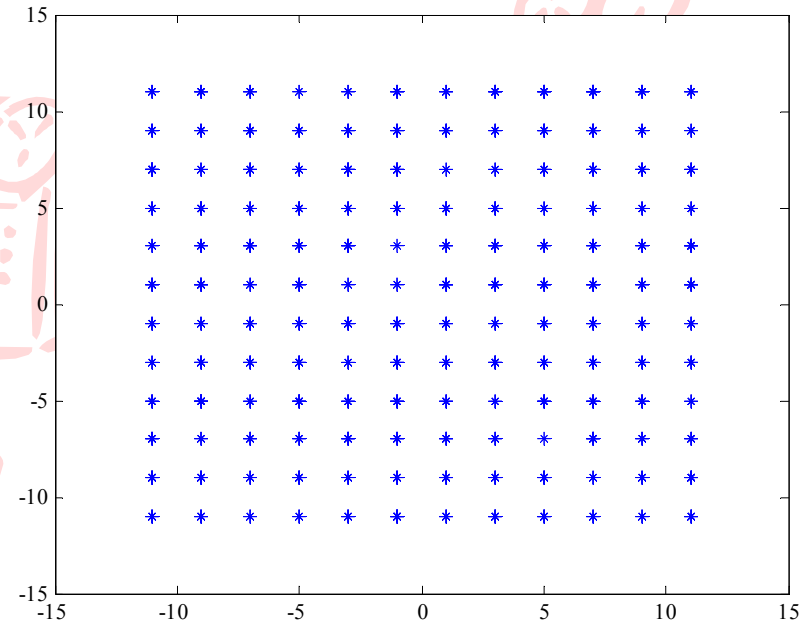
T4 - Escape positions, 3 ESC

11	10	9	Escape positions
0	0	0	AB1, CD1, AB2
0	0	1	CD2, AB3, CD3
0	1	0	AB1, CD1, AB3
0	1	1	AB2, CD2, CD3
1	0	0	AB1, AB2, CD2
1	0	1	CD1, AB3, CD3
1	1	0	AB1, AB2, CD3
1	1	1	CD1, CD2, AB3

2D Constellation View



2D 12PAM "donut"
constellation



2D view of the 12D
12PAM constellation

Frame Structure for 12D 12PAM

- **LDPC block frame of 128 baud**
 - 12D 12PAM mapping
 - 800 MHz baud rate
 - 1600 bits of payload per block
 - 64b/65b coding
 - Clause 49 scrambler / descrambler
 - (1024,833) LDPC
 - 1 baud per frame dedicated to frame alignment

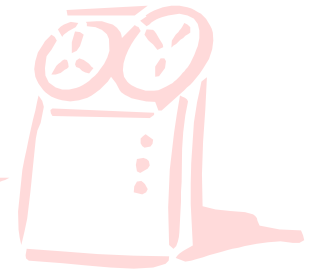


Frame Construction

- **Construct an LDPC block from 25 blocks of 64b/65b coded data**
 - 50 XGMII transfers -> 1600 bits
 - 1600 bits->65/64 -> 1625 bits
 - Add 4 pad bits -> 1629 bits
- **Split into coded/uncoded**
 - 1629 -> 825 coded + 804 uncoded
- **LDPC encode using (1024,833)**
 - Use 825 bits + 8 pad bits (= '0')
 - Generate 191 check bits

Frame Construction

- **LDPC encoded block**
 - 804 uncoded bits
 - 825 coded bits + 191 check bits = 1016 bits
- **Transmit bits over 127 baud frame**
 - 127 baud of 12PAM carries
 $127 \times 8 = 1016$ coded bits
 - 126 baud of 12D 12PAM + 1 baud of
4D 12PAM (2 pairs of 2D) carries
 $126 \times 19/3 + 6 = 804$ uncoded bits



Frame Alignment

- A single baud is added to every 127 baud LDPC block for frame alignment
 - 2PAM: e.g. +7/-7
 - An alternating or PN sequence may be transmitted during this time for alignment testing
 - Or, the LDPC blocks may be grouped into bundles of 8 preceded by an 8 x 4D 2PAM frame alignment symbol (per the Tellado_1_0704 12PAM proposal)



Baud Rate

- **Baud Rate = $128 \times 10G / (1600 \text{ bits})$**
 - = 800Mbaud
 - Easy frequency to generate
 - 25MHz XTAL with small N & M PLL divisors can generate XGMII, XAUI and baud rate clocks
 - Low jitter
 - <1% penalty for frame alignment



Lower baud rate option

- Frames are 127 baud
- Perform frame alignment during the startup process per the 8PAM proposal.
- Alignment status is determined by LDPC decoder
- Baud Rate = $127 \times 10G / (1600 \text{ bits})$
 - = 793.75 Mbaud
 - Uses 25 MHZ XTAL $\rightarrow (25 * 127 / 4)$
 - ~ 1% lower than 800MHz



Additional Codes

- **Extensible to other codes and block sizes**
 - e.g. (2048,1723) with 255 baud block @ 781.25 MHz

12D 12PAM baud rate calculations

LDPC out

LDPC in

baud

1024	2048
833	1723
127	255

pad bits

4

15

payload (bits)

1600

3264

baud rate (MHz)

793.75

781.25

SNR

30.07

30.37

SNR gain vs 825MHz

0.79

1.09

add 1 baud per frame

baud rate (MHz)

800

784.313725

SNR

29.92

30.29

SNR gain vs 825MHz

0.64

1.01

Summary

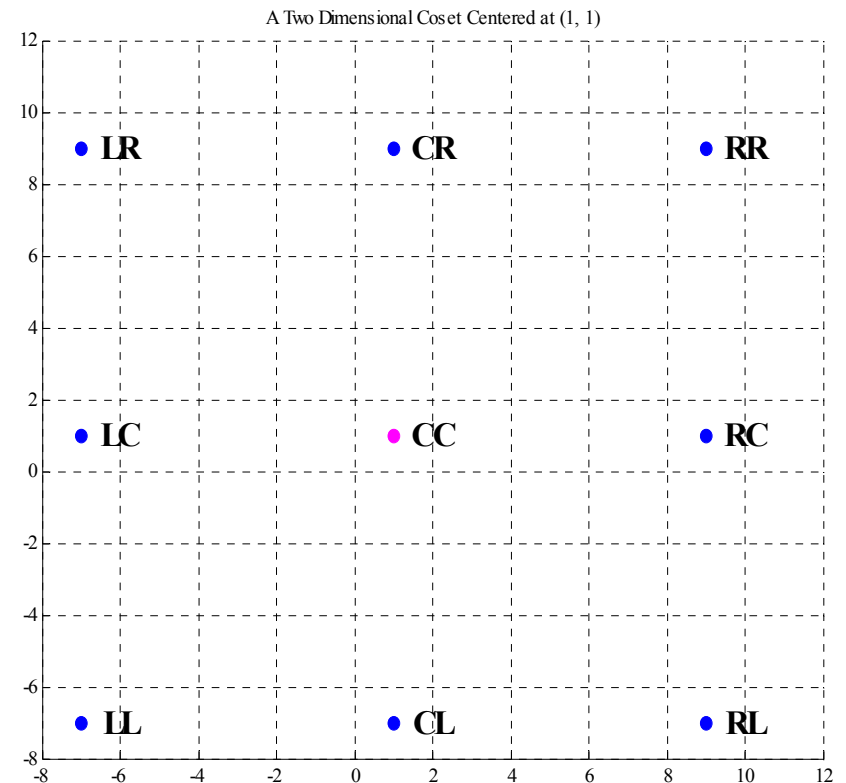
- **This 12D 12PAM mapping and framing proposal provides for:**
 - **800MHz baud rate using (1024,833) LDPC**
 - **0.64 dB SNR gain over prior proposal**
 - **Simple frame construction**
 - **128 baud frames**
 - **1600 bit payload**
 - **Robust frame alignment**
 - **Addresses the baud rate and transmit power penalties of the current 12PAM proposal.**
 - **Utilizes Clause 49 coding and scrambling**

Backup Slides

- **Alternative 12D Mappings**
- **Base-3 Mapping (Jose Tellado)**
 - For each 12D symbol convert the 19 uncoded bits to 12 base-3 values
 - Each base-3 value selects a ternary (L,C,R) partition on a single pair per baud
 - Demapping uses reverse process
- **Refinement to the 12D ESC (Dariush Dabiri)**
 - Equivalent to 12D ESC but requires only 1 table
 - Description follows (from Dariush)

2D Partitioning

- Decompose the 2D constellation into two sets:
 - B: The 8 blue points.
 - R: The red point at the center.



4D Labeling Rules

- Any 4D coset, S , has $3^4 = 81$ points.
- Any 4D coset can be decomposed as:
 - $S = X + Y + Z$ (see the table below).
- Points of X use 2 copies of the 3-bit Gray labeling of B . Each copy is used for 2D. A total of 6bits/4D.
- For points of Y , the MSB chooses between RxB and BxR . Use the 3-bit Gray labeling of B to choose points inside RxB (or BxR) (Note: R has only one point). A total of 4bits/4D.

Set	Formula	Points	No of Bits
X	$B \times B$	64	6
Y	$RxB + BxR$	16	4
Z	$R \times R$	1	0

12D Labeling

- Each constellation subset is identified by a unique prefix (see the next table).
- Points inside each subset are labeled by 3 copies of the 4D labeling of the previous slide. The generated bits are called the 'suffix bits' of each constellation point.
- The next table shows prefixes for the 12D subsets used in our labeling:



Prefix	Subset	No of Suffix Bits	Total Bits
0*	(X, X, X)	18	19
100*	(X, X, Y)	16	19
101*	(X, Y, X)	16	19
110*	(Y, X, X)	16	19
11100*	(Y, Y, X)	14	19
11101*	(Y, X, Y)	14	19
11110*	(X, Y, Y)	14	19
1111100*	(X, X, Z)	12	19
1111101*	(X, Z, X)	12	19
1111110*	(Z, X, X)	12	19
1111111*	(Y, Y, Y)	12	19

Mapper and Demapper

- **Mapper:**
 - Prefix match to find the unique matching prefix and the corresponding subset.
 - Use the suffix bits to specify the constellation points according to the 4D labeling rules.
- **Demapper:**
 - Identify the unique 12D subset for the received 12D symbol.
 - Use the table to find the unique prefix.
 - Use the 4D labeling rules to find the suffix bits.

