Bandwidth Efficient Coded Modulation for SDR

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Objective

- **Explain the limitations of high speed data transmission**
- **Offer a possible solution.**
- **Illustrate practical realization**
- **Present simulated results**

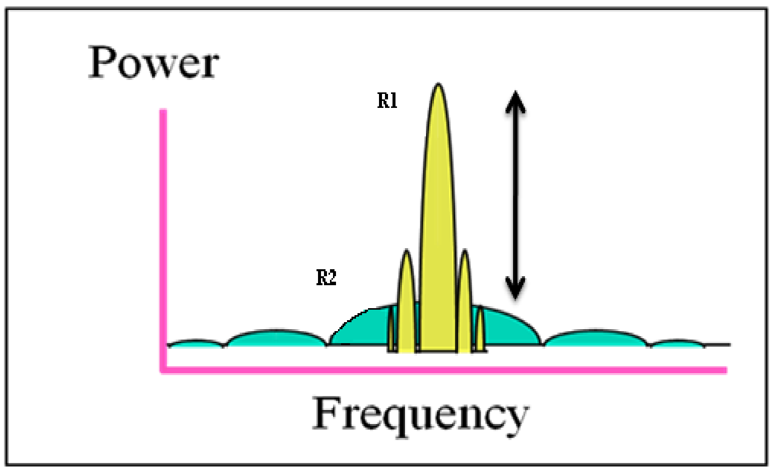
Introduction

- Explosive growth in the wireless industry in the last 20 years.
- Increasing demand on network resources.
- Leading to network congestion.
- Envisioned Solution: SDR (Software Defined Radio)
  - Next generation cellular radio
  - Will share the present platform
  - Variable bit rates (VBR)

Limitations of Transmitting VBR

Limitation I:

- **Variable transmission bandwidth**
  - ➢ **Variable bit rate ➡ Variable bit duration**
  - ➢ **Variable bit duration ➡ Variable Bandwidth**
  - ➢ **Fixed available Bandwidth**



G(dB)= 10log (R1/R2)

Limitation II:

- **Variable RF coverage footprint**
  - **Translates into several dB deficits in the link budget.**
  - **High speed data ⇒ Low coverage**

G(dB)= 10 log (R1/R2)

R1 ⇒ Low Speed Data

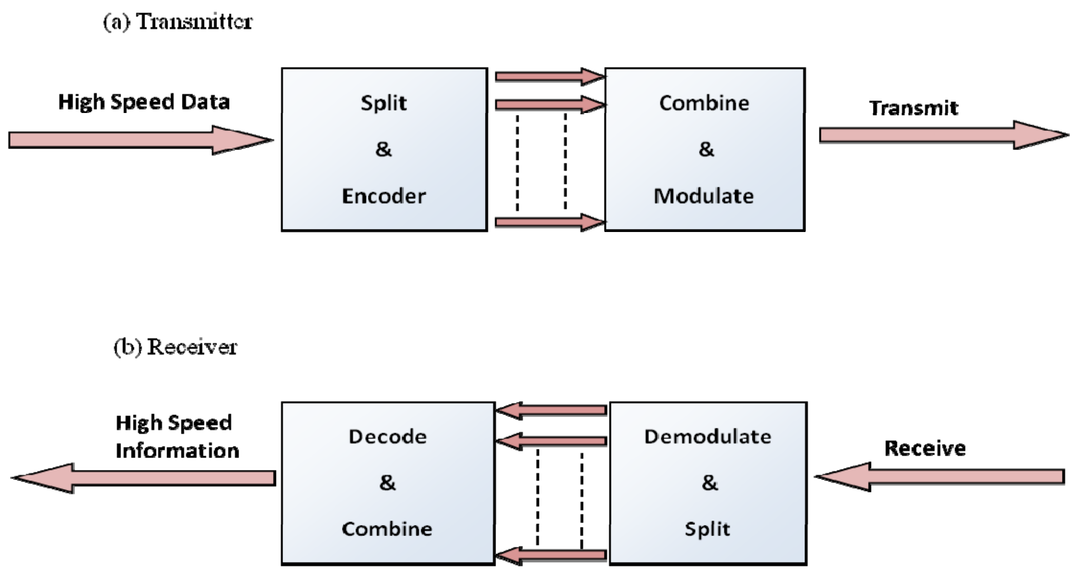
R2 ⇒ High Speed Data

	R_b (kb/s)	G (dB)
Voice	9.6	0
Data	144	-11.76
	384	-16
	2000	-23.2

  - **Coverage hole or coverage overlap**

Proposed Solution

- Introduce delays and reduce the bit rate
- Without sacrificing error control capabilities
    - Reduces the transmission Bandwidth
    - Compensates the deficit in RF footprint

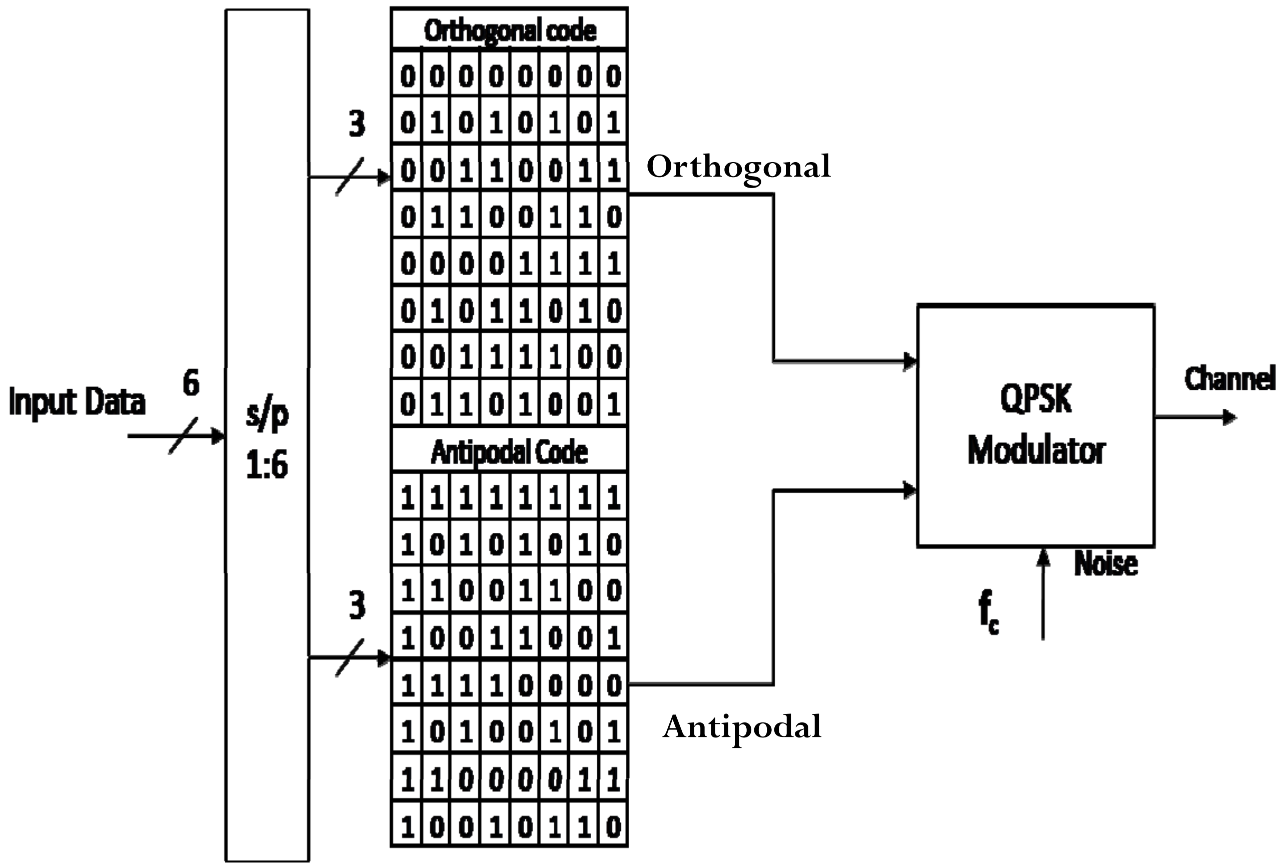


Block Diagram for the Bandwidth Efficient Coding Scheme

Encoding

- Based on Bi-orthogonal codes
- High speed incoming data is split into parallel streams.
- Each stream is separately encoded using Walsh Codes.
- Modulated using M-ary PSK modulator.

The code rate is obtained as $r = 6/8 = 3/4$.



Rate 3/4 bi-orthogonal coded modulation with n = 8

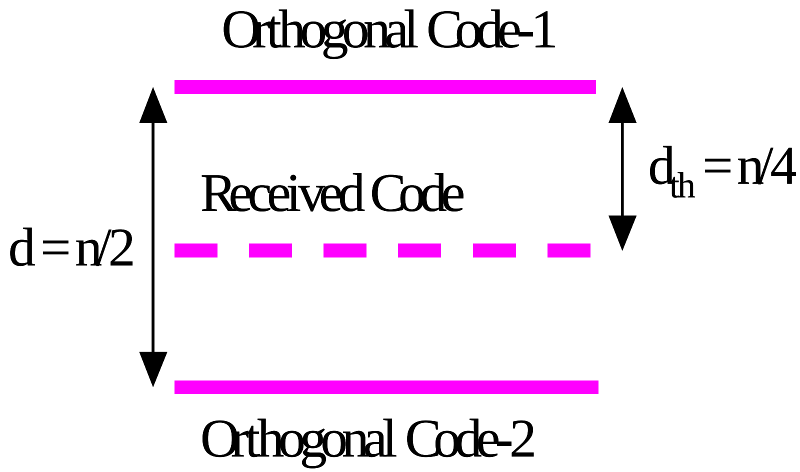
Decoding

- **Properties of orthogonal codes**
    - **Parity generation**
    - **Distance properties**

- **First examined by generating a parity bit.**

- **Impaired received code is then compared to a lookup table for a possible match.**

For n-bit orthogonal code,



Distance, $d = \frac{n}{2}$

Threshold, $d_{th} = \frac{n}{4}$

Correlation output,

$$R(x,y) = \sum_{i=1}^{n} x_i y_i \le \frac{n}{4} - 1$$

Number of errors,

$$t = n - R(x,y) = \frac{n}{4} - 1$$

n	t
8	1
16	3
32	7
64	15

Coding Gain

For PSK,

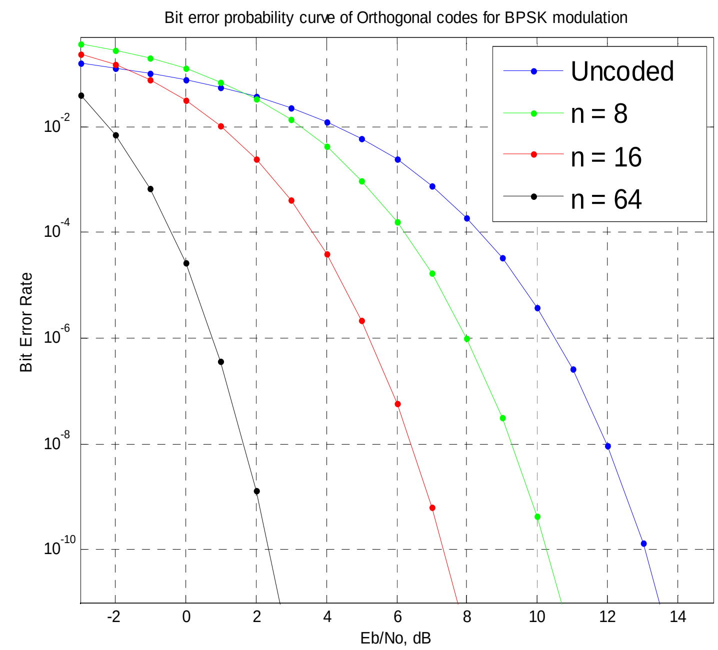
Uncoded BER,

$$Pe(U) = \frac{1}{2} erfc\left(\sqrt{\frac{Eb}{No}}\right)$$

Coded BER,

$$P_{orth} \approx \frac{1}{n} \sum_{j=t+1} j \binom{n}{j} P_{un}{}^{j} (1 - P_{un})^{n-j}$$

$$t = n - R(x, y) = \frac{n}{4} - 1$$



Conclusion

- **BW efficiency by data partitioning and mapping into orthogonal space.**
- **BW efficiency by code partitioning.**
- **Orthogonal codes prove to be stronger codes since they are systematic and has no fragmentation.**

Acknowledgement

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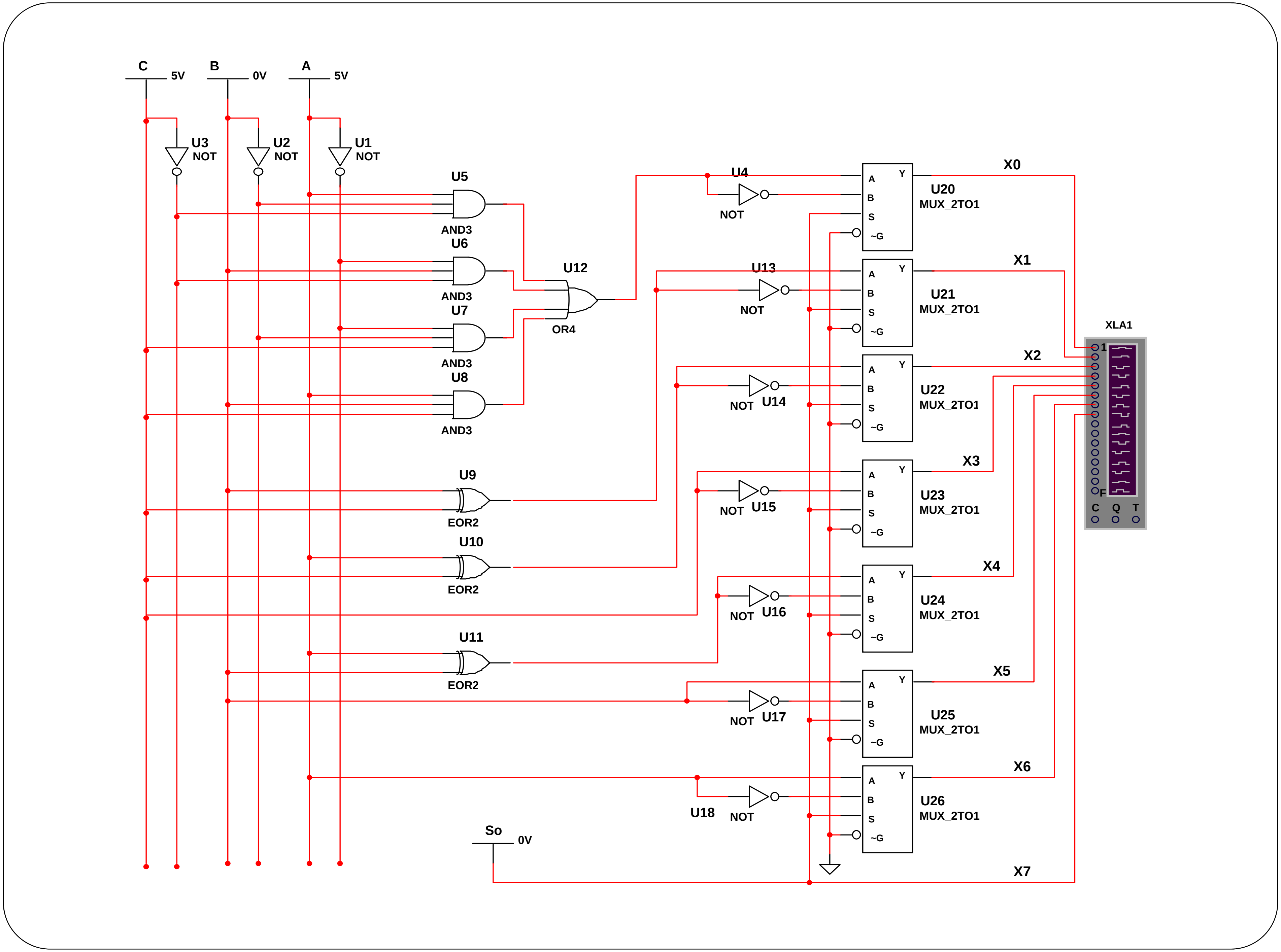
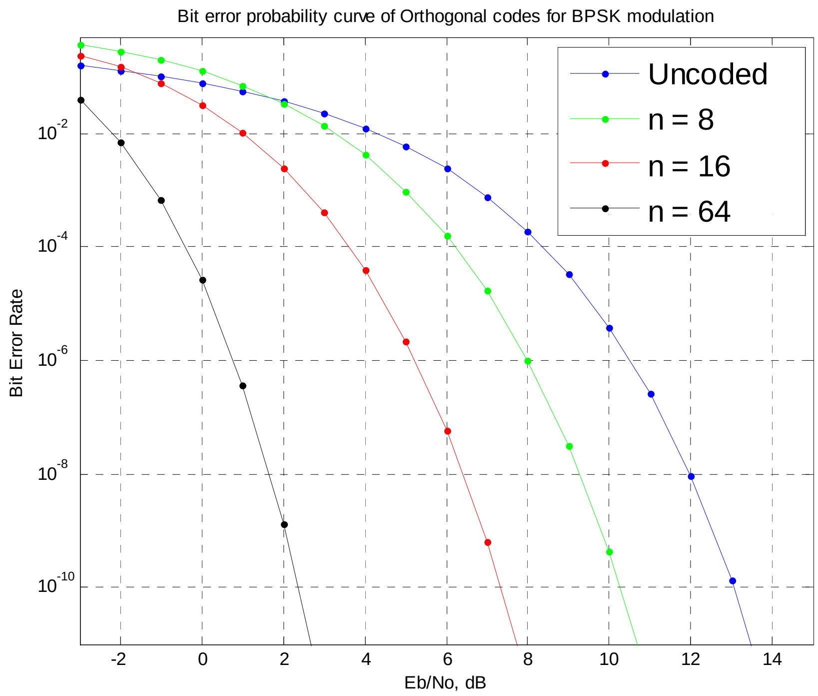
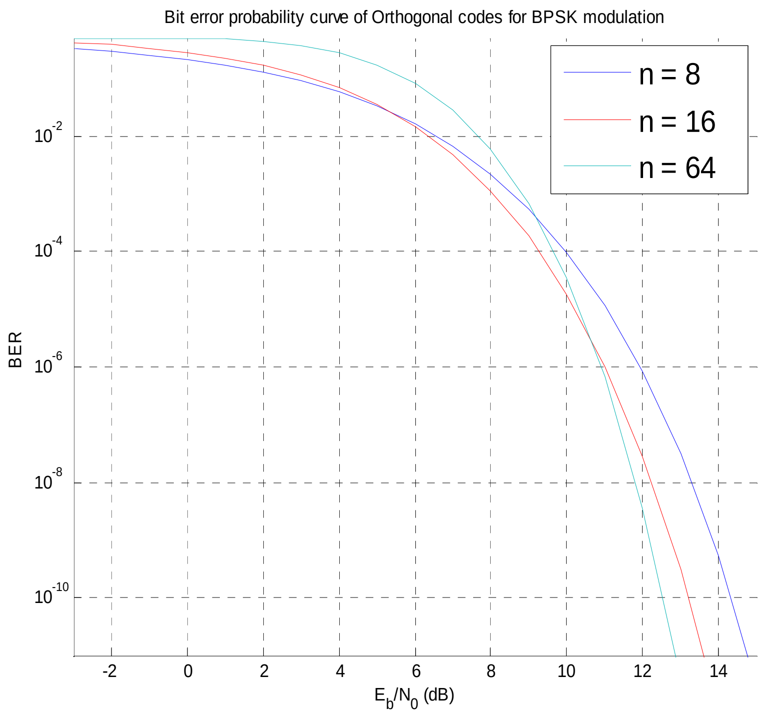

C 5V
B 0V
A 5V
U3 NOT
U2 NOT
U1 NOT
U5 AND3
U6 AND3
U7 AND3
U8 AND3
U12 OR4
U9 EOR2
U10 EOR2
U11 EOR2
U4 NOT
U13 NOT
U14 NOT
U15 NOT
U16 NOT
U17 NOT
U18 NOT
U20 MUX_2TO1
U21 MUX_2TO1
U22 MUX_2TO1
U23 MUX_2TO1
U24 MUX_2TO1
U25 MUX_2TO1
U26 MUX_2TO1
X0
X1
X2
X3
X4
X5
X6
X7
XLA1
So 0V

Comparison with Block Codes (t=1)





$$t = n - R(x,y) = \frac{n}{4} - 1$$

$$t = 1$$