FHT Based CQI Decoder

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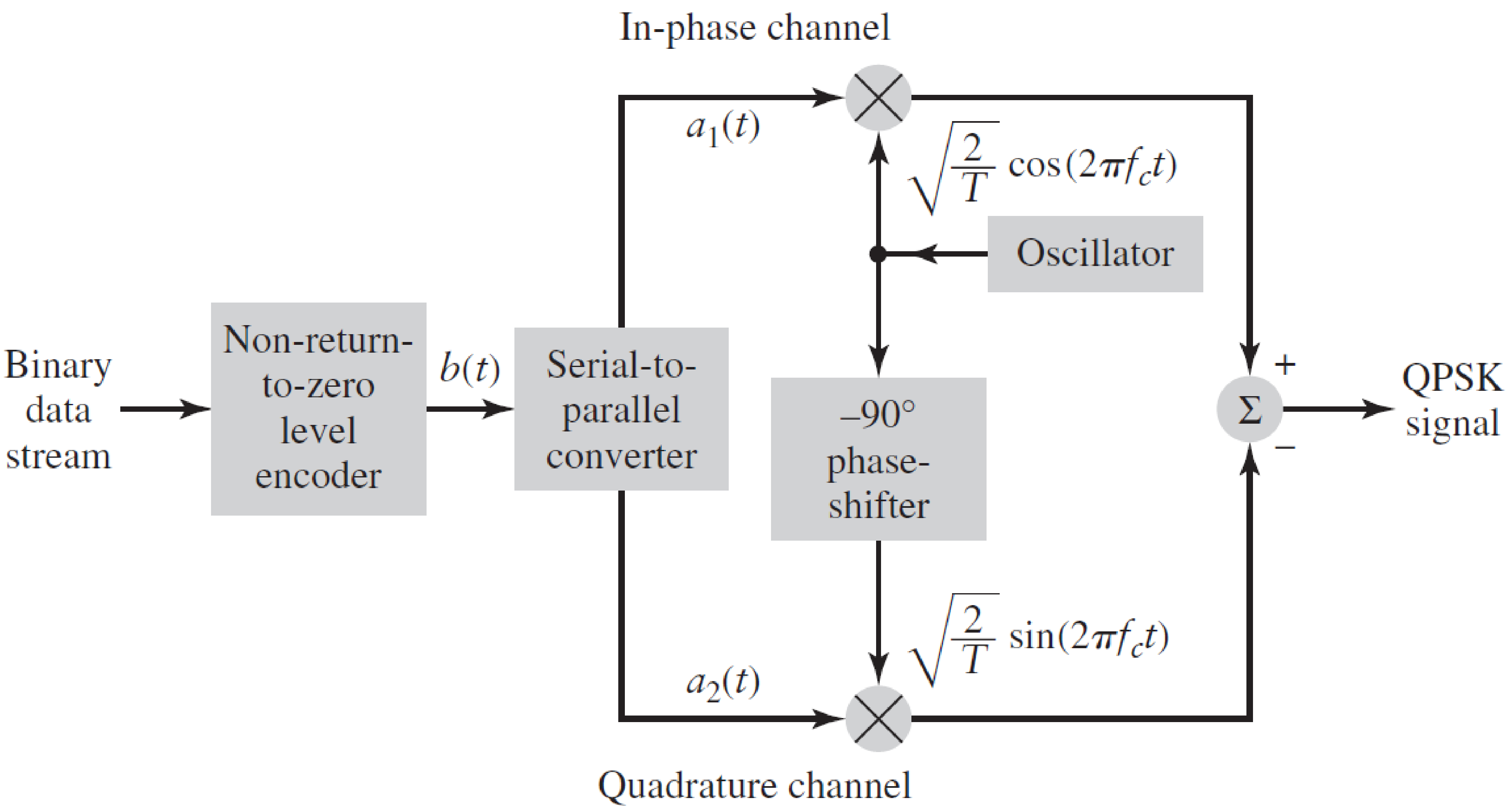
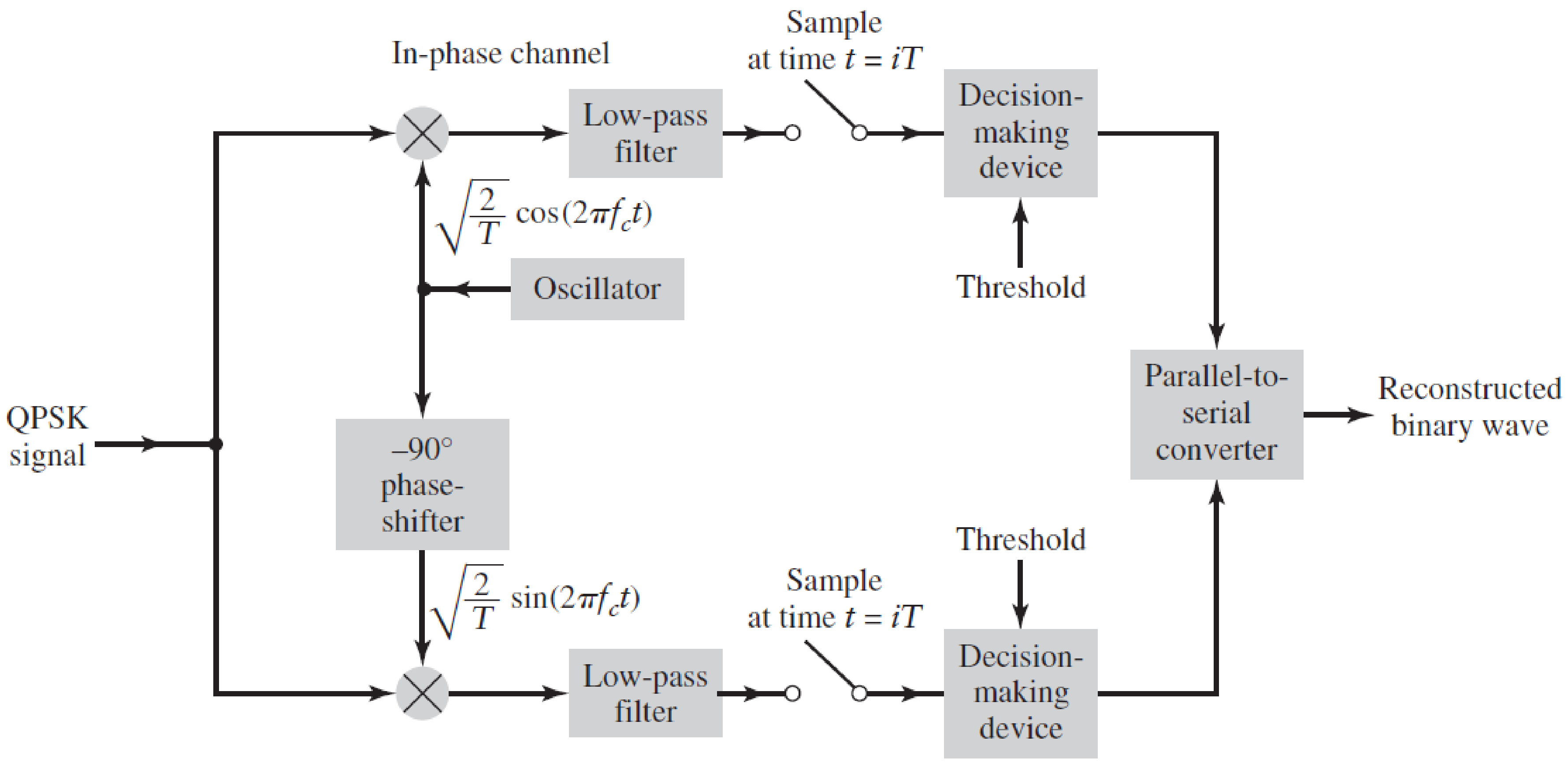
QPSK

TABLE 7.1 ***Relationship Between Index i And Identity of Corresponding Dibit, and Other Related Matters***

		Amplitudes of constituent binary waves		
Index i	*Phase of QPSK signal (radians)*	*Binary wave 1* $a_1(t)$	*Binary wave 2* $a_2(t)$	*Input dibit* $0 \le t \le T$
1	$\pi/4$	$+\sqrt{E/2}$	$-\sqrt{E/2}$	10
2	$3\pi/4$	$-\sqrt{E/2}$	$-\sqrt{E/2}$	00
3	$5\pi/4$	$-\sqrt{E/2}$	$+\sqrt{E/2}$	01
4	$7\pi/4$	$+\sqrt{E/2}$	$+\sqrt{E/2}$	11


In-phase channel
$a_1(t)$
$\sqrt{\frac{2}{T}}\cos(2\pi f_c t)$
Oscillator
Binary data stream
Non-return-to-zero level encoder
$b(t)$
Serial-to-parallel converter
–90° phase-shifter
+
Σ
–
QPSK signal
$\sqrt{\frac{2}{T}}\sin(2\pi f_c t)$
$a_2(t)$
Quadrature channel

(a)


In-phase channel
Sample
at time $t = iT$
Low-pass
filter
Decision-
making
device
$\sqrt{\frac{2}{T}}\cos(2\pi f_c t)$
Oscillator
Threshold
QPSK
signal
–90°
phase-
shifter
Parallel-to-
serial
converter
Reconstructed
binary wave
Threshold
$\sqrt{\frac{2}{T}}\sin(2\pi f_c t)$
Sample
at time $t = iT$
Low-pass
filter
Decision-
making
device

(b)

Additive White Gaussian Noise

$$y(t) = x(t) + n(t)$$

- $x(t)$: transmitted signal
- $n(t)$: white gaussian noise
- $y(t)$: received signal

Gaussian Process

variance (standart deviation) -> average power

mean -> dc power

- If a Gaussian process is applied to a stable linear filter, then the random process $Y(t)$ produced at the output of the filter is also Gaussian.

$$f(x,\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/2\sigma^2}$$

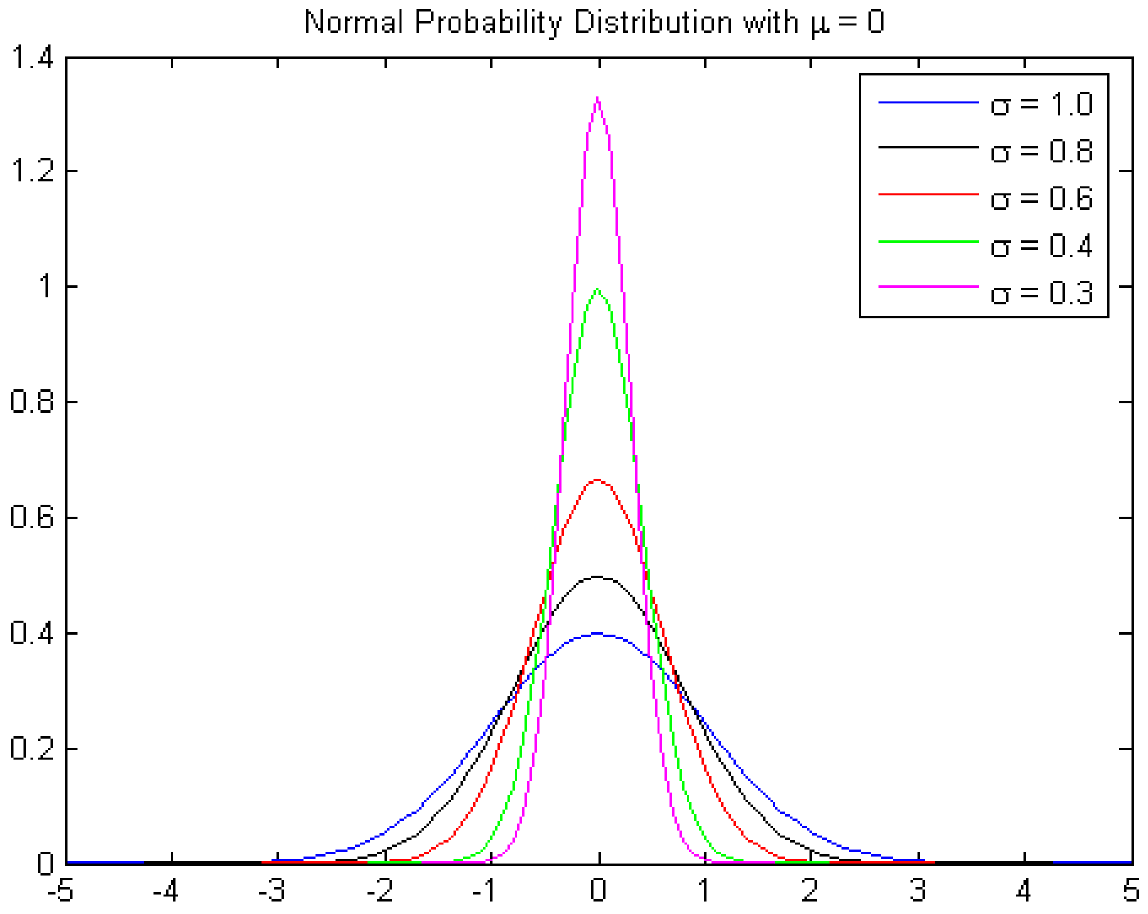
$f(x,\mu,\sigma)$ → normal probability density distribution

μ → mean of x_i

σ → standard deviation of x_i

π → 3.14159

e → exponential constant = 2.71828



White Noise

$$S_W(f) = \frac{N_0}{2}$$

power spectral density (PSD) of *white noise*

$$R_W(\tau) = \frac{N_0}{2}\delta(\tau)$$

inverse Fourier transform of PSD gives the *autocorrelation function* of *white noise*

since the *autocorrelation function* is a weighted *delta function*, $R_W(\tau) = 0$ at any $\tau \neq 0$, any two different *white noise* samples are uncorrelated, no matter how close they are taken in time mean of *white noise* is zero (dc power is zero)

variance of *white noise* is infinite (average power is infinite)

this is not physically realizable, but useful after a filtering process because it will still be a Gaussian

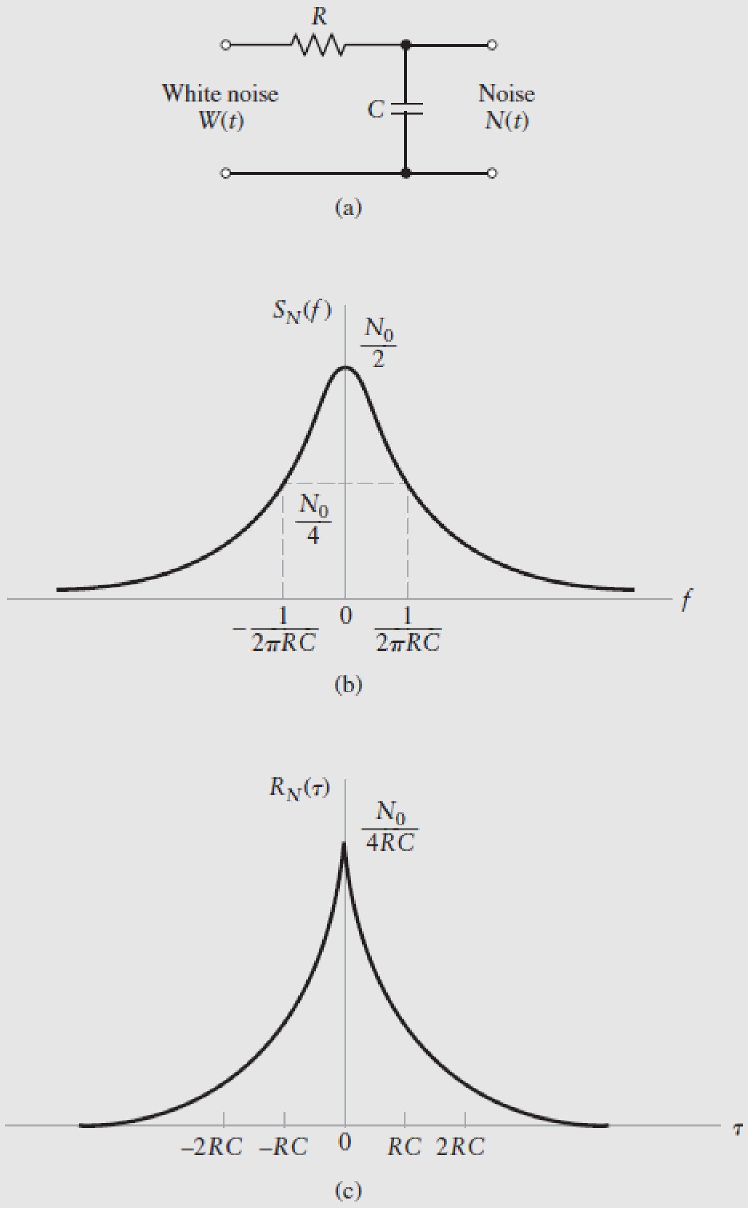


FIGURE 8.20 Characteristics of RC-filtered white noise. (*a*) Low-pass RC filter. (*b*) Power spectral density of output $N(t)$. (*c*) Autocorrelation function of $N(t)$.

SNR - BER

- SNR : signal-to-noise ratio;

$$\frac{P}{N} = \frac{average\ power\ of\ signal}{average\ power\ of\ noise}\ \ [unitless]$$

$$10\log_{10}\frac{P}{N} = SNR \text{ in } [dB]$$

- BER : bit error rate;

$$\frac{bit\ error\ number}{total\ transmitted\ bits}\ [unitless]$$

CQI Encoder

- The channel quality information is first coded using a (32, *O*) block code. The code words of the (32, *O*) block code are a linear combination of the 11 basis sequences denoted $M_{i,n}$ and defined in table below.

i	$M_{i,0}$	$M_{i,1}$	$M_{i,2}$	$M_{i,3}$	$M_{i,4}$	$M_{i,5}$	$M_{i,6}$	$M_{i,7}$	$M_{i,8}$	$M_{i,9}$	$M_{i,10}$
0	1	1	0	0	0	0	0	0	0	0	1
1	1	1	1	0	0	0	0	0	0	1	1
2	1	0	0	1	0	0	1	0	1	1	1
3	1	0	1	1	0	0	0	0	1	0	1
4	1	1	1	1	0	0	0	1	0	0	1
5	1	1	0	0	1	0	1	1	1	0	1
6	1	0	1	0	1	0	1	0	1	1	1
7	1	0	0	1	1	0	0	1	1	0	1
8	1	1	0	1	1	0	0	1	0	1	1
9	1	0	1	1	1	0	1	0	0	1	1
10	1	0	1	0	0	1	1	1	0	1	1
11	1	1	1	0	0	1	1	0	1	0	1
12	1	0	0	1	0	1	0	1	1	1	1
13	1	1	0	1	0	1	0	1	0	1	1
14	1	0	0	0	1	1	0	1	0	0	1
15	1	1	0	0	1	1	1	1	0	1	1
16	1	1	1	0	1	1	1	0	0	1	0
17	1	0	0	1	1	1	0	0	1	0	0
18	1	1	0	1	1	1	1	1	0	0	0
19	1	0	0	0	0	1	1	0	0	0	0
20	1	0	1	0	0	0	1	0	0	0	1
21	1	1	0	1	0	0	0	0	0	1	1
22	1	0	0	0	1	0	0	1	1	0	1
23	1	1	1	0	1	0	0	0	1	1	1
24	1	1	1	1	1	0	1	1	1	1	0
25	1	1	0	0	0	1	1	1	0	0	1
26	1	0	1	1	0	1	0	0	1	1	0
27	1	1	1	1	0	1	0	1	1	1	0
28	1	0	1	0	1	1	1	0	1	0	0
29	1	0	1	1	1	1	1	1	1	0	0
30	1	1	1	1	1	1	1	1	1	1	1
31	1	0	0	0	0	0	0	0	0	0	0

- The encoded CQI/PMI block is denoted by $b_0, b_1, b_2, b_3, \ldots, b_{B-1}$ where $B = 32$ and

$$b_i = \sum_{n=0}^{O-1} \left(o_n * M_{i,n}\right) mod\ 2$$

where $i = 0, 1, 2, \ldots, B-1$. O is the number of CQI bits.

Modulation – Channel Noise – Demodulation Scheme

CQI Decoder

- Step by step decoding algorithm for more than 6 bits CQI

i. bipolar transformation for received block ($\tilde{c}_i = 1 - 2 * c_i$) where c_i received signal and $i = 0, \dots 31$.

ii. interleaving for $\tilde{c}$

iii. constructing mask matrix M_D

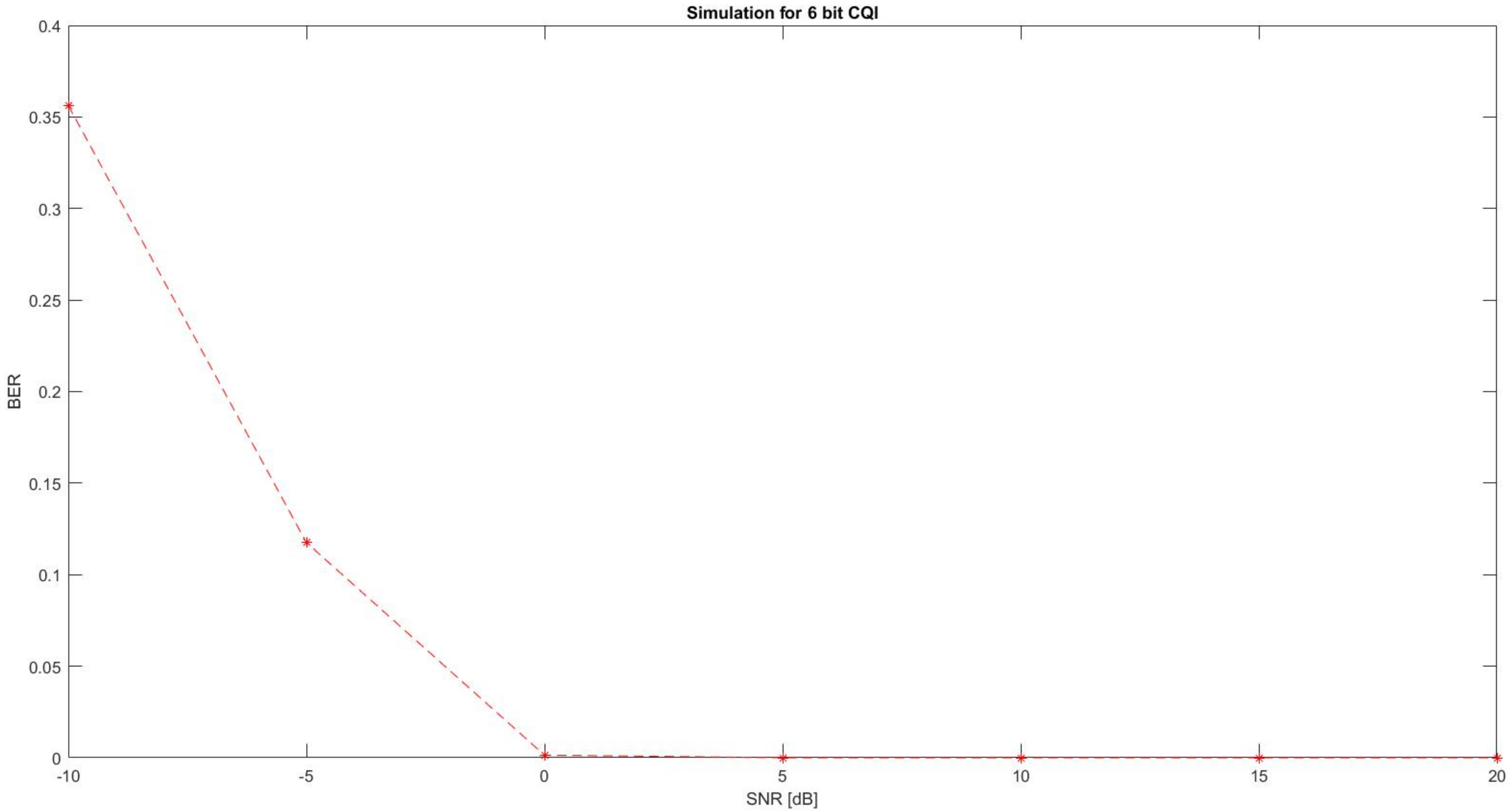
iv. bipolar transformation for each element of M_D, then interleaving for bits of rows of the matrix to obtain decoding matrix $\widetilde{M}_D$

v. Multiply every bit of $\tilde{c}$ with corresponding bit of each row in $\widetilde{M}_D$

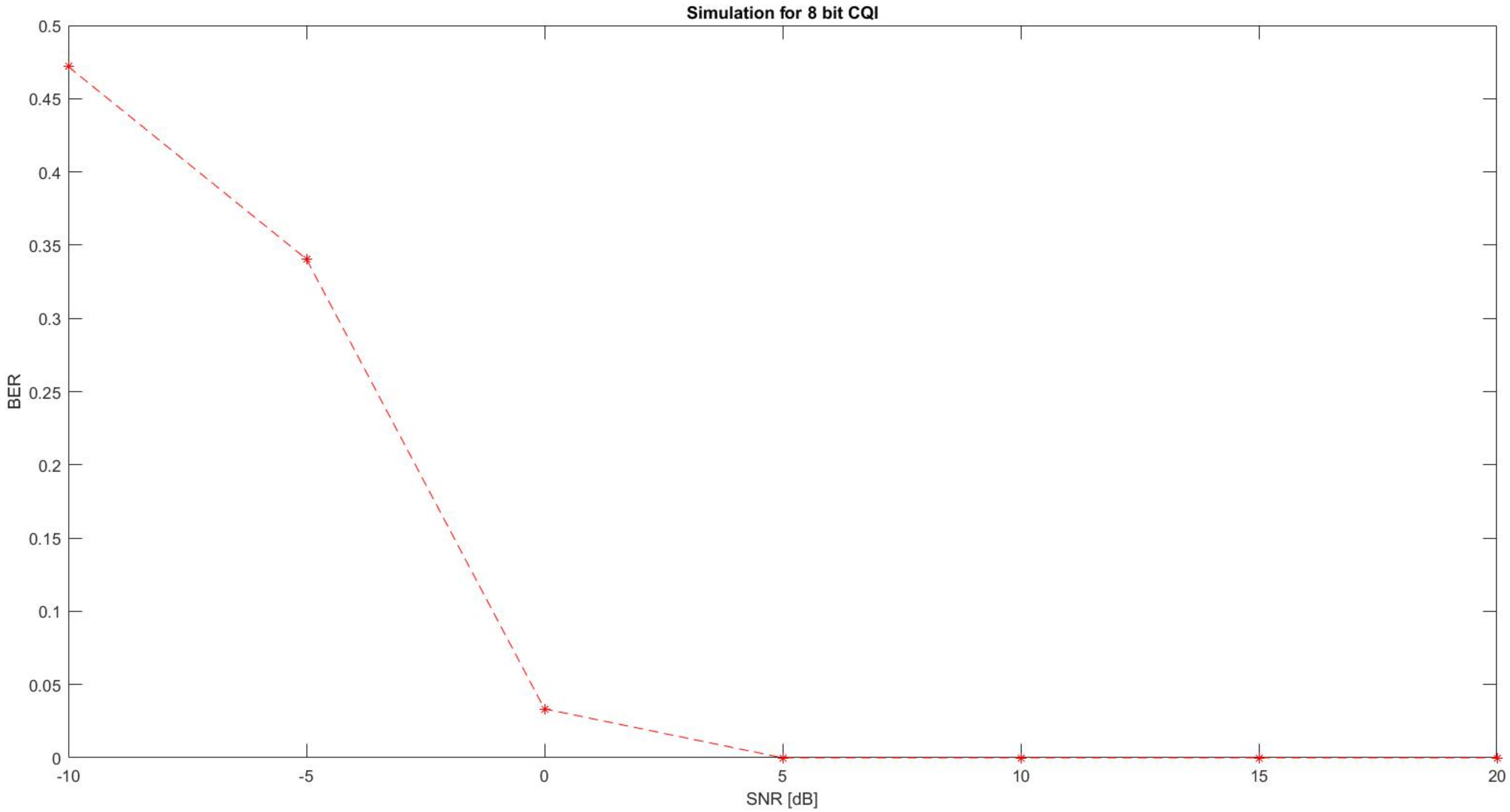
vi. apply FHT for each row of $\widetilde{M}_D$, and the results constitute D_{32x32} matrix

vii. find the element which has the largest magnitude in D_{32x32} matrix

viii. transform the row number of the element to $o_7, o_8, o_9, o_{10}, o_{11}$ bits and transform the column number of the element to o_2, o_3, o_4, o_5, o_6 bits, if the sign of the element is positive, o_1 bit is ‘0’ and if not ‘1’



Simulation for 6 bit CQI
BER
SNR [dB]
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-10
-5
0
5
10
15
20


Simulation for 8 bit CQI
BER
SNR [dB]
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-10
-5
0
5
10
15
20