Discrete Coded Waveforms in Radar Systems

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DELHI

Content

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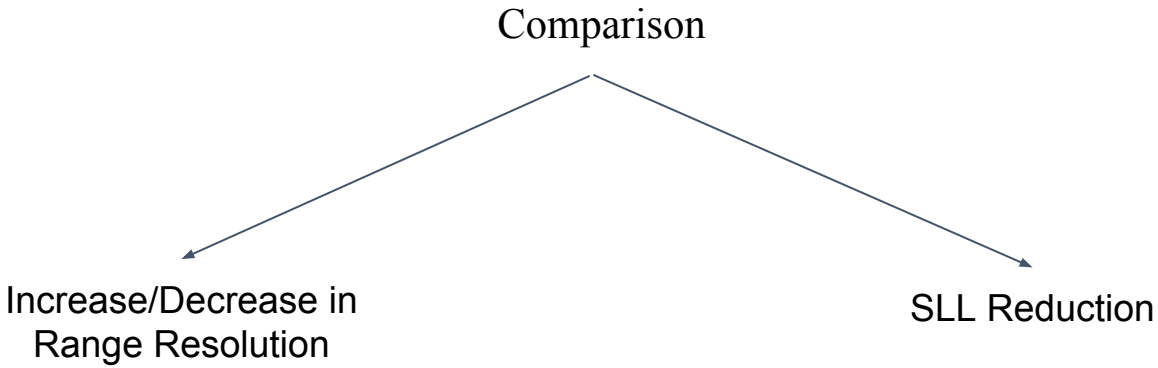
- Objectives
- Simulation Results
- Analysis and Insights
- Acknowledgement & References

Motivation

- Higher range-resolution and reduced Side-Lobe Level (SLL)
- Inherent anti-jamming capabilities
- Phase coding can be used to reduce radio frequency interference (RFI) between adjacent radars

Objectives


Comparison
Increase/Decrease in Range Resolution
SLL Reduction

Simulation Results

- Pulse Train
  - Uniform
  - PRF-Staggered

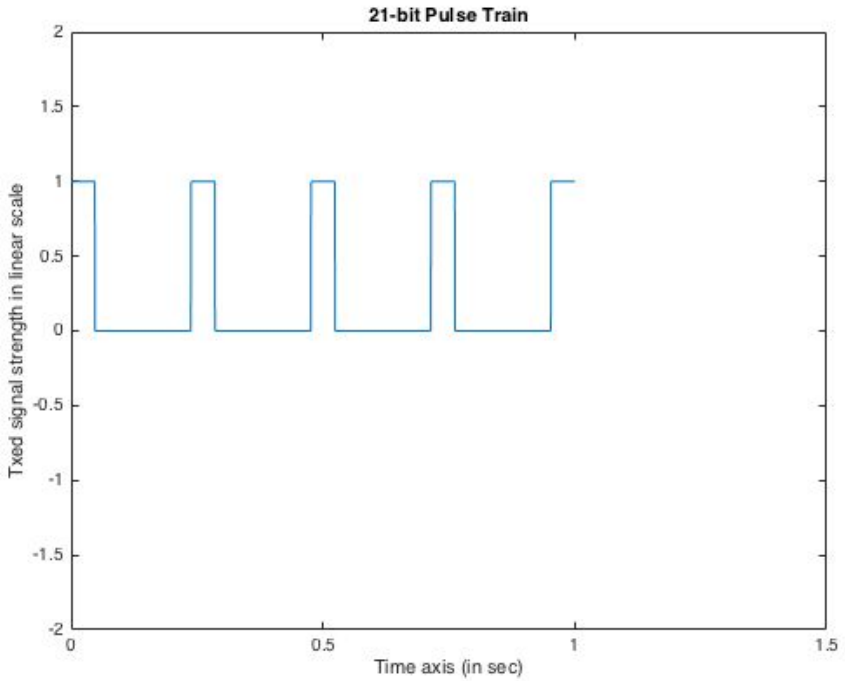
- Barker Codes (Binary-Phase)
  - B_5 , B_4 , B_{54}
  - B_{11} , B_{13} , B_{11_13}

- Polyphase Codes
  - 4, 8 and 12-phase codes

- Pseudo-Random Number (MLS) Codes
  - 15, 31 bit

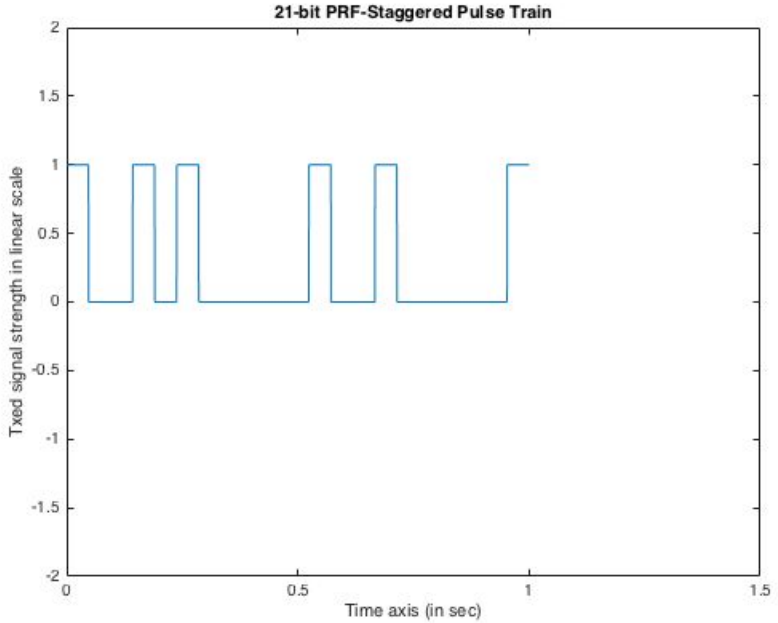
Pulse Train (Uniform)

[1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1]

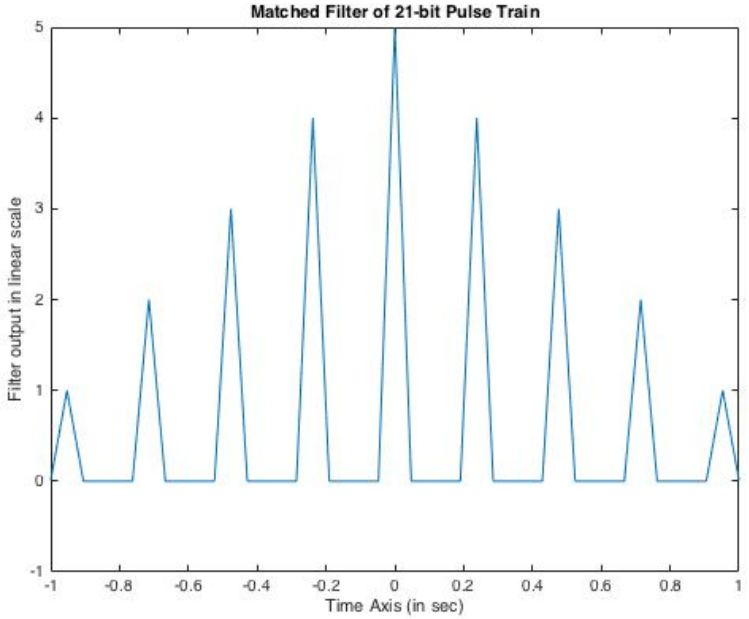


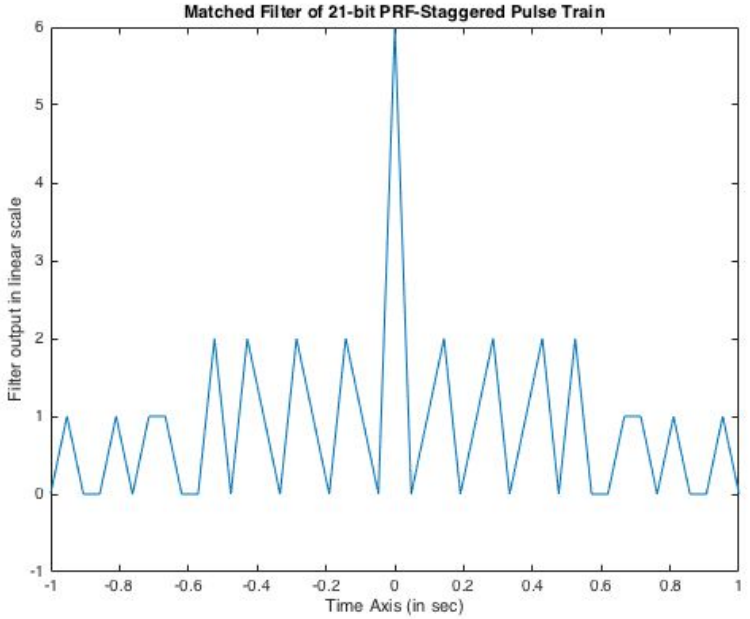
Pulse Train (PRF-Staggered)

- Non-uniform spacing between the pulses to reduce the grating lobes

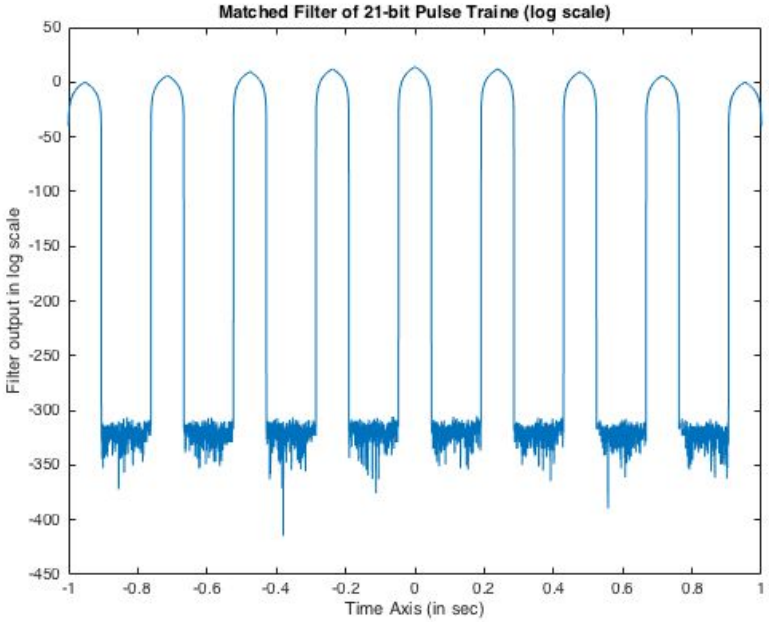


Pulse Train: Uniform v/s Staggered

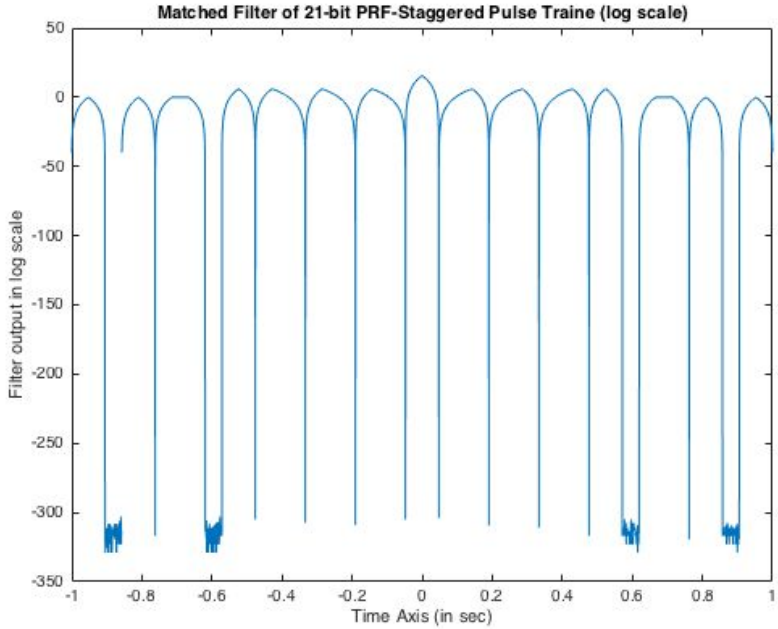




Pulse Train: Uniform v/s Staggered

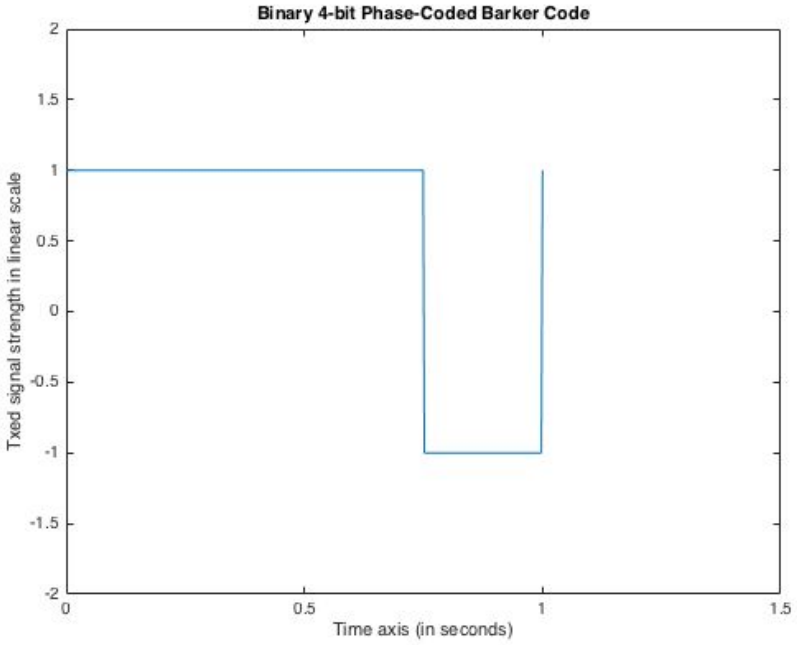


SLL: -2.03 dB

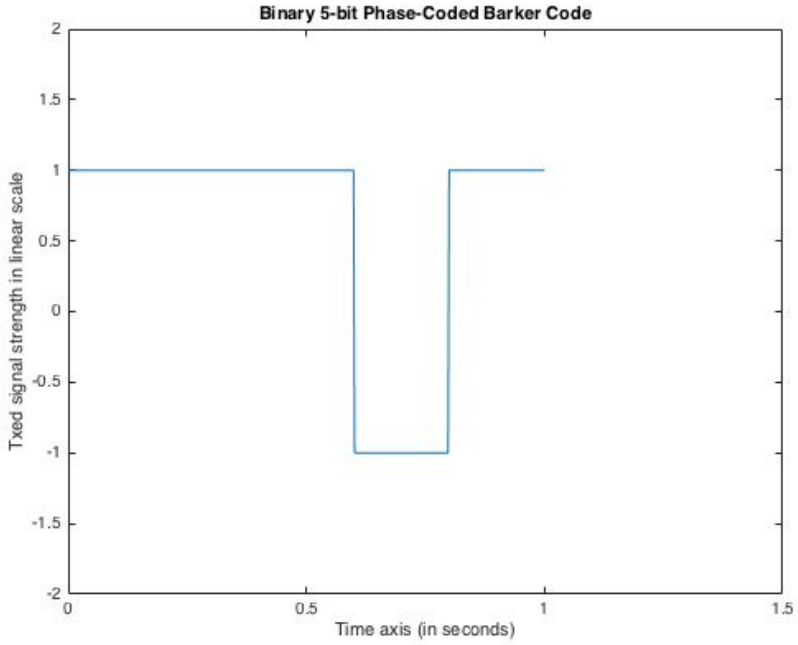


SLL: -9.635 dB

Barker Codes (aka Binary Phase Codes)

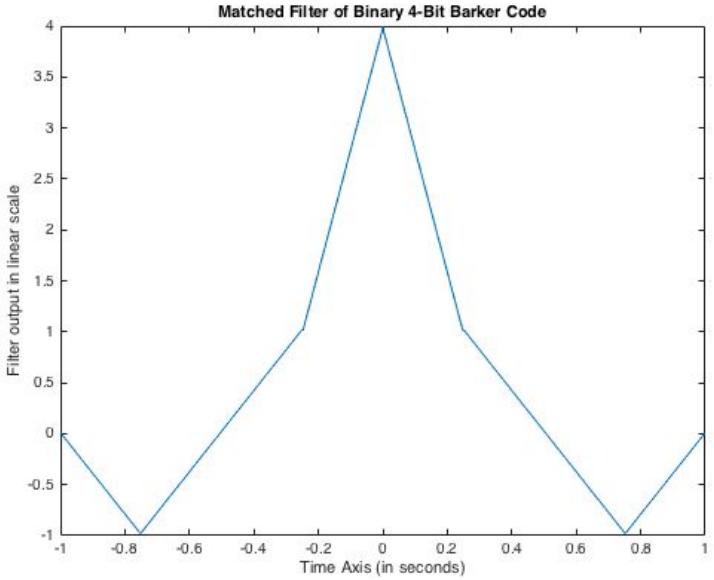


4-bit

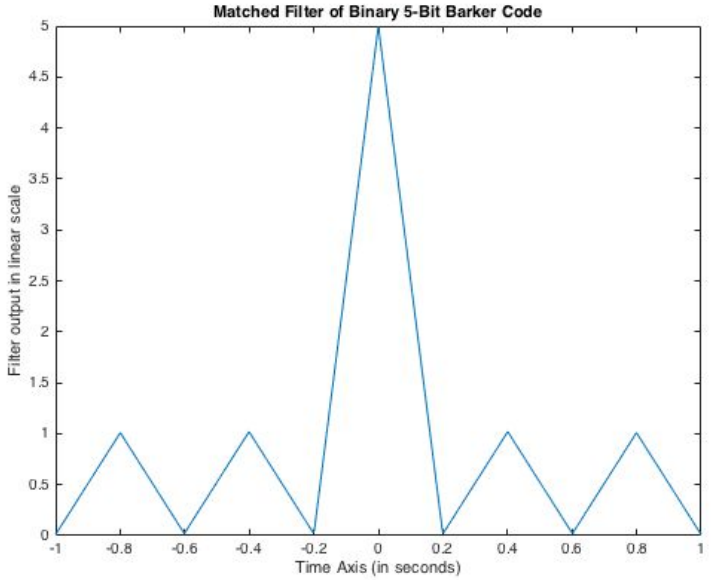


5-bit

Barker Codes: 4 bit v/s 5 bit

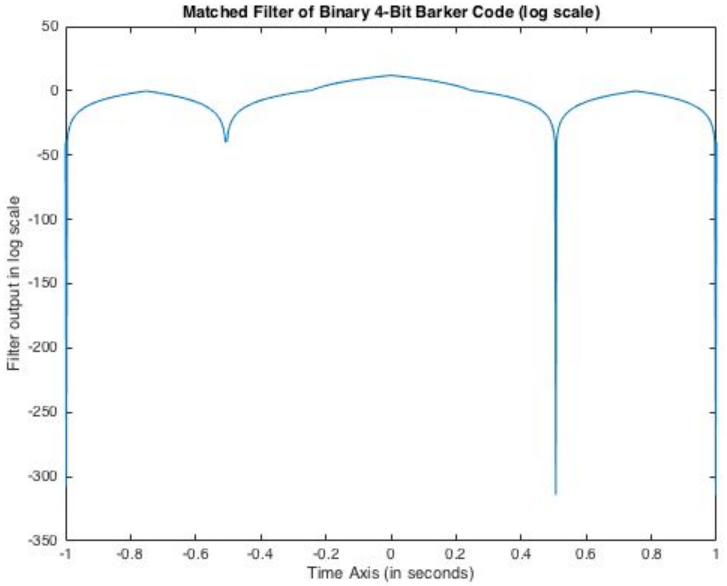


4-bit

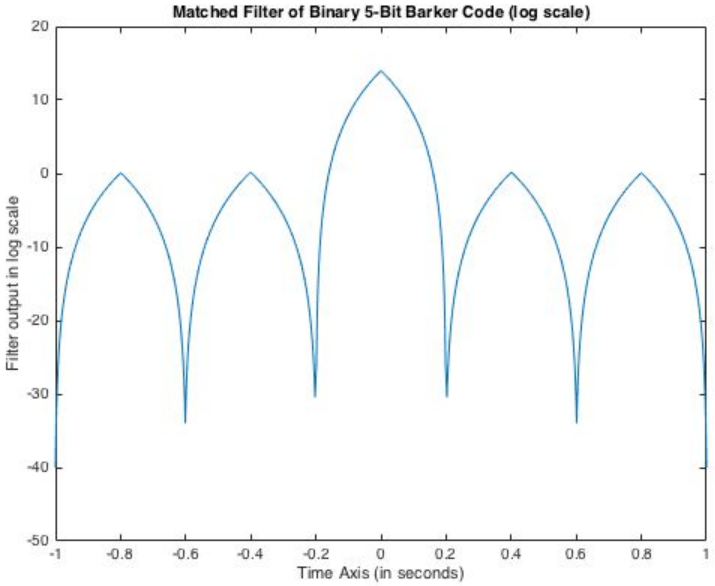


5-bit

Barker Codes: 4 bit v/s 5 bit

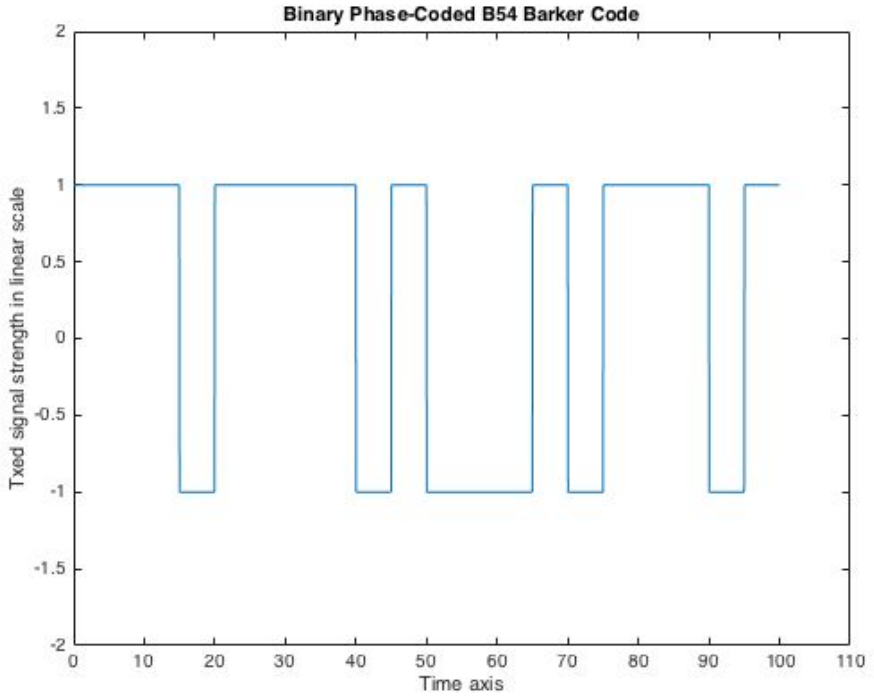


4-bit



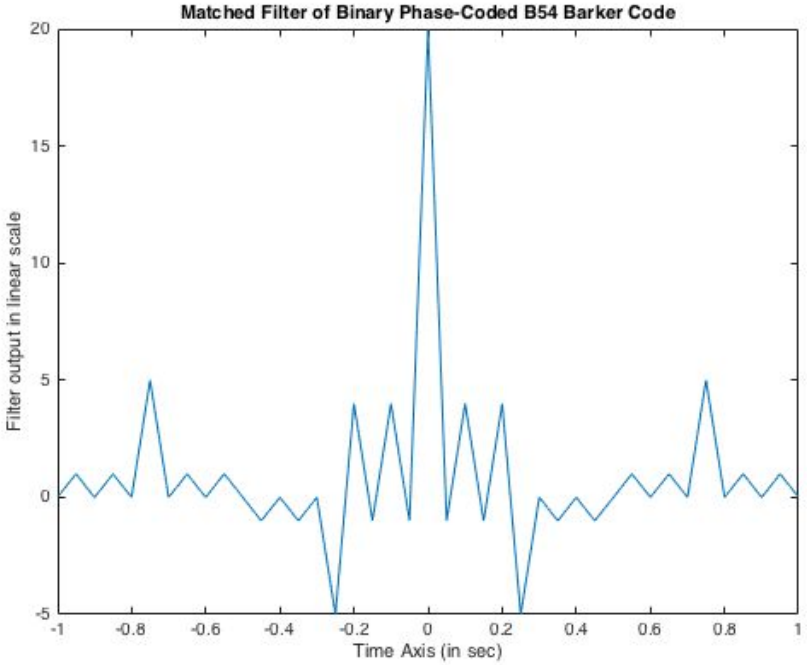
5-bit

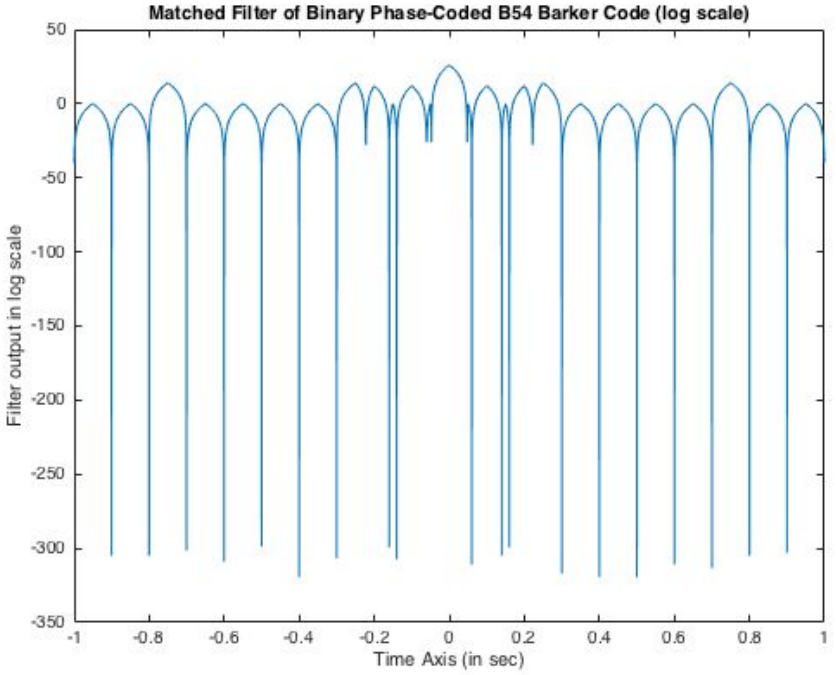
Binary Phase Codes - B_{MN} (B_{54})



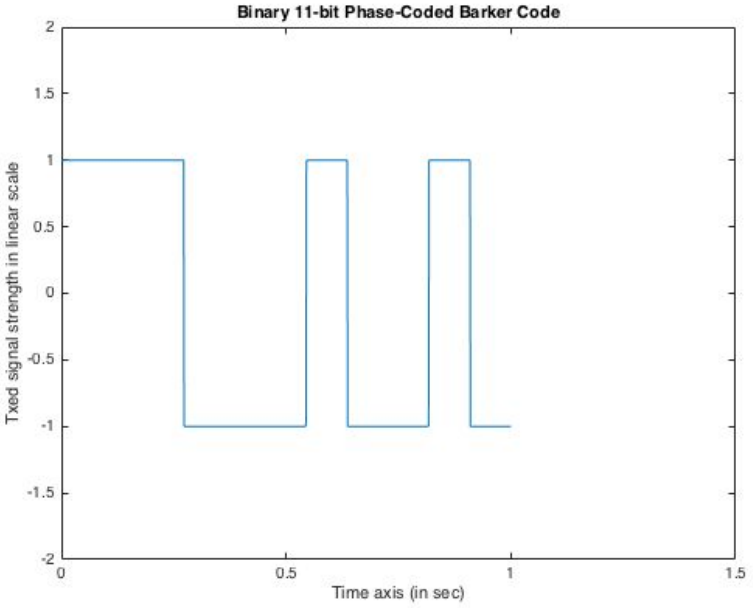
Pulse compression ratio: M*N

B_{54}

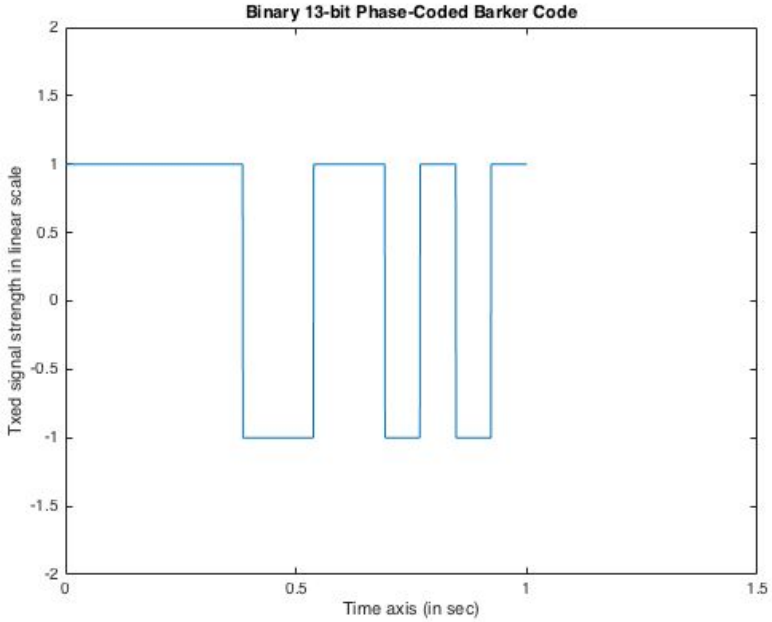

Matched Filter of Binary Phase-Coded B54 Barker Code
Filter output in linear scale
Time Axis (in sec)
20
15
10
5
0
-5
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1


Matched Filter of Binary Phase-Coded B54 Barker Code (log scale)
Filter output in log scale
Time Axis (in sec)
50
0
-50
-100
-150
-200
-250
-300
-350
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

Barker Codes: 11 bit v/s 13 bit

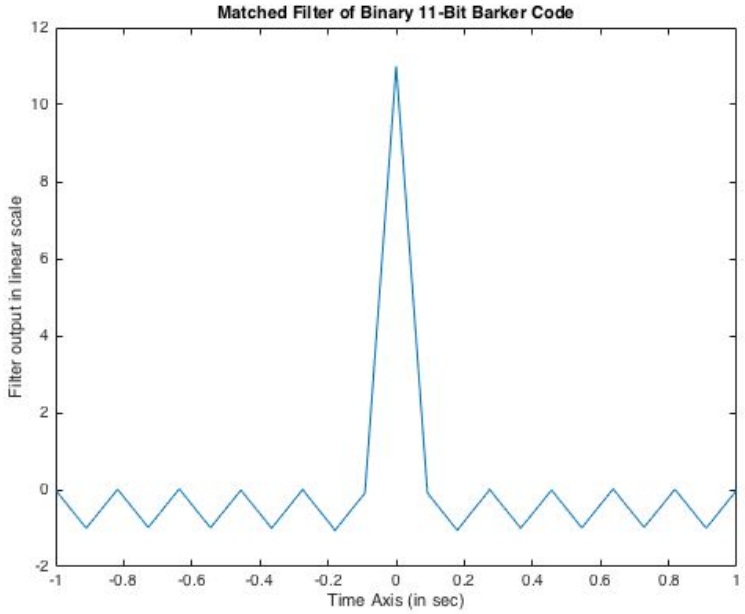


11-bit

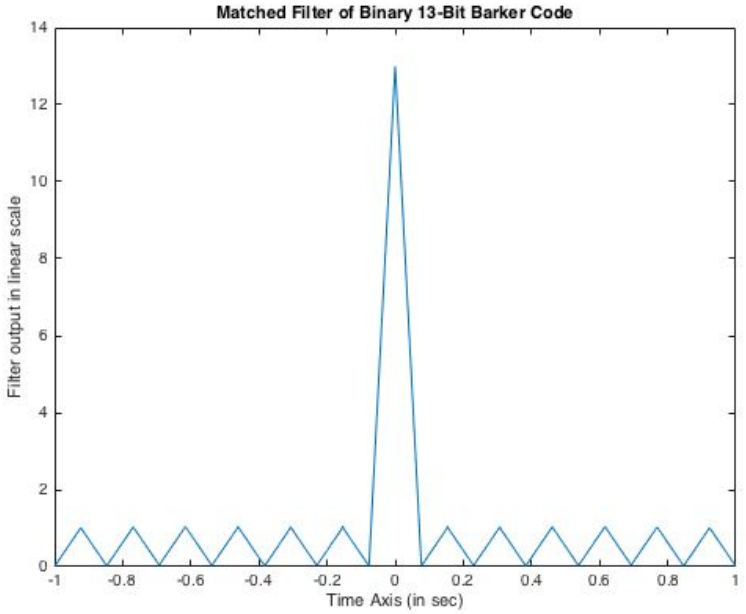


13-bit

Barker Codes: 11 bit v/s 13 bit

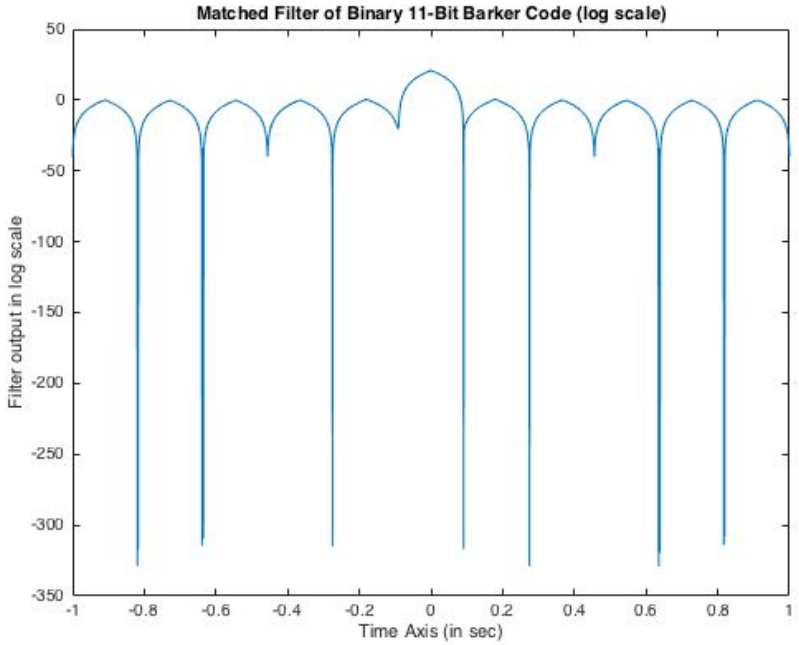


11-bit

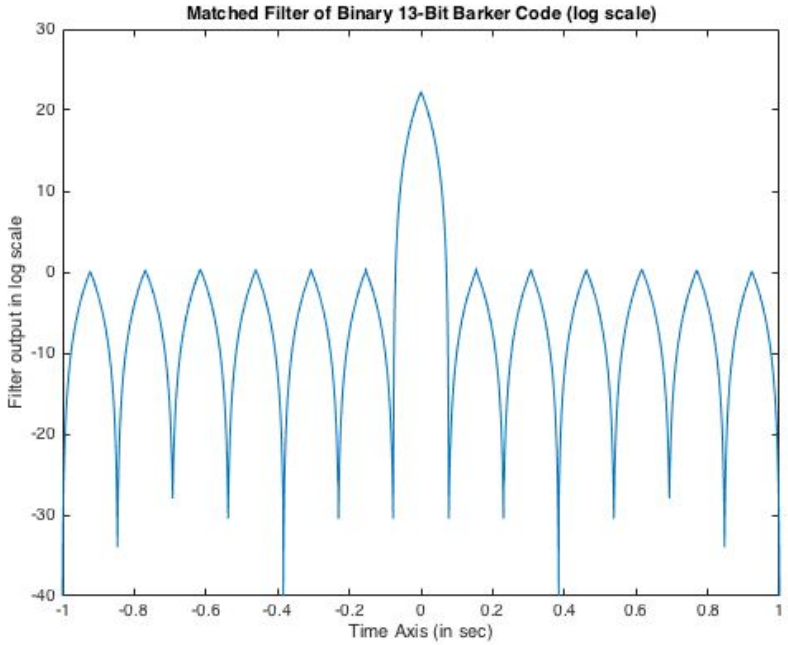


13-bit

Barker Codes: 11 bit v/s 13 bit

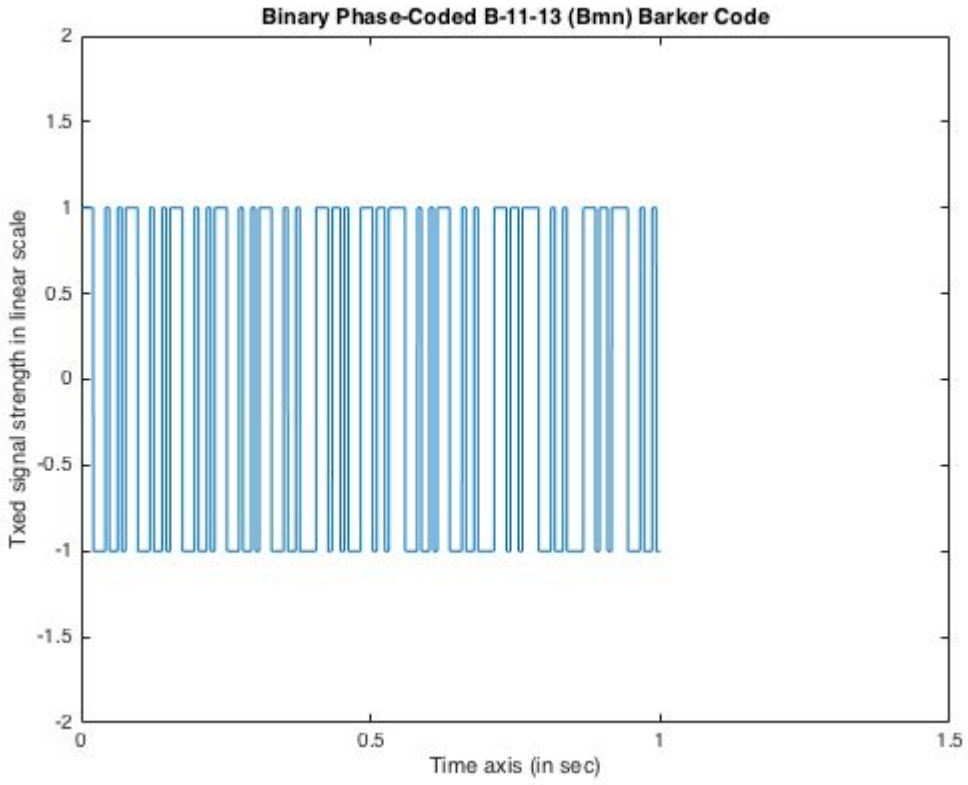


11-bit

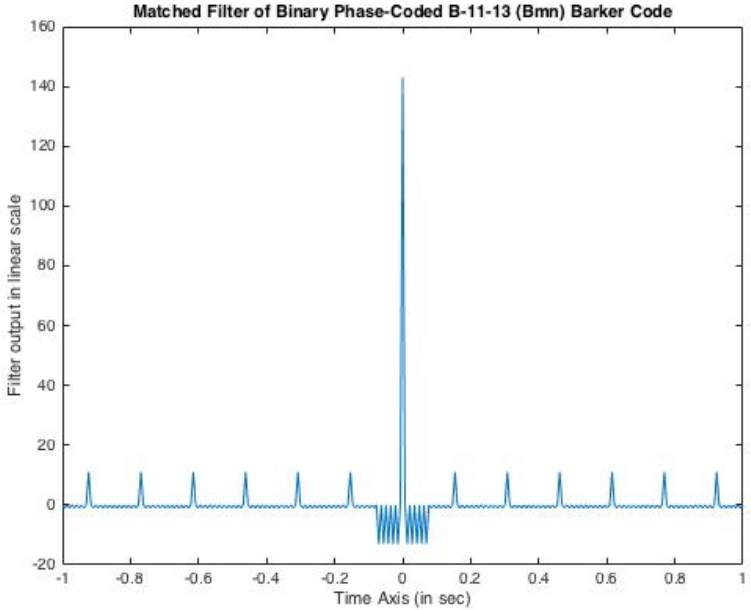


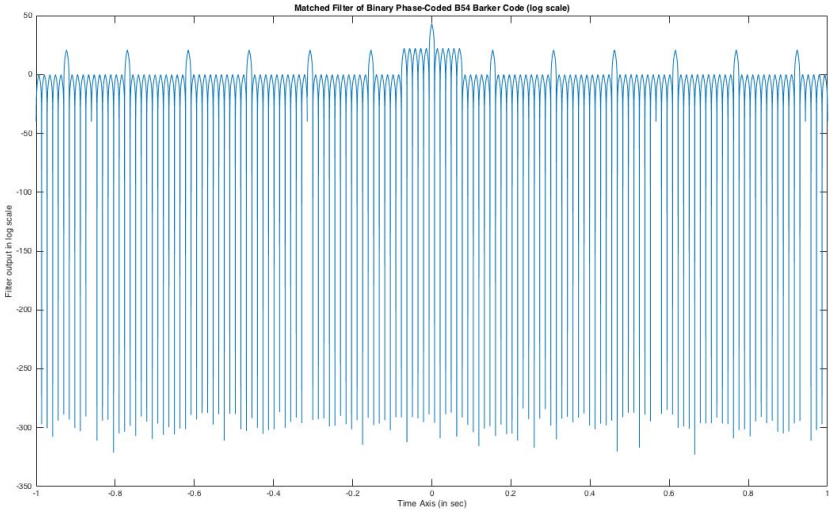
13-bit

B_{MN} (B_{11_13})


Binary Phase-Coded B-11-13 (Bmn) Barker Code
Txed signal strength in linear scale
Time axis (in sec)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.5
1
1.5

B_{MN} (B_{11_13})

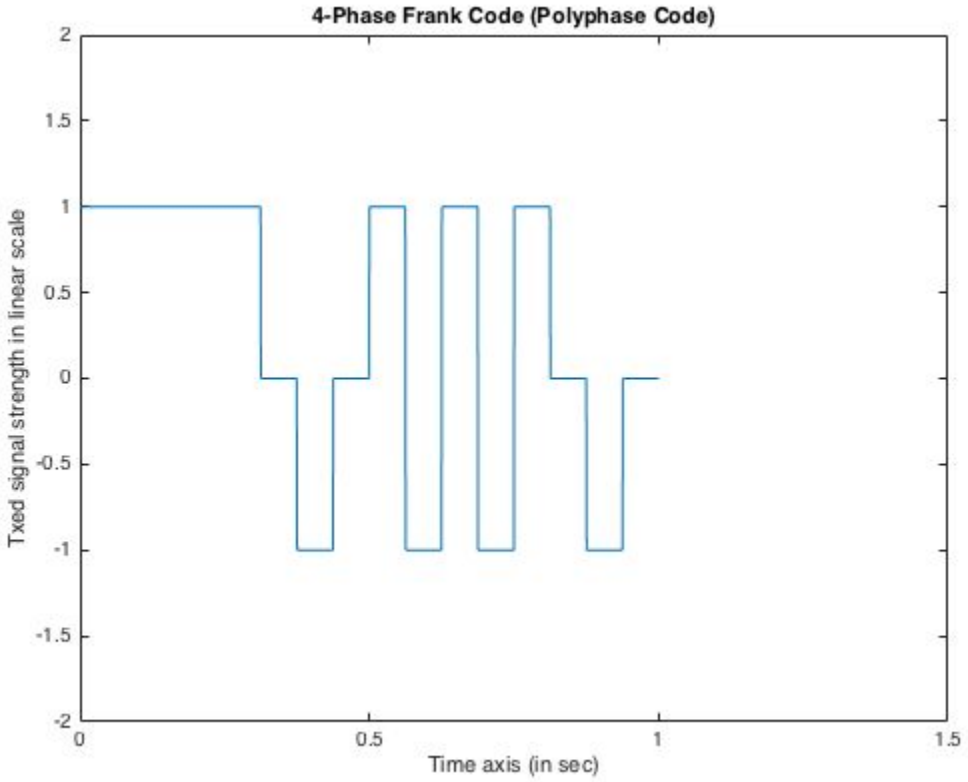

Matched Filter of Binary Phase-Coded B-11-13 (Bmn) Barker Code
Filter output in linear scale
Time Axis (in sec)
160
140
120
100
80
60
40
20
0
-20
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1


Matched Filter of Binary Phase-Coded B54 Barker Code (log scale)
Filter output in log scale
Time Axis (in sec)
50
0
-50
-100
-150
-200
-250
-300
-350
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

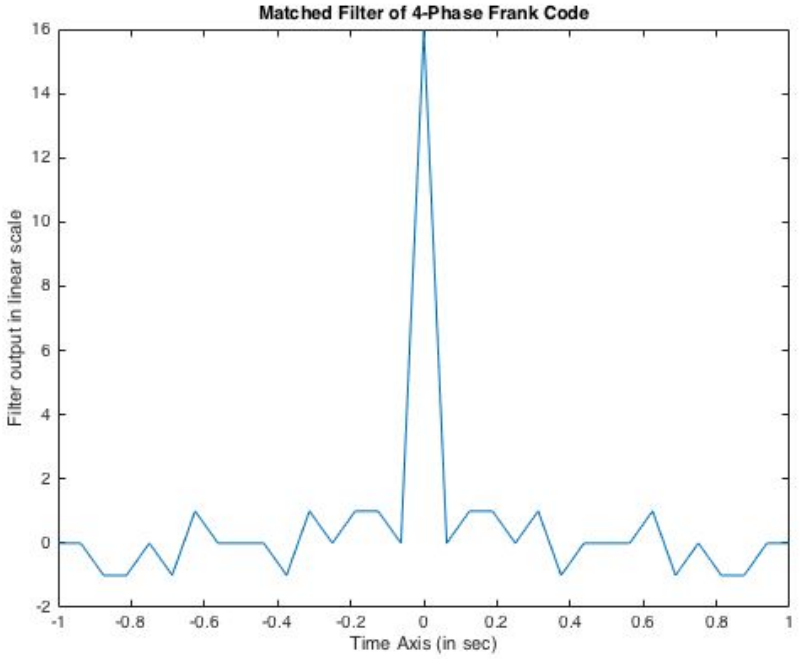
Polyphase Codes - Frank Code

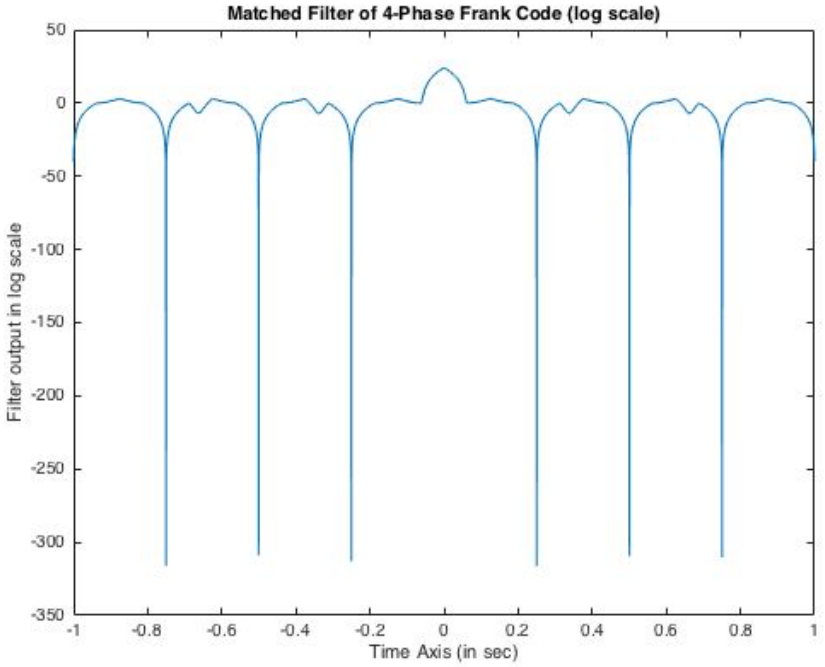
- The Frank Code is a polyphase code modulation format used for pulse compression. It use harmonically related phases which are based on certain fundamental phase increments.

Polyphase Codes: 4-Phase

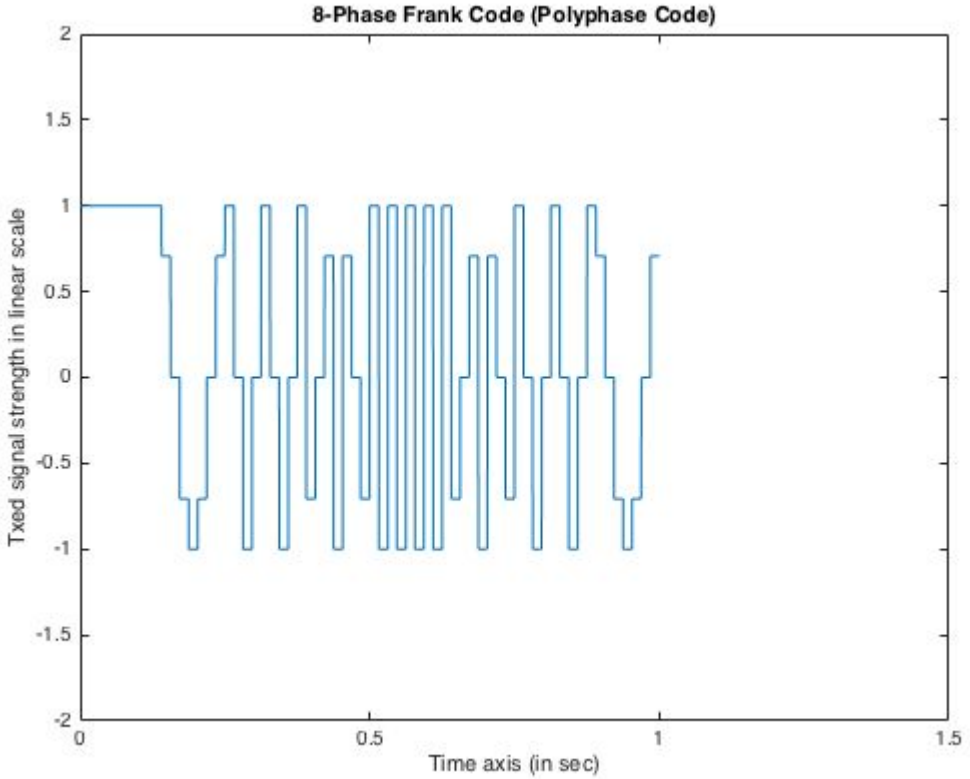


Polyphase Codes: 4-Phase

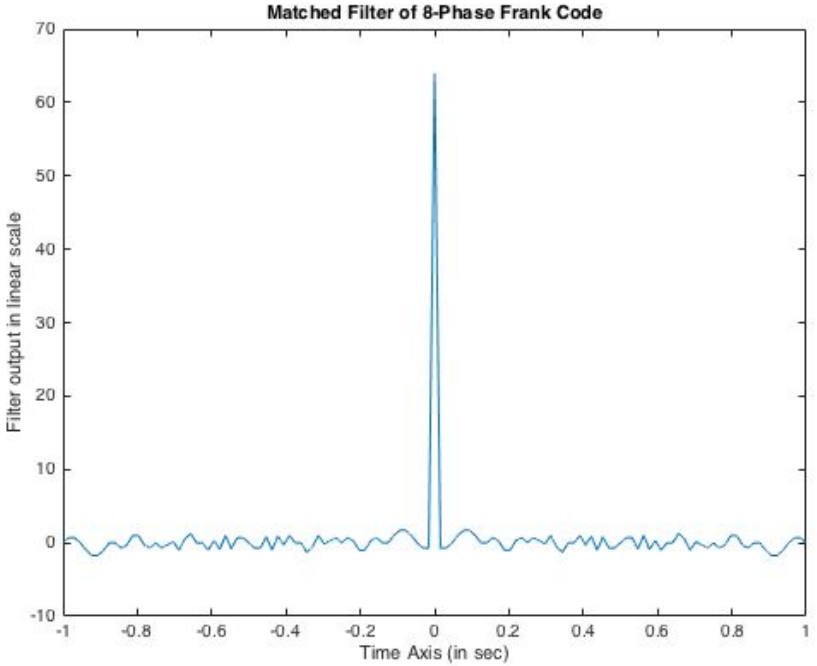


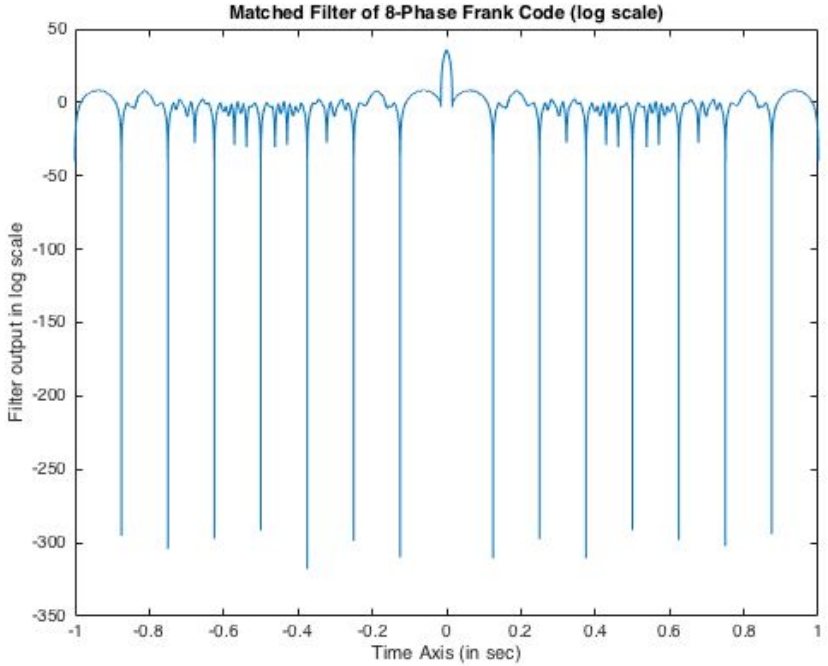


Polyphase Codes: 8-Phase

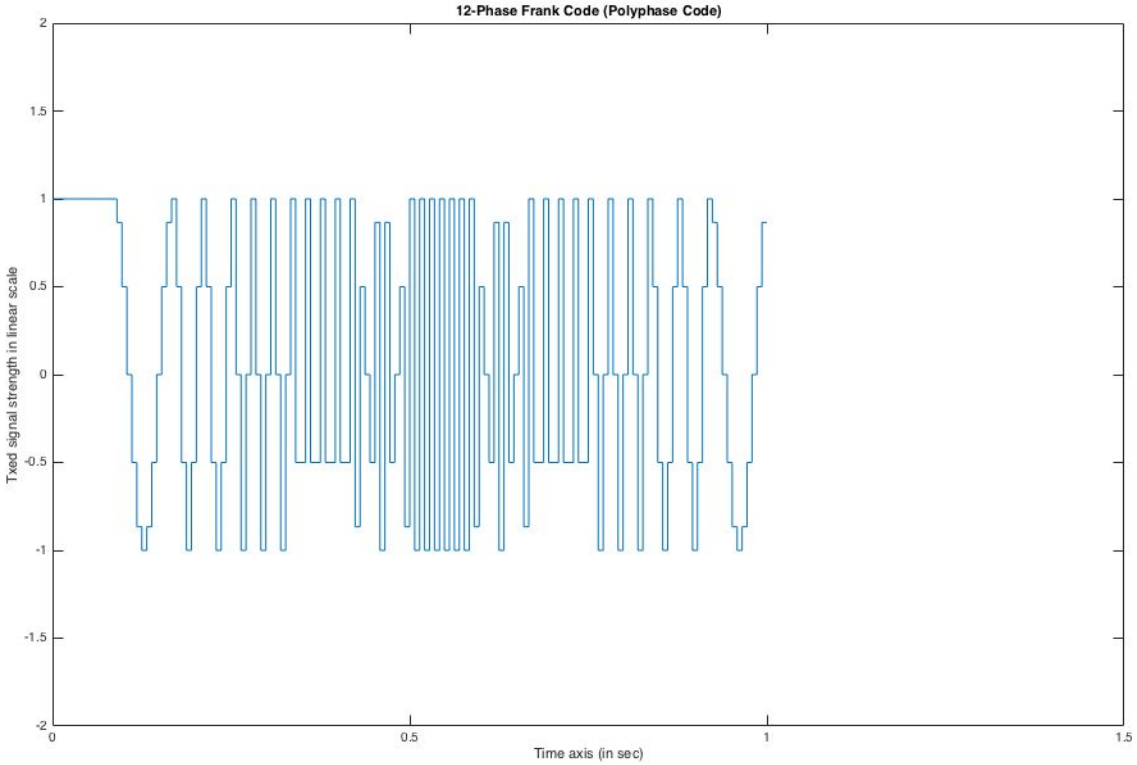


Polyphase Codes: 8-Phase

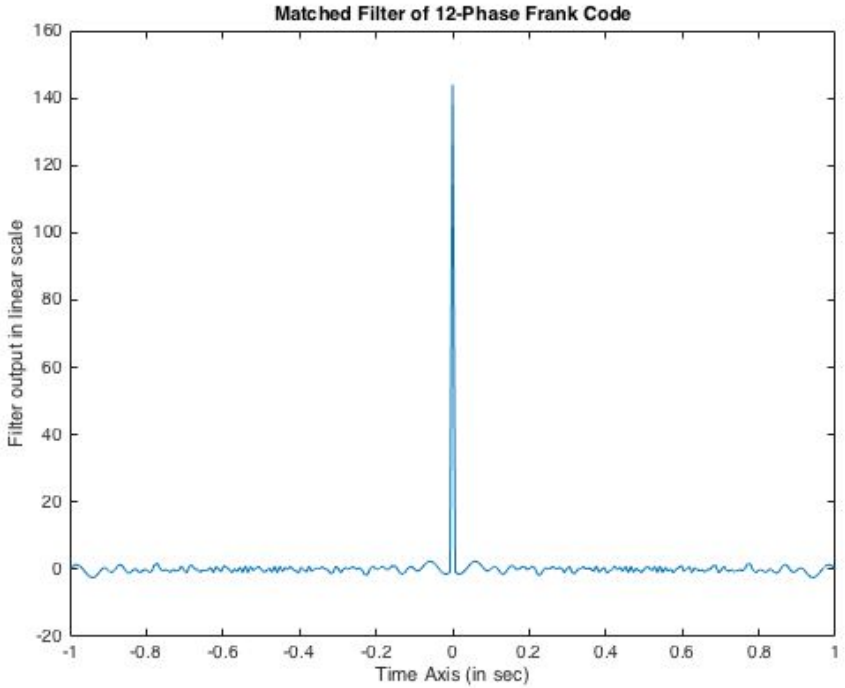


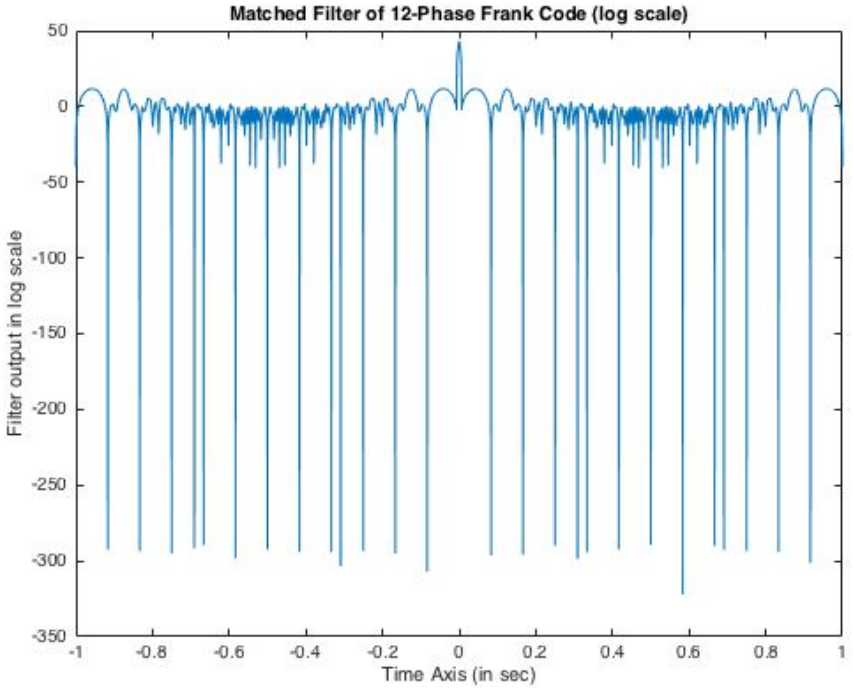


Polyphase Codes: 12-Phase



Polyphase Codes: 12-Phase





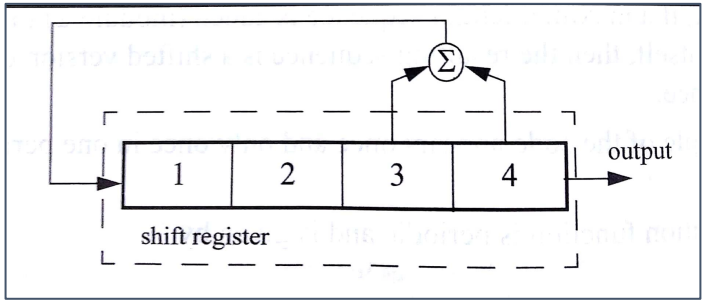
Pseudo-Random Number (PRN Codes)

- Pseudo-random because the statistics associated with their occurrence are similar to those associated with coin-toss sequences

- Also called as *Maximum Length Sequences (MLS)* codes

Generating PRN Codes: Linear Shift Register

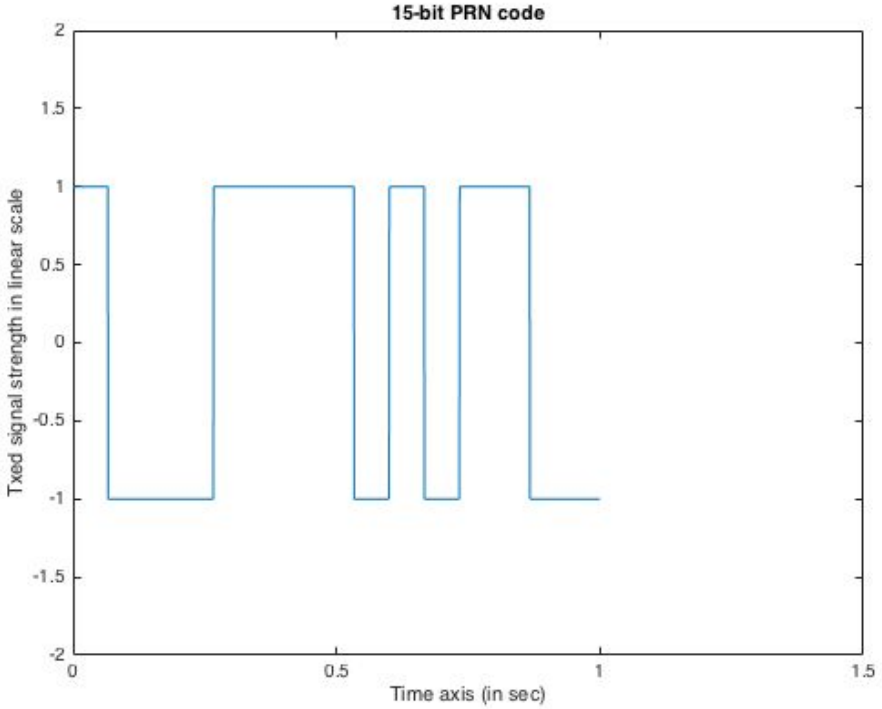
- $L = 2^n - 1$
  - L = length of the sequence, n = number of stages in the shift register generator



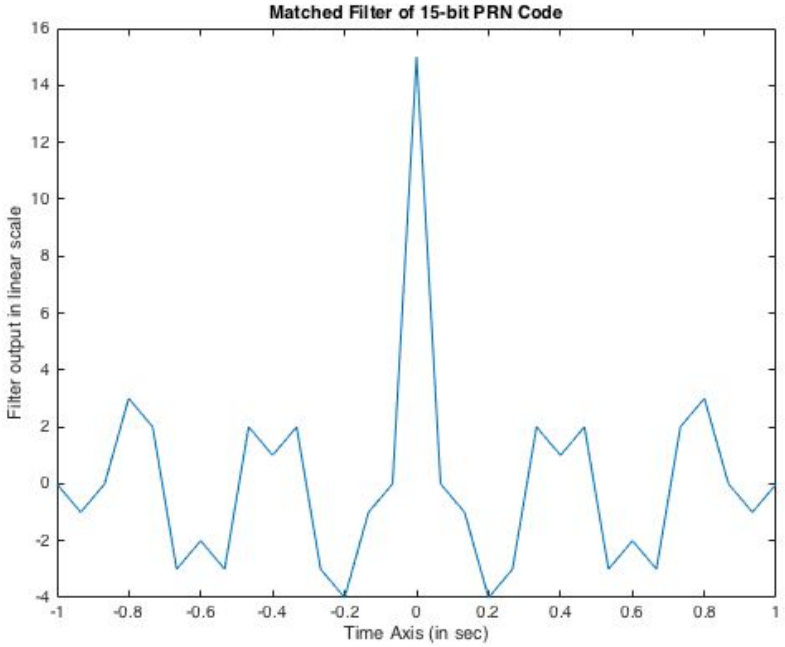
Characteristic Polynomial: $x^4 + x^3 + 1$

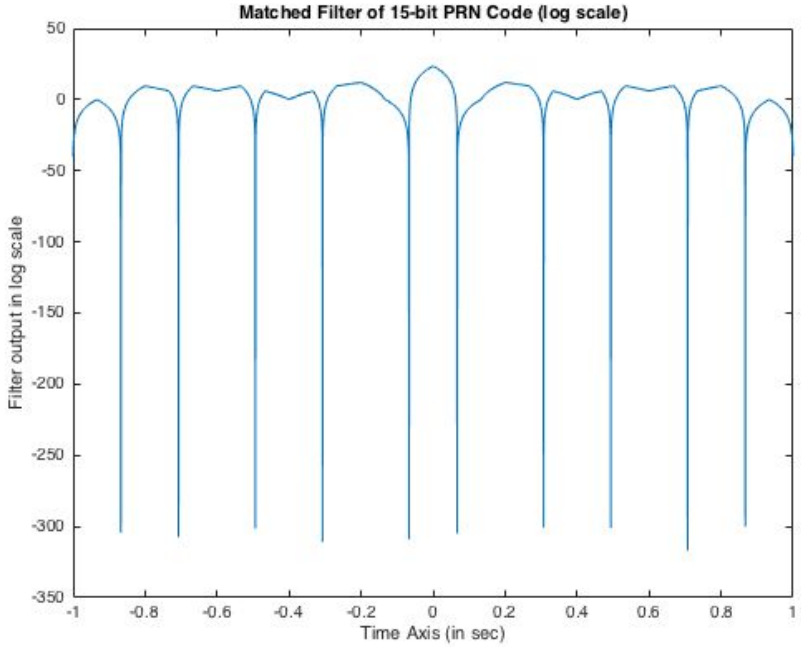
15-Bit PRN Code

$$L = \{1\ -1\ -1\ -1\ 1\ 1\ 1\ 1\ -1\ 1\ -1\ 1\ 1\ -1\ -1\ \}$$



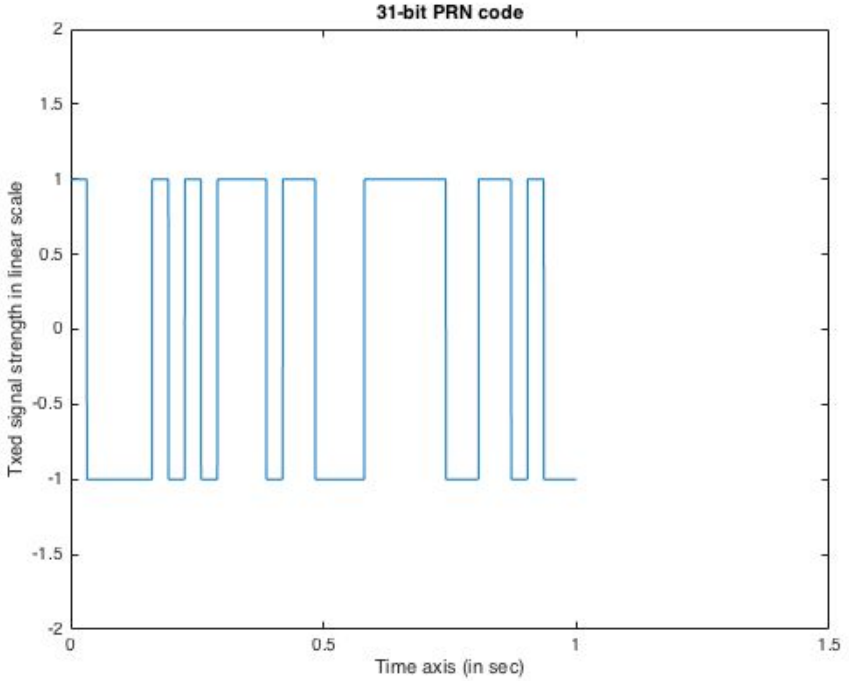
15-Bit PRN Code



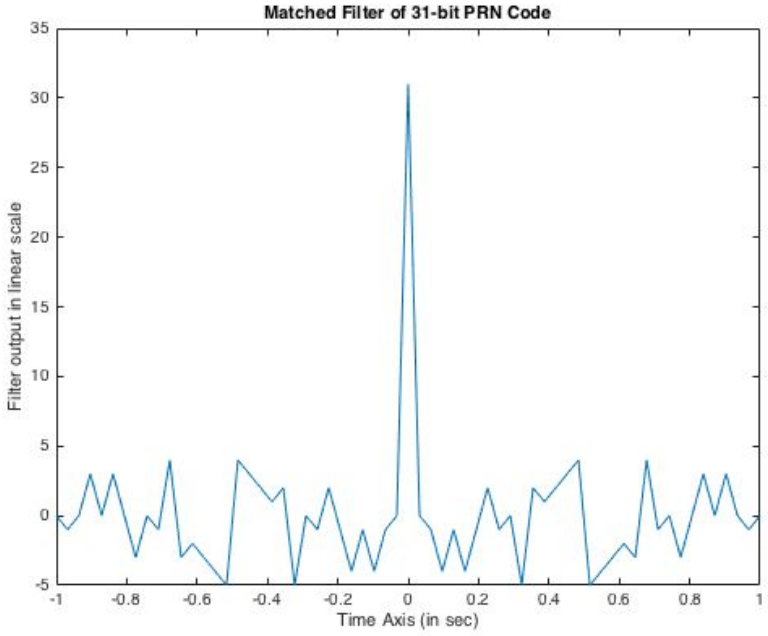


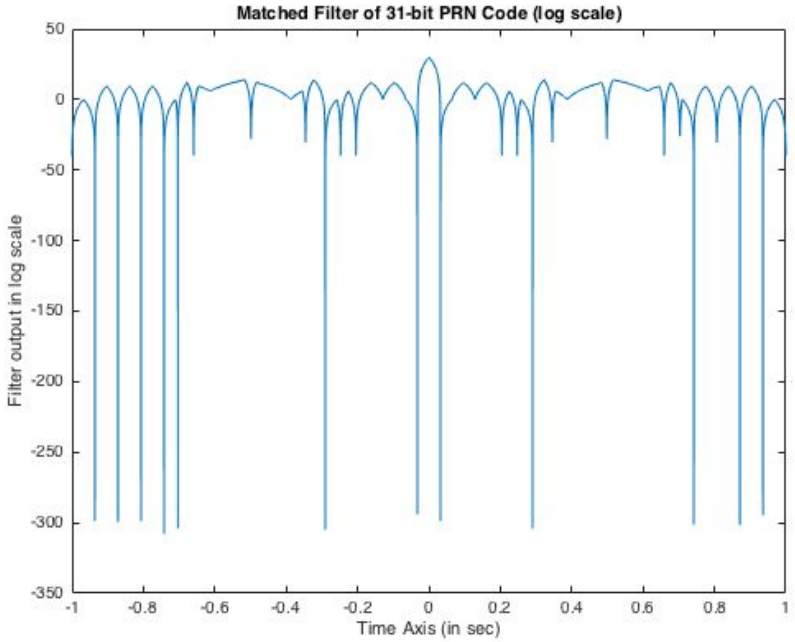
31-Bit PRN Code

L = {1 -1 -1 -1 -1 1 -1 1 -1 1 1 1 -1 1 1 -1 -1 -1 1 1 1 1 1 -1 -1 1 1 -1 1 -1 -1}



31-Bit PRN Code

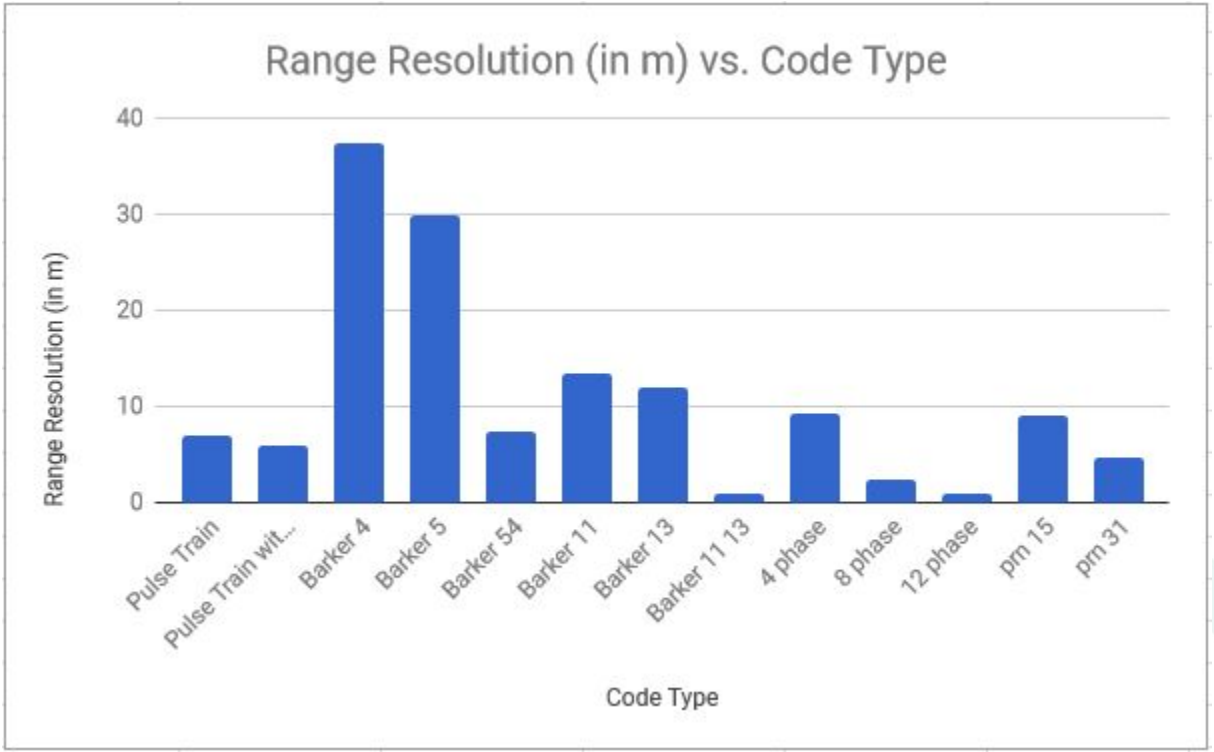




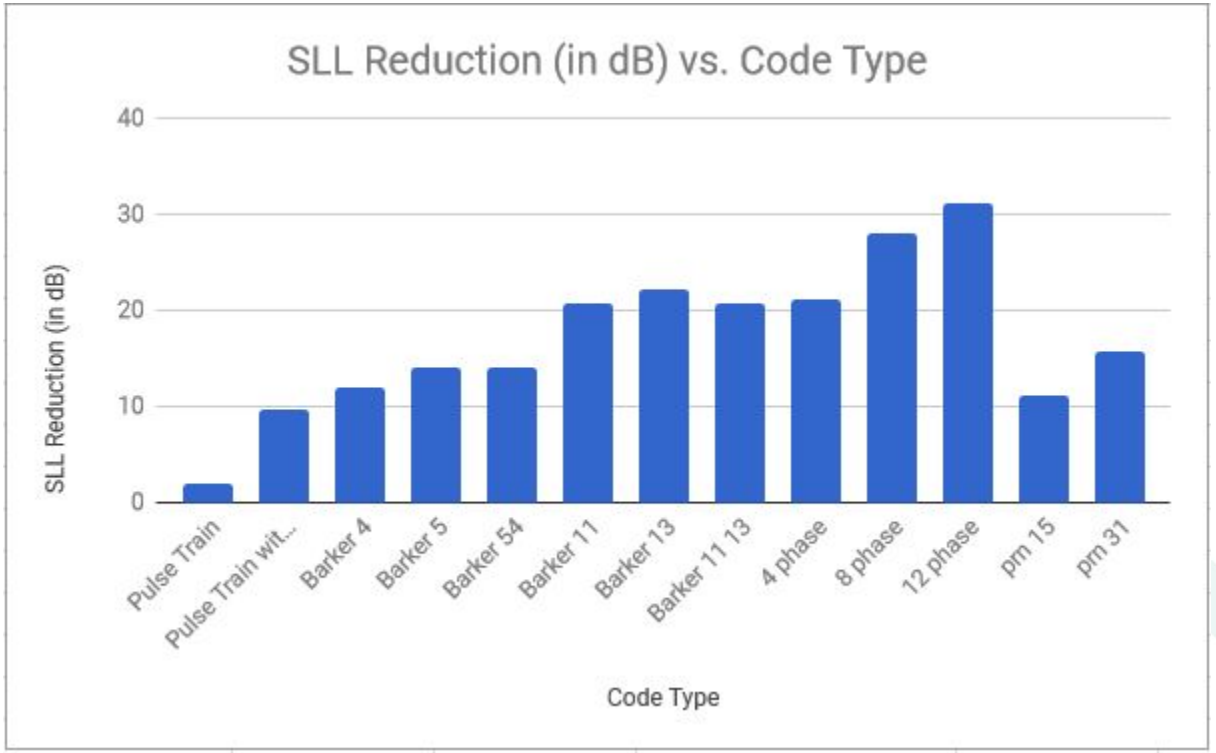
Results

Code Type	Range resolution (in m)	SLL Reduction (in dB)
Pulse Train	7.05	2.03
Pulse Train with Staggering	6	9.635
Barker 4	37.5	12
Barker 5	30	14
Barker 54	7.5	14
Barker 11	13.5	20.8
Barker 13	12	22.3
Barker 11 13	1.05	20.83
4 phase	9.3	21.1
8 phase	2.4	28
12 phase	1.05	31.3
prn 15	9	11.25
prn 31	4.8	15.85

Analysis and Insights



Analysis and Insights



Acknowledgement & References

Acknowledgement

- Instructor **Dr. Shobha Sundar Ram** for her continuous involvement in the project, right from conceptualisation to execution

References

- Radar Signal Analysis and Processing Using MATLAB by Bassem R. Mahafza

Thank you!

Questions?