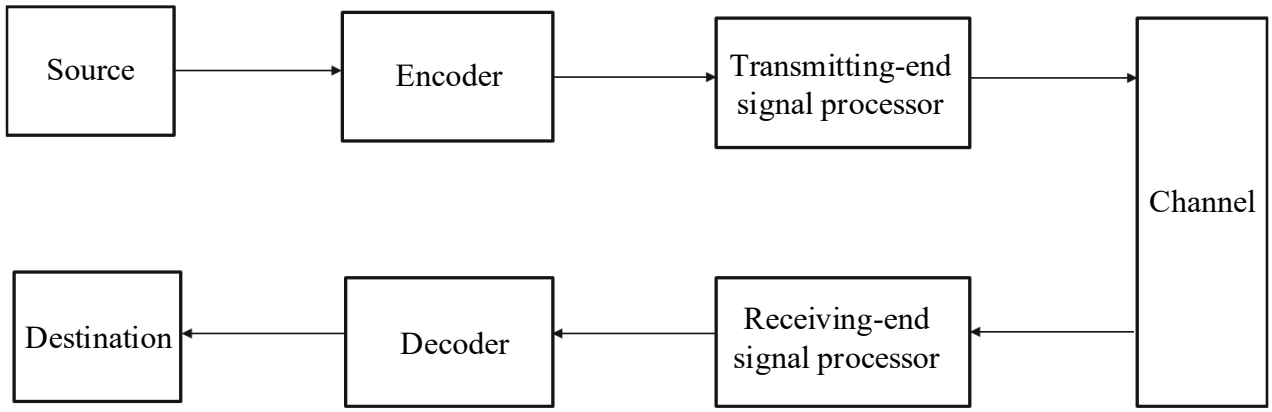

Source
Encoder
Transmitting-end signal processor
Channel
Destination
Decoder
Receiving-end signal processor

FIG. 1

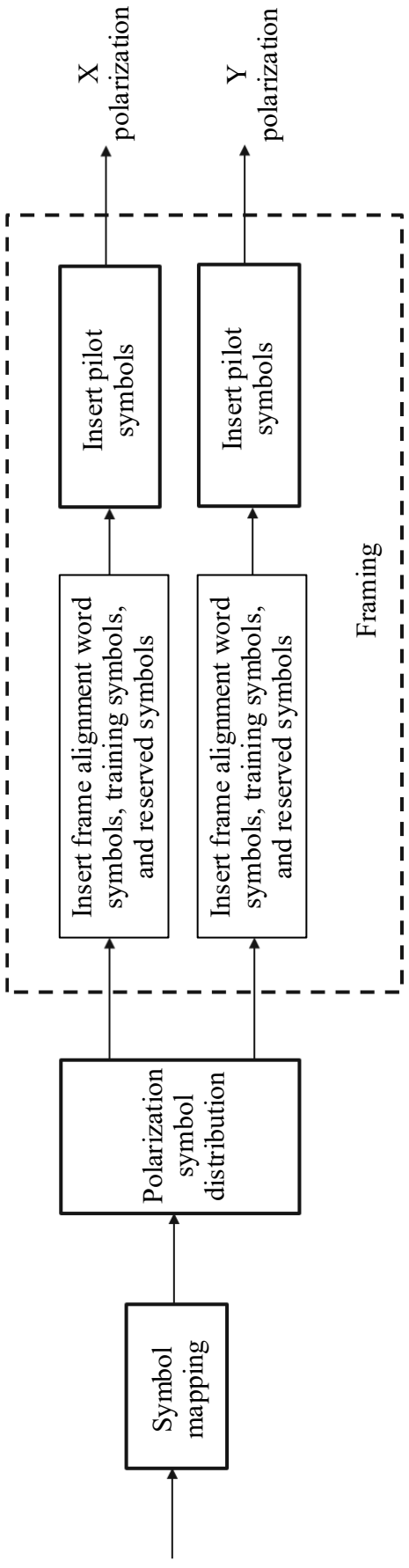

Symbol mapping
Polarization symbol distribution
Insert frame alignment word symbols, training symbols, and reserved symbols
Insert frame alignment word symbols, training symbols, and reserved symbols
Insert pilot symbols
Insert pilot symbols
Framing
X polarization
Y polarization

FIG. 2

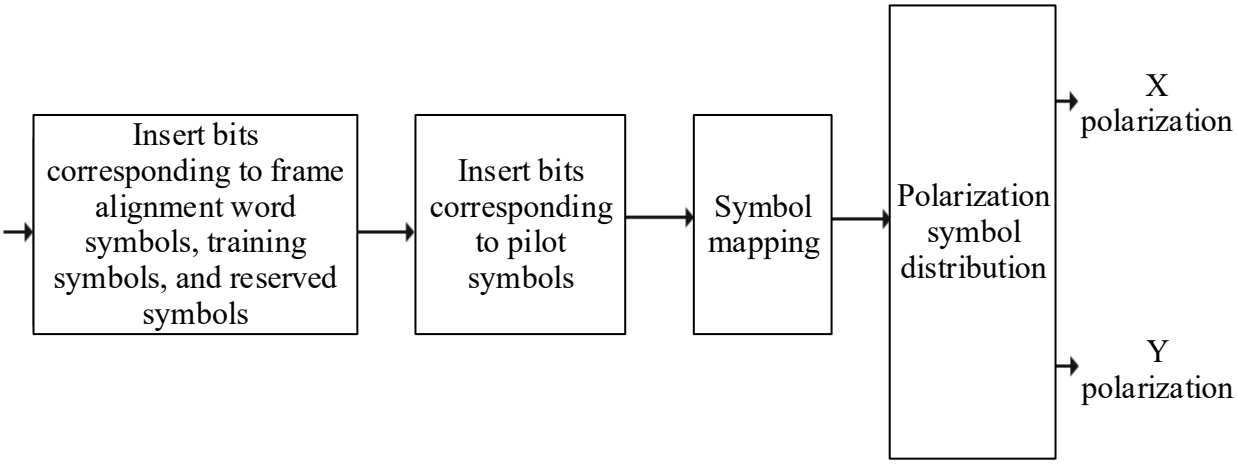

Insert bits corresponding to frame alignment word symbols, training symbols, and reserved symbols
Insert bits corresponding to pilot symbols
Symbol mapping
Polarization symbol distribution
X polarization
Y polarization

FIG. 3

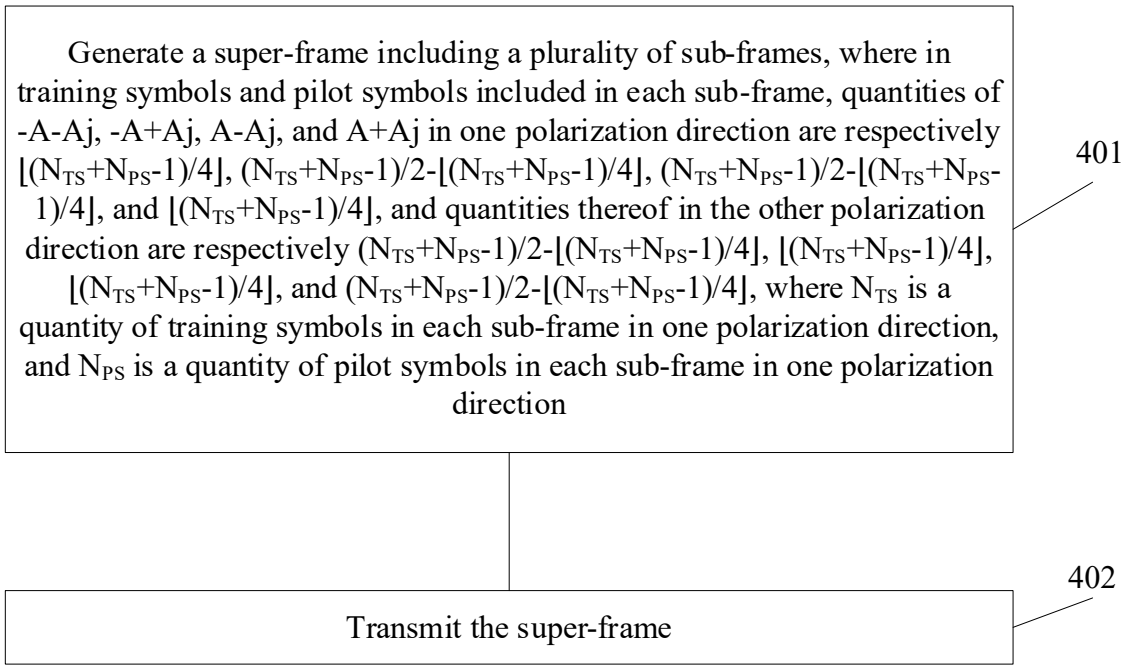
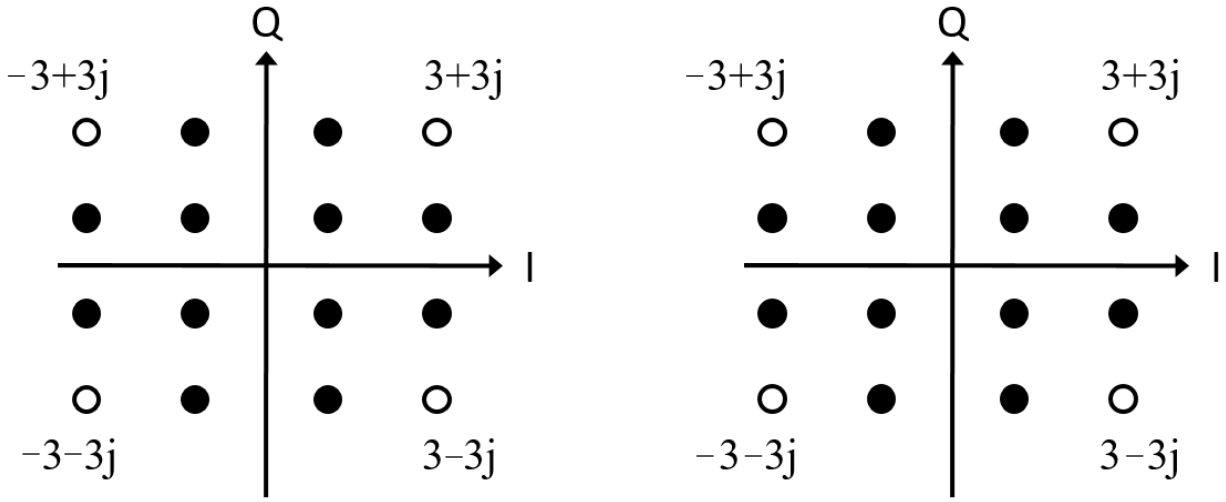
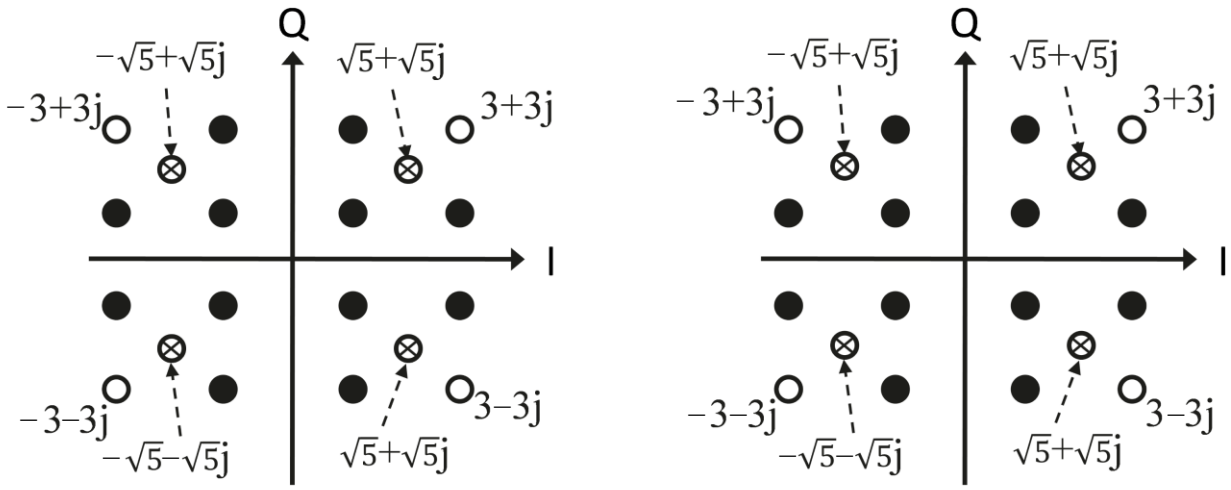

Generate a super-frame including a plurality of sub-frames, where in training symbols and pilot symbols included in each sub-frame, quantities of -A-Aj, -A+Aj, A-Aj, and A+Aj in one polarization direction are respectively ⌊(N_TS+N_PS-1)/4⌋, (N_TS+N_PS-1)/2-⌊(N_TS+N_PS-1)/4⌋, (N_TS+N_PS-1)/2-⌊(N_TS+N_PS-1)/4⌋, and ⌊(N_TS+N_PS-1)/4⌋, and quantities thereof in the other polarization direction are respectively (N_TS+N_PS-1)/2-⌊(N_TS+N_PS-1)/4⌋, ⌊(N_TS+N_PS-1)/4⌋, ⌊(N_TS+N_PS-1)/4⌋, and (N_TS+N_PS-1)/2-⌊(N_TS+N_PS-1)/4⌋, where N_TS is a quantity of training symbols in each sub-frame in one polarization direction, and N_PS is a quantity of pilot symbols in each sub-frame in one polarization direction
401
Transmit the super-frame
402

FIG. 4



X polarization Y polarization

FIG. 5A



X polarization Y polarization

FIG. 5B

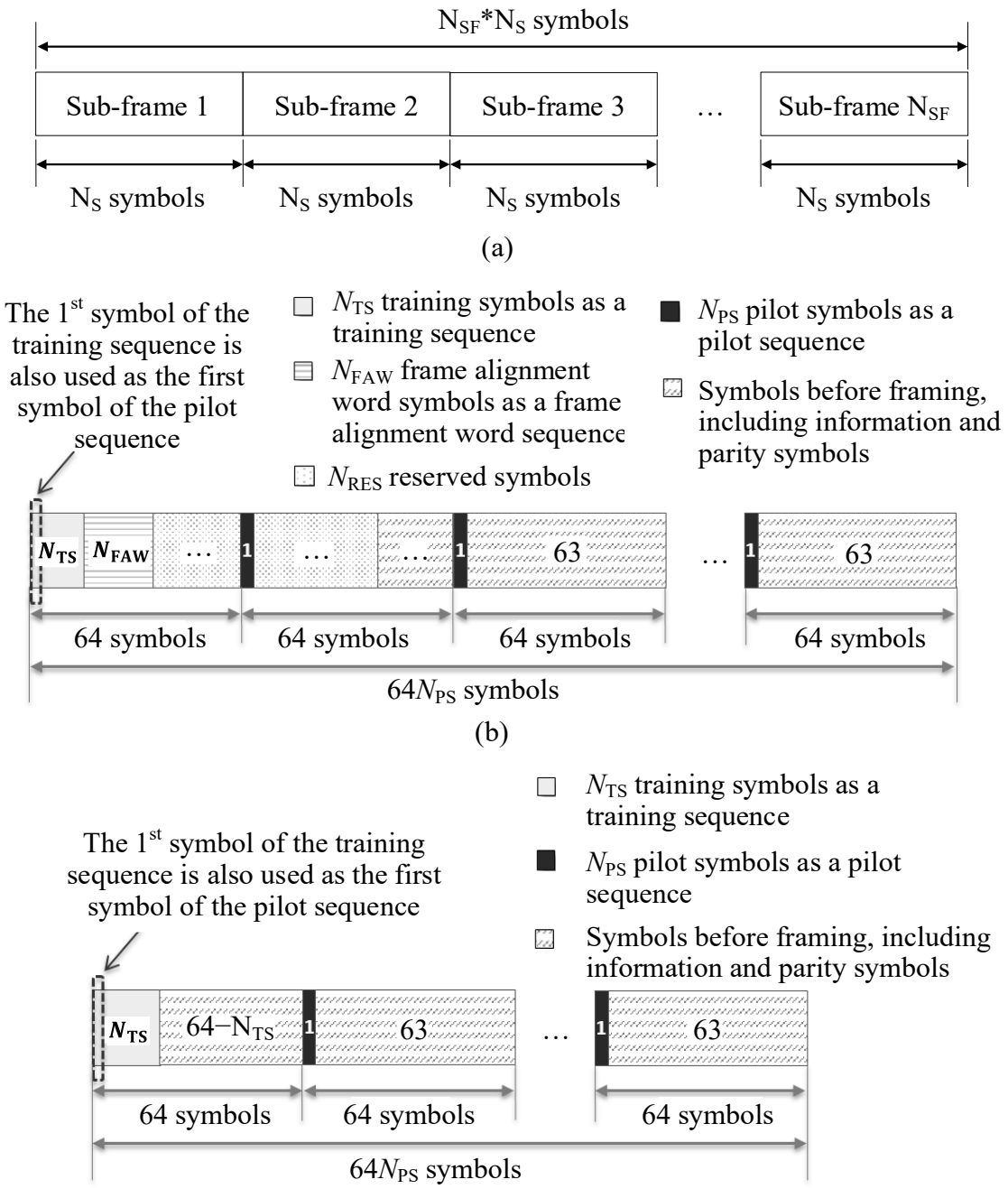

N_SF*N_S symbols
Sub-frame 1
Sub-frame 2
Sub-frame 3
…
Sub-frame N_SF
N_S symbols
N_S symbols
N_S symbols
N_S symbols
(a)
The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
N_TS training symbols as a training sequence
N_FAW frame alignment word symbols as a frame alignment word sequence
N_RES reserved symbols
N_PS pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
N_TS
N_FAW
1
63
64 symbols
64N_PS symbols
(b)
The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
N_TS training symbols as a training sequence
N_PS pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
64−N_TS
64 symbols
64N_PS symbols
(c)

FIG. 6

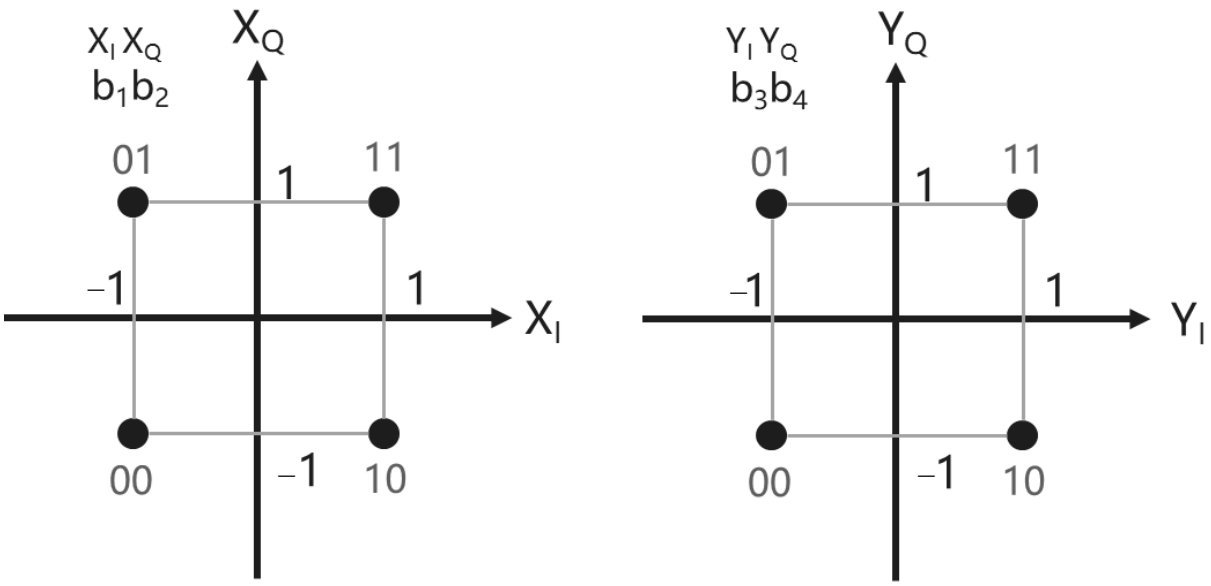

$X_I X_Q$
$b_1 b_2$
X_Q
01
11
1
−1
1
X_I
00
−1
10
$Y_I Y_Q$
$b_3 b_4$
Y_Q
01
11
1
−1
1
Y_I
00
−1
10

FIG. 7

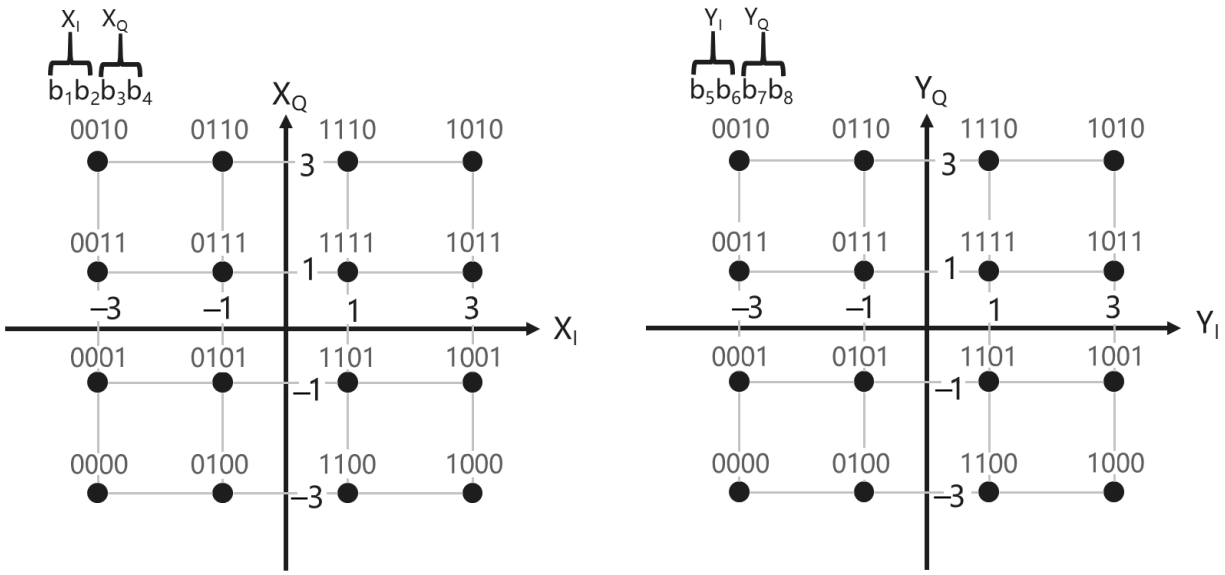
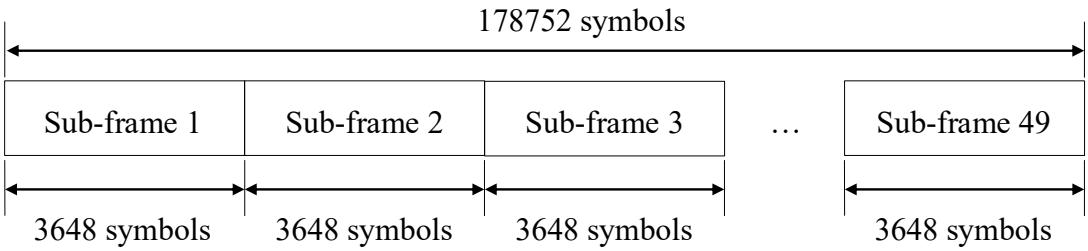
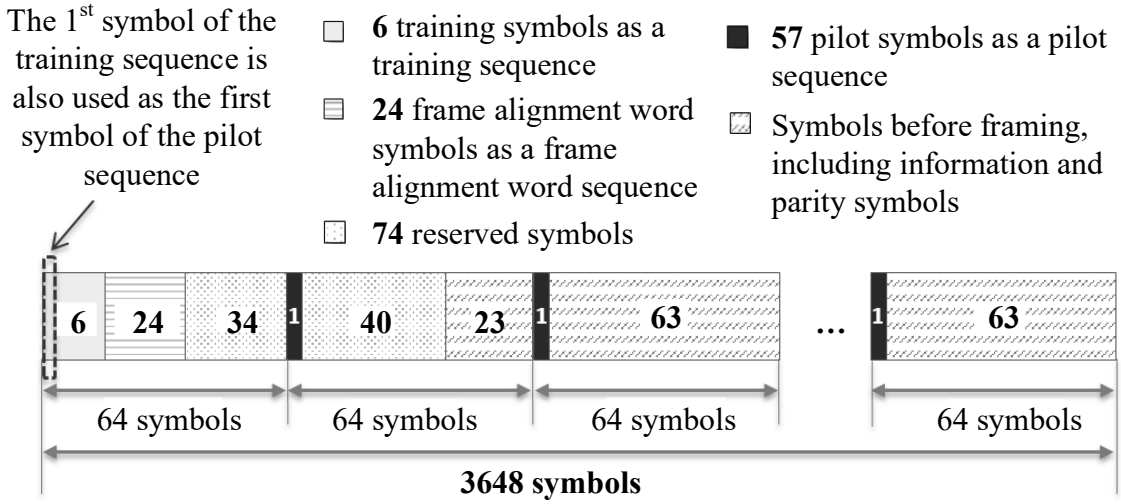

X_I X_Q
$b_1 b_2 b_3 b_4$
X_Q
0010 0110 1110 1010
3
0011 0111 1111 1011
1
−3 −1 1 3
X_I
0001 0101 1101 1001
−1
0000 0100 1100 1000
−3
Y_I Y_Q
$b_5 b_6 b_7 b_8$
Y_Q
0010 0110 1110 1010
3
0011 0111 1111 1011
1
−3 −1 1 3
Y_I
0001 0101 1101 1001
−1
0000 0100 1100 1000
−3

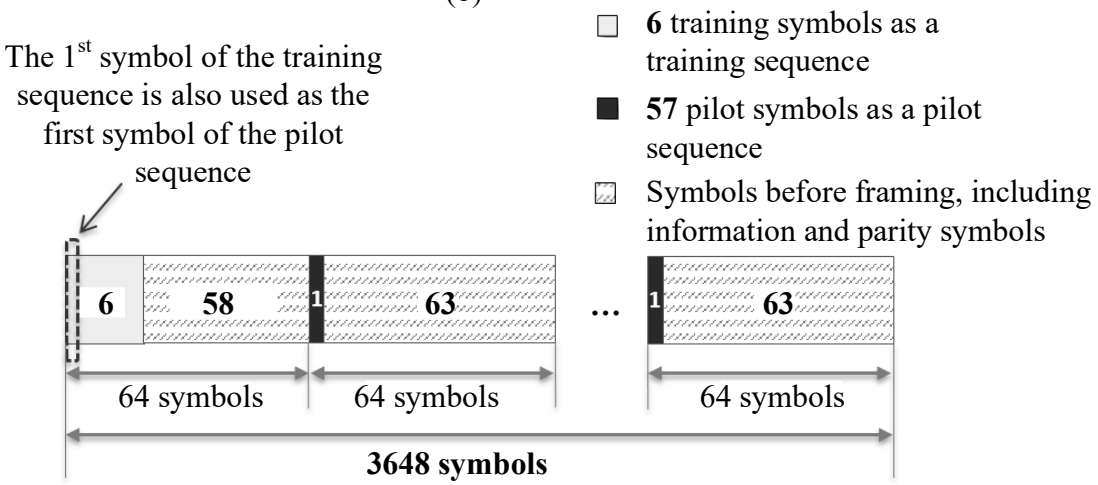
FIG. 8


178752 symbols
Sub-frame 1
Sub-frame 2
Sub-frame 3
…
Sub-frame 49
3648 symbols
3648 symbols
3648 symbols
3648 symbols

(a)


The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
6 training symbols as a training sequence
24 frame alignment word symbols as a frame alignment word sequence
74 reserved symbols
57 pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
6
24
34
1
40
23
1
63
…
1
63
64 symbols
64 symbols
64 symbols
64 symbols
3648 symbols

(b)


The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
6 training symbols as a training sequence
57 pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
6
58
1
63
…
1
63
64 symbols
64 symbols
64 symbols
3648 symbols

(c)

FIG. 9

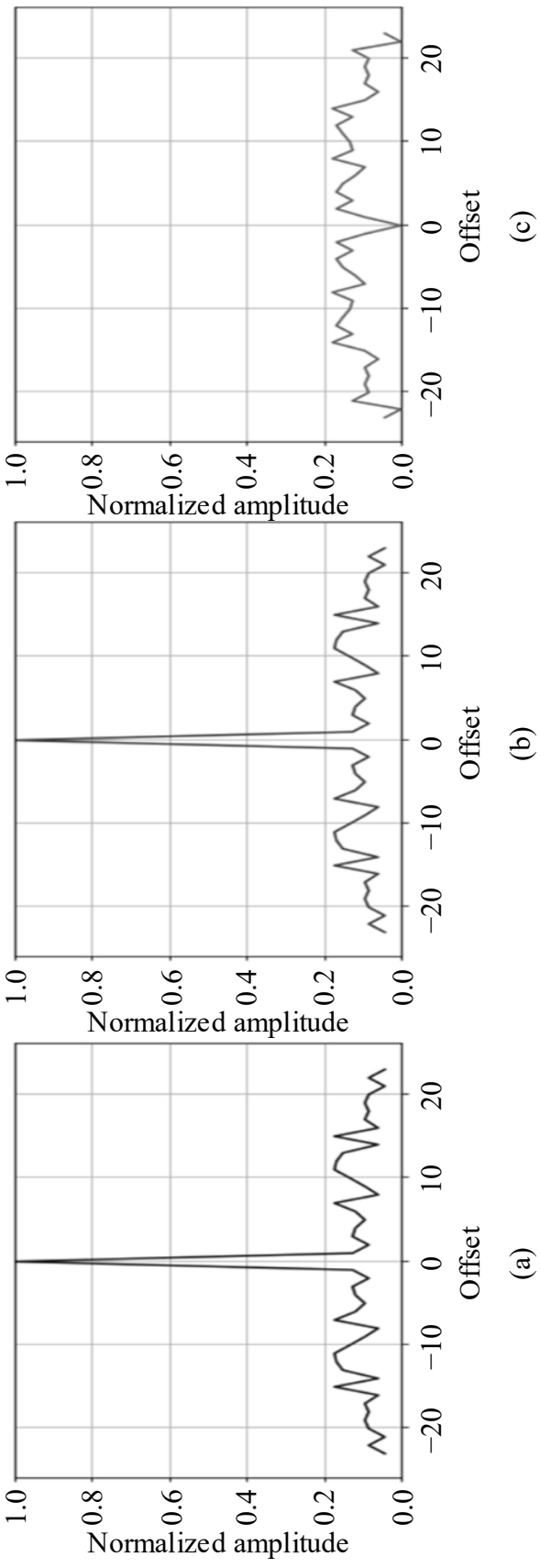


FIG. 10

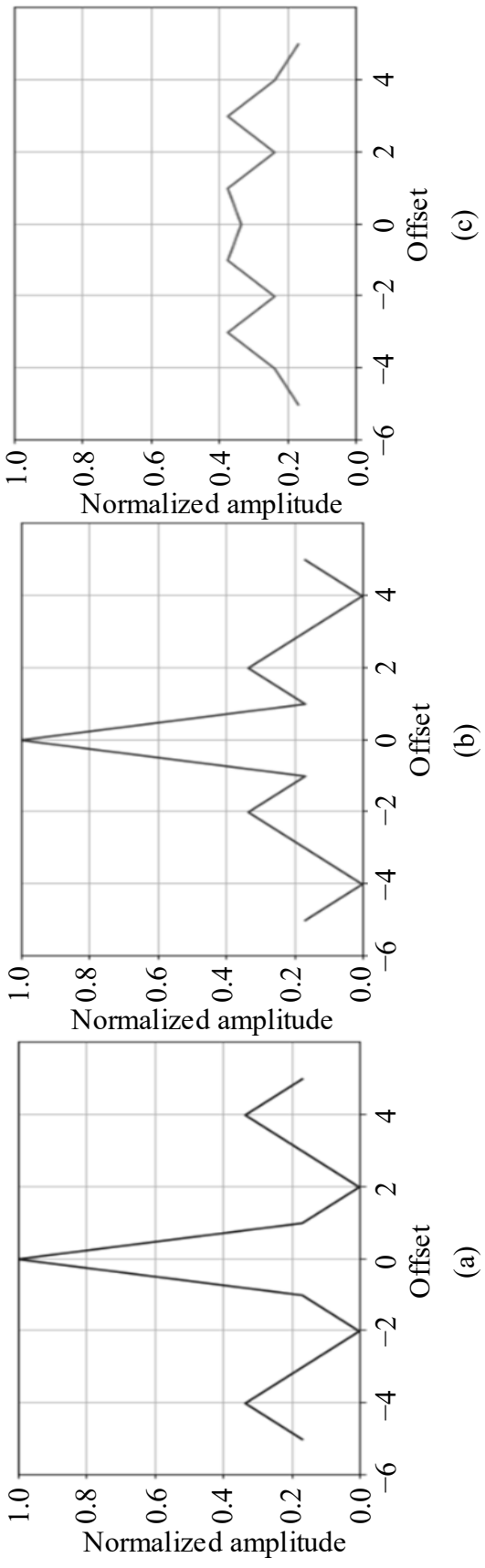


FIG. 11

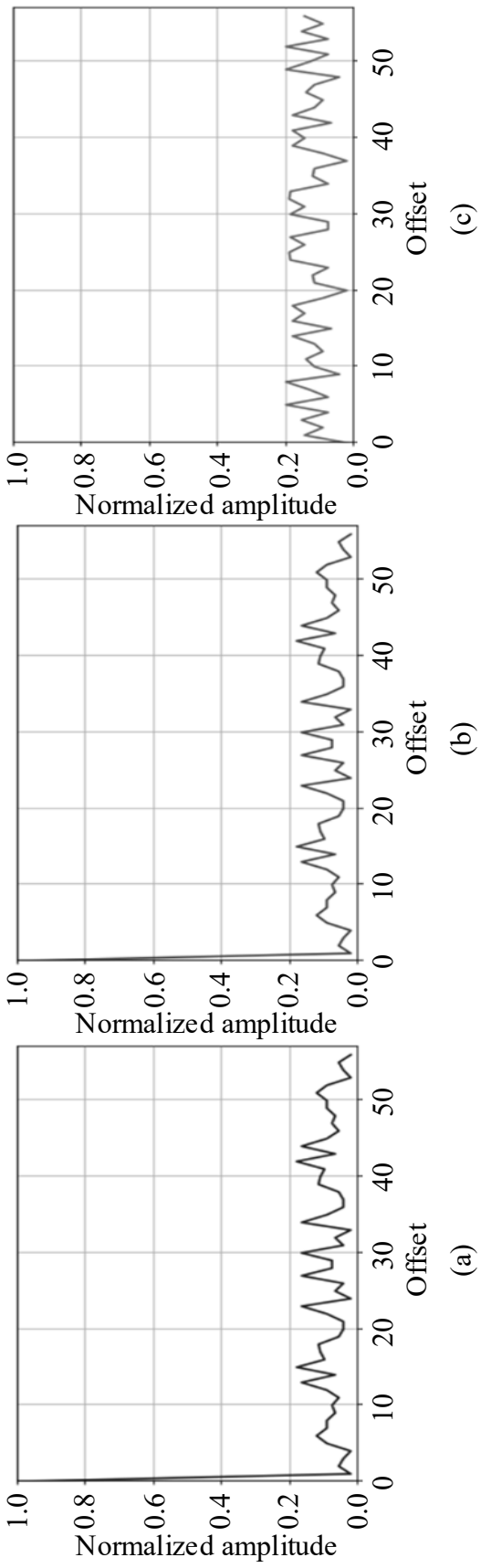

1.0
0.8
0.6
0.4
0.2
0.0
Normalized amplitude
0
10
20
30
40
50
Offset
(a)
(b)
(c)

FIG. 12

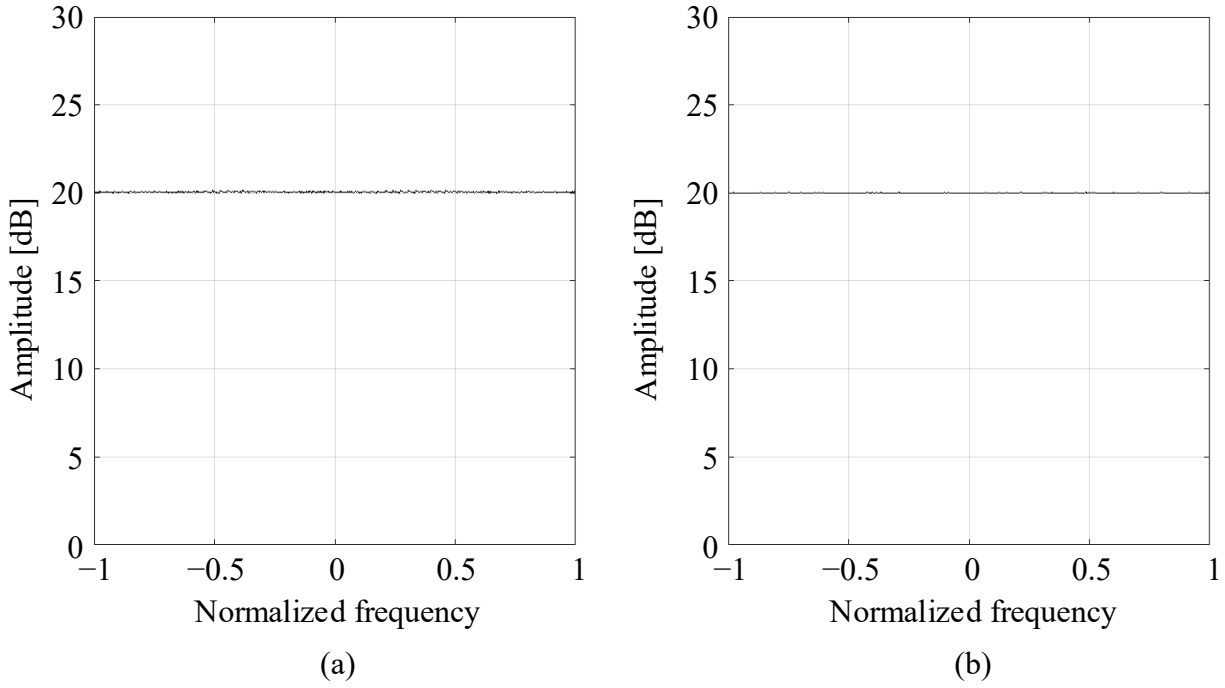

30
25
20
15
10
5
0
Amplitude [dB]
−1
−0.5
0
0.5
1
Normalized frequency
(a)
(b)

FIG. 13

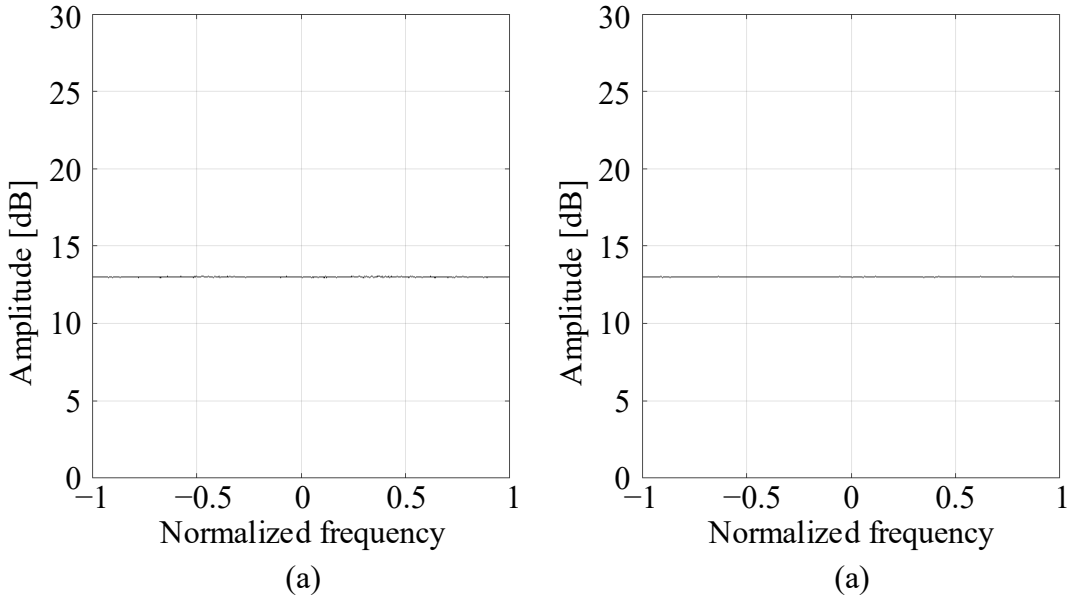
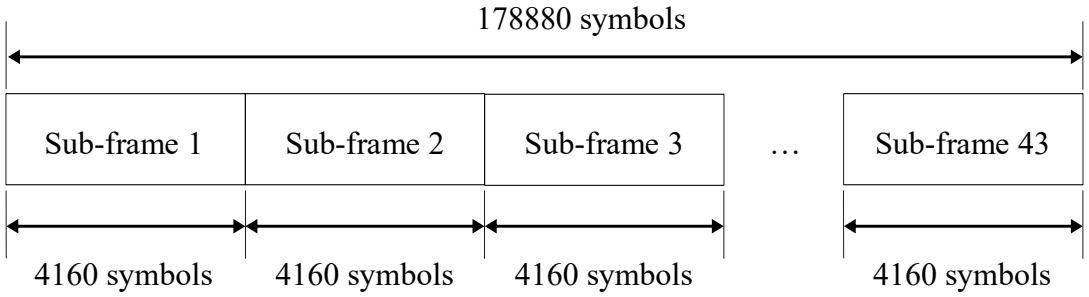
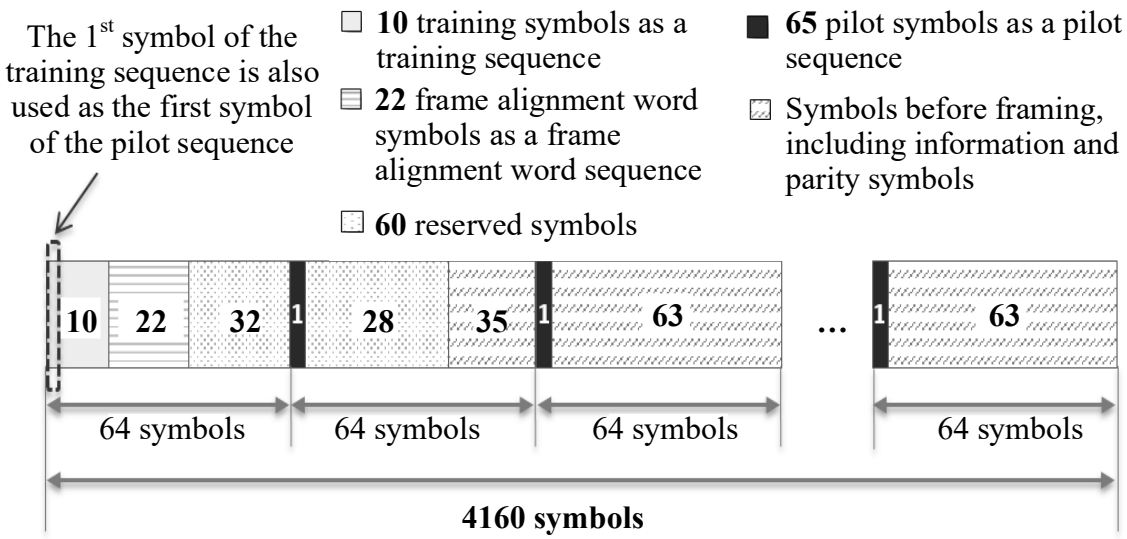

30
25
20
15
10
5
0
Amplitude [dB]
−1
−0.5
0
0.5
1
Normalized frequency
(a)
(a)

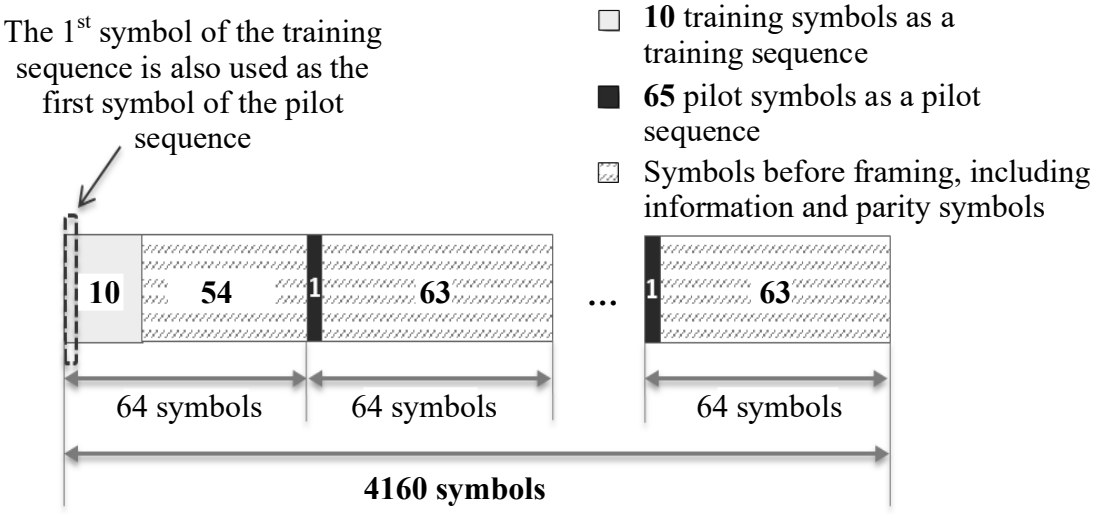
FIG. 14


178880 symbols
Sub-frame 1
Sub-frame 2
Sub-frame 3
…
Sub-frame 43
4160 symbols
4160 symbols
4160 symbols
4160 symbols

(a)


The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
10 training symbols as a training sequence
22 frame alignment word symbols as a frame alignment word sequence
60 reserved symbols
65 pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
10
22
32
1
28
35
1
63
…
1
63
64 symbols
64 symbols
64 symbols
64 symbols
4160 symbols

(b)


The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
10 training symbols as a training sequence
65 pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
10
54
1
63
…
1
63
64 symbols
64 symbols
64 symbols
4160 symbols

(c)

FIG. 15

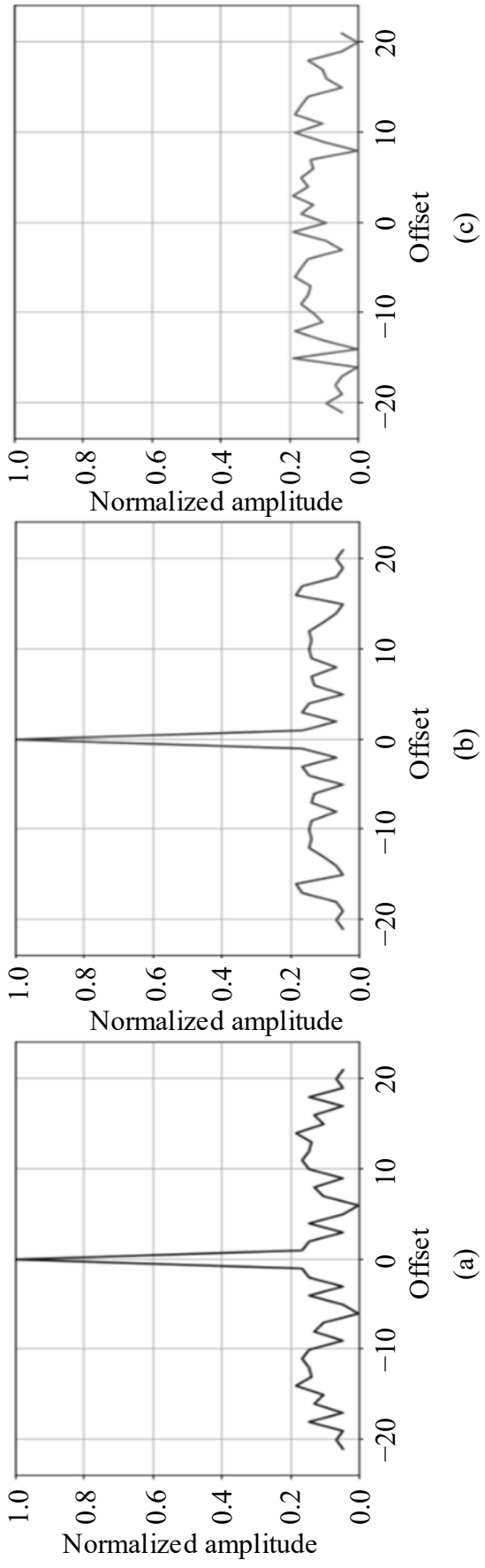


FIG. 16

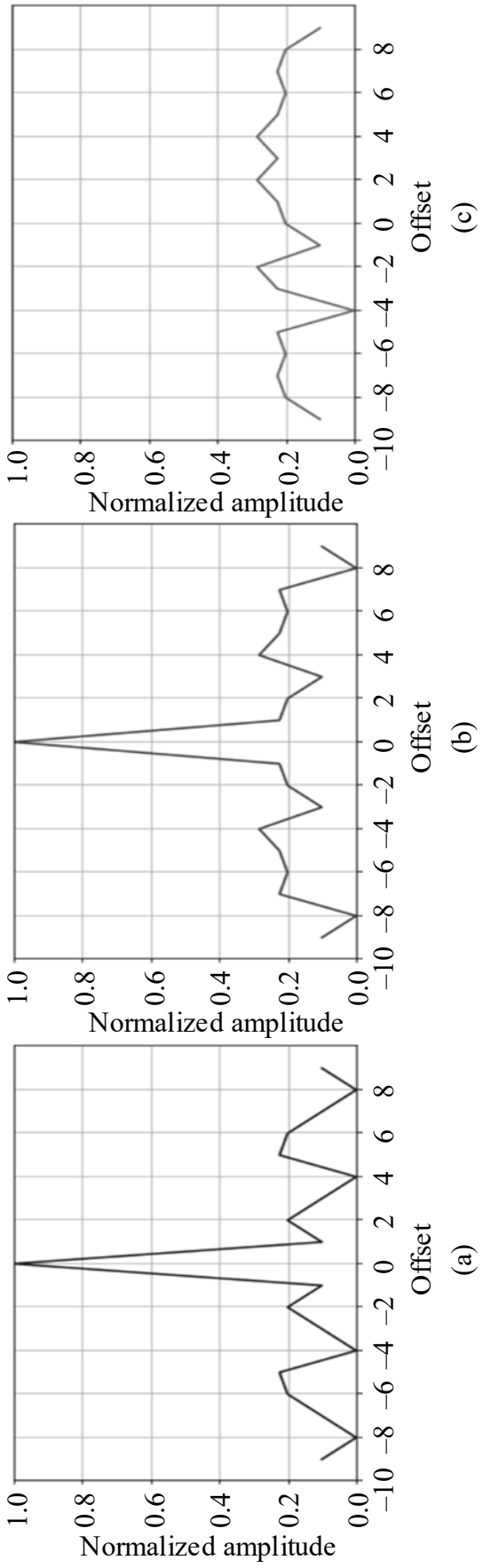

Normalized amplitude
1.0
0.8
0.6
0.4
0.2
0.0
−10 −8 −6 −4 −2 0 2 4 6 8
Offset
(a)
(b)
(c)

FIG. 17

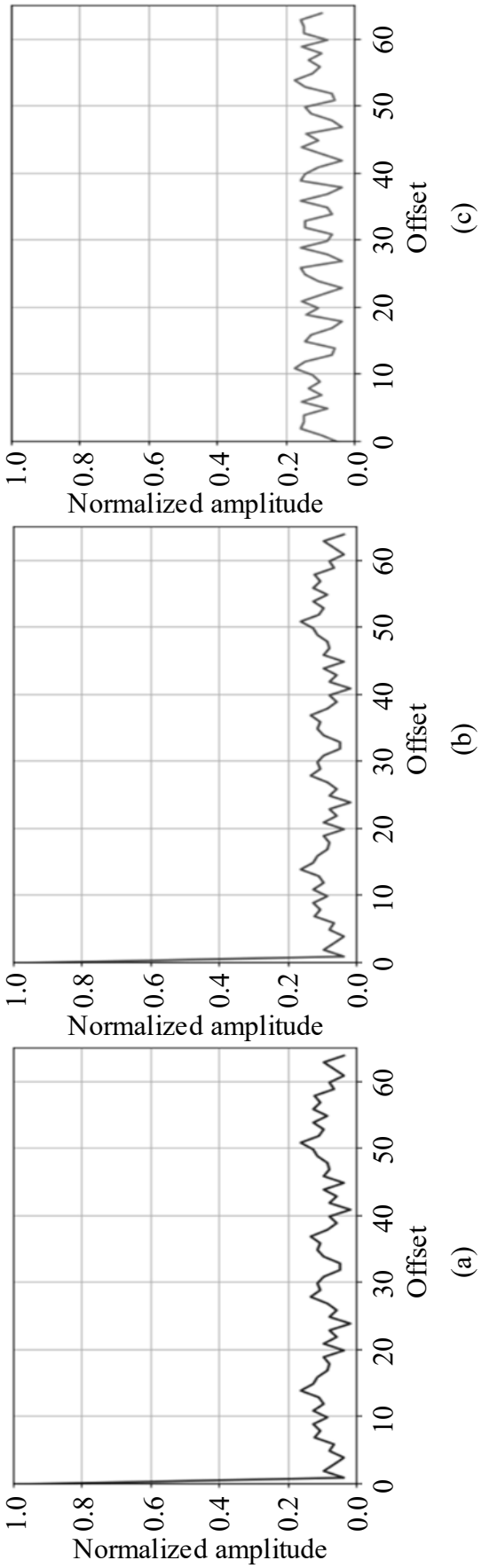

1.0
0.8
0.6
0.4
0.2
0.0
Normalized amplitude
0
10
20
30
40
50
60
Offset
(c)
(b)
(a)

FIG. 18

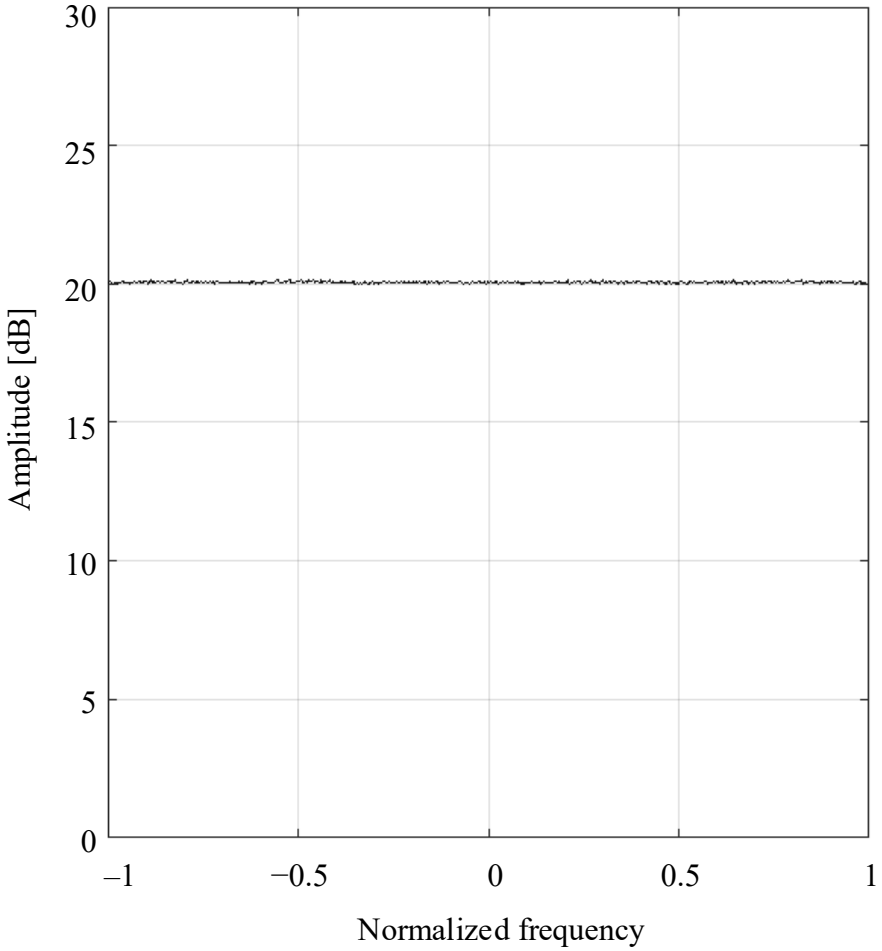
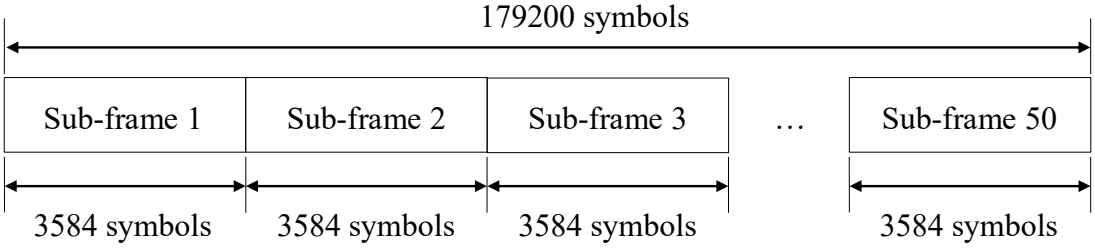
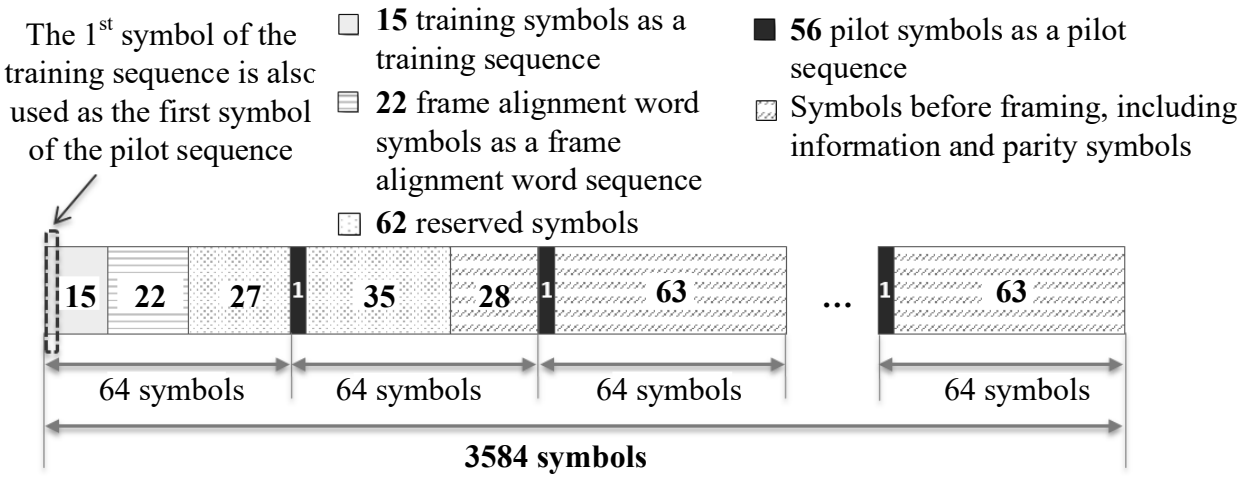


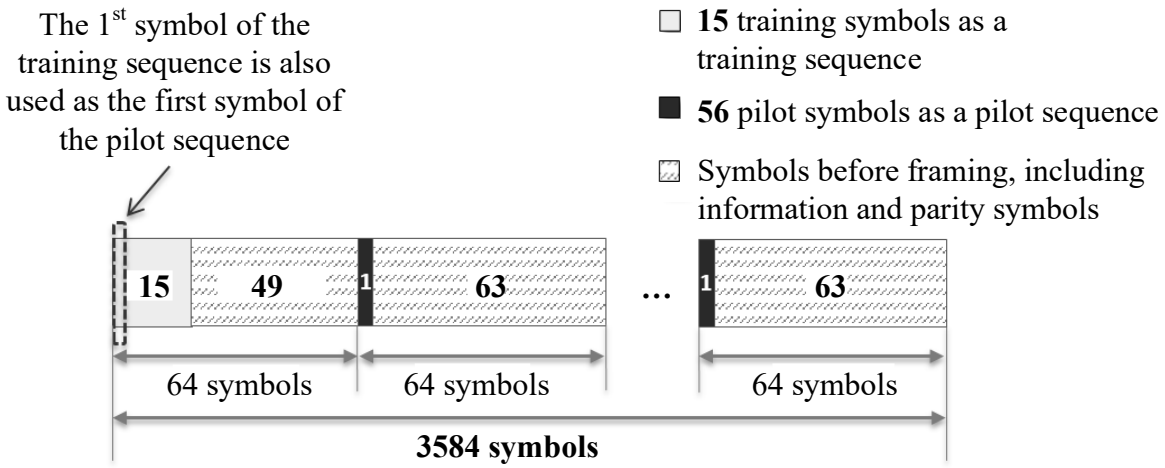
FIG. 19


179200 symbols
Sub-frame 1
Sub-frame 2
Sub-frame 3
…
Sub-frame 50
3584 symbols
3584 symbols
3584 symbols
3584 symbols

(a)


The 1st symbol of the training sequence is alsc used as the first symbol of the pilot sequence
15 training symbols as a training sequence
22 frame alignment word symbols as a frame alignment word sequence
62 reserved symbols
56 pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
15
22
27
1
35
28
1
63
…
1
63
64 symbols
64 symbols
64 symbols
64 symbols
3584 symbols

(b)


The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
15 training symbols as a training sequence
56 pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
15
49
1
63
…
1
63
64 symbols
64 symbols
64 symbols
3584 symbols

(c)

FIG. 20

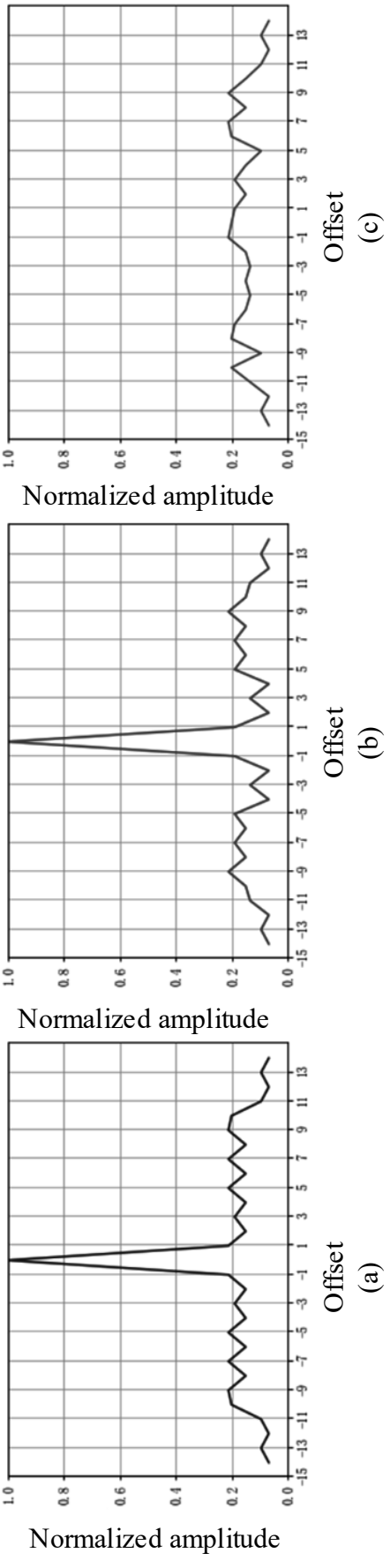

Normalized amplitude
1.0
0.8
0.6
0.4
0.2
0.0
-15 -13 -11 -9 -7 -5 -3 -1 1 3 5 7 9 11 13
Offset
(c)
Normalized amplitude
Offset
(b)
Normalized amplitude
Offset
(a)

FIG. 21

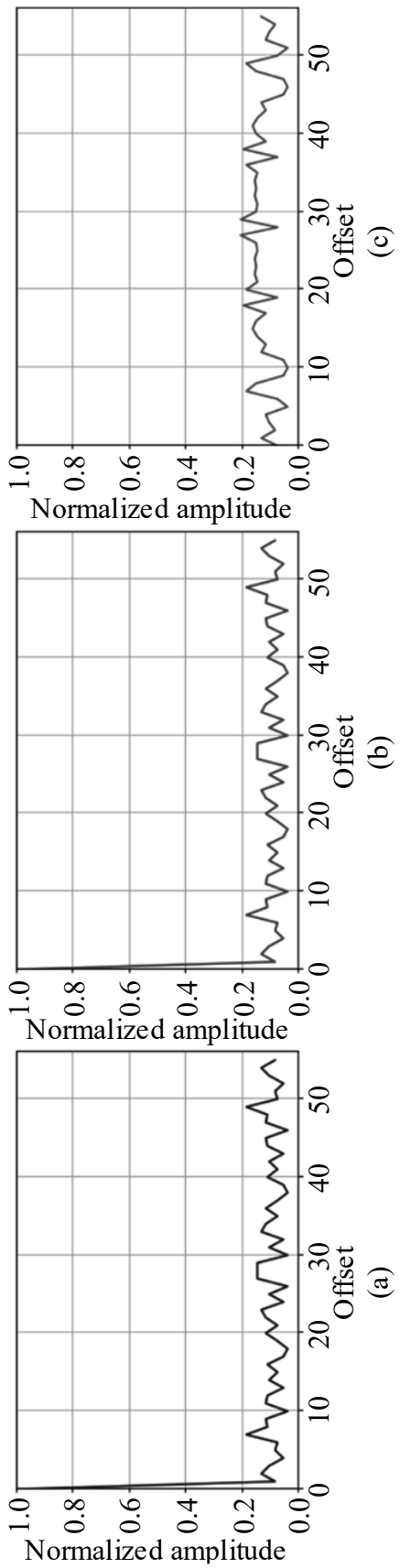

Normalized amplitude
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
Offset
(a)
(b)
(c)

FIG. 22

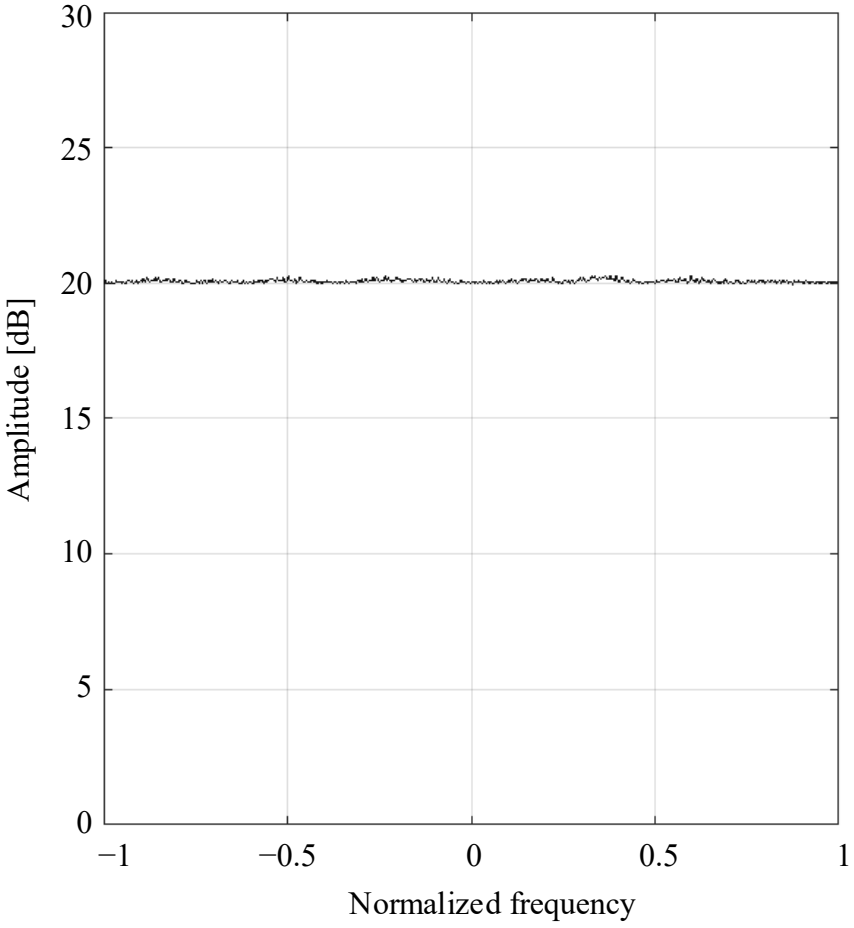
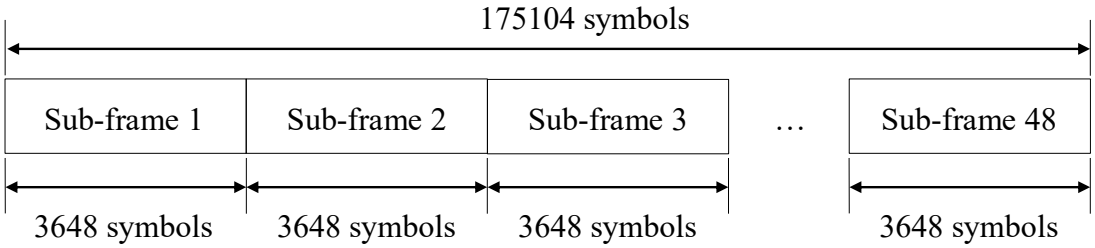
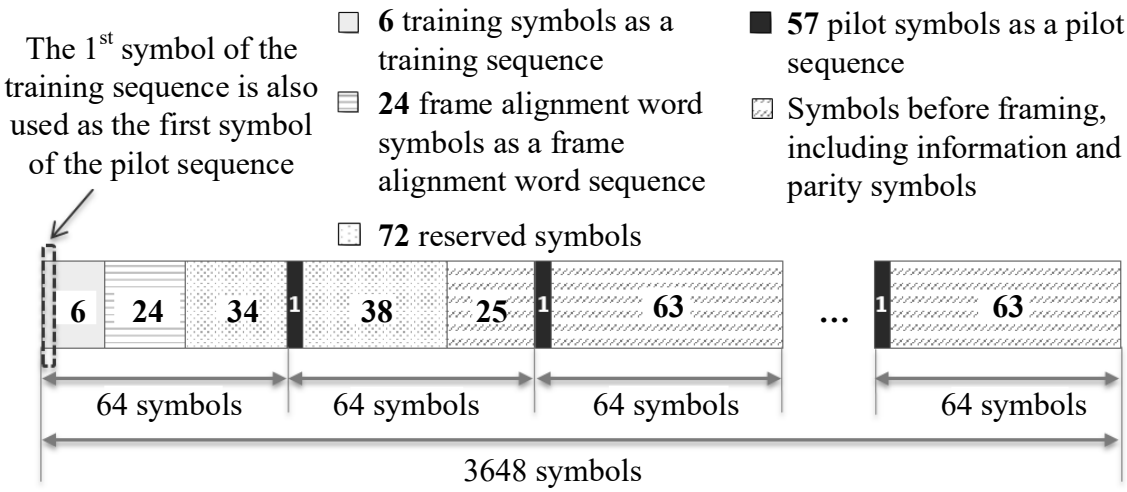


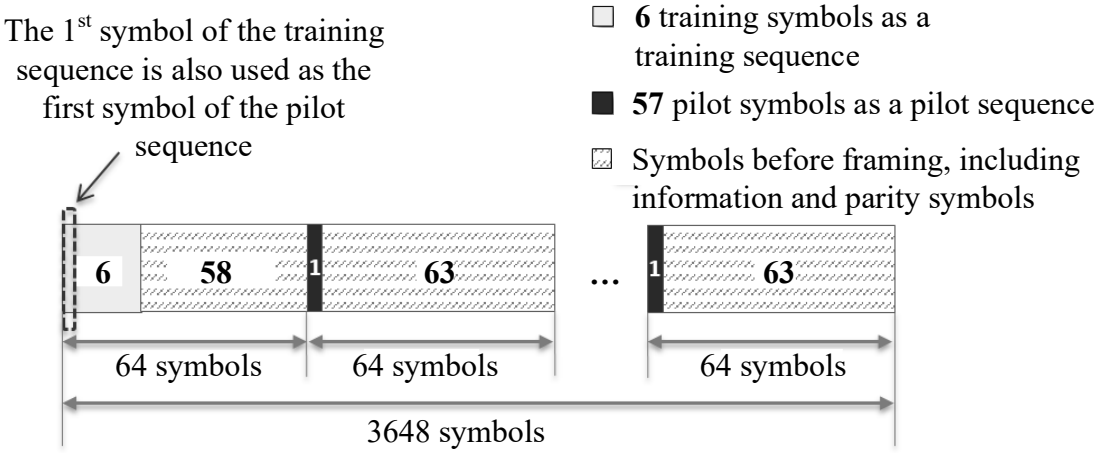
FIG. 23


175104 symbols
Sub-frame 1
Sub-frame 2
Sub-frame 3
…
Sub-frame 48
3648 symbols
3648 symbols
3648 symbols
3648 symbols

(a)


The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
6 training symbols as a training sequence
24 frame alignment word symbols as a frame alignment word sequence
72 reserved symbols
57 pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
6
24
34
1
38
25
1
63
…
1
63
64 symbols
64 symbols
64 symbols
64 symbols
3648 symbols

(b)


The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
6 training symbols as a training sequence
57 pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
6
58
1
63
…
1
63
64 symbols
64 symbols
64 symbols
3648 symbols

(c)

FIG. 24

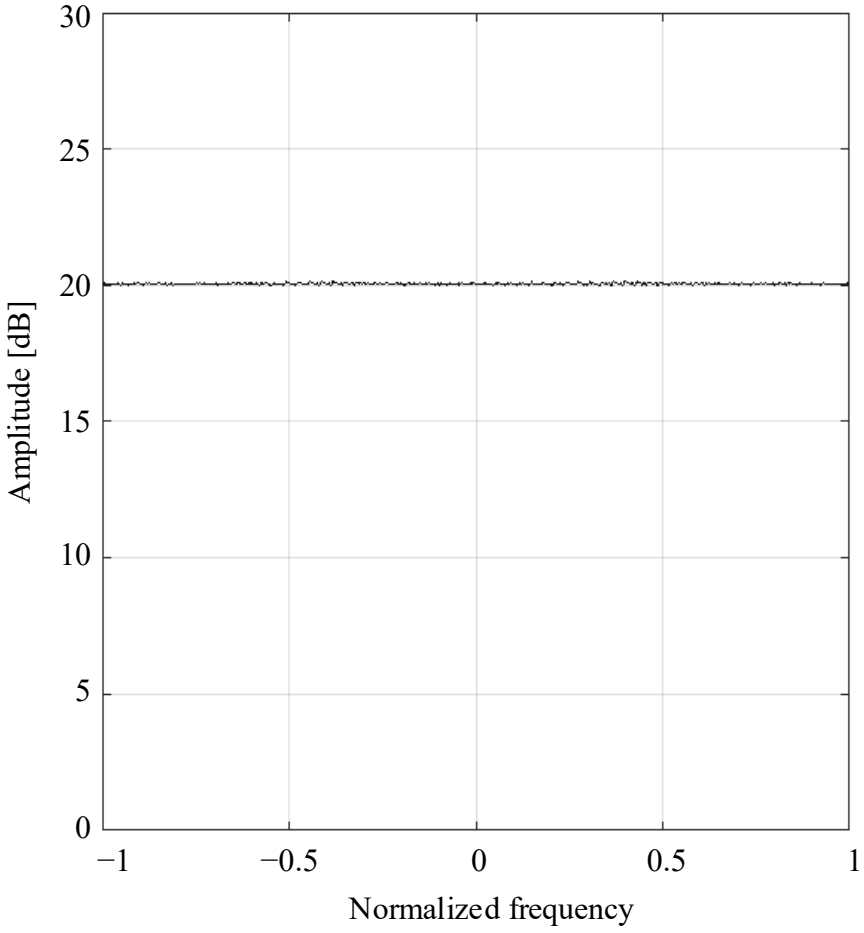
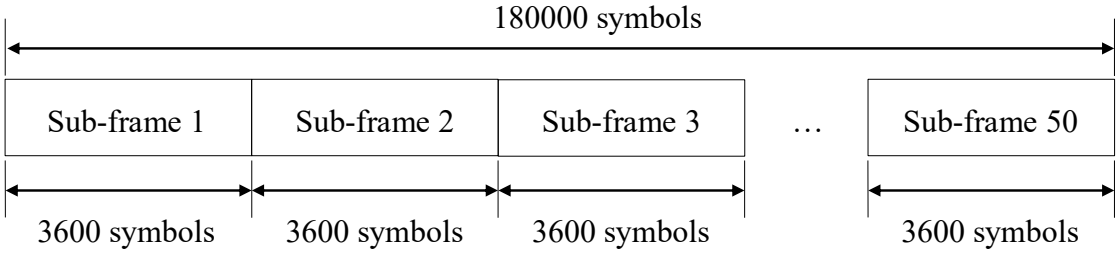
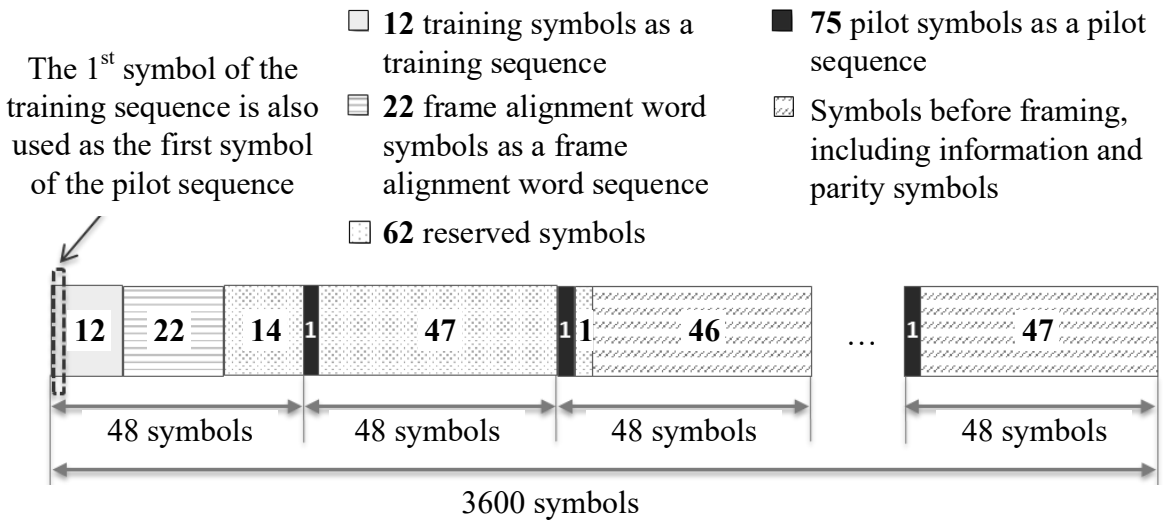


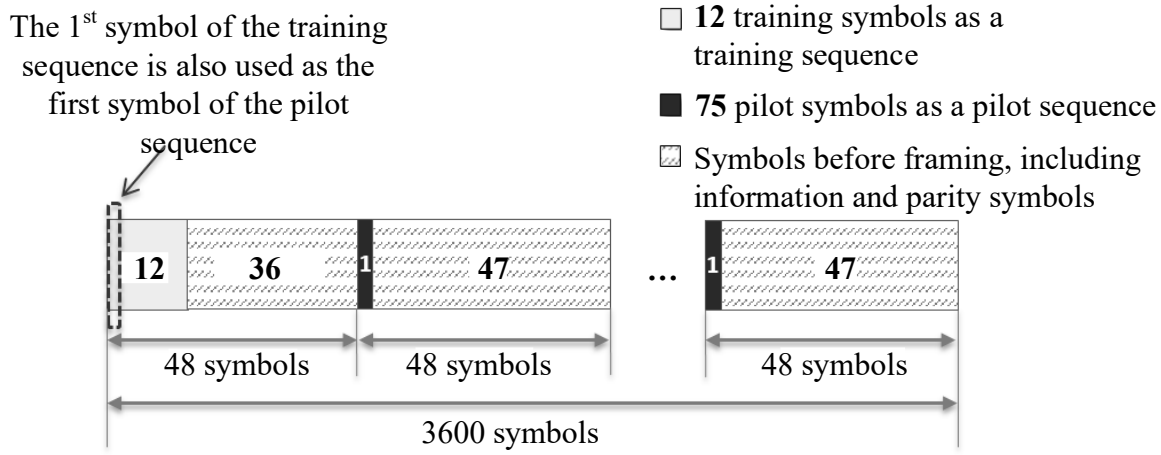
FIG. 25


180000 symbols
Sub-frame 1
Sub-frame 2
Sub-frame 3
…
Sub-frame 50
3600 symbols
3600 symbols
3600 symbols
3600 symbols

(a)


The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
12 training symbols as a training sequence
22 frame alignment word symbols as a frame alignment word sequence
62 reserved symbols
75 pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
12
22
14
1
47
1
1
46
…
1
47
48 symbols
48 symbols
48 symbols
48 symbols
3600 symbols

(b)


The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
12 training symbols as a training sequence
75 pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
12
36
1
47
…
1
47
48 symbols
48 symbols
48 symbols
3600 symbols

(c)

FIG. 26

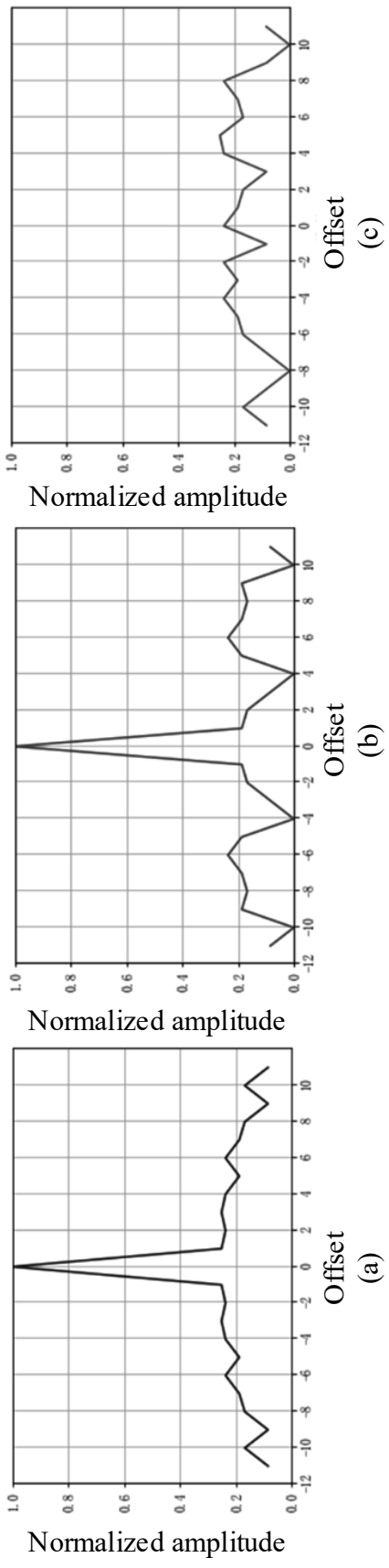

Normalized amplitude
Offset
(a)
Normalized amplitude
Offset
(b)
Normalized amplitude
Offset
(c)

FIG. 27

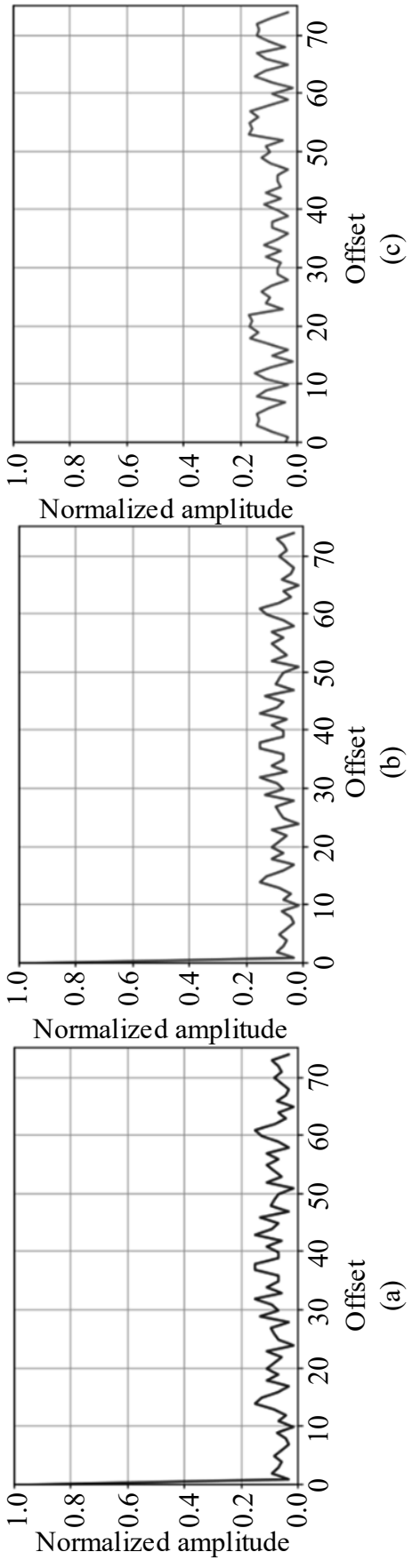

1.0
0.8
0.6
0.4
0.2
0.0
Normalized amplitude
0
10
20
30
40
50
60
70
Offset
(a)
(b)
(c)

FIG. 28

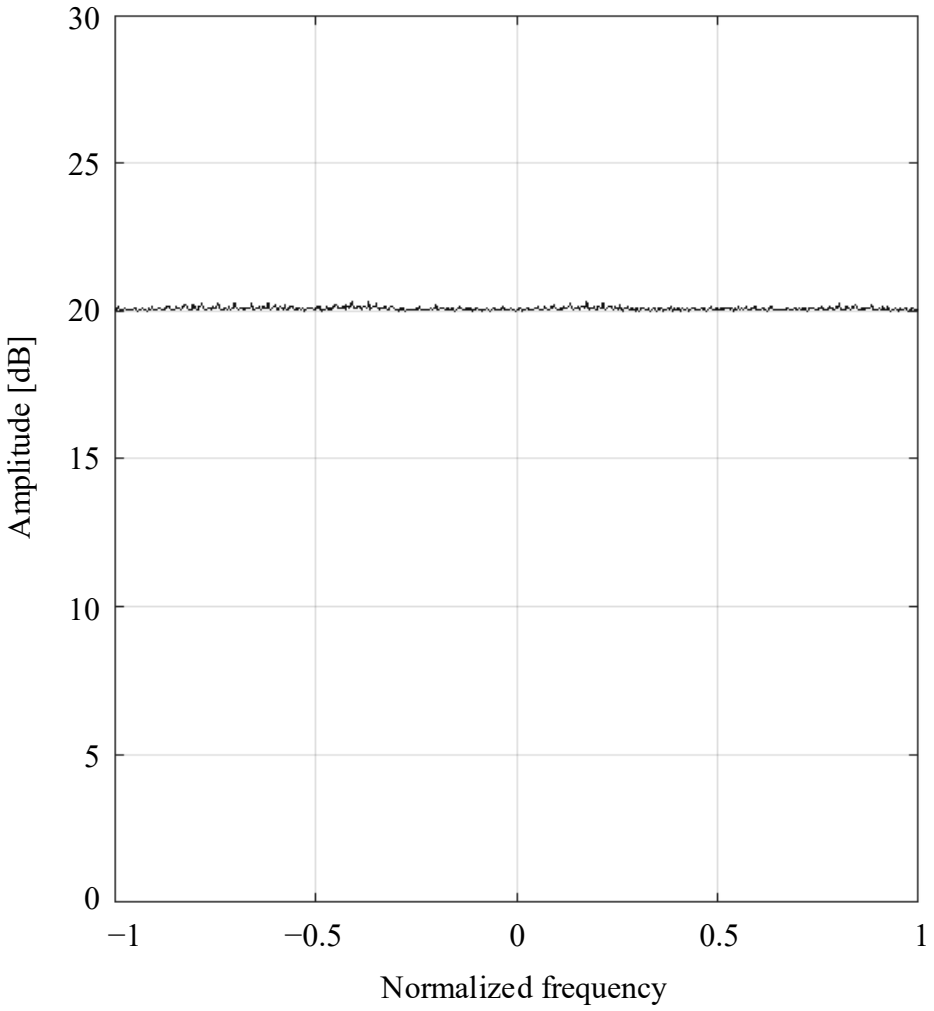


FIG. 29

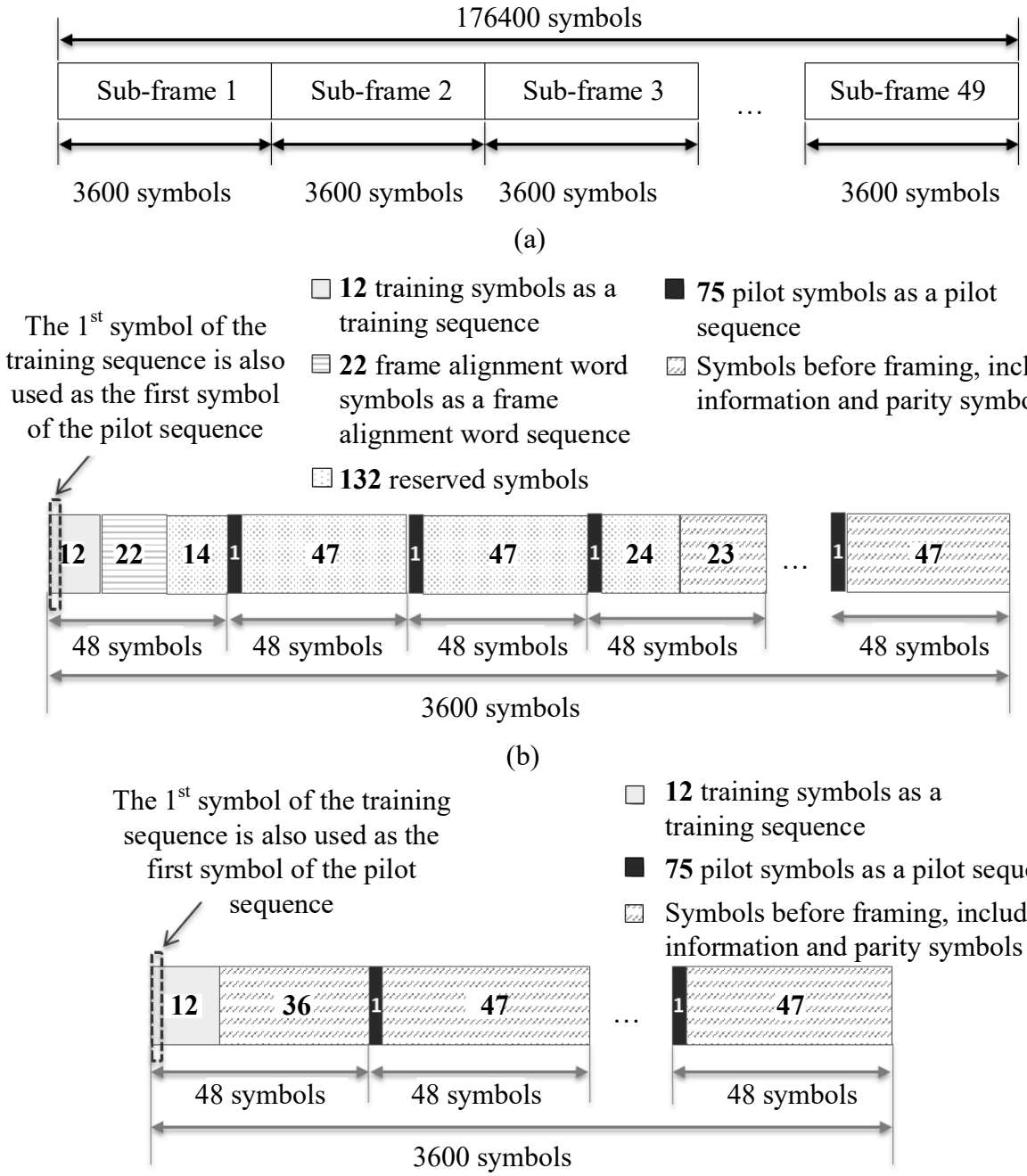

176400 symbols
Sub-frame 1
Sub-frame 2
Sub-frame 3
…
Sub-frame 49
3600 symbols
3600 symbols
3600 symbols
3600 symbols
(a)
The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
12 training symbols as a training sequence
22 frame alignment word symbols as a frame alignment word sequence
132 reserved symbols
75 pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
12
22
14
1
47
1
47
1
24
23
…
1
47
48 symbols
48 symbols
48 symbols
48 symbols
48 symbols
3600 symbols
(b)
The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
12 training symbols as a training sequence
75 pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
12
36
1
47
…
1
47
48 symbols
48 symbols
48 symbols
3600 symbols
(c)

FIG. 30

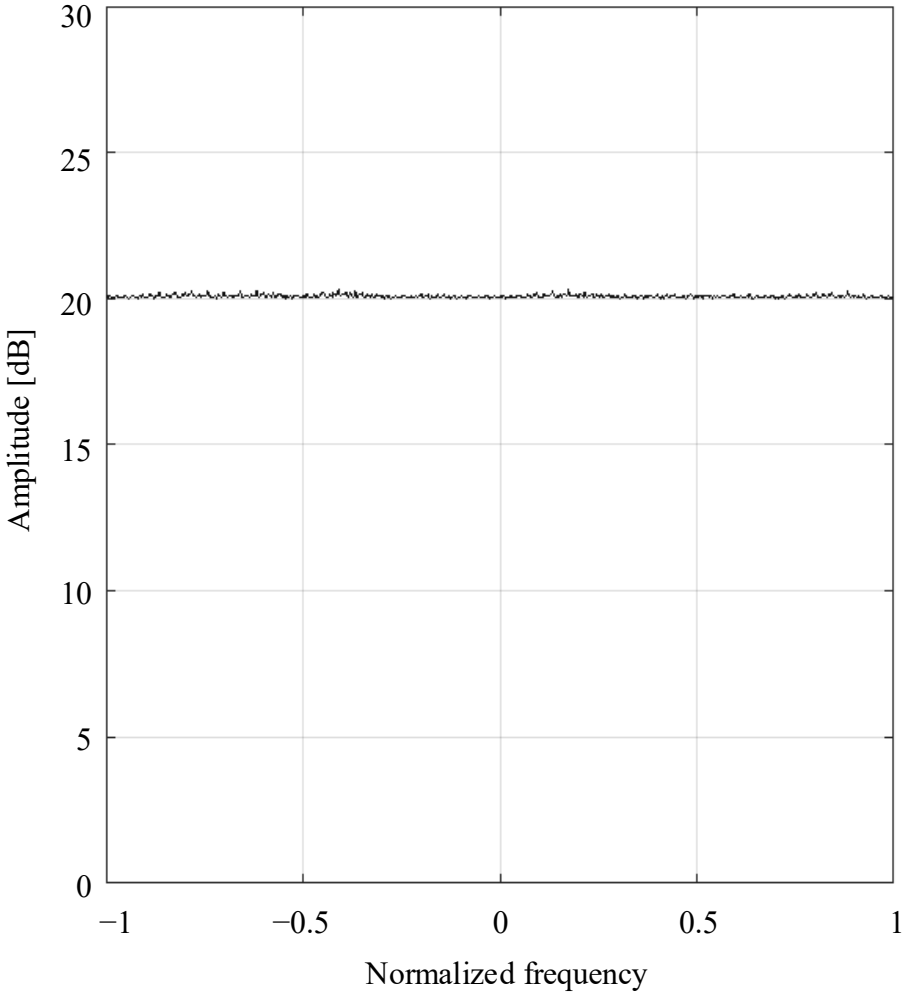


FIG. 31

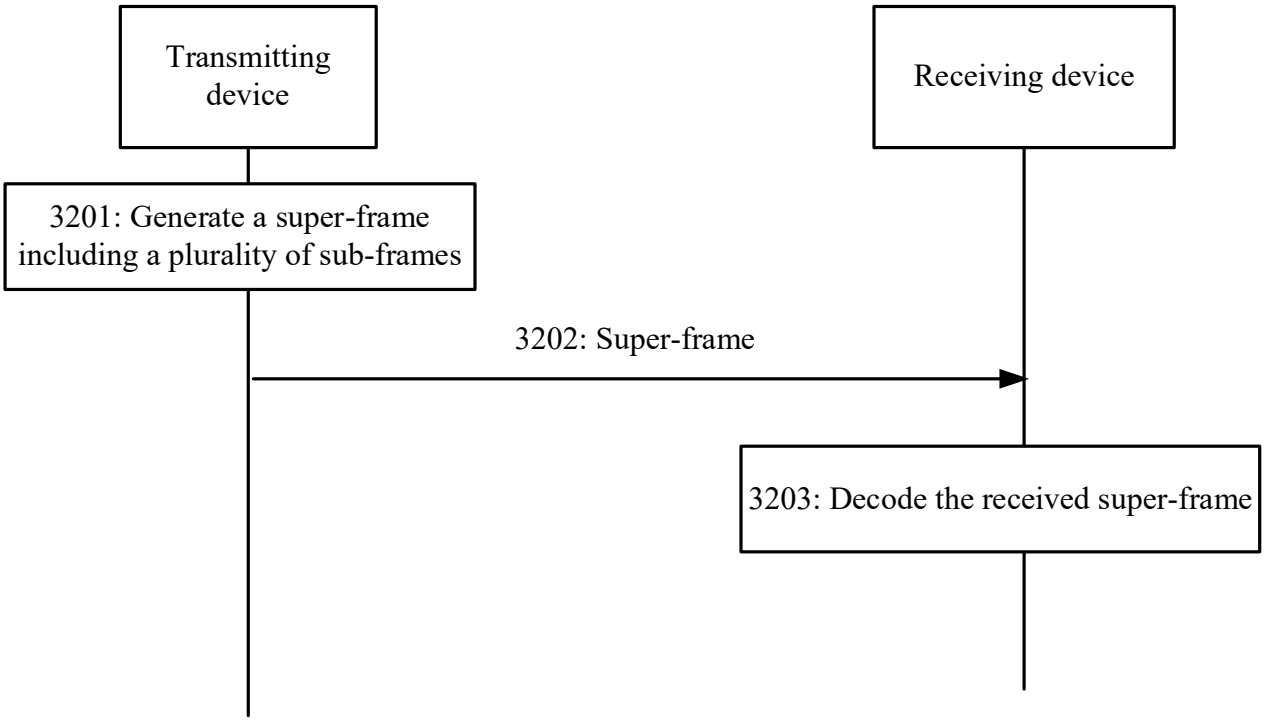
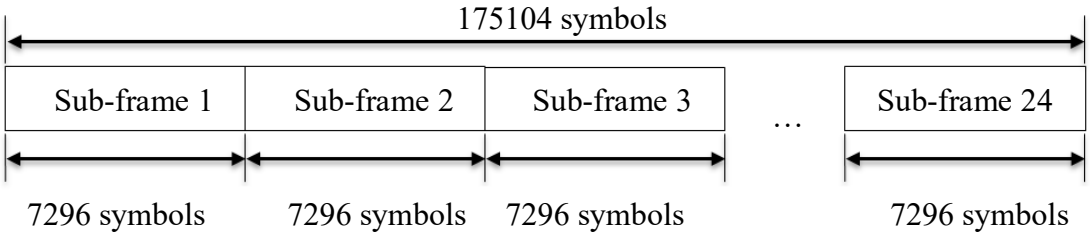
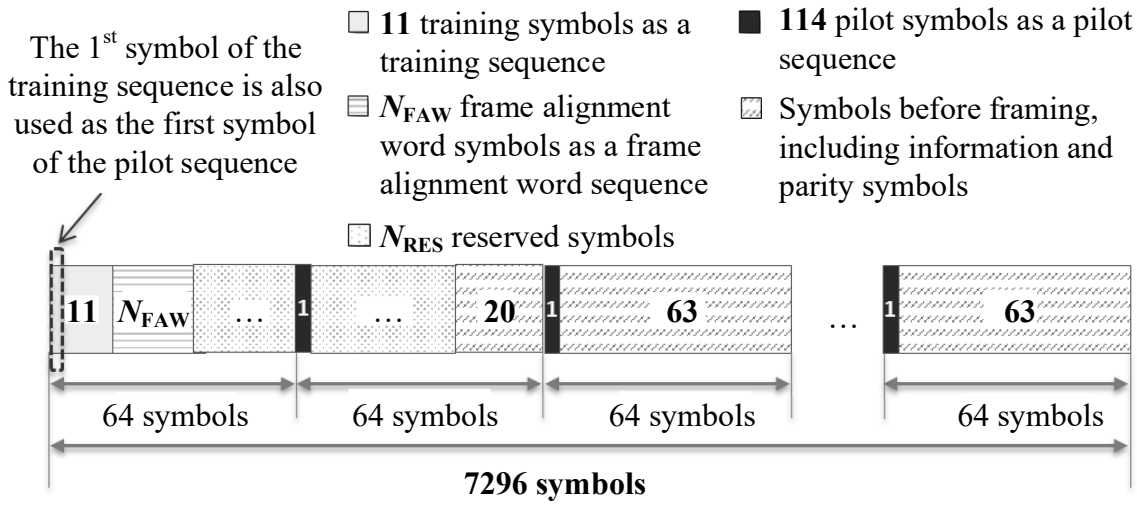

Transmitting device
Receiving device
3201: Generate a super-frame including a plurality of sub-frames
3202: Super-frame
3203: Decode the received super-frame

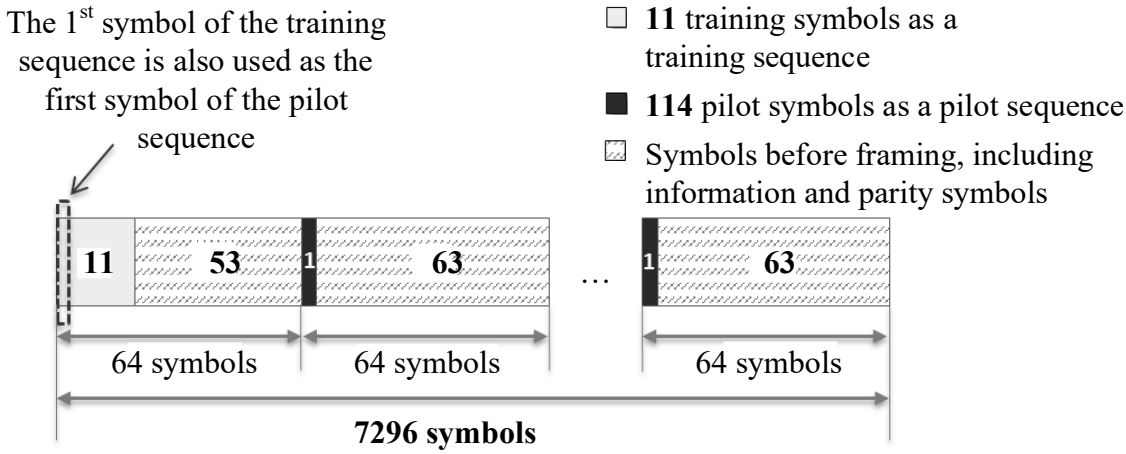
FIG. 32


175104 symbols
Sub-frame 1
Sub-frame 2
Sub-frame 3
…
Sub-frame 24
7296 symbols
7296 symbols
7296 symbols
7296 symbols

(a)


The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
11 training symbols as a training sequence
NFAW frame alignment word symbols as a frame alignment word sequence
NRES reserved symbols
114 pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
11
NFAW
…
1
…
20
1
63
…
1
63
64 symbols
64 symbols
64 symbols
64 symbols
7296 symbols

(b)


The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
11 training symbols as a training sequence
114 pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
11
53
1
63
…
1
63
64 symbols
64 symbols
64 symbols
7296 symbols

(c)

FIG. 33

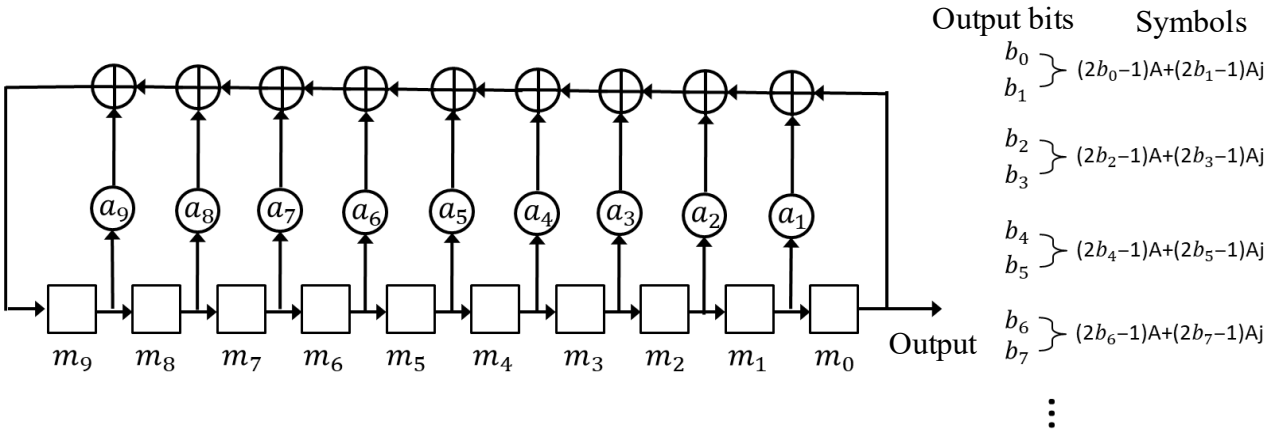

Output bits
Symbols
b_0 b_1 $(2b_0-1)A+(2b_1-1)Aj$
b_2 b_3 $(2b_2-1)A+(2b_3-1)Aj$
b_4 b_5 $(2b_4-1)A+(2b_5-1)Aj$
b_6 b_7 $(2b_6-1)A+(2b_7-1)Aj$
a_9 a_8 a_7 a_6 a_5 a_4 a_3 a_2 a_1
m_9 m_8 m_7 m_6 m_5 m_4 m_3 m_2 m_1 m_0
Output

FIG. 34

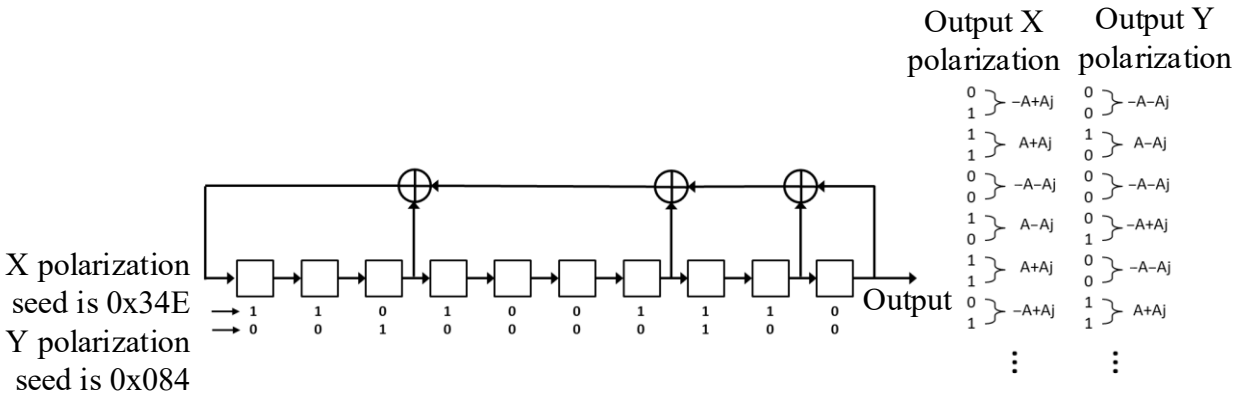

Output X polarization
Output Y polarization
X polarization seed is 0x34E
Y polarization seed is 0x084
1 0 1 0 1 0 0 1 1 0 0 0 1 0 1 1 1 0 0 0
Output
0 1 −A+Aj
1 1 A+Aj
0 0 −A−Aj
1 0 A−Aj
1 1 A+Aj
0 1 −A+Aj
0 0 −A−Aj
1 0 A−Aj
0 0 −A−Aj
0 1 −A+Aj
0 0 −A−Aj
1 1 A+Aj

FIG. 35

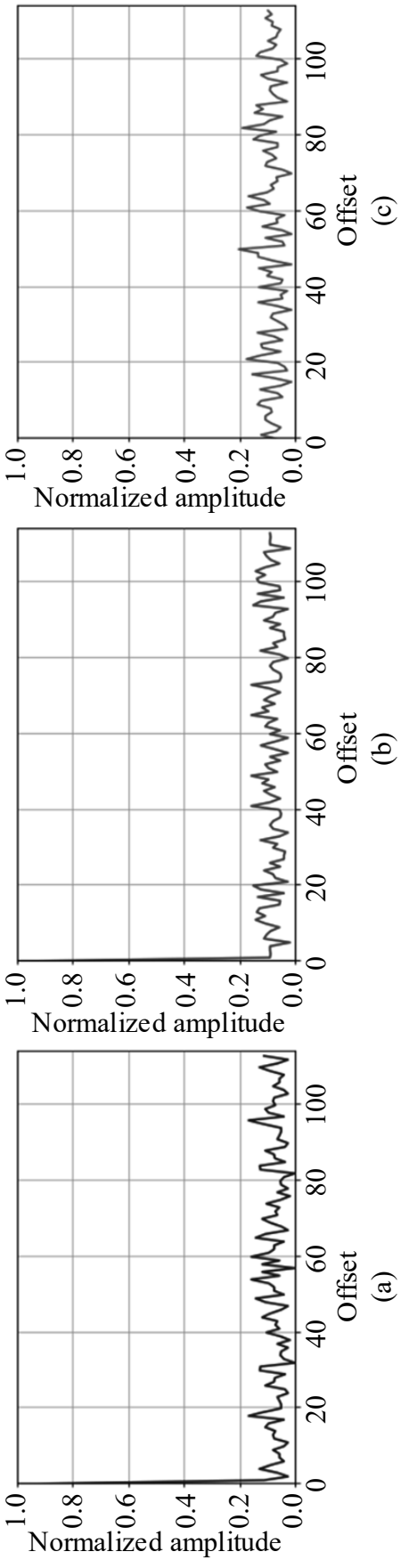

Normalized amplitude
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
Offset
(a)
(b)
(c)

FIG. 36

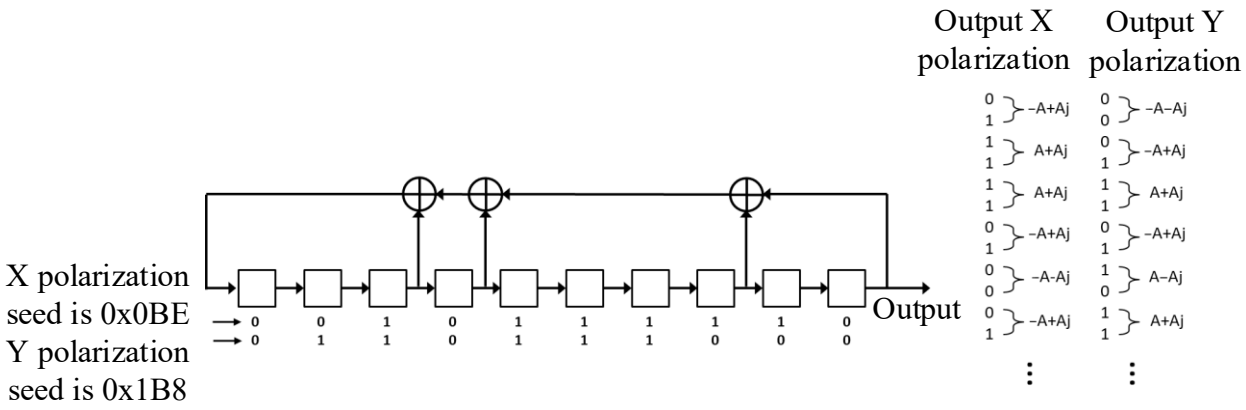

Output X polarization
Output Y polarization
X polarization seed is 0x0BE
Y polarization seed is 0x1B8
Output
-A+Aj
A+Aj
-A-Aj
A-Aj
-A−Aj

FIG. 37

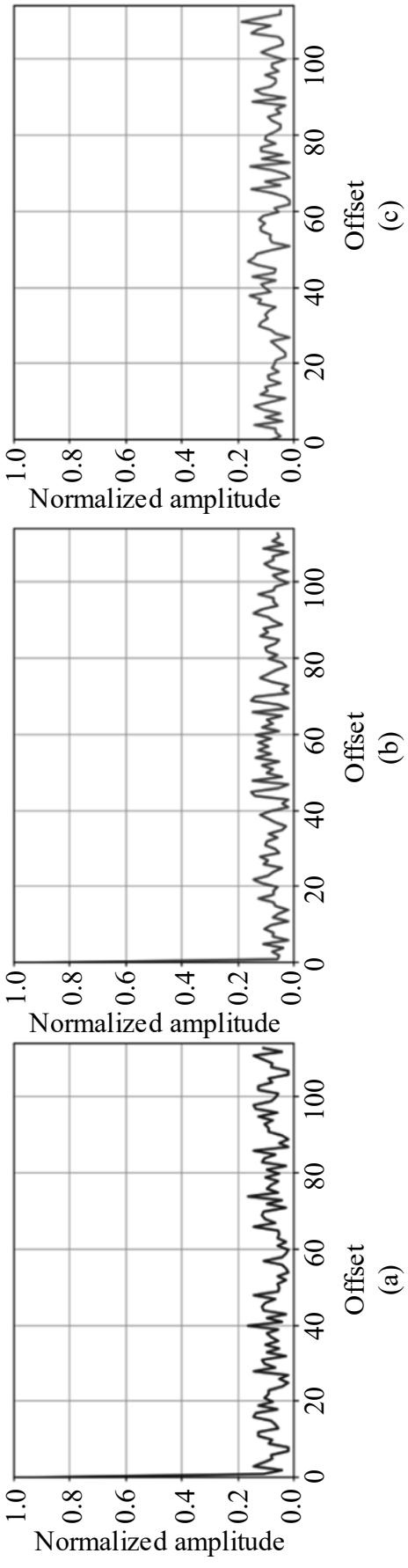
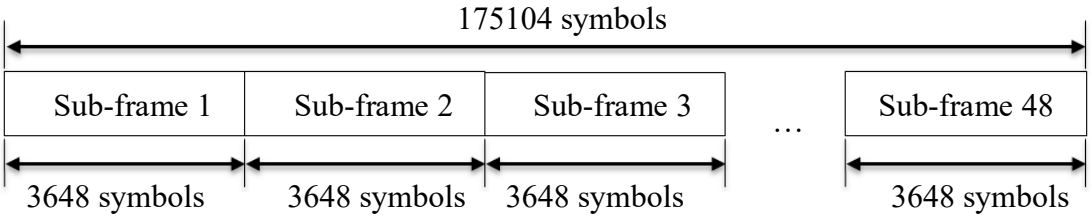
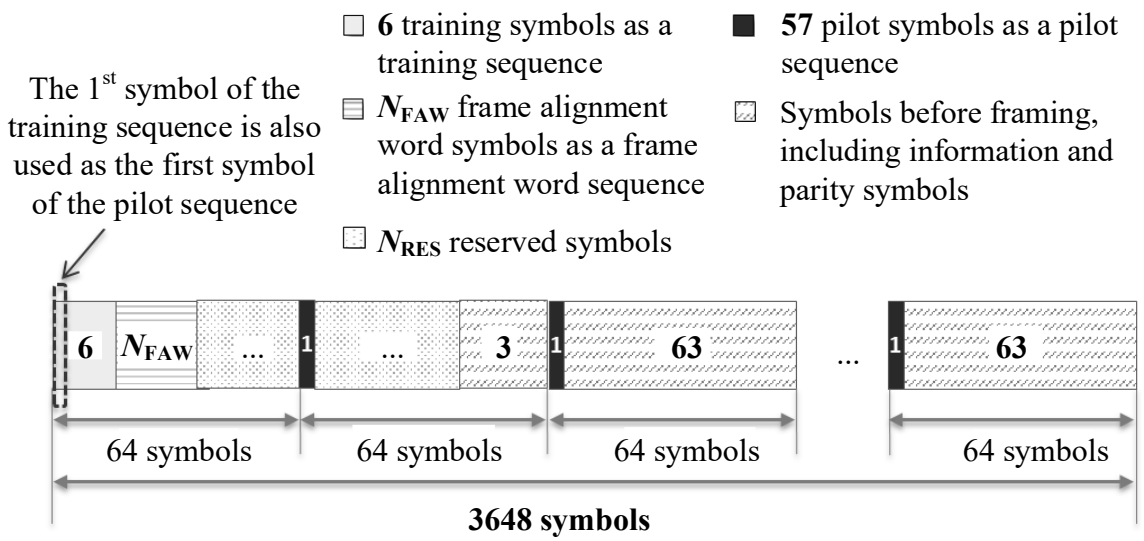

Normalized amplitude
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
Offset
(a)
Normalized amplitude
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
Offset
(b)
Normalized amplitude
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
Offset
(c)

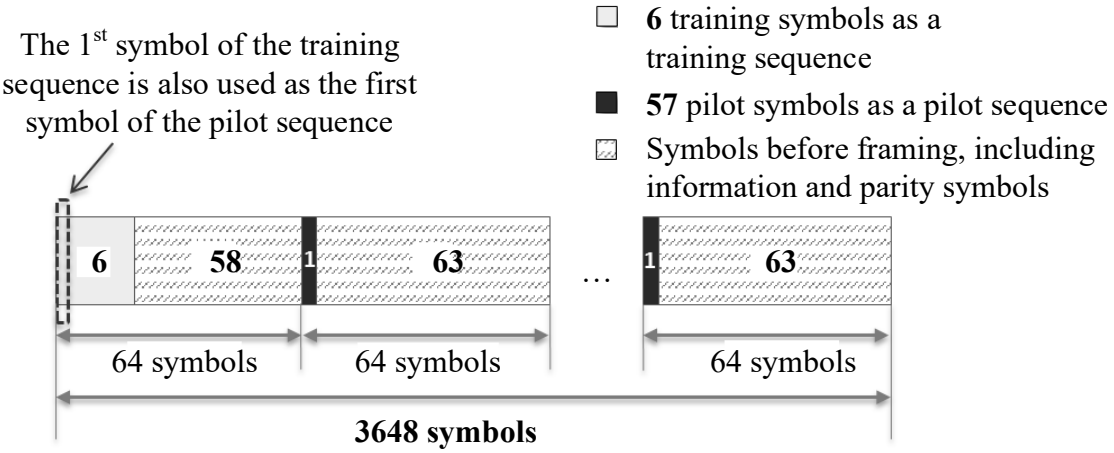
FIG. 38


175104 symbols
Sub-frame 1
Sub-frame 2
Sub-frame 3
…
Sub-frame 48
3648 symbols
3648 symbols
3648 symbols
3648 symbols

(a)


6 training symbols as a training sequence
57 pilot symbols as a pilot sequence
N_{FAW} frame alignment word symbols as a frame alignment word sequence
Symbols before framing, including information and parity symbols
N_{RES} reserved symbols
The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
6
N_{FAW}
...
1
...
3
1
63
...
1
63
64 symbols
64 symbols
64 symbols
64 symbols
3648 symbols

(b)


6 training symbols as a training sequence
57 pilot symbols as a pilot sequence
Symbols before framing, including information and parity symbols
The 1st symbol of the training sequence is also used as the first symbol of the pilot sequence
6
58
1
63
…
1
63
64 symbols
64 symbols
64 symbols
3648 symbols

(c)

FIG. 39

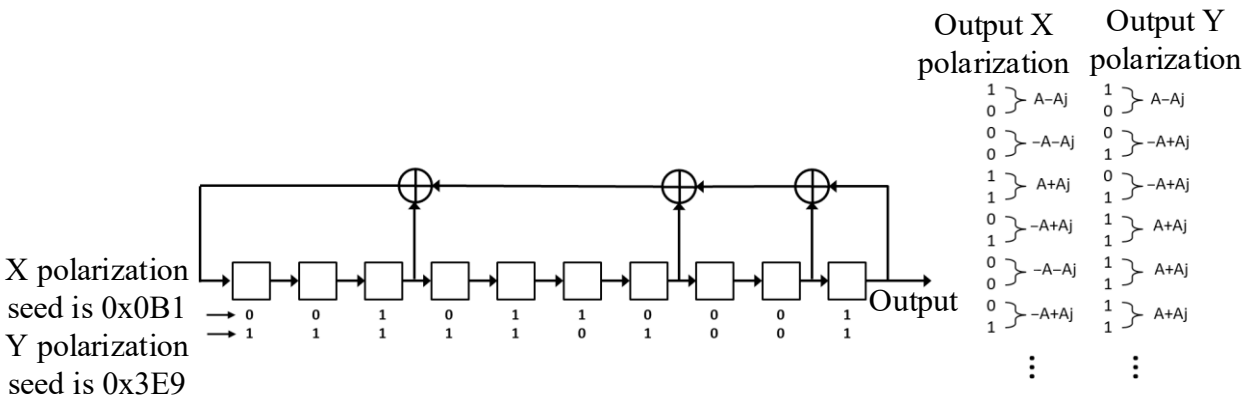

Output X polarization
Output Y polarization
X polarization seed is 0x0B1
Y polarization seed is 0x3E9
Output
A−Aj
−A−Aj
A+Aj
−A+Aj
−A−Aj
−A+Aj
A−Aj
−A+Aj
−A+Aj
A+Aj
A+Aj
A+Aj

FIG. 40

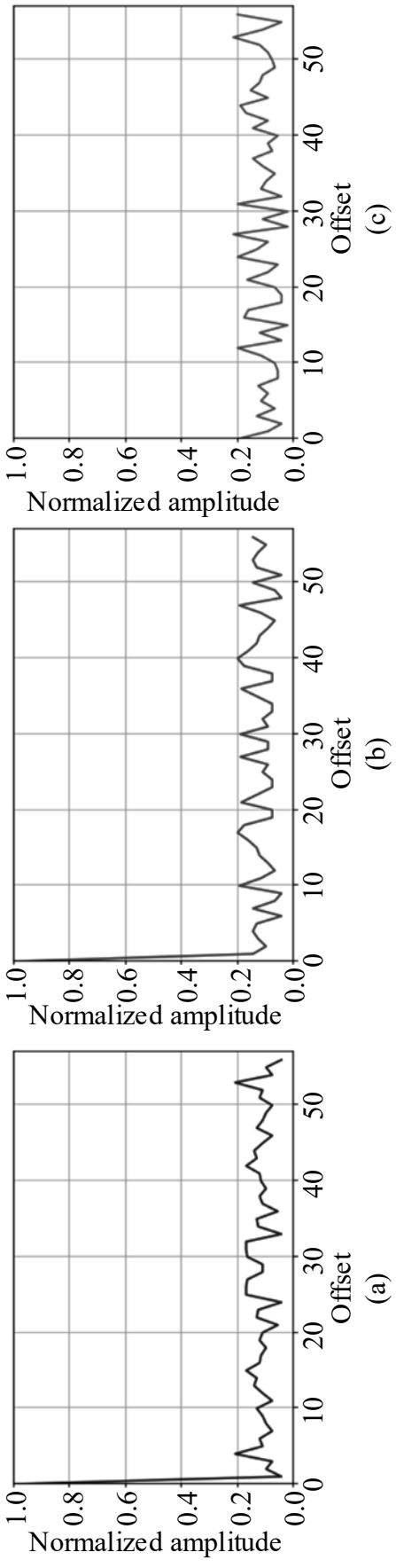

Normalized amplitude
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
Offset
(a)
(b)
(c)

FIG. 41

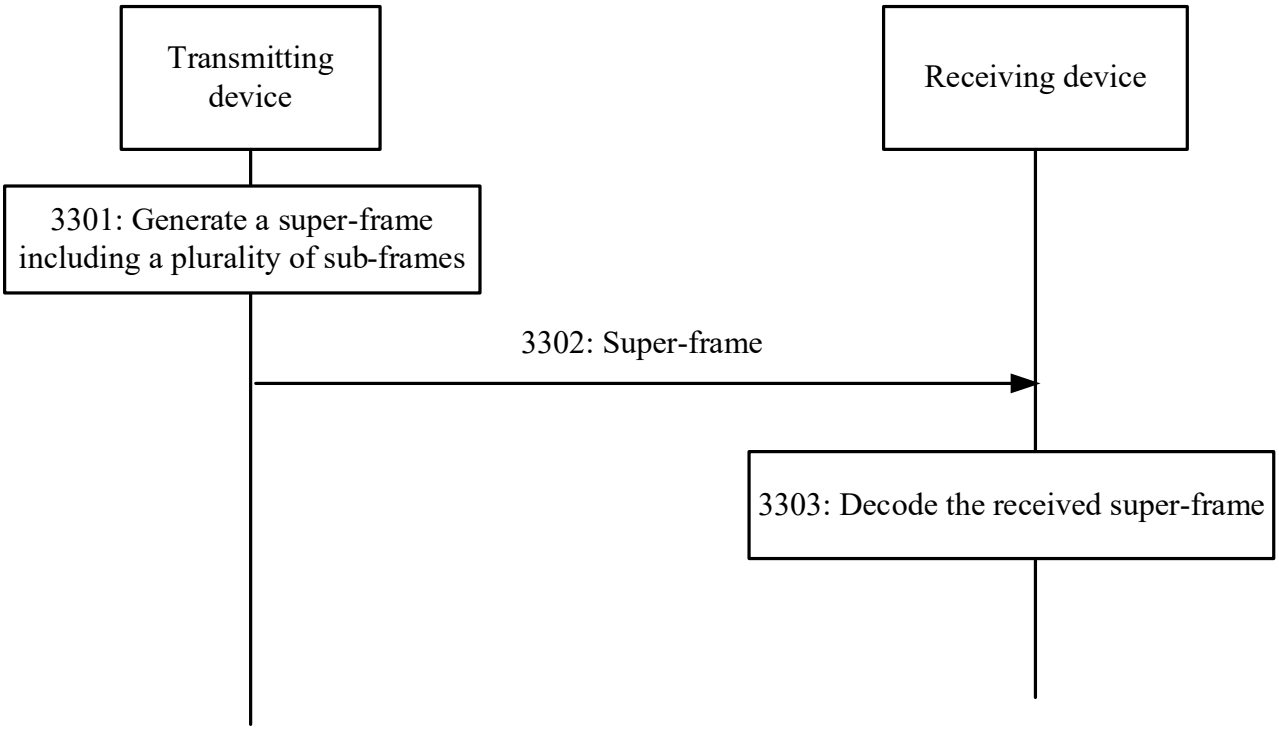

Transmitting device
Receiving device
3301: Generate a super-frame including a plurality of sub-frames
3302: Super-frame
3303: Decode the received super-frame

FIG. 42

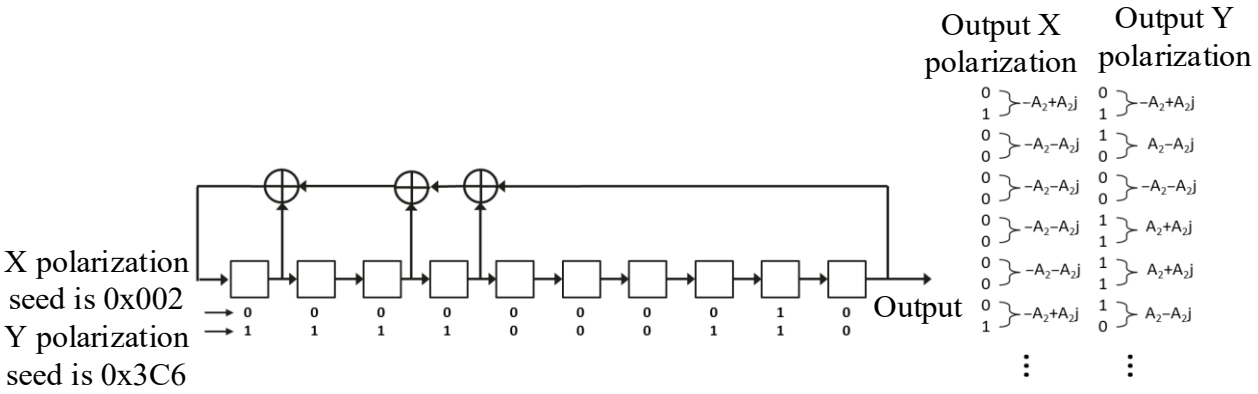

Output X polarization
Output Y polarization
X polarization seed is 0x002
Y polarization seed is 0x3C6
Output

FIG. 43

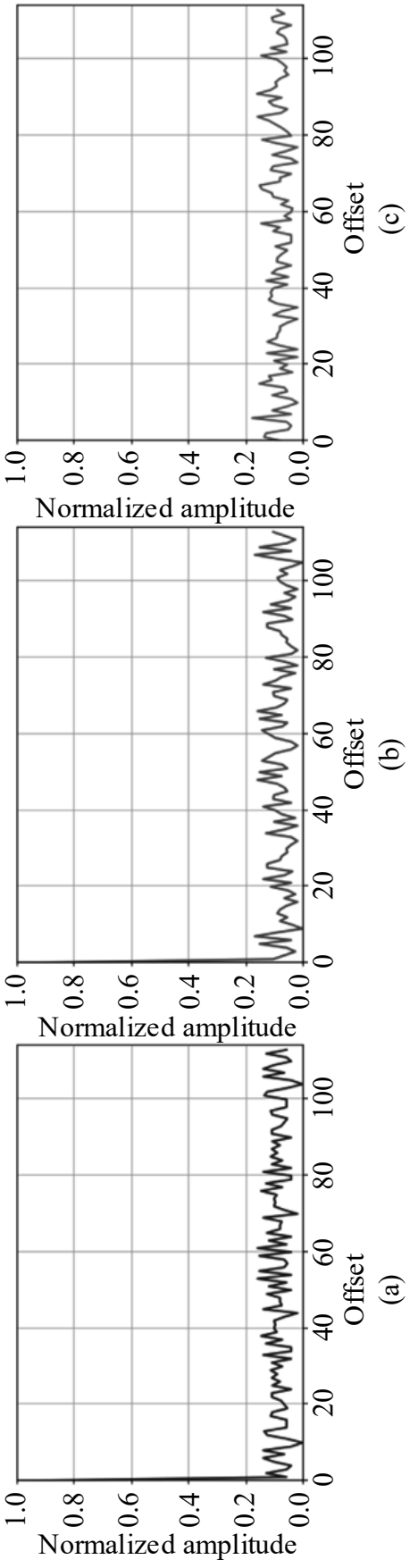

1.0
0.8
0.6
0.4
0.2
0.0
Normalized amplitude
0
20
40
60
80
100
Offset
(a)
(b)
(c)

FIG. 44