Differential Space-Time Block Codes based on simultaneous phase and amplitude modulation

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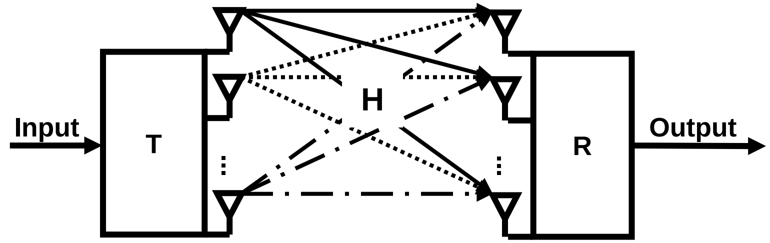
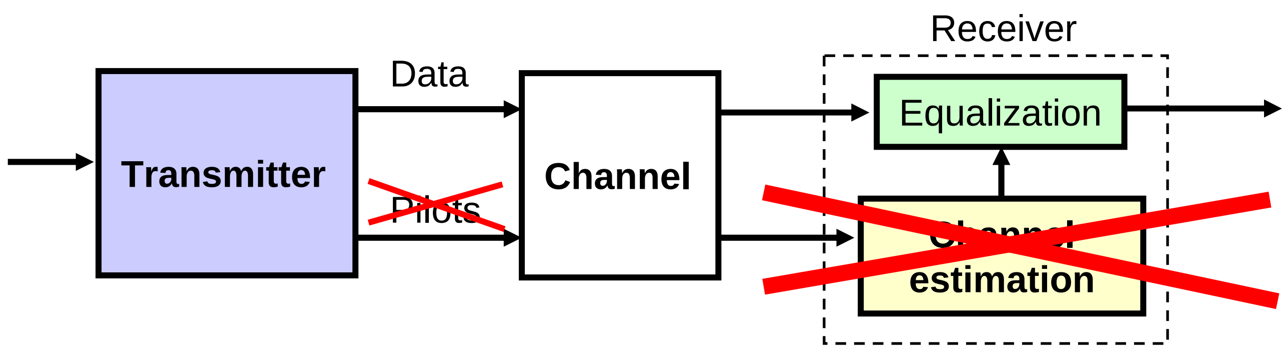
Motivation for noncoherent transmission systems

MIMO System



Coherent transmission system



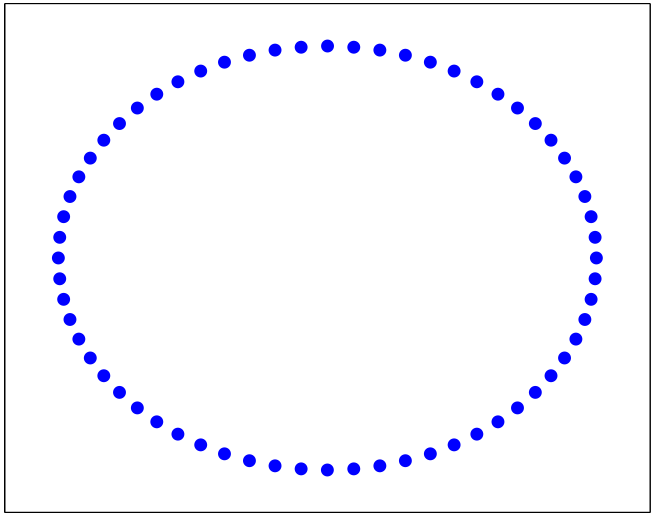
- Drawbacks of coherent transmission systems
  - CSI is never ideal
  - Channel estimation in MIMO is very complex
  - Pilot symbols reduce the useful data rate

Differential Space-Time Block Codes are very attractive in many practical cases

Motivation for higher order modulation

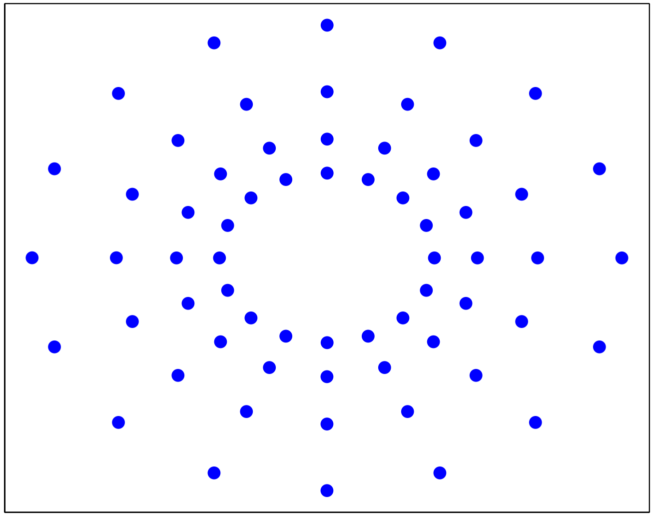
- Common DSTBC: M-PSK modulation
  - small euclidean distance

Example: 64-PSK



- APSK modulation
  - increase euclidean distance

Example: 16-PSK with 4 Amplitudes



Outline

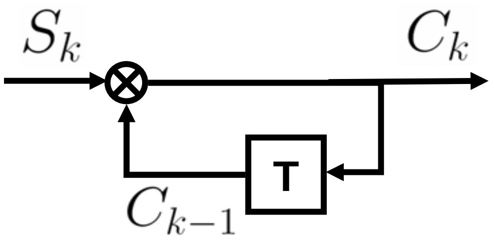
- **Differential Space-Time Block Codes (DSTBC)**
- **Implementation of different DSTBC schemes**
  - **DSTBC based on unitary matrices**
    - M-PSK
    - Differential Amplitude Modulation (DAM)
    - APSK
  - **DSTBC based on non-unitary matrices**
    - 4A16PSK
- **Simulation results**
- **Conclusion**

DSTBC

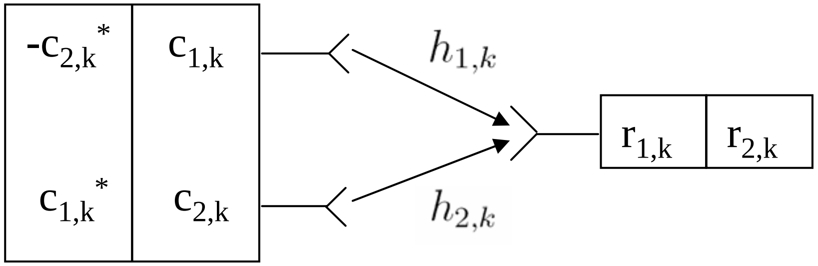
- Symbol matrix S_k

DSTBC: $C_k = S_k C_{k-1}$

$$S_k = \begin{bmatrix} s_{1,k} & s_{2,k} \\ -s_{2,k}^* & s_{1,k}^* \end{bmatrix}$$



- System model



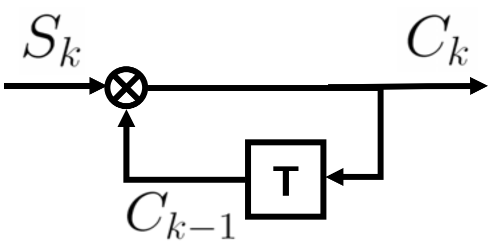
$$\begin{pmatrix} r_{1,k} & -r_{2,k}^* \\ r_{2,k} & r_{1,k}^* \end{pmatrix} = C_k \begin{pmatrix} h_{1,k} & -h_{2,k}^* \\ h_{2,k} & h_{1,k}^* \end{pmatrix} + \begin{pmatrix} w_{1,k} & -w_{2,k}^* \\ w_{2,k} & w_{1,k}^* \end{pmatrix}$$

Matrix notation $$R_k = C_k H_k + W_k$$

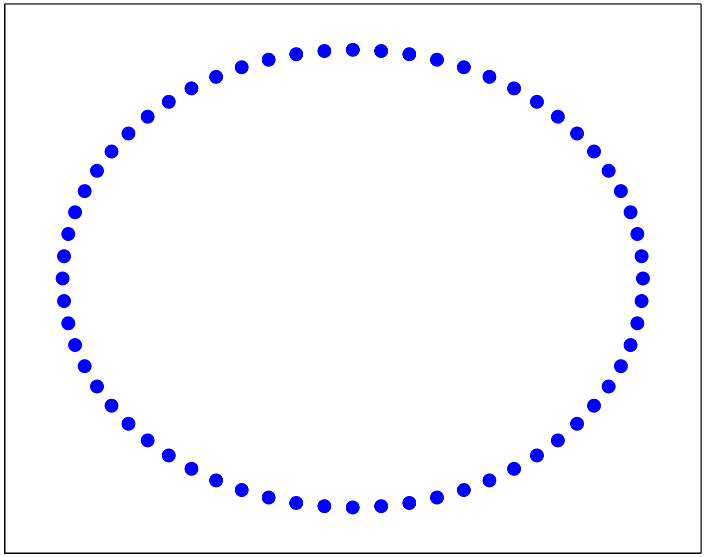
Unitary DSTBC based on 64-PSK

- Coding: Rate=6bits/s/Hz

$$C_k = S_k C_{k-1}$$



Constellation diagram for S_k



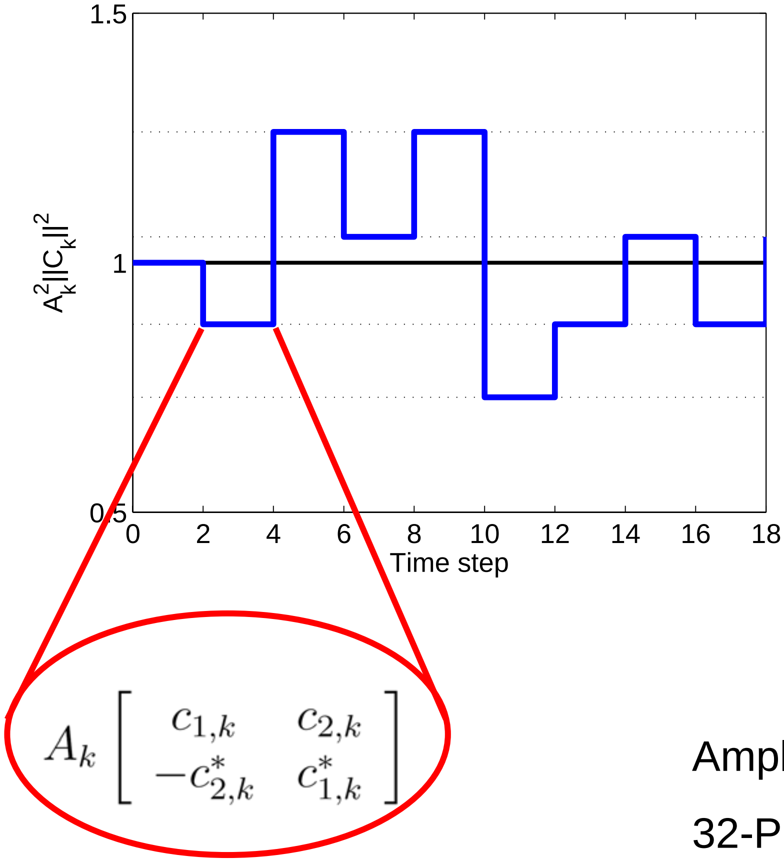
64-PSK: 2*6 bits/Symbol matrix

- Decoding: $R_k R_{k-1}^*$

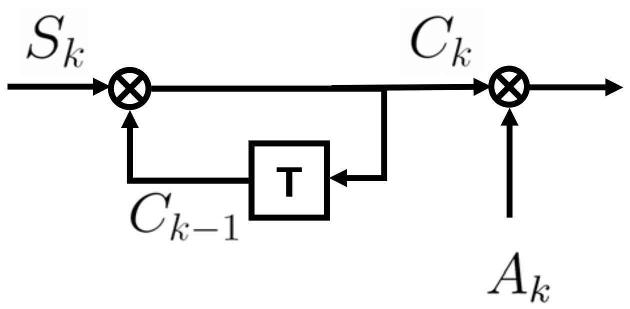
$$R_k R_{k-1}^* = C_k H H^* C_{k-1}^* + noise = \|H\|^2 S_k + noise$$

Unitary DSTBC based on 4-DAM + 32-PSK

- 4-Differential Amplitude Modulation (4-DAM)



$$C_k = S_k C_{k-1}$$



Amplitude: 2 bits/Symbol matrix

32-PSK: 2*5 bits/Symbol matrix

Unitary DSTBC based on 4-DAM + 32-PSK

Decoding

1. Decode amplitude

$$\frac{\|R_k\|}{\|R_{k-1}\|} \simeq \frac{\|H\|\|C_k\|A_k}{\|H\|\|C_{k-1}\|A_{k-1}} = \frac{A_k}{A_{k-1}}$$

2. Decode phase $\boxed{R_k R_{k-1}^*}$

$$\begin{aligned} R_k R_{k-1}^* &= A_k C_k H H^* C_{k-1}^* A_{k-1} + noise \\ &= A_k A_{k-1} \|H\|^2 S_k + noise \end{aligned}$$

Unitary DSTBC based on APSK

- Unitary matrices used in common DSTBC

$$S_k = \frac{1}{\sqrt{2}} \begin{bmatrix} e^{j\phi_{1,k}} & e^{j\phi_{2,k}} \\ -e^{-j\phi_{2,k}} & e^{-j\phi_{1,k}} \end{bmatrix} \quad \Rightarrow \quad S_k^* S_k = I$$

- More general unitary matrices

$$S_k = \begin{bmatrix} A_{1,k} e^{j\phi_{1,k}} & A_{2,k} e^{j\phi_{2,k}} \\ -A_{2,k} e^{-j\phi_{2,k}} & A_{1,k} e^{-j\phi_{1,k}} \end{bmatrix} \quad \Rightarrow \quad S_k^* S_k = (A_{1,k}^2 + A_{2,k}^2) I$$

$A_{1,k}$ and $A_{2,k}$ can be used to code information as long as $A_{1,k}^2 + A_{2,k}^2 = 1$ is fulfilled

Unitary DSTBC based on APSK

- Coding: Rate=6bits/s/Hz

$$C_k = S_k C_{k-1}$$

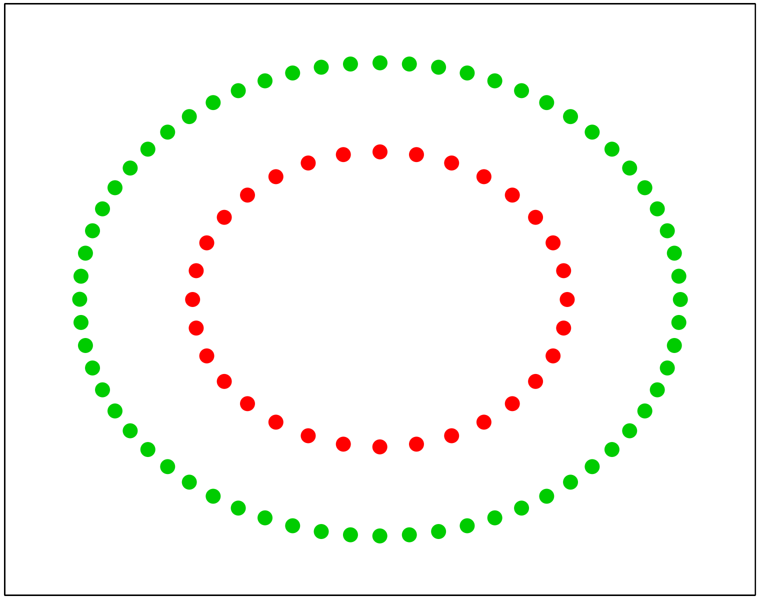
Input bit	$S_{1,k}$	$S_{2,k}$
0	32-PSK	64-PSK
1	64-PSK	32-PSK

$$|s_{1,k}|^2 + |s_{2,k}|^2 = 1$$

Amplitude: 1 bit/Symbol matrix

M-PSK: 5+6 bits/Symbol matrix

Constellation diagram for S_k



- Decoding $$R_k R_{k-1}^* = C_k H H^* C_{k-1}^* + noise = \|H\|^2 S_k + noise$$

	$S_{1,k}$	$S_{2,k}$	Output bit
$\|S_{1,k}\| < \|S_{2,k}\|$	32-PSK	64-PSK	0
$\|S_{1,k}\| > \|S_{2,k}\|$	64-PSK	32-PSK	1

Non-unitary DSTBC based on 4A16PSK

- Coding: Rate=6 bits/s/Hz

$$C_k = S_k C_{k-1}$$

$$S_k S_k^* = (|s_{1,k}|^2 + |s_{2,k}|^2) I$$

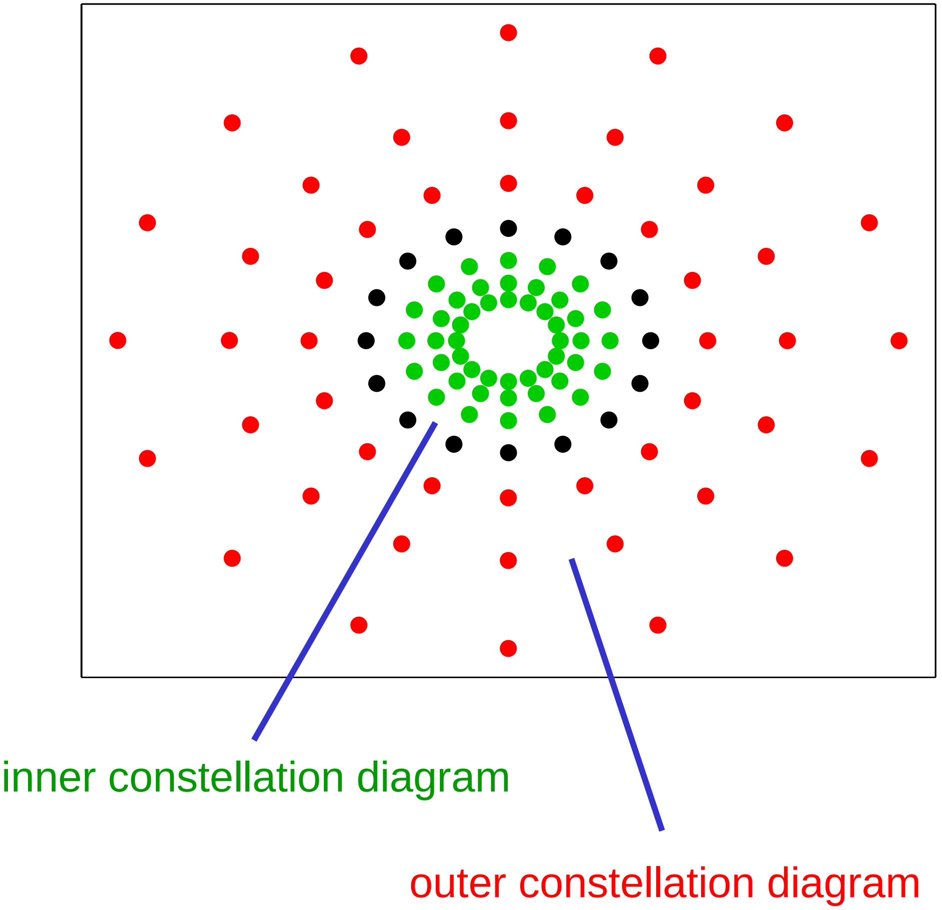
Envelope Control of C_k necessary!!!

Approach: Constellation Expansion

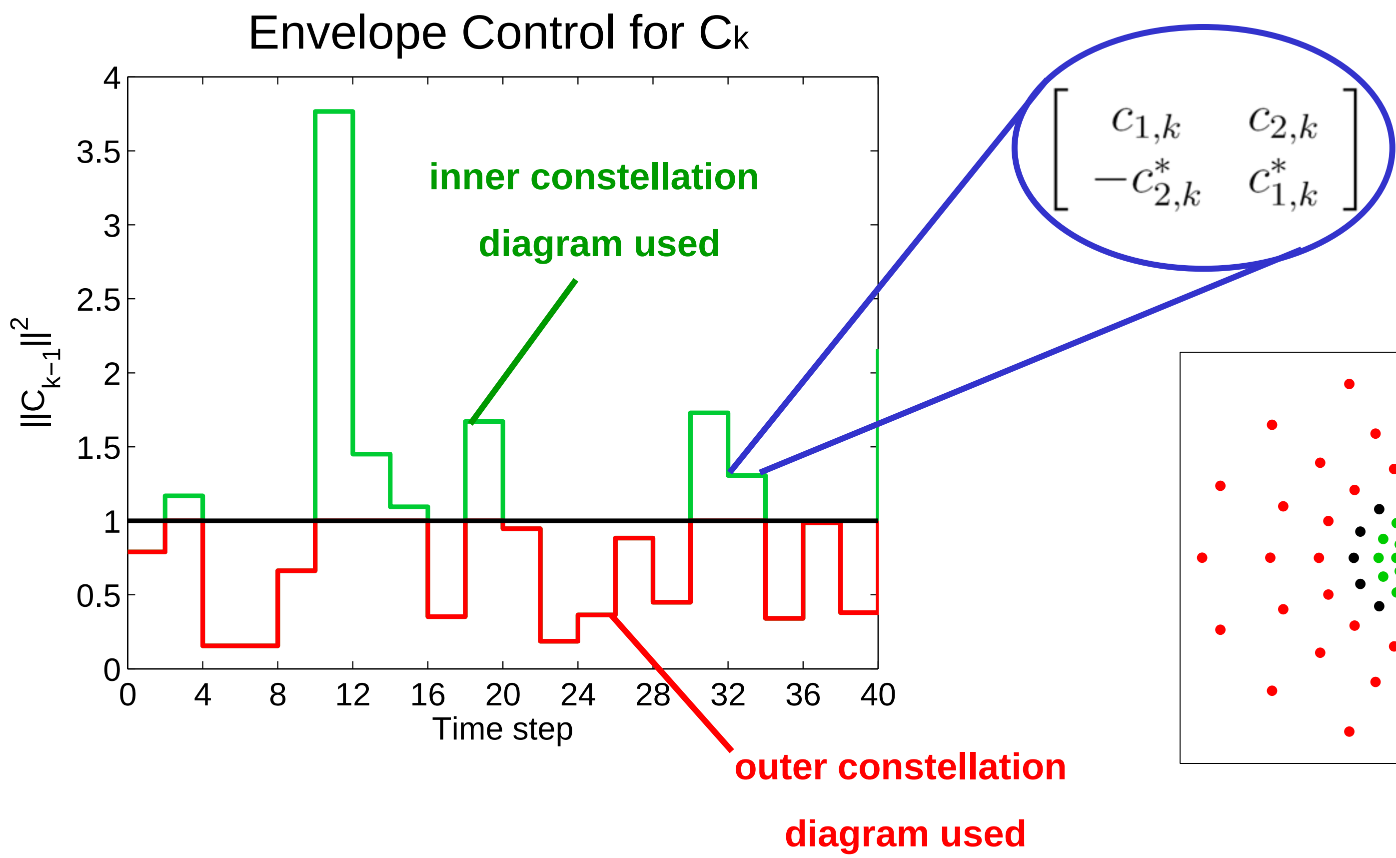
Amplitude: 2*2 bit/Symbol matrix

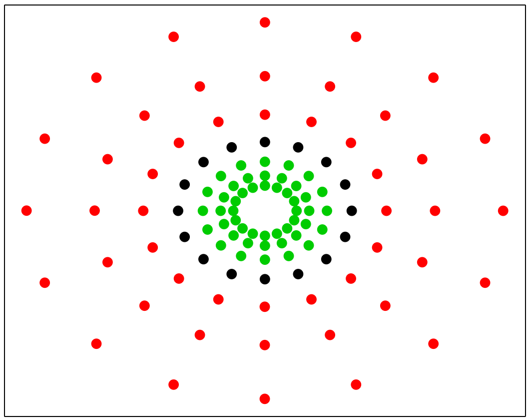
16-PSK: 2*4 bits/Symbol matrix

Constellation diagram for S_k



Non-unitary DSTBC based on 4A16PSK

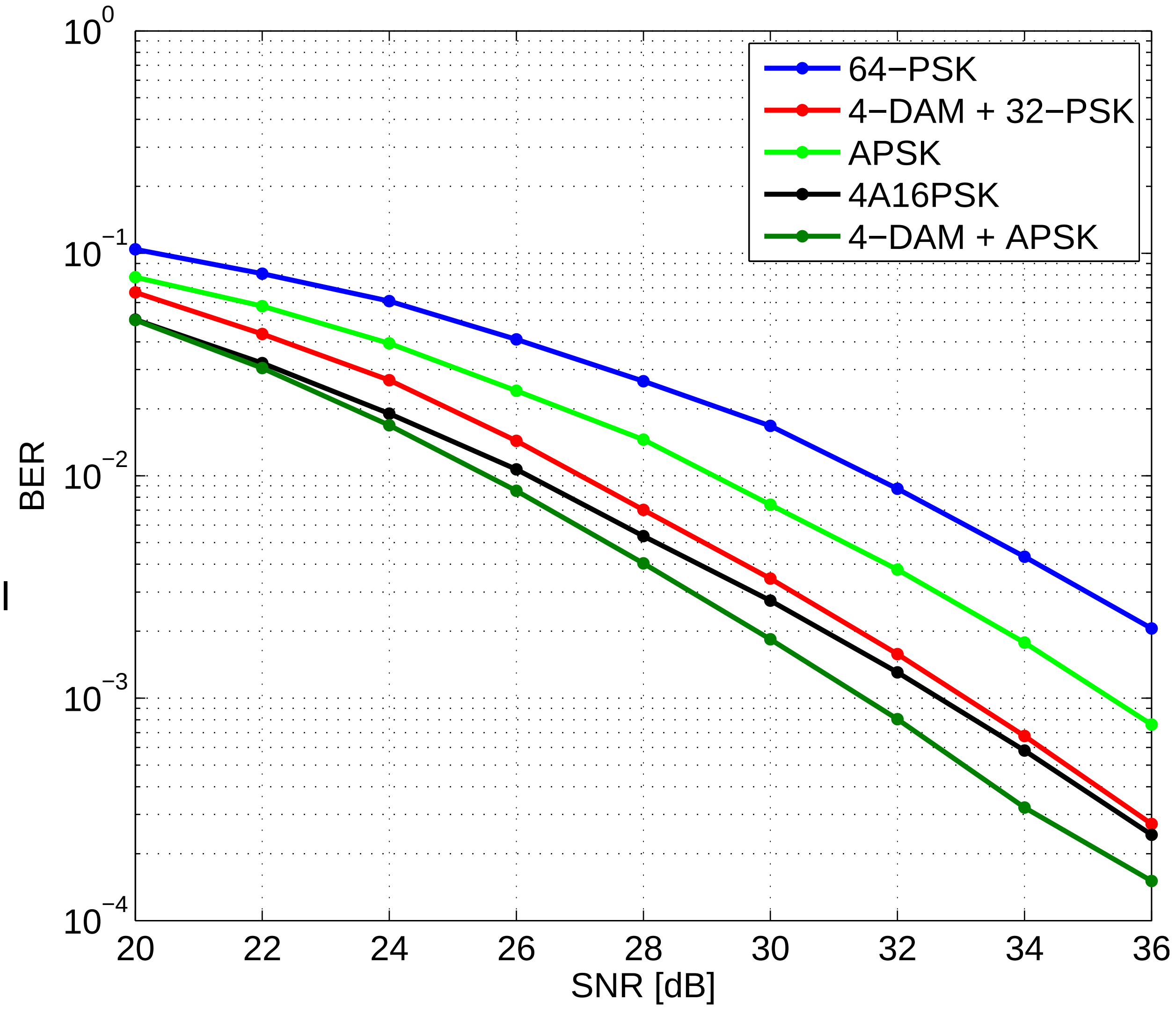




- **New decoding required**

$$R_k R_{k-1}^{-1} = C_k H H^{-1} C_{k-1}^{-1} + noise = S_k + noise$$

Simulation results



Parameters:

- 2 Transmit antennas
- 1 Receive antenna
- Rate: 6bits/s/Hz
- uncoded transmission
- Rayleigh fading channel

Conclusion

- Different modulation alternatives for DSTBC have been considered
- The performance of different modulation alternatives were analyzed and compared for independent Rayleigh fading channel.
- For high bandwidth efficiency of 6 bits/s/Hz the combination 4-DAM + APSK is found to be the best alternative