Time Division Multiplexing for Green Broadcasting

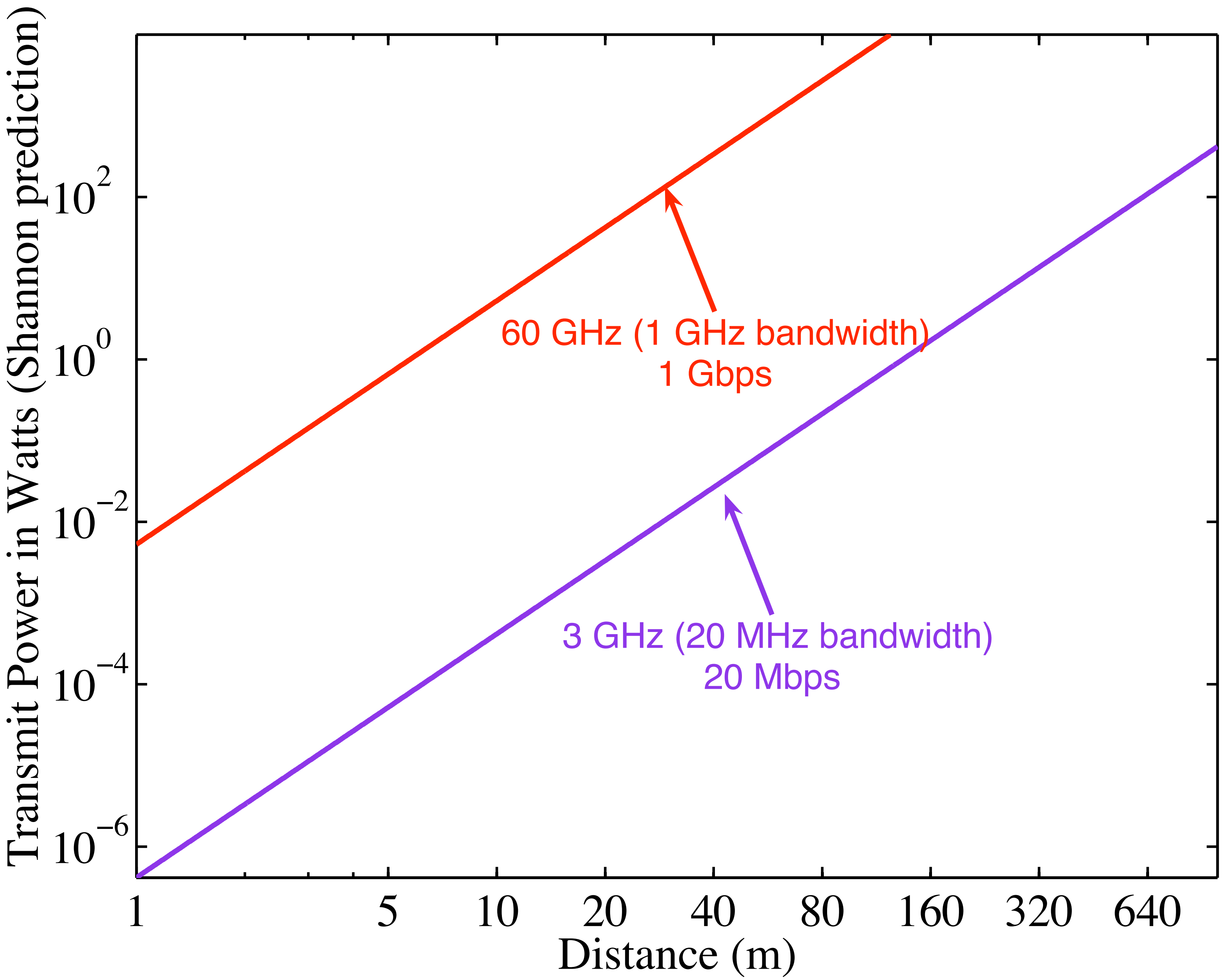
Pulkit Grover
UC Berkeley

with Anant Sahai

There are handouts for this talk. Please take one!

Short-distance green communication

$$C = \frac{W}{2}\log(1 + SNR)$$



60 GHz
path-loss exponent = 3
receiver noise-figure = 5 dB
T = 300 K

3 GHz
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receiver noise-figure = 20 dB
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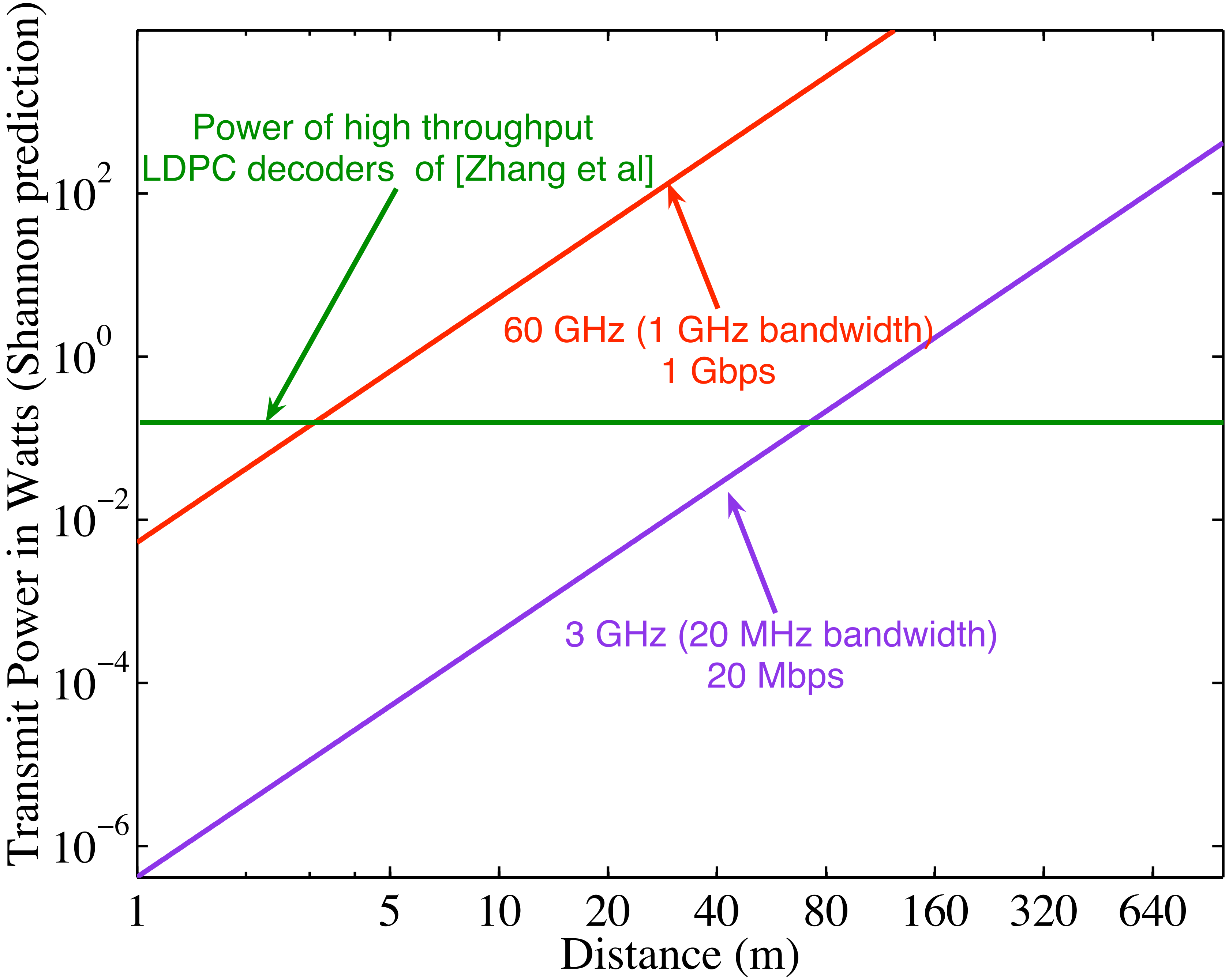

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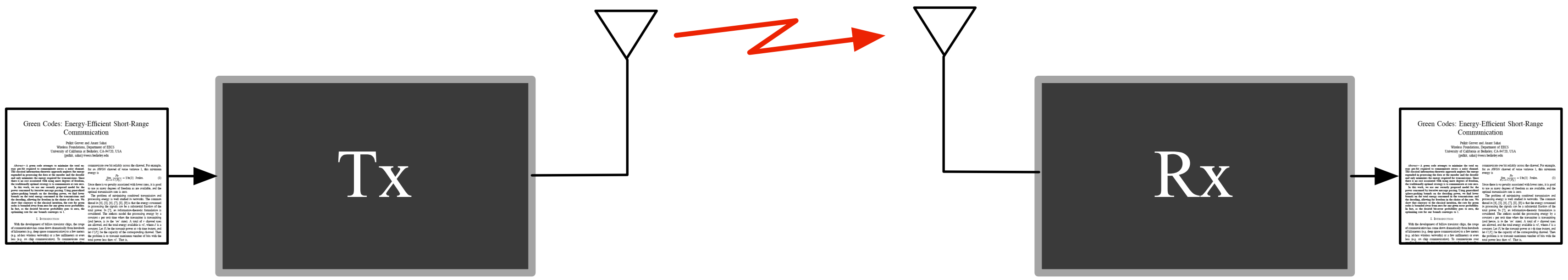
Decoding power
is substantial

The black-box model for decoding energy



[Massaad, Medard, Zheng ’04]

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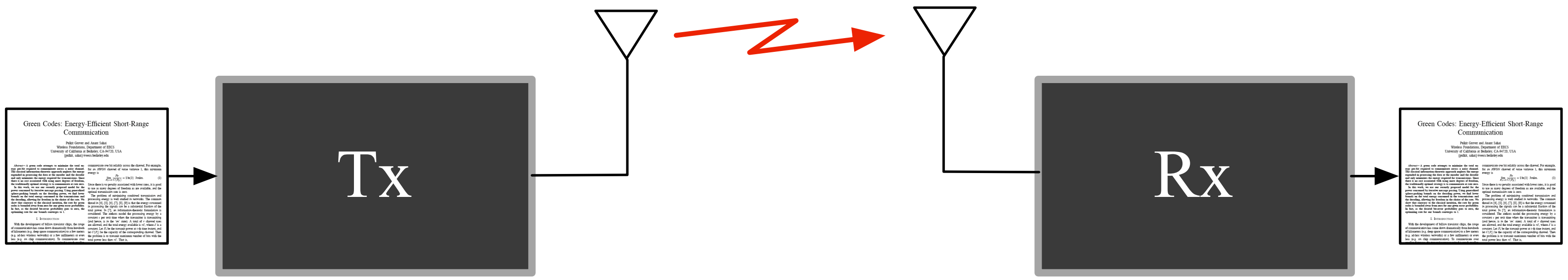

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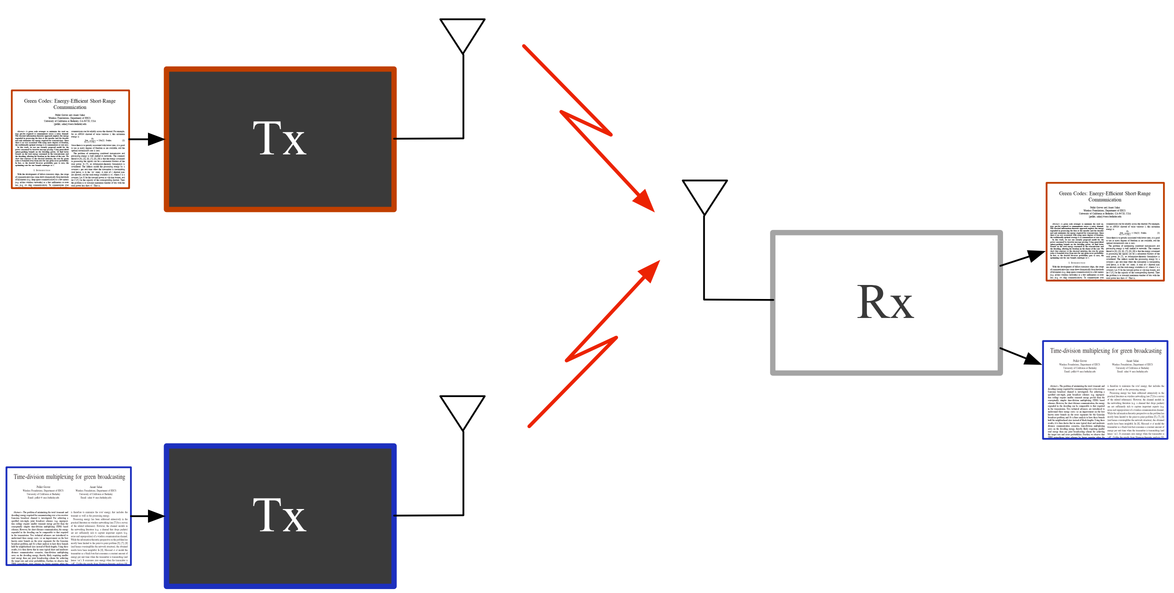

[Massaad, Zheng, Medard '08]

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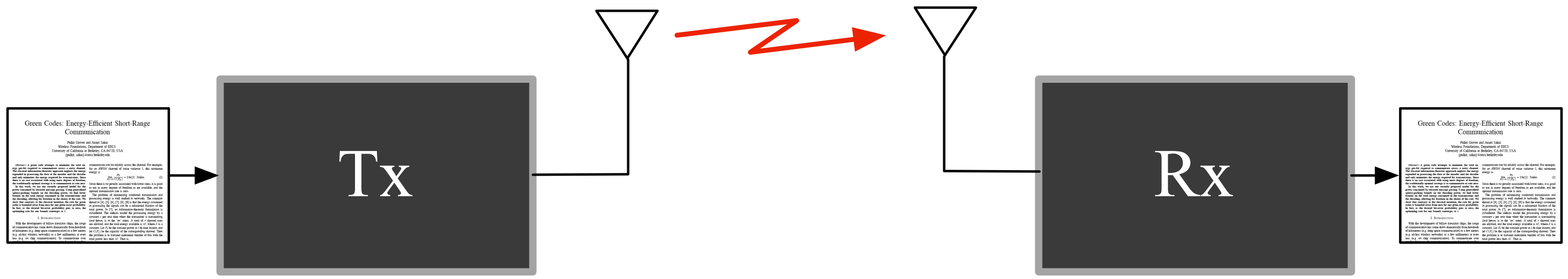

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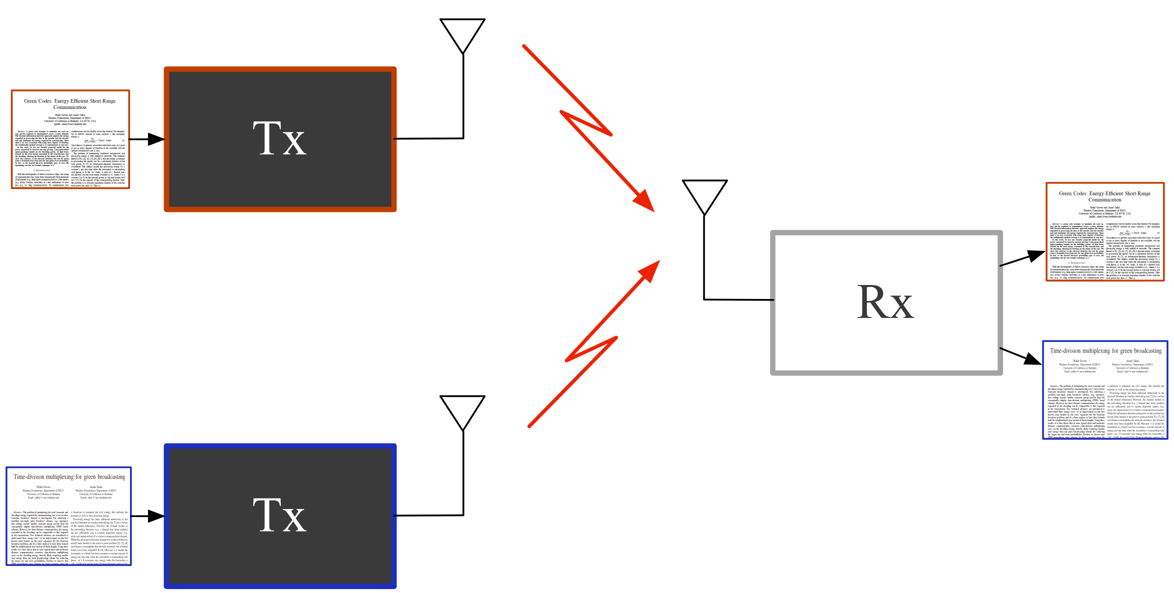

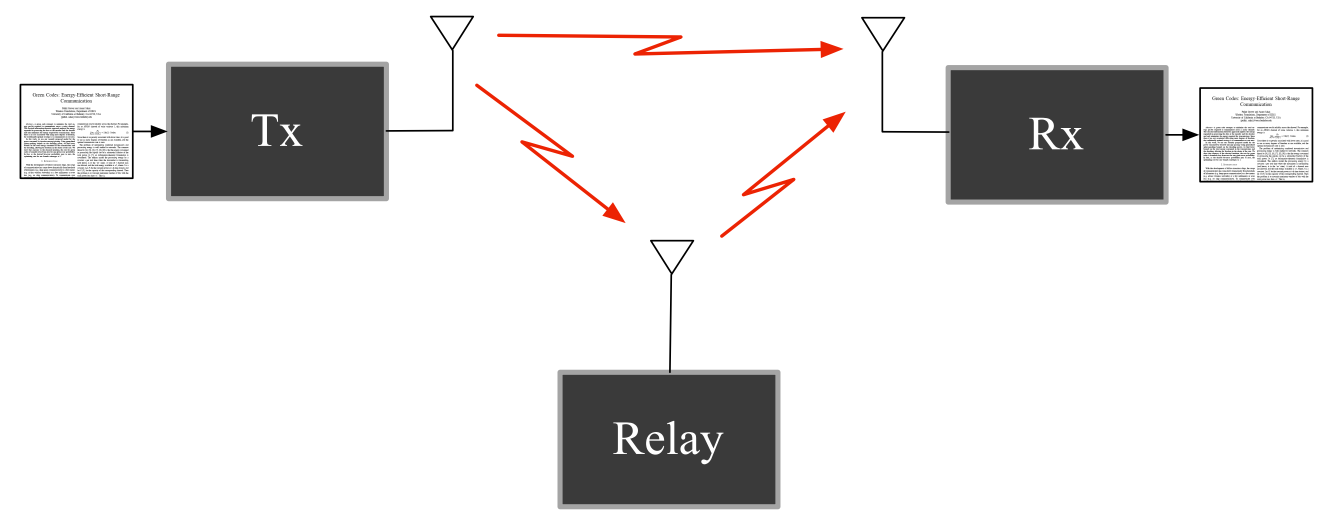

[Massaad, Zheng, Medard '08]

[e.g. Prabhakaran, Kumar '09]

A proxy for decoding energy : Complexity

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Block codes

Block length $$m \approx \frac{\log \frac{1}{P_e}}{E_r(R)}$$ [Gallager] . . . [Wiechman, Sason][Polyanskiy et al]

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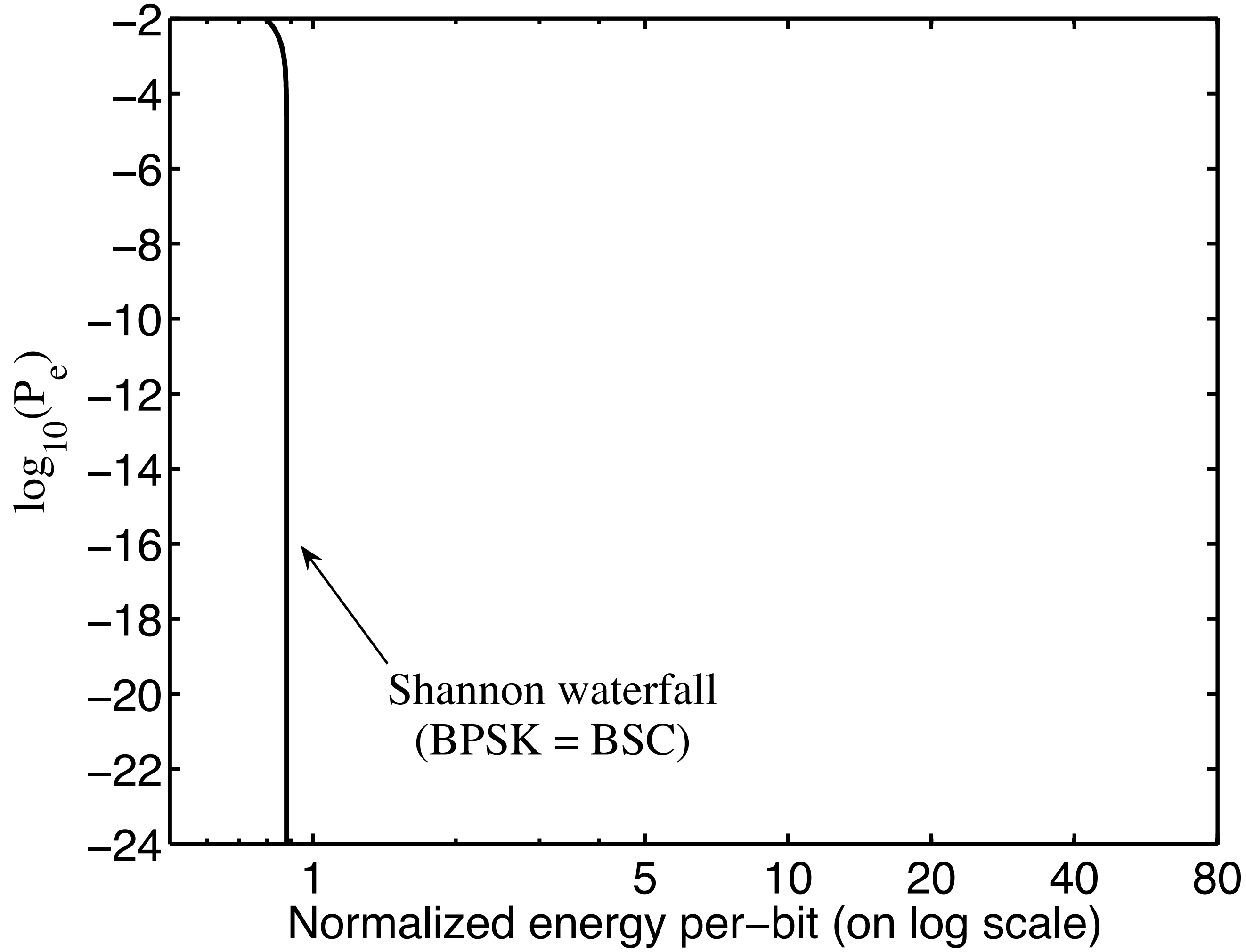

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Rate = 1/3

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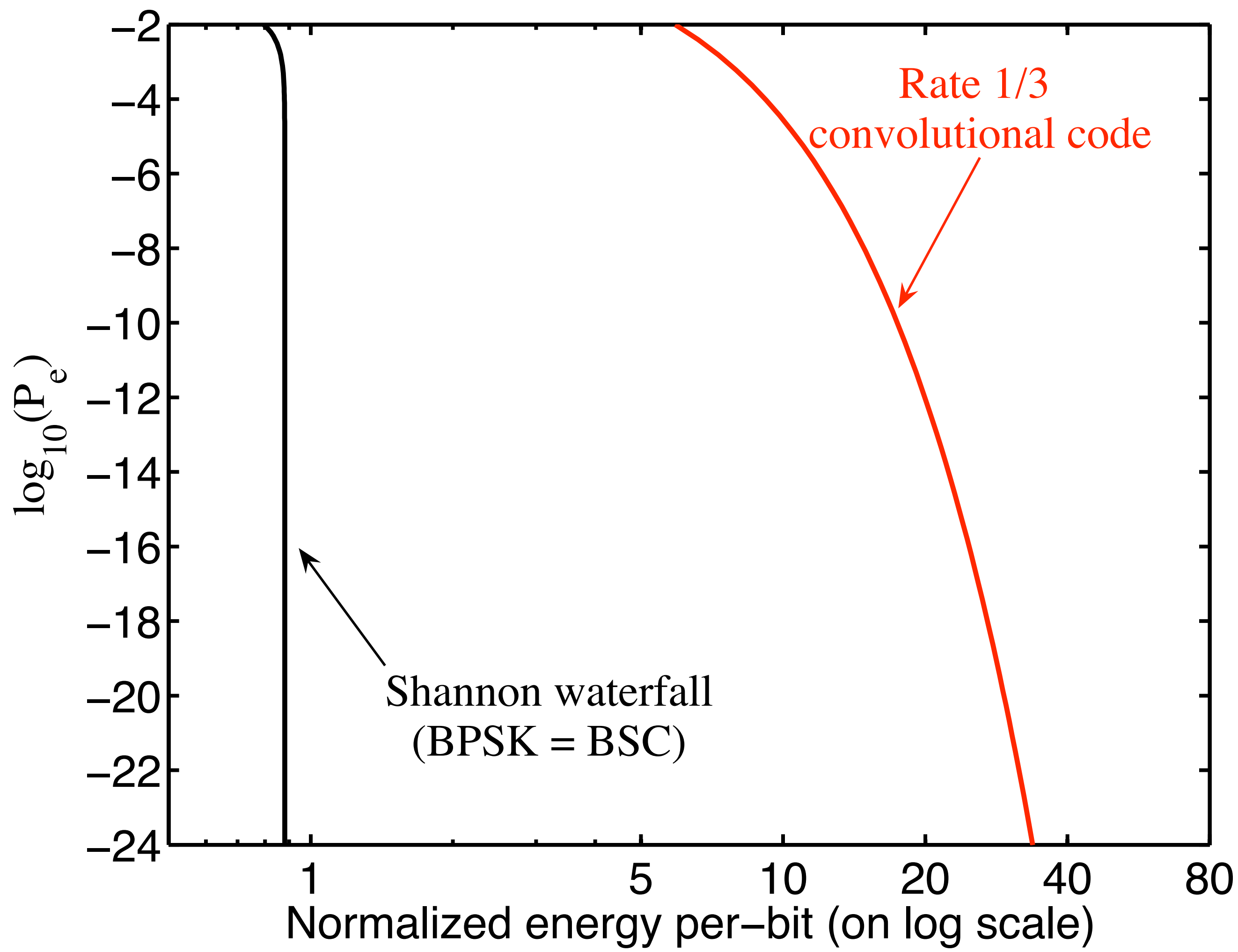

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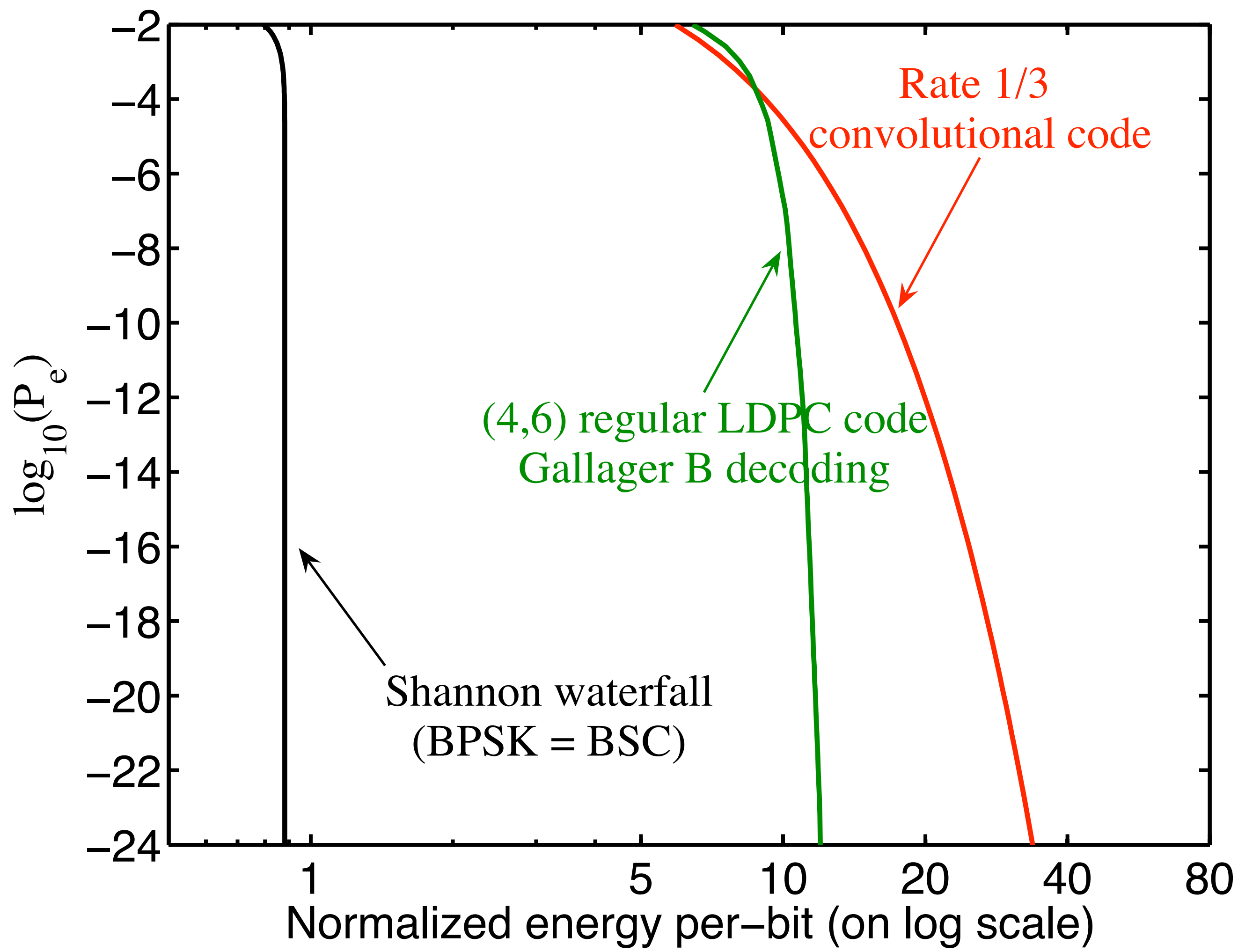

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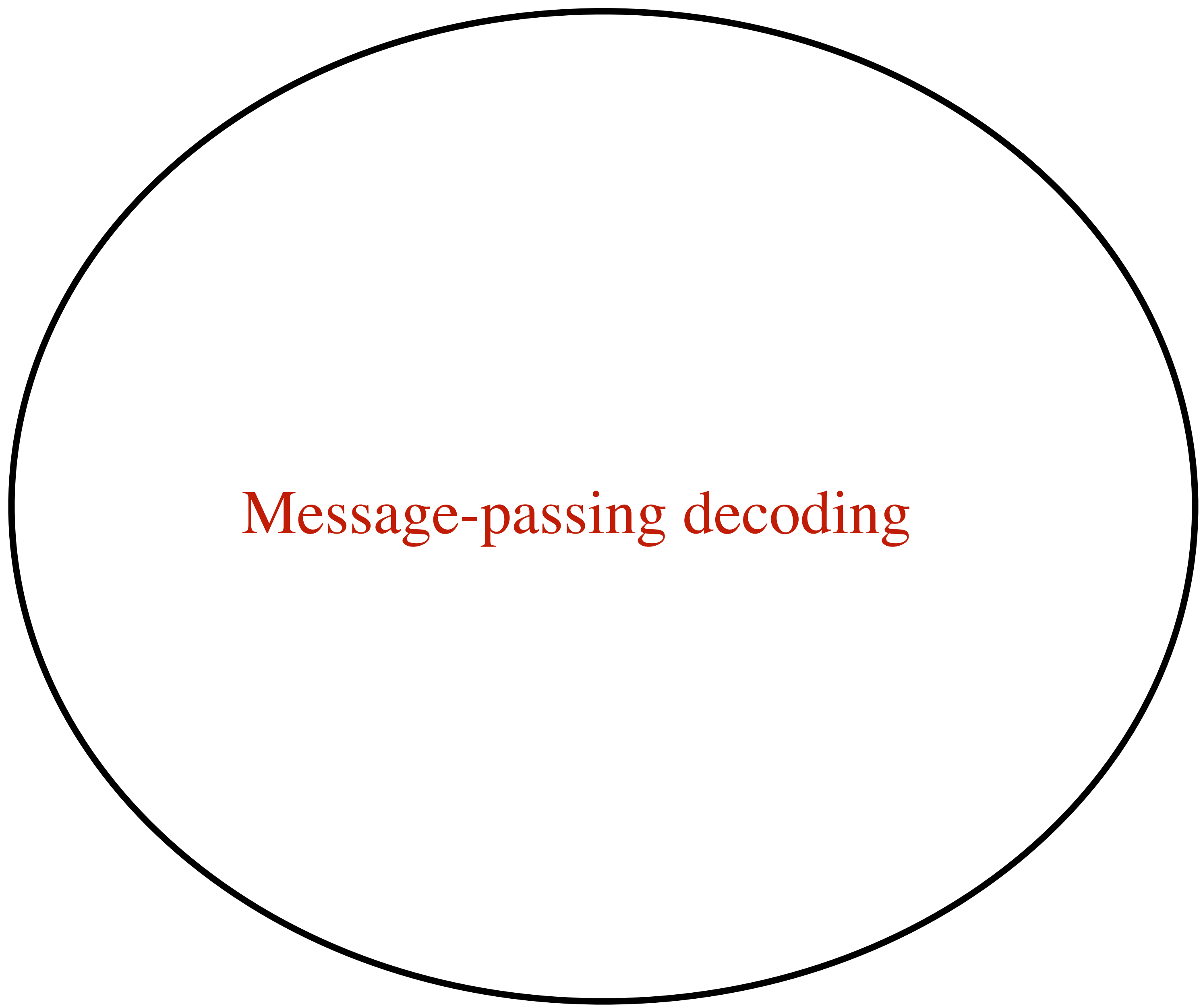
Lower bounds for message-passing decoding



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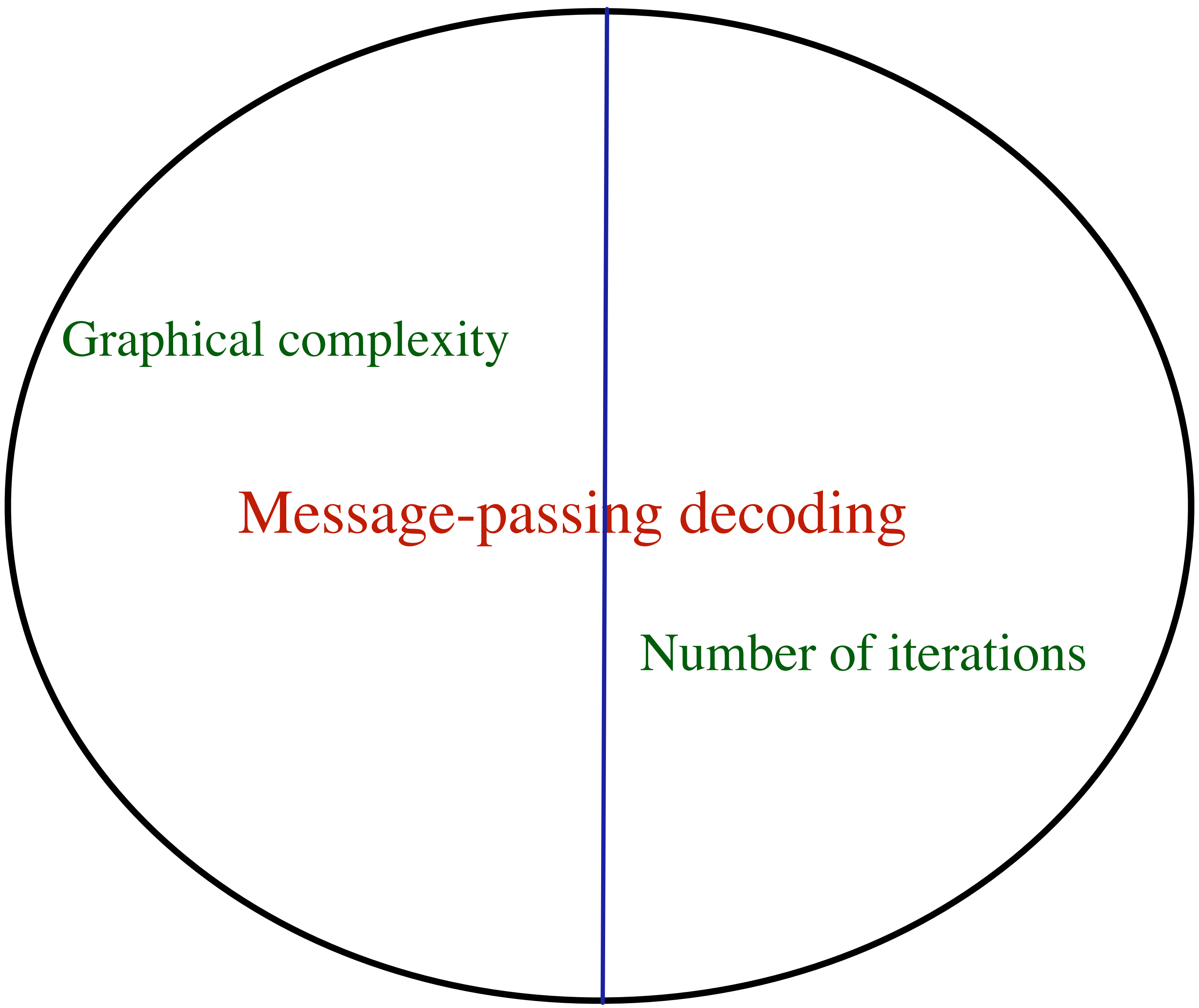

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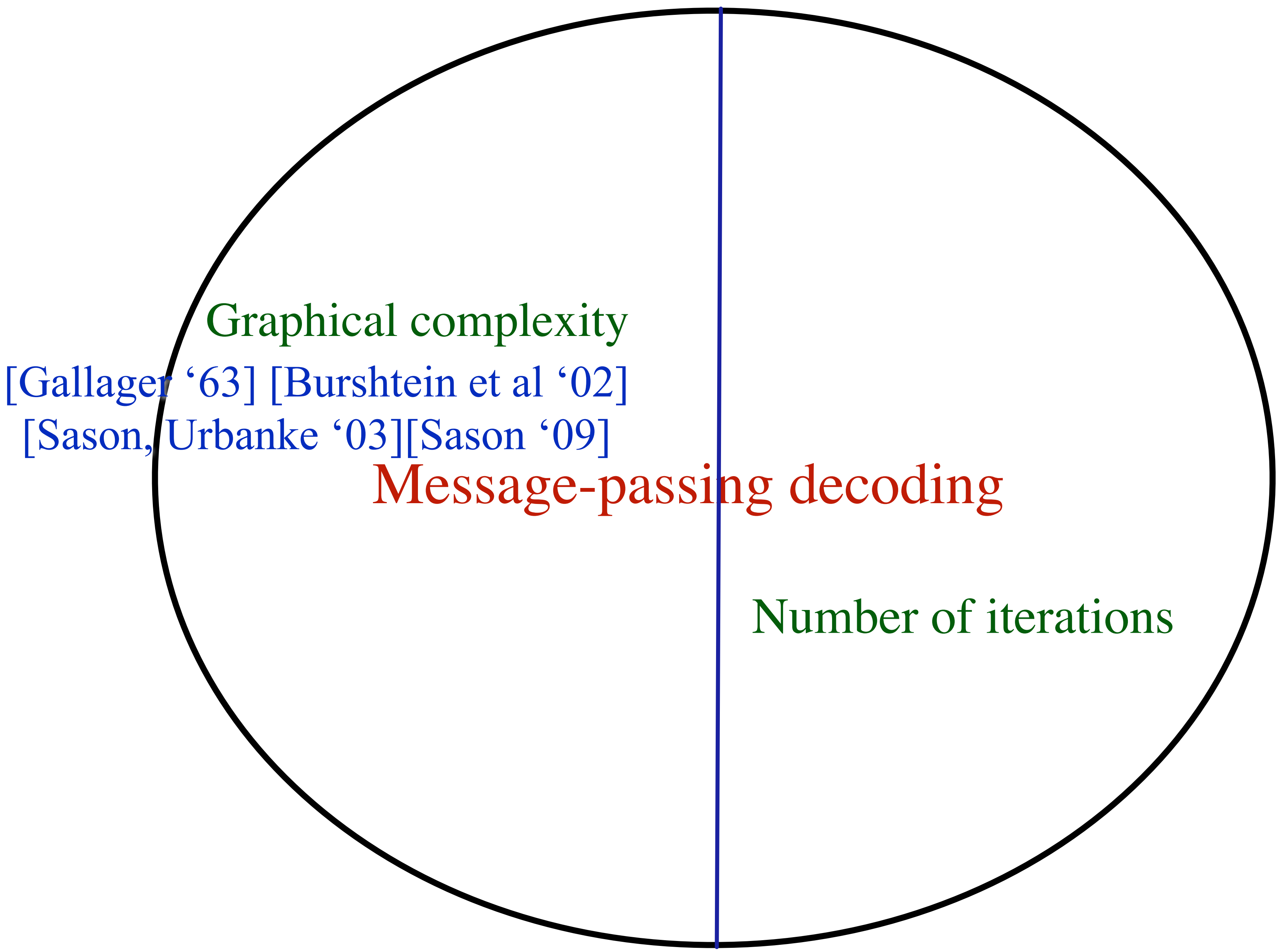

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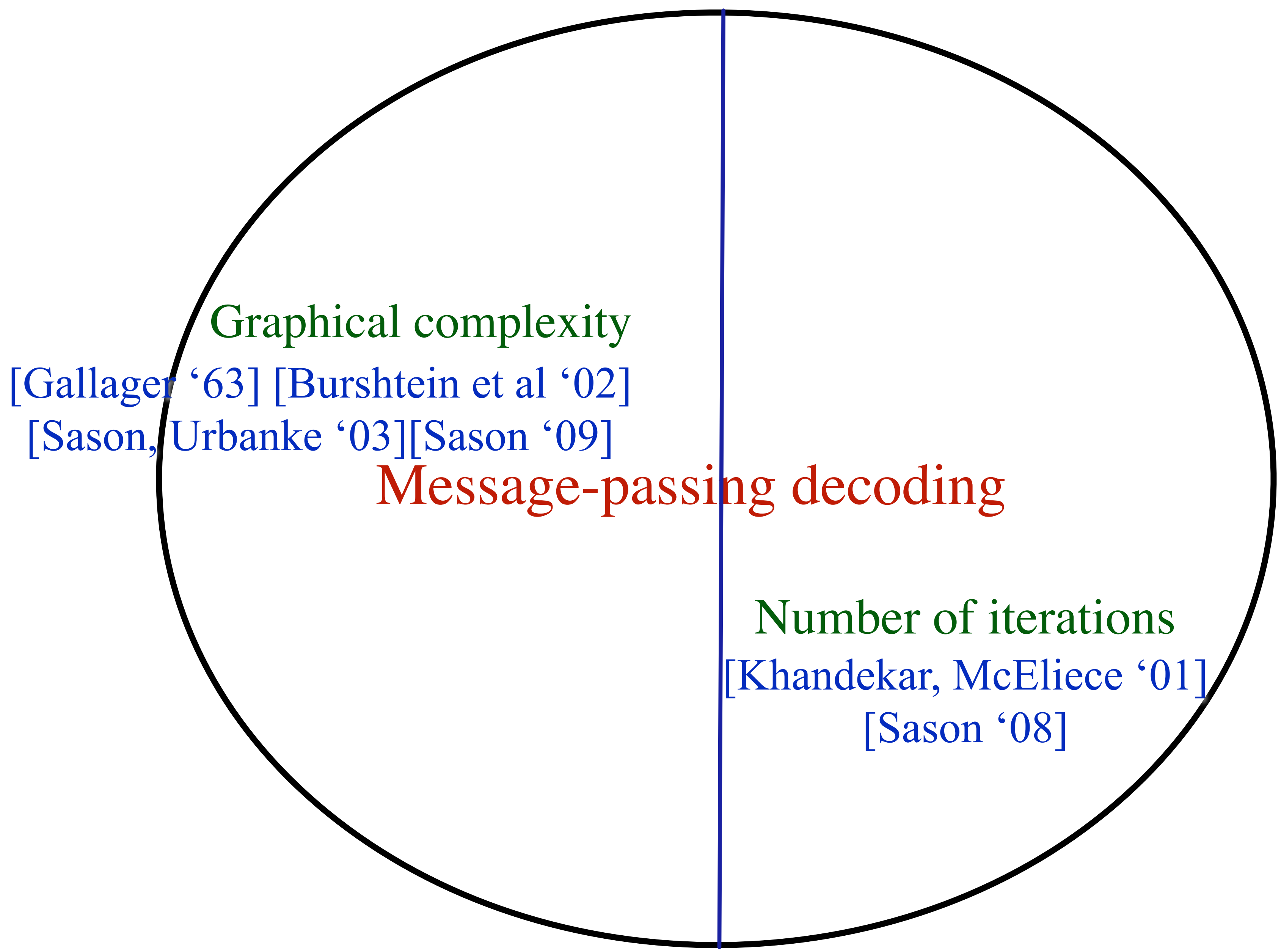

Number of iterations for *any* code

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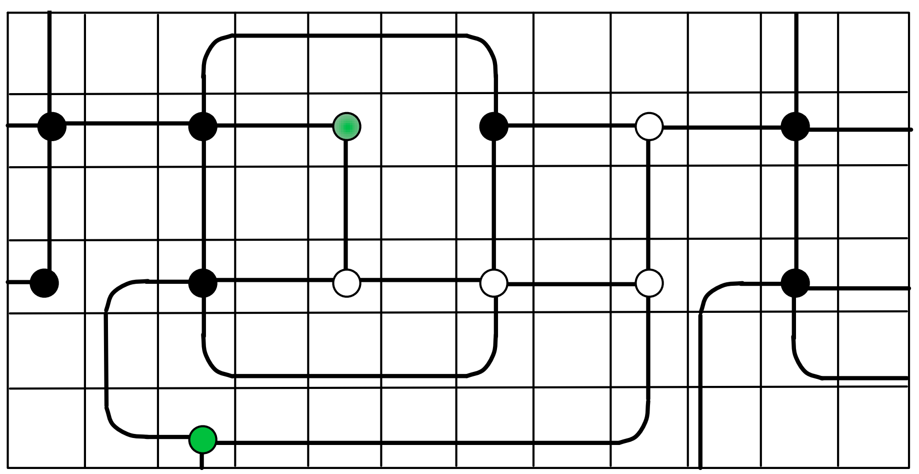
- ○ Bit nodes
- ● Channel output nodes
- Helper nodes



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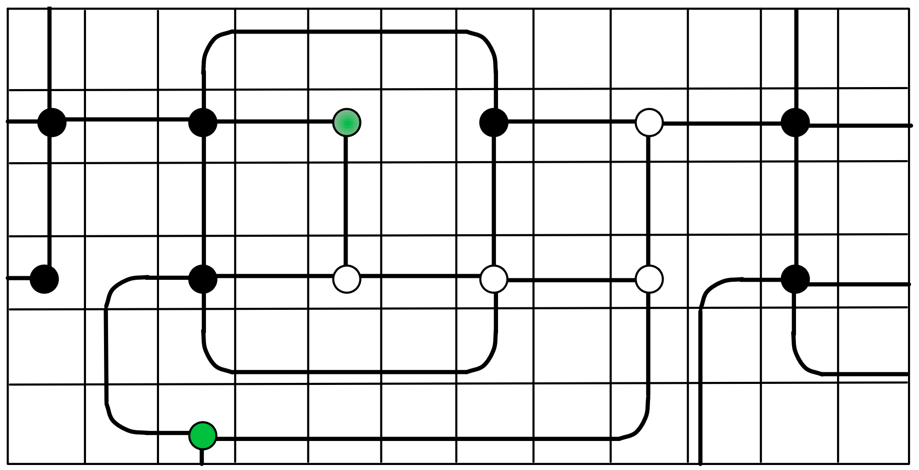

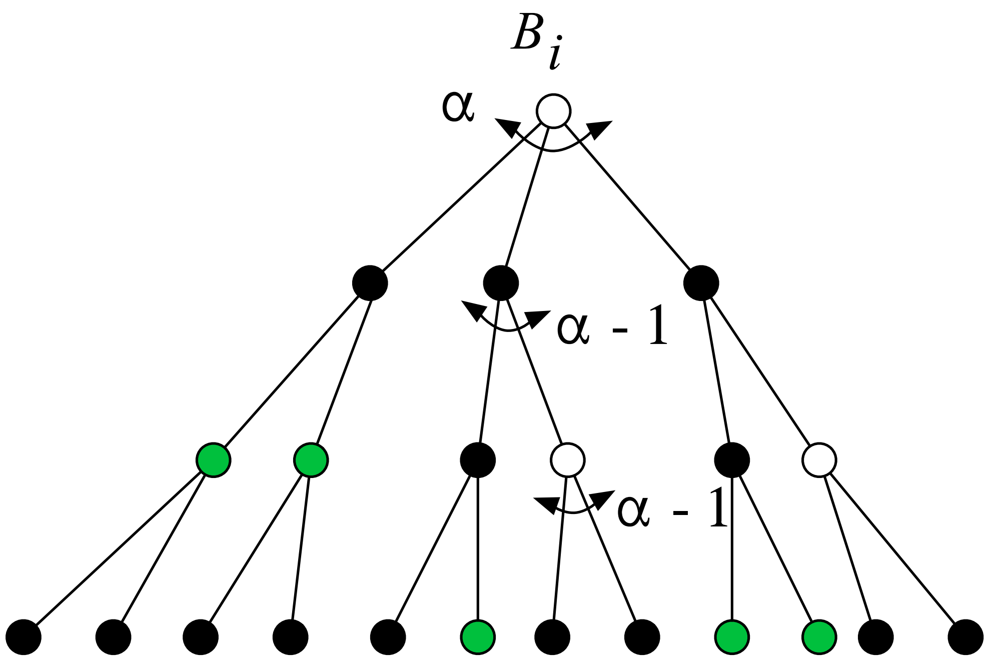

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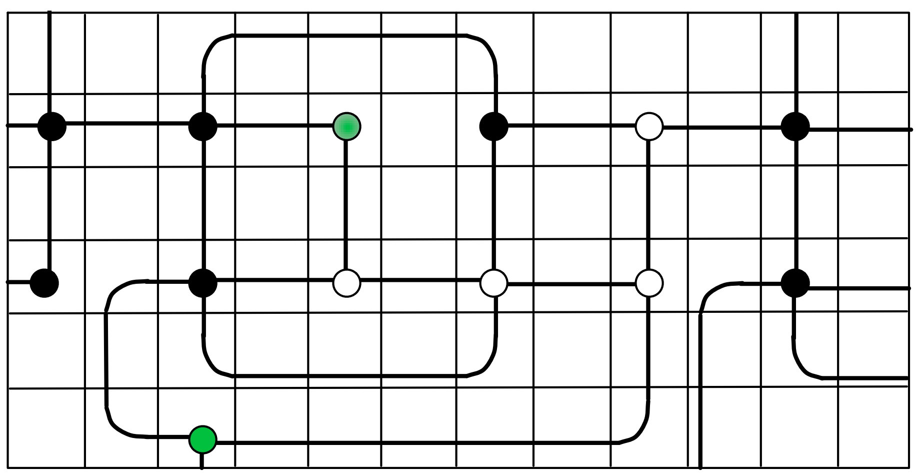

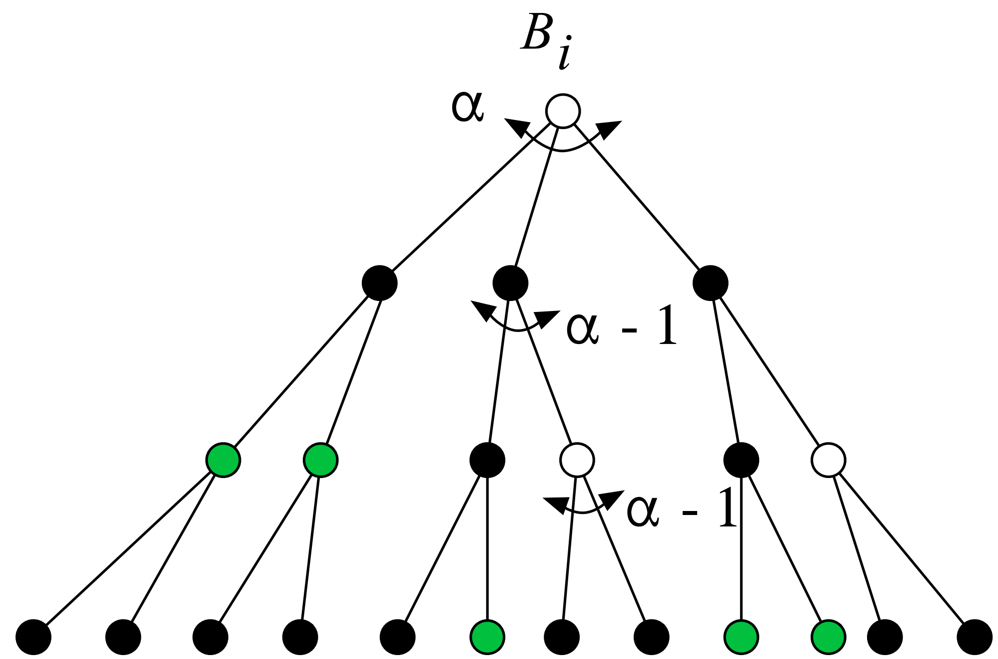

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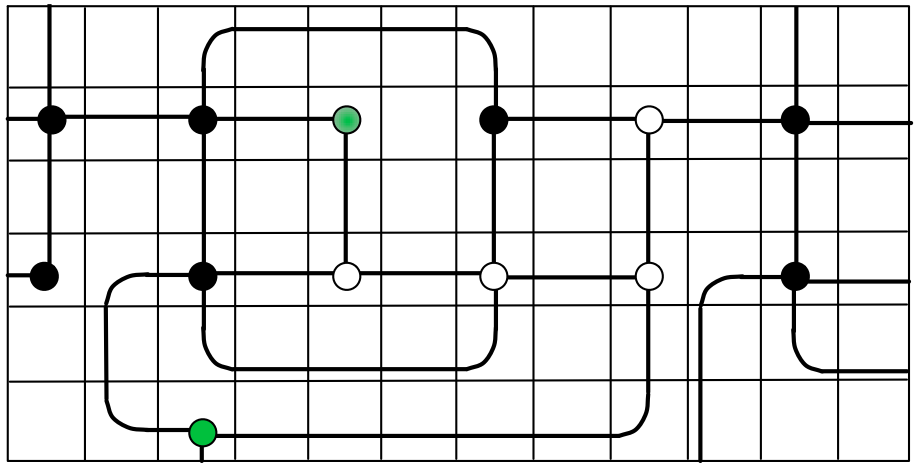

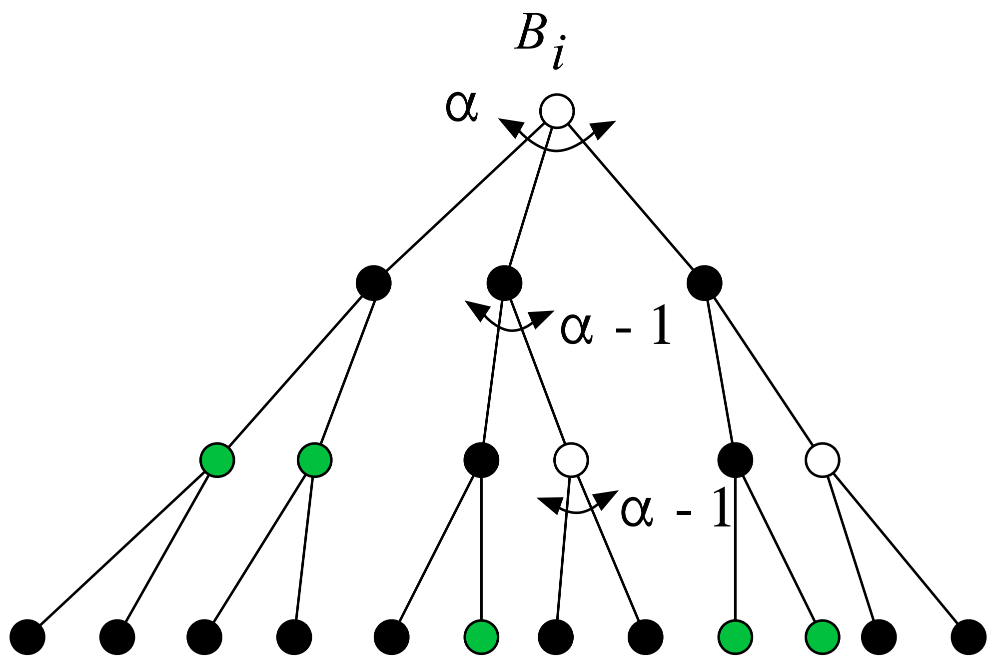

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$$\text{Regular LDPCs}: \quad \#\ \text{iterations} = \Theta\left(\log\left(\log\frac{1}{P_e}\right)\right)$$

Regular LDPC's are order optimal!

energy per operation E = 1 pJ,
distance = 17 m,
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T = 300 K
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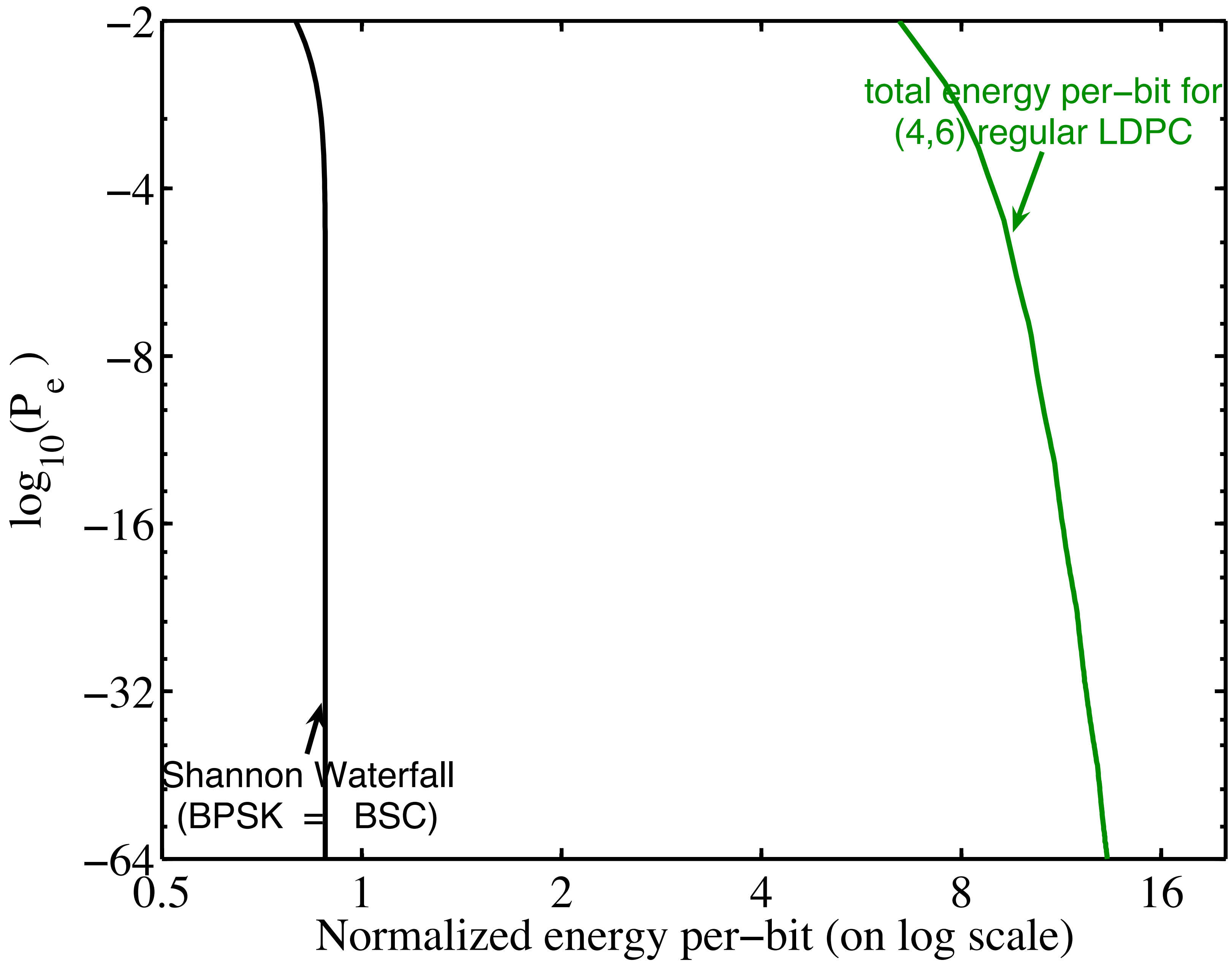

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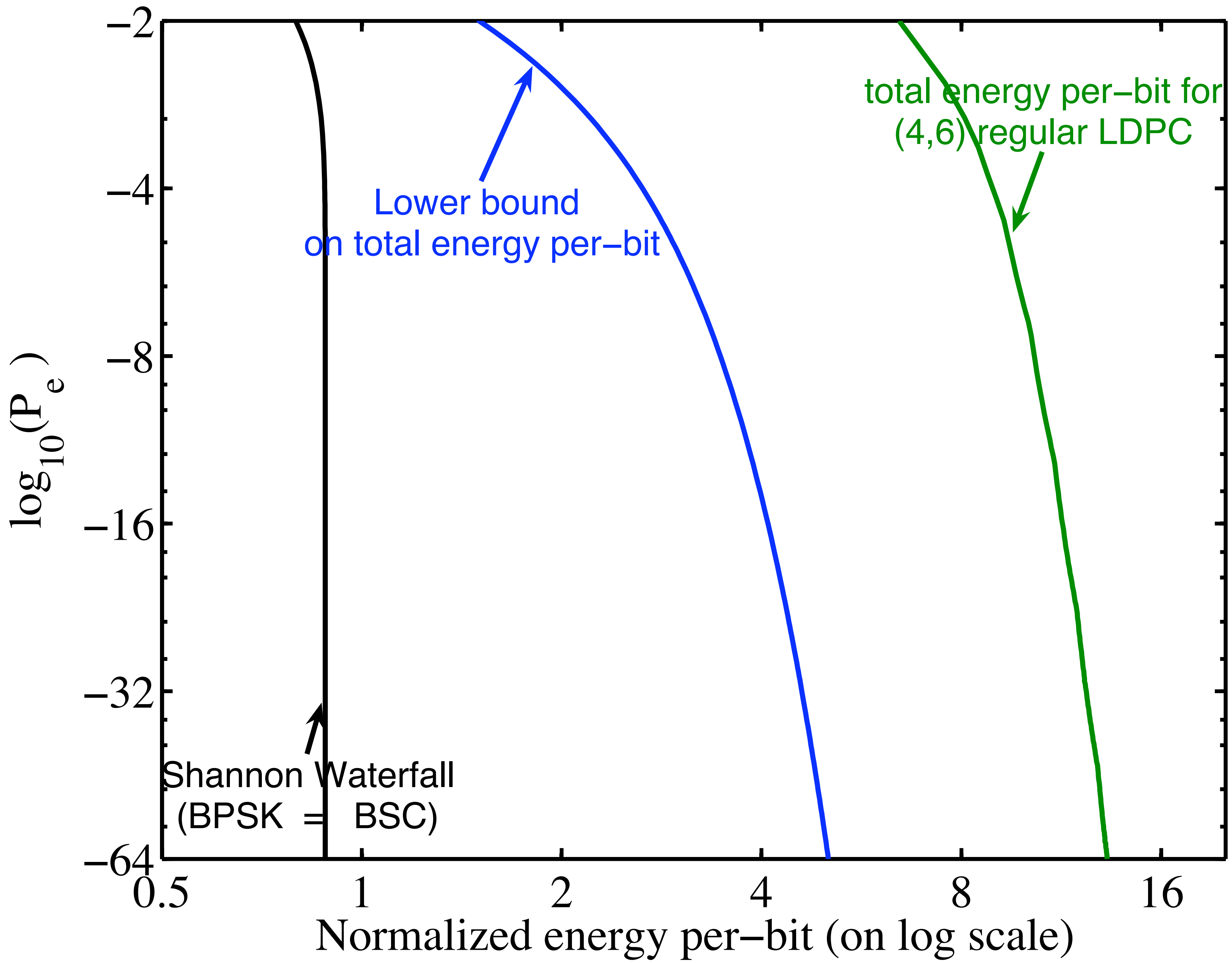

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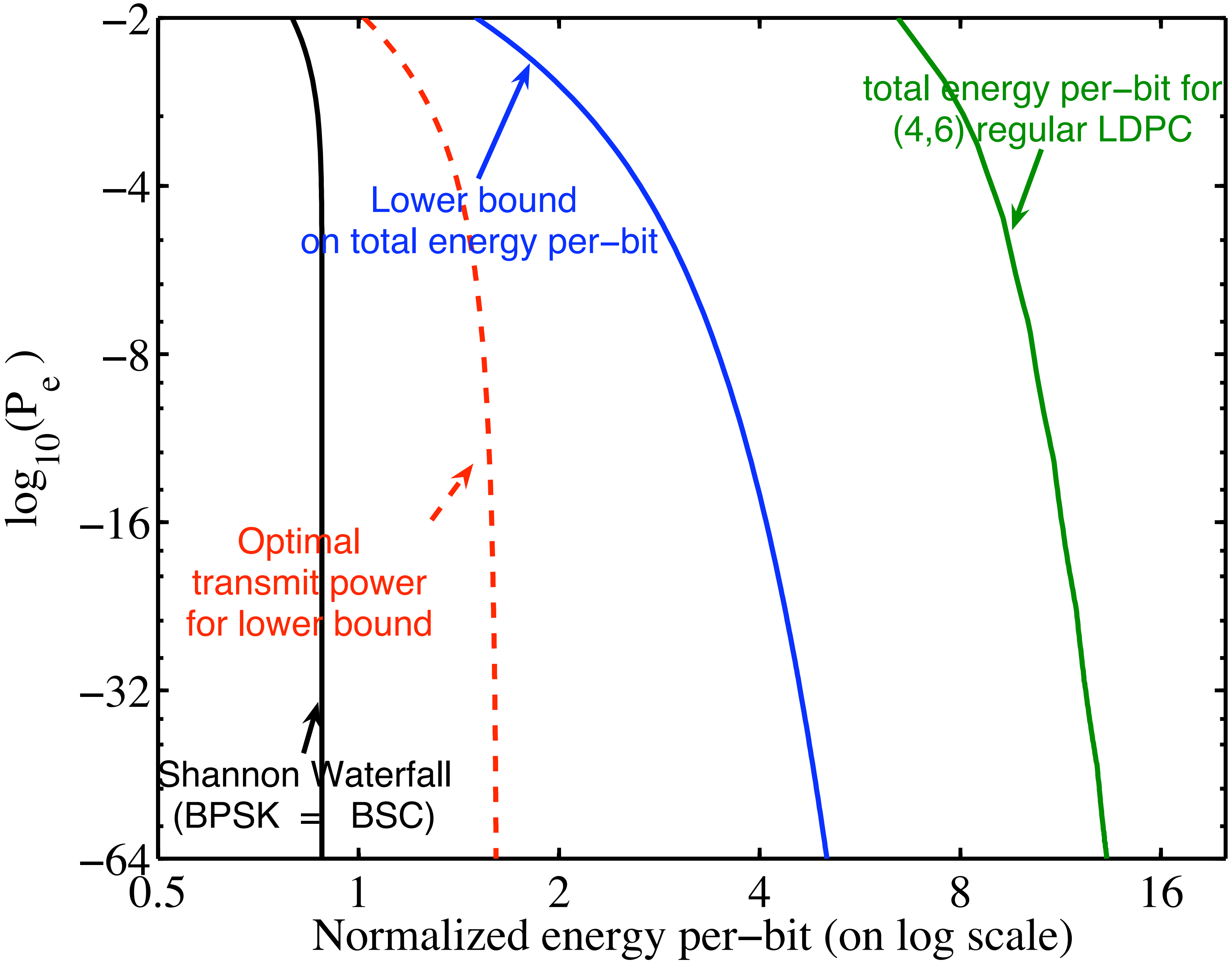

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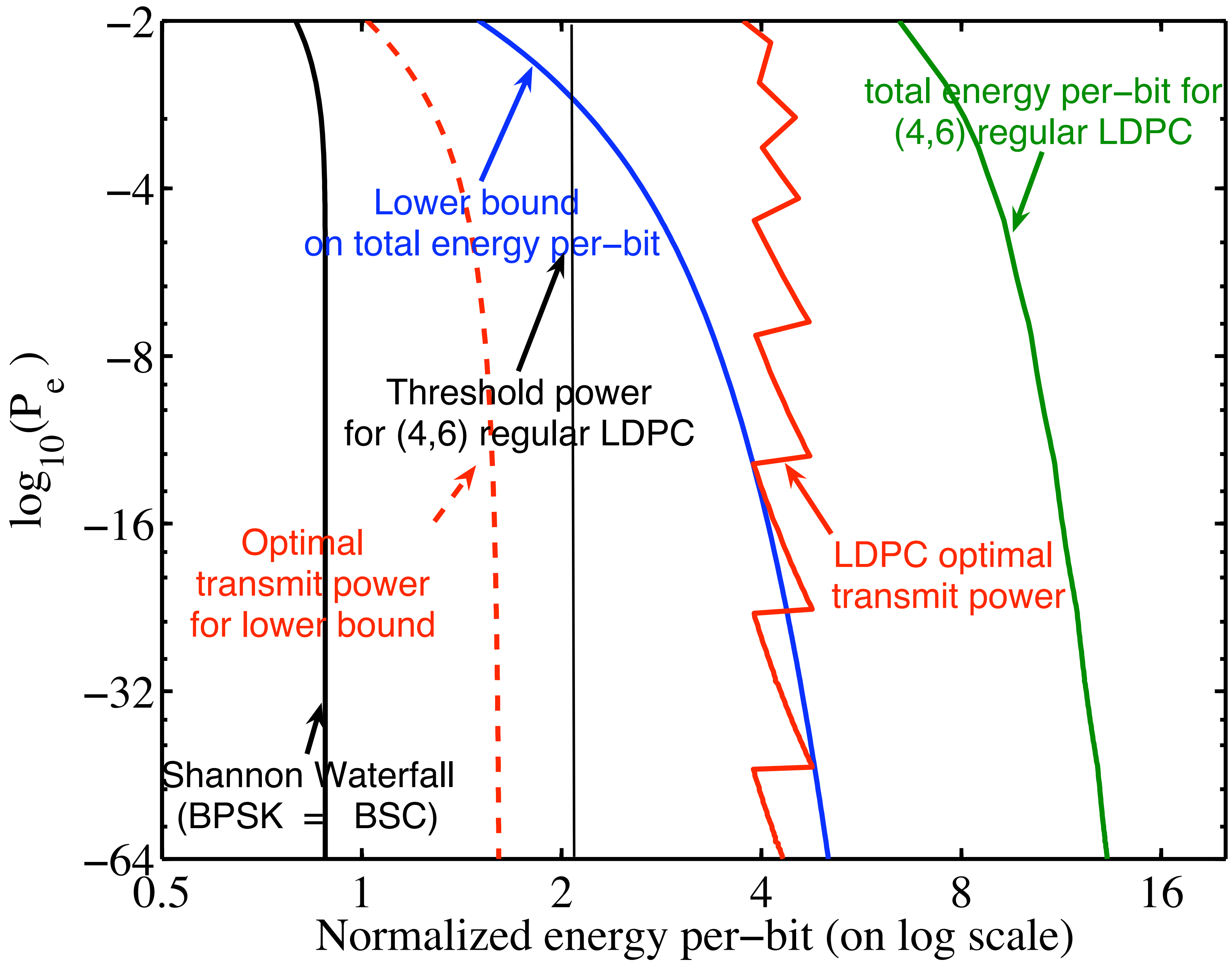

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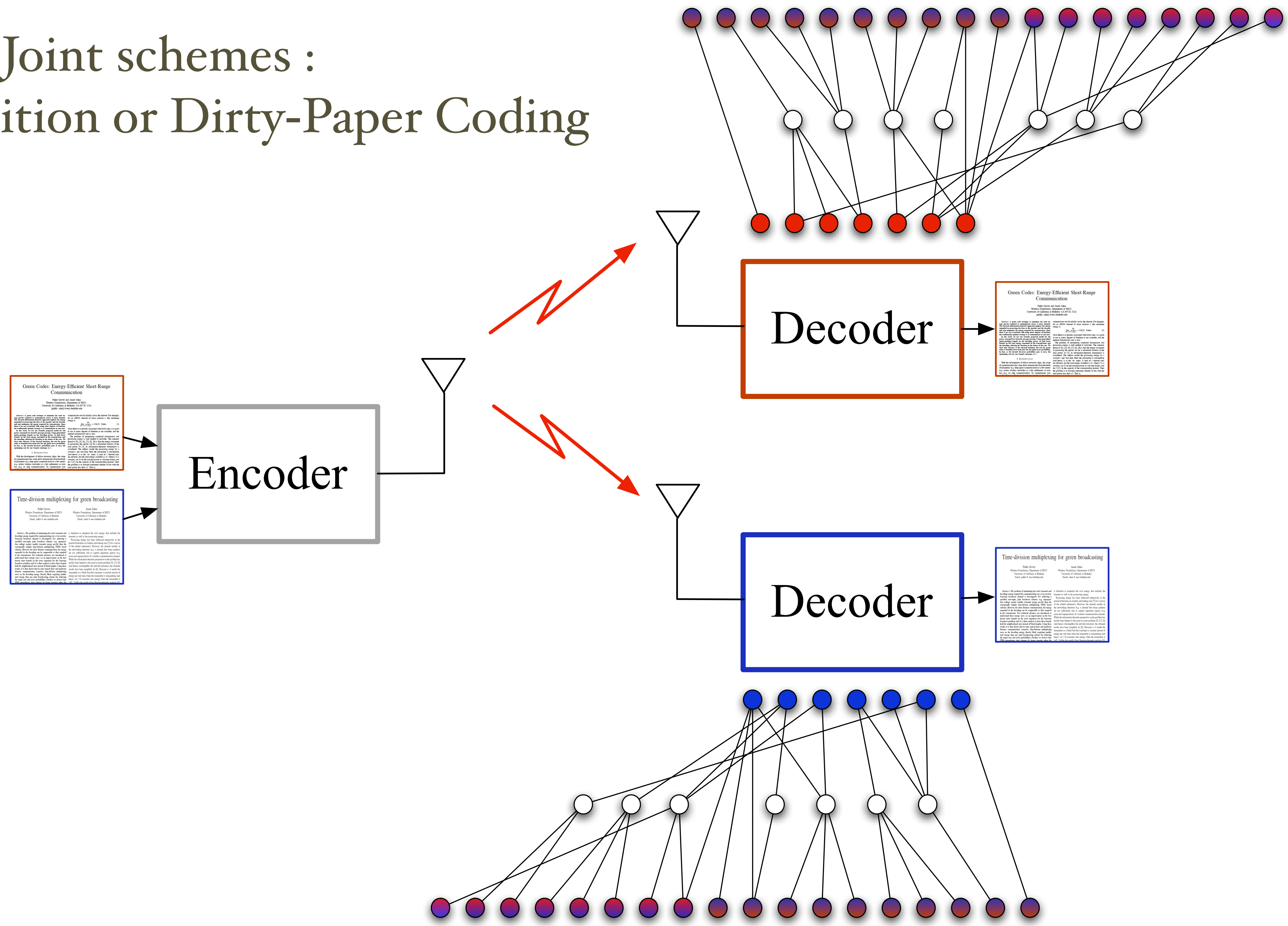
Green broadcasting

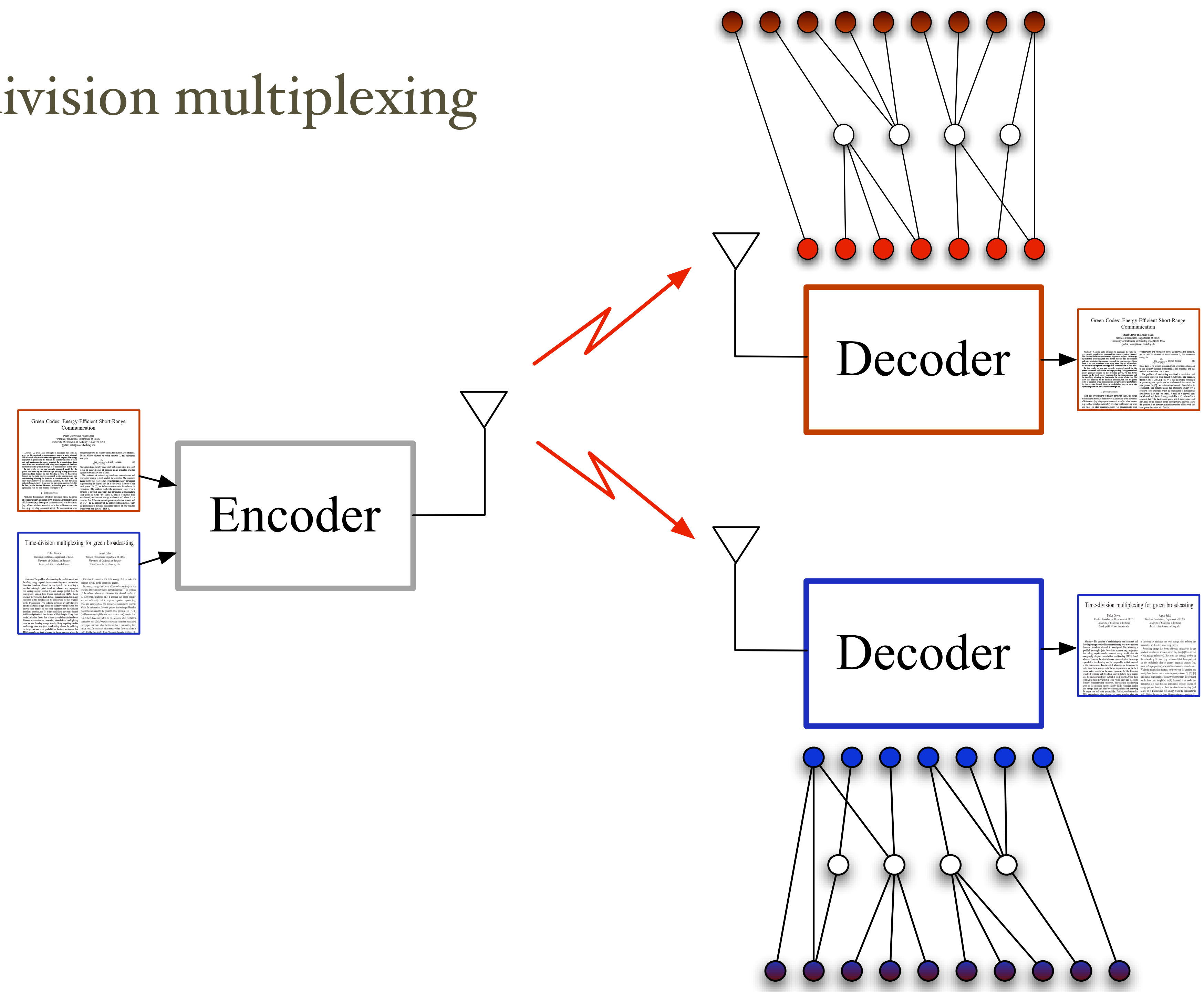
Decoding energy in broadcast channel

Joint schemes :
e.g. Superposition or Dirty-Paper Coding



Decoding energy in broadcast channel

Time-division multiplexing



Outer bounds on error exponents for Gaussian broadcast

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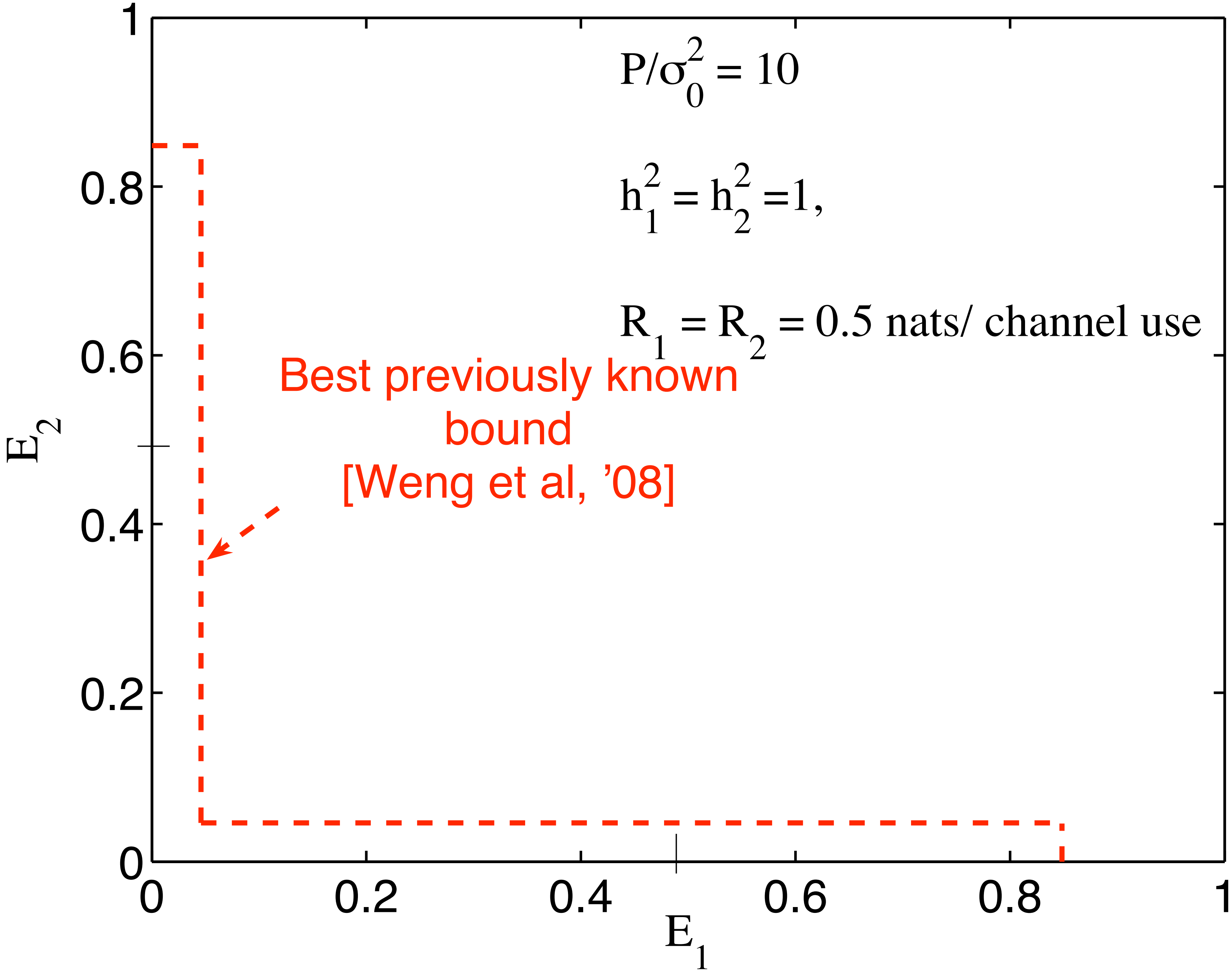

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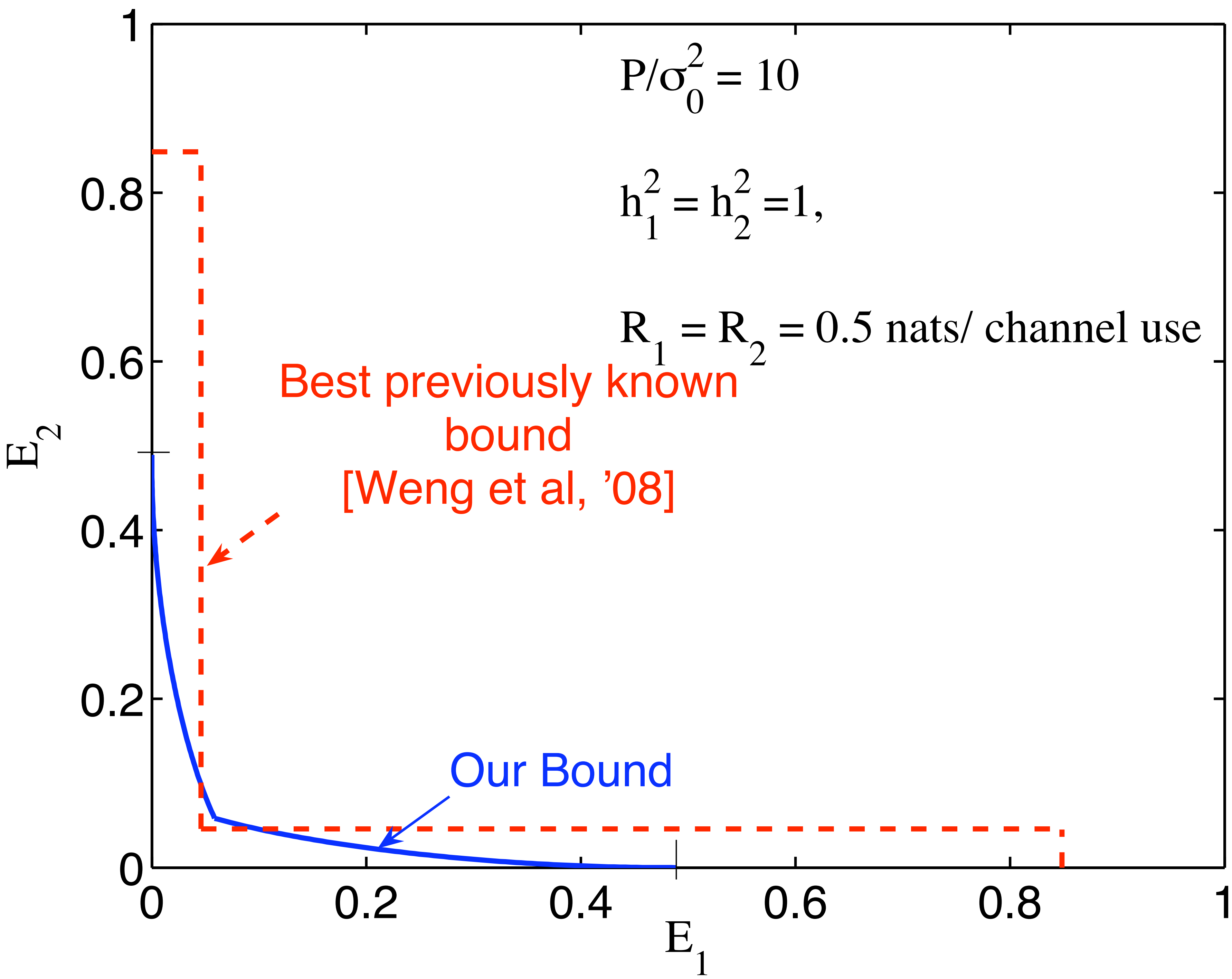
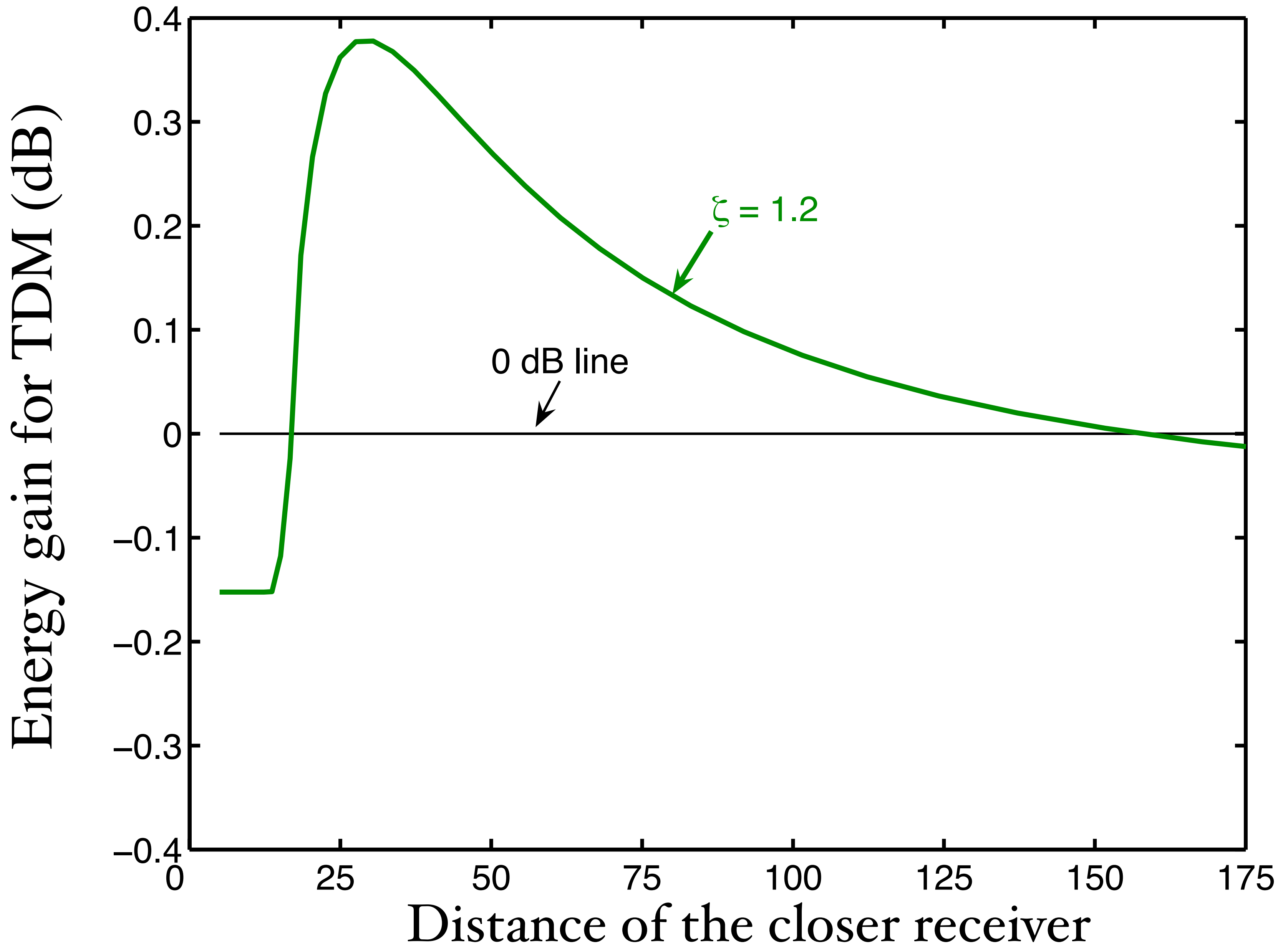


TDM better than superposition/DPC at short distances!



$$\zeta = \frac{r_2^2}{r_1^2}$$

energy per operation E = 1 pJ,
path-loss exponent = 2,
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(Noise + fading) figure = 30 dB

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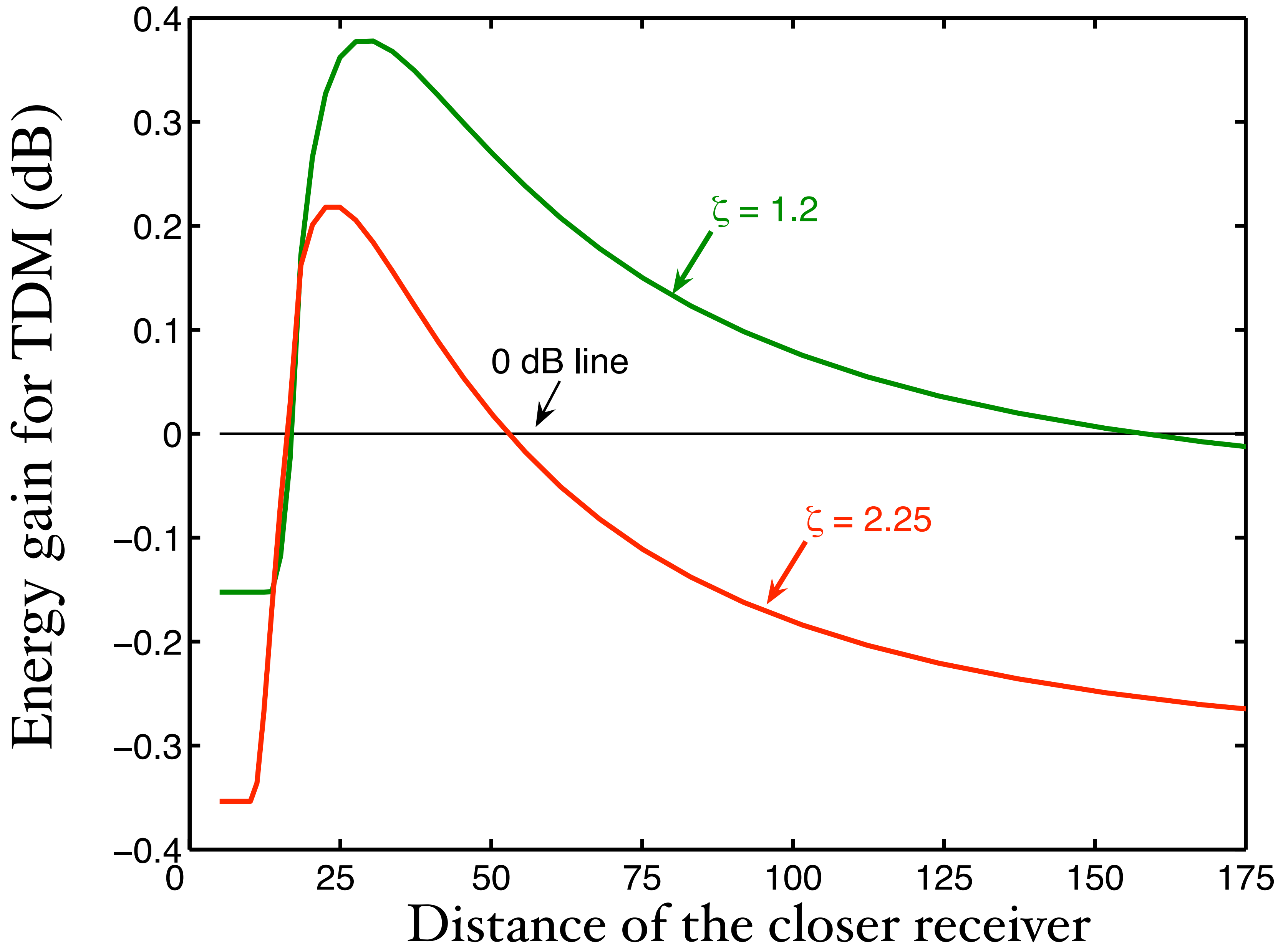

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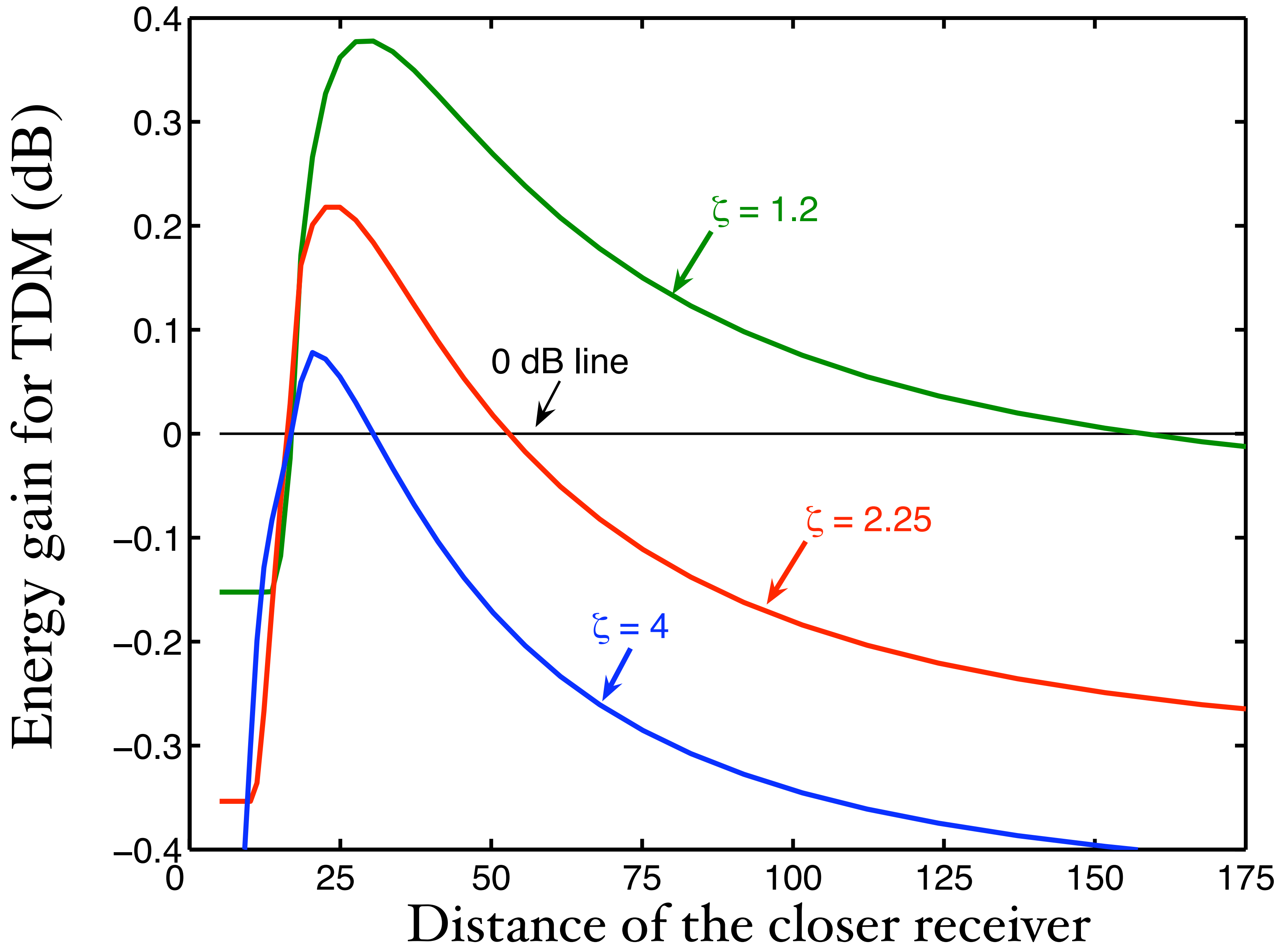

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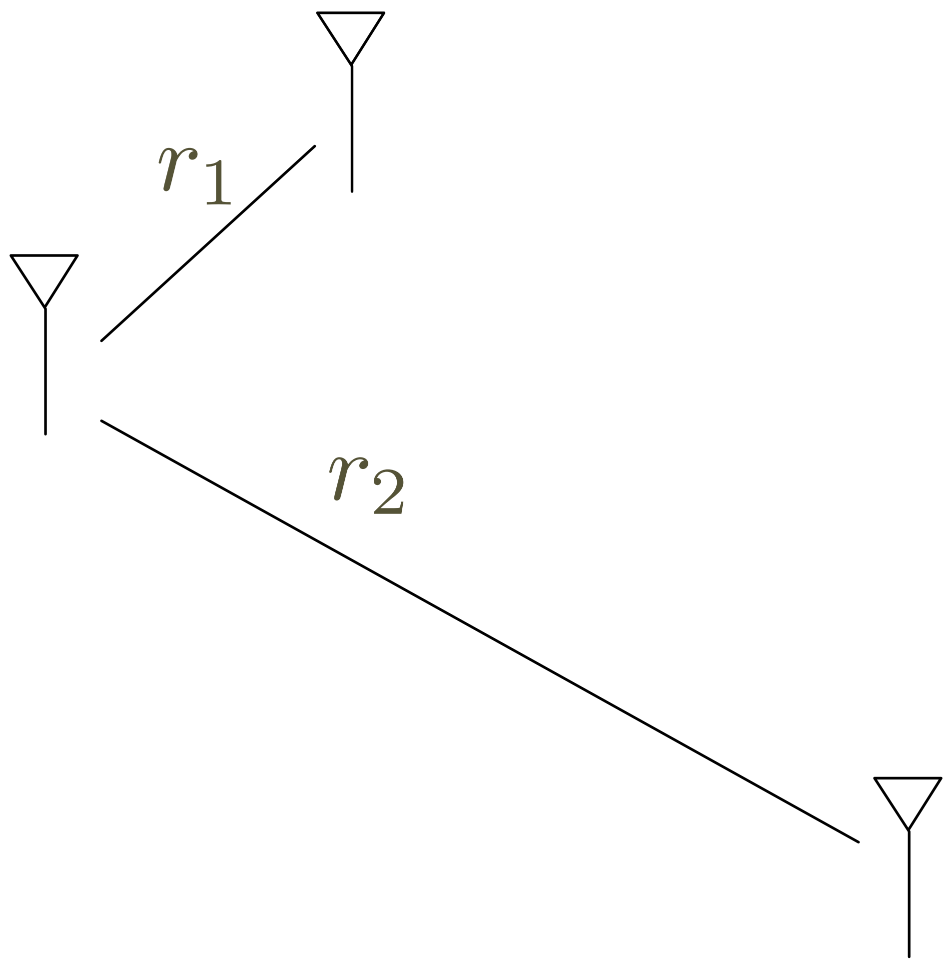

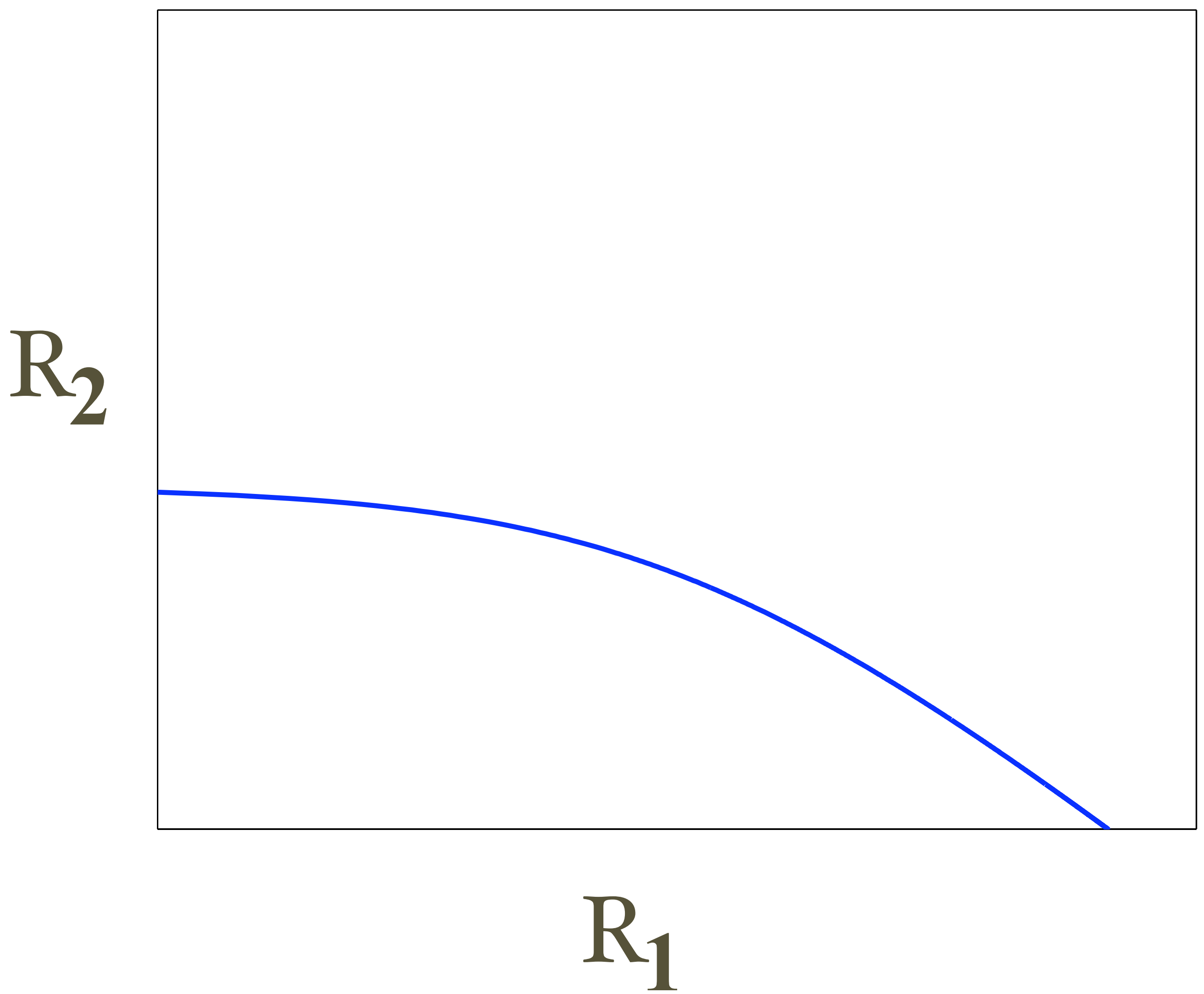

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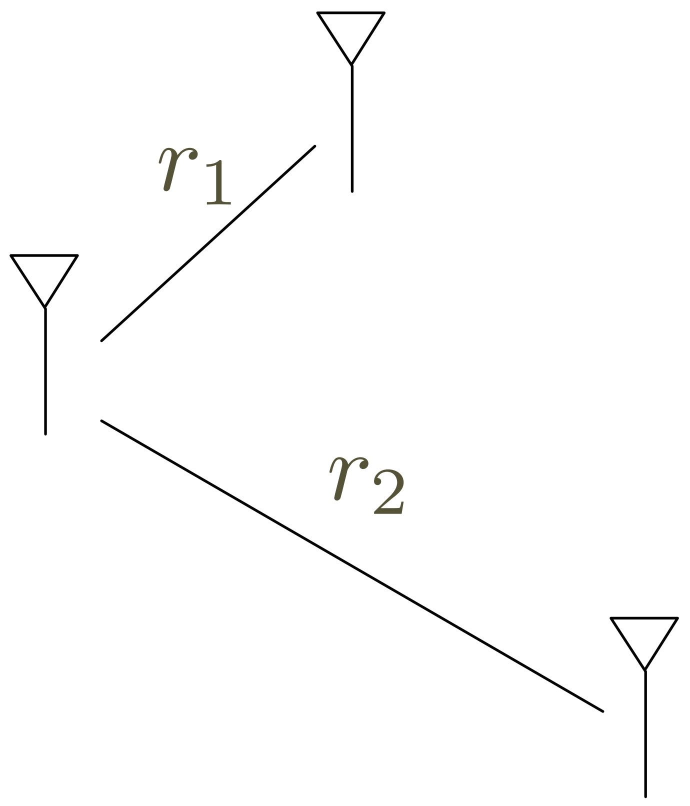

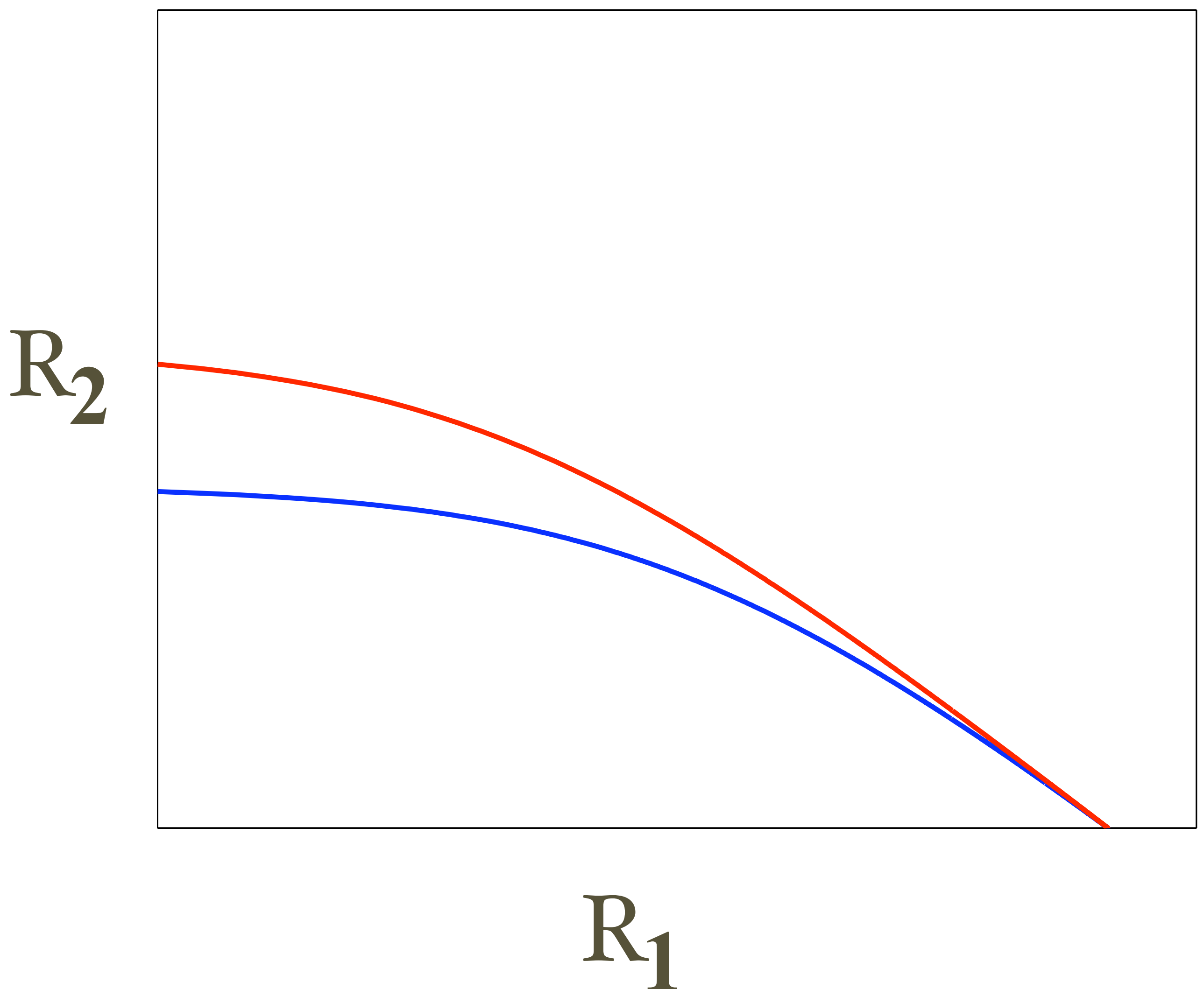

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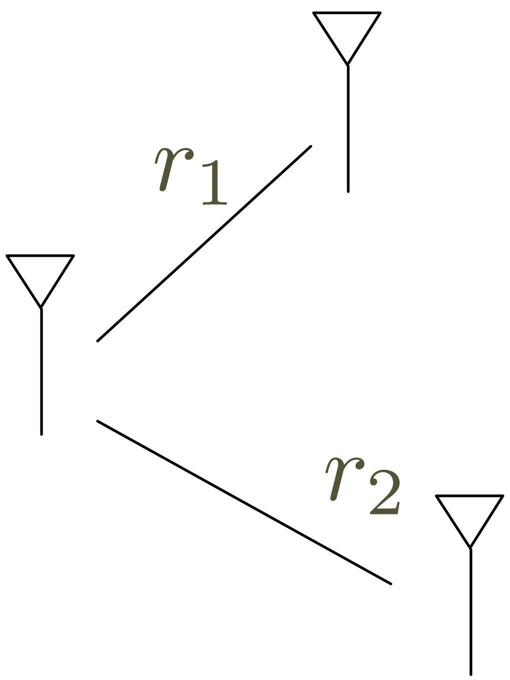

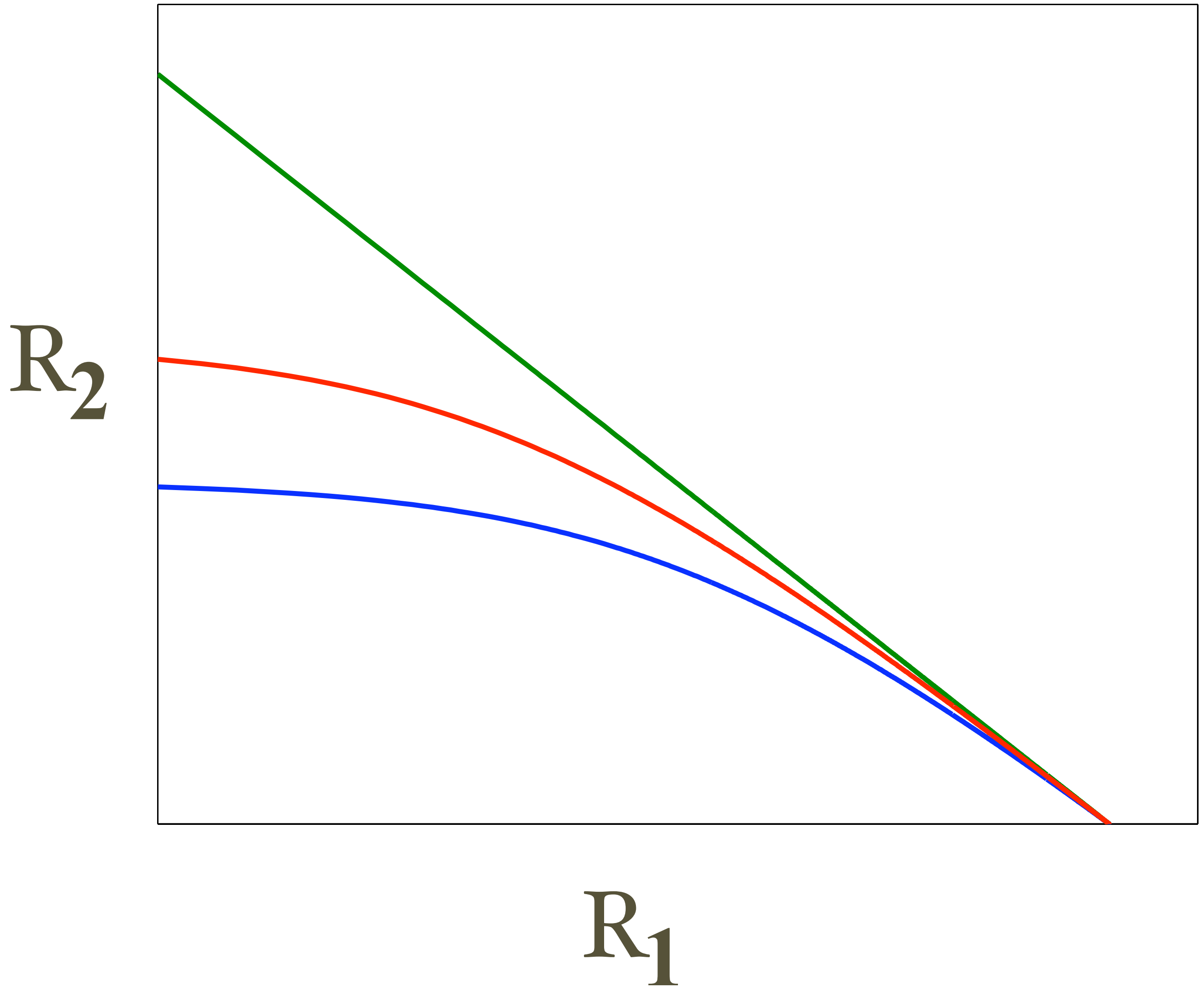

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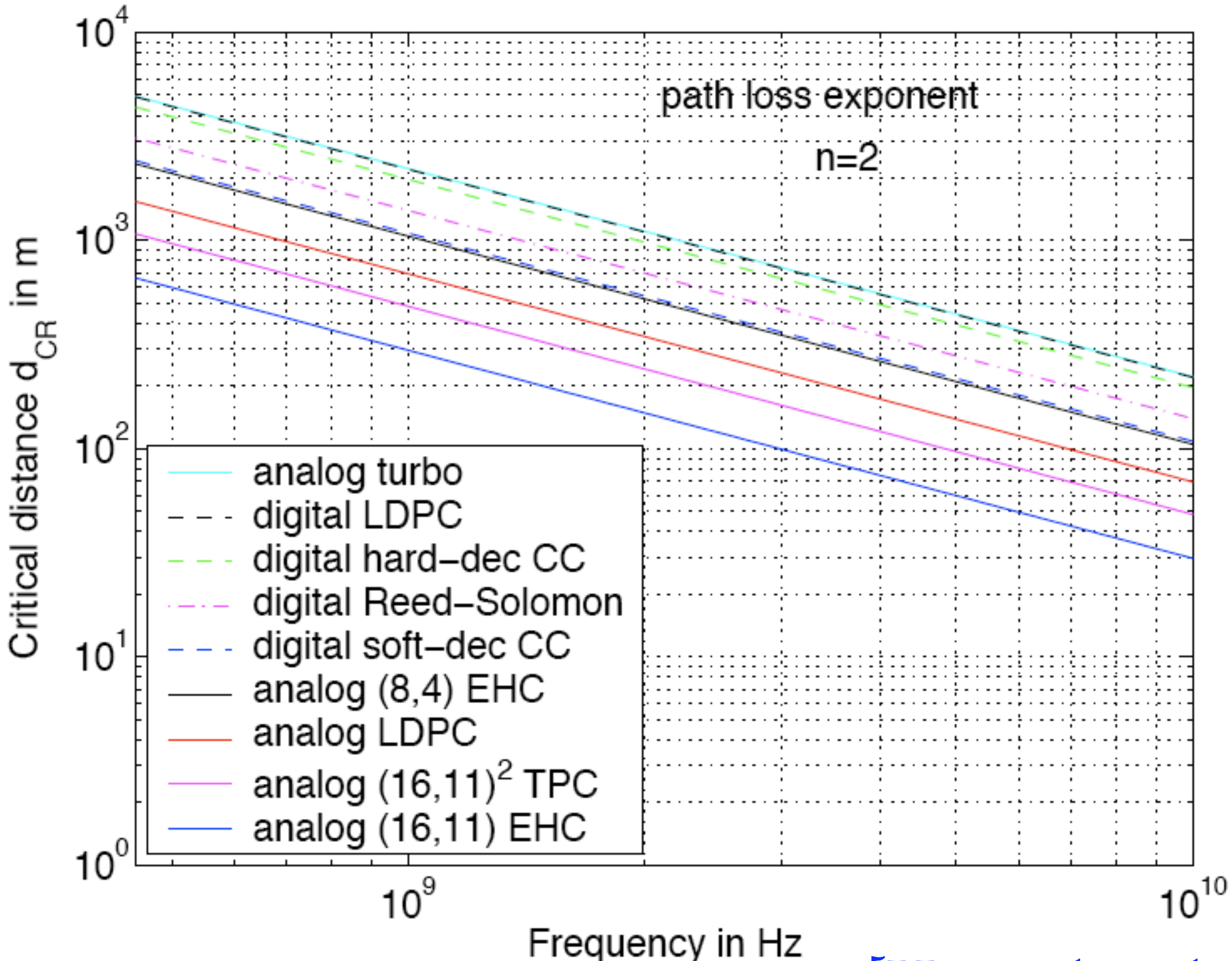
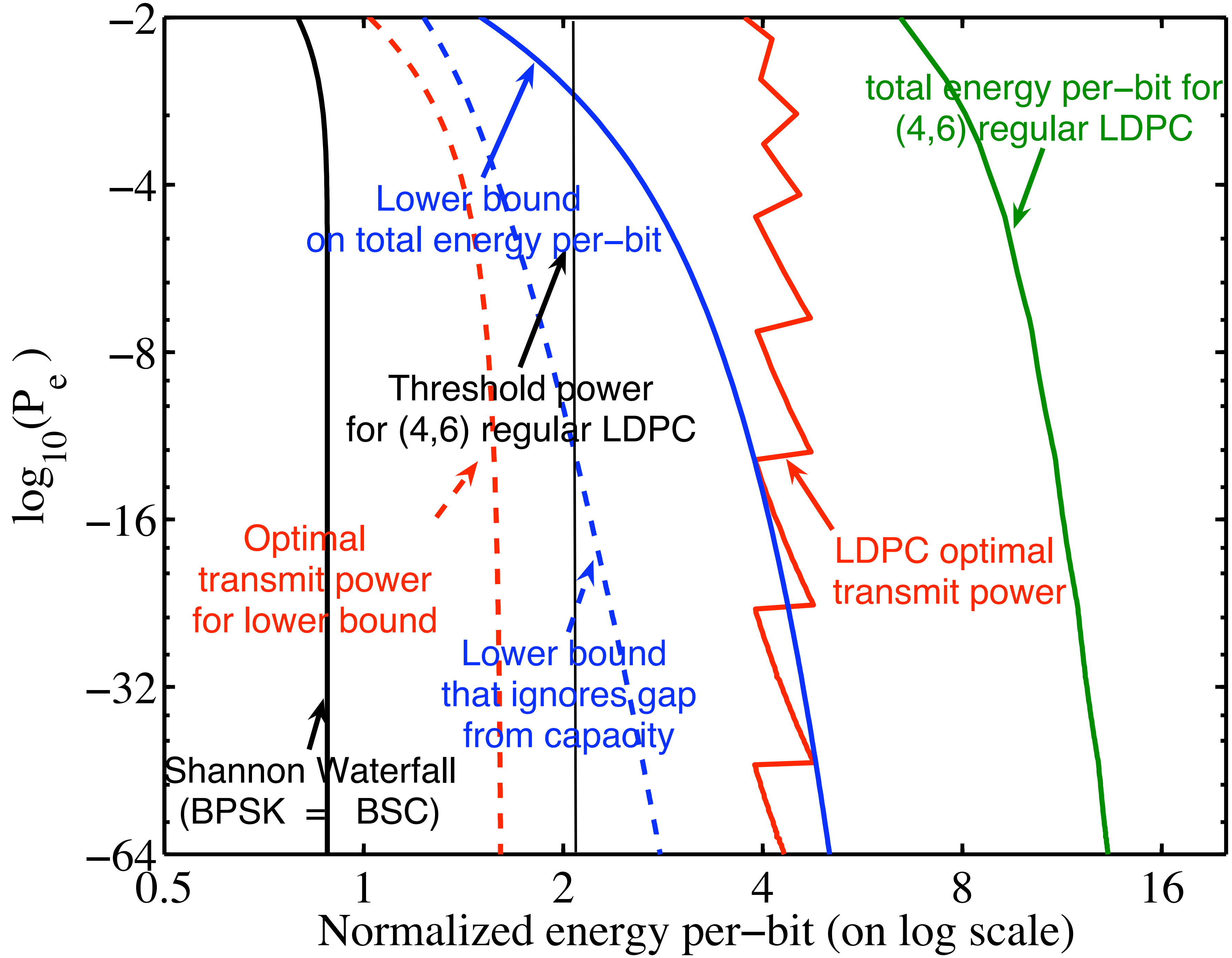
  - we are comparing lower bounds. The hope is that sparse-graph codes approach these bounds.
- Error exponents with neighborhood size and bit-error probability aid in understanding the relevant tradeoffs
  - Tighter bounds can be derived for specific code classes.
- Shannon theory needs augmentation at short distances because of decoding power

Backup slides begin

Uncoded vs coded transmission



[Howard et al, 2006]


total energy per−bit for
(4,6) regular LDPC
Lower bound
on total energy per−bit
Threshold power
for (4,6) regular LDPC
Optimal
transmit power
for lower bound
LDPC optimal
transmit power
Lower bound
that ignores gap
from capacity
Shannon Waterfall
(BPSK = BSC)
−2
−4
−8
−16
−32
−64
0.5
1
2
4
8
16
$\log_{10}(P_e)$
Normalized energy per−bit (on log scale)

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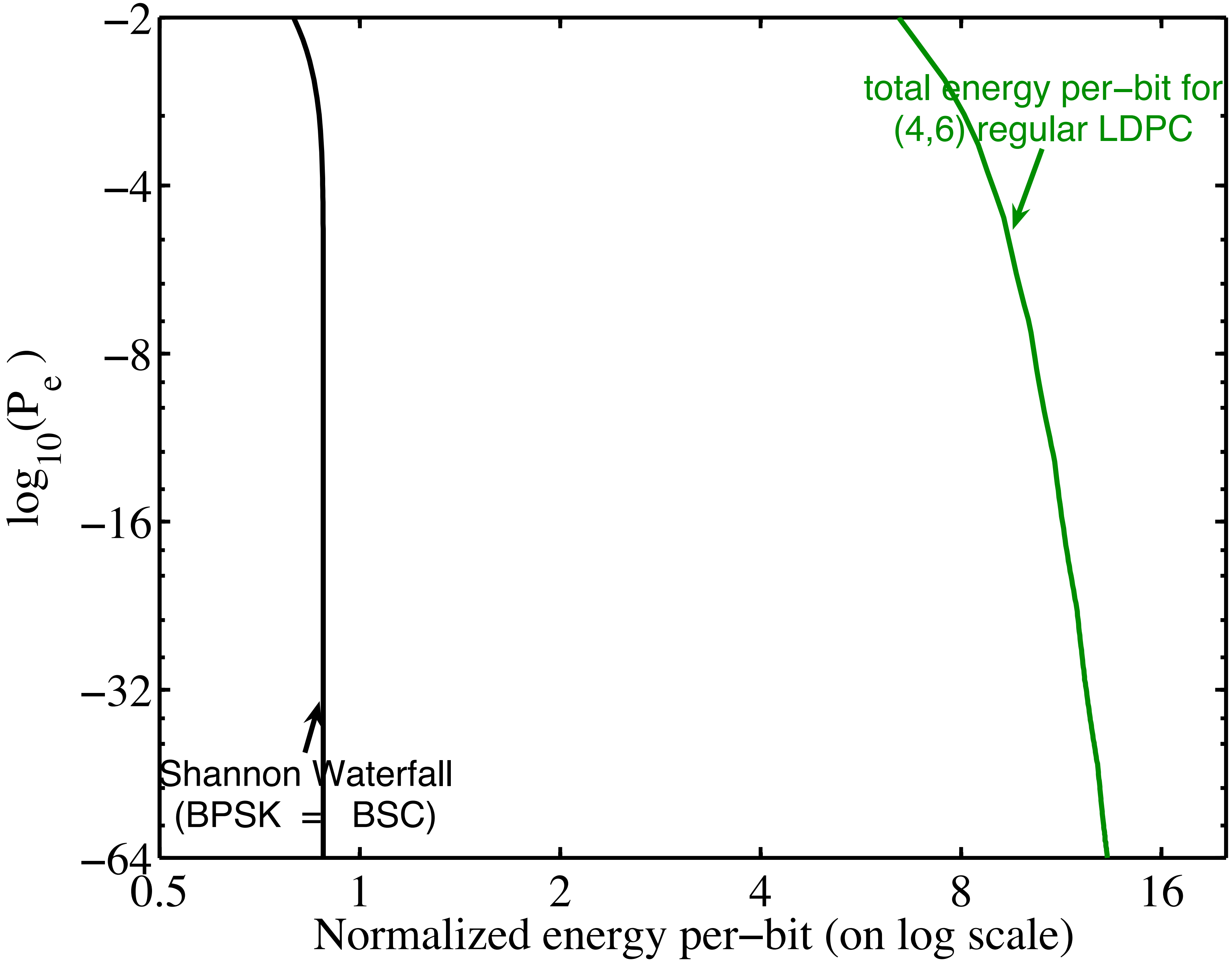

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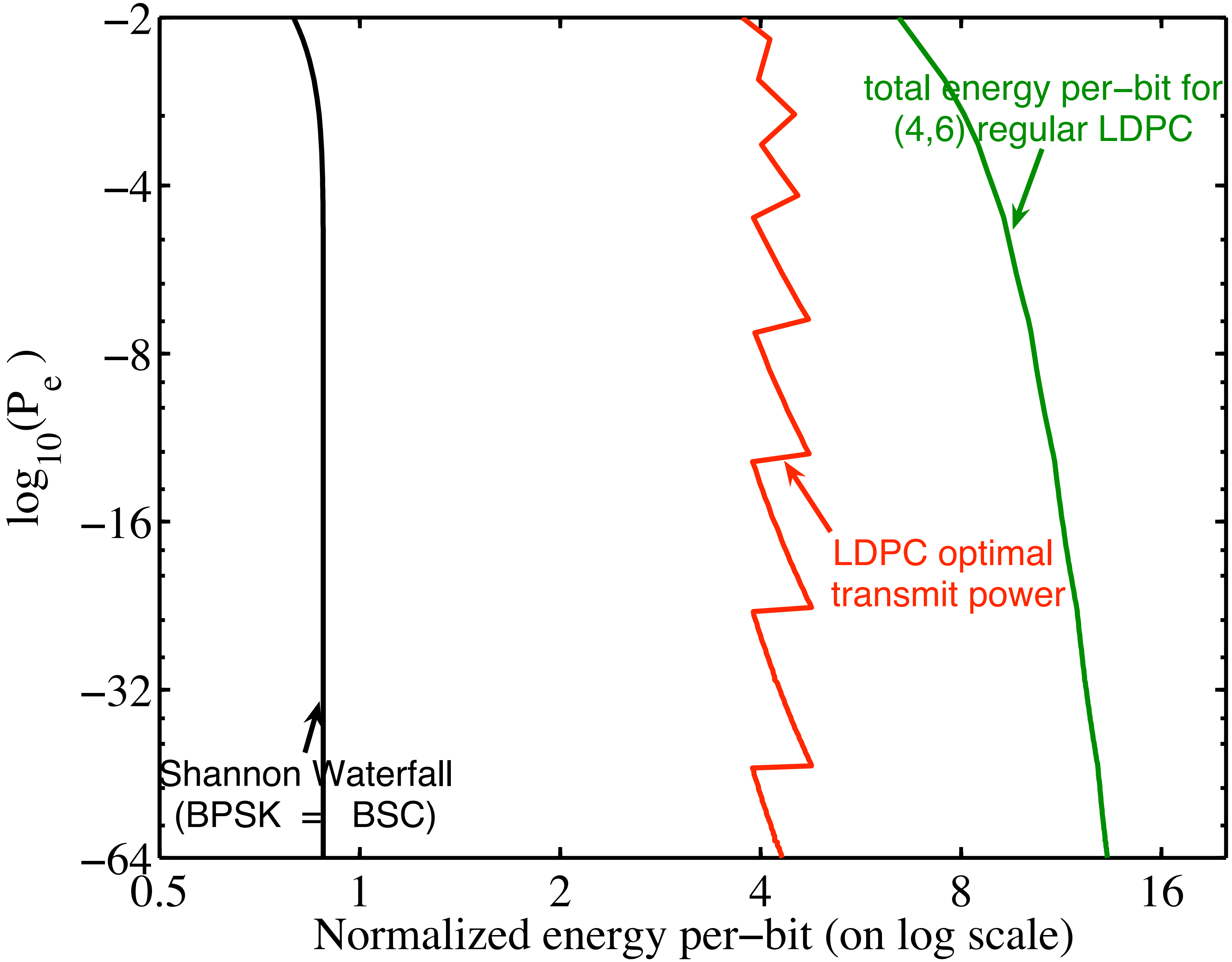

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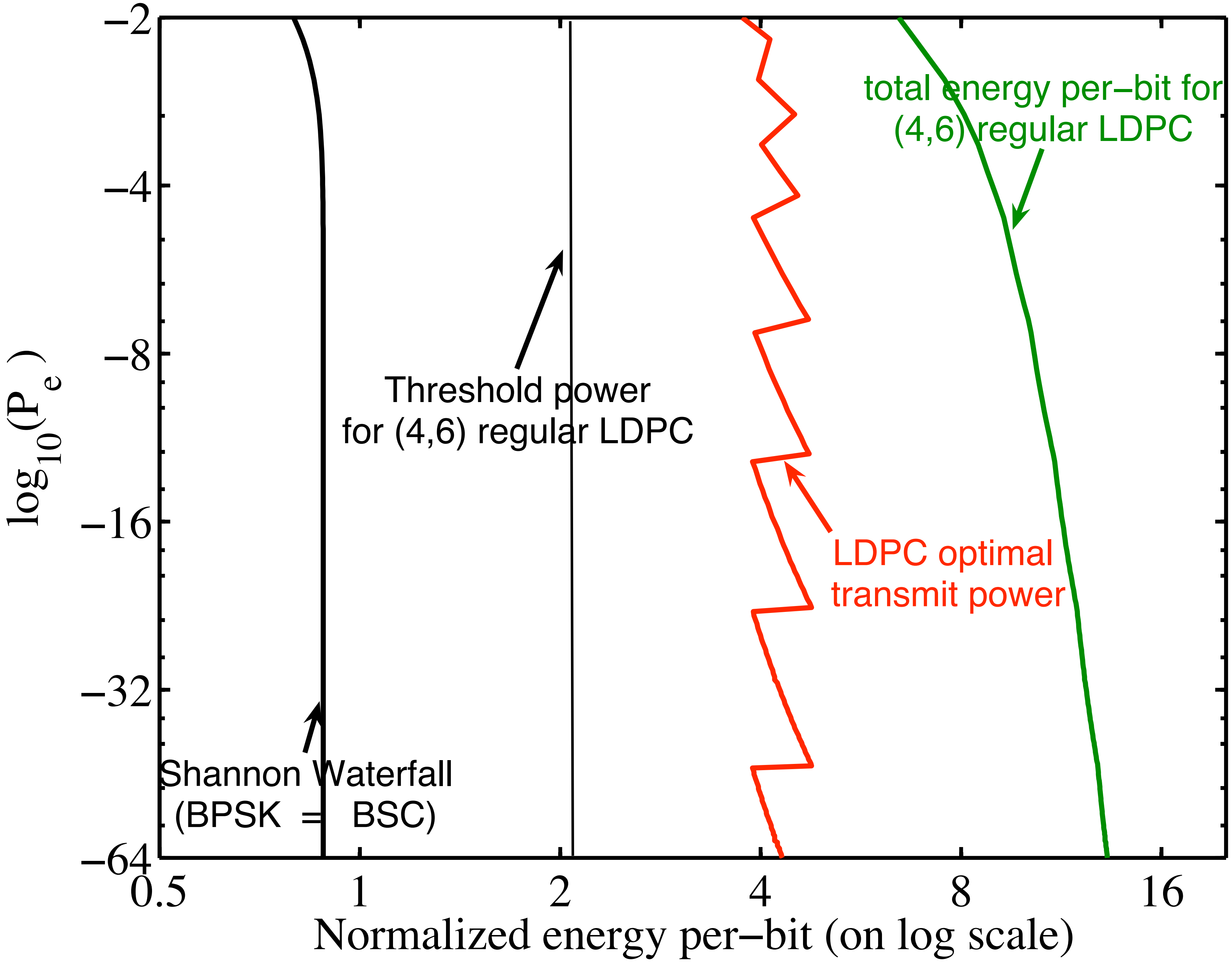

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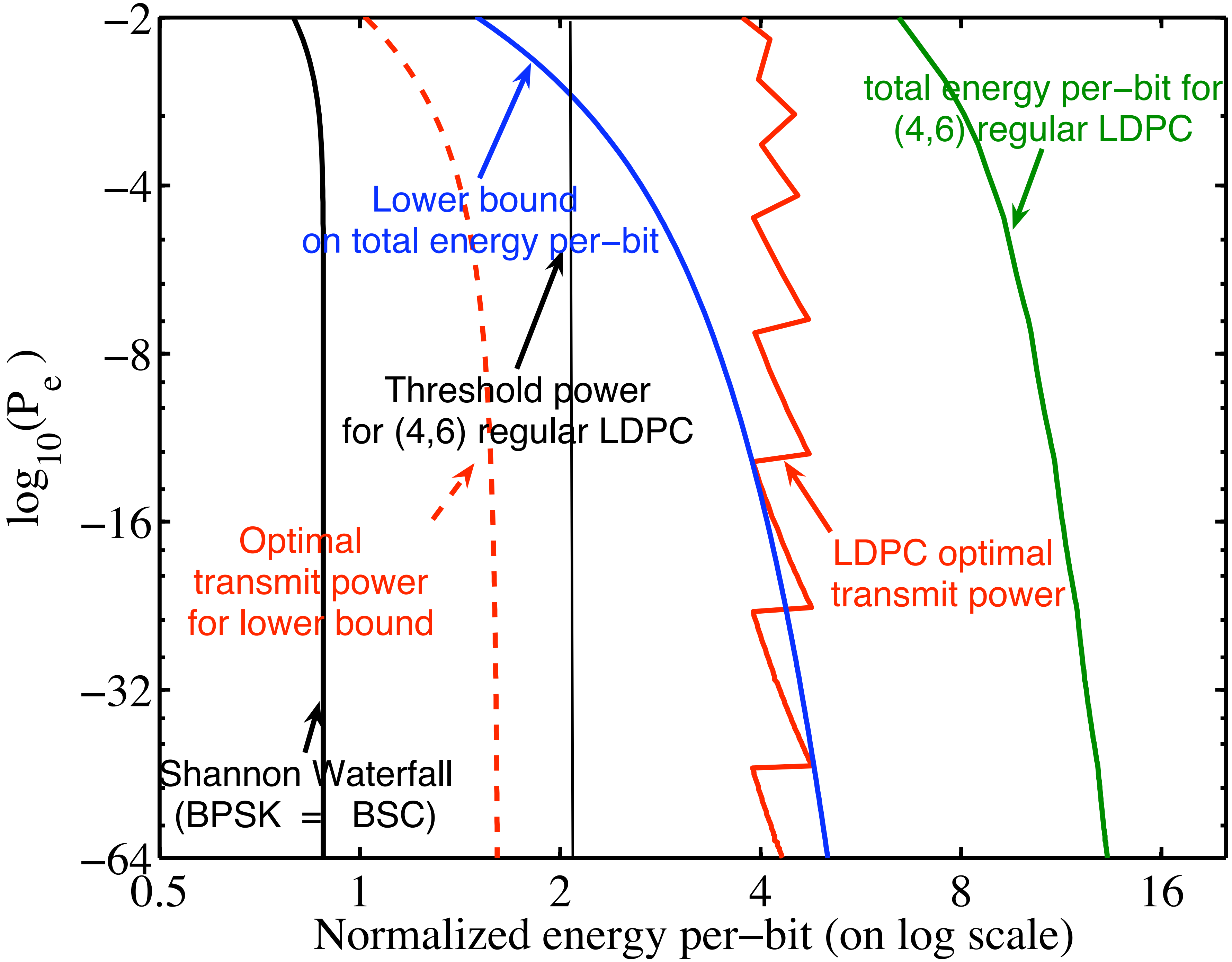

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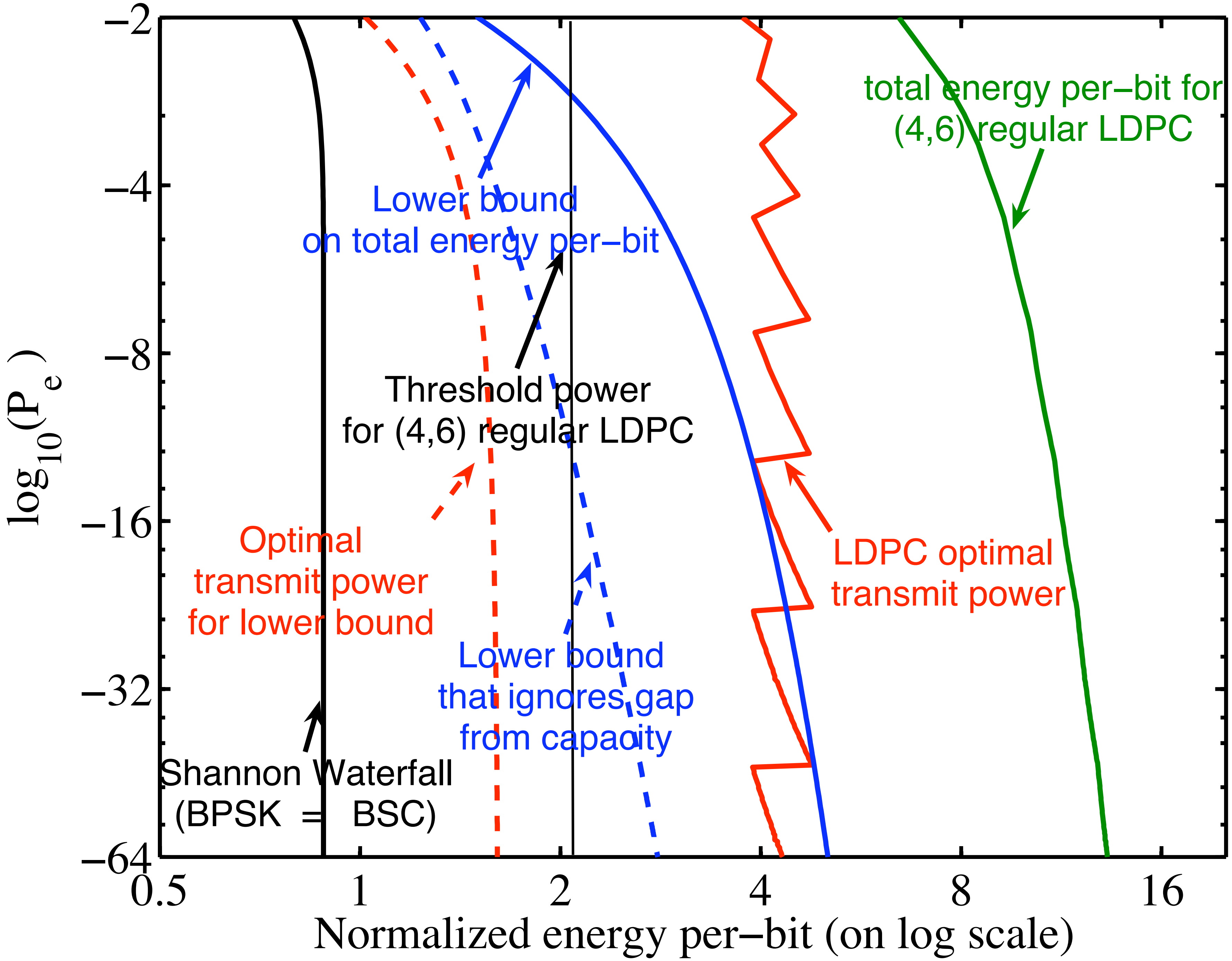

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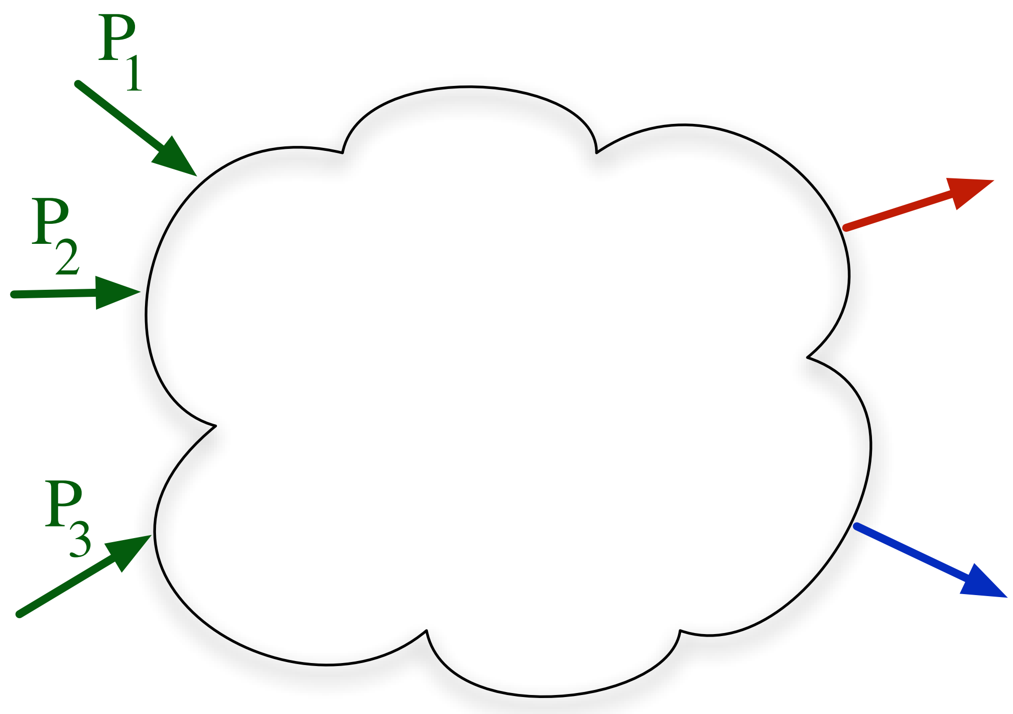

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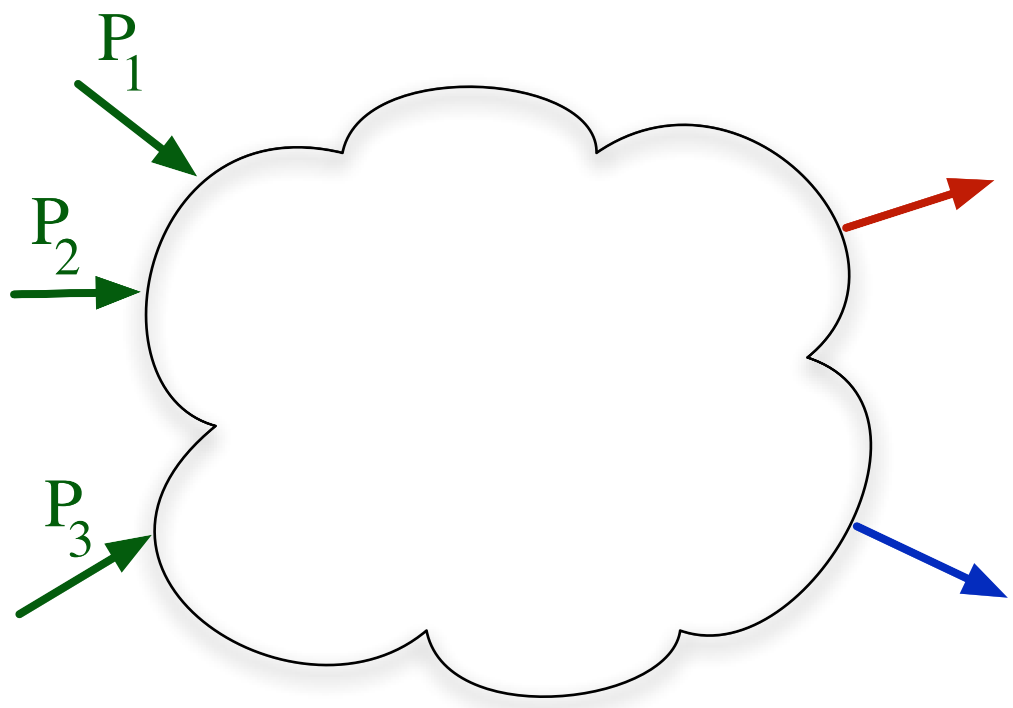
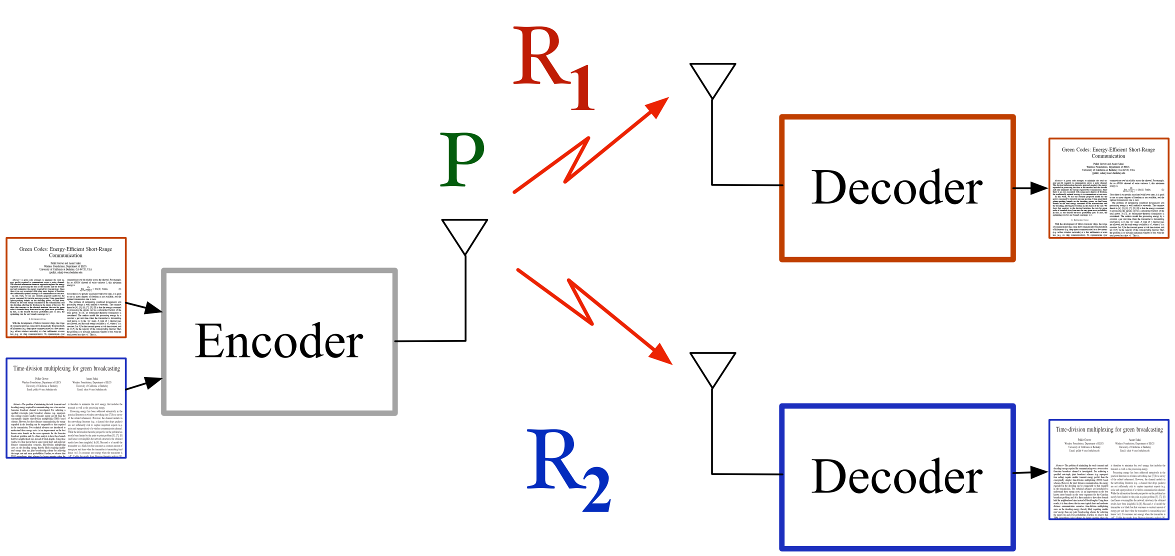
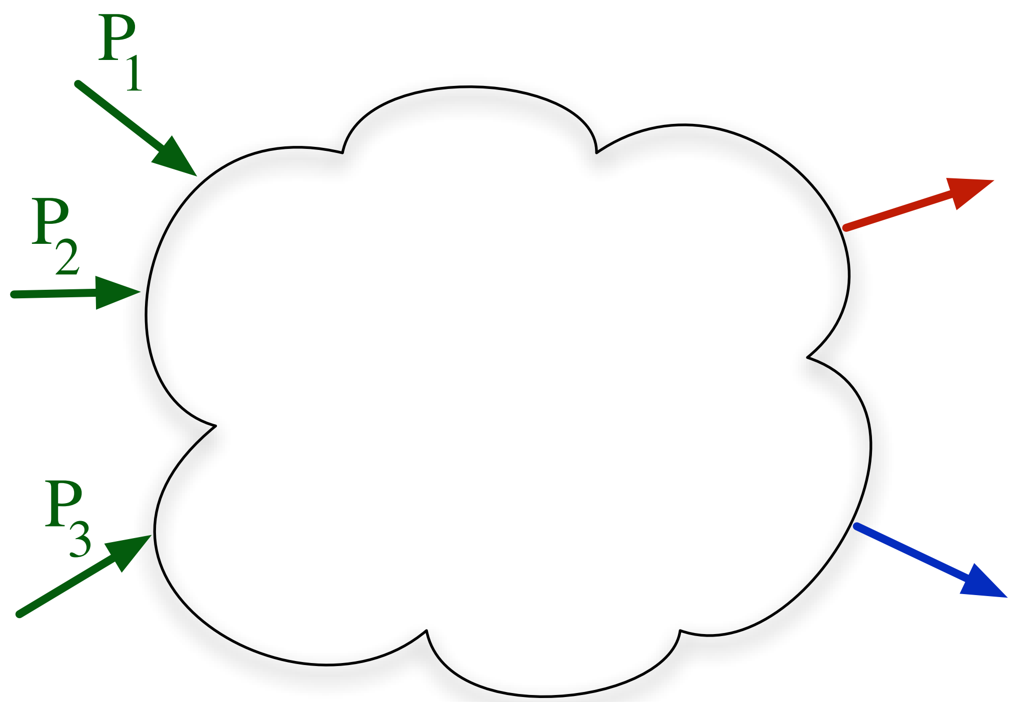
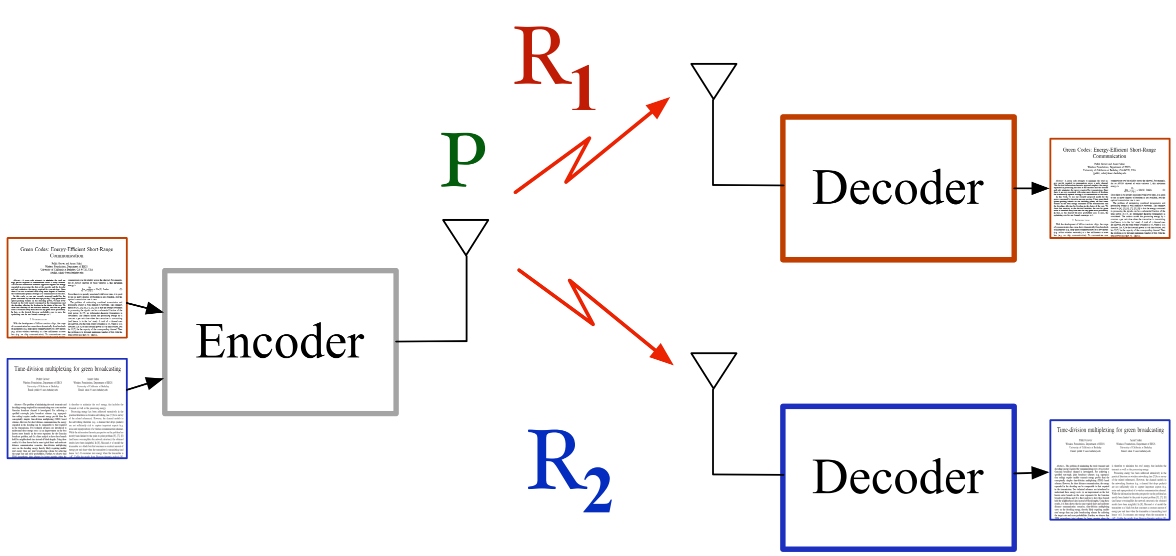
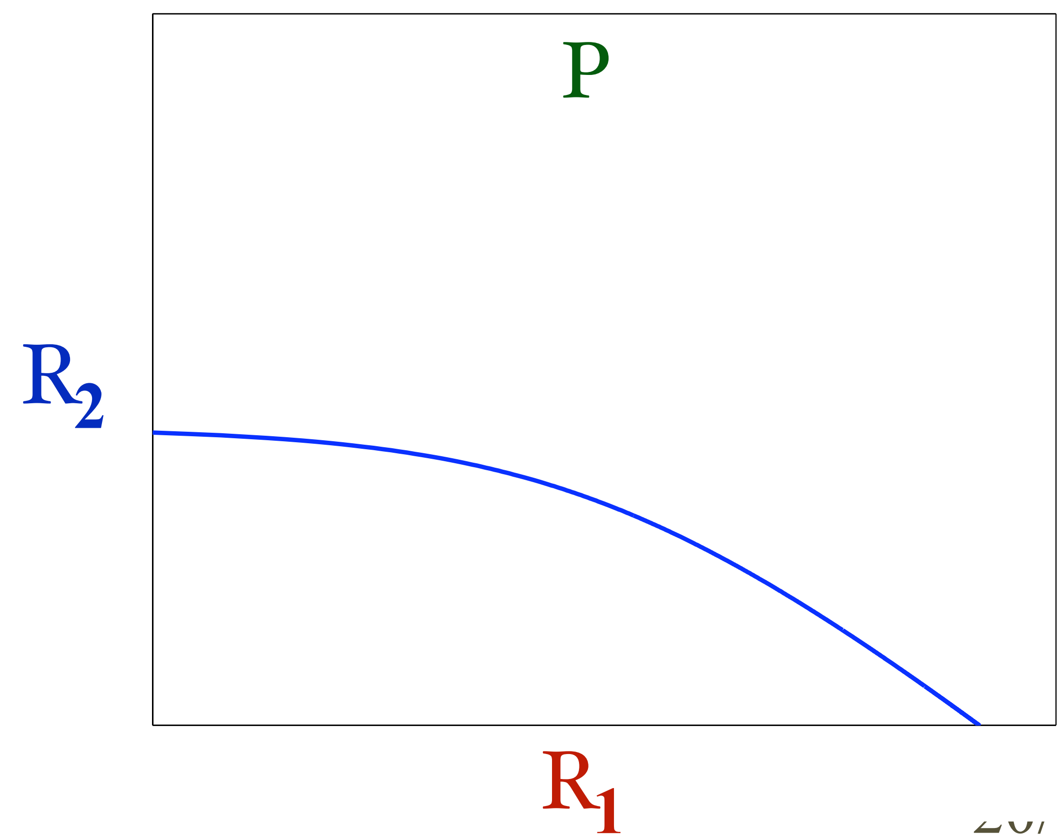




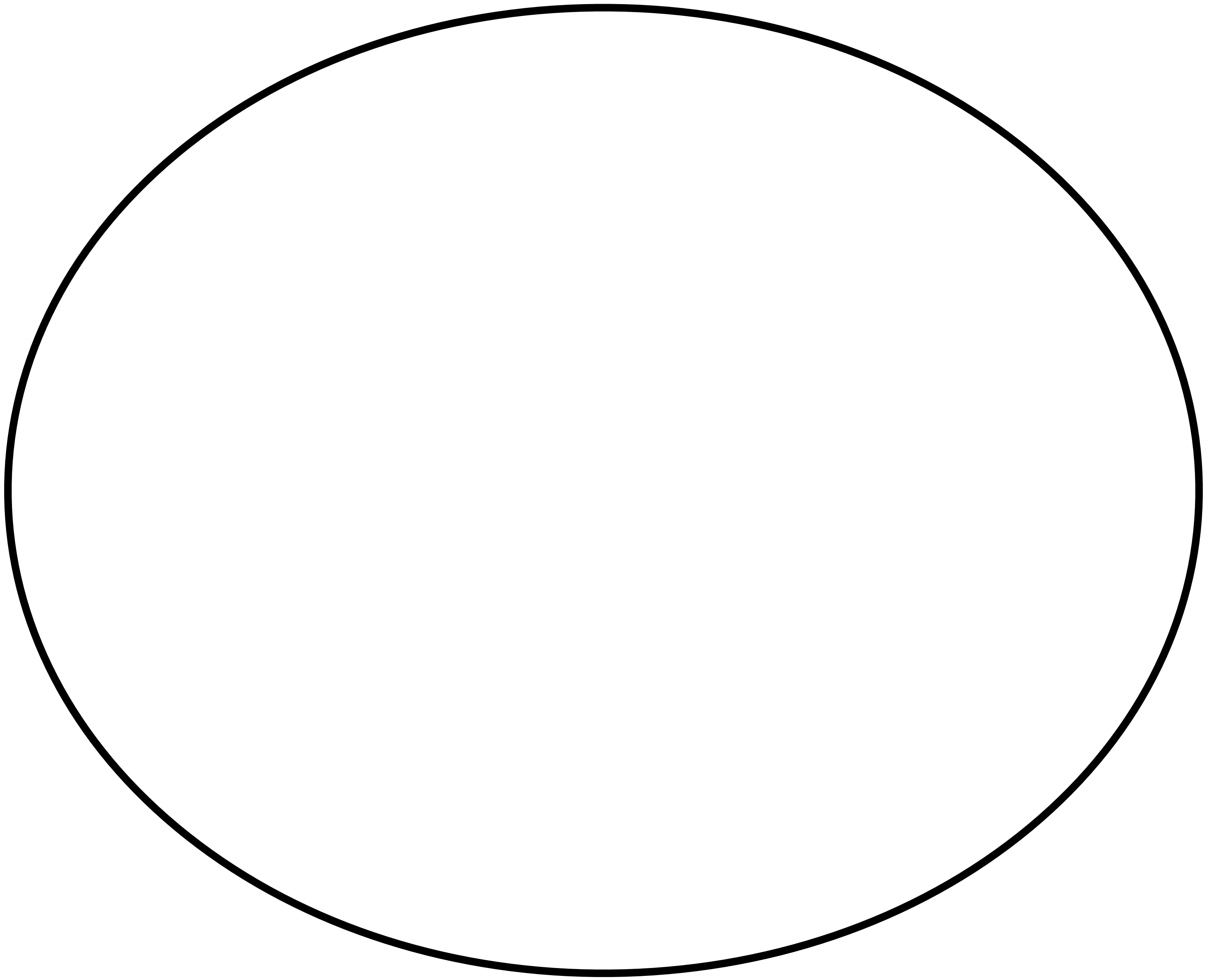
Green communication at long distances



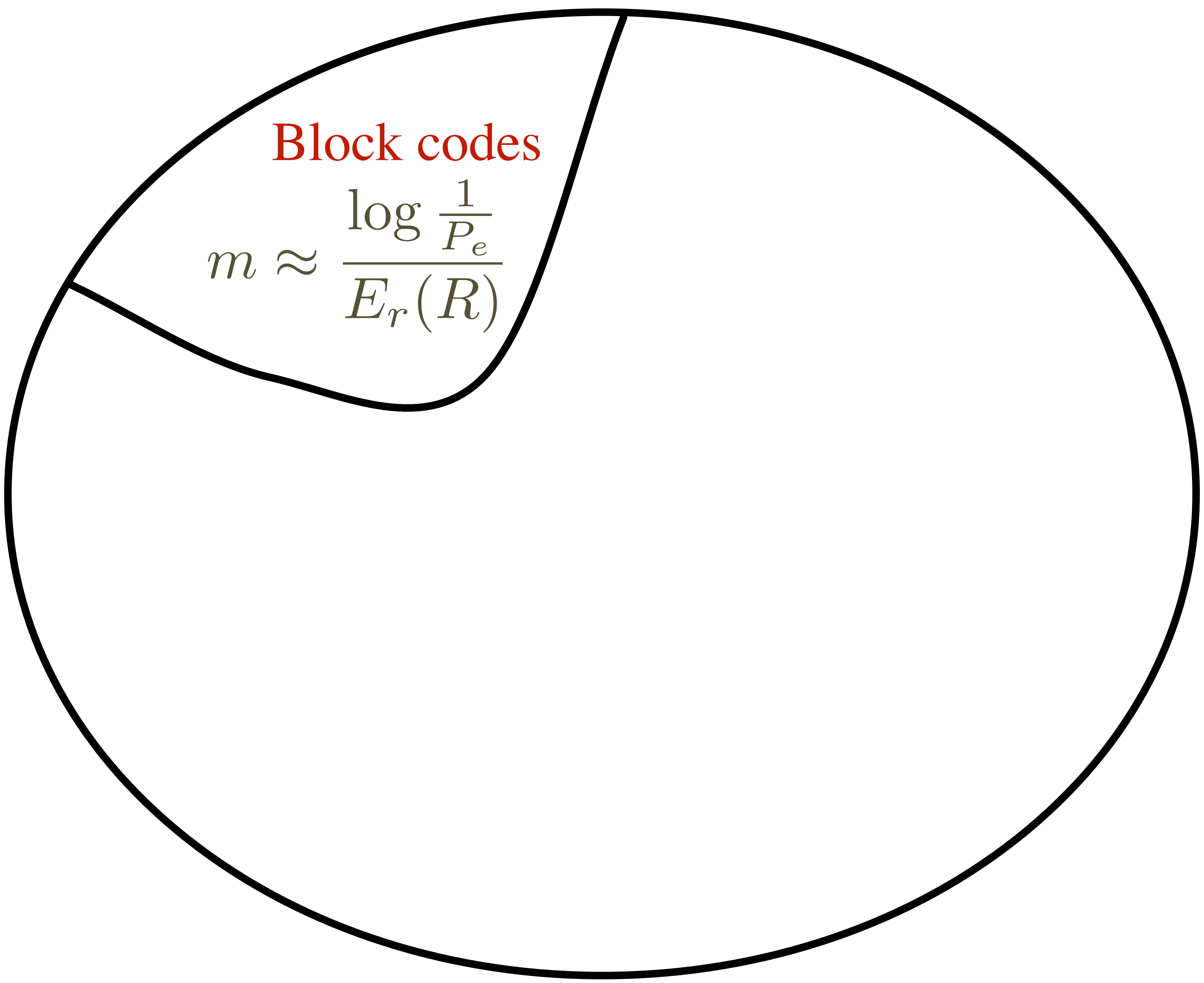




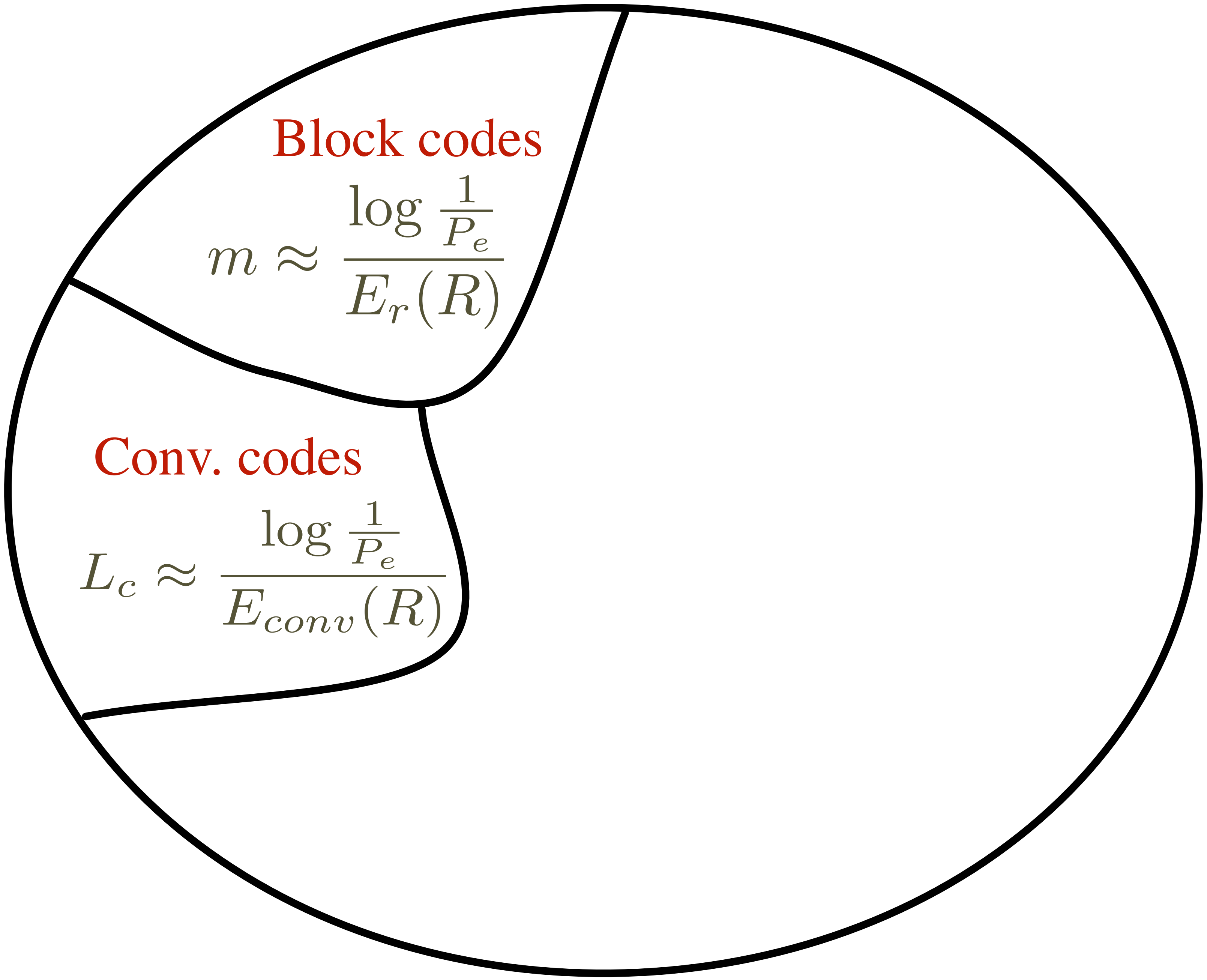
Lower bounds on complexity



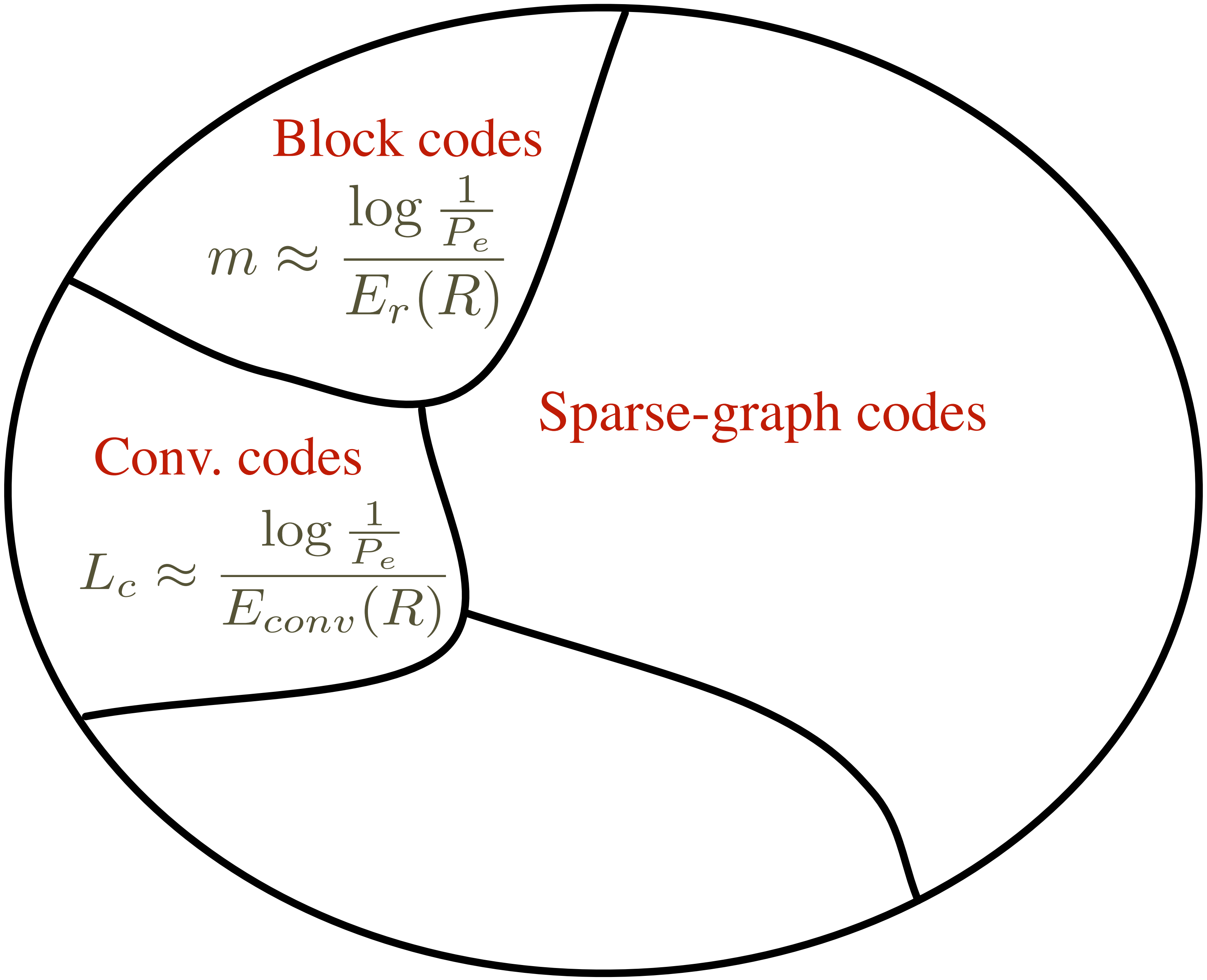
Lower bounds on complexity



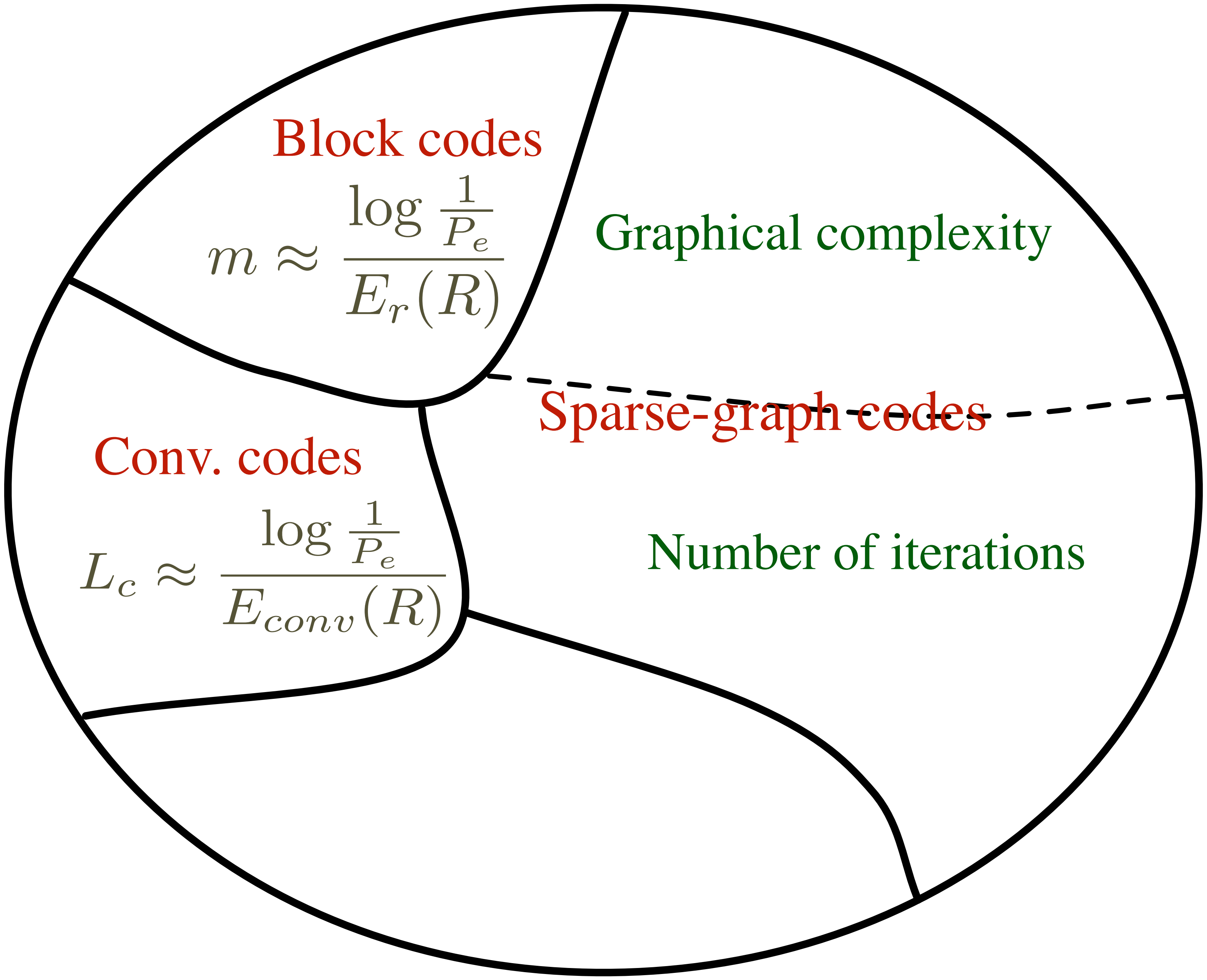
Lower bounds on complexity



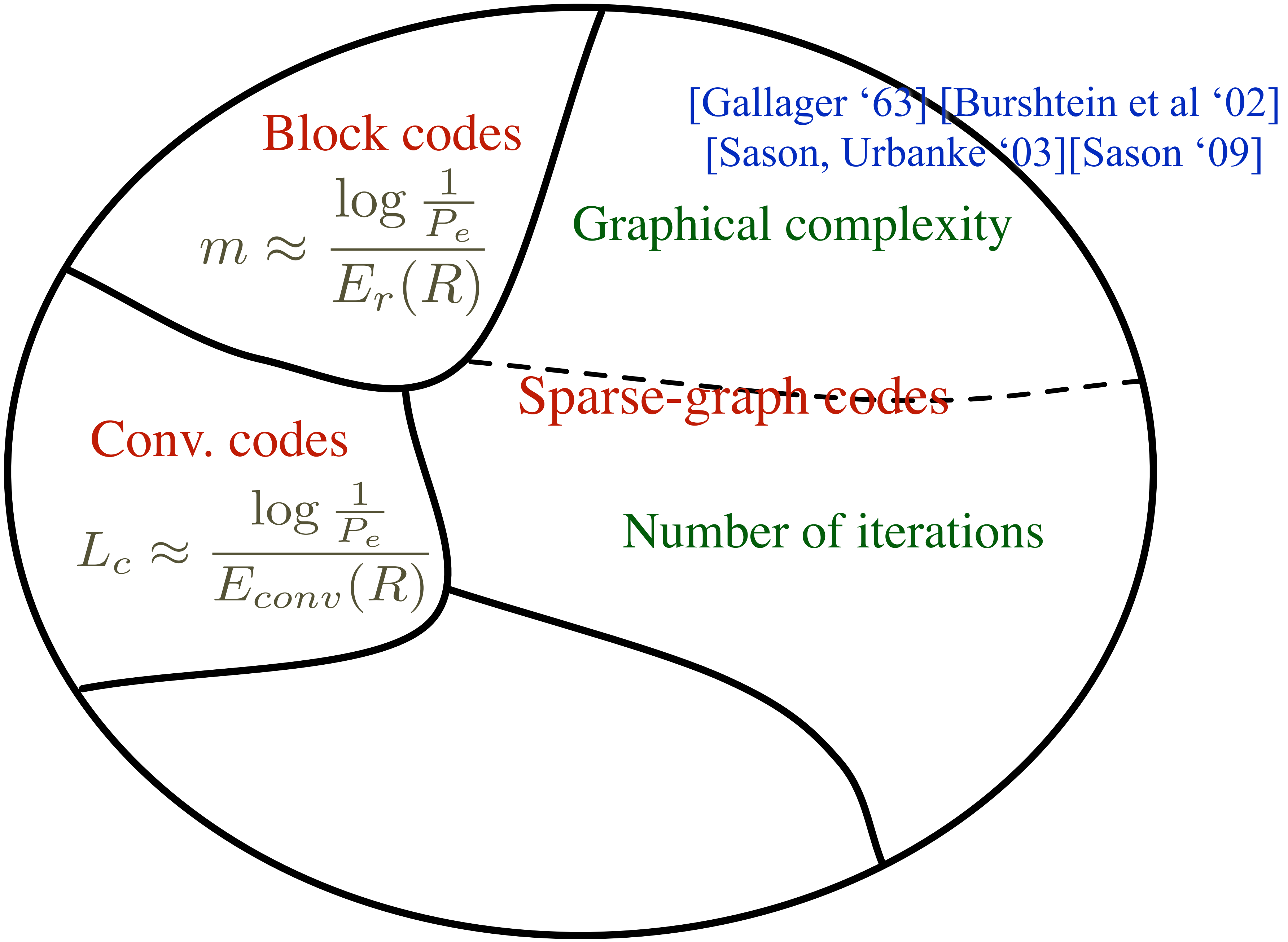
Lower bounds on complexity



Lower bounds on complexity



Lower bounds on complexity



Lower bounds on complexity